Texas Water Development Board

Evaluation of Water Demand Projection Methodologies & Options for Agency Consideration

TWDB CONTRACT NO.1600011921 ▪ July 2016

BY

CDM Smith

in conjunction with

Bureau of Economic Geology

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Section 1

Introduction

The Texas Water Development Board (TWDB) is responsible for development the State Water Plan, which is based on 16 regional water plans that are created over the course of a 5-year regional planning cycle. The regional plans are compiled to develop the State Water Plan.

Water demand projections are a fundamental building block for the Regional and State Water Plan. The plans include water supply planning for six (6) broad water use categories:

- Municipal
- Irrigated agriculture
- Steam-electric power generation
- Manufacturing
- Mining
- Livestock

For each sector, the TWDB establishes a baseline water demand and a projection that describes anticipated future water needs. Developing demand projections for the water planning process since the passage of Senate Bill 1 in 1997 has involved a three-step process. First, the Texas Water Development Board (TWDB) develops draft water demand projections, then the regional water planning groups review the demand projections in concert with their local understanding of current and future conditions within the region and request revisions as necessary, and then finally, the TWDB adopts final water demand projections that then serve as the launching pad for the next regional and state water planning process. Different methods for developing water demand projections have been utilized by the TWDB in developing draft water demand projections for the first four rounds of regional water planning beginning in 1997.

As shown in **Figure 1-1**, three water use categories - irrigated agriculture, manufacturing and steam-electric power generation - utilize significant portions of the state's water and have large impacts on the state's economy. According to the Draft 2017 State Water Plan, water demand projections for irrigated agriculture (7,778,038 acre-feet per year (AFY)), manufacturing, (3,029,981 AFY) and steam-electric power generation (1,739,856 AFY), collectively represent 58.1 percent (12,547,875 AFY) of the 21,597,430 AFY of total water demand projected for Texas in 2070.

Even though the three sectors, irrigated agriculture, manufacturing, and steam electric power, are significant components of the overall water demand, the demand projection methodologies for these water use sectors have not been recently updated for several reasons. One reason is that the methodologies for agriculture and manufacturing were based on proprietary data sources that were difficult to obtain or data services that are no longer available from governmental sources. Additionally, projecting water demands can be quite challenging given the significant influence of market conditions on these sectors- and thus, it was often difficult to match observed water use with those predicted by the projection methodologies.

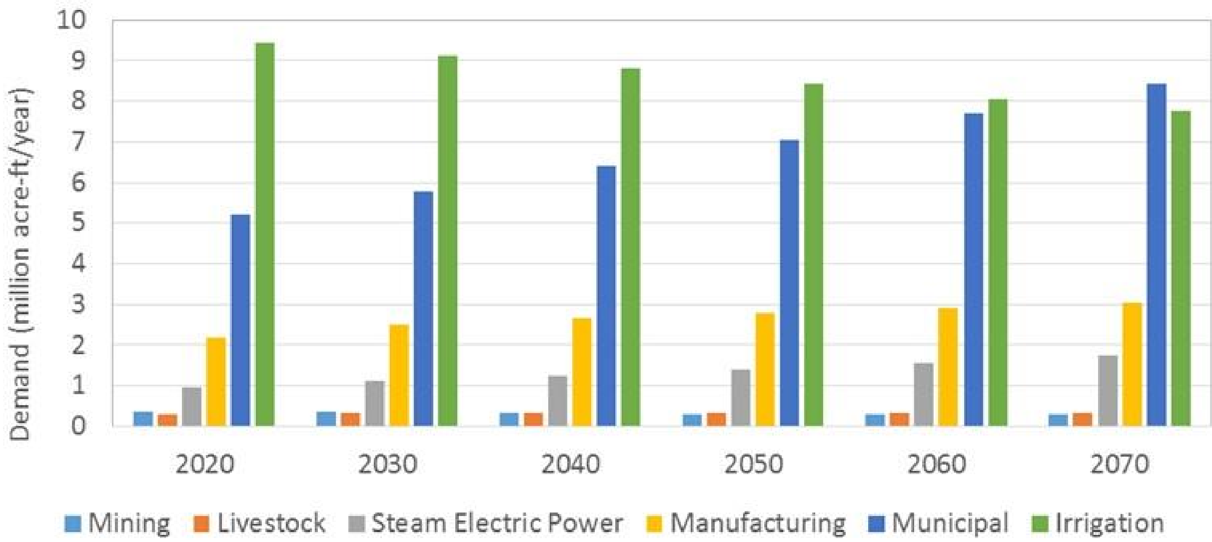

Figure 1-1 Water Demand Projections from the Draft 2017 Texas Water Plan

This report will outline proposed demand projection methodologies for each of the three sectors that might be considered as potential options for the TWDB to use in developing projections. The proposed demand projection methodology for each of the sectors aims to address some of the challenges described previously through a combination of predictive and adaptive planning review. The use of an adaptive planning process is not new in Texas water planning. Water planning in the State of Texas has always been based on an ongoing, adaptive process of reviewing and updating the primary elements of the water cycle on a statewide, regional, and local basis. Every five years, the major components of the water planning process are reviewed in order to recognize and incorporate changed conditions. This adaptive management approach is fundamentally driven by policies implemented as a result of legislative initiatives. For example, both state and regional water plans are to be updated as often as necessary but at least every five years per Texas Water Code Section 16.051 (a) and Texas Water Code Section 16.053 (i), respectively. Similarly, groundwater conservation districts are to review, amend as necessary, and adopt statements of desired future conditions and management plans as necessary, but at least every five years (Texas Water Code Section 36.108 (d) and Texas Water Code Section 36.1072 (e), respectively).

Following is a review of these methodologies for the three water use sectors included in this study, along with a review of how other states are developing water demand projections for similar water use sectors, and finally a discussion of potential alternative methodologies that CDM Smith recommends for the 2017 – 2022 water planning cycle.

Section 2

Current and Previous TWDB Methodologies

The following sections outline the methodologies that have been used in the Texas Water Planning process for the three subject sectors, manufacturing, irrigated agriculture and steam electric power generation.

2.1 Manufacturing Sector

Water demands for the manufacturing sector of the Texas State Water Plan includes water needed at large, self-supplied industrial facilities for processing and producing food, goods, and other materials. Water used in the manufacturing process supports critical economic activities throughout the state. According to the draft 2017 State Water Plan, manufacturing demands are estimated to increase by 40 percent from 2020 to 2070. Region H and Region I constitute 63 percent of the projected 2020 total statewide manufacturing demands. The methodology used for estimating future water demand for the manufacturing sector in the State's water plan has been in place since 1996. The following section provides an overview of current and previous manufacturing demand project methodologies.

2.1.1 Previous Methodology (1996 through 2012)

For the 1996 and 2002 State Water Plan, demands for manufacturing were projected by Perryman and Consultants based on weighted water use coefficients for water use per unit of output and projections of future output, both by county.

Subsequently, Waterstone and the Perryman Group prepared a formal report providing decadal water demand estimates for 2000 through 2050 (2003). Water use coefficients were derived from reported historical water use and economic output data. TPG projected gross county product specifically for use in the demand forecast. Three demand scenarios were produced representing an expected future, and minimum and maximum demands.

Water use (in acre-feet (AF)) by county by source (reservoir, river, or aquifer) by manufacturing sector was derived from data collected annually through the TWDB Water Use Survey (WUS), and aggregated by manufacturing sector for each county. Water use data were collected from 1984 to 1999, but only data from 1996 to 1999 were used. U. S. Department of Commerce data on gross county product by manufacturing sector were obtained for all counties in Texas and by Metropolitan Statistical Area (MSA). These data were then proportioned to regions, and Texas Employment Commission manufacturing employment data by county were used to proportion the regional gross product by sector to the county level. With this information, an estimate of water use per gross product by county by sector was determined (AF/gross product). The water use coefficient is assumed constant in the future.

Estimates of the future gross product were generated by TPG's "Texas Econometric Model" for the state based upon a variety of inputs including population, wages, employment rates, retail sales, inflation, interest rates, real estate transactions and oil prices under multiple scenarios

(Waterstone and the Perryman Group, 2003). These statewide projections of gross product were proportioned to regions, and then counties. The base year water use per gross product by county by sector was multiplied by the projection of gross product by county by sector to derive a projection of water demand by manufacturing sector. The resulting water demand by sector by county was then multiplied by a water use efficiency factor by sector that was estimated in 1993 to derive the estimate of manufacturing water demand by county.

TPG projections of statewide gross product included three scenarios, which were applied to develop three scenarios of growth in the manufacturing water use sector. In addition to the forecast driven by gross product, TWDB added a 'no growth' scenario in which manufacturing demands were held constant from the base year for all forecast planning periods.

Demands estimated in the 2012 State Water Plan were based on demands from the 2007 State Water Plan. For the 2012 demands, regions were asked to review the 2007 demand projections. Some regions then requested changes to the demands citing changed conditions.

2.1.2 Current Methodology (2016)

For the 2017 State Water Plan, draft manufacturing water demand projections utilized 2004-2008 data from TWDB's WUS. Even though response rate to the WUS for industries is quite high, it is not 100 percent. Thus, for each county, the number of employees from the WUS is compared to employment data from the Bureau of Economic Analysis (BEA) and the county water use is adjusted. County water use estimates in manufacturing are then derived from output-water use coefficients utilizing TPG gross product model. The rate of change for projections from the 2011 regional water plans was then applied to the new base for the counties within the given region.

2.2 Irrigation

Irrigated agriculture consumes the largest amount of water of all sectors in the state, using 7.6 million acre-feet (MAF) on over 6 million acres of crops in 2010 with 75 percent of the demand met with groundwater [TWDB, 2010]. Total groundwater storage in the Texas High Plains has decreased by 46 MAF since irrigation began in the 1950s, with water level declines of approximately 4.27 feet per year [Scanlon et al., 2010]. Annual groundwater recharge is estimated to range from 0.1 to 4.6 inches across Texas, where annual average precipitation ranges from 8.8 inches in the west to 46.4 inches in the east [Keese et al., 2005]. Thus, due to the slow rates of recharge in most of the aquifers across Texas, groundwater across much of the irrigated lands in Texas is nonrenewable from a generational perspective. The 2012 Texas State Water Plan predicts irrigation conservation to increase two-fold from 0.624 MAF in 2010 to 1.125 MAF by 2020 [TWDB, 2012]. These water conservation strategies include improvements in water use efficiency and the adoption of new technologies that can allow farmers to grow more with less irrigation. Precipitation variability and increased water demand from growing population centers in urbanized areas of Texas present water planners with difficult decisions of allocating a potentially exhaustible resource.

With predicted shortages of irrigation water supplies, measuring actual irrigation water use in Texas is a valuable tool for future planning and conservation efforts. Many studies predict Texas will become more climatically extreme [Banner et al., 2010]. Additionally, federal farm policies and regulations combined with agricultural economics fundamentally impact agricultural production and ultimately irrigated water demands. In particular, federal farm policies adopted in each successive Farm Bill by Congress can have profound effects on water use in irrigated agriculture. The need for Texas to have a robust irrigation water demand projection methodology that is simple yet defensible, and that recognizes and quickly responds to the realities of changing conditions, including the effects of climate, governmental policies, and commodity prices, is critical to the fundamental integrity of the water planning process.

2.2.1 Previous Methodology (1997 through 2007)

The 1997 Texas Water Plan, which represented a significant transition in the water planning process in Texas, included irrigation water demand projections that were determined from a mathematical optimization model developed and implemented by Texas A&M University. The model was structured to solve for the maximization of farm income based on the profitability of specific crops grown in Texas using the resources necessary for their production. Several types of variables were used in the modeling procedure to determine future irrigation water demands by geographic location. These variables included crop prices, yields, production costs, water costs, and six types of irrigation delivery systems. The base year of 1990 was chosen and used thereafter for the 50-year forecast.

Three scenarios were defined to represent possible economic conditions based on varying degrees of economics, federal farm policy and improved irrigation technologies:

- Scenario 1: Variable crop prices, annual yields and production costs; constant policy and irrigation technologies.
- Scenario 2: Variable crop prices, annual yields and production costs; expected irrigation technologies; constant federal farm policy.
- Scenario 3: Variable crop prices, annual yields and production costs; aggressive irrigation technologies implemented; farm subsidies reduced by half in the federal farm policy.

The model essentially balanced water supply and irrigation technologies with irrigation costs, commodity prices, land constraints and federal farm policies, to maximize on-farm economics. This method required numerous data sources including Crop Enterprise Budgets (Texas Agrilife), crop statistics (Texas Agriculture Statistics Services), U.S. Agriculture Outlook Report (Food and Agriculture Policy Research Institute), Irrigation Survey Information (TWDB), and many other economic impact assessment reports. The extensive data required for this methodology likely limited the viability of implementing it over the long-term. This method was discarded after the 1997 Water Plan; subsequent projections were revised based on regional information and requests

2.2.2 Current Methodology (2012 and 2016)

More recently, irrigated agriculture water demand projections for the water planning process have been based on annual estimates of agriculture irrigation use produced by TWDB in lieu of a producer water use survey.

The annual agricultural water use estimates are developed by TWDB staff by comparing the most recent five-year average of estimated irrigated with an estimate of draft irrigated acres provided by the Farm Service Agency (FSA). TWDB staff estimates the draft irrigated acres. TWDB staff then estimates draft irrigation rates primarily upon the previous five-year average (for each crop within each county), rather than a theoretical potential evapotranspiration (ET) crop water use requirement (as was the case in historical years 2003-2009). This results in the estimates being more closely tied to actual water availability and cultural practices (e.g., deficit irrigation). TWDB staff utilizes satellite imagery (MODIS) and available weather data (ET networks) to establish a county-level weather adjustment factor (based on the MOD 16 tool developed by NASA and University of Montana) to account for any changes in weather conditions experienced during the growing season compared to the previous five years.

The total estimated consumptive water use is calculated based on irrigation rates for each crop in each county based on county-level data multiplied by irrigated acres to derive irrigation water use per crop. The mean crop consumptive water use employed in the methodology was determined by Borelli et al. [1998] for Texas using state-wide monthly reference ET from weather stations, respective basal crop coefficients from National Agricultural Statistics Service (NASS) for 16 major crops as well as field and vegetable crops, citrus, deciduous fruit and nut trees, and grapes. The crop irrigation requirements are calculated based on mean potential ET and an empirical correction factor based on historical data over the past 5 years. The adjusted crop irrigation requirement is multiplied by irrigated acres to determine total irrigation water use.

The source of irrigation water is then classified based on surface water irrigation diversion data from Texas Commission on Environmental Quality (TCEQ), TWDB Water Use Survey data and other sources.

These data are compiled into county crop sheets summarizing the data used to calculate irrigation water use by crop and provided for review by all groundwater conservation districts as well as key river authorities and other regional water providers with significant irrigation diversion to refine the irrigation estimates. The revised estimates are used as the baseline for future water demand projections.

2.3 Steam Electric Power Generation Sector

The estimated water use for steam-electric power generation facilities represents the volume consumed in the cooling process and not returned to streams and rivers. The following describes the basic methodology and some fundamental assumptions in estimating water use for steam electric power generation in Texas. This current methodology is based on the University of Texas Bureau of Economic Geology study conducted for TWDB in 2008 [King et al., 2008]. The methodology subdivided the time period into current, near term (approximately 10-year projection), and long-term (beyond 10-year to 50-year projection).

2.3.1 Previous Methodology (2007)

The methodology and projections prepared for the 2007 Texas Water Plan was developed by representatives of investor-owned Texas utilities, under contract with TWDB. They based projections on the anticipated demand for electricity and the amount of water needed to produce each unit of electricity in kilowatt-hours (kWh). Demand for electricity was assumed to grow in direct proportion to the population and to commercial and manufacturing sectors. The projections also included savings in the first 20 years generated by more efficient production methods.

2.3.2 Current Methodology (2012 and 2017)

For the current water demand methodology, consumption was estimated based on the power plant fleet and water consumption related to fuel type, generator technology (or prime mover), and cooling system.

The baseline demand was established for 2006, which was selected because it was the first year with data available and also represented a relatively dry year which would provide a conservative basis for the projections. For forecasting water demand for steam-electric power generation, two primary scenarios were considered in the methodology:

- Near term: The near term projection (10-year) was based on the initial or current geographic distribution of water consumption from the existing power plant fleet plus plants that were under construction or announced to the Public Utility Commission of Texas (PUCT) or Electric Reliability Council of Texas (ERCOT), or plants that were being permitted or have recently been permitted at TCEQ. The "Near Term" water demand projections are based on a water consumption factor that was estimated for existing or proposed power plants: gallons of water consumed per kWh of net generation (gal/kWh). These factors were calculated using data from TCEQ, TWDB, and industry representatives.
- Long term: For the long term projections, the water consumption factors, gal/kWh factors, were assumed to remain constant from the near term projections (2015 in the report by King et al., 2008). A gal/kWh factor was obtained per fuel category and per county. In this manner, the 'per county' projected electricity generation per fuel was multiplied by the gal/kWh factor for each fuel in each county to obtain the amount of water demand in each county.

All of the scenarios considered projected increases in renewable energy. These projections assumed that wind power will constitute 20 percent of electrical consumption or demand by 2060, which was considered feasible even without widespread large-scale storage to mitigate intermittency issues [Department of Energy (DOE), 2008]. In addition, renewable energy for 2060 was projected to consist of: wind (65 percent), photovoltaic (PV) solar (17.5 percent), and concentrated solar power (CSP) (17.5 percent) with wet closed loop cooling towers consuming water at a rate of 0.8 gal/kWh [DOE, 2006]. Thus, for all scenarios by 2060, renewables as a category were assumed to provide approximately 30 percent of Texas electric generation.

The projections by King et al. [2008] assumed an annual electricity growth rate of 1.8 percent based on data from ERCOT 2008 Planning Long-Term Hourly Demand Energy Forecast [ERCOT, 2008]. The projected growth rate for the ERCOT region was assumed to extend throughout Texas until 2060. The projections based on King et al. [2008] considered four bounding scenarios:

1. High natural gas prices with no incentive for carbon capture;
2. High natural gas prices with incentive for carbon capture;
3. Low natural gas prices with no incentive for carbon capture; and
4. Low natural gas prices with incentive for carbon capture (see Table ES-1).

The projections also included two electricity demand targets for each scenario: a "business-as-usual" (BAU) case and a "low energy usage" (L) case. An annual electricity growth rate of 1.8 percent was assumed for the BAU case based on the ERCOT 2008 Planning Long-Term Hourly Demand Energy Forecast [ERCOT, 2008]. The "low energy usage" case assumes that programs are established to decrease electricity consumption by 50 million mega-watt hours (MWh) by 2023 and another 42 million MWh from 2023 through 2060 [American Council for an Energy Efficient Economy (ACEEE), 2007].

King et al. [2008] noted a large discrepancy between their 2006 water demand estimate for power generation (482,000 AF) and that from the 2007 State Water Plan (678,000 AF). The difference of 196,000 AF was attributed to overestimation of the year 2000 mean water consumption rate (0.6 gal/kWh) relative to that in King et al. [2008] for 2006 mean rate (0.39 gal/kWh). This difference accounts for approximately 241,000 AF using 2000 Texas electricity generation of 378 million MWh. King et al. (2008) explains that *"Although, the previous analysis upon which the TWDB relied upon recognized that a majority of Texas steam turbine power plants used "once-through" cooling systems with a typical consumption rate of 0.35 gal/kWh versus fossil-fueled steam turbines cooled using cooling towers resulting in ~ 0.6 gal/kWh; the authors used the 0.6 gal/kWh value instead of the weighted average of power plant consumption rates thus causing an overestimate of water consumption for power generation."* Another factor contributing to differences between projected water demand and actual water use is differences in the estimated annual electricity demand growth rate (1.8 percent - King et al., 2008; 2.0 percent - Representatives of Investor-Owned Utility Companies of Texas, 2003). This difference would result in 150,000 AFY lower water consumption for 2060 relative to projections based on a 2 percent annual growth rate for electricity prior to that annual growth rate for electricity [Representatives of Investor-Owned Utility Companies of Texas, 2003].

Section 3

Projection Methodologies Used by Other States

State water planning efforts occur in most if not all states in the U.S. on some level. The extent of the planning, however, is different from state-to-state as each faces unique water resource challenges, opportunities, budgetary constraints, legal requirements for planning, and many other variables. What is the most important factor in the planning effort for one state, may not even be considered in another. Some states do not quantify demands but rather focus on municipal water supply expansion needs, for example. For those states that do quantify demands, there are several key drivers that contribute to the development, selection, and implementation of the approach adopted. Some key factors include:

- **Data Availability**: Data availability and quality considerations are typically driving factors in selecting the best methodology to project any sector's water demand. Water use projections are often based on self-reported water use data collected at the state-level. Confidence in these data may drive the approach in one direction or another. Data for the "driver" of demand is a standard component of the approach and the available sources must be considered when developing the adopted methodology.

- **Intensity of Water Use**: Another factor that drives selection of one methodology over another is the prevalence and intensity of the water use sector within the state. Often the sector that accounts for the greatest proportion of water use will have a methodology of greater detail and complexity, especially if growth in that sector is probable, unsure, or has a greater chance of intensifying water use. In addition, the real or perceived limitations of a local or regional water supply may also contribute to the demand methodology selected. Conversely, sectors that use a smaller amount of the resource will typically have more simplified methodologies employed.

- **Economic Considerations**: The importance of the sector to the economic foundation of the state can sometimes drive a detailed methodology, even when water use for that sector is a small percentage of the overall state water use. As an example, in Oklahoma, the oil and gas industry uses a small of amount of water in comparison to other sectors, yet a great level of effort went into characterizing and forecasting water use for oil and gas activities for the state's most recent water plan because the sector is of extreme importance to Oklahoma's economy. Stakeholder involvement drove the methodology to a more detailed level.

This section provides details on the methodologies, processes, and approaches used in other state planning efforts for the manufacturing, agriculture, and steam electric sectors. Specifically, details are provided on the Georgia State Water Plan (GA SWP), Colorado State Water Supply Initiative (SWSI), the Oklahoma Comprehensive Water Plan (OCWP), and the Arkansas Water Plan (AWP). CDM Smith was either partially or entirely tasked with the state planning efforts for the studies presented and can thus provide insight into why one methodology for estimating current and future demand was selected over another, the data sources utilized, and the level of detail at which the estimates were made. The examples provided within this section were selected because of the similarity to Texas state water planning efforts in terms of scope and process or to the similarity in the extent of water use within the given sector.

3.1 Manufacturing Sector

The following subsections provide an overview of the methodologies and data sources employed for characterizing and projecting manufacturing water use for four state water plans: Georgia, Colorado, Arkansas, and Oklahoma. Three of the four states used forecasted county employment growth by industry as a proxy to estimate growth in county industrial water use. Colorado was the exception, where a general data collection effort was undertaken for most of the state and more detailed study was conducted for select basins.

3.1.1 Arkansas

In Arkansas, water withdrawal data are stored and compiled using a remote web-based data entry and storage system called the Arkansas Water User Data Base (WUDBS). This system is under the purview of the Arkansas Natural Resources Commission (ANRC) and is managed by the USGS. Site specific water use data are directly reported to ANRC annually from water users that withdraw 1 AFY or more of surface water or wells with the capability of pumping 50,000 gallons per day (GPD) or more of groundwater. The data collected include monthly information on withdrawal amounts, water sources, water use, and return flows.

For the AWP 2014 update, base period water use from each county was obtained from data in the WUDBS. The average reported water use from 2008 to 2010 was derived for each industrial registrant. The average water use for the industries was summed by county and 3-digit North American Industry Classification System (NAICS) to arrive at the base year water use estimate.

The driving factor for the industrial sector water demand forecast was employment. Two sources of employment projections specific to Arkansas were used in the forecast. Employment growth rates for the near-term forecast (2010 to 2020) were derived from projections developed by a state agency for ten regions that covered the state by 3-digit NAICS. The long-term forecast (2020 to 2050) utilized employment projections by 2-digit NAICS from an independent firm that specializes in long-term county economic and demographic projections (Woods & Poole). The growth rate from the projections was applied to the base year water use estimates.

3.1.2 Colorado

The Colorado Water Conservation Board (CWCB) conducted the SWSI to quantify the existing and future water demand throughout the state of Colorado, specifically the water demand for urban water providers and major self-supplied water users. Self-supplied users in Colorado include a small number of industrial plants, mines, and ski resorts (for snow-making). Also included in this sector were water demands for energy development.

Because there was not readily available data on self-supplied industries present in Colorado, let alone the water they consume, previous studies were reviewed for key information on the industries, including their current water use levels. The water use for these plants were assumed constant in the future.

The water demands from mining activities were adopted from a detailed multi-basin level study conducted for the Colorado, Yampa, and White River Basin Roundtables Energy Subcommittee in support of the state water planning efforts (URS 2008). Low, medium, and high water use projections were developed for mining natural gas, coal, uranium, and shale oil. These demands were then disaggregated to the county level based on the location of the mine.

Given the nature of industrial water use in Colorado, the state planning process allowed for detailed study of mining water use, both currently and in the future, but did not require such analysis for the other industrial subsectors.

3.1.3 Georgia

The GA SWP hinges on the development of regional water plans. Eleven regional water plans were developed by regional planning councils to identify management practices to be employed following state policy and guidance to ensure that anticipated demands can be met. While the methodology and data sources were specified by the state, regional planning councils were allowed some flexibility in the implementation.

Regional future industrial water need was calculated as follows:

Future Water Need by Industry = Current Water Need x Employment Growth Rate [3-1]

The Georgia Environmental Protection Division (EPD) provided employment projections for the major industrial water use sectors in the state by NAICS code to each region's planning council. Other employment, such as retail, services, government, etc. was included as part of the municipal demand, and was not included in the industrial methodology. The regional growth rate of employment by industry for the forecast periods was derived from EPD employment projections.

The regional water use for each industrial sector was identified using the 2005 EPD industrial permit data and U.S. Geological Survey (USGS) 2005 listings of large industrial water users. Data from other years in accordance with readily available data were also examined. Industrial water use was further identified by watersheds and aquifers based on current use and/or credible input from industry leaders regarding factors used in selecting future industry locations.

Future water use by industry was calculated by multiplying current industry water use (within a watershed and aquifer) by the industry specific rate of growth for the region. Analysis was completed to provide future projections for 10, 20, 30, and 40 year horizons through 2050. In the base scenario, industry growth was assumed to occur only at current industry locations, increase at the respective industry employment rate of growth, and remain proportional throughout the watershed/aquifer units, as shown in the equation below:

Future Water Need by Industry = Industry Water Need in the Watershed or Aquifer Unit x Regional Industry Rate of Growth [3-2]

As part of the forecast development, EPD conducted outreach meetings with industry stakeholders. Due to proprietary constraints and the complexities of manufacturing processes (e.g., different water requirements for different types of products), industries were not able to provide water use per product or projections of future product production.

EPD's industrial water withdrawal data covers industries that are self-supplied and have permits allowing them to withdraw over 100,000 GPD from either a surface or groundwater source. Industries that are self-supplied, but withdraw less than 100,000 GPD are not required to have EPD permits and their actual withdrawals are not tracked by EPD. This category of industrial water use is not captured in the forecast, however, it was expected to be have a minimal impact on the overall forecast.

In one region, the planning council elected to develop an alternate forecast that included an additional (above the baseline forecast) 5 million gallons per day (MGD) of industrial demand starting in 2020 and added incrementally every 10 years. While the planning council did not identify the specific industries or locations, the general consensus was that the region was attractive to industry from a cost of operations and abundant water resources perspective.

3.1.4 Oklahoma

Industrial demands developed for the 2012 OCWP were split into public supplied industrial demands and self-supplied industrial demands. For each of these sectors the forecast was estimated at the county level. Only details on the self-supplied industrial demands are provided herein.

Self-supplied industrial demands were estimated using water use and employment data obtained from Oklahoma Water Resources Board (OWRB) annual water use reports completed by registered water users. These demands include water use from large users that have access to their own supply source requiring a permit from the OWRB. The methodology involved tracking the following data for each industry: county, water source (groundwater or surface water), industry name, 4-digit Standard Industrial Classification (SIC) code, employee count (most recent), and average annual consumption. To determine the consumption, the average reported water use over the previous eight-year period was derived for each industry. Average water use was then divided by reported employee count for each industrial user to determine the gallons per employee per day.

Employment projections developed by a state agency for the near term (10 years) were used to project demands to 2016. These projections were developed at the 2- and 3- digit NAICS. Beyond 2016, through 2060, employment was assumed to grow in direct constant proportion to county population projections.

Employment growth rates, by industry type, were applied to base year employment counts for each industry based on the match of the SIC to NAICS. The base period water use per employee was multiplied by the projected employment to generate the forecast. Results in the 2012 OCWP were presented rolled-up by county.

3.2 Irrigated Agriculture Sector

In statewide planning, the projection methodology employed to estimate irrigated agriculture demand is dependent on a multitude of factors that are very specific to each state. First, and foremost, the methodology must consider the availability and quality of agriculture-related data. In states where irrigation is a large water-using sector, data are generally more available when compared to states where irrigation is not as prevalent. This is especially true of data collected and released by the United States Department of Agriculture (USDA). Even where data are readily available, the quality of the data must be considered, as much of agriculture data related to acres irrigated and water withdrawn are self-reported.

Another factor to consider is the potential for additional growth in the agriculture sector within the state of interest. If there is minimal potential for additional growth in irrigated acres, then the challenge is in characterizing the current conditions with a high degree of accuracy and making simplified assumptions about how this may or may not change in the future. However, if irrigated acres within a state are increasing year-to-year at a significant rate, then a more detailed methodology is needed that considers how that number will continue to grow into the future and at what point the growth will decline or irrigated acres will reach its maximum.

Stakeholder participation and perceptions can also drive the adoption of a particular methodology or data source over another. Most, if not all, state planning efforts includes stakeholder involvement with varying degrees of participation and interest. Agriculture producers can often provide valuable information that can be mined to refine or even define projection methodologies.

A final factor is to consider what has influenced water use in the historical data. It is important to understand these factors in order to control and mitigate, if needed, the impact of these factors on the forecast. For example, historical years or periods of drought may be expressed in the data as an abandonment in irrigation practices (acres) if water was not available. Volatility in the commodity markets can drive up the production of one crop over another. Periods of high fuel costs can cause decreases in irrigated acres. Methodologies can be crafted in order to properly model and control for changes in these variables present in the historical data.

The sections below provide details on the methodology and data sources used to characterize and forecast agriculture irrigation demands for Arkansas, Georgia, and Oklahoma. Relevant details from additional select studies are also provided.

3.2.1 Arkansas

The agriculture irrigation forecast for the AWP was completed through direct coordination with an agriculture work group, which consisted of representatives from the organizations and affiliations with the greatest involvement in agricultural activities across the state. The work group was very active and instrumental in developing the methodology and selecting the best available data sources, as stakeholder buy-in to the process and resulting recommendations was very important to the overall project.

The forecast was conducted at the county level and aggregated to planning regions. The methodology provided a means of maintaining consistency in the forecasting effort while still allowing for regional variations in agriculture production to be captured. In Arkansas, irrigation practices vary across the state, with rice irrigation dominate in the Mississippi River Delta and traditional row cropping with various degrees of irrigation present in the western counties of the state.

A basic methodology to estimate irrigation water demands was employed that captures the components driving irrigation water withdrawals in Arkansas for the base year and in the future to 2050. The base year was characterized based on actual, known data and conditions. Forecast years, were thus estimates of future conditions that stem from the base year conditions. The basic methodology is executed at the county level and is defined as total irrigated acres by crop type times the average application rate for the respective crop specific to that county. The algorithm estimated the gross irrigation water requirement and thus includes what the crop requires and what is applied to the scheme in addition to what the crop required, referred to as system losses or inefficiencies.

Determining the best data source for use in the forecast was a challenging task. For irrigated acres, the base year value was collected from two sources. USDA's National Agricultural Statistics Service (NASS) County Agricultural Production (CAP) survey provided the 2010 irrigated acres for soybeans and rice. The WUDBS provided the 2010 irrigated acres for cotton, corn for grain, and all other minor crops.

The estimate irrigated acres for the forecast years were derived using a trend analysis methodology. Eleven years of data were used in the trend analysis, and the best-fit model, either total irrigated acres or specific group in acres by crop type, was selected for each county using a standardized process. If neither total irrigated acres nor irrigated acres by crop type produced good fit models, irrigated acres by crop type were held constant throughout the forecast period.

In any instance where growth was forecasted in a county, the overall growth in irrigated acres was compared to the Total Tillable Row Crop acres in 2010 for that county, derived from the NASS Crop Data Layer (CDL). When the forecasted irrigated acres reached the Total Tillable Row Crop acres, the county was assumed to be at a fully irrigated status. Total Tillable Row Crop acres was defined as the sum of the following fields from the CDL geographic information system (GIS) layer: alfalfa, corn, cotton, oats, rice, sorghum, soybeans, sunflowers, winter wheat, and double cropped. The concept draws on the assumption that, while irrigated acres will continue to grow at the assessed 10-year historical rate, land which is most likely to become irrigated is finite and thus the forecast must respect this land availability component at the county scale. The concept also assumes that irrigation is most likely to first be adopted on dryland acres that are used to produce row crops using convention agricultural cultivation methods prior to being adopted on land classified as pastures, orchards, wooded areas, etc., due to economic profitability.

To determine the average application rate by county and crop type, the data reported in the WUDBS. Within the WUDBS structure, monthly irrigation amounts were associated with total irrigated acres. The monthly application rate values from 2000 to 2010 were derived and then averaged by county and crop type to calculate the average monthly application rates during the period of analysis. Averaging the application rates in this way provided a value for each county and crop type that was not linked to a particular weather event. Off-season water use was then removed from the average application rates.

The county-specific average application rates for a crop are a product of the type of irrigation system used, average weather over the period of analysis, soil type, and producer behaviors. The calculated values were carefully compared and validated against the range of values expected according to a literature search.

For the AWP, the decision was made, in close coordination with the goals of purpose of the study, stakeholders, and the ANRC, to constrain the growth in irrigated acres (and thus irrigation demand) according to land availability rather than available water supply. While it was known that current groundwater pumping rates in certain areas of the state were unsustainable, there were no existing policies in place to prevent over pumping to the point of exhausting groundwater resources. The findings of the study recommended large-scale development of surface water supplies to support agriculture irrigation, thus offsetting groundwater pumping.

3.2.2 Georgia

CDM Smith was responsible for developing projections of water use for the GA SWP, however, the agriculture irrigation demands for the entire state were developed by a team of academics from the University of Georgia (UGA) College of Agricultural and Environmental Sciences. Details provided herein reflect the methodology developed and employed by that team.

The initial modeling approach was informed through direct coordination and participation with state agency representatives and water planners. The approach was then refined according to public participation, which allowed individual producers to review mapped irrigation fields and submit omissions, and allowed state leaders and stakeholders to comment on data sources used. As with other states where agriculture production is a key economic activity, the public response and interest was ultimately a driving force in the final methodology and approach.

Agricultural irrigation water demand was projected for groundwater and surface water sources for the years 2011, 2020, 2030, 2040, and 2050. Each year's projection included a wet, normal, and dry year estimate, in alignment with the goals of the water plan. Summaries were provided by planning regions and counties, as well as designated local drainage areas. Additionally, reports were generated with individual county data such as the monthly withdrawal, number of systems and area irrigated by selected equipment, major sources, projected irrigated field area, and seasonal irrigation application depth for major crops.

Withdrawal quantities were computed for each county or drainage area as the product of three values:

- Projected irrigated area for a crop (acres)
- Predicted monthly irrigation application depth (inches)
- Proportion of irrigation water derived from a source (fraction)

Base year irrigated acreage was determined using aerial imagery for farms that were identified as irrigated by the Georgia EPD Agriculture Water Permitting Unit, the Georgia Soil and Water Conservation Commission's Agriculture Meter Program, and UGA spatial imagery identification efforts. The proportion of existing irrigated acreage of each major rotation crop was taken from the UGA Cooperative Extension Irrigation Survey. The projected growth rate for each year for each crop was based on the arithmetic average of projections from three economic-based models.

The irrigation amounts were computed and summarized statistically to represent monthly applications that would be needed to meet normal crop water needs in wet, average, and dry years. To compute the fraction of a drainage area or county irrigation water supply, each field with a known source was assigned a fractional water supply. Fields irrigated by wells only were assigned as 100 percent groundwater, those from surface, 100 percent surface, and those labeled as ponds refilled by wells were assigned 70 percent from groundwater and 30 percent from surface water.

3.2.3 Oklahoma

For the 2012 OCWP, agriculture irrigation withdrawals were estimated for the base forecast, representing existing water use patterns and attitudes, market conditions, and average weather from the base year throughout the forecast period. Additional forecasts were generated to characterize impacts of increased agriculture conservation practices and climate change.

The methodology for forecasting agriculture irrigation demands is based on the fact that irrigation demands had declined in the state, as whole, since peak irrigation experienced in the 1980s. The forecast was thus derived to assume that those peak periods represent a maximum buildout environment and that demands will not likely exceed those levels.

The methodology, data, and results were vetted through agriculture stakeholders as a part of the planning process, including a large group of state agriculture academics. With proper explanation of the goals of the OCWP and planning context, the methodology was accepted by the stakeholders.

The base demand methodology was developed to represent a reasonable maximum demand for each county under average weather and current economic conditions. The methodology is total irrigated acres in a county times the weighted-average crop irrigation requirement per irrigated acre by county.

Determining the weighted crop irrigation requirement for each county required several data sources. The most recent USDA NASS Census of Agriculture (COA) at the time of the forecast was from 2007. Data from COA provided estimates of irrigated acres by commodity type and county. The commodities included corn for grain and silage, cotton, barley, edible beans, forage, orchards, oats, peanuts, potatoes, rice, sod, sorghum, soybeans, sunflowers, watermelons, and wheat. In some instances, irrigated acres by crop type were withheld due to privacy agreements. The undisclosed values were estimated by comparing the statewide irrigated acres for a given commodity and evenly distributing the difference between the known values and unknown values to the undisclosed counties.

Total irrigated land by county was also obtained from the COA. This COA category includes all land watered by any artificial or controlled means, such as sprinklers, flooding, furrows or ditches, sub-irrigation, and spreader dikes. The COA category irrigated lands is more accurate for total irrigated acres when compared to the sum of irrigated acres by commodity type, which has withheld county data.

Crop irrigation water requirements were obtained for most of the crops from the Natural Resource Conservation Service (NRCS) Irrigation Guide Report, Oklahoma Supplement (USDA NRCS 1997). The Irrigation Guide provides monthly crop irrigation water requirements at 11 locations in Oklahoma. Crop types available in the guide include alfalfa, corn for silage, corn for grain, cotton, grain for sorghum, peanuts, pasture grasses, potatoes, soybeans, spinach, sunflowers, watermelons, and wheat. Irrigation requirements were collected from the guide by crop type for both average and dry years. Crop types from the COA data by county were matched with irrigation requirements in the NRCS guide for one of the 11 reporting locations based on proximity and rainfall zone.

Once the irrigated crop and water requirement data were collected and processed, the weighted crop irrigation requirement was calculated for each county. The weighted crop irrigation requirement captures annual water demands for irrigation considering the unique mix of crop type, crop irrigation requirements, and precipitation zone for each county. The weighted crop irrigation requirement for each county is assumed to remain constant in the future. That is, the mix of crops planted and irrigated, as well as the water required for these plants, is assumed to remain the same in future years for each county as it is in the base year.

Estimation of future water requirements for irrigation was based upon the projection of future irrigated acres within each county. Thus, estimates were developed to project the total number of irrigated acres by county through 2060. Historical levels of irrigated acres by county as reported in the COA were reviewed. The maximum number of acres irrigated from 1987 to 2007 was assumed to represent the build-out irrigated acres in 2060. For a number of counties, irrigated acres were highest in 2007 in comparison to that time period thus resulting in "no growth" in the forecast. For these counties, the maximum from 1977 to 2007 was assumed instead of the 1987 to 2007 period. For a few counties, irrigated acres was currently at its highest, even since 1977. For these counties, no growth was assumed. The number of irrigated acres per forecast year is interpolated from the 2007 current acreage to the 2060 build-out maximum using linear interpolation.

A final step was taken to adjust the irrigation water demands to capture on-farm losses from irrigation distribution systems. In order to adjust preliminary irrigation water demands to account for these losses, a field application efficiency factor was applied as a function of irrigation methods (surface, sprinkler or drip irrigation). Field application efficiencies were determined following an extensive literature review. Data were extracted from the Oklahoma 2003 Farm and Ranch Irrigation Survey to determine ratios of irrigation types to overall farm acreage.

The percentage of acres irrigated by each irrigation method by county was calculated from 2005 USGS data. These percentages by irrigation method were weighted to determine an overall weighted field application efficiency for each county. The applicable weighted field application efficiencies were used to adjust the preliminary estimates of water demand for irrigation.

The gross irrigation water requirement, or the amount of water to be withdrawn and applied to the irrigation scheme, were calculated as total crop irrigation requirements divided by the weighted field application efficiency. The gross irrigation water requirement thus includes the estimated crop irrigation water requirement plus water losses. The weighted field application efficiency for each county is assumed to remain constant over time.

3.2.4 Others

For the U.S. Army Corps of Engineers (Corps), CDM Smith conducted an assessment of present and future water demands for the Great Lakes watershed basin. Agriculture irrigation was included as a water use sector in the study. The assessment began with a characterization of total irrigation withdrawals, irrigated acres, and the average application rate for a 20-year historical period using readily available data collected by federal entities in both Canada and the U.S. While the report to the Corps did not include an actual forecast of irrigation demands, it did summarize numerous studies and projections of future demand produced for various entities and purposes.

Of interest is a study conducted by Tate and Harris (1999 and 2000) in which they forecasted agriculture irrigation demands for the U.S. and Canadian Great Lakes basins. The authors employed a forecasting model based upon the econometric method of an input-output analysis. In the model three factors contributed to arriving at a demand forecast. These factors were economic activity and its growth (GDP), the state of production technology, and water use coefficients.

The study developed demand forecasts based on seven future water use scenarios:

- Trend Line - Simple trend extrapolation based on changes in water used between for a ten-year period using exponential growth rates.
- Medium Economic Growth – Holds all growth rates at historical levels.
- High Economic Growth – Water use coefficient growth held at historical levels, economic growth set at 175 percent of historical rates.
- Low Economic Growth – Water use coefficient growth held at historical levels, economic growth set at 25 percent of historical rates.
- High Water Coefficient Growth – Economic growth held at historical levels, water use coefficients multiplied by 175 percent of historical rates.
- Low Water Coefficient Growth – Economic growth held at historical levels, water use coefficients multiplied by 25 percent of historical rates.
- Conservation – Economic growth rates were held at historical levels. The scenario assumes that in industries with negative growth in water use coefficients, on-going water conservation efforts are increased by 50 percent while in sectors with positive growth rates in water use coefficients, water conservation efforts are initiated and succeed in reducing the growth in water use coefficients by 50 percent.

The forecast of irrigated agriculture water use produced by each scenario produced a range of future water withdrawal levels. The data needed to conduct the analysis was readily available estimates of irrigated acres and water withdrawals. The simplified approach is powerful in that it brackets the possible levels of future agriculture irrigation given the high level of uncertainty in future economic, climatic, and technological conditions that drive irrigation withdrawals.

3.3 Steam Electric Power Generation Sector

The following paragraphs provide an overview of methodologies for projecting thermoelectric water use for the relevant state water plans.

3.3.1 Colorado

For the 2004 SWSI, information was collected for 15 steam electric power generating facilities within the state. Data were obtained directly from power producers, as well as supplemental data provided by a consulting firm that reported power needs for one of the basins. Data included county and basin location, facility type (coal-fired, natural gas, or gas-fired combined cycle), year 2000 water demand and water consumption in AFY, estimated increase in water demand and water consumption by 2030, and year of expected increase. When the timing of facility expansion (i.e., increase in future water use) was unknown, the increase was assumed to occur in 2015, the mid-point of the 2000 to 2030 planning period.

The 2008 update of SWSI hinged on the work completed for the 2004 report. It assumed baseline demands from 2004 unless the basin roundtables provided information to adjust the steam electric demands. The only adjustments were related to mining efforts for steam electric demand, assuming future anticipated mining activities would result in an increase in thermoelectric power demands due to:

- Additional power required to operate machinery, equipment, facilities, etc. associated with natural resource extraction and production.
- Increase in municipal electrical demands attributable to the direct and indirect worker populations.

These assumptions were translated into utility-provided electrical power demand, expressed in KWh, for each of the expansion scenarios studied for natural gas, coal, uranium, and oil shale mining and considered plant capacity and fuel source (URS, 2008). Average water use rates at the power plants within the region were estimated at 0.48 gallons per KWh.

The calculated increase in KWh was multiplied by the average gallons per KWh to produce additional water use requirements for those regions due to future mining activities. These estimated increases in water demand for power generation were added to the prior (2004) estimates of water needs for thermoelectric power generation.

3.3.2 Georgia

To forecast thermoelectric (steam electric) water demands, water use data were obtained from the EPD water withdrawal and consumption permit database which provided self-reported water withdrawals and consumption flows for each permitted facility in the state. Facility-level power generation, generating capacity, fuel type, prime mover, and cooling type data were obtained from online databases managed by the U.S. Department of Energy (DOE) and Energy Information Administration (EIA). An analysis of water withdrawals and consumption per unit of power produced, expressed in gallons per MWh, was completed for each permitted facility in the state using five years of data. The fuel type, prime mover, and cooling type, collectively referred to as a power generation combination, was identified for all permitted facilities. Five unique thermoelectric power generation combinations were identified. The results of the analysis, as well as a literature review, indicated that facilities with the same power generation combination have similar water requirements for energy production. Thus a statewide average rate of use weighted by individual facility power generation was calculated for each year for each power generation combination. The average of the five years was calculated to derive a statewide rate of withdrawal and consumption for each power generation combination.

To forecast future water needs from thermoelectric, a statewide energy needs forecast was developed. To begin, a regression modelling techniques were employed to examine the relationship between statewide electric utility power generation and state population over 18 years. Using the results of the regression analysis and projected statewide population data, statewide power needs were forecasted through 2050. Forecasted demands were determined by applying the rate of water withdrawal and consumption to the forecasted statewide power needs by individual power generation combination. Aggregating statewide future water demand, in any given forecast year, to the five power generation combinations was determined based on historical trends and insights from an energy sector ad hoc group.

3.3.3 Oklahoma

For the OCWP, estimates of thermoelectric power generation demands were developed using a methodology that employed gallons per megawatt hour (MWh) and estimates of MWh production from the active thermoelectric power plants in the state. The estimate of the gallons per day needed by thermoelectric power plants per MWh was developed for both consumptive use and total withdrawal based on USGS 2005 data for Oklahoma. The statewide average assumed for withdrawals was 775 gallons per MWh, except for a select few utilities operated by a participating stakeholder who provided detailed data.

Estimates of base year net MWh generated was collected from the DOE and, EIA. Data collected included the plant name, location, 2004 net MWh generated, and 2007 net MWh generated. Consumptive use was assumed at 480 gallons per MWh, based on regional studies.

To determine base year water use, a database was compiled for active plants in the state. The assumed gallons per MWh was multiplied by the plant's 2007 MWh production, as reported by the EIA. To forecast thermoelectric water demands, base year estimates were increased according to the projected growth rate for electrical consumption as reported in the EIAs Annual Energy Outlook (AEO) report. This approach assumed a linear relationship between the amount of electricity generated and the amount of water used (i.e., the rate of water use is constant). Results were then summarized by county and water planning region.

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Section 4

Demand Projection Methodology Options and Recommendations

4.1 Manufacturing Sector

The proposed methodology option for estimating current use and future water demands for the self-supplied manufacturing sector in Texas represents a streamlined approach which relies on readily available and consistently updated data. This section describes the approach and data sources proposed for forecasting manufacturing water demands in Texas at the county level.

4.1.1 Recommended Methodology Options

Industries require water for processes, sanitation, cooling, and other purposes, in addition to employee water use. In most cases, the water requirements of an industry are directly linked to production. Typically, historical production data and more importantly estimates of future production are proprietary information and not readily available. Employment data, however, are typically available at the county level and are often projected by NAICS code. Because employment is often linked to production, it can be indirectly linked to water requirements and serve as a proxy for production and used to forecast the future water requirements of an industry.

This methodology for forecasting water demand at the industry level assumes that water demand per production unit, and production per employee, remain the same over the forecast period. Thus, future manufacturing water demand (by industry and county, $FIWD$) is estimated based on base manufacturing water use (BWU), current employment ($E_{current}$) and future employment (E_{future}) as follows:

$$FIWD = \frac{BWU}{E_{current}} * E_{future} \qquad [4\text{-}1]$$

Since future employment is the current employment times a rate of growth ($r_{employment}$), the formula can be further simplified as:

$$FIWD = BWU + \left(BWU \times r_{employment}\right) \text{ where} \qquad [4\text{-}2]$$

$$r_{employment} = \frac{\left(E_{future} - E_{current}\right)}{E_{current}}$$

It is recommended that any growth rate calculated as negative be limited to zero, meaning the assumption is that neither growth nor decline in water use will occur over time for that particular industry in the county. This is a conservative approach that assumes any water assigned to manufacturing will be utilized by other sectors.

This methodology requires estimates of base period water use, current employment, and future employment. For base water use, we propose to utilize the water use survey (WUS) data from the previous 5 years, extracting for each surveyed industry the following data:

- 3-digit NAICS code
- county identification
- source (reservoir, river, or aquifer)
- number of employees
- reported water use data (intake by source, water purchases, and water sales).

Using data reported, the net water use for each industry can be calculated as intake by source *plus* water purchases *minus* water sales. Thus, this value becomes the basis for annual water use. These data should be summarized by all industries of the same 3-digit NAICS within a county on an annual basis for the previous 5-years of available data. *Recent droughts in Texas provide justification for a longer water use period for determining average use, in order to better balance out short-term climatic impacts on water use. The utilization of a 5-year reporting period is also consistent with the 5-year planning update cycle.*

Before proceeding, it is recommended that the aggregate 5-year water use data be reviewed for any noticeable omissions or data inconsistencies. As an additional data quality check, reports of employment and the facility count for the same time period could be reviewed, observing any inconsistent trends over time. These data are available from the annual WUS. While the TWDB WUS has a high response rate, review of the aggregate water use data by county can alert the analysts to any reporting omissions or errors. Assuming no apparent data errors, average water use over the previous 5 years can be calculated to determine the base period (current) water use. The varying average is recommended to consider recent droughts, economic conditions, or other data anomalies that may be reflected in the data.

4.1.2 Example Calculation for Travis County

The data in **Table 4-1** provides an example of the calculated water use for Travis County. For illustration purposes only, we utilized a 3-year reporting period.

Table 4-1. Example Manufacturing Base Year Water Use Calculation

NAICS 3-Digit Code		Net Use Summary from Water Use Survey (gallons)				AF
No.	Name	2011	2012	2013	3-Year Average	Average
311	Food Manufacturing	32,790,200	60,350,300	131,055,699	74,732,066	229
312	Beverage and Tobacco Product Manufacturing	38,283,200	33,558,800	33,558,800	35,133,600	108
325	Chemical Manufacturing	220,934,425	223,780,094	240,751,089	228,488,536	701
327	Nonmetallic Mineral Product Manufacturing	84,044,770	77,968,570	76,851,290	79,621,543	244
333	Machinery Manufacturing	90,831,700	57,986,200	43,102,600	63,973,500	196
334	Computer and Electronic Product Manufacturing	2,229,922,154	2,603,963,446	2,660,041,445	2,497,975,682	7,666
339	Miscellaneous Manufacturing	3,656,500	1,877,300	1,898,500	2,477,433	8
424	Merchant Wholesalers,	82,900	95,500	506,719	228,373	1

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NAICS 3-Digit Code		Net Use Summary from Water Use Survey (gallons)				AF
No.	Name	2011	2012	2013	3-Year Average	Average
	Nondurable Goods					
511	Publishing Industries	4,677,700	2,223,000	1,220,800	2,707,167	8
541	Professional, Scientific, and Technical Service	70,035,000	9,073,000	9,743,000	29,617,000	91
Total		2,775,258,549	3,070,876,210	3,198,729,942	3,014,954,900	9,252

Current and future employment projections by county can be obtained from the Texas Workforce Commission. This state agency provides 10-year projections of employment by 3-digit NAICS for 28 Workforce Development Areas (WDAs). The data are easily accessed online at www.tracer2.com and are updated every 2 years. An example of the projections with the 10-year growth rate calculated is provided in **Table 4-2** for Travis County.

Table 4-2 Texas Workforce Commission Employment Projections for Travis County

No.	Name	2013	2023	Growth Rate ($r_{employment}$)
311	Food Manufacturing	1,570	1,860	18%
312	Beverage and Tobacco Product Manufacturing	510	800	57%
325	Chemical Manufacturing	1,830	1,920	5%
327	Nonmetallic Mineral Product Manufacturing	940	1,060	13%
333	Machinery Manufacturing	2,360	2,450	4%
334	Computer and Electronic Product Manufacturing	22,530	26,290	17%
339	Miscellaneous Manufacturing	2,280	2,600	14%
424	Merchant Wholesalers, Nondurable Goods	4,550	5,100	12%
511	Publishing Industries	7,260	7,740	7%
541	Professional, Scientific, and Technical Service	60,120	77,570	29%

The rate of industry employment growth ($r_{employment}$) for the identified manufacturing sectors at the WDA level can be assumed applicable to all counties within the WDA. To estimate growth in base year water use, aggregate county water use can be matched with the corresponding employment projections by NAICS by county and the growth rate applied, as shown in **Table 4-3**.

Table 4-3 Texas Workforce Commission Employment Projections for Travis County

NAICS 3-Digit Code		Water Use Estimate (AF)	
No.	Name	Base Year (*BWD*)	Base Year + 10 *Years* (*FIWD*)
311	Food Manufacturing	229	271
312	Beverage and Tobacco Product Manufacturing	108	169
325	Chemical Manufacturing	701	736
327	Nonmetallic Mineral Product Manufacturing	244	276
333	Machinery Manufacturing	196	204
334	Computer and Electronic Product Manufacturing	7,666	8,946
339	Miscellaneous Manufacturing	8	9

NAICS 3-Digit Code		Water Use Estimate (AF)	
No.	Name	Base Year (*BWD*)	Base Year + 10 *Years* (*FIWD*)
423	Merchant Wholesalers, Durable Goods	-	-
424	Merchant Wholesalers, Nondurable Goods	1	1
511	Publishing Industries	8	9
541	Professional, Scientific, and Technical Service	91	117

Given the extreme difficulty and inaccuracies inherent in projecting statewide economic activities and the localized impact on the manufacturing sector, the recommended methodology option is to hold manufacturing water demands constant past the initial 10-year projection period. While proprietary long-term projections of county employment could be purchased, it is not recommended for this methodology due to the fundamental adaptive approach on which the Texas regional and state water planning process is based. Plans are reviewed and updated on a 5-year cycle, so that any significant change in conditions (economic, demographic, and climatic) can be addressed in the next planning cycle. Also, from a historical perspective, the use of proprietary data in the planning process has become increasingly more difficult, due to the inability to utilize proprietary data in the public forum, and also due to the increasing costs of proprietary data when, at the same time, resources available for planning continue to decline.

4.1.3 Limitations and Assumptions

Several assumptions are implicit in the development and application of the proposed methodology option. They are as follows:

- Employment is a reasonable proxy for gross production in forecasting water demand for the manufacturing sector.
- The ratio of gross production to water use remains constant in the future, i.e. no future efficiencies are assumed.
- The ratio of employment to gross production remains constant in the future, i.e. no improvements in per employee gross production is assumed.
- While declines in water use are likely, due to either natural replacement of indoor plumbing fixtures or active conservation efforts, they are difficult to quantify. Therefore, it is assumed that the primary driver of demand is production of goods and materials which is a more dominant component of the forecasting process.
- Where negative growth in an industry's employment is projected, the growth in water demands is assumed to remain constant to the base year demand, rather than forecasting declining demands.
- One major limitation of this approach is that the TWDB WUS does not cover 100 percent of industry use. Recent survey response rates, however, are on the order of almost 95 percent.

4.2 Irrigation

The basic equation for estimating water withdrawals used for irrigated agriculture is expressed as the number of acres irrigated times a rate of application per acre. The application rate varies state-to-state, county-to-county, and even field-to-field. The following lists the primary driving factors that influence the amount of water applied for agriculture irrigation:

- Delivery method and efficiency rate of the irrigation system (e.g., lined canals, dirt canals, or center pivot);
- Type of crops irrigated;
- Genetic make-up of the crops planted (e.g. drought resistant strain vs non-GMO);
- Salinity of soils;
- Use of precision controls and soil moisture controls;
- Weather;
- Water availability;
- Cultural practices
- Government policies and programs; and
- Commodity prices.

The estimate of future irrigated acres is typically based on historical trends, with a reasonable limit placed on the growth so that the number of irrigated acres does not increase to more than what is reasonably available in terms of land or water resources, whichever is the restraining factor. Application rates are typically derived from data collected by governmental agencies that require water use reporting. When no such source is available, or when the data quality are thought to be poor, then application rates can be derived based on theoretical models of the crop evapotranspiration (ET) rate, taking into consideration realized rainfall within the given state or for a particular region, basin, or county as well as producer behaviors and irrigation system efficiencies. Application rates are forecasted based on historical or projected crop trends, improved efficiency, or, in some instances, held constant from the base year for a portion or all of the planning horizon.

In the State of Texas, irrigated agriculture water demands are projected, from both a near term and long-term perspective, to decline. This reduction is primarily expected to come from declining groundwater resources (predominantly in unconfined aquifers) and increasing costs of groundwater extraction, the adoption or conversion to drought resistant crops, and voluntary transfer of agriculture surface water rights to municipalities. Conservation practices such as improved canal delivery systems of surface water and more efficient on-farm irrigation systems implemented both regionally and on-farm may further reduce future irrigated agriculture water demands. Additionally, the TWDB has implemented a voluntary metering program that is showing significantly lower annual applications than the estimated crop water requirements, implying deficit irrigation practices (applying water at rates less than necessary for optimal crop growth/production) are occurring [Turner et al., 2011]. In many areas across the state, irrigated agriculture water demands from groundwater sources is and/or will be physically constrained by the actual amount of water available, with availability being determined either from adopted policies or physical measurements of the resource. Thus, accurate estimates of both the current trends and any physical limitations are required, based on adopted policies or physical measurements of the local/regional water resource. An examination of the history of developing additional water resources for irrigated agriculture in Texas over the past 50-years documents that both the costs and engineering challenges of water resources importation for irrigated agriculture are no longer feasible in areas such as the High Plains. Therefore, in the regional water planning process, the only options available for planning groups to address the realities of these physical constraints is the adoption of water conservation strategies (including weather modification programs) that will act to extend the life of the finite resource.

Accurate decadal irrigation water demand forecasts are challenged by climate variability, governmental policies, and socioeconomics. With irrigated agriculture being the biggest water consumer state-wide, a primary goal of water planners is to continually work to develop a more reliable, reproducible and defendable forecast methodology. The annual crop irrigation requirement is primarily based upon the recent 5-year historical irrigation rates for each crop within each county and adjusted based upon weather conditions experienced during the growing season. In most situations, this crop irrigation requirement would be a maximum amount and subject to accurate data on irrigated acres, yields, and cropping schedules – all of which can vary significantly across counties with decadal variations. A base year can be developed from mean climatology data [Narasimhan et al., 2005] and crop coefficients [Borrelli et al., 1998] across Texas. A similar methodology is used in Oklahoma.

4.2.1 Physical and Policy Constraints on Total Available Water for Irrigated Agriculture

Given five or more years of annual crop irrigation requirements or reported/measured water use, any trend (e.g. linear regression) can be used to project at decadal increments for the 50-year forecast. However, the projection may be improved when the projection is constrained to the physical reality of available water resources, which are most typically an integration of physical properties, adopted policies, and to some degree, economics (commodity prices and costs to produce).

In past water planning, significant efforts have been made to project trends in commodity prices as a factor to be considered in the development of irrigated agriculture water demands. However, the resulting demand projections have not been widely accepted by agriculture stakeholders, in large part because of the inherent inaccuracies in projecting the future of commodity prices in a global economy where market pressures and thus commodity prices are often driven by dynamics occurring across the country or even on the other side of the world. Although the impact of commodity prices on irrigated agriculture water demand projections is beyond the scope of this study, it is clearly recognized that fluctuating agriculture economics/commodity process will inevitably have an impact on water demands. For example, either market driven or policy driven commodity process can fluctuate significantly over a short time period that is beyond the ability of any predictive tool or analytical approach to project.

Changes in commodity prices may either result in a reduction in irrigated agriculture water demands as a result of falling commodity prices for more water-intensive crops, for example, or may result in the economic justification to recover and utilize more water resources in the near term due to significant increases in commodity prices and changes in market trends. As an example, as a result of the federal government's adoption of programs deemed necessary to increase the production of ethanol as a sustainable energy source, there was a dramatic increase in Texas in the number of acres of irrigated corn, and thus, an increase in irrigated agriculture water demands. This change in irrigated agriculture water demands was not a result of natural market forces of supply and demand, but rather of a change in federal policy that resulted in a tangential but significant increase in irrigated agriculture water demands. These fluctuations in water demands cannot be predicted or modeled with any level of confidence over a 50-year planning horizon. Therefore, the options discussed below for developing irrigated agriculture water demand projections are built on the fundamental principle that the irrigated agriculture water demand projections, which are based on accurate characterization of current water use, will be routinely reviewed and revised on a 5-year cycle. This review and revisions process is necessary to reestablish the baseline and thus capture any changed conditions that may have occurred in the previous 5 years due to changes in the physical resources, policies and economics that drive irrigated agriculture in Texas.

The use of surface water in Texas is highly regulated and only conveyance improvements are likely to positively impact future irrigated agriculture water demands (in addition to changing policies and economics as discussed above). Conversely, as oversight of surface water rights continues to increase across Texas (through the use of water masters to enforce water diversions based on water rights and water availability), irrigated agriculture water rights with the more junior priority dates will become less reliable during periods of low stream flow. As such, on a case by case basis, with respect to surface water-based irrigated agriculture, water demand projections may need to be constrained by the limitations of the water right/contract. For example, recent experiences in the Lower Colorado River Basin and in the Rio Grande Basin have documented the vulnerability of irrigated agriculture during drought conditions when surface water supplies are interruptible due to terms of contracts and provisions of the individual water right. Any physical or policy constraints applied to irrigated agriculture water demand projections will need to be evaluated on a case-by-case basis, since provisions contained in surface water rights, contracts, and the impacts of the reliability of surface water availability to drought conditions is a unique, site-specific condition.

4.2.2 Considerations for Irrigated Agriculture using Groundwater

Adopted policy and physical limitations on groundwater resources for irrigated agriculture are much more broad, firm, and significant in many regions of the state and therefore may be considered in the development of irrigated agriculture water demand projection scenarios on local, regional, and statewide scales. In support of developed irrigated agriculture demand projections, there are a number of options available for considering adopted policy and physical resource constraints on groundwater availability. For the purposes of this study, the following presents the identified options:

1. Water demand projections constrained by the cumulative volume of groundwater available to meet all water demands based on adopted statements of Desired Future

Conditions (DFCs) and estimates of Modeled Available Groundwater (MAGs) summed for the 50-year planning horizon (referred to as the DFC/MAG Option),

2. Water demand projections constrained by the volume of groundwater available to meet all water demands based on estimates of total groundwater in storage, adjusted by estimates of annual recharge, fully utilized within the 50-year planning horizon given a growth decay equation (referred to as the Uniform Total Storage Option),

3. Water demand projections constrained by the volume of groundwater available to meet all water demands based on estimates of total groundwater in storage, adjusted by estimates of recharge, allocated initially at a constant rate equivalent to the current estimate of water use (the five-year average) and fully utilized within the 50-year planning horizon (referred to as the Flat Total Storage Option),

4. Water demand projections constrained by the volume of groundwater available to meet all water demands based on estimates of total recoverable storage, adjusted by estimates of annual recharge, fully utilized within the 50-year planning horizon given a growth decay equation (the Uniform Total Estimated Recoverable Storage (TERS) Option), and

5. Water demand projections constrained by the volume of groundwater available to meet all water demands based on TERS, adjusted by estimates of recharge, initially allocated at a constant rate equivalent to the current estimate of water use (the five-year average), and fully utilized within the 50-year planning horizon (the Flat TERS Option).

Each of these options are explained in more detail below along with example water demand projections. As detailed below, there are challenges associated with the application of these methodologies and a recommended option that addresses these challenges will be described in **Section 4.2.3**.

4.2.2.1 DFC/MAG Option

The DFC/MAG Option is derived from the requirement included in Texas Water Code Section 36.108 (d) that groundwater conservation districts in a groundwater management area adopt DFCs on at least a five-year basis. A DFC is defined in Texas Water Code Section 36.001 (a)(30) as a *quantitative description, adopted in accordance with Section 36.108, of the desired condition of the groundwater resources in a management area at one or more specified future times*. Texas Water Code Section 36.001 (a)(25) defines MAG as *the amount of water that the executive administrator determines may be produced on an average annual basis to achieve a desired future condition established under Section 36.108*. Therefore, the TWDB Executive Administrator has produced and released estimates of MAG for all major and minor aquifers in Texas for which the applicable groundwater management area has adopted DFCs during the process of joint planning. As stated in the statutory definition above, an estimate of MAG is the amount of groundwater that may be produced *on an annual* basis to achieve a DFC. As such, in a county for which there is established irrigated agriculture groundwater production which is projected to continue for some period into the future, the estimate of MAG may be utilized as an adopted policy constraint for the DFC/MAG Option in developing water demand projections. Since the calculation of MAG by the Executive Administrator takes into consideration recharge and other physical variables of a groundwater system, there is no need to account for recharge in the utilization of MAGs as a constraint to irrigated agriculture water demand projections with the DFC/MAG Option.

One important aspect regarding the use of the DFC/MAG Option is that the estimates of MAG are based on an assumption that the amount of pumping quantified in the MAG is the amount of groundwater that “may be” produced on an “average annual basis” to achieve a DFC. However, in many areas of the state, the average volume of annual irrigated agriculture water use for the most recent five years is less than the MAG for the aquifer in question. Therefore, it will be important to evaluate the MAG from a cumulative perspective, where current use may be less than the MAG in early years and less than the MAG in later years, but when evaluated cumulatively, the MAG may not be a constraint to irrigated agriculture water demand projections.

4.2.2.2 Total Storage / Flat Total Storage / TERS / Flat TERS

The four options based on Total Storage and TERS are centered on the fact that for all major and minor aquifers in Texas for which a DFC has been adopted, as required by Texas Water Code Section 36.108 (d), the Executive Administrator of the TWDB has quantified the Total Storage and TERS for all aquifers with DFCs. Total Storage is simply the porosity-adjusted volume of an aquifer. TERS is defined as the estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25 percent and 75 percent of the porosity-adjusted aquifer volume (31 Texas Administrative Code Section 356.10 (a)(24)). It is recognized that the application of TERS for certain planning applications may not be representative of the actual limiting factor, for example when subsidence or socioeconomic impacts are determined to be primary issues. This option requires the policy decision that if the water demand projections are constrained, then the Total Storage or 75% TERS volume will be fully utilized over the 50-year planning period, with zero Total Storage or 75% TERS volumes remaining at the end of the planning period.

The Uniform Total Storage Option and Flat Total Storage Option utilize the porosity-adjusted volume of an aquifer on county scale, as determined by the Executive Administrator, to represent the maximum volume of water available for which water demand projections, for all water use sectors including irrigated agriculture, may be included in the regional water planning process. This volume would be adjusted upward by the addition of an estimate of recharge to the aquifer under average conditions based on the best available science. In the Uniform Total Storage Option, if the average volume of annual irrigated agriculture water use for the most recent five years, when multiplied by the 50 years represented in the next planning horizon, *is less than* the Total Storage (adjusted by 50 years of recharge), then there will be *no constraint* on the irrigated agriculture water demand projection and the water demands utilized in the regional water planning process will be held constant at the most recent 5-year average volume of irrigated agriculture water use for the county. If the average volume of annual irrigated agriculture water use over the most recent five years, when multiplied by 50, *is greater than* the Total Storage (adjusted by 50 years of recharge), then a constraint *will be* applied on the irrigated agriculture water demand projections. This constraint will be applied using a negative exponential growth (decay) algorithm in which annual withdrawals are *reduced* exponentially each year in a way that Total Storage is equal to 0 in planning year 50.

The Flat Total Storage Option is identical to the Uniform Storage Option, except for how the difference between Total Storage (adjusted by 50 years of recharge) and the average volume of annual irrigated agriculture water use over the most recent 5 years, and multiplied by 50, is distributed over the 50-year planning horizon. In the Flat Total Storage Option, irrigated agriculture water demand projections are held constant at the annual irrigated agriculture water use over the most recent five years from year 1 until of the cumulative amount withdrawn *is greater than* the volume of water in storage. For the decade during which the total storage is exhausted, irrigated agriculture water demand projections will be reduced so as to evenly distribute the remaining water in storage for the final decade. This option assumes irrigated agriculture withdrawals remain constant in the future until the point in the future when the groundwater resource is exhausted.

It is recognized that both the Uniform Total Storage and Flat Storage Options, when constraints are utilized, are both predicated on a policy of fully utilizing all remaining groundwater resources within the 50-year planning horizon. Both of these options are based on an assumption that all groundwater in storage can be extracted, which is not consistent with the concept of "recoverable storage" that will be utilized in the remaining two options. Also, the addition of 50 years of recharge to the Total Storage volume will, in cases where a constraint is necessary prior to the end of the 50-year planning horizon, will result in a slight over prediction of the volume of water in storage, however, this value will be very small in comparison to the overall calculations and is considered insignificant for planning purposes.

The Uniform TERS Option and the Flat TERS Option are executed in the same manner as the two options based on Total Storage, except that the volume utilized as the constraint is the TERS estimate, as determined by the Executive Administrator and adjusted by recharge over the 50-year planning horizon. The use of TERS in these options is based on an assumption that no more than 75 percent of Total Storage = TERS, adjusted by a reasonable estimate of recharge, should be considered as reliable water available for the regional water supply planning process.

4.2.2.3 Limitations

None of the options outlined take into account depth to groundwater, which can be a significant limitation given energy and pump requirements needed to access deeper resources. Likewise, the calculations for each of the options presented do not take into account the declining yields of wells as artesian heads in confined aquifers and saturated thickness in unconfined aquifers decline. Finally, these options do not consider the impacts of water quality, especially with respect to the use of the resource for irrigated agriculture, as the socioeconomic impacts of any water treatment requirement prior to use for irrigation will, in almost every case, be cost prohibitive.

4.2.2.4 Comparison of Options based on Region O

In the most recently completed cycle of regional water planning, the correlation between DFCs/MAGs, Total Storage, or TERS with respect to irrigated agriculture water demands was not taken into account. To illustrate the problem, **Table 4-4** presents irrigated agriculture water demand projection for the 2016 Llano Estacado Regional Water Plan (Region O) and its 21 counties, all of which show decreasing irrigated agriculture water demand projections through 2070. In the 2016 Llano Estacado Regional Water Plan, the cumulative water demand projection for the Llano Estacado regional water planning area is for approximately 158 MAF of water over the 50-year planning horizon through 2070. However, TERS, for example, for the Ogallala Aquifer in the Llano Estacado regional water planning area (assumed to be the only viable water resource for irrigated agriculture in the region), based on the use of TERS, the most optimistic estimate at 75 percent of Total Storage is only 93 MAF. Assuming a regional recharge rate of 0.1 inches per year, the aquifer recoups 5.3 MAF over the 50-year planning horizon. Based on these regional totals, irrigated agriculture water demand projections for the Ogallala Aquifer in the 2016 Llano Estacada Regional Water Plan are approximately -59 MAF greater than the actual volume of water that is available for irrigated agriculture when constrained by TERS. This scenario is, to varying degrees, exacerbated by the fact that this simple analysis does not account for the fact that, in certain counties, there will be competing demands for water from other use sectors such as municipalities, manufacturing, livestock, mining, and steam-electric power generation. Due to the widely disparate value of water for these other water use sectors versus the irrigated agriculture water use sector, it is anticipated that the volume of groundwater, available for irrigated agriculture will be even further constrained.

4.2.3 Recommended Methodology Options

The five options discussed above are all based on a comparison of a certain volume of groundwater being available for constraining irrigated agriculture water demand projections for the 50-year planning horizon. As such, the actual calculations are reasonably parallel, except for the constraint of the volume of water available and how the constraint is applied over the 50-year planning horizon. For illustrative purposes, the specifics of quantifying the level and rate of application of groundwater available for use in the development if irrigated agriculture water demand projections based on the Uniform TERS Option is presented below. With the other options discussed, the process will be largely the same except for the volume of water available initially.

The simple, yet physically constrained irrigated agriculture water demand projection methodology for the Uniform TERS Option presented herein uses county-based historical water use to produce projected 50-year water demands and, for areas where groundwater is the source for irrigated agriculture, TERS to constrain withdrawals at an annual time step. The historical (2000 to 2013) irrigation water demand usage from groundwater and surface water can be supplied by the Water Use Survey Historical Summary Estimates available by county at: http://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/.

It is unlikely that any statistically significant trend exists in these data, we therefore recommend simply using the average irrigation from groundwater and surface water of the five most recent years to represent a maximum future demand for irrigated agriculture on a county basis. The five-year average smooths the data for annual fluctuations in weather, crop rotations, and economic drivers. A longer or shorter average period may be necessary, depending on the weather conditions present in the historical data (i.e., select a longer period to calculate the average if three of the most recent five years were droughts).

Table 4-4.Decadal Irrigated Agriculture Water Demand Projections for the Ogallala Aquifer in the 2016 Llano Estacado Regional Water Plan (AFY)

County	Area (ac)	2020	2030	2040	2050	2060	2070	Σ50 yr Total Demand	75% TERS	Σ50 yr Re-charge	Delta
BAILEY	529,288	119,268	116,407	113,614	110,888	108,227	105,752	5,548,880	2,175,000	220,537	-3,153,343
BRISCOE	575,990	37,260	35,908	34,604	33,348	32,137	31,052	1,670,490	1,575,000	239,996	144,506
CASTRO	574,755	387,976	373,101	358,796	345,040	331,812	320,029	17,287,780	7,125,000	239,481	-9,923,299
COCHRAN	495,930	102,229	98,284	94,489	90,841	87,334	84,214	4,551,620	2,175,000	206,637	-2,169,983
CROSBY	575,990	117,362	112,634	108,095	103,742	99,564	95,864	5,198,990	9,000,000	239,996	4,041,006
DAWSON	577,226	106,630	100,619	94,945	89,594	84,544	80,286	4,499,880	5,550,000	240,511	1,290,631
DEAF SMITH	958,007	193,410	187,282	181,349	175,604	170,041	164,985	8,792,610	6,225,000	399,169	-2,168,441
DICKENS	578,461	9,363	9,085	8,814	8,550	8,293	8,060	428,020		241,025	
FLOYD	634,800	147,725	141,841	136,191	130,767	125,559	120,941	6,552,990	9,000,000	264,500	2,711,510
GAINES	961,219	379,779	360,000	341,251	323,477	306,629	292,238	16,235,950	8,250,000	400,508	-7,585,442
GARZA	573,519	11,621	10,937	10,299	9,697	9,130	8,655	487,180	825,000	238,966	576,786
HALE	643,201	369,812	357,560	345,713	334,258	323,183	313,161	16,738,750	7,125,000	268,001	-9,345,749
HOCKLEY	581,179	131,207	126,077	121,146	116,409	111,858	107,813	5,833,030	4,425,000	242,158	-1,165,872
LAMB	650,120	325,356	312,802	300,732	289,129	277,974	268,045	14,486,820	6,450,000	270,883	-7,765,937
LUBBOCK	575,990	169,242	159,740	150,773	142,310	134,322	127,582	7,147,270	5,250,000	239,996	-1,657,274
LYNN	570,801	84,566	80,019	75,711	71,641	67,790	64,515	3,596,760	3,750,000	237,834	391,074
MOTLEY	632,823	9,439	9,159	8,884	8,617	8,359	8,123	431,420		263,676	
PARMER	564,376	329,806	326,305	322,840	319,413	316,021	312,736	15,973,150	2,925,000	235,157	-12,812,993
SWISHER	575,990	196,895	203,171	202,011	200,857	199,709	198,581	10,043,290	5,700,000	239,996	-4,103,294
TERRY	569,566	143,461	136,107	129,129	122,508	116,226	110,848	6,148,180	3,900,000	237,319	-2,010,861
YOAKUM	511,991	146,083	139,091	132,435	126,095	120,060	114,838	6,325,190	1,650,000	213,330	-4,461,860
Total	12,911,222							157,978,250	93,075,000	5,379,676	-59,523,574

For groundwater, Total Storage and TERS data for each county and relevant aquifer for irrigation are available for each groundwater management unit at (http://www.twdb.texas.gov/groundwater/management_areas/TERS.asp). In most cases, Total Storage and TERS were originally estimated in reports provided by the Executive Administrator in 2014 based on the most recent groundwater availability model from which the total aquifer volume for the final year of transient model calibration was available. In many of the heavily irrigated regions of the state, irrigated agriculture water demand at the historical rate cannot be maintained over the projection period when constrained by the 75 percent TERS value. The demand methodology equation should also include an estimate of the aquifer recharge volume, typically for planning purposes expressed in AFY.

The overall proposed Uniform TERS Option methodology where groundwater provides all or parts of the water source for irrigated agriculture, by county and source, is to assume the base year demands are equal to the average historical irrigation water use. Future demands are assumed constant at the base year water use. An initial calculation is executed for counties where groundwater management units have TERS data available. The cumulative annual demand is calculated, and, if that demand exceeds the 75 percent TERS value plus 50 years of recharge, then that groundwater demand is adjusted according to a formula that prevents the 50-year cumulative demands from exceeding availability. The equations and steps for first determining if cumulative demands exceed availability, and then adjusting groundwater demands according to the TERS data are provided below.

Estimated unconstrained cumulative groundwater demand ($CD_{unconstrained}$) over the planning horizon can be calculated as the base year water use (*Base*) times the number of years in the forecast plus the Base, or Base times 51:

$$CD_{unconstrained} = Base * 51 \qquad [4\text{-}3]$$

The total available irrigation water (*TAIW*) can be calculated for each county from the 75 percent TERS value (expressed in AF) plus the average annual recharge rate (*RC*, expressed in AFY) as:

$$TAIW = 75TERS + (50 * RC) \qquad [4\text{-}4]$$

Compare the cumulative projection to the total available irrigation water demand. If the cumulative demands are greater than the available supply, then proceed to the next step.

The target cumulative demand (CD_{target}) is the TAIW. In a spreadsheet model, setup the calculation for annual demands assuming cumulative negative growth, where a dummy value is assumed for the rate of growth (R_{proxy}) and P is equal to the period. Do this for periods 1 through 50.

$$Y_n = Base * (1 + R_{proxy})^{\wedge}P \qquad [4\text{-}5]$$

Comparing the cumulative annual demands over the base period plus all 50 planning years to the *TAIW*, adjust the rate of growth until the difference is close to zero and the cumulative sum of annual demands for the base period and 50 years is approximately equal to $TAIW$. Suggested starting values can be developed, based on current percentage of demand to $TAIW$.

$$Y_n = Base * (1 + R)^\wedge P \quad \text{where} \quad \sum Y_n \approx TAIW \qquad [4\text{-}6]$$

4.2.4 Example Calculation for Hale County

To illustrate how the formulas are applied, an example calculation is provided for Hale County, which is located in the Llano Estacado regional water planning area and in Groundwater Management Area 2. Recharge for the aquifer in that county is assumed to be 0.1 inches per year over an area of 643,203 acres yielding 5,360 AFY. As shown in **Table 4-4**, the 50-year projected water demand forecast decreases from 369,812 AFY in 2020 to 313,161 AFY in 2070, clearly exceeding aquifer recharge. Historically, annual water use in Hale County is dominated by irrigation with a mean demand of 334,000 AFY (**Table 4-5** and **Figure 4-1**).

Table 4-5 Historical Water Use Survey Data in Hale County (AFY)

Year	County	Municipal	Manufacturing	Mining	Steam Electric	Irrigation	Livestock	Irrigation Ground-water	Irrigation Surface Water
2000	HALE	6,083	2,606	0	0	367,700	2,546	367,700	0
2001	HALE	5,685	2,676	0	0	337,770	2,548	337,770	0
2002	HALE	3,536	3,232	0	0	385,812	2,607	385,812	0
2003	HALE	7,468	3,296	0	0	394,509	3,042	393,087	1,422
2004	HALE	5,468	2,423	0	0	355,609	2,217	354,210	1,399
2005	HALE	5,499	2,623	0	0	243,039	2,530	242,795	244
2006	HALE	5,778	2,476	0	0	278,131	4,163	277,885	246
2007	HALE	4,780	2,504	0	0	491,767	2,493	491,650	117
2008	HALE	5,557	2,501	109	0	530,560	3,533	530,510	50
2009	HALE	5,504	2,568	190	0	368,654	3,544	368,617	37
2010	HALE	3,586	828	271	0	219,643	3,102	219,525	118
2011	HALE	6,633	753	252	0	389,173	3,403	389,019	154
2012	HALE	5,942	799	0	0	364,467	3,332	364,360	107
2013	HALE	4,241	2,363	0	0	330,563	3,836	330,365	198
						5 Year Mean		334,377	

CDM Smith

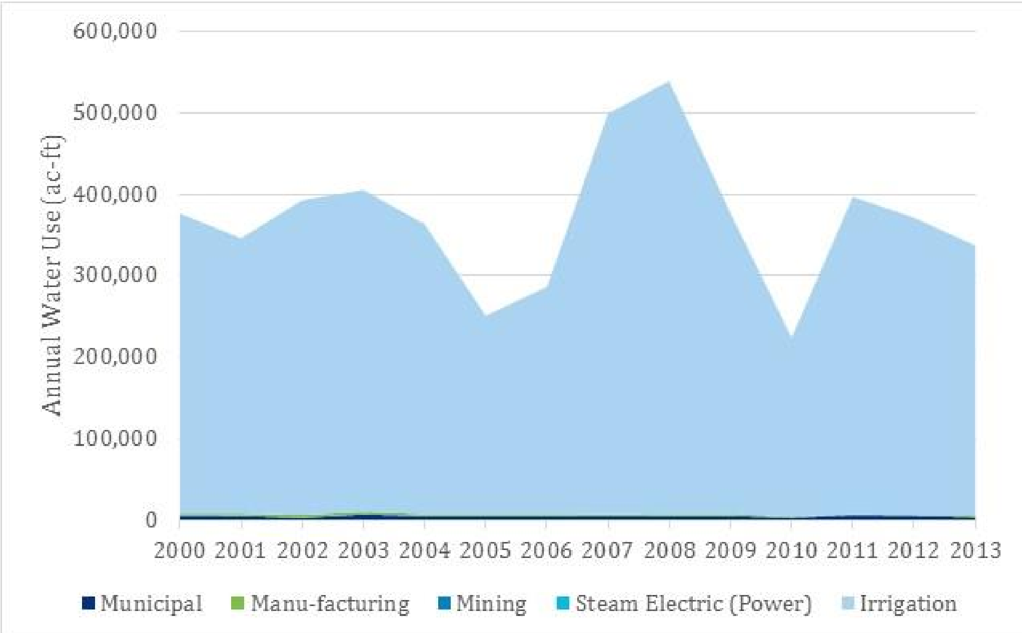

Figure 4-1 Historical Water Use in Hale County

The Hale County TERS database lists three major aquifers: the Dockum, the Edwards-Trinity and the Ogallala. The salinity in the Dockum Aquifer in Hale County limits its use for irrigation. Given the 75 percent TERS value of 7,777,500 AF (combined for both usable aquifers) and the annual recharge rate 5,360 (AFY), the TAIW is calculated as 8,045,501 AF (**Table 4-6**).

Table 4-6 TERS Calculation for Hale County (all values in AF)

Aquifer	75 Percent TERS	Recharge Over 50 Years	Total Available Irrigation Water (TAIW)
EDWARDS-TRINITY	652,500		
OGALLALA	7,125,000		
Total	7,777,500	268,001	8,045,501

The base year demand in 2020 of 330,365 AFY yields a cumulative unconstrained demand ($CD_{unconstrained}$) of 16,848,615 AF, which is more than double the *TAIW*. The adjusted annual growth rate is calculated to be -0.03404279, which yields a cumulative demand of 8,045,501.

Figure 4-2 illustrates the projection methodology, where the dashed line (z-axis) represents *TAIW* which is slightly increasing over time to account for recharge. The dark blue line aligns with the X-axis and shows declining annual demands (negative exponential decay growth). The green line (z-axis) is the cumulative demands over time, meeting with the TAIW at the end of the planning period.

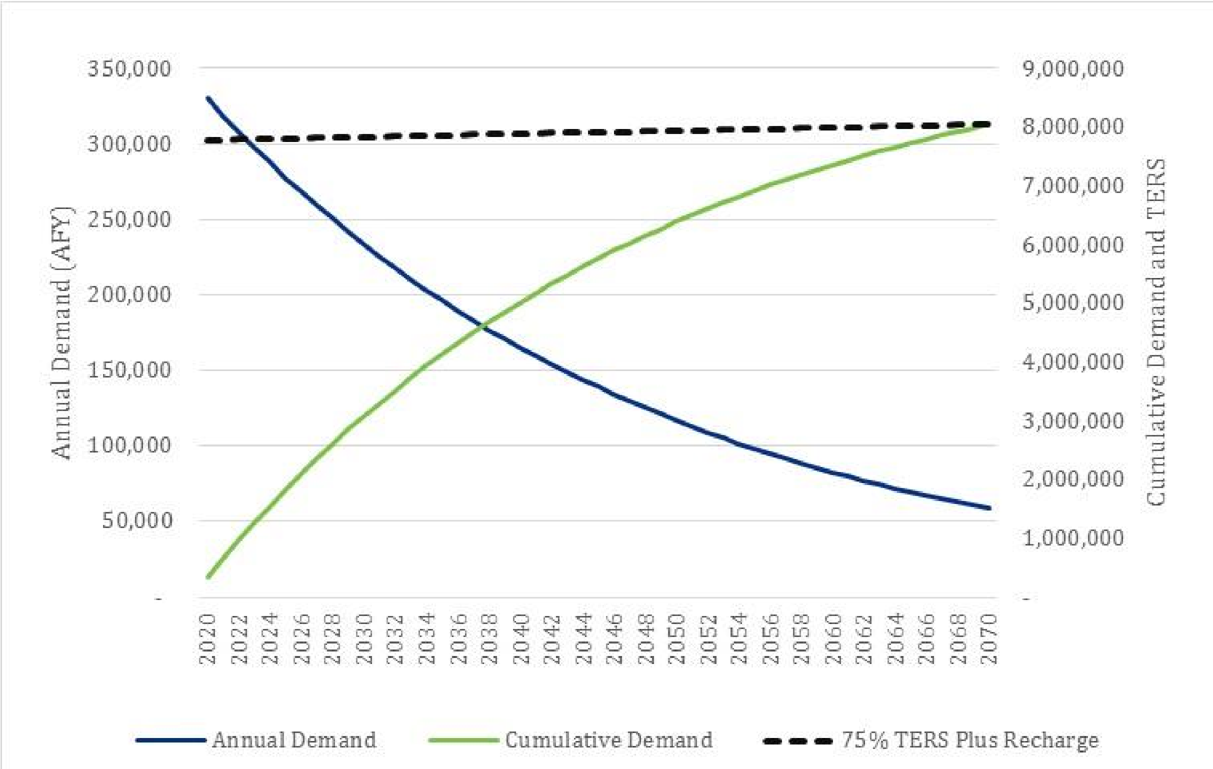

Figure 4-2 Hale County Example Demand Projection Constrained by TAIW (AFY)

4.2.5 Limitations and Assumptions

The recommended method is relatively simple and based on easily attainable data per county. It does rely on estimated historical water use estimates. Several assumptions are made, however, which must be specified.

First, in the option highlighted above, the methodology assumes the 75 percent TERS value as the starting point for the analysis; however, TERS values were calculated, in this example, in 2000, and for other years in other regions of the state. Updates will occur at different times, and thus, updating TERS with each cycle of regional and state water planning would be important to maintaining a valid TAIW.

Second, the base year water estimate is based on WUS data and the projections are only as good as the quality of these WUS estimates. The WUS data could be significantly improved upon, as described in the next section.

Third, the example provided removed the Dockum from the TAIW calculation – some care must be exercised when deciding which aquifers are currently or will be in the future utilized. Lastly, the methodology assumes that the aquifer will be fully exhausted at the end of the 50-year planning period. High pumping costs or other factors may cause even steeper declines, or the declines may happen quicker (i.e., the shape of the decline growth curve is unknown),

Finally, and from a more statewide perspective, the use of Total Storage and TERS options as physical constraints will primarily be a factor with unconfined aquifers such as the Ogallala and

Seymour aquifers. In confined aquifers such as the Trinity, Carrizo-Wilcox, and Gulf Coast aquifers, Total Storage and TERS will typically be much greater than the cumulative effects of pumping at levels recorded over the past five years. However, in these aquifers, the management of artesian pressures is often the post important policy issue, and as such, the DFC/MAG option will be more applicable in these regions.

4.2.6 Potential Advances for Irrigated Agriculture Water Estimation Methodology

More robust models are available to determine historical irrigation and future water demands. Application of more advanced crop irrigation requirement models regionally involves the following considerations:

1. Spatial structure and resolution at which water balance variables will be calculated (i.e. gridded area elements or point weather stations),
2. Soil classes and characteristics that govern infiltration and water holding capacity,
3. Crop characteristics that describe root access to soil moisture and related effects on *ET*,
4. Meteorological variables forcing the simulations (i.e. precipitation, temperature, solar radiation, humidity, and wind speed) and ET_r type (i.e. simple temperature based or physically based),
5. Model structure and physics such as simulation of energy balance, soil water balance, non-growing season *ET* and precipitation accumulations, seasonal crop development and harvest for different crop types, and variable growing season lengths,
6. Rime step for simulating the soil water balance, crop development, and ET_C (i.e. daily or monthly), and
7. Calibration objectives such as simulated versus measured green-up and harvest dates, killing frost temperatures, or actual field *ET* measurements.

Among the existing models of this type, one uses a reference ET-based approach daily soil water balance method outlined by the American Society of Civil Engineers (ASCE) and Food and Agriculture Organization (FAO) of the United Nations, FAO Irrigation and Drainage Paper 56 [*Allen et al.*, 1998; *ASCE-EWRI*, 2005]; the other uses a full crop simulation and growth models that consider the water, nitrogen, and carbon balances, such as the Decision Support System for Agrotechnology Transfer (DSSAT) [*Jones et al.*, 2003], or Cupid soil-plant-atmosphere model [*Norman*, 1979]. Lastly, there are agro-economic models which could supply future scenarios and optimize commodity prices with water demands [*McCarl and Spreen*, 1980; *McCarl et al.*, 1999].

While full crop simulation and growth models have many research advantages, and are largely physically based, the ASCE and FAO-56 irrigation water demand methodology is well suited for robust application at local and regional scales. This methodology also has wide spread acceptance among the ASCE and international agricultural engineering community, and is currently being used in Arizona, California, Colorado, Idaho, Kansas, Nebraska, Nevada, New Mexico, and by the Bureau of Reclamation for the Lower Colorado River Accounting System (LCRAS) and ET Toolbox models [*Jensen*, 1998; *Brower*, 2008]. The ET Demands Model implements a dual crop coefficient, soil water balance model based on FAO-56 where actual ET for multiple crop types is estimated at each grid cell or weather station following the FAO-56 dual crop coefficient approach. The soil and root zone water balance in ET Demands is based on a two stage drying procedure following the work of Allen et al. [1998; *2005*]. Soil attributes are obtained from the NRCS State Soil Geographic (STATSGO) database. STATSGO is a spatial soils GIS database. Crop lands are typically identified utilizing the CDL and meteorological data is either from gridded sources (NLDAS from NOAA) or ground-based stations. Historical analysis is possible over the NLDAS period (1980 to present) or the length of the recording station.

Lastly, remote sensing of the land surface energy budget can inform historical irrigated water demand estimates. Most remote sensing *ET* models are based on thermal infrared (*TIR*) measurements used to derive land-surface temperature (*LST*) from for each pixel of a satellite image generally Landsat (1985 to present) or MODIS (1999 to present). *LST* is used to estimate various components of the surface energy balance and scale estimates potential *ET* from either ground-based measurements or land surface models (NLDAS). Remote sensing ET algorithms require satellite-based thermal images to produce an instantaneous map of *ET*, normalized vegetative indices (*NDVI*) to determine K_c or albedo, and land cover and land use to map crop type and irrigated agriculture for *CIR*. Time integration of the instantaneous satellite snapshots requires accurate meteorological data for both ET_r and precipitation.

4.3 Steam Electric Power Generation Sector

Steam electric power generation requires water primarily for cooling and other purposes, in addition to employee water use. Water use for steam-electric power generation is influenced by many factors, such as:

- Population growth;
- Power markets;
- Gas prices;
- Weather conditions; and
- Efficiency standards;

The relationship between power generation, water demand and population is not a one-to-one relationship – while there is an upward pressure on water demand as a result of population growth, there is a downward pressure as technology improves and more renewable energy comes on-line.

The methodology developed in the following section builds from the previous projection methodology developed by King et al. [2008] and more recent analyses by Scanlon et al., [2013(a)]. We agree with many of the assumptions and calculations for projecting water demand. However, we have suggested a methodology that will streamline the current approach and reduce the number of complexities (such as scenarios for various economic conditions and fuel mixes) and use only a single projection, rather than a combination of near-term and long-term projections.

The revised methodology will also allow for an adaptive process to reset baseline and projected demands for each planning cycle. The methodology will provide both a mechanism to reset the demands to a new baseline at the beginning of every planning cycle as well as provide an upper and lower bound for the water demand projections to validate regional water planning group recommended water demands.

4.3.1 Baseline Demand

The current methodology used by the TWDB estimates current water demand based on the existing power plant fleet. Baseline demands for the current power plant fleet will be obtained from the previous 5-years of available data from the EIA database, Texas Commission on Environmental Quality (TCEQ), and TWDB data. The EIA database provides generation, fuel source, generator technology, fuel consumption and cooling system at the power plant. The database includes facilities that generate combined heat-power as well as facilities that use reclaimed water. Facilities that use reclaimed water will be carried through the analysis, but will not be included in the final decadal projections.

Next, water use for these plants can be estimated by multiplying the electrical generation for the selected baseline year by water intensity factors based on the most recent data available for Texas [Scanlon et al., 2013(a)]. A summary of those factors is presented in **Table 4-7** by fuel type, generator technology and cooling system. A recommendation would be to update these factors each five years using data from EIA, TCEQ, and TWDB to reflect current innovations in water use and efficiency for power generation facilities.

The EIA data can be supplemented by data from the Texas Commission on Environmental Quality (TCEQ) which tracks surface water use through their water rights database and with data from TWDB WUS data. It is important to note, however, that some limitations with these data sources exist as outlined in King et al. [2008], including the following:

- The TCEQ water right database provides details on consumption, diversions and return flows for surface water only, but not groundwater; however, there is very little groundwater used in steam-electric power generation.
- The TWDB WUS provides details on diversions of surface water and groundwater, but not consumption.

While King et al. [2008] noted some deficiencies with EIA data, this database has been significantly improved in recent years. The EIA database includes data on withdrawal, diversions, consumption and return flows of surface water and groundwater. Improvements in the database include reporting of the hours of service, rates of diversion, withdrawal, consumption and discharge in gallons/minute rather than cubic feet per second, and reporting of cumulative total volumes per month.

All three data sources (EIA, TCEQ, and TWDB) should be used because of lack of reporting for some plants in different databases. These data can then be used to develop water demand factors for different types of power plants by fuel source, generator technology, and cooling system, similar to those reported in **Table 4-7**.

Table 4-7 Water Demand Factors (after Scanlon et al., 2013)

Fuel type	Generator technology	Cooling system	No. Plants	Net generation (TWh)[a]	Consumption		Withdrawal	
					(kaf)[d]	(gal/kWh)	(kaf)	(gal/kWh)
Nuclear	Steam turbine	Once-through	4	41.3	59.0	0.46	4,619	36
Coal	Steam turbine	Once-through	25	103.3	166.4	0.52	12,182	38
		Tower	14	47.4	82.0	0.56	90	0.62
Natural gas	Steam turbine	Once-through	63	17.1	23.1	0.44	7,406	141
		Tower	34	6.8	14.3	0.68	15	0.71
		Cogeneration[b]	9	0.9	0.3	0.12	0.4	0.15
	Combined cycle	Once-through	23	9.8	3.5	0.12	1,779	59
		Tower	140	75.6	53.8	0.23	61	0.26
		Cogeneration[b]	44	29.6	13.2	0.14	18	0.20
Other	Steam turbine	Tower	13	1.7	3.6	0.68	3.8	0.71
		Cogeneration[c]	8	0.4	0.2	0.12	0.2	0.15
Natural gas	Steam turbine	Cogeneration[c]	5	0.5	0.2	0.12	0.2	0.15
	Combined cycle	Cogeneration[c]	61	19.9	7.1	0.12	10	0.16
All	Steam turbine, Combined cycle	All	443	354.3	426.7	0.39	26,184	24
All	All	All	867	410.9	426.7	0.34	26,184	21

Notes: [a]Terawatt hour; [b]Cogeneration with reported water use; [c]Cogeneration with no reported water use; [d]Thousand AF

4.3.2 Recommended Methodology Options

The projected water demand is directly related to the amount of electricity generation required over the same period, and thus is a critical input to establishing demand.

Our proposed methodology recommends use of the annual electricity growth rate projected by ERCOT in their “Long-Term Hourly Peak Demand and Energy Forecast” report to establish the required electricity for near-term projections [ERCOT, 2016(a)]. For the 2016 forecast, the current estimate of the average annual electricity growth rate is 1.1 percent from 2016 – 2025 for the system peak demand. The ERCOT electricity projection is based on a county level forecast of economic and demographic data from Moody’s and 13 years of historical weather data provided by Schneider Electric/DTN for 20 weather stations. Additionally, the EIA has projections of total capacity from 2013 – 2040 at the same growth rate (1.1 percent) as in the ERCOT report (EIA, 2016). These projections are developed at approximately one to one-and-one-half year timescales as in the ERCOT report [EIA, 2016]. Given the challenges and inaccuracies inherent in projecting economic activities across the state and the localized impact on the steam electric power generation sector, this methodology recommends holding that growth rate constant through the 50-year planning horizon.

Next, the electricity generation projections will be aligned with the known locations /generation capacities of future plants using the following data sources:

- Listings of new plants that are being permitted or have recently been permitted at TCEQ.

- ERCOT [2016(b)] identified new plants that come online as well as plants that are retired, either seasonally or permanently, in their biannual Capacity, Demand, and Reserves (CDR) Report. Plants included in this list are those that are permitted and have acquired the necessary water rights. Data available from the CDR report include:
  - Facility name
  - Facility County
  - Fuel-Type
  - Year of Projected Commercial Operations
  - Capacity (MW)
  - Summer Capacity (MW)
- Retirement information is also available from the Public Utility Commission of Texas (PUCT) and EIA databases.

Water use factors (*WUF*, gal/kWh) based on the preceding five-year period will be used to assign water demands for existing and new facilities for a given generator technology and cooling system as shown in the equation below:

$$SEWD = WUF * NG * t_{operational} * 1000 \quad [4\text{-}7]$$

Where steam electric power generation water demand in gallons is defined as *SEWD*; the amount of time the facility is operational is defined as $t_{operational}$ (in hours) and net generation in MWh is defined as *NG.* For new plants that are coming online, it is critical to identify them as baseline or peaking plants in order to properly define $t_{operational}$. For baseload plants, $t_{operational}$ should be defined as if the facility is operational around the clock (24 hours a day, 7 days a week, 365 days per year); however, natural gas combined cycle plants can operate as baseload or peaking plants. Therefore, in the absence of better data, a conservative assumption is to treat all new plants as baseload facilities. Once the plant comes online, it would be recommended to use plant data to adjust the runtime of the facility at that time.

Any remaining generation capacity that has not been specifically allocated to a plant or facility (including capacity associated with retired facilities) must be assigned a water demand. There are several options, which include:

- Maintaining current fuel mix (i.e., combination of generator technology and cooling system)
- Adjust fuel mix to reflect anticipated changes in generator technology based on projected changes in the industry
- Assume 100 percent renewable power generation with zero water demand.

This study recommends the use of 100 percent renewable power generation. While this assumption may seem aggressive, use of wind power has increased significantly since 2000 as shown in **Figure 4-3**. Industry trends indicate that wind power generation is expected to continue growing along with increases in other renewable technologies, such as solar. This assumption of 100 percent replacement with renewable energy is recognized as one, but not the only option, that may be used in developing water demand projections for steam-electric power generation. As with other methodologies presented in this report, the actual use of renewables should be routinely reviewed with each round of water demand projection updates to confirm the validity of this assumption. Should this assumption not be feasible, a tool could be developed to allow for evaluation of various fuel mix, generator type and cooling systems to facilitate development of potential scenarios.

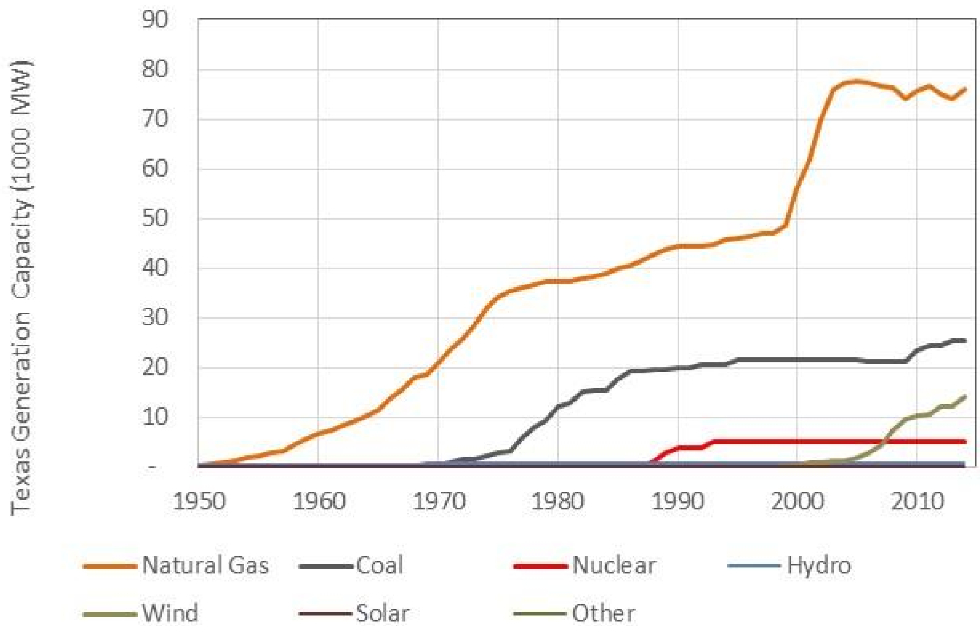

Figure 4-3 Texas Electricity Generation by Generator Technology (taken from Scanlon et al., 2013(b))

4.3.3 Example Calculation for Bexar County

To illustrate how the projections will be developed, an example calculation is provided for Bexar County, which is located in the Coastal Bend regional water planning area (Region N). This county has a total of five power plants that are operational according to the 2013 EIA database. Consumption is calculated on the factors presented in **Table 4-8** to derive baseline water use as shown in **Table 4-8**. According to the CDR Report from ERCOT, the JT Deely plant is scheduled to be retired (i.e., "mothballed") in 2018.

Table 4-8 Operational Steam Electric Power Plants in Bexar County

Plant Name	Net Electricity Generation (MWh, 2013)	Generator Type	Fuel Type	Cooling Type	Water Use (ac-ft)
O W Sommers	800,447	ST	NG	OT	1,080.85
V H Braunig	519,009	ST	NG	OT	700.82
J T Deely	4,650,764	ST	Coal	OT	7,421.78
J K Spruce	7,536,022	ST	Coal	OT	12,026.13
Arthur Von Rosenberg	1,617,112	CC	NG	OT	595.53
TOTAL	15,123,354	-	-	-	21,825.12

Note: ST = Steam Turbine, CC = Combined Cycle, NG = Natural Gas, OT = Once Through

To establish water demand projections, the next step is to apply the projected growth rate to establish future decadal water demands. As described above the annual growth rate for electricity demands is estimated to be 1.1 percent, therefore this rate is applied to the net electricity generation. For illustration purposes, it is assumed that this power will be generated from 100 percent renewable energy (and therefore exerts no water demand); however, this assumption could be refined to assign some portion of the increased demand at existing facilities based on local knowledge. Additionally, it is assumed that the J T Deely plant is replaced starting in 2019 as outlined in the CDR Report and based on information reported in local news reports, will be replaced with energy generated by a natural gas plant located in Guadalupe County. Therefore, water demands associated with this facility are assumed to be zero for Bexar County.

Table 4-9 Example Water Demand Projections for Steam Electric Power Generation

Decade	Water Demand (acre-ft)
Baseline	21,825
2020	14,403
2030	14,403
2040	14,403
2050	14,403
2060	14,403
2070	14,403

4.3.4 Limitations and Assumptions

There are several considerations that should be noted regarding the proposed methodology:

- Facilities that use cogeneration of power and heat are included in the manufacturing demands rather than steam electric.
- Reclaimed water demands are not currently considered in the proposed methodology. They are included as part of the electricity generation, but can be excluded from the demand calculations.
- It should be noted that while the ERCOT region accounts for over 90 percent of the electrical load in the state of Texas, there are other electricity providers operating in the state. As shown in **Figure 4-4**, these include the Midcontinent Independent System Operator (MISO), Southwest Power Pool (SPP) and the Western Electricity Coordinating Council (WECC). It is recommended that the ERCOT projections be applied to the other regions.
- It is recommended that all future power generation capacity be assumed to come online as renewable (i.e., wind and solar) power. The water demand associated with these types of power sources is assumed to be zero in this methodology.

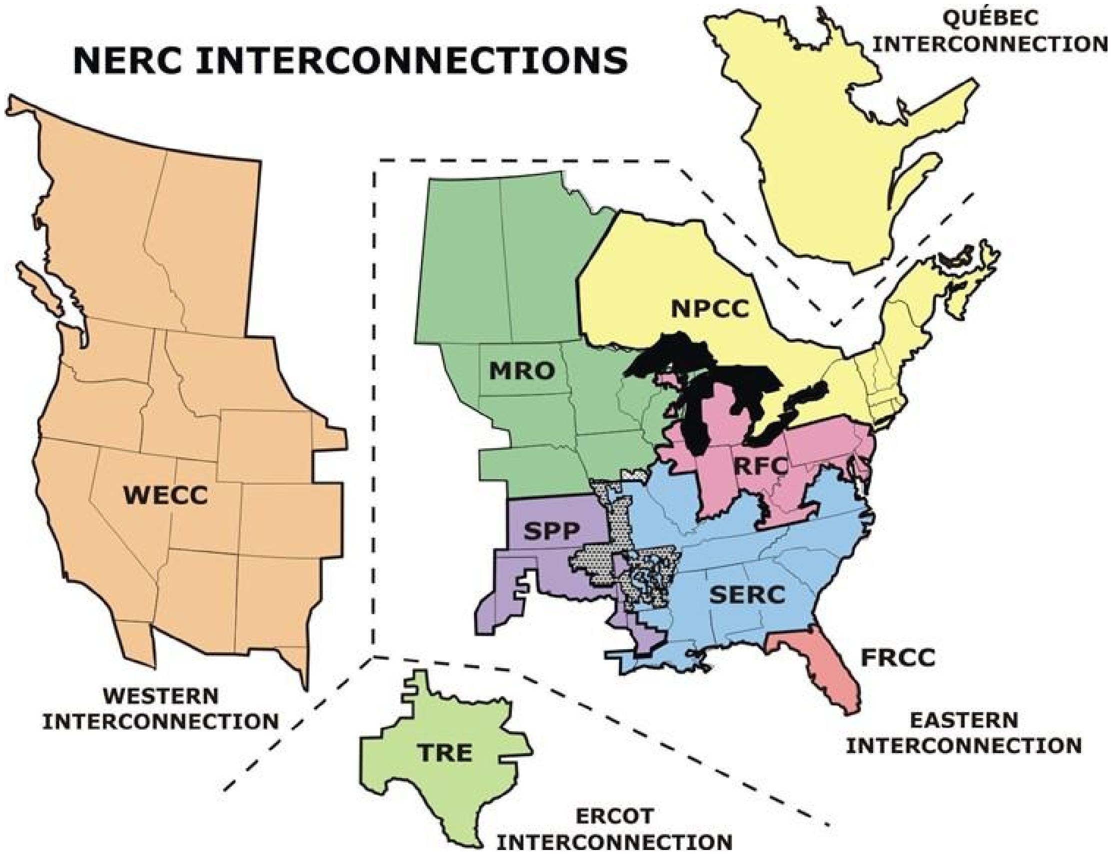

Figure 4-4 North American Electric Reliability Corporation Regional Entities

Section 5

Future Study Recommendations

This report has proposed water demand projection methodologies for three sectors, manufacturing, irrigated agriculture and steam electric power. The following sections provide recommendations for future study to extend and or expand the methodologies that were described in this study.

5.1 General Recommendations

The proposed methodologies in this study rely on a significant amount of data and information to generate the demand projections. One recommendation for future study is to develop a series of spreadsheet tools that standardize inputs, outputs and the overall development of demand projections. Besides streamlining the demand projection process, the tool would allow for flexible adjustments of key assumptions to develop scenarios that would allow for evaluating potential upper and lower bounds of the demand projections.

5.2 Manufacturing Sector

The proposed approach to develop water demands for the manufacturing sector has significant reliance on the TWDB WUS. While the TWDB WUS is nationally recognized as one of the most complete water use databases for cities and industry, efforts to increase the overall response rates and accuracy of reported information would significantly improve the value of this database. As such, the TWDB may consider a public awareness campaign to get the word out to all industries (and cities and steam-electric power) to close the gap.

5.3 Irrigated Agriculture Sector

There are several key areas as they relate to irrigated agriculture that warrant further investigation and study. They are detailed in the following sections.

5.3.1 Historical Irrigated Water Use

The future projections methodology relies on historical WUSs. The validity of these surveys cannot be easily assessed. Satellite data exists to produce 30+ years of historical water consumption over Texas using more advanced algorithms such as the Surface Energy Balance Algorithm for Land (SEBAL) [Bastiaanssen et al., 1998] or Mapping Evapotranspiration with Internalized Calibration (METRIC), which is internally calibrated ground-based reference ET to establish and maintain energy balance conditions at the wet and dry pixels [Allen et al., 2007]. Such methods could feed into both annual water use reports and inform long-term forecasts.

5.3.2. Hydro-Meteorological Data

Irrigation demand is primarily controlled by atmospheric conditions and available soil moisture – neither are adequately monitored in Texas. However, this is also a proposed feasibility study at TWDB which could evaluate this data gap.

5.3.3. Irrigated Acreage Estimates

Since the FSA classified irrigated acreage in 2008, there is no longer a source of either tabular or spatial data on annual state-wide irrigated acreage. Such estimates are required by virtually all irrigation water demand methods. The only operational product is the CDL which is annual and based on aggregated growing season satellite reflectance measurements from Landsat (30m resolution). Although it is often considered 'wrong' at the individual field scale, it is constantly being updated and refined by the USDA. Currently, NASS reports an 80 percent accuracy in Texas. However, it cannot differentiate multiple rotations or cover cropping nor can it determine irrigated from dryland agriculture. Unlike much of the arid West, which receives most of its rainfall over the non-growing season, most of Texas receives rainfall throughout the growing season making irrigated agriculture more difficult to differentiate. Remote sensing likely holds the key to accurately determining irrigated agriculture from dryland but this is not a simple task.

5.4 Steam Electric Power Generation Sector

The proposed approach for steam electric power sector requires significant reliance on water use factors. Water use factors for steam electric power generation should be recalibrated prior to development of each new State Water Plan with the most recent data. These factors should use EIA, TCEQ, and TWDB data to increase reporting for each plant. Because these databases rely on self-reported data, the reported estimates of water withdrawal and consumption should be checked for representative power plants using the combined heat and water budgets proposed by Diehl et al. [2013, 2014]. Factors that may impact water use for power generation should be evaluated, such as the impact of EPA regulations on fuel sources and expansion of dry cooling could also significantly reduce water consumption for thermoelectric generation. During such a review, trends in water use for thermoelectric generation in the U.S. should be reviewed to identify changes in efficiency standards and potential impact of any new innovations in the industry. As an example, currently there are two dry cooling plants in the state and their performance should be evaluated.

Additionally, modifications to the TWDB WUS may further support the recalibration effort. If data relevant to development of steam electric power demands were captured, the WUS itself could be used as part of the evaluation. Potential variables to add to the WUS include:

- Amount of power generated at the facility
- Consumption of surface and groundwater

Section 6
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