CLIMATE CHANGE AND TEXAS WATER REGULATION

HELEN CURRIE FOSTER
GRAVES, DOUGHERTY, HEARON & MOODY, P.C.
401 Congress Avenue
Suite 2200
Austin, Texas 78701

State Bar of Texas
THE CHANGING FACE OF WATER RIGHTS 2011
February 24-25, 2011
San Antonio, Texas

CHAPTER 16

HELEN CURRIE FOSTER
Graves, Dougherty, Hearon & Moody, P.C.
401 Congress Ave., Suite 2200 Austin, Texas 78701
512-480-5681
hfoster@gdhm.com

EDUCATION
B.A., Wellesley College; Wellesley College Scholar
M.A., The University of Texas
J.D. , magna cum laude, University of Michigan; Order of the Coif

PRACTICE FOCUS
Helen Currie Foster's practice focuses on environmental law and on trial and appellate litigation, both in court and before administrative agencies. In addition to general business and regulatory litigation, she has special experience with environmental issues, permitting and remediation, response cost liability, and statutory requirements (CERCLA, Clean Water Act, Endangered Species Act, RCRA). She counsels on a wide range of land and water issues, including environmental considerations in real estate transfers, storm water management, and environmental liability (common law and statutory). Recent experience includes representation of clients on groundwater rights and water supply issues, cleanup resulting from oil and gas-related activities, and cleanup of underground storage tank or dry cleaner facilities. Her experience includes successful representation of intervenor mineral owners in landfill litigation, and of trusts in issues involving Texas Solid Waste Disposal Act and Railroad Commission requirements; successful resolution of water supply contract disputes for a Texas municipality; and client defense in Enron-related securities litigation (federal and state).

PROFESSIONAL ACTIVITIES
Past Chair and Board Member, Texas Board of Legal Specialization
Member: Austin Bar Association (Administrative Law Section)
Member: American Bar Association (Litigation Section; Section of Environment, Energy and Resources)
Member: State Bar of Texas (Litigation Section)
Past Member: Alabama State Bar (Past President, Environmental Law Section)

Listed in The Best Lawyers in America® published by Woodward/White, Inc., Administrative Law 2010-2011.

LAW RELATED PUBLICATIONS AND PRESENTATIONS:
Author/speaker, "Federal Preemption in Regulatory Litigation," Fifth Annual Advanced Texas Administrative Law Seminar, September, 2010.
Author/speaker, Environmental Ethics – "I've Got No Strings," 22nd Annual Texas Environmental Superconference, August, 2010.
Co-Author, "'As Is' In a Contaminated World," 19th Annual Robert C. Sneed Texas Land Title Institute, December 2009, San Antonio, Texas.
Author/Speaker, Complying with Storm Water Regulations, Lorman Seminars, Texas Storm Water Law and Regulations, August 12, 2009, Austin, Texas.
Author/Speaker, "Complying with Storm Water and Surface Water Management Regulations," HalfMoon Seminars, LLC, Texas Water Laws and Regulations, April 30, 2009, Austin, Texas.
Author/Speaker, "New Phase I Requirements for Real Estate Transactions: Implications of the New 'All Appropriate Inquiries' Rule," State Bar of Texas 28th Annual Advanced Real Estate Law Course, June 29 – July 1, 2006, San Antonio, Texas.
Author/Speaker, Curious Characteristics of Karst: Legal Environmental Considerations, American Bar Association Section of Environment, Energy and Resources, October 3-7, 2001, Adam's Mark Hotel, St. Louis, Missouri.
Faculty Member and Author/Speaker, Recent Developments – Texas Water Law, the University of Texas School of Law 3rd Annual Conference on Land Use Planning Law, March 4-5, 1999, Austin, Texas

COMMUNITY
Active Fundraiser for KUT Radio (Austin, Texas NPR Affiliate)
Masters Level sweep rowing with Austin Rowing Club (port oar)
Helen has a special interest in Texas Hill Country land management (grasses, storm water and roads).

TABLE OF CONTENTS

Page

CLIMATE CHANGE AND TEXAS WATER REGULATION

INTRODUCTION. Current statutory constraints require Texas water planning to base projected water supplies on the worst drought conditions in the historical hydrological record (the "drought of record"). In other words, current planning is based on the assumption of "climate stationarity," i.e., that future climate variability is predicted by historic climate records. Yet planners now acknowledge that climate trends are turning away from existing conditions. And, importantly, the broader historical record, with *proxies* for historic hydrological data (such as tree ring data), indicates greater variability in past climate than is captured by the current drought of record, the Texas drought of the 1950s. Recent studies (including by the Texas Water Development Board) now suggest incorporating climate uncertainty as part of the statutory planning process. It appears we are now at the early stages of a major transformation in the way we are thinking about state water planning. Failure to address climate change in planning may impact the predictive capability and usefulness of Texas water planning. In combination with anticipated increased population growth and increased water demand, such a failure could have serious consequences.

I. LOOKING BACKWARD: RELIANCE ON HISTORIC HYDROLOGY AND THE "DROUGHT OF RECORD." Current Texas statutory water planning documents center on historical data, and in particular on a 50-year planning process which is based on a repeat of the historical drought of record, as required by Senate Bill 1 (SB 1), a comprehensive state water planning statute passed in June 1997 by the 75th Texas Legislature. *See* Tex. Water Code § 16.053(e)(4) (requiring "specific provisions for water management strategies to be used during a drought of record"). This statutory process essentially means that the worst drought to be used for planning purposes for the *upcoming* 50 year period is generally the worst drought in the *past* 50 years. Of necessity, then, while the planning process can be said to look forward on issues such as water demand, it generally looks backward (with exceptions) on availability of water supplies.

A. Regional Water Plans. Beginning in 2001, and updating every five years, each of the sixteen water planning regions designated by the Texas Water Development Board ("TWDB") must submit for TWDB approval a regional water plan which provides water management strategies to be used during a drought of record. 31 TAC § 357.5(e)(2). In developing their plans, regions must evaluate the adequacy of "existing" water supplies available during a drought of record, considering "surface water and groundwater data from the state water plan" and other planning and water supply studies. 31 TAC § 357.7(a)(3). "Existing" means "water supply available at the beginning of this task." *Id.* Furthermore, analysis of surface water available during drought of record shall be based on "firm yield." Firm yield analyses determine the amount of water that is available on an annual basis during a repeat of historical drought of record conditions and assuming all the water in the reservoir is available for use. *Id.*

B. State Water Plan. Regional water plans, upon approval, become part of the State Water Plan, a comprehensive water plan covering a 50-year planning period. 31 TAC § 358.2(11).

C. Required use of TCEQ's Water Availability Models. SB 1 required TCEQ to prepare water availability models ("WAMs") for evaluating the adequacy of surface water supplies. Once those models become available, the regional planning groups *must* use them to evaluate the adequacy of surface water supplies. 31 TAC § 357.7(a)(3).

1. WAMs predict surface water supply. TCEQ's WAMs are computer-based simulations predicting the amount of water that would be available in a river or stream under a specified set of conditions. The model for a specific river basin consists of two parts: the modeling program, called "WRAP," short for Water Rights Analysis Package; and a text-file that contains basin-specific information for WRAP to process.

2. WAM input is historically based. The WRAP simulation of a WAM is *historically based - based on historic hydrology*. Per TCEQ personnel, the goal is to "adequately account for the historic range of variability" (from very high to the drought of record). One input to the WAM is naturalized streamflow. "For most Texas river systems, the naturalized flows encompass at least a fifty-year period of record that includes the drought of the 1950s." Kathy Alexander, TCEQ, *Water Availability Modeling*. "A typical WRAP simulation study involves assessing capabilities for meeting specified water management/use requirements *during a hypothetical repetition of historical hydrology*. For example … the analysts may choose to analyze reliabilities of existing or proposed reservoirs and other facilities to supply year 2001 water needs, with basin hydrology represented by sequences of monthly naturalized

streamflows and reservoir net evaporation-precipitation rates at all pertinent locations *for each of the 720 months of a 1940-1999 hydrologic period-of-analysis."* R. A. Wurbs, *Reference and Users Manual for the Water Rights Analysis Package (WRAP*), p. 1 TR-180, Texas Water Resources Institute, July 2001.

3. WAMs are used for permitting as well as planning. WAMs are also used by TCEQ to determine whether water would be available for a newly requested water right (i.e., application for water rights permit or amendment).

a. The Full Authorization simulation, in which all water rights use their maximum authorized amounts, is used to evaluate applications for *perpetual* water rights and amendments.

b. The Current Conditions simulation, which includes return flows, is used to evaluate applications for *term* water rights and amendments.

D. Required use of TWDB's Groundwater Availability Models. TWDB's Groundwater Availability Models (GAMs) are numerical models that simulate the flow of groundwater, predicting groundwater response to external stresses such as pumping. TWDB GAMs must be used by regional planning groups, groundwater conservation districts, and groundwater management areas. Once groundwater availability modeling is available from TWDB for an area within a region, the region must incorporate that groundwater information in the next planning cycle "unless better site-specific information is available." 31 TAC §357.7(3). Groundwater conservation districts (GCDs) must also use TWDB GAM information. *See* Tex. Water Code § 36.1071(h) ("In developing its management plan, the district shall use the groundwater availability modeling information provided by the executive administrator [of TWDB] together with any available site-specific information that has been provided by the district to the executive administrator for review and comment…."). Furthermore, House Bill 1763, passed in 2005, introduced the concept of "groundwater management areas" and of "desired future condition" of aquifers through joint planning of the GCDs located within a groundwater management area (GMA).[1] GAM information must also be considered by the GCDs within a GMA, in determining "desired future condition" of the aquifers within a GMA. Tex. Water Code. § 36.108(d).

1. GAMs must meet statutory requirements. Statute specifies information from the GAM that must go into a GCD groundwater management plan. *See* Tex. Water Code § 36.1071(e)(3). This includes:

a. Annual amount of recharge from precipitation to groundwater resources within the GCD;

b. For each aquifer within the GCD, the annual volume of water that discharges from the aquifer to springs and any surface water; and

c. The annual volume of flow into and out of the GCD within each aquifer and between aquifers in the GCD.

2. "Desired future condition" determinations rely on GAMs. The GCD must also include in its management plan estimates of the "managed available groundwater" (the amount of water that may be permitted by a district for beneficial use in accordance with the desired future condition of the aquifer) based on the "desired future condition" (desired, quantified condition of groundwater resources at a specified time) established under Tex. Water Code § 36.108. Section 36.108 (joint planning in management area) requires GCDs within a GMA to "consider groundwater availability models and other data or information" in establishing the desired future condition for relevant aquifers in the GMA.

3. TWDB provides two types of GAM runs, for two different purposes. According to TWDB, GAMs for the GMA predictive model runs use a *30-year average recharge amount* since variability in the magnitude and frequency of droughts and wet periods with impact on recharge is hard to predict. However, for the GCD management plans, TWDB extracts historical water budget information to address the requirements of Tex. Water Code § 36.1071 (i.e., include annual recharge from precipitation only). The recharge values for GCD management plans are averaged from the "historical calibrated transient period" which typically covers a *twenty year recharge* period from 1980-1999. Thus, historic precipitation for the 20-year period would be used.

4. The more flexible predictive GAM can address climate issues. According to TWDB personnel, while Tex. Water Code § 36.1071 establishes the data to be included in the GAM modeling for the groundwater management plan, modifications can be made to the predictive "desired future condition" GAM to deal

[1] TWDB was required to designate GMAs covering all major and minor aquifers in the state, under Tex. Water Code §35.004, "with the objective of providing the most suitable area for the management of the groundwater resources." *Id.*

with climate issues. For example, TWDB recently produced a GAM model run for GMA 9 (Comal, Hays, Travis Bexar, Medina, Bandera, Blanco, Kendall, and Kerr counties). William R. Hutchison, Ph.D., P.E., P.G., TWDB, GAM Task 10-005, September 3, 2010. The model used tree ring data from 1587 to 1972 for the Edwards Plateau, and ran 387 50-year simulations based on the tree-ring precipitation estimates over the 435-year period. *Id.*, p. 3.[2] The results were used to evaluate relationships between pumping versus drawdown, spring and base flow and outflow across the Balcones Fault Zone. *Id.* The flexibility of the GAM for "desired future conditions" predictive modeling provides an opportunity for inclusion of climate change uncertainties in the modeling. This flexibility, in combination with the five-year planning updates required by statute, offers a mechanism to update groundwater availability as climate change models become better tailored to Texas (*see* Part III.B.5 below).

5. TWDB considers the GAMs "living tools" subject to updates. The opportunity to use updated GAMs is built into the water planning process, with its required updates: Regional Plans are to be updated every five years (Tex. Water Code § 16.053(i)), as are groundwater management plans for GCDs (Tex. Water Code § 36.1072(e)), and desired future conditions for GMAs (Tex. Water Code § 36.108(d)).

II. CURRENT STATE REPORTS: SILENT ON CLIMATE CHANGE. The current regional water plan reports, groundwater management area reports, and the TWDB Legislative Priorities Report generally omit reference to climate change.

A. Regional Water Plans. Executive summaries for the sixteen 2010 Regional Water Plans submitted to the TWDB by Regions A-P, with limited exceptions (*see* Region E, Far West), do not even mention the term "climate change." Several plans do, however, refer to the possibility of future conditions more severe than the drought of record.

1. Region B. Region B states, "Experts at the University of Arizona's Climate Assessment Project for the Southwest recently indicated that Texas might be heading into a significant dry period. Since 1995 climatic patterns have shifted, bringing warmer drier weather to the Southern United States This phenomenon called the Pacific Decadal Oscillation usually lasts 20 to 30 years…. If this happens, then the region may be entering a new drought period that may surpass the historical drought of record and the firm yield may overestimate the available water supply. However, it is still too early to assess the impact of this weather shift."

2. Region E. Region E, Far West, reports it held the Far West Climate Change Conference in 2008, as required by SB 1762, authored by State Senator Eliot Shapleigh during the 80th Texas Legislative session, and includes the Conference proceedings as an exhibit.

3. Region L. Region L, South Central, states that it has proposed strategies "over and above those apparently needed to meet projected demands." One of the listed reasons is "to ensure adequate supplies in the event of a drought more severe than that which occurred historically."

4. Region N. Region N, Coastal Bend, notes that "safe yield analyses are becoming commonly used in anticipation of future drought greater in severity than the worst drought of record," and adopts use of safe yield (as opposed to firm yield) analyses for supply from the CCR/LCC/Lake Texana System.

B. TWDB Legislative Priorities Report. TWDB "Legislative Priorities Report" to the 82nd Legislative Session does not apparently refer to the term "climate change," though referencing "the state's susceptibility to severe drought."

C. Groundwater Management Area reports. Groundwater Management Area reports, i.e., the "desired future condition" submittals (Tex. Water Code § 36.108(d)) required of Groundwater Management Areas by House Bill 1783, do not generally reference climate change. However, TWDB's webpage of frequently asked questions (http://www.texaswatermatters.org/groundwater_faq.htm) for Groundwater Management Areas does reference climate change:

> *Should we consider drought conditions in our GAM?*
> Yes. In Texas, a drought is never far away. **And with climate change increasing the amount and intensity of droughts in the foreseeable future**, planners need to incorporate drought of record conditions into their model to accurately predict how groundwater pumping will affect an

[2] As information, precipitation for the 50-year period ending in 1593 was about 96% of average, and represents the driest 50-year period in the record; aside from the generally dry conditions in the late 1500s and early 1600s, there are three other relatively dry periods in the early 1800s, the early 1900s, and the most recent period that ended in 1972. *Id.*, p. 4.

aquifer and its outflows during drought. Though the results of incorporating drought of model often show a very drastically lowered aquifer level during a drought, this is a reality that cannot be ignored. Because incorporating a drought of record into a GAM is an easy request, it is in everyone's best interest to have a full understanding of their aquifer during all conditions. Most models can be calibrated to account for drought contingency plans that reduce the amount of pumping during a drought, so that the model depicts as close to a real scenario as possible. (Emphasis added.)

We didn't consider drought conditions in our GAM, should we re-run the model?

This is a very important piece of information that should be considered in the development of every DFC. Drought is a part of life in Texas and we need to make sure that we have water supplies for at least basic needs available during drought as well as normal climactic conditions. This is especially true in areas that are already experiencing stress on their groundwater resources.

III. RECENT STUDIES: NEED TO ADDRESS CLIMATE UNCERTAINTY. Recent studies recognize the need to incorporate climate change uncertainty in Texas water planning. Recent studies indicate general agreement on the existence of climate change impact (though not its details), as well as a need to "downscale" climate change models so they are of greater use in Texas regional water planning. A recent TWDB study proposes addition of climate change scenarios in water planning. The recent inaugural article in the Texas Water Journal calls for additional actions, including incorporation of large droughts of the past into water planning, advancement of adaptive management strategies for Texas water, and calculating potential cost of climate change on the state's economy (including the cost of taking no action).

A. TWDB 2010: A modest proposal. A recent TWDB study recognizes the predictive limitations of WAMs and GAMs, recognizes Texas' vulnerability to climate change, and attempts to develop modeling strategies to address the need to consider uncertainties – including climate change uncertainty – in water planning. Abhishek Singh, Srikanta Mishra, *et al., Analyzing Uncertainty and Risk in the Management of Water Resources for the State of Texas*, TWDB July 2010, Contract 090483057. TWDB calls this an "incremental approach" which "preserves the fundamental elements of the well-established planning process." *Id.*, p. vii.

1. The study proposes adding climate change scenarios to the planning process. The methodology is to select appropriate global climate change models, select multiple "emission futures" to feed into the global climate change models, run multiple emission futures with multiple models to obtain an ensemble of "climate scenarios," and run a hydrologic model to assess response of water resources to the climate scenarios. Using resulting streamflows and other data for different climate scenarios, a WAM would be used to assess water supply in drought conditions (so that each climate scenario then leads to a projection of water supply under drought conditions). In addition, GAMs may be run with inputs (such as aquifer recharge) derived from climate scenarios, to predict groundwater supply.

2. The study recognizes the existence of climate uncertainty. The TWDB study recognizes that there is evidence to show that worse droughts than the current drought of record have occurred in the past and may occur in the future (i.e., there is uncertainty in the drought conditions which are used as the basis for the planning process). *Id.*, p. 2-6. Furthermore, the current planning framework is based on the assumption of climate stationarity, i.e., that future climate variability is captured in the historic climate records. *Id.* But the study recognizes there is reason to believe that climate trends are turning away from existing conditions (i.e., there is climate uncertainty as well in the water planning process). *Id.*

3. The study also recognizes modeling uncertainty and emissions uncertainty. The study notes that modeling uncertainty results from the fact that while multiple global climate models exist, they are best suited for global-scale processes. Yet *regional* climate predictions, which are critical for water supply predictions, are considerably more difficult. Emissions uncertainty (increase or decrease in carbon dioxide emissions) also exists: different human responses to climate change could lead to different emission paths, which in turn will impact climate differently. "For example, a move towards 'green' technology would likely lead to lower emissions, while maintaining the status-quo would likely lead to higher emissions." *Id.*, p. 2-9.

4. The study recognizes WAM/GAM vulnerability to climate change. The study recognizes that WAMs rely on the assumption of hydrologic stationarity (based on the drought of record), while climate change may challenge the notion of hydrologic stationarity. *Id.* p. 2-11. GAMs are also calibrated to historical data, and hence vulnerable: "Climate, too, can impact

GAM inputs…, especially inputs such as recharge and evapotranspiration that may be sensitive to climate conditions." *Id.,* p. 2-12.

5. "Texasville" should plan for climate uncertainty. The study develops a hypothetical case study of "Texasville," located in the Colorado river basin, to demonstrate the concepts. *Id.*, p. 4-1. Climate is assumed to be the main driver for supply uncertainty. The basis for quantifying uncertainty in water supply due to climate change was a recent study for a proposed project by the Lower Colorado River Authority and San Antonio Water Supply (CH2M HILL, 2008). The CH2M HILL study combined two carbon emission futures with two climate models to yield four climate scenarios. Results from the resulting hydrologic modeling indicated that annual streamflow in the Colorado was projected to decrease under all climate change scenarios by 2050, despite the fact that certain climate change scenarios predicted a small increase in precipitation (indicating that evapotranspiration was the dominant hydrologic process affecting runoff and streamflow for this river basin). *Id.*, p. 4-3. TWDB then combined the four scenarios from the CH2M HILL study with a "baseline" scenario, representing historic records (scenario without climate change). Significantly, "accounting for climate change led to a reduction of projected supply for all climate scenarios. Thus, the baseline supply projection (based on historic records) could be considered overly optimistic for this case." *Id.*, p. 4-21. The "Texasville" hypothetical also examines population uncertainty and water usage rate uncertainty, as well as possible strategies. "This indicates that the city of Texasville should be cognizant of the uncertainties in climate and population projections, and plan ahead for changes in both these underlying factors. This also indicates that future planning cycles may need to reassess and refine assumptions regarding climate and population growth, thus allowing the city to better adapt to changes in the future." *Id.*, p. 4-22.

B. 2010 White Paper: A call to action. A recent white paper in the inaugural issue of the online Texas Water Journal, published in cooperation with the Texas Water Resources Institute, calls for action to address climate change impacts. Jay L. Banner, Charles S. Jackson, *et al., Climate Change Impacts on Texas Water: A White Paper Assessment of the Past, Present and Future and Recommendations for Action,* Texas Water Journal Vol. 1., No. 1, pp. 1-19, September 2010 (http://journals.tdl.org/twj) (hereafter "White Paper"). In the introduction, former TCEQ Commissioner Larry R. Soward states that almost all climate model projections show that Texas is "extremely susceptible to significant future climate variability" with "strong potential of extreme stress on its water resources." "This fact, coupled with a rapid and concurrent population growth, will likely push water supply and demand issues in the state, especially in the urban areas, to the 'breaking point.'" White Paper, p. 2.

1. The Southwest as "danger zone." The Southwest has been characterized as a "danger zone" due to its combined vulnerability to significant future climate change and rapidly growing population. Texas is projected to have a population at least twice as large (at 35.8 million projected for 2040) as in 1990 (when it was 17.0 million). *Id.,* pp. 3, 13.

2. The "Drought of Record" isn't. While the 1950s drought of record is commonly used as Texas' worst-case-scenario for drought planning, it is not unprecedented. Climate records now extend further back in time using proxies such as tree rings, which show that more severe and sustained droughts occurred prior to the 20th century. The most severe occurred in west Texas during much of the 13th century, and in central Texas during the last half of the 16th century (a "megadrought") and at the turn of the 18th century. *Id.*, p. 5.

3. "How hot" depends partly on emissions. IPCC climate change models project average surface air temperature for Texas will increase by 2-5ºC over the 21st century. *Id.* p. 8. Projected temperatures for Texas are dependent on which greenhouse gas emissions scenario is ultimately applicable. *Id.,* p. 10, Fig. 6. (showing that in a higher emissions scenario, some regions of Texas could shift from 10-20 days above 100ºF in the recent past to more than 100 days per year in which the temperature exceeds 100ºF).

4. Rain? Variable. Precipitation forecasts for Texas in the 21st century show more variability and uncertainty. However, two factors indicate evaporation may be a more important determinant of water availability in Texas. First, there is more agreement among forecasts of temperature increase; second, evaporation plays a large role in Texas' hydrologic cycle. Estimates are that nine out of every 10 drops of rain that fall on Texas leave Texas as evaporation, rather than as runoff to streams. *Id.*, p. 10.

5. Predictions for Texas water. The White Paper concludes that implications of climate change for Texas' unique water resource conditions include the following:

a. With projected warming, rivers and reservoirs will lose water to evaporation. The White Paper notes that few studies have examined projected impacts of climate change on Texas water resources. A 2002 study of the San Jacinto River Basin was the only study to find an increase in stream flow (20% increase in flow, 30% increase in variability in a a50-year model projection from increased flood flows in spring and fall). A 2005 model projection of the Brazos found reduced streamflow and a 5% reduction in reliability of the resource. Multiple climate model projections for 2050 for the Colorado River Basin yield estimates of significantly decreased runoff in the basin in central Texas, with estimates of future streamflow to the Colorado River expected to decrease by 13% to 34% (*citing* CH2M HILL 2008). The White Paper concludes that, combining the impacts of increased water demand due to population growth and projections in climate change by 2050, under drought conditions, Texas' surface water supply will fail to meet the state's water-use demands. *Id.*, p. 11.

b. Agriculture, aquatic ecosystems, and estuaries that depend on fresh-salt water balances could be damaged by drastic reduction of streamflow in the Rio Grande and other rivers.

c. Some studies suggest more intense rainfall events are associated with global warming, with implications such as potential to increase runoff and decrease infiltration, with resulting potential to exacerbate water quality problems.

d. Cooling water for coal-fired, natural gas, and nuclear power plants represents 40% of freshwater extraction in the United States, and severe drought could mean that such water is also under demand for other sectors of the economy. *Id.*, pp. 12-13.

e. Rising sea level and changes in stream discharge into Gulf of Mexico estuaries would threaten coastal freshwater aquifers, as well as the benefit from tourism, recreation, and fishing. *Id.,* p. 13. The Texas coast has experienced among the greatest sea level rises in the United States over the past 50 years and is projected by the end of the century to experience among the greatest rises, including a projected 3.5 foot rise in Galveston. *Id.*

f. The White Paper notes that if temperatures rise as projected, human health will likely be affected by heat-related illnesses, water quality impacts, and northward spread of tropical diseases and pests, and that in addition more regions in Texas will not attain EPA ground-level ozone standards. *Id.*

6. Sweeping recommendations. The White Paper's recommendations include:

a. Establish a Texas Climate Consortium reporting to the TWDB.

b. Go beyond the 1950s drought of record, and incorporate large droughts of the past into water planning.

c. Establish a statewide real-time monitoring network of climate and hydrologic variability to apply leading edge scientific understanding of Texas' climate and water to Texas' needs.

d. Improve applicability of climate models for the Texas region.

e. Continue to advance the use of adaptive management strategies for Texas' water resources, anticipating water quality changes resulting from climate change, such as increased water temperatures, reduced base flows, etc., and maximizing options, such as conservation.

f. Determine the impact and calculate the costs of projected climate change to the state's economy, including the cost of no action.

g. Advance research on the connection of water supply and energy use.

h. Encourage education programs on the science and policy of climate change and water resources. *Id.,* pp. 14-15.

C. 2008 Proceedings of Far West Texas Climate Change Conference. Region E, Far West, held the Far West Texas Climate Change Conference in 2008. TWDB was required to submit the written report on the conference findings to the Legislature by December 31, 2008. The Introduction to the Far West Texas Climate Change Conference Study Findings and Conference Proceedings, TWDB December 2008, acknowledged that the current Texas statutory approach to water planning, based on the mid-20th century drought of record, is based on the concept of "stationarity," assuming a relatively stable "envelope of variability." The Introduction lists the challenges to this "stationarity" approach faced by water planners, from evidence of even greater droughts in the past, to human impact on hydrology, to global climate change:

> "Water Managers in Texas and beyond are struggling with how to incorporate the consideration of potential impacts of climate change in short-and long-term water supply planning efforts. Traditionally, water planners have assumed that weather patterns documented in the historical record will persist into the future…. Planners have relied on the concept of 'stationarity,' which assumes that natural systems fluctuate within a relatively stable envelope of variability.... However, the range of natural processes has recently been challenged by tree ring-based reconstructions of streamflow that show that the window of natural variability is actually much broader than documented by the historical record. In fact, far worse droughts have occurred in previous centuries than the mid-20th century drought upon which Texas water planning is based. The stationarity assumption has also been challenged by human disturbances in watersheds such as land cover and land use changes, drainage modifications, large-scale infrastructure, and other alterations in natural hydrology that aggravate flooding, water quality, and water supply problems…One of the most daunting challenges to the stationarity assumption is mounting evidence, most recently highlighted by the International Panel on Climate Change, that the world's climate itself is changing enough that it could have profound impacts on water resources and their management around the world." (Citations omitted.)

1. Surface water at risk. The Proceedings cautiously conclude that surface water resources within Far West Texas and the rest of the state are at risk from potential impacts of climate change. Proceedings, p. 35.

2. Emissions-related impacts. The Proceedings reference studies suggesting that over the 20th century the global average surface temperature has increased by 1ºF, while many areas, including the Northern Hemisphere and the tropics, are experiencing increased precipitation. The studies attribute some changes to human activities that have increased the concentration of carbon dioxide, methane, and other greenhouse gases trapping heat in the Earth's atmosphere. "The greatest contribution to the human-caused greenhouse effect is the large amount of carbon dioxide produced by burning carbon-based fuels such as coal, oil, and natural gas. Greenhouse gases are also released during manufacturing processes, oil and gas production, and as a result of deforestation and agricultural practices."[3] *Id.*, p. 14.

3. IPCC-projected impacts. The Proceedings reference the 2007 Summary for Policymakers released by the Intergovernmental Panel on Climate Change (IPCC) set up by the World Meteorological Organization and the United Nations, which lists some projected impacts in North America: "Rising temperatures that occur more frequently would be virtually certain to cause effects on water supplies relying on snow melt. Heat waves with increasing frequency could also very likely cause increased water demand and water quality problems. Heavy precipitation events would likely cause adverse effects on water quality and contamination of water supplies but may relieve some water scarcity." *Id.,* p. 15.

4. Increased evapo-transpiration. Global models show variability for Texas, though most predict less rainfall for West Texas. *Id.*, p. 17. Focusing on Far West Texas, the Proceedings note that water resources in drier climates are more sensitive to climate change, in part because evaporation is likely to increase with a warmer climate, which could result in lower river flow in the Rio Grande and in reservoirs. If streamflow and lake levels drop, groundwater could also be reduced. However, average rainfall does not appear to have changed significantly this past century in Texas on either a regional or statewide basis; temperature trends in Texas also have not changed significantly, and temperature trends are probably more significant than rain fall in water resources planning because of their relationship to surface water evaporation and irrigation demand. *Id.,* p. 16.
\

5. Specifics from conference presenters. Conference presenters offered more specific conclusions.

a. Dr. Gerald North, distinguished professor in atmospheric sciences and oceanography at Texas A&M for the past 22 years, concluded, "The models are now good enough to make projections into the future of climate for such regional areas as the US.Southwest and perhaps even Texas. All models

---

[3] Texas released 670 million metric tons of carbon dioxide into the atmosphere in 2003, enough that Texas would rank seventh in the world if it were its own country, according to the most recent figures from the U.S. Energy Information Administration. The amount is more than California and Pennsylvania — the second- and third-ranking states — combined.

say that Texas will be several degrees Celsius warmer over this century. Water is a primary concern and although precipitation and evaporation are more difficult to model, the indications are that available water will be scarcer in the next 50 years, particularly in the western portion of our state." *Id.,* p. 22.

b. Dr. John Nielsen-Gammon, Texas State Climatologist/Professor of Meteorology, Texas A&M Department of Atmospheric Sciences, stated, "Computer-based climate models are in complete agreement that Far West Texas should become warmer and probably drier as greenhouse gases continue to accumulate.... Temperatures have increased across Far West Texas over the past century ... in contrast to the rest of Texas and the southeastern United States." He also concluded, "temperatures are very likely to continue to increase and precipitation is more likely than not to decrease slightly. Because rising temperatures would lead to increased water demand by cities, agriculture and ecosystems even if precipitation remained steady, the effects of droughts are likely to become more severe over time." *Id*., pp. 23-24.

6. Need to "regionalize" global climate change models. The Conference recognized the need for a downscaling approach to permit regional hydrological application. Because global climate change typically have a resolution of 100-200 miles by 100-200 miles, and because most hydrological applications require information at a 30-mile, TWDB issued a Request for Qualifications on choosing the appropriate downscaling approaches and models for hydrological applications in Texas. According to TWDB personnel, Texas Tech was contracted to identify which climate change models best represent Texas conditions, with results expected by mid-2011. This is seen as a prerequisite before downscaling is undertaken.

D. 2008 Groundwater Study: aquifer impact will vary, with karst most vulnerable. A 2008 study indicates Texas' karst aquifers (like the Edwards) could potentially be more affected than other aquifers by climate change. A 2008 study by Robert Mace and Shirley Wade on Texas groundwater indicates that impact of climate change may vary depending on the geology of the aquifer, with the sensitivity of the aquifer to climate change being related to the residence time of water in the aquifer. Accordingly, karstic aquifers will be more susceptible to impact. In dipping aquifers with local discharge in the unconfined part of the aquifer and pumping primarily in the confined part of the aquifer, climate change may have little to no effect. Mace and Wade, *In Hot Water? How Climate Change May (or May Not) Affect the Groundwater Resources of Texas,* Gulf Coast Association of Geological Societies Transactions, v. 58, p. 655-668. (This study is available on the TWDB website.) For example:

1. Fractured and karstic aquifers may be more susceptible to climate change. Climate change may have greater impact on fractured and karstic Texas aquifers, such as the Edwards Aquifer, the Hill Country portion of the Trinity, and the Bone Spring – Victorio Peak Aquifer. Mace and Wade conclude that "The Edwards Aquifer is particularly susceptible to climate change because it recharges so quickly and is closely tied to surface water runoff." *Id.,* p. 665. The Edwards, for instance, is very responsive to changes in precipitation, which affects water levels, spring flows, and how much water can be pumped out of the aquifer. For karstic aquifers that rely on streams and rivers for substantial recharge, climate change effects on surface water and runoff will affect recharge. *Id.*, p. 659.

2. Carrizo-Wilcox, Trinity and Gulf Coast Aquifers may be less impacted by climate change. Mace and Wade do not expect the Carrizo-Wilcox, the Trinity north of the Colorado River, and the Gulf Coast Aquifers to be directly affected by climate change because of the dipping geology and location of much of its pumping in the confined part of the aquifers. However, both could be indirectly affected by pumping if the climate gets drier and they are sought as conjunctive water sources. *Id.,* p. 660. Also, if the climate in the Hill Country gets drier, groundwater levels can be expected to go even lower, including the outcrop area of the Trinity north of the Colorado River. *Id.*, p. 661.

3. Hueco Bolson Aquifer may be affected by dependence on Rio Grande. Mace and Wade expect the Hueco Bolson Aquifer to be affected by climate change because of its reliance on leakage from the Rio Grande for recharge. *Id.*

4. Ogallala Aquifer may be relatively insensitive to direct effects. Mace and Ward expect the Ogallala to be relatively insensitive to the direct effects of climate change, but note that increases in pumping due to a probable drier climate will accelerate depletion of the aquifer. *Id.*

IV. REGULATORY IMPACTS. A wide range of potential regulatory impacts may result from climate change. A few, and questions, are suggested below.

A. Edwards Aquifer: more pumping restrictions? An impact of climate change could be more frequent pumping restrictions in the Edwards. If, as predicted, the Edwards is one of the Texas aquifers most vulnerable to climate change, it may face more "critical period stage" situations. During a "critical period stage" the Edwards Aquifer Authority may interrupt groundwater withdrawal amounts for permit holders. EAA Rule 715.218.

1. For the San Antonio Pool, a Critical Period is declared when the 10-day average of the rate of springflow at either the Comal or San Marcos springs, or aquifer readings at the J-17 Index Well in Bexar County, drop below the Stage I trigger level.

2. Mace and Wade note, "Our modeling work with the San Antonio segment of the Edwards Aquifer suggests that pumping may have to be reduced by about 40,000 acre-ft per year to maintain spring flows if recharge declines 30 percent." Mace and Wade, *supra*, p. 665.

B. Planning based solely on historic conditions may prove inadequate.

1. WAMs and permits. Regional planning groups depends on WAMs for assessing availability of surface water supplies for purposes of their five-year updates to their regional plans.

a. Impact of climate change could render WAMs based solely on the drought of record less accurate in predicting availability of surface water (including for water rights permits and amendments).

b. For instance, Tex. Water Code § 11.023 provides, "To the extent that state water has not been set aside by the commission under Section 11.1471(a)(2) to meet downstream instream flow needs or freshwater inflow needs, state water may be appropriated, stored, or diverted" for the listed purposes. The accuracy of the WAM is key to determining the extent to which water is available for appropriation.

c. If permits continue statutorily to be based on a drought-of-record WAM, might more adaptive management requirements be required in permits, including water rights permits? One recommendation of the White Paper is to advance the use of adaptive management strategies for Texas' water resources.

d. Will TWDB accept an updated regional plan (building block for the State Water Plan) which proffers management strategies not based on the drought of record, as set forth in Tex. Water Code § 16.053(e)(4)?

2. GAMs and GCD management plans. GAMs for GCD management plans (as opposed to GAMs for GMA "desired future condition" predictive modeling) may be constrained by a reliance on average historic recharge, particularly for karst aquifers which are more susceptible to climate change impact. Addition of climate change considerations to GAM development may alter "desired future condition" outcomes, with consequent effects on permits and pumping.

3. Drought contingency planning limited to drought of record. TCEQ is to require wholesale and retail public water suppliers and irrigation districts to develop drought contingency plans consistent with the appropriate approved regional water plan, to be implemented during periods of water shortages and drought. Tex. Water Code § 11.1272(a). TCEQ and the TWDB by joint rule are to identify quantified target goals as guidelines for drought contingency plans. Tex. Water Code § 11.1272(d). Drought contingency planning using the 1950s drought of record may underestimate the worst-case scenario. For example, retail public water suppliers must produce a drought contingency plan which is consistent with the appropriate approved regional water plans, and which includes drought or emergency response stages providing for measures in response to "at least" "reduction in available water supply up to a repeated of the drought of record." 30 TAC § 288.20(a)(1)(E)(i). The "Texasville" case study described by Singh et al. (part III.A.5 above) shows the potential peril of planning for the drought of record, without incorporation of climate change scenarios.

End note: The author gratefully acknowledges the generous assistance of TWDB and TCEQ personnel in obtaining the information referenced. However, any inferences and conclusions herein are the responsibility of the author.