Carrizo-Wilcox Aquifer Study

Final Executive Summary

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Executive Summary Overview

The 81st Texas Legislature directed the Texas Commission on Environmental Quality (TCEQ) to *"conduct a study of the characteristics and impacts on groundwater planning in the Carrizo-Wilcox Aquifer."* (General Appropriations Act, Article VI, Texas Commission on Environmental Quality, Rider 36) In order to accomplish the legislative intent of this study, the TCEQ entered into a research contract with the Bureau of Economic Geology at The University of Texas at Austin (BEG) to collect and review a wide variety of information, develop datasets and conduct a series of analyses regarding current activities related to groundwater management of the Carrizo-Wilcox Aquifer in Texas.

This Executive Summary prepared by the BEG is submitted to fulfill requirements of the TCEQ Carrizo-Wilcox Study, Project 582-8-75374-119. Specifically, this Executive Summary provides an overview of results from the Carrizo-Wilcox Study (the Study). This Executive Summary is organized into the following five major thematic sections: (1) analysis and results from stakeholder surveys developed to solicit input from interested parties, including groundwater conservation districts (GCDs) with jurisdictional responsibilities over the Carrizo-Wilcox Aquifer, (2) summary of the adequacy of science utilized by GCDs during development and adoption of desired future conditions, management plans, rules, and formal procedures, (3) evaluation of desired future conditions, management plans, rules, regional water plans, and the potential for conflict, (4) an evaluation and critique of the State's Groundwater Availability Models for the Carrizo-Wilcox Aquifer, and (5) an assessment of whether the presence of anthropogenic contaminants in the recharge area of the Carrizo-Wilcox Aquifer and potential pollution of the aquifer are issues that should be addressed.

All information presented in this Executive Summary has been compiled and summarized from information contained in a series of eight Summary Reports developed to address specific tasks in the Study scope of work. These eight Summary Reports are available for review at the Study Website located at http://www.beg.utexas.edu/cswr/aquiferstudy/.

1.0 Survey Results from Interested Stakeholders

1.1 Carrizo-Wilcox Aquifer Stakeholders

At the beginning of the Study, our efforts were primarily focused on identifying, contacting, and soliciting feedback from targeted interest groups and individuals directly or indirectly involved with the Carrizo-Wilcox Aquifer. In order to compile and contact potential stakeholders of the Carrizo-Wilcox Aquifer, the following efforts were completed.

- A project website was created at http://www.beg.utexas.edu/cswr/aquiferstudy/ that contained a link inviting individuals and interested groups to sign up as a stakeholder.
- State agencies, trade and professional organizations such as Texas Alliance of Groundwater Districts, Texas Water Conservation Association, Texas Rural Water Association, and Texas Section American Water Works Association were contacted with requests to post links on the organization's websites advertising the Study and the request for stakeholders to participate.
- A list of water user groups with contact information from the 2006 and draft 2011 regional water plans for all regional water planning groups currently using or planning to use the Carrizo-Wilcox Aquifer at any point in the 50-year planning horizon were obtained from the TWDB.
- A list of water users of the Carrizo-Wilcox Aquifer and their contact information that have submitted a water use survey was obtained from the TWDB.
- A variety of sources were used to compile a complete list of all GCDs with jurisdictional responsibilities over the Carrizo-Wilcox Aquifer, including current contact information.
- Sign up lists from a 2009 Carrizo-Wilcox Aquifer Symposium held at Texas A&M University were obtained from the TWDB.

The final stakeholder list contains approximately 517 names, the majority of which include email contact information (see separate electronic attachment). This stakeholder list was used throughout the course of the Study to disseminate results, findings, and information on future meetings.

1.2 Carrizo-Wilcox Study Online Survey

The primary process for soliciting comments from stakeholders of the Carrizo-Wilcox Aquifer was through online surveys developed specifically for this Study. Two separate surveys were developed to solicit focused information from (1) interested parties and from (2) GCDs. Draft surveys were presented to TCEQ for review prior to their release. Complete surveys are available for review at the Study Website located at http://www.beg.utexas.edu/cswr/aquiferstudy/.

1.3 Summary and Representative Responses to Carrizo-Wilcox Aquifer Study Survey

There are a variety of stakeholders within the Carrizo-Wilcox Aquifer, representing numerous interests such as municipalities, regional water suppliers, environmental interests, private property owners, agriculture, industry, and locally governed GCDs. All identified interests were invited to participate in the Study by responding to surveys developed to collect information regarding the Carrizo-Wilcox Aquifer and any predominant groundwater management and protection concerns. The following sections summarize selected responses to the survey questionnaires. For the complete set of responses, the reader is referred to the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/.

1.4 Interested Parties' Responses

There were 65 unique responses received, either directly to the BEG (via email or other correspondence) or through the online Carrizo-Wilcox Aquifer Interested Parties Survey.

In the Interested Parties Survey, participants were asked to *"Provide a brief description of any predominant groundwater management or protection issues and concerns related to the Carrizo-Wilcox Aquifer."* This was the question for which almost all responses were focused. Generally, the responses can be divided into four broad categories:

- Wholesale and retail water providers concerned about the future of groundwater management in the Carrizo-Wilcox Aquifer
- Environmental interests concerned with inadequate focus on environmental protection during adoption of desired future conditions, management plans, and rules by Carrizo-Wilcox GCDs
- Citizens concerned about property rights being violated by the Lost Pines Groundwater Conservation District
- Citizens in Gonzales County concerned about their ability to sell their groundwater due to actions by the Gonzales County Groundwater Conservation District

Wholesale and retail water providers survey comments focused on a number of issues related to their ability to continue to provide water supplies to their current and future customers. For example, San Antonio Water System and Schertz Seguin Local Government Corporation commented on difficulties they experienced during water supply project implementation due to inconsistencies in the permitting process from one district to another and their inability to obtain long-term commitments for water supply permits. San Antonio Water System commented regarding the variability in local groundwater conservation district philosophies and rules that "*This regulatory inconsistency adds unnecessary difficulty to both long-term planning for water supply projects, as well as planning for the aquifer on a hydrologic basis.*" Canyon Regional Water Authority commented that the "crisis" in management of the Carrizo-Wilcox Aquifer is not based on actual hydrologic data. Specifically, Canyon Regional Water Authority commented that, "*Over the past several years, public awareness of groundwater issues and concerns over the availability of future supplies has grown dramatically. Fueling much of the anxiety is a fear of the impending "drying up" of Texas' aquifers. However, the common perception that we are recklessly "mining" groundwater and that future generations will be left with meager and dwindling supplies is unfounded. On the contrary, the large amount of available hydrogeologic data indicates that the Carrizo-Wilcox aquifers are vast and largely underdeveloped resources that contain enough water to supply all of Central and South Texas' needs for centuries.*"

The City of Bryan submitted two sets of comments to the Study. The following is a portion of the comments submitted by the City of Bryan along with recommendations:

"…When Senate Bill 2 passed in 2001, the Texas Water Development Board was directed to 'designate groundwater management areas covering all major and minor aquifers in the state…Each groundwater management area shall be designated with the objective of providing the most suitable area for the management of the groundwater resources. To the extent feasible, the groundwater management area shall coincide with the boundaries of a groundwater reservoir or a subdivision of a groundwater reservoir.' (Sec. 35.004, Senate Bill 2, 77th Texas Legislature).

In response to this directive, the Texas Water Development Board designated 16 groundwater management areas, based almost exclusively on the boundaries of major and minor aquifers throughout the state. Recognizing the natural hydrologic divide effect that the Colorado and Trinity rivers have on groundwater flow in this critical groundwater resource, the Carrizo-Wilcox Aquifer, which covers all or parts of more than 60 counties in Texas, was divided into three groundwater management areas.

It is noteworthy to reflect on the directive from the Texas Legislature in 2001, 'Each groundwater management area shall be designated with the objective of providing the most suitable area for the management of the groundwater resources'. If the Carrizo-Wilcox Aquifer is to be managed as effectively as possible in order to ensure that it remains a high quality, cost-effective, reliable water supply for the citizens of Texas, including the City of Bryan, then the most effective form of groundwater management should be utilized. However, the Carrizo-Wilcox Aquifer is currently managed, in part by 24 groundwater conservation districts, and in other areas, still has no management.* (*- reader's note - for this study, it has been determined that there are 21 confirmed GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer.)

Therefore, the City of Bryan requests;

- *Continued legislative review to ensure hydrologically-based management of the Carrizo-Wilcox Aquifer,*
- *Continued legislative support for financial resources necessary to develop, update, and maintain science necessary to make sound policy and regulatory decisions, and*
- *Legislative review regarding ownership of groundwater as it relates to investments made by political subdivisions, such as the City of Bryan, to ensure that these investments will not be negatively harmed by any adopted desired future conditions or regulatory methods developed and adopted by groundwater conservation districts."*

The Brazos River Authority, a large wholesale water supplier over a significant portion of the Carrizo-Wilcox Aquifer expressed concerns regarding (1) GCDs that treat local use differently than nonlocal use in permitting, (2) that current regulations encourage "use it or lose it" mentality, i.e., current district rules give no incentive to keep water in place, (3) the rules do not address conjunctive use with any specificity and in practice work against the concept, (4) permits

give no assurance to continued access to the water in the "out" years, and (5) differences in groundwater management philosophies of adjacent GCDs managing and regulating essentially the same supply of water will result in recurring problems and conflicts with no clear solutions.

Environmental Stewardship submitted comments regarding concerns that the groundwater management area joint planning process and individual GCDs need to adequately capture the need to sustain spring flows and base flows to streams and rivers as a component of establishing desired future conditions. Environmental Stewardship's primary conclusion is that the groundwater management area process and GCDs have a duty and obligation to include rivers, streams and springs in the adopted desired future conditions of the Carrizo-Wilcox Aquifer.

Thirty-five comment letters (form letters) were received from landowners who are concerned that their property rights are being violated through the actions of the Lost Pines Groundwater Conservation District. This letter states that the moratorium placed on groundwater permits in the Lost Pines Groundwater Conservation District is preventing the citizens from selling their water to the Guadalupe-Blanco River Authority for future water supplies. The letter is reproduced below in its entirety.

"As a constituent landowner in Texas, I am writing to let you know I feel my property rights are being violated. The Lost Pines Groundwater Conservation District (LPGCD) is blocking my rights to sell my ground water. The Rule of Capture has been in effect in the State of Texas since 1904. Although tested more than once, the Texas State Supreme Court has upheld this law in every case. The legislative creation of groundwater conservation districts has, because of the actions and policy of our local district, taken away my rights to my water, and has given it to the District. The District is not bound to either its constituents or science. "Life" terms for board members, and appointee vs. elected official status, gives board members free rein to act on political motivation and personal bias, with no accountability to anyone. Across the state, districts are "hoarding" resources that are the property rights of landowners. The Carrizo Wilcox aquifer has more than enough water to meet the projected demands in our district for decades beyond the 50-year planning period. The Guadalupe Blanco Water Authority has signed a letter of intent to purchase much needed municipal water supplies from my land, water that I have a legal right to sell. In addition, the project would generate considerable revenues for our county. The Lost Pines Groundwater Conservation District is attempting to block this sale. The District has placed a moratorium on issuing any permits for water to be exported outside the district pending the setting of Desired Future Conditions (DFC's) by the TWDB. The neighboring district, Post Oak Savannah Groundwater Conservation District, does not have a moratorium and is still issuing permits regardless of the DFC's. The district has denied the landowners the right to participate or comment on rules, reservations, or any action that could impact landowners by refusing to post all meetings, except their regularly scheduled monthly meetings, and denying attendance in any meeting met with less than a forum. Therefore, the LPGCD is interfering with the free market system and placing all landowners within the District at a disadvantage because of denying due process."

Thirteen comments were received from a group of landowners and board members of Gonzales-Carrizo Management, Inc. This is a group of landowners who organized and arranged to lease groundwater to Texas Water Alliance—a division of the San Jose Water Company. These survey responders state that they own property in eastern Gonzales County. This set of comments states, "*Our main concern is being able to lease our water rights. We want parity (for our eastern side of the county) with the western side of the county, with regard to the number of allocable acre feet that we are allowed to lease*."

In response to a request to *"Provide a list, with sufficient detail to allow for an availability analysis, of any new or alternative water management strategies that are being considered for future implementation that may impact groundwater availability in the Carrizo-Wilcox Aquifer, but are not currently in the regional and state water plans"*, two responses were received. First, the Schertz-Seguin Local Government Corporation submitted a preliminary project description for expansion of the existing Schertz-Seguin Local Government Corporation Project well fields in Gonzales and Guadalupe counties to include wells and/or well fields in Wilson County to provide a project yield of 10,000 acre feet per year by the year 2020. Second, Environmental Stewardship submitted a substantial set of comments and information that supported the process of establishing desired future conditions. Environmental Stewardship has been involved in the joint planning process leading to the establishments of desired future conditions, and is supporting the need to ensure sustainable management of the groundwater resources including the protection of spring flow and base flow into streams and rivers from the Carrizo-Wilcox Aquifer. Due to the volume of information submitted by Environmental Stewardship, the reader is encouraged to review the complete set of comments and information submitted by Environmental Stewardship on this survey request at the Study website. Canyon Regional Water Authority submitted a lengthy commentary under this question, titled *Observations on the Regulation of the Carrizo-Wilcox Aquifer in Central and South Central Texas*. However, the content of this commentary was determined to not be related to this question. It is included in its entirety on the Study website link for survey responses.

One question from the Interested Parties Survey asked *"Are you aware of any compatibility issues that have already been documented or that may occur as a result of the implementation of any district's management plan? If yes, please describe the nature of the compatibility issue."* Six "yes" responses addressing Question 7 were received, all but one of which were from either wholesale or retail water suppliers. The main concerns raised were (1) conflicts between GCDs over different approaches to the issuance of production permits and in their interpretation and application of Chapter 36 requirements, (2) conflicts between regional water planning groups and GCDs in that the regional water planning groups have incorporated water supplies from the Carrizo-Wilcox Aquifer in volumes that are reported to be in excess of what the Carrizo-Wilcox Aquifer ecosystem can sustain, (3) that GCDs through the groundwater management area joint planning process should submit desired future conditions that are based on preferred hydrogeologic parameters and not geographically specific production amounts, which will allow

TWDB to calculate a managed available groundwater estimate for the GCDs to manage, and (4) absence of required coordination between GCDs and regional water planning groups will lead to significant uncertainty about the reliability of water management strategies in the regional water plans. There were 12 "no" responses.

Another question posed in the Interested Party Survey was *"Are you aware of management gaps or regulatory gaps that have led to or could lead to contamination of the recharge zone or production areas of the Carrizo-Wilcox Aquifer? If so, please describe the management or regulatory gaps related to past, current or potential aquifer contamination."* The Schertz-Seguin Local Government Corporation reported that "…there are numerous wells in the Carrizo Formation. Some are old wells that were originally used for irrigation of crops. There are also numerous oil wells that have been converted to water wells. Some of these wells are deteriorated and should be plugged but landowners are reluctant to assume financial responsibility for maintaining wells that are no longer in use." Bexar Metropolitan Water District pointed to possible management or regulatory gaps because of the many different GCDs and their rules and the lack of consistency between them. The absence of any interstate and bi-national management of the aquifer could lead to potential future contamination of the aquifer. The City of Bryan reported that they were unaware of what regulatory controls are in place to manage the recharge zone. The City of Bryan went on to suggest that the recharge zone should be considered a sensitive area in order to protect these areas from sources of contamination such as from manufacturing or commercial industries. Forty-eight respondents did not answer this question.

Finally, a few other comments were received regarding the need for the Study and other issues that were not specific to the questions posed in the survey. These comments are included in the online database.

1.5 Carrizo-Wilcox Aquifer Groundwater Conservation Districts' Responses

For the purposes of this Study, 21 confirmed GCDs are recognized as having statutory responsibilities regarding the management and conservation of groundwater resources in the Carrizo-Wilcox Aquifer. The 21 GCDs are:

1. Anderson County Groundwater Conservation District
2. Bee Groundwater Conservation District
3. Bluebonnet Groundwater Conservation District
4. Brazos Valley Groundwater Conservation District
5. Evergreen Underground Water Conservation District
6. Fayette County Groundwater Conservation District
7. Gonzales County Underground Water Conservation District
8. Guadalupe County Groundwater Conservation District

9. Live Oak Underground Water Conservation District
10. Lost Pines Groundwater Conservation District
11. McMullen Groundwater Conservation District
12. Medina County Groundwater Conservation District
13. Mid-East Texas Groundwater Conservation District
14. Neches and Trinity Valleys Groundwater Conservation District
15. Panola County Groundwater Conservation District
16. Pineywoods Groundwater Conservation District
17. Plum Creek Conservation District which is a WC&ID
18. Post Oak Savannah Groundwater Conservation District
19. Rusk County Groundwater Conservation District
20. Uvalde County Underground Water Conservation District
21. Wintergarden Groundwater Conservation District

The confirmation election for the Harrison County Groundwater Conservation District was defeated by the voters during a May 8, 2010, election. It is not authorized to hold any subsequent election, and therefore is dissolved.

Sixteen GCDs (76 percent of the total) responded to the survey request. Survey responses were not submitted by:

1. Anderson County Groundwater Conservation District
2. Bee County Groundwater Conservation District
3. Guadalupe County Groundwater Conservation District
4. Live Oak Groundwater Conservation District
5. McMullen County Groundwater Conservation District

The overarching purpose of the survey was to collect information necessary to evaluate the scientific foundation of the management plans, rules and regulations promulgated by these Carrizo-Wilcox Aquifer GCDs.

The 16 responding GCDs had three common responses to the survey question regarding predominant groundwater management and/or protection issues and concerns related to the Carrizo Wilcox Aquifer. These responses can be characterized as concerns regarding (1) availability of water supplies and challenges involved in the establishment of desired future conditions (2) need for continuous improvement of available science for purposes of decision

making (3) and perceived lack of regulatory oversight by the RRC regarding oil and gas activities. Allegations are made in some of the surveys that lack of regulatory oversight has contributed to contamination of local groundwater supplies.

Of the 16 GCDs, 7 responded that their districts' primary concern was establishment of desired future conditions that will result in protection and conservation of available groundwater resources in their district. For example, Plum Creek Conservation District (PCCD) stated their primary concern was incorporation of desired future conditions into their management plan and were also concerned that "permitting outside the boundaries of the PCCD that could impact the amount of water that would be available to satisfy local needs in the future". Lost Pines Groundwater Conservation District stated that "it appears that LPGCD has already permitted more than the anticipated total of the MAGs for the district" that were established by Groundwater Management Area 12. Moreover, Lost Pines Groundwater Conservation District noted that export of groundwater resources outside of the district is on the rise and that "13.5 percent of the total pumpage from nonexempt wells was exported from the district." Current and future groundwater production capabilities are of serious concern to three quarters of the districts that responded to the survey.

Of the 16 GCDs, 3 cited a lack of readily available groundwater science resources that could help them make important short-term and long-term decisions. Rusk County GCD stated the need for more technology specifically aimed at monitoring "pumping, spring flow and aquifer volume." Brazos Valley Groundwater Conservation District concerns included establishment of groundwater production limits and development of Depletion Management Zones to "alleviate the depletion stress on the aquifer," which are to be based upon "best available science." Post Oak Savannah Groundwater Conservation District stated "our District has significant concerns with the reliability of the GAM predictions of the groundwater levels in the CW Aquifer". Districts throughout the Carrizo-Wilcox Aquifer expressed uncertainty derived from the availability of accurate local groundwater science and districts ability to forecast future demand.

RRC of Texas (RRC) groundwater management policies and enforcement procedures were a primary concern for 6 of the 16 GCDs. The RRC ability to comprehensively regulate oil and gas exploration, production, and transportation companies is contested because of the perceived inability to effectively regulate groundwater support wells and their inability to eliminate the occurrence of orphan or abandoned wells. Neches and Trinity Valleys Groundwater Conservation District stated concerns regarding *"inadequate oversight by the RRC of oil and gas wells and rig supply wells, including the many old wells within the district, which has presented many potential sources of contamination of groundwater."* GCDs in the eastern region of the Carrizo Wilcox Aquifer, including Panola County Groundwater Conservation District, Plum Creek Conservation District, Neches and Trinity Valleys Groundwater Conservation District, and Rusk County Groundwater Conservation District noted that there are regulatory concerns with the management of oil and gas exploration and the oversight provided by Texas agencies including the RRC and Texas Department of Licensing and Regulation (TDLR). For instance,

Rusk County GCD stated *"With each oil/gas exploration well drilled, a water well is drilled to support the operation. Due to lack of staffing, the TDLR does not conduct any construction inspections of these water wells. Our concern is for the illegal practice of screening more than one zone to gain the quantity of water needed. This practice, although not a major problem while the rig is in use, becomes a problem when the well is capped and left idle. The RCGCD purchased a down hole video camera in 2008 and requires inspection of each of these support wells within 180 days of the oil/gas rig leaving the pad. We have inspected over 300 wells and have found that about 11% were screened in more than one zone."* Neches and Trinity Valleys GCD stated *"Inadequate oversight by the RRC of the oil and gas wells and rig supply wells, including the many old wells within the District, which has presented many potential sources of contamination of groundwater."* Panola GCD stated *"lack of regulation by RRC of water wells involved in oil and gas operations and mining."* Plum Creek CD stated *"There are management and regulatory gaps from the RRC that could possibly lead to contamination of the recharge zone. These gaps are from past production practices and casing leaks."* The aforementioned comments were submitted to the Carrizo-Wilcox Aquifer Study GCD survey.

Moreover, Rusk County GCD noted that the recharge zone for the Carrizo Wilcox Aquifer extends beyond the borders of Texas and suggested that a management or regulatory gap could lead to contamination of the recharge zone. Rusk County GCD suggested that this gap should be addressed by the TWDB or some other state entity if it is not currently under study. Rusk County GCD also noted extensive strip mining operations in the recharge area. The strip mining process includes removing 200 to 300 feet of earth to mine the lignite. Once mined, the overburden is then replaced. This mixing of the overburden and removal of the lignite may have an effect on recharge for the Carrizo Wilcox Aquifer. Rusk County GCD noted that this issue should be evaluated in future studies.

1.6 Carrizo-Wilcox GCDs' Enforcement of Substantial Violations

As part of the Study, information was compiled regarding the enforcement of substantial violations of Carrizo-Wilcox GCDs rules. The BEG was asked to *"Evaluate each groundwater conservation district for enforcement of substantial compliance with its rules. Tabulate number of enforcement actions since September 1, 2007. This information will be obtained from the groundwater conservation districts (GCDs) using an online survey.*"

In the survey to the 21 GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer, the specific information requested was "*Provide a list of all substantial enforcement actions taken for violations of district rules since September 1, 2007. The district should include in this list the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance*." Enforcement actions that promote current and future compliance with GCD rules are considered positive enforcement actions. Alternatively, enforcement actions where violators simply choose to pay a fine and

continue to be in noncompliance are considered by the Study team to be negative enforcement actions. That is, the enforcement approach is not a deterrent to future violations

Of the 16 GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer that responded to the survey 13 indicated that they did not pursue either formal or informal enforcement actions for violations of their rules. Three GCDs indicated that they had carried out formal enforcement action under their rules since September 1, 2007. Pineywoods GCD cited nine enforcement actions since September 2007. Eight of the nine violations were resolved through positive enforcement actions. These violations include failing to register a well, well contamination, and well construction without a permit. Fines and fees were assessed by the Pineywoods GCD and paid by the violators. The violations were resolved resulting in compliance with the rules. Neches & Trinity Valley GCD reported two enforcement actions that had been ongoing or resolved since September 1, 2007. In both enforcement actions the Neches & Trinity GCD was able to bring the violators into compliance through the use of the courts and assessing fines. These actions may be considered positive enforcement actions as the violators did not simply elect to pay the fees and continue to violate district rules. Post Oak Savannah GCD made a total of six positive enforcement actions, for which a total of $1,700 in fines was assessed from April 8, 2008 through February 9, 2010. The following Post Oak Savannah GCD rules were violated: one infraction of Rule 7.12, Drilling Permits; two infractions of Rule 7.13, Drilling or Altering a Well; two infractions of Rule 7.3, Records, Reports, and Drillers Logs;, and one infraction of Rule 8.2, Application for Transport Permit. The fines assessed per violator ranged from $100 to $900.

The Interested Parties Survey contained the following parallel request: *"Provide a list of any substantial enforcement actions, regardless of ultimate resolution, taken for violations of district rules since September 1, 2007. In as much detail as possible, include the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance."* Of the 65 responses to the Interested Party Survey, there were no responses regarding enforcement actions taken by the GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer.

2.0 Adequacy of Science Utilized by GCDs during the Development and Adoption of Desired Future Conditions, Management Plans, and Rules

A significant element of the Study was to, *"Examine rules, plans and procedures adopted by each groundwater conservation district (GCD) to determine if they are based on sound scientific principles. This information will be obtained from the GCDs using an online survey. Link individual GCD rules to (1) statutory authority and (2) to any science that was considered during development of the rules. Link individual GCD plan goals, objectives, and performance standards to any science that was considered in their development. Link individual GCD permitting procedures and decisions since September 1, 2007 to any science used in their development."* In order to accomplish this task, we requested specific information from the

GCDs in an online survey.

An evaluation of GCD management plans, rules, and procedures was conducted in order to determine whether they are based on sound scientific principles. The complete responses provided by the 16 GCDs that submitted requested information to the Study's survey questionnaire are now available for review at the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/ .

We reviewed 20 complete sets of management plans and rules in order to evaluate and link specific rules to both broad or GCD-specific statutory authority and any supporting science that was considered during the development of the management plans and rules. One additional management plan for Anderson County Groundwater Conservation District was obtained from the TWDB, but no rules have been located. A complete set of management plans and rules are available for review online at the Carrizo-Wilcox Aquifer Study website at http://www.beg.utexas.edu/cswr/aquiferstudy/gcd_rules.php/.

2.1 Groundwater Science and Texas Water Law

Eleven of sixteen GCDs provided supporting information to the Study's request for "*electronic copies of any scientific data, reports, or presentations presented to and considered by the district during development of the current management plan.*" All 16 GCDs articulated, to varying degrees, their reliance on groundwater science, including information from groundwater availability models that are produced and provided by the Texas Water Development Board. Nine of the 16 GCD's cited the 2007 State Water Plan and applicable regional water plans as a source for science used in developing their management plans.

The history of groundwater science in Texas is long and rich, with substantial contributions made by state agencies such as the Texas Water Development Board (and the predecessor agency, the Texas Board of Water Engineers), the Texas Commission on Environmental Quality (and predecessor agencies), groundwater conservation districts, and federal agencies such as the United States Geological Survey. After the passage of Senate Bill 1 in 1997 by the 75th Texas Legislature, the need for improved, more site-specific groundwater science was realized. This need for improved groundwater science was at least initially the result of (1) the new requirement that GCDs develop and adopt management plans (Texas Water Code, §36.1071), and (2) the regional water planning process requiring water plans be developed for the next 50 years (Texas Water Code, §16.053). As a result of this realization, the 77th Texas Legislature passed Senate Bill 2 in 2001. This legislation, in part, requires that, "*the executive administrator* (of the Texas Water Development Board) *shall obtain or develop groundwater availability models for major and minor aquifers in coordination with groundwater conservation districts and regional water planning groups created under Section 16.053 that overlie the aquifers. Modeling of major aquifers shall be completed not later than October 1, 2004. On completing a groundwater availability model for an aquifer, the executive administrator shall provide the*

model to each groundwater conservation district and each regional water planning group created under Section 16.053 overlying that aquifer" (Texas Water Code, §16.012(l)). In recognition of the improved groundwater science that would ultimately result from this directive, Texas Water Code, Chapter 36 was also amended to provide guidance to GCDs with regards to one of the primary sources of groundwater science to be considered in developing management plans and rules necessary to achieve the goals adopted in the management plans. Texas Water Code §36.1071(h) states, "*In developing its management plan, the district shall use the groundwater availability modeling information provided by the executive administrator together with any available site-specific information that has been provided by the district to the executive administrator for review and comment before being used in the plan."* Specifically, Texas Water Code §36.1071(e)(3)(E) requires that a GCD management plan contain estimates of "*the annual volume of flow into and out of the district within each aquifer and between aquifers in the district, if a groundwater availability model is available.*" During the joint planning process required by Texas Water Code §36.108(d), the following requirement directing GCDs to consider the TWDB groundwater availability modeling results is included: "*Not later than September 1, 2010, and every five years thereafter, the districts shall consider groundwater availability models and other data or information for the management area and shall establish desired future conditions for the relevant aquifers within the management area.…*"

Therefore, it is clear in statute that it is the intent of the Texas Legislature that one of the primary sources of groundwater science to be utilized by GCDs during their development of management plans and their adoption of desired future conditions is to be the groundwater availability models and groundwater science developed and made publically available by the executive administrator of the TWDB. If it is the intent of a GCD to utilize local, site-specific information in the development of a management plan, or in the adoption of desired future conditions, in addition to or in lieu of the groundwater science and groundwater availability models developed and provided by the executive administrator, the GCD must submit and obtain the prior approval of the executive administrator to use this alternative source of information (Texas Water Code §36.1071(h) and §36.108(d).

Our review of the submitted survey questionnaire responses and/or management plans submitted confirms the linkage between sound groundwater science provided by the TWDB to the GCDs for their use in the development of their management plans, as required by Texas Water Code §36.1071. In addition, 5 of 16 responding GCDs cited scientific literature published by the BEG describing the hydrogeology of the Carrizo-Wilcox Aquifer. Six GCDs referenced material utilized in joint planning sessions within their Groundwater Management Areas. Ten GCDs worked with technical consultants to develop their individual GCD management plans and rules.

The GCDs were also asked to submit "*electronic copies of any scientific reports presented to and considered by the district during the development of the current district rules.*" A review of current statute documents that the current sequence of management activities and decision points is (1) adoption of desired future conditions, (2) adoption of a management plan designed to

achieve desired future conditions, and (3) adoption of rules designed to achieve the goals of the management plan. Therefore, it is not surprising that for most GCDs, the majority, if not all science developed to address an affected provision included in GCD rules was originally developed during deliberations leading up to the adoption of desired future conditions and management plans. This reality was evidenced by the limited nature of the response by GCDs to the request for information considered during development of rules.

2.2 Linkage Between Sound Scientific Groundwater Principles and GCD Management Plans and Rules

All 16 GCDs that responded to the online survey, either in their direct response or in the text included in their management plan, stated that they utilized sound scientific principles in their adopted management plans. As discussed earlier, this use of sound scientific principles is in large part a result of the direct linkage in statute between the groundwater science produced by the TWDB and requirements for certain elements to be included in GCD management plans. However, the linkage between sound scientific principles and rules adopted by Carrizo-Wilcox GCDs is, for the most part, dependent upon the assumption that necessary science considered during the development of a management plan was adequate for the subsequent development and adoption of rules. To review, one of the objectives of the Study was to, "*Examine rules, plans and procedures adopted by each groundwater conservation district (GCD) to determine if they are based on sound scientific principles. This information will be obtained from the GCDs using an online survey. Link individual GCD rules to …any science that was considered during development of the rules…Link individual GCD permitting procedures and decisions since September 1, 2007 to any science used in their development.*" After an examination of the rules and scientific information provided by the GCDs, the following observations are noted. First, 6 of the 16 GCDs that responded to the Study survey questionnaire provided information regarding the request for scientific information utilized during rule making. Next, of those six GCDs, one GCD clearly articulated the direct linkage between the scientific information that was utilized with the corresponding rule(s) that was subsequently adopted. This district was the Pineywoods GCD. However, it is noted that in the process of adopting rules, decisions made by GCD boards of directors may be based on the cumulative consideration of a number of information sources, such as local studies, regional studies such as regional water plans, and groundwater availability modeling studies, and not just one specific study. Perhaps more importantly, it is also noted that the main focus of scientific efforts from a process perspective is during the adoption of desired future conditions and management plans. The development and adoption of rules is a process designed to achieve the adopted desired future conditions and management plan, and therefore the consideration of science has already occurred earlier in the decision process.

2.3 Linkage Between Sound Scientific Groundwater Principles and Desired Future Conditions

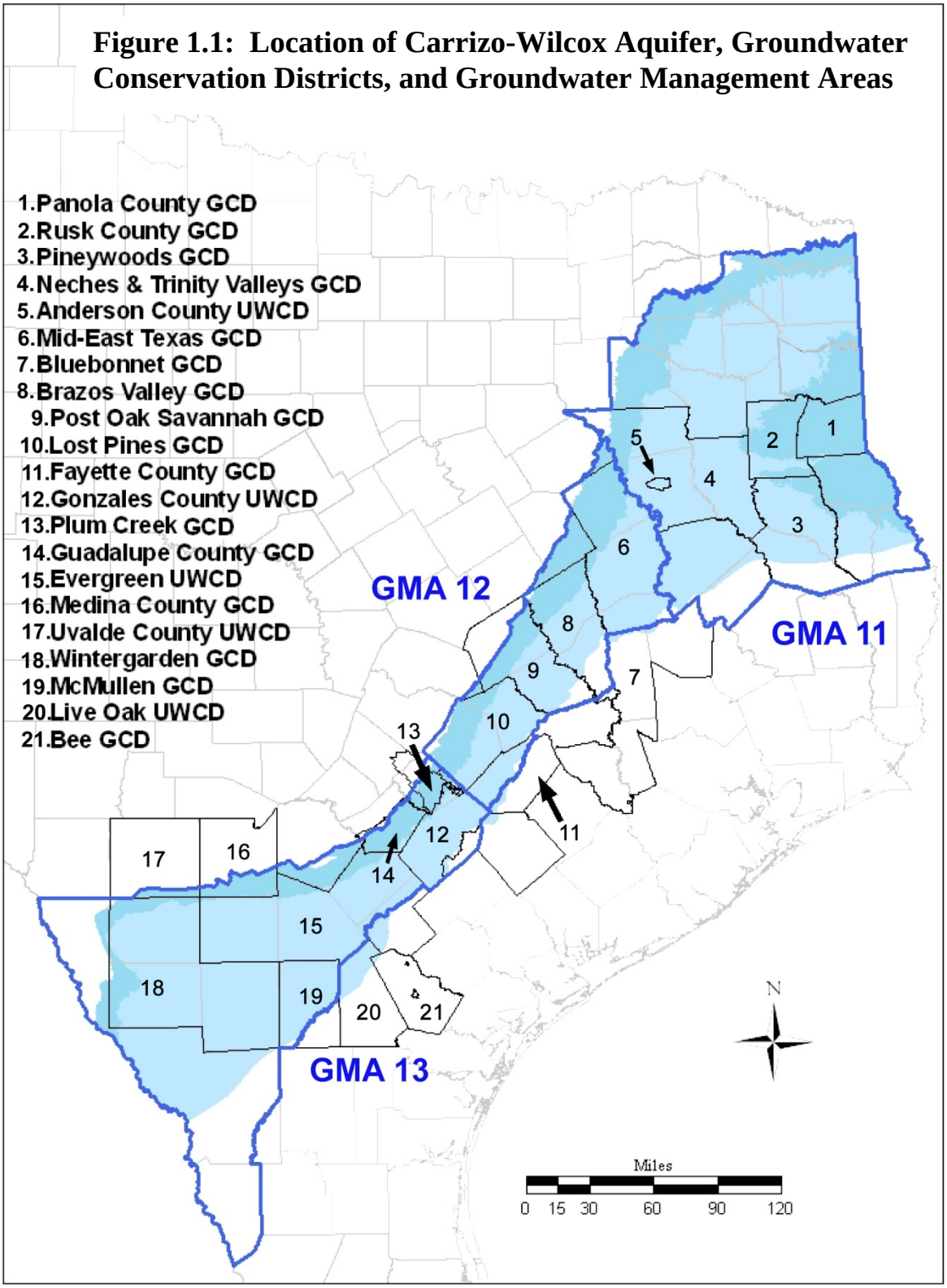
One task included in the Study directed the BEG to "*Review available records from GMAS 11, 12, and 13 and evaluate science behind ultimate Desired Future Conditions (DFCs)*

recommendations. "The Study was designed to collect this information regarding science considered during the joint-planning process by utilizing the online survey developed specifically for the Study. The BEG was also tasked to "*Evaluate whether the rules adopted by the appropriate GCDs are designed to achieve the probable DFC for each GMA."* Later in this Executive Summary in Section 3.1 and in *Final Summary Report for Task 3* the challenges presented by the various timelines for joint-planning by GCDs in GMAs, and the development and adoption of Regional and State Water Plans are discussed. As was the case with the evaluations presented in *Final Summary Report for Task 3,* ideally, this evaluation would occur after the 2011 Regional Water Plans were adopted ***and*** all Carrizo-Wilcox GCDs had amended their respective management plans to reflect adopted DFCs and estimates of Managed Available Groundwater (MAG). At the time of this writing however, all estimates of MAG are still in draft form and the Carrizo-Wilcox GCDs have not had sufficient time to amend their management plans to integrate their adopted DFCs and the resulting estimates of MAG. As such, it is not possible for the purposes of the Study to determine whether the Carrizo-Wilcox GCDs have adopted rules (or management plans) designed to achieve their adopted DFCs. A realistic review of time requirements for this task by the Carrizo-Wilcox GCDs (revise and adoption of rules) suggests that initial efforts to first review and amend the respective management plans and ***then*** adopt revised rules to achieve the applicable DFCs will not be initiated until late 2010—early 2011. Given similar previous efforts, this task by the Carrizo-Wilcox GCDs could take as long as 1 to 2 years to complete, once initiated.

The primary source of information available for evaluation of science used by the three GMAs during their deliberations of potential DFCs was information provided by the representative GCD through the Study's online survey. Information provided by the three GMAs regarding science considered during the first round of joint planning was compiled and reviewed. Additional information was provided after the survey process was completed by Post Oak Savannah GCD and reviewed for the Study.

When the TWDB delineated (by rule, 31 Texas Administrative Code §356.21-23) the boundaries of the groundwater management areas (GMAs) for Texas, as required by Senate Bill 2 (77th Texas Legislature, 2001), all or parts of 58 counties were included in the three GMAs covering the Carrizo-Wilcox Aquifer (Figure 1.1). According to information from the TWDB, there are 18 GCDs within GMAs 11, 12, and 13 (Table 1.2). Three other GCDs with jurisdictional boundaries that include at least some area within the boundaries of the Carrizo-Wilcox Aquifer were included in other GMAs, due primarily to the relatively minor amount of Carrizo-Wilcox Aquifer resources within the three GCDs as compared to the primary aquifer for those GCDs, which in this case is the Gulf Coast Aquifer (see Figure 1.1). These three are the Bluebonnet GCD, Bee GCD, and the Live Oak GCD.

Figure 1.1: Location of Carrizo-Wilcox Aquifer, Groundwater Conservation Districts, and Groundwater Management Areas



In response to the Study survey, the Carrizo-Wilcox GCDs designated as the administrator for GMA 11, 12, and 13 provided information regarding any science considered by the Carrizo-Wilcox GCDs throughout the joint planning process. The details provided through the survey were quite variable. *Final Summary Report for Task 5* provides a detailed summary of the science considered throughout the joint planning process in GMA 11–13, respectively.

Our review of the science considered during the joint planning process for GMAs 11, 12, and 13, based on information provided by the Carrizo-Wilcox GCDs for the Study, has documented that in each GMA, the core science considered in the adoption of DFCs was science developed by the TWDB as part of the GAM Program. The degree to which the results from additional scientific information was considered ranges from no additional substantive information being considered by in GMA 11 to multiple scientific presentations that were local or sub-GMA in scope for GMAs 12 and 13. For example, in GMA 12, results from scientific studies regarding surface water/groundwater interactions were considered as the different possible DFCs were being evaluated. Our review of meeting minutes from GMA 12 documented 11 other presentations by interested stakeholders and consultants. For GMA 13, we documented 12 presentations by the TWDB, the San Antonio Water System and consultants. There were six additional TWDB documents that were mentioned in the meeting minutes of GMA 13, which consisted of GAMs that were conducted and presented to GMA 13.

As was noted in our review of science utilized in t the development of management plans and rules above, the primary source of science utilized by two of the three GMAs (11 and 13) was information derived from the Carrizo-Wilcox Aquifer GAMs. The TWDB provided a number of model simulation results to these two GMAs based on draft DFC requests from the GMAs throughout the DFC process. By design, this was an iterative process, whereby TWDB staff would present model results to the GMAs, and then the GMAs would modify the modeling requests to better understand the potential MAGs that could result from the draft DFCs being considered. Further, there is no record in the meeting minutes from GMA 12 that the TWDB independently presented any GAM results during the joint planning process.

3.0 Evaluation of Desired Future Conditions, Management Plans, Rules, Regional Water Plans, and the Potential for Conflict

3.1 Regional and State Water Plans and Their Potential Conflicts with Carrizo-Wilcox GCD Management Plans

One of the primary focuses of the Study was to "*Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans; conduct stakeholder meetings to present the goals and results of the Study, and to identify, tabulate and describe every existing and projected water user group strategy or alternative strategy that is presently or is likely to impact groundwater use from the Carrizo-Wilcox Aquifer including but not limited to strategies for the use of brackish groundwater."* In the scope of work for the

Study, the use of the phrase "*…Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans"* resulted in some unique challenges with respect to the timing of the plans in question. The following are provided to illustrate these challenges:

- The Study was initiated by the Texas Commission on Environmental Quality (TCEQ) with an original deadline for this task of September 1, 2010
- GCDs, through their participation in the joint planning process, were statutorily required (TWC §36.108(d) to adopt Desired Future Conditions (DFCs) and submit them to the TWDB by September 1, 2010
- Regional water planning groups were required by rule (31 TAC §357.5(b)(2)) to submit updated regional water plans to the TWDB for approval by September 1, 2010 (note that a few regions were granted time extensions of approximately one month), and finally,
- The TWDB is statutorily required to submit an updated state water plan reflecting the 2011 regional water plans (that were submitted on September 1, 2010) by January 5, 2012 (TWC §16.051(a)).

This effort was designed to evaluate regional and state water plans and GCD management plans in order to identify conflicts that may exist between the two planning processes. Ideally, this evaluation would occur after the 2011 regional water plans were adopted ***and*** all Carrizo-Wilcox GCDs had amended their respective management plans to reflect adopted DFCs and estimates of Managed Available Groundwater (MAG). Due to the very recent submission of DFCs at the time of this writing, all estimates of MAG are still in draft form and the Carrizo-Wilcox GCDs have not had sufficient time to amend their management plans to integrate the adopted DFC.

In order to provide a meaningful evaluation that generally reflects the intent and goal of this task, accommodations were made for the following realities of the various timelines. These include:

- At the time of this analysis (early fall, 2010) the data provided by the TWDB were provisional in nature, in that TWDB staff were still engaged in the final review and approval of regional water plans, and as such, certain water management strategies may have changed.
- It is also understood that the MAGs provided by the TWDB to the BEG for the Study are currently in draft form, pending review and comment from the Carrizo-Wilcox GCDs regarding quantification of exempt use. After exempt use has been established for each county and aquifer, that amount will be deducted from the MAGs utilized in this report. The sum of exempt use and MAG estimates will then represent the total amount of pumping consistent with the adopted DFC. While the MAG estimates may change due to comments from the GCDs, the estimates of total amount of pumping consistent with the DFCs (referred to as MAGs in this report) are not expected to change. This total amount of pumping is what is directly analogous to groundwater availability in the regional water plans. It is expected that the 2016 regional water plans will include this total amount of

pumping (exempt use + MAG). Until exempt use has been quantified, for the purposes of this report only, MAG is equated to total amount of pumping consistent with the DFC.

- With respect to a review of the regional and state water plans, it is recognized that we are currently in the interval between adoption of regional water plans and adoption of a state water plan. As such, the current state water plan is now four years old, and in many cases, inconsistent with recently adopted regional water plans. For the purposes of this report, in order to utilize the most current information and to avoid unnecessary confusion, information regarding currently available supplies and water management strategies from the recently adopted regional water plans was utilized for this analysis. Information from the 2007 State Water Plan was reviewed, but will not be presented in this report.
- In the 2016 regional water plans and the 2017 State Water Plan, the total amount of groundwater available to meet current and future needs can be no more than the MAG for the most recently adopted DFC. The BEG was directed to "*Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans"*. What is not defined explicitly during this transitional stage of planning (both regional water planning and joint planning for GCDs) is what constitutes a conflict. For reference, 31 TAC §356.2(a)(6) states a conflict is "*A situation where the managed available groundwater identified in a management plan or the adopted state water plan is not the managed available groundwater based on the desired future conditions set by the groundwater conservation districts in the groundwater management area*." This definition will be universally applicable during the 2016 regional water plans and 2017 State Water Plan. However, due to the timing of submission of DFCs and calculation of MAGs by the TWDB, none of the Carrizo-Wilcox GCDs were able to provide official MAGs in time for inclusion in the 2011 regional water plans. Therefore, technically, no conflict can exist at this time. For the purposes of the Study, we did compare, on a county by county basis, the sum of Carrizo-Wilcox Aquifer availability and water management strategies that rely on the Carrizo-Wilcox Aquifer to the draft estimates of the MAG for the Carrizo-Wilcox Aquifer from the initial round of joint planning that just concluded on September 1, 2010. Therefore, solely for the purposes of this evaluation, a "potential conflict" is defined as "where, on a county-level evaluation, the sum of current water supplies available from the Carrizo-Wilcox Aquifer and water management strategies that rely on groundwater from the Carrizo-Wilcox Aquifer in a county are greater than or exceed the MAG for the same county."

This evaluation was conducted using three different types of data: (1) amount of water supplies currently available from the Carrizo-Wilcox Aquifer based on information contained in the recently adopted 2011 regional water plans, (2) amount of additional water to be obtained from the Carrizo-Wilcox Aquifer recommended as water management strategies in the recently adopted 2011 regional water plans, and (3) draft estimates of MAG from the recently completed joint planning process. Information for 1 and 2 were provided by TWDB Water Resources

Planning and Information staff (email dated October 7, 2010) and MAG estimates were provided by TWDB Water Science and Conservation staff (email dated October 5, 2010).

In order to compare the relevant data, an examination of the different data sources is appropriate. Water supplies available from the Carrizo-Wilcox Aquifer, as reported in the regional water plans on a decadal basis, are defined, in part, in 31TAC §357.7(a)(3) as the "*…existing water supplies legally and physically available to the regional water planning area for use during drought of record….*" In other words, the water supply has to be legally available (i.e., permits obtained) and infrastructure to transport the water to the current or future users has to be in place in order for the water to be counted as a current water supply. If the groundwater cannot be legally produced at this time or the infrastructure is not in place at the time of the plan development, then the groundwater may not be counted as a currently available supply. Any incremental increase in water to meet future water supply needs over what is currently available must be included as a recommended water management strategy in the applicable regional water plan. To include a future supply as a recommended water management strategy, the amount of water must be quantified on a decadal basis in the regional water plan. For the purposes of this evaluation, it is assumed that all water management strategies will be implemented in the amount and time prescribed in the 2011 regional water plans.

For the purposes of this analysis, 64 counties were included in data provided by the TWDB containing information from the 2011 regional water plans and/or estimates of MAG. Table 1.1 contains information on the 64 counties, including the regional water planning area, groundwater management area, and on a decadal basis, (1) the sum of currently available water supplies and water management strategies, (2) the MAG, and (3) the difference between (1) and (2) which is referred to as "*Difference*". Figures 5.1 – 5.3 illustrate the decadal values for (1) and (2) for the years 2010 and 2060, for all counties within the jurisdictional boundaries of a Carrizo-Wilcox GCD. "*Difference*" values noted in Table 1.1 with parentheses (xxx) documents that the sum of currently available supplies and water management strategies for the Carrizo-Wilcox Aquifer in the county and decade referenced in the 2011 regional water plans is greater than the total amount of pumping consistent with the DFC (or for the purposes of this report as discussed earlier, the MAG). In these cases where the *Difference* value is negative for the decade referenced, a potential conflict exists. It is important to note that when the *Difference* is a negative number, this means for that county in that decade, there is insufficient managed available groundwater to implement all water management strategies based on the use of the Carrizo-Wilcox Aquifer in the 2011 regional water plans, while achieving the desired future condition.

Included in Table 1.1 are six counties, Bee, DeWitt, Graves, Live Oak McLennan and Travis, that have either currently available supplies or water management strategies from the Carrizo-Wilcox Aquifer, but for which there is no MAG. This situation may occur under multiple scenarios. For example, water supplies from the Carrizo-Wilcox Aquifer may be either currently imported or being planned for importation into a county, which is most often the case.

Alternatively, as is the case in Travis County (which does not have any Carrizo-Wilcox Aquifer present in the county; a political subdivision, such as the City of Elgin, may be located in two or more counties [in the case of the City of Elgin, Bastrop and Travis counties]). For regional water planning purposes, the source of water supplies or water management strategies is identified on a county by county basis. Therefore, even though the physical source of the groundwater supplies is located in Bastrop County, for regional water planning purposes, Carrizo-Wilcox Aquifer water supplies for the City of Elgin will be included for both counties.

Alternatively, there are two counties within GMA 11; Red River County with a MAG of 0 acre-feet per year and Trinity County with a MAG of 2,215 acre-feet per year, but neither have any currently available supplies or water management strategies from the Carrizo Wilcox Aquifer in the 2011 regional water plans. This situation typically occurs when an aquifer is overlain by another aquifer that is shallower and of superior water quality and quantity such that there is no planned or current use of the aquifer. This is especially true in areas where the freshwater portion of the Carrizo-Wilcox Aquifer is at its most downdip limits. For example, Bee County GCD and Live Oak Underground Water Conservation District both have jurisdictional boundaries that include at least some area within the boundaries of the Carrizo-Wilcox Aquifer; however, these GCDs were included in other GMAs, due primarily to the relatively minor amount of Carrizo-Wilcox Aquifer resources within the GCDs as compared to the primary aquifer for those GCDs, which in this case is the Gulf Coast Aquifer.

There are three counties in GMA 11 - Angelina, Henderson and Van Zandt; seven counties in GMA 12 – Bastrop, Brazos, Burleson, Freestone, Navarro, Uvalde and Williamson; and ten counties in GMA 13 – Atascosa, Dimmitt, Frio, Gonzales, Guadalupe, Karnes, LaSalle, Maverick, Medina and Webb with potential conflicts for at least one decade during the 50 – year planning horizon from 2010 – 2060. Bastrop, Dimmitt, Frio, Guadalupe, LaSalle, Navarro, Webb, and Williamson counties have potential conflicts for all of the decades during the 50-year planning horizon. These potential conflicts range in magnitude from 13 acre-feet per year in Maverick County to 176,615 acre-feet per year in Frio County. Of the 56 counties analyzed that are included as a current supply or water management strategy in the 2011 regional water plans and have an estimate of the MAG from the recently completed joint planning process, 20 have potential conflicts, representing 35 percent of the total. Of these 20 counties with potential conflicts, five are not within the jurisdictional boundaries of a GCD. Van Zandt County has a potential conflict in 2060; Maverick County has potential conflicts in four decades, 2020-2060; Navarro, Webb and Williamson counties are among the counties with potential conflicts in all decades of the 50-year planning horizon. Without a groundwater conservation district, there is no mechanism to implement management activities to achieve the DFC.

Strictly for the counties within the jurisdictional boundaries of a GCD in GMAs 11, 12, and 13, an evaluation was conducted to quantify, on a GMA basis, the sum of the negative, positive, and net values presented in Table 1.1. These values are presented for 2010 and 2060 in Table 1.2. While the net values for GMA 11 and 12 have a net positive value for both 2010 and 2060, it is

interesting to note that the net value for GMA 13 is negative, (84,793) acre-feet per year in 2010 and negative (158,902) acre-feet per year in 2060. Based on this analysis, if the estimates of the MAG (the total amount of pumping consistent with the DFC) remain the same in the 2016 regional water plans as it is today, then the volume of water from Carrizo-Wilcox Aquifer recommended to meet future water supply needs will have to be reduced significantly.

Table 1.1: Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year. RWPA: Regional Water Planning Area. GMA: Groundwater Management Area.

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Anderson**	MAG	10,077	10,077	10,077	10,077	10,077	10,077
		Anderson	Supplies + Strategies	9,291	9,393	9,514	9,614	9,614	9,614
			Difference	*786*	*684*	*563*	*463*	*463*	*463*
I	**11**	**Angelina**	MAG	26,414	26,414	26,414	26,414	26,414	26,414
		Angelina	Supplies + Strategies	22,569	22,533	24,339	24,599	26,679	27,051
			Difference	*3,845*	*3,881*	*2,075*	*1,815*	*(265)*	*(637)*
L	**13**	**Atascosa**	MAG	67,949	68,776	70,369	71,947	73,786	75,808
		Atascosa	Supplies + Strategies	67,872	69,043	69,921	69,987	70,051	72,526
			Difference	*77*	*(267)*	*448*	*1,960*	*3,735*	*3,282*
K	**12**	**Bastrop**	MAG	16,866	19,979	20,666	24,833	28,018	28,498
		Bastrop	Supplies + Strategies	21,129	31,489	38,622	46,388	54,275	58,321
			Difference	*(4,263)*	*(11,510)*	*(17,956)*	*(21,555)*	*(26,257)*	*(29,823)*
N	**15&16**	**Bee**	Supplies + Strategies	380	394	394	394	394	394

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
L	**13**	**Bexar**	MAG	26,278	26,278	26,278	26,278	26,278	26,107
		Bexar	Supplies + Strategies	15,916	16,264	12,987	12,993	13,000	13,006
			Difference	*10,362*	*10,014*	*13,291*	*13,285*	*13,278*	*13,101*
D	**11**	**Bowie**	MAG	11,126	8,216	7,976	7,533	7,533	7,083
		Bowie	Supplies + Strategies	4,153	4,296	4,365	4,365	4,194	4,053
			Difference	*6,973*	*3,920*	*3,611*	*3,168*	*3,339*	*3,030*
G	**12**	**Brazos**	MAG	33,925	38,835	44,847	49,421	53,970	57,169
		Brazos	Supplies + Strategies	44,380	44,502	44,386	47,432	47,439	47,434
			Difference	*(10,455)*	*(5,667)*	*461*	*1,989*	*6,531*	*9,735*
G	**12**	**Burleson**	MAG	3,750	23,249	28,047	32,518	36,492	38,701
		Burleson	Supplies + Strategies	4,369	4,369	4,669	27,433	30,053	31,557
			Difference	*(619)*	*18,880*	*23,378*	*5,085*	*6,439*	*7,144*
L	**13**	**Caldwell**	MAG	44,546	44,546	44,137	44,137	43,561	43,561
		Caldwell	Supplies + Strategies	7,706	11,718	18,676	16,902	18,108	20,997
			Difference	*36,840*	*32,828*	*25,461*	*27,235*	*25,453*	*22,564*
D	**11**	**Camp**	MAG	4,041	4,041	4,041	4,041	4,041	4,041
		Camp	Supplies + Strategies	2,071	2,077	2,083	2,088	2,093	2,098
			Difference	*1,970*	*1,964*	*1,958*	*1,953*	*1,948*	*1,943*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
D	**11**	**Cass**	MAG	3,533	3,533	3,533	3,533	3,533	3,533
		Cass	Supplies + Strategies	3,258	3,294	3,375	3,457	3,527	3,527
			Difference	*275*	*239*	*158*	*76*	*6*	*6*
I	**11**	**Cherokee**	MAG	11,222	11,222	11,222	11,222	11,222	11,222
		Cherokee	Supplies + Strategies	8,774	8,821	8,872	8,927	8,973	9,016
			Difference	*2,448*	*2,401*	*2,350*	*2,295*	*2,249*	*2,206*
L	**15**	**Dewitt**	Supplies + Strategies	71	71	71	71	71	71
L	**13**	**Dimmit**	MAG	3,359	3,359	3,359	3,359	3,359	3,359
		Dimmit	Supplies + Strategies	13,536	13,536	13,536	13,536	13,536	13,536
			Difference	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*
L	**12**	**Falls**	MAG	865	867	875	884	895	895
		Falls	Supplies + Strategies	667	667	667	667	667	667
			Difference	*198*	*200*	*208*	*217*	*228*	*228*
K	**12**	**Fayette**	MAG	1,000	1,000	1,000	1,000	1,000	1,000
		Fayette	Supplies + Strategies	380	453	542	611	690	803
			Difference	*620*	*547*	*458*	*389*	*310*	*197*
11	**D**	**Franklin**	MAG	9,746	9,484	9,484	9,484	9,484	9,484
		Franklin	Supplies + Strategies	1,677	1,651	1,644	1,637	1,617	1,597
			Difference	*8,069*	*7,833*	*7,840*	*7,847*	*7,867*	*7,887*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
12	**C**	**Freestone**	MAG	5,138	5,305	5,317	5,315	5,262	5,259
		Freestone	Supplies + Strategies	5,783	5,223	5,223	5,223	5,223	5,223
			Difference	*(645)*	*82*	*94*	*92*	*39*	*36*
13	**L**	**Frio**	MAG	81,551	79,089	76,734	74,439	72,222	70,030
		Frio	Supplies + Strategies	246,645	246,645	246,645	246,645	246,645	246,645
			Difference	*(165,094)*	*(167,556)*	*(169,911)*	*(172,206)*	*(174,423)*	*(176,615)*
13	**L**	**Gonzales**	MAG	52,483	62,316	70,317	75,791	75,970	75,970
		Gonzales	Supplies + Strategies	15,740	35,648	44,928	55,561	67,821	80,540
			Difference	*36,743*	*26,668*	*25,389*	*20,230*	*8,149*	*(4,570)*
11	**D**	**Gregg**	MAG	7,649	7,649	7,649	7,649	7,649	7,649
		Gregg	Supplies + Strategies	5,621	5,707	5,847	6,281	6,560	7,038
			Difference	*2,028*	*1,942*	*1,802*	*1,368*	*1,089*	*611*
14	**G**	**Grimes**	Supplies + Strategies	236	226	221	217	217	217
13	**L**	**Guadalupe**	MAG	10,241	10,833	11,283	13,021	13,541	14,041
		Guadalupe	Supplies + Strategies	19,832	23,162	25,779	26,384	28,029	29,570
			Difference	*(9,591)*	*(12,329)*	*(14,496)*	*(13,363)*	*(14,488)*	*(15,529)*
11	**D**	**Harrison**	MAG	8,911	8,837	8,786	8,698	8,683	8,639
		Harrison	Supplies + Strategies	5,332	5,786	6,042	6,258	6,601	6,959
			Difference	*3,579*	*3,051*	*2,744*	*2,440*	*2,082*	*1,680*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
11	**C&I**	**Henderson**	MAG	9,253	9,186	9,186	9,186	9,186	9,186
		Henderson	Supplies + Strategies	8,833	9,565	9,567	9,851	9,853	9,895
			Difference	*420*	*(379)*	*(381)*	*(665)*	*(667)*	*(709)*
11	**D**	**Hopkins**	MAG	3,433	3,391	3,391	3,391	3,391	3,391
		Hopkins	Supplies + Strategies	2,227	2,234	2,237	2,238	2,232	2,226
			Difference	*1,206*	*1,157*	*1,154*	*1,153*	*1,159*	*1,165*
I	**11**	**Houston**	MAG	5,356	5,356	5,356	5,356	5,356	5,356
		Houston	Supplies + Strategies	2,272	2,655	2,765	3,397	3,852	4,358
			Difference	*3,084*	*2,701*	*2,591*	*1,959*	*1,504*	*998*
L	**13**	**Karnes**	MAG	1,059	1,117	1,182	1,231	1,259	1,280
		Karnes	Supplies + Strategies	1,141	1,141	1,141	1,141	1,141	1,141
			Difference	*(82)*	*(24)*	*41*	*90*	*118*	*139*
L	**13**	**La Salle**	MAG	6,454	6,454	6,454	6,454	6,454	6,454
		La Salle	Supplies + Strategies	8,013	8,013	8,013	8,013	8,013	8,013
			Difference	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*
G	**12**	**Lee**	MAG	22,259	24,023	23,402	24,624	26,827	27,380
		Lee	Supplies + Strategies	10,584	10,987	10,987	10,988	8,913	12,619
			Difference	*11,675*	*13,036*	*12,415*	*13,636*	*17,914*	*14,761*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
H	**12**	**Leon**	MAG	14,682	14,475	14,647	14,892	15,172	15,196
		Leon	Supplies + Strategies	4,818	5,128	5,334	5,407	5,459	5,558
			Difference	*9,864*	*9,347*	*9,313*	*9,485*	*9,713*	*9,638*
G	**8&12**	**Limestone**	MAG	11,321	11,306	11,436	11,616	11,918	11,918
		Limestone	Supplies + Strategies	7,403	7,591	7,780	7,968	8,157	8,347
			Difference	*3,918*	*3,715*	*3,656*	*3,648*	*3,761*	*3,571*
N	**16**	**Live Oak**	Supplies + Strategies	60	60	60	60	60	60
H	**12**	**Madison**	MAG	2,838	2,859	2,768	2,654	2,552	2,542
		Madison	Supplies + Strategies	1,409	1,493	1,571	1,551	1,518	1,518
			Difference	*1,429*	*1,366*	*1,197*	*1,103*	*1,034*	*1,024*
D	**11**	**Marion**	MAG	2,077	2,077	2,077	2,077	2,077	2,077
		Marion	Supplies + Strategies	1,981	2,001	2,008	2,014	2,020	2,028
			Difference	*96*	*76*	*69*	*63*	*57*	*49*
M	**13**	**Maverick**	MAG	2,043	2,043	2,024	1,677	1,570	1,532
		Maverick	Supplies + Strategies	1,792	2,056	2,058	2,060	2,073	2,444
			Difference	*251*	*(13)*	*(34)*	*(383)*	*(503)*	*(912)*
G	**8**	**McLennan**	Supplies + Strategies	29	29	29	29	29	29

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
N	**13**	**McMullen**	MAG	1,819	1,819	1,819	1,819	1,819	1,819
		McMullen	Supplies + Strategies	430	438	442	446	450	453
			Difference	*1,389*	*1,381*	*1,377*	*1,373*	*1,369*	*1,366*
L	**13**	**Medina**	MAG	2,568	2,545	2,533	2,533	2,533	2,533
		Medina	Supplies + Strategies	7,597	7,597	7,597	7,597	7,597	7,597
			Difference	*(5,029)*	*(5,052)*	*(5,064)*	*(5,064)*	*(5,064)*	*(5,064)*
G	**12**	**Milam**	MAG	38,183	23,923	20,206	19,112	21,359	22,319
		Milam	Supplies + Strategies	13,686	13,686	13,686	12,828	12,941	12,941
			Difference	*24,497*	*10,237*	*6,520*	*6,284*	*8,418*	*9,378*
D	**11**	**Morris**	MAG	2,616	2,616	2,558	2,558	2,558	2,558
		Morris	Supplies + Strategies	1,381	1,381	1,381	1,381	1,381	1,381
			Difference	*1,235*	*1,235*	*1,177*	*1,177*	*1,177*	*1,177*
I	**11**	**Nacogdoches**	MAG	21,385	21,385	21,385	21,385	21,385	21,385
		Nacogdoches	Supplies + Strategies	16,375	16,375	16,986	17,258	18,043	18,402
			Difference	*5,010*	*5,010*	*4,399*	*4,127*	*3,342*	*2,983*
C	**12**	**Navarro**	MAG	15	15	15	15	15	15
		Navarro	Supplies + Strategies	88	88	88	88	88	88
			Difference	*(73)*	*(73)*	*(73)*	*(73)*	*(73)*	*(73)*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Panola**	MAG	9,097	8,227	8,227	8,069	8,069	8,069
		Panola	Supplies + Strategies	6,609	6,615	6,623	6,631	6,639	6,649
			Difference	*2,488*	*1,612*	*1,604*	*1,438*	*1,430*	*1,420*
D	**11**	**Rains**	MAG	1,703	1,703	1,620	1,620	1,620	1,583
		Rains	Supplies + Strategies	785	809	822	825	823	820
			Difference	*918*	*894*	*798*	*795*	*797*	*763*
D	**11**	**Red River**	MAG	0	0	0	0	0	0
G	**12**	**Robertson**	MAG	44,886	45,435	45,814	46,238	46,582	46,583
		Robertson	Supplies + Strategies	34,552	34,562	34,567	24,349	24,348	24,347
			Difference	*10,334*	*10,873*	*11,247*	*21,889*	*22,234*	*22,236*
I	**11**	**Rusk**	MAG	39,772	42,188	50,336	46,940	48,128	48,119
		Rusk	Supplies + Strategies	11,478	11,459	11,441	11,578	11,555	11,526
			Difference	*28,294*	*30,729*	*38,895*	*35,362*	*36,573*	*36,593*
I	**11**	**Sabine**	MAG	6,866	6,858	6,858	6,858	6,858	6,858
		Sabine	Supplies + Strategies	358	358	358	440	440	440
			Difference	*6,508*	*6,500*	*6,500*	*6,418*	*6,418*	*6,418*
I	**11**	**San Augustine**	MAG	1,781	1,781	1,781	1,781	1,781	1,781
		San Augustine	Supplies + Strategies	677	677	777	827	927	927
			Difference	*1,104*	*1,104*	*1,004*	*954*	*854*	*854*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Shelby**	MAG	12,044	11,217	10,901	10,447	10,311	9,729
		Shelby	Supplies + Strategies	5,304	6,404	7,004	7,004	7,559	7,566
			Difference	*6,740*	*4,813*	*3,897*	*3,443*	*2,752*	*2,163*
D&I	**11**	**Smith**	MAG	33,249	33,249	33,249	33,239	33,225	33,225
		Smith	Supplies + Strategies	26,916	27,212	27,597	28,468	29,910	31,244
			Difference	*6,333*	*6,037*	*5,652*	*4,771*	*3,315*	*1,981*
D	**11**	**Titus**	MAG	10,856	10,321	10,019	9,868	9,638	9,638
		Titus	Supplies + Strategies	5,214	6,379	6,959	7,391	7,628	8,503
			Difference	*5,642*	*3,942*	*3,060*	*2,477*	*2,010*	*1,135*
K	**8,9, &10**	**Travis**	Supplies + Strategies	1,499	1,718	1,901	2,025	2,153	2,300
H&I	**11**	**Trinity**	MAG	2,215	2,215	2,215	2,215	2,215	2,215
D	**11**	**Upshur**	MAG	7,115	7,115	7,115	7,115	7,115	7,115
		Upshur	Supplies + Strategies	6,610	6,697	6,756	6,799	6,835	6,885
			Difference	*505*	*418*	*359*	*316*	*280*	*230*
L	**12**	**Uvalde**	MAG	2,971	1,230	828	828	828	828
		Uvalde	Supplies + Strategies	2,846	2,846	2,846	2,846	2,846	2,846
			Difference	*125*	*(1,616)*	*(2,018)*	*(2,018)*	*(2,018)*	*(2,018)*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
D	**11**	**Van Zandt**	MAG	10,614	10,283	10,283	10,283	10,283	10,051
		Van Zandt	Supplies + Strategies	7,499	8,170	8,645	8,982	9,645	10,292
			Difference	*3,115*	*2,113*	*1,638*	*1,301*	*638*	*(241)*
M	**13**	**Webb**	MAG	916	916	916	916	916	916
		Webb	Supplies + Strategies	3,882	6,824	9,138	9,712	9,711	9,710
			Difference	*(2,966)*	*(5,908)*	*(8,222)*	*(8,796)*	*(8,795)*	*(8,794)*
G	**12**	**Williamson**	MAG	7	7	7	7	7	7
		Williamson	Supplies + Strategies	8,412	8,412	8,412	8,522	8,522	8,522
			Difference	*(8,405)*	*(8,405)*	*(8,405)*	*(8,515)*	*(8,515)*	*(8,515)*
L	**13**	**Wilson**	MAG	35,560	36,986	38,717	40,486	42,531	44,794
		Wilson	Supplies + Strategies	20,823	21,621	24,374	26,297	32,343	33,631
			Difference	*14,737*	*15,365*	*14,343*	*14,189*	*10,188*	*11,163*
D	**11**	**Wood**	MAG	21,716	21,539	21,451	21,408	21,333	21,311
		Wood	Supplies + Strategies	8,930	9,021	9,074	9,083	9,087	9,098
			Difference	*12,786*	*12,518*	*12,377*	*12,325*	*12,246*	*12,213*
L	**13**	**Zavala**	MAG	35,859	35,859	35,521	35,388	35,288	34,969
		Zavala	Supplies + Strategies	23,935	23,935	23,935	23,935	23,935	23,935
			Difference	*11,924*	*11,924*	*11,586*	*11,453*	*11,353*	*11,034*

Table 1.2: Summation of differences between the sum of currently available supplies and water management strategies for the Carrizo-Wilcox Aquifer in the county and decade referenced in the 2011 regional water plans compared to the total amount of pumping consistent with the DFC (or for the purposes of this report as discussed earlier, the MAG). In these cases where the *Difference* value is negative (xxx), for the decade referenced, a potential conflict exists. This comparison is only for counties in GMA 11, 12, and 13 that are within the jurisdictional boundaries of a GCD. All values are in acre-feet per year.

GMA	Difference is (+) 2010	Difference is (-) 2010	Net 2010	Difference is (+) 2060	Difference is (-) 2060	Net 2060
11	43,291	0	43,291	43,665	1,346	42,319
12	58,419	15,982	42,437	74,149	29,823	88,652
13	101,710	186,503	*(84,793)*	49,548	208,450	*(158,902)*
Total	203,420	202,485	935	167,362	239,619	*(27,931)*

The BEG was also directed to evaluate the water management strategies in the regional water plans "*that is presently or is likely to impact groundwater use from the Carrizo-Wilcox Aquifer including but not limited to strategies for the use of brackish groundwater*." Table 1.3 provides summary information on all Carrizo-Wilcox Aquifer water management strategies in the 2011 regional water plans and the counties receiving the supplies. It is important to note that the amount of water represented in Table 1.3 is a subset of the sum of currently available supplies and water management strategies reported in Table 1.1. No water management strategies are planned for implementation prior to 2020. The volume of brackish groundwater recommended as water management strategies in the 2011 regional water plans begins at 12,260 acre-feet per year in 2020 and increases to 37,357 acre-feet per year in 2060. Six counties are scheduled to receive brackish groundwater supplies based on recommended water management strategies in the 2011 regional water plans. These are Bexar, Comal, Guadalupe, Hays, Maverick, and Wilson counties, with the majority going to Bexar County.

Table 1.3: County-level sum of water management strategies in the 2011 regional water plans that are based on the use of brackish groundwater from the Carrizo-Wilcox Aquifer. All values are in acre-feet per year.

County	2010	2020	2030	2040	2050	2060
Bexar	0	12,000	21,750	27,150	27,903	27,903
Comal	0	0	880	880	1,762	1,762
Guadalupe	0	0	1,630	1,630	4,203	4,203
Hays	0	0	336	336	1,728	1,728
Maverick	0	260	260	260	272	641
Wilson	0	0	0	1,120	1,120	1,120
Total	0	12,260	24,856	31,376	36,988	37,357

As part of the Study, the BEG was to "*Determine other long-term impacts of the GCD rules and plans on the entire Carrizo-Wilcox Aquifer, considering projected agricultural, industrial and municipal demands for water from the aquifer.*" In order to evaluate long-term impacts on the Carrizo-Wilcox Aquifer, the primary focus for this evaluation was to review the potential socio-economic impacts of not meeting future water supply needs that are the result of policy decisions made in the joint planning process resulting in the adopted DFCs for the Carrizo-Wilcox Aquifer. Socio-economic impact data developed for this evaluation was provided by the TWDB. This information is required as part of the regional water planning process in Texas. 31 Texas Administrative Code §357.7(a)(4)(A) states, in part, that a Regional Water Plan shall include, "…*The social and economic impact of not meeting these needs shall be evaluated by the regional water planning groups and reported by regional water planning area and river basin. The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs."* A fundamental component of the regional water planning process is the evaluation of what are the socio-economic impacts at the regional, county, and sector (municipal, manufacturing, mining, etc.) level, of not meeting future water supply needs. During this evaluation, several impacts are modeled and quantified, including social impacts such as population, school enrollment, and economic impacts such as regional income, state and local business taxes, and the number of full and part time jobs. These evaluations are modeled for the major water use sectors; municipal, agricultural, livestock, steam-electric power generation, and mining. One of the outputs from the socio-economic impact analysis that is included in all Regional Water Plans is the total monetary losses per acre foot of water need that is not met by a water management strategy. In other words, what is the monetary impact to a water use sector if future water supply needs are not met?

The water supply shortages that may result as a consequence of the adopted DFCs in GMAs 11, 12, and 13 were quantified in the *Summary Report for Task 3* and are included as Table 1.1 above. Readers are encouraged to refer to this report for a full explanation of methodologies utilized. It is important to note that it is not possible to determine which water use sector would be impacted by the "potential conflicts" if the 2016 Regional Water Plans are not able to develop additional water management strategies to meet these needs. Therefore, if the *potential conflicts* are not resolved, the economic impacts will be dependent upon which water use sector(s) has the unmet need. For example, the total monetary losses per acre foot of water needs in 2020 for Bastrop County ranges from $125 for irrigation use to $4,277 for municipal use. Therefore, if all unmet needs are realized by the irrigation water use sector in Bastrop County, and the unmet need is 4,263 acre-feet in 2010 (see table 1.4), then the economic impact as expressed by the total monetary loss is estimated to be $532,875. However, if the unmet needs are evenly divided between the irrigation water use sector and the municipal water use sector, then the total monetary loss for 2010 would be $9,382,863 ([2,131.5 acre-feet × $125 for irrigation water use sector] + [2,131.5 × $4,277 for municipal water use sector]). Practically speaking, however, if a repeat of drought of record conditions were to occur, it is very difficult to make categorical

projections of which water use sector will be asked or expected to realize what portion of the shortage. For example, would manufacturers or power generators be asked to cut back on production, or would businesses and homes be expected to reduce water use in order to meet total demands? These types of modeling assumptions have a very significant impact on the final analysis of total monetary loss, and are clearly beyond the scope of the Study.

Table 1.4: Socio-economic impacts results from 2011 Regional Water Plans (* denotes county that did not have any water supply needs during the 50-year planning horizon; therefore, no monetary losses have been calculated).

Region C		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Freestone	Steam-electric	$0	$0	$0	$0	$24,617	$24,617
Freestone	Municipal	$0	$40,561	$40,569	$23,452	$17,637	$15,461
Navarro	Steam-electric	$0	$98,083	$98,083	$98,083	$98,083	$98,083
Navarro	Municipal	$0	$1,766	$1,620	$1,699	$3,084	$5,845
Navarro	Manufacturing	$0	$81,977	$81,967	$82,005	$163,979	$163,974
Region D		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Van Zandt	Municipal	$941	$957	$1,011	$1,459	$8,131	$18,473
Region G		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Brazos	Municipal	$119	$2,221	$3,170	$8,637	$9,389	$10,770
Williamson	Municipal	$6,205	$10,545	$15,826	$23,391	$30,033	$31,340
Williamson	Manufacturing	$107,880	$107,880	$107,880	$107,880	$107,880	$107,880
Williamson	Mining	$24,139	$24,139	$24,139	$24,139	$24,139	$24,139
Region I		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Angelina	Livestock	$0	$0	$0	$60,362	$60,362	$60,362
Angelina	Steam-electric	$72,631	$72,631	$72,631	$72,631	$72,631	$72,631
Angelina	Mining	$76,776	$82,394	$0	$0	$0	$0
Angelina	Manufacturing	$12,474	$24,942	$24,941	$49,883	$49,883	$49,883
Angelina	Municipal	$5,067	$18,406	$18,297	$18,020	$30,419	$23,349
Henderson	Livestock	$0	$60,362	$60,362	$60,362	$60,362	$60,362
Henderson	Steam-electric	$0	$0	$160,127	$160,127	$160,127	$160,127
Henderson	Municipal	$2,456	$10,609	$8,808	$12,159	$19,747	$24,469
Region K		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bastrop	Municipal	$576	$4,277	$7,214	$11,737	$14,765	$21,624
Bastrop	Irrigation	$125	$125	$125	$125	$125	$125
Bastrop	Manufacturing	$63,229	$63,229	$63,229	$63,229	$63,229	$126,458
Bastrop	Steam-electric	$0	$0	$0	$27,719	$27,719	$27,719

Table 1.4 (continued): Socio-economic impacts results from 2011 Regional Water Plans.

Region L		Total Monetary Losses Per Acre-Foot of Water Supply Need					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Atascosa	Municipal	$6,578	$8,445	$6,869	$7,037	$7,842	$9,232
Atascosa	Irrigation	$194	$194	$194	$194	$194	$194
Atascosa	Steam-electric	$7,760	$0	$0	$0	$7,760	$7,760
	Needs	*	*	*	*	*	*
Dimmit	Satisfied						
	Needs	*	*	*	*	*	*
Frio	Satisfied						
	Needs	*	*	*	*	*	*
Gonzales	Satisfied						
Guadalupe	Municipal	$11,780	$13,865	$18,150	$32,188	$30,322	$25,502
Karnes	Municipal	$9,011	$18,867	$28,839	$31,147	$32,065	$34,289
	Needs	*	*	*	*	*	*
La Salle	Satisfied						
Medina	Municipal	$9,493	$7,342	$7,545	$10,195	$10,721	$10,845
Medina	Irrigation	$174	$174	$174	$174	$174	$0
Uvalde	Municipal	$14,089	$14,139	$14,180	$14,202	$14,220	$14,247
Region M		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Maverick	Municipal	$833	$1,285	$1,622	$5,772	$6,348	$7,040
Maverick	Irrigation	$397	$200	$200	$200	$200	$200
Webb	Municipal	$899	$1,387	$5,941	$12,445	$14,410	$23,944
Webb	Irrigation	$293	$293	$293	$293	$293	$293
Webb	Steam-electric	$0	$0	$0	$0	$9,645	$9,645

3.2 Review and Characterization of Carrizo-Wilcox GCD Management Plans

As part of the Study the BEG was directed to, *"Characterize Groundwater Conservation District (GCD) plans with respect to their ability to conserve and protect the aquifer. Compare each GCD's plans, rules and procedures with those of each adjacent GCD for compatibility."* We compared each GCD's plans, rules and procedures with those of each adjacent GCD for compatibility. The complete responses provided by the 16 GCDs that submitted requested information to the Study's survey questionnaire are available for review at the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/. The remaining five GCD management plans and rules were acquired from the Texas Water Development Board (TWDB) and from district websites. We reviewed 20 complete sets of management plans and rules in order to evaluate and link specific plans, rules, and procedures that support the GCDs' ability to conserve and protect the Carrizo-Wilcox Aquifer. One additional management plan for

Anderson County Underground Water Conservation District was obtained from the TWDB, but no rules were available.

Programs developed by Carrizo-Wilcox GCDs to conserve and protect the groundwater resources under their jurisdiction vary greatly, from simple to complex, from narrow to broad in scope, and from passive to aggressive. During our review, the compatibility of programs designed to conserve and protect groundwater resources within groundwater management areas, between neighboring Carrizo-Wilcox GCDs, and between Carrizo-Wilcox GCDs and adjacent counties that are not under the jurisdiction of a GCD were evaluated. Solely based on a review of groundwater management plans and rules, no compatibility issues were identified within groundwater management areas and between existing Carrizo-Wilcox GCDs. However, there will always be the potential for conflict and incompatibility between adjacent counties where one county is within a GCD and a neighboring county is not. Progressive conservation of groundwater resources through programs developed and implemented in a GCD management plan can and has led to economic development shifting to neighboring counties that are not in a GCD. Potential incompatibility may also occur between existing, adjacent Carrizo-Wilcox GCDs that have significantly different approaches to permitting strategies, for example. However, compatibility issues resulting from disparate permitting strategies are not discernable solely from a review of management plans.

According to Section 36.1071 of the Texas Water Code (TWC), GCDs are to *"…develop a comprehensive management plan which addresses the following management goals, as applicable."* Therefore, we reviewed seven of the eight management goals required for a management plan, excluding the management goal requiring a GCD to establish their desired future conditions of aquifers within their jurisdictional boundaries because they have only very recently been adopted and management plans have not been amended to implement adopted desired future conditions at this point in time.

The following management goals were reviewed:

1. Providing the most efficient use of groundwater (TWC §36.1071(a)(1));
2. Controlling and preventing waste of groundwater (TWC §36.1071(a)(2));
3. Controlling and preventing subsidence (TWC §36.1071(a)(3));
4. Addressing conjunctive surface water management issues (TWC §36.1071(a)(4));
5. Addressing natural resource issues (TWC §36.1071(a)(5));
6. Addressing drought conditions (TWC §36.1071(a)(6));
7. Addressing conservation, recharge enhancement, rainwater harvesting, precipitation enhancement, or brush control, where appropriate and cost effective (TWC §36.1071(a)(7)).

In order to accomplish this task, the BEG requested specific information from the GCDs in the survey developed for the Study. According to the Survey results, 15 of the 16 GCDS responded to the request to "*Summarize significant programs included in the District's management plan specifically designed to conserve and protect the Carrizo Wilcox Aquifer."* Six of the GCDs, including Panola County GCD, Rusk County GCD, Fayette County GCD, Gonzales County GCD, Post Oak Savannah GCD, and Brazos GCD provided summaries of programs included in their management plans that have been designed to conserve and protect the Carrizo-Wilcox Aquifer. Other districts responded to the Survey with more abbreviated descriptions of programs designed to preserve and protect that Carrizo-Wilcox Aquifer. Each of the GCDs independently developed management plans to address conservation and protection of the aquifer. The GCDs methodologies and metrics were broad and varied in how they addressed the need to conserve and protect the Carrizo-Wilcox Aquifer within their respective jurisdictions.

All 21 GCDs addressed the management goal, "*providing the most efficient use of groundwater,"* in their management plans. The nature and scope of management objectives and performance standards varied greatly among the 21 Carrizo-Wilcox GCDs. A complete matrix of management goals, objectives, and performance standards currently included in the 21 Carrizo-Wilcox GCD management plans is included in ***Final Summary Report for Task 3*** produced for the Study. Approaches to providing the most efficient use of groundwater, if achieved, within the GCDs were varied, largely because of diverse regional socio-economic and developmental pressures and environmental concerns represented in the three different groundwater management areas and 21 GCDs. The Carrizo-Wilcox GCDs have established objectives and performance standards that are geared towards influencing the public's perception and consumption practices through education, collection of basic groundwater data for use during development of policy or regulations, and taking physical steps to regulate groundwater consumption via establishment of well permitting, registration, and metering programs. These soft and hard policy measures have been developed by the individual Carrizo-Wilcox GCD Boards of Directors to satisfy the management goal requirement to provide for the most efficient use of groundwater. The phrase "most efficient use" has clearly been viewed differently within the various Carrizo-Wilcox GCDs. Landowners and boards of directors in East Texas may perceive the use of groundwater in surface ponds as economically beneficial and efficient whereas landowners in South-Central Texas may find that development and transport of groundwater resources to metropolitan areas to be the most efficient use of their groundwater resources.

All 21 Carrizo-Wilcox GCD's addressed the goal "*controlling and preventing waste of groundwater*" in their respective management plans. The Carrizo-Wilcox GCDs, as would be expected due to varied local conditions, have adopted different methods of addressing the management of groundwater resources in order to prevent and control the waste of groundwater.

Eighteen of the 21 Carrizo-Wilcox GCDs explicitly stated in their management plans that controlling and preventing subsidence is not applicable to their districts due to the geologic and

hydrogeologic profile of the region. Two other districts characterized and stated why their GCD was not managing subsidence within their respective GCD. Only the Anderson County UWCD included an objective and standard for this goal, but upon review, its relationship to controlling subsidence was not established.

Of the 21 management plans, 14 Carrizo-Wilcox GCD have established management objectives and performance standards to address goal 4 *"conjunctive surface water management issues."* Of the 14 Carrizo-Wilcox GCD's, 5 state they will achieve this goal by attending meetings of regional water authority's, such as the Brazos River Authority, Guadalupe-Blanco River Authority, and the Nueces River Authority. Further, eight of the GCD's have elected to attend regional water planning meetings with the appropriate regional water planning group. Of the 21 Carrizo-Wilcox GCDs management plans, 8 reviewed stated that goal 4 related to conjunctive surface water management issues was not applicable to their jurisdiction: Four Carrizo-Wilcox GCDs included management objectives and performance standards that went beyond meeting with regional water planning groups and river authority's to address goal 4. The degree of intergovernmental cooperation at the local and regional level varies by GCD.

In summary, participation in governing local groundwater and surface water resources is varied. Groundwater resources and surface water resources interaction differs regionally because of different hydrological and hydrogeological interactions in the environment. From this review, it is apparent that regional water planning groups and river authorities are the focal point for the coordination of groundwater and surface water issues for Carrizo-Wilcox GCDs.

Of 21 Carrizo Wilcox GCDs, 14 included management objectives and performance standards for goal 5, "*addressing natural resource issues*." Seven districts elected not to include any management objectives or performance standards addressing natural resource issues.

Natural resource issues that could be monitored cooperatively by Carrizo-Wilcox GCDs and the RRC including the regulation and plugging of abandoned oil and gas wells, well construction of oil and gas production wells and related Class 2 disposal wells, and the documentation and monitoring of active pipelines, inactive pipelines, and other pipelines that may pose a threat to the quality of Carrizo-Wilcox Aquifer groundwater resources were not addressed as frequently as possible in the management plans reviewed for the Study.

However, the 18 other Carrizo-Wilcox GCDs elected not to address the contamination monitoring through cooperation with the RRC on oil and gas activity within their respective jurisdictions under goal 5 "*addressing natural resource issues.*" Other opportunities for addressing natural resource issues that were not included in the management plans reviewed include: (1) monitoring of point source or non-point-source pollution that may be of concern for natural resources within their jurisdiction, (2) natural sources of groundwater contamination, and (3) opportunities such as partnering with the TCEQ's Groundwater Planning and Assessment Team, which provides "support and coordination of interagency efforts toward preventing and

managing contamination of groundwater by pesticides," or the Texas Groundwater Protection Committee. Texas Water Code §5.236 requires the TCEQ to provide notice to local officials regarding groundwater contamination which may affect drinking water supplies in their area. Notification is provided to county judges and public health officials to supply information on groundwater impacts to drinking water supplies within the county. However, the Carrizo-Wilcox GCDs did not include management objectives or performance standards recognizing or utilizing this source of information from state agencies and committees regarding groundwater contamination. Eighty percent of the management objectives and performance standards focused on water quantity concerns and not water quality concerns.

All Carrizo-Wilcox GCDs included management objectives and performance standards for goal 6, *"Addressing Drought Conditions."* Each Carrizo-Wilcox GCD elected to address drought conditions through establishing a Drought Contingency Plan, monitoring the Palmer Drought Severity Index, or to maintain updates with the Drought Preparedness Council Situation Report. GCDs have created rules that trigger conservation by water users in their jurisdictions. Largely, Carrizo-Wilcox GCD boards of directors and general managers are responsible for implementing plans and notifying residents of the water conservation measures established by the individual districts. Thirteen out of 21 Carrizo-Wilcox GCDs stated that they would monitor the Palmer Drought Severity Index; however, several districts did not include detailed management objectives and performance standards necessary to determine whether or not the goal is being achieved. Precipitation and climate vary from east to west in the state as do the hydrologic and hydrogeological characteristics. Generally prolonged droughts in Texas are perceived as a threat to the environment, human welfare, and to the economy of the state. According to our evaluation, six of the Carrizo-Wilcox GCD's called for development of Drought Contingency Plans or Drought Management Strategy Plans when "addressing drought conditions". Our review of the GCD management plans suggests that more may have to be done at the local level of government to ensure that strategic groundwater resources important to the environment and economy are more adequately monitored during drought conditions. Another observation is that certain Carrizo-Wilcox GCD management plans could benefit from the utilization of more than just one well as a drought monitor well, considering that some GCDs have expansive jurisdictions. Drought conditions impact groundwater resources differently from region to region and this is recognized from this review.

All 21 GCDs addressed goal 7 *"Addressing Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, or Brush Control, Where Appropriate and Cost-Effective."* We found that the Carrizo-Wilcox GCDs are not, as would be expected, uniformly addressing this goal due to the varied conditions and aquifer characteristics in regions from northeast to southwest. Overall, recharge enhancement and brush management were not generally supported objectives of the Carrizo-Wilcox GCDs. Only a few districts specifically stated they would participate in rain harvesting or precipitation modification programs.

4.0 Evaluation and Critique of the State's Groundwater Availability Models for the Carrizo-Wilcox Aquifer

The BEG examined and critiqued the Groundwater Availability Models (GAMs) to

(a) Assess model runs of representative pumpage scenarios in the northern, central, and southern Carrizo Wilcox aquifer

(b) Estimate spatial and temporal variability of recharge and modeling of recharge

(c) Evaluate sources of water for pumpage (outcrop zone [increased recharge, reduced discharge], confined zone [change in aquifer storage, increased recharge from overlying Queen City Sparta), and timescales for impacts of pumpage on outcrop and Queen City Sparta aquifer.

The current Queen City Sparta Groundwater Availability Models (QCSP GAMs) include the Carrizo-Wilcox Aquifer. It was built upon the original Carrizo-Wilcox GAM (Dutton et al., 2003) by adding the Queen City and Sparta Aquifers and it superseded the original Carrizo-Wilcox GAM. A simplified cross section of the Carrizo-Wilcox Aquifer and the conceptual groundwater flow model for the Queen City and Sparta GAM can be find in the main text (Figure 8.1 and 8.2). In this text, we refer QCSP GAM as "Carrizo-Wilcox Queen City Sparta GAMs" or simply GAMs.

A general critique of the GAMs was conducted. The value of the GAMs in the process of establishing desired future conditions was recognized. Important factors to consider in future updates of the GAMs include role of faults in flow system because barrier faults significantly reduce water availability for future pumpage, importance of groundwater-surface water interactions, improved recharge estimates, incorporating the Yegua Jackson Aquifer and Brazos River Alluvium Aquifer into the Carrizo-Wilcox Queen City/Sparta GAM, refining the groundwater pumping database, linking steady state and transient models, including groundwater quality, and incorporating new information into the Carrizo-Wilcox Queen City Sparta GAMs. One of the critical issues with respect to the conceptual model is whether the central Carrizo Wilcox GAM should include **faults** as barriers to flow and evaluation of the location of such faults. Universal application of faults as barriers in the Central Carrizo Wilcox Queen City Sparta GAM significantly impedes horizontal flow. Modeling analysis indicates that the impact of these faults may be more important in predicting future drawdown than it was for transient calibration. Current stresses to the system from pumping are too low to evaluate the impacts of these faults on horizontal flow in the system. Future Carrizo-Wilcox GAMs should consider models with and without faults to provide bounding estimates on groundwater availability. **Groundwater-surface water interactions** are also an important component of the Carrizo-Wilcox Queen City Sparta GAM. Because pumpage captures groundwater discharge to streams, it is important that simulations of groundwater–surface-water interactions are realistic and reliable. Although current GAMs simulate groundwater-surface water interactions, incorporating

an additional shallow layer into the Carrizo-Wilcox Queen City Sparta GAM may improve simulations of these interactions and allow an improved approximation of the potential to reduce baseflow discharge to streams and capture of surface water by future pumpage. Evaluating impacts of pumpage on stream baseflow is extremely important for future environmental flows. **Recharge** is a critical parameter for GAMs. The impact of grid resolution on recharge estimates in the models also needs to be considered. Recharge rates are important for model calibration because they help to constrain the hydraulic conductivity field (Kelley et al., 2004). Field studies should be conducted to better quantify groundwater recharge to the aquifer. Improvements in the **groundwater pumping** database are very important and should include reevaluation of groundwater production in Brazos and Robertson Counties (by Bryan College Station, TAMU and industrial commercial pumping). Because most of the pumping in the aquifer in GMA 12 is in the Simsboro Formation, additional information should be collected or any existing data used to better describe the thickness and hydraulic conductivity distribution of this unit. The current Carrizo-Wilcox GAM within the Queen City Sparta GAMs uses the predevelopment period for the **steady state** simulation; however, the **transient simulation** does not begin until 1980. Groundwater pumping expanded significantly between predevelopment and 1980, and this expansion is not captured in the GAMs. Two different approaches could be used to address this problem: (1) begin the transient simulation in the 1920s and 1930s and simulate the expansion of pumpage from that time similar to that of the original Carrizo Wilcox GAM (Dutton et al., 2003) or (2) use 1980s data to simulate steady state conditions if the aquifer was relatively stable at that time. These different options should be considered. Future revisions of the GAMs should incorporate any basic data collected in the aquifers since the GAMs were developed. Such information should include structure data and hydraulic properties, including hydraulic conductivity and storativity, and calibration data, including hydraulic heads and stream gain/loss data. While TWDB collects data on these parameters throughout the aquifer, the GCDs are also collecting substantial quantities of data that should be incorporated into TWDB databases. Detailed pumping tests and water level data from mines in the region, including the Sandow Mine, Walnut Creek Mine, and others, should be evaluated and fully used in the GAMs. **Uncertainties** in conceptual models, input parameters, such as recharge and ET and hydraulic parameters, should be considered in GAM modeling. Uncertainties in the conceptual models could be considered through bounding calculations, e.g. models with and without faults in the Central Carrizo Wilcox Aquifer. Model sensitivity analyses should be used to guide future data collection in areas where the GAM is sensitive to different parameters. It is important that stakeholders and others are aware of uncertainties in GAM data and calibration and do not try to use the GAMs beyond the level at which the data can support them. **Groundwater quality** was not simulated by the GAMs; however, groundwater quality is a critical aspect of groundwater availability. The GAM program should consider expanding simulations to explicitly simulate groundwater quality. **Postaudits** can be done at this stage to test the reliability of GAM predictions. The Carrizo-Wilcox GAM was calibrated from 1980 through 1999. As stated earlier, new information has been collected since then. Postaudits involve using the existing GAM

structure and new boundary conditions to assess how model output compares with new available target information. It should be recognized that these enhancements of the GAMs will require additional data collection beyond what is currently being collected.

(a) GAM runs of representative pumpage scenarios for GMA 11, 12, and 13 were based on the desired future conditions obtained from TWDB staff. GAMs for establishing DFCs were run by TWDB staff for GMAs 11 and 13 and by consultants for GMA12. Mean drawdowns corresponding to DFCs for the GMA regions are as follows:

Simsboro: GMA 12: ~100 to 300 ft

Middle Wilcox: GMA 11: 15 ft and GMA 13: ~ 25 ft

Carrizo: GMA 11: 38 ft; GMA 12: ~ 60 ft, GMA 13: 31 ft

(b) Spatial and temporal variations in groundwater recharge were reevaluated for the GAMs. Recharge rates were estimated using a variety of different approaches. Recharge rates based on groundwater chloride data from the TWDB database range from 0.4 in/yr (2 percent of precipitation) in the semiarid southern part to 4.0 in/yr (8% of precipitation) in the humid northern part of the aquifer. Point recharge rates based on unsaturated zone chloride data in the central Carrizo Wilcox Aquifer are spatially variable (0.7 to 1.6 in/yr) but generally consistent with those based on groundwater chloride data. Recharge rates based on unsaturated zone modeling results range from 0.4 in/yr (2 percent of precipitation) in the southern part to 5.1 in/yr (10 percent of precipitation) in the northern part of the aquifer.

(c) Impacts of pumpage on water resources depend on the source of water for pumpage. Prior to groundwater development, groundwater recharge to the aquifer equaled groundwater discharge through streams, evapotranspiration (ET), and deep recharge to the confined portion of the aquifer. Water for pumpage associated with groundwater development can be derived from various sources, including aquifer storage, increased recharge, and/or decreased discharge. The transient GAM model indicates that after decades of pumping (1999) groundwater storage represents a significant fraction of total pumpage. Total cross-formational flow is reversed in all portions of the aquifer from the overlying Queen City Aquifer. Analysis of sources of water for pumpage related to the desired future conditions for 2060 shows that aquifer storage contributes 44 to 58 percent of pumpage. Cross-formational flow contributes 40 percent of pumpage in GMA 13 because most pumpage is from the Carrizo Aquifer, which is adjacent to the overlying Queen City Aquifer. In contrast, pumpage in GMA 12 is mostly from the Simsboro Aquifer and is separated from the Queen City Aquifer by the Carrizo Aquifer; therefore, cross-formational flow is much less (19 percent). Low cross-formational flow in GMA 11 (19 percent) may be related to generally low pumpage in the Carrizo Aquifer. Understanding the sources of pumpage is important for determining the impacts of pumpage on the flow system. Temporal variability in water sources for pumpage shows that aquifer storage contributions decrease from 100 percent to

~50 percent over the 50-yr modeling period, whereas contributions from cross-formational flow, streams, and ET increase through time. It will be important to design monitoring programs to evaluate these changes through time.

5.0 Assessment of Anthropogenic Contamination in the Recharge Area of the Carrizo-Wilcox Aquifer and Potential Pollution of the Aquifer

The distribution of contaminants was evaluated primarily from the TWDB database. The main objective of the TWDB monitoring program is to evaluate regional variations in groundwater quality, and the monitoring program is not designed to assess local contamination. Water quality in the Carrizo-Wilcox Aquifer outcrop (unconfined) area from the TWDB groundwater quality database was evaluated for compliance with U.S. Environmental Protection Agency (EPA) Maximum Contamination Level (MCL) concentrations, including 17 primary and 11 secondary inorganic and radioactive constituents. Given the analysis of the TWDB groundwater quality database, there are no widespread violations of any of the primary MCL constituents, with only 27 individual violations for all primary MCL constituents. The most significant violation is for nitrate-N, which accounts for 19 of the primary MCL exceedances. These nitrate exceedances are found largely in domestic and irrigation wells and are most likely related to septic tank and fertilizer applications. The number of secondary MCL exceedances ranges from ~200 to 350 for various elements. These exceedances are dominated by TDS, chloride, sulfate, iron, and manganese. The percentage of wells that exceeded the TDS MCL is much greater in the southern (62%) than in the central or northern Carrizo Wilcox Aquifer (25 and 27%), and median TDS concentrations are also greatest in the southern region (587 mg/L) relative to the central and northern regions (331 and 325 mg/L). Iron and manganese MCL exceedances are also widespread. Median iron concentrations range from 79 to 133 ug/L. These exceedances may be related to lignite distribution. Occurrence of pH values outside the 6.5 to 8.5 range are greatest in the north and may cause problems of scaling and corrosion.

There are 147 documented groundwater contamination cases from the TCEQ database and 23 documented cases from the RRC data in the outcrop area of the Carrizo Wilcox Aquifer in the 2010 Draft Groundwater Quality Portion of the Water Quality Inventory of the State of Texas, required by EPA according to Section 305B of the Clean Water Act. The most common contaminants reported include gasoline and diesel related to petroleum storage tanks. Additional contaminants include volatile organic compounds (such as benzene, toluene, ethylbenzene, xylene, and BTEX), chlorinated solvents, TCE, TPH, creosote, heavy metals, chloride, and arsenic. These contaminants are generally related to local sources and do not represent widespread impacts on the aquifer.

We reviewed previous studies of groundwater quality in the aquifer that focused mostly on regional evolution of groundwater chemistry from oxidizing acidic water in the recharge zone to

reducing basic water in the confined zone in the East Texas Basin. Poor-quality water in the unconfined aquifer was attributed to wells in Calvert Bluff muddy sediments. Groundwater generally evolved from calcium-rich water to sodium-rich water, attributed to cation exchange on clays. Highest salinity was found in the southern part of the aquifer, which was attributed to cross-formational leakage into the aquifer. Lignite and lignite mining can also impact groundwater quality. Leaching of mine spoils may generate moderately brackish waters (<10,000 mg/L) that could degrade groundwater quality near a mine. Although the primary lignite host, the Eocene Wilcox Group, is a major aquifer, lignite and groundwater resources in the Wilcox Group generally occur at different stratigraphic intervals and geographic locations, reducing potential contamination. There are no reported cases of groundwater contamination from the surface mining group of the RRC.

Potential pollution of the aquifer was evaluated from an online survey conducted as part of this study. Most groups did not submit any response to this question, many responded negatively, and a few pointed to some issues, such as the need to plug old oil wells, inconsistencies in rules among groundwater conservation districts, and importance of developing regulations to protect the recharge zone of the aquifer. Lignite mining was listed as a potential cause of groundwater pollution in the aquifer because of removal of the filtering capacity of lignite and replacement with mine spoils; however, others have suggested a relationship between lignite deposits and kidney disease and/or renal pelvic cancer with a syndrome termed Balkan Endemic Nephropathy (BEN). There is no reported case of groundwater contamination from the surface mining group of the RRC.

The distribution of fracing wells in the Carrizo Wilcox outcrop area was evaluated as a potential source of groundwater contamination. The EPA is currently conducting a study on potential groundwater contamination from fracing operations. Projected increases in groundwater pumpage in the confined part of the Carrizo Wilcox Aquifer should enhance flow from surrounding confining units, such as the Hooper and Calvert Bluff units, which could degrade groundwater quality, depending on the quality of groundwater in the confining units. The likelihood of this cross-formational flow into the aquifer degrading groundwater quality should be evaluated in future studies.

The main management or protection regulatory gap identified through the online survey was concern expressed by 6 of the 16 groundwater conservation districts related to the groundwater-management policies and enforcement procedures of the RRC. The ability of the RRC to effectively regulate hydrocarbon production companies and their well operations is contested owing to its perceived inability to effectively regulate groundwater support wells or to eliminate the occurrence of abandoned wells. Whereas water quality of Public Water Supply wells is regulated by TCEQ, these regulations are restricted to water quality at entry points and do not assess raw water quality. The Texas Groundwater Protection Committee identified the lack of oversight of water quality of private wells as a major regulatory gap that should be addressed in the future.