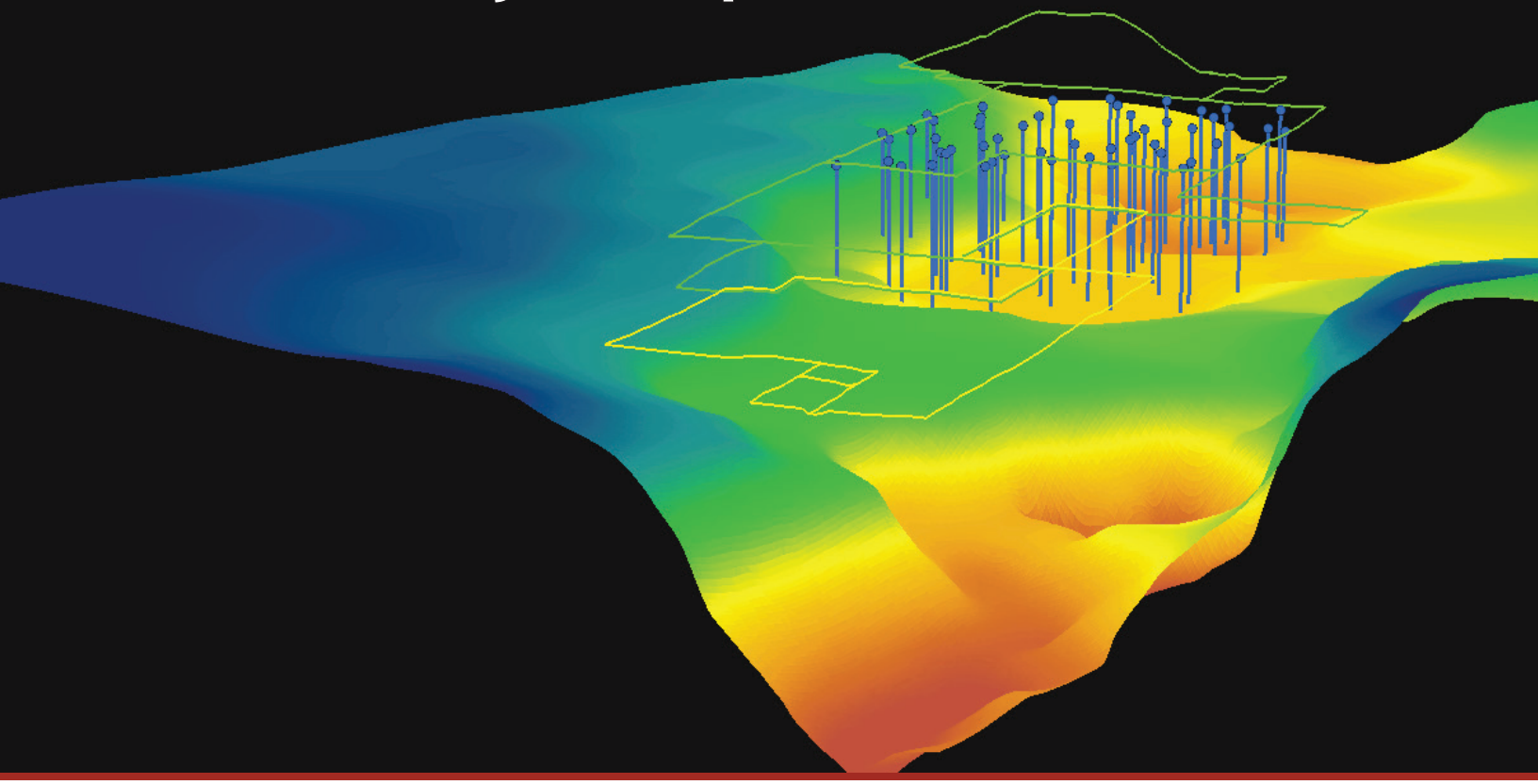



Brackish Groundwater Project Experience



DBS&A

Daniel B. Stephens & Associates, Inc.

a Geo-Logic Company

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Brackish Water Resource Study

Blaine Aquifer System, Texas

Client

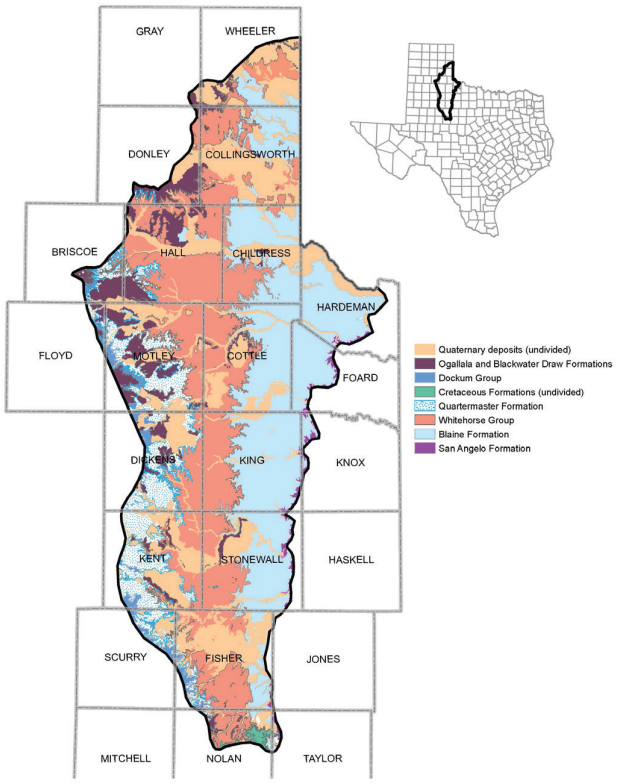
Texas Water Development Board

Highlights

- Extensive hydrogeologic data collection, analysis and documentation in accordance with GAM and BRACS protocols
- Quantitative assessment of brackish groundwater resources
- Stakeholder involvement

The 84th Texas Legislature passed House Bill 30 (HB-30) in 2015 directing the Texas Water Development Board (TWDB) to conduct studies of the brackish groundwater resources of four aquifers. The mandated studies are a continuation of the Brackish Resources Aquifer Characterization System (BRACS) program, the goal of which is to map and characterize the brackish portions of aquifers in Texas to provide useful information to regional water planning groups and other interested parties.

The Blaine Aquifer was one of the first aquifers required to be studied under HB-30. The DBS&A team (including ARS LLC) was selected by the TWDB to complete the study. The project area included approximately 10,400 square miles in all or portions of 20 counties in the Rolling Plains region of north-central Texas. Significant effort was devoted to the compilation of basic hydrogeologic data including geologic structure, water levels, spring locations, water quality, and aquifer properties to construct a complete hydrogeologic conceptual model of the aquifer system so that the potential effects of brackish groundwater development could be assessed.



Blaine Aquifer system outcrop

Available information from water wells and oil and gas wells was used to develop aquifer stratigraphy and hydraulic characteristics. Data sources included the existing the TWDB groundwater and BRACS databases, the Bureau of Economic Geology Geophysical Log Facility historical well drillers' reports (cable tool) and scout tickets, the Texas Department of Licensing and Regulation database of submitted drillers' reports, information from the U.S. Geological Survey, and numerous publications.

The Blaine Aquifer is predominantly a karst aquifer, where the aquifer permeability is the result of solutioning, collapse, and disruption of soluble rocks such as gypsum. Well yields and production zones are highly variable, as is water quality. Fresh water occurs over limited portions of the aquifer system in topographically high regions, which are the zones of groundwater recharge.

Potential production areas for brackish groundwater were identified outside of exclusion zones selected to protect known regions of significant municipal, domestic, and agricultural groundwater use. The effects of future groundwater pumping within several potential production areas was assessed.

Lower Rio Grande Valley Basin Study

Cameron, Willacy, and Hidalgo Counties, Texas

Client

Rio Grande Regional Water Authority and Bureau of Reclamation

Highlights

- Assessed water availability over 50-year planning horizon
- Evaluated range of water management strategies
- Developed preliminary engineering design and cost estimates for three regional brackish groundwater desalination facilities

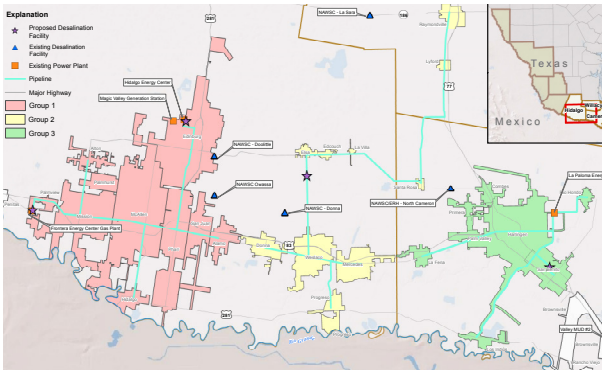
The Lower Rio Grande Valley of Texas is facing a water supply shortage as a result of rapidly growing population on both the Mexico and the United States sides of the Rio Grande. The Bureau of Reclamation, Rio Grande Regional Water Authority and its 53 member entities, in collaboration with the Texas Region M Planning Group, Texas Water Development Board, Texas Commission on Environmental Quality, and International Boundary and Water Commission, conducted a Basin Study to evaluate the impacts of climate variability on water availability over a 50-year planning horizon.

Study participants performed hydrologic projections of future water supply and demand in order to develop a planning objective: Alleviate projected water supply imbalances in the study area by developing one or more alternatives in Cameron, Willacy, and Hidalgo Counties. This will:

- Provide a minimum of 86,000 acre-feet of water year-round by 2060
- Protect existing water rights
- Be compatible with regulations, policies, and environmental law
- Be implementable within the reasonable control of study sponsors

DBS&A evaluated a range of water management strategies based on the planning objective. Brackish groundwater desalination (BGD) was selected for more detailed study, and three BGD alternatives were considered: 1. A single regional BGD facility, 2. Expansion of existing facilities, and 3. Three regional BGD systems. Of these three alternatives, only the three regional BGD systems concept met the evaluation criteria, and was therefore selected for DBS&A to develop a preliminary engineering design and cost estimate.

Key components of the preliminary engineering design include the co-location with power plants and a phased construction approach. Two of the three proposed BGD systems are co-located with power plants. The Texas Public Utility Commission allows power to be purchased at wholesale rates if the purchaser can connect directly to the generation facility. Co-location with a power plant not only decreases energy costs, but may also improve the reliability of power; the source of significant maintenance costs in other reverse osmosis plants in the region. The facility construction is proposed in two phases in which the 2040 demands were used to drive Phase 1, and 2060 demands used to drive Phase 2. Proportional demand calculations were used to develop proposed delivery volumes that meet and exceed the planning objective minimum of 86,000 acre-feet per year.



Proposed plant locations and pipelines

Brackish Groundwater Evaluation to Supplement Surface Water Municipal Supply

Shackelford County, Texas

Client

West Central Texas Municipal Water District

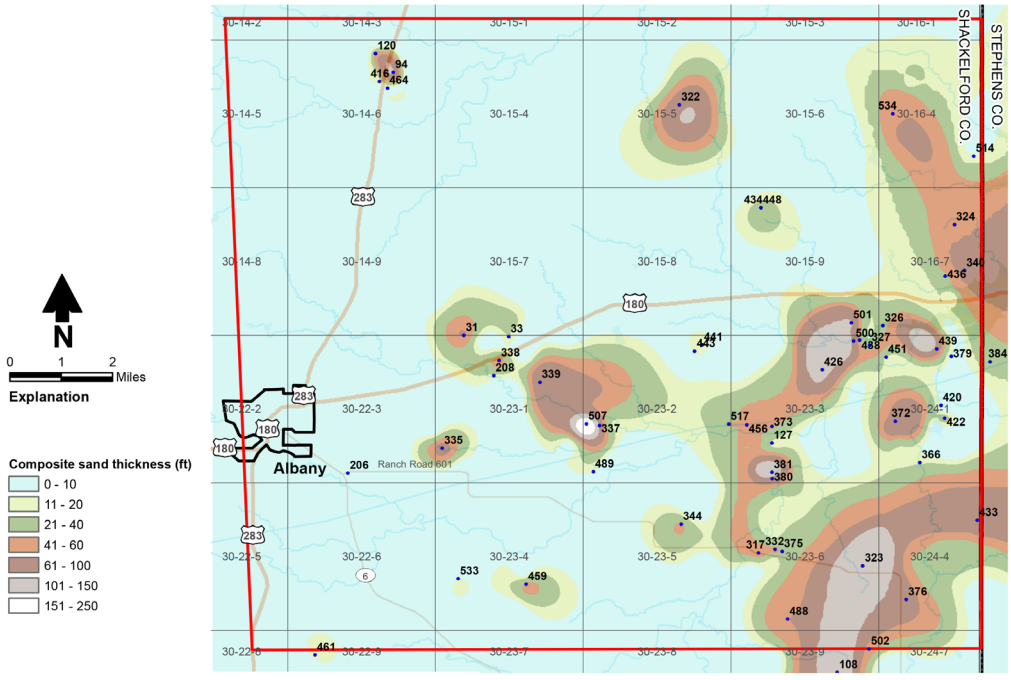
Highlights

- Conducted brackish groundwater resource evaluation to supplement surface water supplies diminished due to drought
- Identified multiple production zones with depth, estimated lateral connectivity, and estimated potential well yields and water quality

On behalf of the West Central Texas Municipal Water District (WCTMWD), DBS&A was the prime contractor for a study to identify potential brackish groundwater supplies to supplement surface water sources under severe pressure due to drought. Project goals were to identify a brackish groundwater supply of 2 million gallons per day adjacent to WCTMWD's existing water distribution system within a 150 square mile region west of Albany, Texas.

Project objectives were achieved through mapping, based on available data, the distribution of water-saturated sand within Permian strata in the subsurface. Aquifer characteristics, potential well production rates, and water quality were estimated based on available data. Over 500 drillers' reports were identified for the study area and screened for applicability; 429 drillers' reports were retained for detailed analysis. The driller's report geological descriptions were used to identify sand intervals greater than 10 feet thick from 200 feet below land surface (ft bls) to 3,000 ft bls. Potential brackish water production intervals were mapped for multiple depth intervals, and available water quality information was used to estimate the total dissolved solids content of groundwater.

Study conclusions were that brackish groundwater production is possible from Permian-age geologic units beneath the study area, although target areas are limited in geographic extent and well yields would likely be insufficient to meet WCTMWD goals. In addition, the expected water quality would be highly saline, leading to significant treatment costs.



Composite Sand Thickness Map for Depth Interval 1,500 to 3,000 Feet Below Ground Surface

Brackish Groundwater Availability Analysis

University Lands, Multiple Counties, West Texas

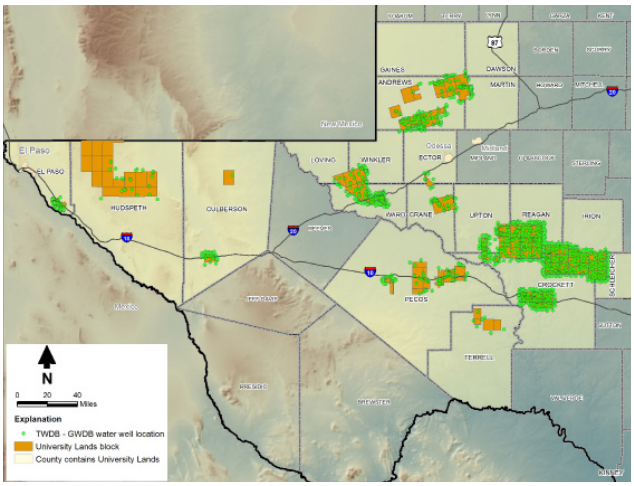
Client

University Lands

Highlights

- Detailed groundwater resource analysis (primarily brackish) within 12 counties in west Texas based on analysis of 2,000+ water well and oil and gas geophysical logs
- Utilized existing GAMs and BRACS database (TWDB Report 382)

DBS&A is prime contractor assisting University Lands with evaluating, documenting, and quantifying groundwater resources from land surface to 3,000 feet beneath their holdings in 12 counties of west Texas.



DBS&A's analysis is focused on the production capacity of brackish water aquifers, such as the Dockum.

The analysis was based on a comprehensive review of existing reports and data, and involved the analysis of over 2,000 oil and gas geophysical logs, water well logs and cable-tool driller reports obtained from University Lands, Texas Railroad Commission and the Bureau of Economic Geology well log libraries. Much of the analysis is focused on the production capacity (net sand analysis) of brackish water aquifers such as the Dockum, since University Lands requires operators to utilize deeper brackish water resources for fracking and rig supply where feasible.

Other portions of the project include 1) development of a web site where oil and gas operators and other University Lands lease holders can apply for water supply well permits and upload completed well information, such as well diagrams, geophysical logs and water quality, and 2) constructing of a comprehensive water well database for all University Lands throughout Texas. These tasks coincide with the hydrogeologic analysis, since water well applications and proposed screen intervals can be checked against aquifer structural surfaces using custom GIS programming to confirm permitted well completion.

Groundwater Modeling for Brackish Water Availability

Pecos Valley Aquifer, West Texas

Client

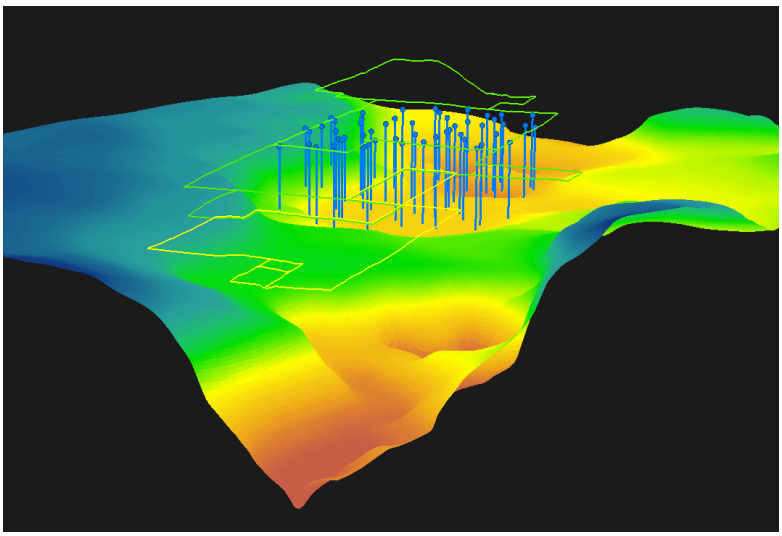
Colorado River Municipal Water District

Highlights

- Groundwater flow and solute transport modeling using MODFLOW, SEAWAT, MT3DMS, PEST and Groundwater Vistas to predict water quality at municipal well fields
- Brackish groundwater resource evaluation using geophysical log analysis and BRACS database (TWDB Report 382)

DBS&A constructed a three-dimensional regional groundwater flow model of the Pecos Valley Aquifer within the Monument Draw Trough in Ward and Winkler Counties, Texas, for the Colorado River Municipal Water District (CRMWD). The model was applied to evaluate well-field sustainability and expected changes in water quality for multiple groundwater production scenarios. GIS data was integrated from multiple sources. Modeling codes applied include the United States Geological Survey's (USGS) MODFLOW-2000, SEAWAT, MT3DMS, the parameter estimation software PEST, and Groundwater Vistas for pre- and post-processing.

DBS&A constructed an 8-layer model with grid cells ranging from 440 feet to one mile on edge for an area of approximately 880 square miles (22 miles wide by 40 miles long) that included CRMWD's well fields and water right holdings in Ward and Winkler Counties. Wells and well fields for the towns of Grandfalls, Kermit, Monahans, Pecos, Wickett, and Wink are also included in the model. DBS&A used data from the Texas Water Development Board's (TWDB) Brackish Resources Aquifer Characterization System (BRACS) database to define the aquifer geometry and develop conceptual models of water quality outside the well-field area. Detailed configurations of water quality were determined for CRMWD's well field areas based on water quality sampling and geophysical log analysis from test borings. In this portion of the Pecos Valley Aquifer, a shallow zone of fresh (< 1,000 mg/L TDS) water occurs along the eastern margin of the Monument Draw Trough. This freshwater zone is underlain by brackish water at depth and is abutted by brackish water to the west, thereby creating a pseudo-coastal type aquifer system where solute concentrations vary laterally and with depth.



Base of Pecos Valley Aquifer from BRACS study and existing Ward County municipal production wells.

DBS&A calibrated the model to historical conditions over the period 1948-2009 using PEST to adjust the hydraulic conductivity field to simulate over 5,000 observations of hydraulic head through time at 85 wells. The optimization was conducted using the pilot point method where aquifer hydraulic conductivity for designated points is estimated in the model, and these points serve as the basis for the interpolation of aquifer permeability throughout the model domain using kriging.

Professional Hydrogeology Services for a Statewide Water Resources Study on Permanent School Fund Lands for the General Land Office

Statewide Texas

Client

Texas General Land Office

Highlights

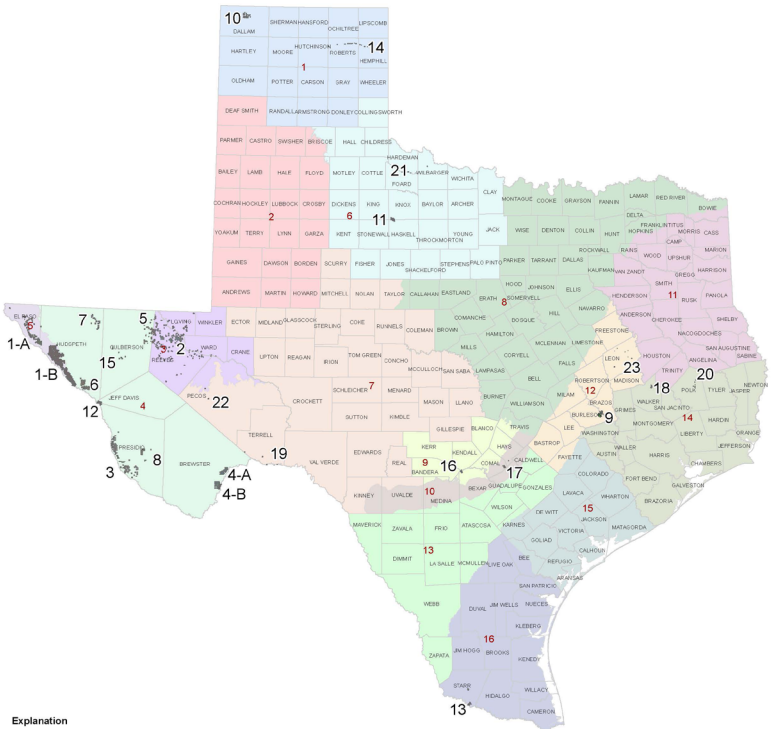
- Evaluated groundwater resources and water rights statewide
- Constructed GIS database
- Studies groundwater marketability factors

The Texas General Land Office (GLO) is responsible for the management of about 900,000 acres of groundwater rights on Permanent School Fund (PSF) land. The groundwater beneath these lands is a valuable asset and an important source of revenue for the PSF.

DBS&A served as the groundwater expert on a team of consultants retained by the GLO to evaluate the groundwater resources and water rights under GLO control statewide. DBS&A also provided an overview of aquifer characteristics, such as depth to water, production capacity, and the quantity and quality of groundwater.

DBS&A constructed a geographic information system (GIS) database that included the results of the investigation, including aquifer type, groundwater volume, well yield, water quality, aquifer properties, and other attributes relevant to groundwater utilization potential. Once the locations of the approximately 900,000 acres of PSF lands were confirmed, GIS specialists overlaid properties or groups of properties selected for further analysis by GIS coverages of major and minor aquifers, Regional Water Planning Groups, Groundwater Management Areas and Groundwater Conservation Districts to construct a framework to guide the remainder of the project. The study also identified 1) regulatory factors that could impact the marketability of the groundwater, 2) factors that influence the potential value of the groundwater, and 3) other factors that may impact the development of the groundwater resources by the GLO. Properties were then ranked according to groundwater development potential based on these physical, administrative, and legal factors.

The study provided the GLO with a framework for identifying PSF lands that warrant further investigation based on the marketability of the water beneath a given tract. Water supply strategies provided in the Texas Regional Water Plans were also used in the rankings to help GLO to leverage its groundwater assets for the best financial benefit of the PSF.



The study helped GLO identify the marketability of the water beneath a given tract.

Groundwater Availability Modeling, Southern Ogallala Aquifer

Western Texas and Eastern New Mexico

Client

Texas Water Development Board (TWDB)

Highlights

- Developed geologic and groundwater flow models
- Constructed a detailed base-of-aquifer map
- Integration of data obtained from multiple sources
- Planned and executed eight public forums

DBS&A developed the Southern Ogallala groundwater availability model (GAM) for the Texas Water Development Board; the aquifer underlies approximately 29,000 square miles in western Texas and eastern New Mexico.

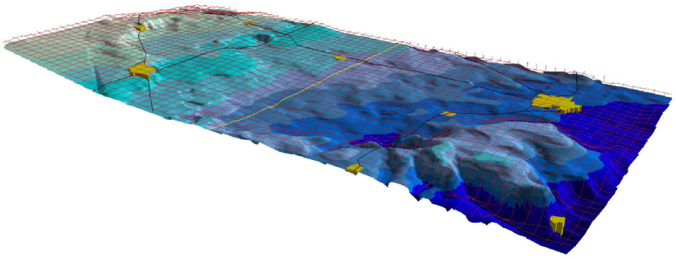


Illustration of Ogallala Formation contact with underlying Dockum Group and Edwards-Trinity (High Plains) aquifers

The availability and sustainability of groundwater is a critical concern in this region encompassing large portions of two states; 95 percent of the water use is for irrigated agriculture, which is the largest contributor to the region's economic base. The Southern Ogallala GAM (as updated by DBS&A in 2008) is the most comprehensive model of the region constructed to date, and has been used or considered by seven Groundwater Conservation Districts (GCDs) and three Regional Water Planning Groups for water planning and future use alternatives/needs assessment. The model was constructed using detailed analyses of aquifer properties correlated to geological depositional environments of the Ogallala Formation based on thousands of well logs.

Data used for geologic and hydrogeologic model development was obtained from the TWDB, GCDs, the Texas Commission on Environmental Quality (TCEQ), and other sources. DBS&A has constructed a detailed base-of-aquifer map based on numerous existing maps that were digitized and joined in the GIS project. Recharge in natural settings and beneath irrigated lands was studied through a cooperative agreement with the U.S. Geological Survey. Historical water use was estimated through application of PET network information and analysis of satellite imagery. Predevelopment and historical (1940-2000) models were developed, calibrated, and verified using numerical simulation techniques.

A total of eight public forums were held to introduce the model to the public and solicit input and suggestions on the model and the final report. The final public meeting consisted of model training conducted at Texas Tech University in Lubbock, Texas. Results of the study have been presented at more than 10 local, national and international forums.

Ward County Water Supply

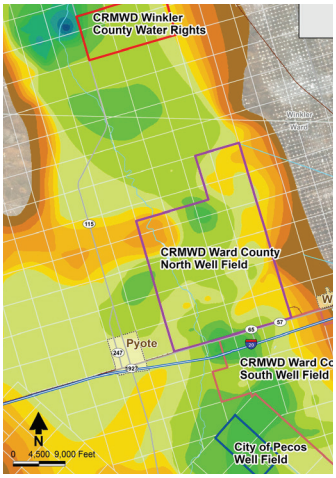
Ward County, Texas

Client

Colorado River Municipal Water District

Highlights

- Developed innovative methodology to characterize complex subsurface hydrogeologic conditions and evaluate water quality
- Well design, installation oversight, and testing for 21 high capacity raw water supply wells
- Exceeded target groundwater production and water quality goals



Monitoring a pumping test of the completed production well

The Colorado River Municipal Water District (CRMWD) in west Texas serves member communities with a growing economy. Existing water supplies are stressed as surface water supplies from CRMWD's three major reservoirs have declined due to long-term drought conditions. To provide an emergency water supply source in times of drought, CRMWD acquired an existing well field in Ward County with an initial production capacity of approximately 15 million gallons per day. Worsening drought conditions in 2011 resulted in severe rates of reservoir depletion and CRMWD decided to expand the well field with the goal of doubling its production capacity. By mid-2011 projections of water use suggested that CRMWD's surface water sources could be extremely limited by early 2013. This situation required an aggressively accelerated construction schedule to bring the new groundwater supply online before December 2012.

DBS&A planned and executed a Phase 1 test drilling investigation to characterize subsurface hydrogeologic conditions and evaluate water quality. This investigation was followed by Phase 2 design work, contracting, and construction oversight of 21 new supply wells in the Ward County North well field. DBS&A developed an innovative well design methodology to meet targeted water quality and employed a science-based approach to develop multi-screen designs matching complex and variable subsurface lithology within the Pecos Valley Aquifer. Understanding of detailed well field stratigraphy was required, and detailed interpretations of reworked Dockum Group sediments that compose portions of the Pecos Alluvium versus proper Dockum Group geologic contacts were necessary. DBS&A also designed, assisted with procurement, and oversaw installation or construction of submersible pumps and wellhead completions and controls.

DBS&A worked with CRMWD to coordinate planning and contracting in a timely manner and oversaw a fast-track construction schedule that enabled the client to meet the project deadline. The wells were completed on-time and within budget to provide additional operational capacity that exceeds project goals for groundwater production and water quality.

Groundwater Availability Modeling, Edwards-Trinity (High Plains) Aquifer

West Texas/Eastern New Mexico

Client

Texas Water Development Board

Highlights

- Developed a comprehensive ArcGIS geodatabase to help delineate model layers within the Cretaceous sequence underlying the Ogallala Formation
- Reviewed and screened more than 10,000 driller's reports
- Created a three-dimensional stratigraphic framework of the Edwards-Trinity (High Plains) Aquifer
- Constructed and calibrated three-dimensional groundwater flow model

DBS&A developed the Edwards-Trinity (High Plains) minor aquifer groundwater availability model (GAM). The aquifer occurs beneath the Southern Ogallala Aquifer in West Texas and Eastern New Mexico. A major task of this project was to develop a comprehensive ArcGIS geodatabase to help delineate model layers within the Cretaceous sequence underlying the Ogallala Formation for a 14-county area in the Southern Texas Panhandle.

The Edwards-Trinity (High Plains) Aquifer occurs beneath the Southern Ogallala Aquifer in West Texas and Eastern New Mexico.

DBS&A integrated data from various sources (including the Texas Natural Resources Information System, the Texas Water Development Board, the U.S. Department of Agriculture, and the U.S. Geological Survey) into ArcGIS, and developed a geodatabase that linked USGS, TWDB, and other various datasets to GIS utilizing TWDB GAM data standards.

More than 10,000 driller's reports were initially reviewed and screened for accurate location information, detailed drillers' lithologic descriptions, and well depth. Drillers' lithologic descriptions from almost 1,800 driller's reports were integrated with 111 geophysical logs to create three-dimensional isopach maps of these subsurface hydrogeologic units. Structural contour elevation surfaces and isopach maps were created for all units (top of Dockum Group, Antlers sandstone, Edwards and Comanche Peak limestones, Duck Creek and Kimichi shales) to create a three-dimensional stratigraphic framework of the Edwards-Trinity (High Plains) Aquifer. Detailed analysis of aquifer extents was required for Dawson and Gaines counties.

A three-dimensional groundwater flow model that includes the Ogallala and Edwards-Trinity (High Plains) aquifers was constructed and calibrated to predevelopment (1930) and post-development (1931-2000) aquifer conditions.

Three-Dimensional Hydrogeologic Model for Fresh and Brackish Groundwater Evaluation

Fayette County, Texas

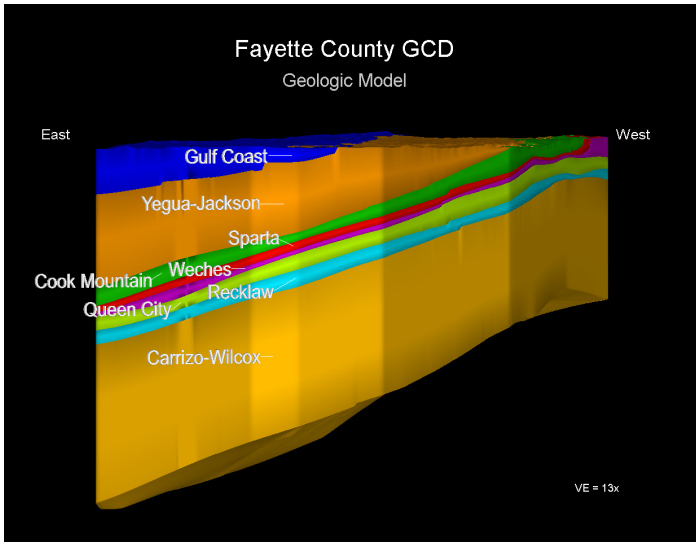
Client

Fayette County Groundwater Conservation District

Highlights

- Created a comprehensive three- dimensional hydrogeologic model
- Evaluated brackish and freshwater resources
- Conducted geophysical log analysis for aquifer characterization
- Determined spatial variability of water availability

DBS&A was contracted by the Fayette County Groundwater Conservation District to create a three dimensional (3-D) hydrogeologic model of Fayette County. The project included the identification and analysis of hydrogeologic and stratigraphic data within the county, and construction of an ArcGIS geodatabase to store and manage the applicable data. Geophysical logs were collected and interpreted to determine the top and bottom surfaces (where feasible) of the seven freshwater aquifers utilized in the county, as well as the brackish aquifers within the Calvert Bluff and Simsboro Formations of the Wilcox Group. The geophysical logs were also utilized to determine net sand thickness for each aquifer investigated. Driller's reports and well logs were then collected and classified by aquifer in order to further delineate the net sand content for each aquifer. Finally, estimates of groundwater in storage were made based on the net sand evaluations, aquifer extent, and assumptions regarding effective porosity. Results of the hydrogeologic analysis were compared to aquifer properties and other information in the groundwater availability model (GAM) to better understand and cross check the simulation framework.



3D Subsurface Aquifer Stratigraphy of Fayette County, Texas

All GIS data was developed utilizing ArcGIS software. The project data were integrated into a 3-D software package to create a 3-D hydrostratigraphic model of the county which could be used to conducted volume calculations and estimate the spatial variability of water availability. The 3-D model was used to assist with the development of desired future conditions (DFCs) of regional aquifers, including the Carrizo Wilcox.

Technical Assistance Regarding Hydrogeologic, Water Quality and Permitting Issues

Goliad County, Texas

Client

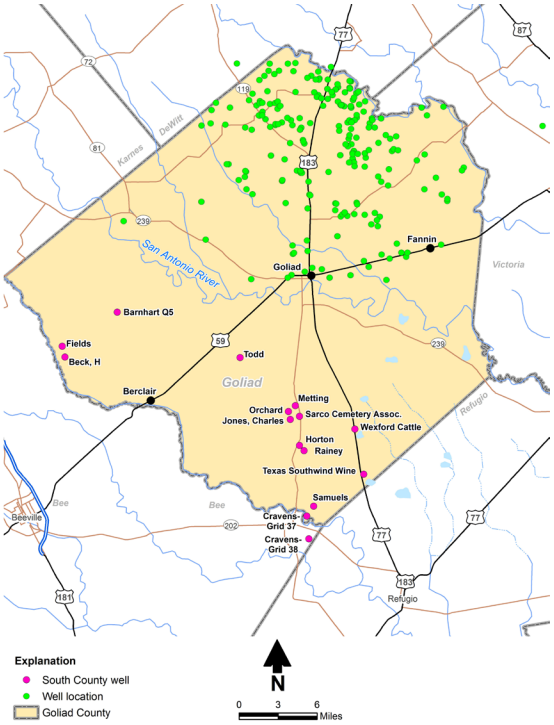
Goliad County Groundwater Conservation District

Highlights

- Developed flow and transport model to assess potential effects of ISL uranium mining in the County; utilized Gulf Coast GAM
- Evaluated aquifer tests for the Evangeline and other coastal aquifer units, including the effects of faults and confining units on groundwater flow and solute tranport
- Analyzed water quality issues, including arsenic and brackish water

DBS&A provided technical assistance to the Goliad County Groundwater Conservation District (GCGCD) regarding multiple hydrogeologic, water quality, and permitting issues. DBS&A's support for the GCGCD includes the following:

- Evaluated the hydrogeology of the Evangeline and other coastal aquifer units, including recharge, hydraulic properties, groundwater-surface water interaction the effects of faults and confining units on groundwater flow and solute transport.
- Developed a groundwater flow and solute transport model to assess the potential effects of in-situ leach (ISL) uranium mining in the northern portion of the County. The model focused on groundwater flow paths, particularly in the vertical dimension between aquifer units. The local model was developed based on the regional groundwater availability model (GAM) for Gulf Coast Aquifer.



Well locations for geochemical analysis throughout Goliad County.

- Provided technical support and input regarding GCGCD's opposition to the proposed aquifer exemption before the U.S. EPA, and provided expert testimony during a Texas Commission on Environmental Quality hearing related to a proposed ISL mine.
- Provided technical analyses regarding other water supply and water quality issues within the County, including the natural occurrence of arsenic, impacts to a supply well by saltwater, and consideration of brackish water.

Development of Structure and Stratigraphy of the Capitan Reef Aquifer

West Texas

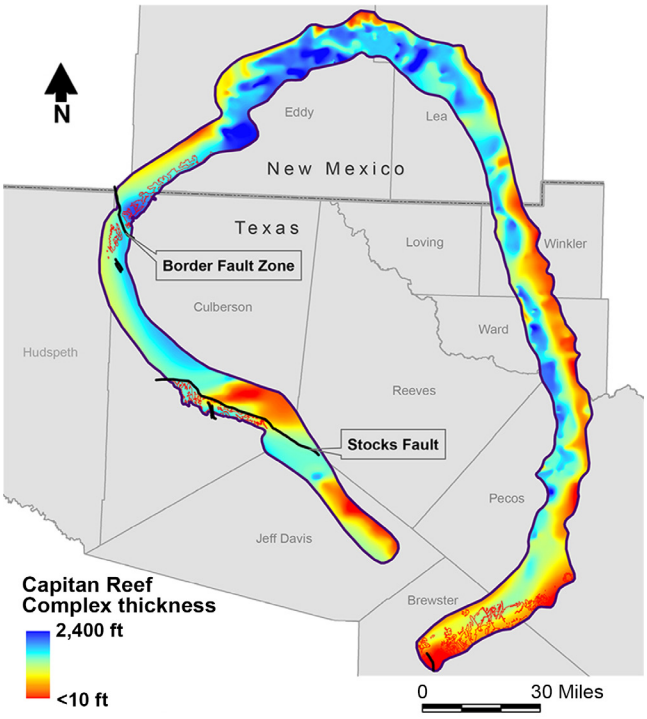
Client

Texas Water Development Board

Highlights

- Compiled surface and subsurface geological data and information
- Constructed GIS geodatabase
- Built detailed stratigraphic geologic model
- Mapped hydrostratigraphic units

DBS&A completed a contract with the Texas Water Development Board (TWDB) for the construction of a structural and stratigraphic framework of the Capitan Reef Aquifer located in a seven-county area within the Delaware Basin. The study area covers approximately 22,000 square miles in far west Texas and southeastern New Mexico, including all or portions of Winkler, Loving, Ward, Pecos, Reeves, Jeff Davis, Culberson, Brewster, and Hudspeth counties in Texas, and Eddy and Lea Counties in New Mexico. The project consisted of compiling surface and subsurface geological data and information (primarily geophysical logs from oil and gas wells), constructing a GIS geodatabase, and building a stratigraphic geologic model. Thousands of geophysical logs, driller's reports and scout tickets were reviewed and high-graded to select the final data set of 726 points compiled into a geographical information system (GIS) geodatabase that was used to create Capitan Reef Complex surface, thickness, and base GIS shape files and grids. The formal extent of the TWDB's Capitan Reef Complex Aquifer outline was modified based on available data. The DBS&A team also compiled GIS shapefiles of the formations overlying and underlying the Capitan Reef Complex. The study completed by DBS&A serves as one of the most comprehensive, up-to-date resources for entities considering obtaining water supplies, including brackish water from the Capitan Reef Aquifer.



Stratigraphic geologic model