Groundwater Availability Modeling (GAM) for the Central Gulf Coast Aquifer - Preliminary Conceptual Model

A Presentation to: Stakeholder Advisory Forum
Harry Hafernick Center
Edna, Texas
August 6, 2001
Presentation Topics

- Review of GAM Objectives
- Conceptual Model of Groundwater Flow for Central Gulf Coast GAM
- GAM Schedule
GAM Objectives

• Include substantial Stakeholder input
• Create standardized, publicly available numerical groundwater flow models with supporting data
• Provide information on groundwater availability through 2050 for normal and drought-of-record conditions
• Provide strategic water-management tools for regional water planning
GAM Regions

- **Ongoing:**
  - Carrizo-Wilcox (9-11)
  - Ogallala south (7)
  - Gulf Coast central (8)
  - Gulf Coast north (12)
  - Lower Rio Grande (5)
  - Edwards Trinity (6)

- **Completed:**
  - Trinity HC (1)
  - Hueco Bolson (2)
  - Ogallala north (3)
  - Edwards - BS (4)

http://www.twdb.state.tx.us/gam
Conceptual Model Topics

- Schematic Diagram of Aquifer System
- Model Region and Boundaries
- Geology/Hydrostratigraphy
- Structure
- Water Levels & Regional Groundwater Flow
- Hydraulic Properties
- Recharge
- Discharge
- Water Quality
- Subsidence
Schematic Diagram of Flow System

Legend
- Stream
- Salt Water
- Infiltration
- Evapotranspiration
- Precipitation
- Runoff
- Leakance
- Groundwater Flow Direction

Geology adapted from Baker (1979, 1986)
Groundwater Modeling Steps

1. Define model objectives
2. Conceptual model
3. Code selection
4. Field data
5. Calibration*
6. Verification
7. Prediction*
8. Reporting
9. Post-audit

*Includes sensitivity analysis

Comparison with field data

Field data
# Geologic Formations

Adapted from TAMU-CC (2000)

<table>
<thead>
<tr>
<th>System</th>
<th>Series</th>
<th>Stratigraphic Units</th>
<th>Hydrogeologic Units</th>
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<tbody>
<tr>
<td>Tertiary</td>
<td>Miocene</td>
<td>Oakville Sandstone</td>
<td>Middle Miocene Permeable</td>
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<td></td>
<td></td>
<td>Catahoula Tuff</td>
<td>Middle Miocene Confining Unit</td>
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<td>Anahuac Fm.</td>
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<td>Goliad Sand</td>
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<td>Beaumont Clay</td>
<td>Lower Pleistocene-Upper Pliocene Permeable Zone</td>
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<td>Montgomery Fm.</td>
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<tr>
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<td>Bentley Fm.</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Willis Sand</td>
<td>Upper Chicot Aquifer</td>
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Hydrogeologic Units:
- Upper Chicot Aquifer
- Lower Chicot Aquifer
- Lower Pleistocene-Upper Pliocene Permeable Zone
- Evangeline Aquifer
- Middle Miocene Permeable
- Middle Miocene Confining Unit
- Lower Miocene-Upper Oligocene Confining Unit
- Lower Miocene-Upper Oligocene Permeable Unit

Adapted from TAMU-CC (2000)
<table>
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<td>Oakville Sandstone</td>
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<td>Catahoula Tuff</td>
<td>Jasper Aquifer</td>
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</tr>
<tr>
<td></td>
<td>Catahoula Confining System</td>
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Preliminary Geologic Outcrops
Hydrostratigraphic Structure: Data Sources

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<td>♦</td>
<td>♦</td>
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<tr>
<td>Evangeline</td>
<td>♦</td>
<td>♦</td>
<td>♦</td>
</tr>
<tr>
<td>Burkeville</td>
<td>♦</td>
<td></td>
<td>♦</td>
</tr>
<tr>
<td>Jasper</td>
<td>♦</td>
<td></td>
<td>♦</td>
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Note: Chicot was further divided into Upper & Lower units based on Ryder (1988).
Hydrostratigraphic Structure

- **Baker (1979)—TWDB Report 236**
  - 7 cross sections defining all 5 hydrostratigraphic layers
- **Carr et al. (1985)—TWDB Report 289**
  - Detailed contour maps define base of Chicot and Evangeline
  - About 400 electric logs used to define contours
- **Chowdhury (in progress)—Southern Gulf Coast GAM**
  - Model overlap with SGC GAM
  - Used Baker (1979), Carr et al. (1985) and about 50 additional borehole electric logs
- **TAMU—CC**
  - Used their subdivision of Upper Chicot
HSU Structure – Evangeline

Legend

- Texas counties
- GAM Boundary
- Evangeline base elevation (feet)
  - 500 to -500
  - -500 to -1500
  - -1500 to -2500
  - -2500 to -3500
  - -3500 to -4500
Water Levels & Regional GW Flow

- Develop water level maps
  - Predevelopment water levels for model initialization
  - 1980 - 1990 water levels for calibration
  - 1990 - 2000 water levels for verification
- Hydrographs for calibration
- Evaluate cross-formational flow
Water-Level Data Sources

- TWDB Groundwater Database
- USGS Reports
- TWDB and predecessor reports
Anomalous Data: Gulf Coast Aquifer Wells?
Evangeline Aquifer – Kleberg Co.

Hydrograph for 8326401, Kleberg County

Date

Water level (feet), referenced to lsl


-200 -150 -100 -50 0 50
Water-Level Data Analysis

- All data are *not* equal
  - The only situation worse than no data is bad data
  - Evaluate and analyze anomalous water-level measurements
    - Prioritized based upon rank assigned from moving neighborhood
    - Special attention to predevelopment water levels in highly developed areas such as municipalities
    - Utilize spatial data and point data
    - Attribute (flag) each measurement
Aquifer Hydraulic Properties

Properties related to aquifer’s ability to transmit and store groundwater

- Hydraulic conductivity (K)
- Storativity (S)
- Specific Yield ($S_y$)
Data Sources and Approach

Data sources:
- Myers 1969 – TWDB aquifer test summary report
- County groundwater reports
- TWDB online database of specific capacity results

Coordinates used where provided, otherwise reconciled with TWDB well database

Contoured information not used since underlying data is unknown

Grouped by aquifer and analyzed
## Data Status

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<td>Aquifer Tests (K, S)</td>
<td>Yes</td>
<td>Yes</td>
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<td>Net or % sand</td>
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## Preliminary Summary of Results from Aquifer Tests

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<td>9.1E-04</td>
<td>4.6E-5 - 4.0E-03</td>
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<td>3.3E-04</td>
<td>1.8E-05 - 1.0E-03</td>
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<td>4</td>
<td>6.0E-03</td>
<td>1.3E-04 - 1.0E-02</td>
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<td>Jasper</td>
<td>6</td>
<td>3.7E-03</td>
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<td><strong>K (ft/d)</strong></td>
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<td>51</td>
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<td>19</td>
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<td>16</td>
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<td>2 - 120</td>
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<td>(outcrop)</td>
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<td>12</td>
<td>11</td>
<td>0.8 - 36</td>
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Hydraulic Conductivity Data Review

- Potential errors in assignment to proper model layers
  - To be evaluated during calibration
  - QC screened interval against layering geometry in GIS
- Data represent horizontal hydraulic conductivity, no vertical hydraulic conductivity reported
- Burkeville data scarce since not usually a water source
- Derived K data is a starting point—calibrate to final K
Storativity Data Review

- Potential error in assignment to proper model layers
  - To be evaluated during calibration
  - QC screened interval against layering geometry in GIS

- Specific storage will be estimated from pumping test data

- Specific yield data
  - Can be reasonably estimated for these types of materials
Sand Percent

- Aquifer deposits are derived from streams and deltas
  - Sandier parts represent channels
- Sandier parts have higher ability to transmit groundwater (hydraulic conductivity)
- In other Texas aquifer systems it is possible to relate hydraulic conductivity to amount of sand to provide extra information about the aquifer
- Obtained Wilson and Hosman (1988) analysis of geophysical well logs for sand percent
Evangeline Sand Percentage

Legend
- GAM Boundary
- Major rivers
- Texas counties
- Evangeline data points

Evangeline percent sand
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
Jasper Sand Percentage

Legend
- GAM Boundary
- Major rivers
- Texas counties
- Jasper data points
- Jasper percent sand:
  - 1 - 10
  - 10 - 20
  - 20 - 30
  - 30 - 40
  - 40 - 50
  - 50 - 60
  - 60 - 70
  - 70 - 80
  - 80 - 90
  - 90 - 100

Scale: 0 - 80 Miles

Direction: North
Data Use in Calibration

- Use sand percentage to establish areas of similar properties
- Use test data to establish initial K, S, and Sy
- Calibrate vertical hydraulic conductivity (no test data)
Recharge

- Infiltration
  - Precipitation
  - Temperature
  - Evaporation and ET
  - Irrigation/Crop Use

- SW/GW interaction
Land Use

Legend
- GAM Boundary
- Interstate
- Major rivers
- River basins
- Texas courtes
- Land use data:
  - Open Water
  - Residential
  - Commercial/Transportation
  - Bare Rock/Soil
  - Transitional
  - Forest
  - Shrubland
  - Grasslands/Herbaceous
  - Agriculture
  - Fallow
  - Urban/Recreational Grasses
  - Woody Wetland
  - Emergent Herbaceous Wetland
  - Quarry/Strip Mine/Gravel Pit
Target values for stream/aquifer interaction

Stream/Aquifer Interaction

Daily streamflows (uncontrolled)

Stream gain and loss data

Hydrograph Separation (HYSEP, Furey...)

Base flow

Target values for stream/aquifer interaction
## Presentation of Findings

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<td>Yes</td>
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<td>Stream flow</td>
<td>Yes</td>
<td>Yes</td>
<td>Partial</td>
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Infiltration - Current Status

- Current data gaps: NEXRAD data
- Furey algorithm vs. HYSEP program for base flow separation
- Which ET package to use?
Discharge

- Baseflow to rivers, lakes, springs
  - Parameters and hydrograph calibration targets (WAM & USGS)
  - Streamflow, lake, and drain MODFLOW packages

- Cross-formational flow

- Pumping
  - Historical (pre-development to 2000)
  - Projected
Pumpage Data

Data sources
- TWDB, USGS (historical-1980-2000),
- RWPGs, TAG, GWCDs (predictive, 2000-2050)

Data gaps
- GW-use data in TX extends through 1997

Data analysis
- Well specific locations for municipal, power, mining and industrial uses
- Land use distribution for livestock and irrigation uses
- Population density for rural domestic uses
Pumpage by County (1980) – All Uses

Gulf Coast Pumpage for All Uses by County/Basin 1980 (Acre-feet/year)

PARSONS ENGINEERING SCIENCE
Pumpage by County (1990) – Irrigation

Pumpage (Acre-feet/Year)

1 - 5000
5001 - 10,000
10,001 - 30,000
30,001 - 50,000
50,001 - 70,000
70,001 - 90,000

Wharton/Lavaca
Wharton/Colorado-Lavaca
Wharton/Colorado-Lavaca
Jackson/Lavaca
Jackson/Colorado-Lavaca

Gulf Coast Pumpage for Irrigation Uses by County/Basin 1990 (Acre-feet/year)

PARSONS ENGINEERING SCIENCE
Water Quality Data

Approach
- Develop water quality distributions for TDS and another constituent of interest

Data sources
- TWDB, TNRCC (1944-2000)
- Reports from Bureau of Economic Geology
Evangeline TDS Data Locations

Central Gulf Coast - Evangeline Aquifer
Approximate Distribution of Total Dissolved Solids Data Points

PARSONS ENGINEERING SCIENCE

Extent of Outcrop
Data Points
Jasper TDS

Central Gulf Coast - Jasper Aquifer
Approximate Distribution of
Total Dissolved Solids Concentrations

PARSONS ENGINEERING SCIENCE

TDS Levels (mg/L)
- 0 - 299
- 300-499
- 500-999
- 1000-2999
- 3000+

Extent of Outcrop
Jasper TDS Data Locations

Central Gulf Coast - Jasper Aquifer
Approximate Distribution of
Total Dissolved Solids Data Points

PARSONS ENGINEERING SCIENCE

Extent of Outcrop
Data Points
Land Subsidence

- Dropping groundwater levels reduces pore pressures causing compaction in clays and silts
- Subsidence caused by over pumping and compaction
- Houston is a notable Gulf Coast example
  - Up to 1 ft of compaction per 100 ft of water level decline
  - Up to 20% of water released from storage this way
- Subsidence believed to have occurred in SE Jackson and W Matagorda counties as long ago as 1941-1951
Land Subsidence (cont.)

- Not required under GAM
- Neglecting it may make model difficult to calibrate (will have to evaluate during process)
- However, given all other uncertainties we may not be able to distinguish subsidence effects
- Sensitivity analysis on effects may be performed
**Project quarter**  
- Start
- Assemble SAF
- Intro SAF Meeting

**Major milestone**
- Overview of Project
- Preliminary conceptual model presentation
- TWDB review of conceptual model
- Review of steady-state calibration

**Monthly Reports**
- Quarterly Stakeholder Advisory Forum (SAF) meeting

**Technical meetings with TWDB**
- Assemble SAF
- Overview of Project
- Preliminary conceptual model presentation
- TWDB review of conceptual model

**TWDB major tasks**
- Assemble SAF
- Overview of Project
- Preliminary conceptual model presentation
- TWDB review of conceptual model
CENTRAL GULF COAST GAM STAKEHOLDERS ATTENDENCE LIST

SECOND QUARTERLY MEETING

HELD

AUGUST 6, 2001 IN EDNA, TEXAS

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<td>Patrick Brzozowski</td>
<td>X LNRA</td>
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<tr>
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<td>LNRA</td>
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<td>Frank Samuel Jr</td>
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X = Unable to confidently decipher name
Introduction

The second Stakeholder Advisory Forum (SAF) for the Central Gulf Coast Groundwater Availability Model (GAM) was held on August 6th at the Harry Hafernick Center on Lake Texana near Edna. The presentation included a review of the GAM Project Team and GAM Objectives and Expectations, and a presentation of the Conceptual Model of Groundwater Flow in the Central Gulf Coast Aquifer. The presentation material is posted at the TWDB GAM website at:

http://www.twdb.state.tx.us/gam/glfc_c/SAF2_GC-c.pdf

Meeting Questions & Responses: (not necessarily listed in the order in which they were asked or discussed)

1. Because the area where the meeting is being held is near the edge of the model region, will it be addressed? What is northernmost county included?

Response: Because of the model overlap that is defined as a requirement by the TWDB, the Edna region will be included in both the Central Gulf Coast GAM and the Northern Gulf Coast GAM (USGS). The Central Gulf Coast GAM extends east to the western part of Austin, Fort Bend, and Brazoria County. The Northern Gulf Coast GAM extends west to include most of Lavaca and Jackson Counties and a small part of Calhoun County. While the local area (Edna) is located near the western boundary of the Northern Gulf Coast GAM, it is a large distance from the eastern model boundary of the Central Gulf Coast GAM.

2. What are examples of field data that are used at the conceptual model stage of the project?

Response: Examples of field data that are evaluated in developing the conceptual model include: geologic logs, water levels, aquifer tests, stream gage levels, precipitation, temperature, evaporation, historical pumpage, water-quality parameters, etc.

3. What version of MODFLOW will be used?

Response: The TWDB has prescribed that MODFLOW-96 (Harbaugh and McDonald, 1996, USGS Open-File Report 96-485) must be used for all GAMs.
4. The geology in the model region is a complex alluvial system that is not consistent throughout the study area. The problem is that it does not represent well as layers.

Response: Yes we are aware of this fact and realize that there is uncertainty in subdividing it into model layers. The complex depositional environment (different river stages, fluvial deltas, etc.) contributes to this complexity and the difficulty in representing it in model layers.

5. Are the Baker (1979) and Carr et al. (1985) reports available?

Response: A listing of all TWDB reports is located at the TWDB website at: [http://www.twdb.state.tx.us/publications/publications.htm](http://www.twdb.state.tx.us/publications/publications.htm). Baker (1979, TWDB Report 236) is available at the TWDB website at: [http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/GWreports.htm#236](http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/GWreports.htm#236). Note that Figure 1 is not included in this online version. Copies of these reports are available for a fee through TWDB’s TNRIS office at [http://www.tnris.state.tx.us/ordering.htm](http://www.tnris.state.tx.us/ordering.htm) or 512-463-8337.

6. How many cross sections are included in Baker?

Response: There are 12 cross sections for the entire Gulf Coast in Baker (1979). Within our model region there are five cross sections perpendicular to the Gulf coast and one cross section parallel to the coast.

7. At any location, the Evangeline may consist of 5 or 6 sand units interbedded with clay lenses. How will this be modeled?

Response: A regional scale model is being developed with properties input on a 1-mile by 1-mile grid scale areally and one layer vertically for the Evangeline. This modeling scale does not allow simulation of these individual sand and clay units within the Evangeline. Because the sand and clay units are not considered continuous over very large distances, they are lumped together to represent one aquifer unit consistent with the hydrostratigraphic interpretations of Baker (1979) and Carr et al. (1985). This is a model limitation. Modeling regionally at a smaller scale vertically is impractical because the necessary data are not available.

8. What does the Evangeline predevelopment water-level map show?

Response: This map is intended to show the distribution of hydraulic head or water-level elevation in the Evangeline Aquifer prior to development by pumping. The water-level elevation is calculated as the elevation of the top of the well minus the depth to water measured from the top of the well. Flow directions in the aquifer can be determined based on differences in water-level elevation in different wells. Water-level data from the early 1900s were used where possible in developing this map.

9. Did we look at Taylor for predevelopment data?
Response: Yes. (Full reference is: Taylor, T.U., 1907. Underground Waters of Coastal Plain of Texas. USGS Water-Supply and Irrigation Paper No. 190.)

10. What is the source of data and why are they sparse in areas? Are you using TWDB well information? General discussion of TWDB database.

Response: The principal source of well data is the TWDB website. We need additional information in areas of data gaps. [Please contact either Waterstone or TWDB if you are aware of measurements not currently listed in the TNRCC or TWDB database, especially early measurements.] Some wells may be plugged and no longer visible from surface. Some wells do not have proper locations. Advances in technology (GPS units) and methodologies of historically locating wells spatially (using topographic maps) were discussed. Also screen intervals, well depths and how they may change depending on driller and the driller’s report were discussed.

11. Will some data be ignored or eliminated?

Response: We may if the data are so uncertain that they cannot be properly assigned.

12. Have you done a frequency analysis on hydraulic property data? This should be included in final report.

Response: Various types of statistical analyses will be performed when the aquifer property database is completed and documented. These analyses will be documented in the final report.

13. What are K and QC?

Response: K refers to hydraulic conductivity, which is a measure of the ability of the geologic unit to transmit water. QC is quality control.

14. Have you looked at oil field logs?

Response: Open discussion. The cost to acquire data from oil companies is not available in the project budget. A quote of $600/mile was received from a seismic broker. If stakeholders can assist in this process, it would be appreciated. It is believed that hydrostratigraphic interpretations included in Baker (1979), Carr et al. (1985), and various reports from the USGS Regional Aquifer Systems (RASA) investigations have utilized some oil field logs in their research.

15. Have you looked at uranium mines? A stakeholder thought they were required to conduct geophysical surveys for TNRCC.

Response: [Steve Musick – TNRCC] stated they have some electric logs and pump test information in their files [not digital and does not cover a large area, mostly located around Evangeline outcrop in western portion of study area].
16. How are we going to use physical properties (e.g., sand percentages)?

Response: We will attempt to correlate $K$ and sand percentage to assist in mapping the distribution of $K$ during model calibration. We will try to look at directional $K$ properties relative to depositional environment.

17. Open discussion of model scale. GWCDs appear to want a “micro” answer and model is more “macro” in scale. The model may not be able to answer all questions or concerns.

Response: The model can answer some questions but one needs to be aware of the model’s limitations. This model will include averaging of properties at a 1-mile by 1-mile scale. We need to be aware of the spatial limitations. The model will not be able to answer if a neighbor’s well will impact someone. The model may be on a larger scale than required to address some questions. An option is to “telescope” the model and put in finer detail at a later date (beyond scope of current GAM project).

18. Open discussion of problems with well completions. Some wells are screened in wrong intervals or are poorly developed. Specific capacity may increase substantially after well-development activities.

19. Will the interbed storage package in MODFLOW be used? Is the scope for Northern Gulf Coast GAM and Central Gulf Coast GAMs the same except for use of the interbed storage package? Why are model areas not using same options and how it will impact the overlapping area?

Open discussion of using interbed storage package: We discussed that the subsidence package was not completed when the scope for the Central Gulf Coast GAM was defined. According to a Harris-Galveston Subsidence District representative, the package appears to have correctly forecasted subsidence in the Houston area. It is important to have data to correlate/calibrate the results against. Subsidence has been studied in the Houston area and a useful database collected over a long time period has been developed. Very limited subsidence data is available within the Central Gulf Coast GAM region as compared with the Houston region. We do not know the importance of subsidence on the Central Gulf Coast model region. We will include scoping or approximate calculations on the magnitude of the impact of subsidence on water budgets. All models are required to calibrate within a particular range. Both models are using the same geologic structure in the overlap area and are using publicly available data for developing model inputs. Therefore both models should provide somewhat similar results, with the exception of the use of the interbed storage package. The Northern Gulf Coast model should include most of the key areas experiencing subsidence (it extends west to include most of Lavaca and Jackson Counties and a small part of Calhoun County).

20. What is the TWDB’s commitment to the groundwater districts?
Response: The TWDB is tasked with completing models of the major aquifers in the next couple of years. The TWDB has been tasked to model the minor aquifers but has not received the funds to do so. Waterstone will provide a training session to the stakeholders at the end of the Central Gulf Coast modeling project so that stakeholders can use the model themselves. The TWDB will assist the GWCDs as time, staff, and funds permit. In the meantime, it is important for the districts to get familiar with their resources and where additional research and/or data are needed. Modeling efforts [and groundwater management] can only be improved with better data.

21. Can we identify type of data and where needed, and contact names for persons who have data available?

Response: The types of data that are being compiled and evaluated for the model have been outlined in the presentation including key data sources. (Note: the presentation is provided on the TWDB website). If anyone has data that they feel would supplement the presented data, they are welcomed to provide it. Data for model areas that currently show sparse data would be useful. Examples of data that are needed include predevelopment water levels. Contact persons include Cindy Ridgeway at the TWDB (512-936-2386) and Patrick Williamson at Waterstone (303-444-1000).