Groundwater Availability Modeling (GAM) for the Queen City and Sparta Aquifers

Stakeholder Advisory Forum No. 2

San Antonio River Authority
San Antonio, Texas
June 12, 2003
Outline of Presentation

- GAM Objectives and Expectations
- Hydrogeologic Setting
  - Supporting Database Review
  - Preliminary Conceptual Model
- Preliminary Approach to Model Implementation & Integration with Carrizo-Wilcox GAMs
- Review of Project Milestones & Schedule
- Expectations for the next SAF Meeting
GAM Objectives

- Develop realistic and scientifically accurate GW flow models representing the physical characteristics of the aquifer and incorporating the relevant processes
- GAMs are designed to be tools to help GWCDs, RWPGs, and individuals assess groundwater availability through 2050 based upon current data
- Promote stakeholder participation which is critical to the success of the GAM program
Stakeholder Advisory Forums - SAFs

- Held on 4 month schedule
- First SAF introduced basic information and requested data for the model
- Today’s meeting and future meetings will:
  - provide updates on progress
  - provide an opportunity to offer feedback
- SAF presentations and questions & responses from meetings will be posted at 
  http://www.twdb.state.tx.us/gam/qc_sp/qc_sp.htm
Why Groundwater Flow Models?

- In contrast to surface water, groundwater flow is difficult to observe.
- Aquifers are typically complex in terms of spatial extent and hydrogeological characteristics.
- A groundwater model provides the best means for integrating available data for the prediction of groundwater flow at the scale of interest.
Definition of a Model

Merriam-Webster Online Dictionary: a description or analogy used to help visualize something (as an atom) that cannot be directly observed

Domenico (1972) defined a model as a representation of reality that attempts to explain the behavior of some aspect of reality and is always less complex than the real system it represents

Wang & Anderson (1982) defined a model as a tool designed to represent a simplified version of reality
A Model is a Tool

- Model heads are calculated based upon:
  - Recharge
  - Aquifer properties
  - Pumping
  - Natural Discharge

- Model heads are compared to observed water levels

- The tool is used to predict future water levels

(modified from DBS&A 2001)
Modeling Protocol

1. Define model objectives
2. Data compilation and analysis
3. Conceptual model
4. Model design

Field data: New data

- Calibration
  - Steady State*
  - Transient*
  - Verification
  - Prediction
  - Reporting
  - Future Water Strategies

Comparison with field data

*Includes sensitivity analysis
GAM Model Specifications

- Three dimensional (MODFLOW-96)
- Regional scale (1000’s of square miles)
- Grid spacing of 1 square mile
- Implement
  - recharge
  - groundwater/surface water interaction
  - pumping
- Calibration to observed water levels
Queen City-Sparta GAM Specifications

- The Queen City and Sparta aquifer GAMs will be incorporated into the current Carrizo-Wilcox GAMs
  - Carrizo-Wilcox GAMs will be modified only as needed to properly add the Queen City and Sparta aquifers and recalibrate the entire model

- The product will be delivered as three models (southern, central, and northern regions)

- One modeling report will be produced
GAM Model Periods

Pre-development and transient calibration periods represent different hydrologic conditions.
Hydrogeologic Setting

- Study area
- Hydrostratigraphy
- Hydraulic properties
- Regional groundwater flow
- Recharge
- Discharge
  - Pumping
- Streams
Model Domains

Northern Model Area

Southern Model Area

Central Model Area
Model Grid Scale – Gonzales Co. Area

20,000 acres represents Approximately 5 grid blocks

Grid - 1 square mile each
Same Grid as Carrizo-Wilcox GAMs

Gonzales

Nixon
Regional Water Planning Groups

Ten of the Sixteen RWPGs are represented in the three GAM regions
Yearly Average Rainfall

Model Boundary
County/Parish Boundaries
State Line

Active Model Grid Limits
Land Surface Elevation

Land Surface Elevation (FT MSL)

- Model Boundary
- State Line
- Major Rivers & Streams
- Major Lakes
- Major Towns & Cities

Miles

N

0 40 80
Major River Basins

Every major river basin is intersected by at least one of the three model domains
Eco Regions
Model Stratigraphy

File: Geologic Stratigraphy.fh8
Queen City & Sparta Aquifers

The Queen City and Sparta Aquifers extend from South Texas northeastward through East Texas into Ark. & La.

- Sediments of the Tertiary Claiborne Group
- Queen City aquifer consists of sand, loosely-cemented sands, and interbedded clays
- Sparta Aquifer consists of sand and interbedded clays with massive basal sands which gently dip toward the Gulf Coast (average thickness of 400 ft.)
- Aquifers are separated by the Weches Formation which is a marine confining unit
Queen City Aquifer
Geologic Structure Data Sources

- Structure – Refers to the elevation of the tops of the Queen City, the Weches, and the Sparta formations.

- MS Thesis – TCEQ well log database
  - Guevara (1972) & Garcia (1972) – Queen City
  - Ricoy (1976) - Sparta
    - 700 Logs available across the 3 model areas

- Sand thickness maps:
  - Guevara (1972) & Garcia (1972) – Queen City
  - Ricoy (1976) and Payne (1968) - Sparta
Sparta Aquifer – Structure Control
Queen City Aquifer – Structure Control
Aquifer Thickness - Draft
Hydrogeologic Cross Section

Northern Model Region

- Queen City outcrops over the majority of the East Texas Basin
- Queen City and Sparta eroded across the Sabine Uplift
- South of Sabine Uplift aquifers dip into the Gulf Coast Basin
Central and Southern Models

- Outcrops are very narrow
- Dips are very steep averaging 100 ft/mile or >
Hydraulic Properties

- Published Reports:
  - USGS
    - Payne (1968)
    - RASA – Prudic (1991)
  - BEG
    - Guevara & Garcia (1972)
    - Ricoy (1977)
  - TWDB
    - Myers (1969)
    - County Reports

- TCEQ file search of the drillers logs
  - Estimates of specific capacity will be used to augment published values

- Stakeholder provided data
Hydraulic Conductivities

- Completed a literature review for available hydraulic conductivity measurements (TWDB reports, TWDB GWDB, BEG publications).
- BEG has compiled specific capacity data from the TCEQ records (>2000 estimates).
- We will add hydraulic conductivity estimates from Mace et al. (2000) if they vertically fall within the Queen City and are without aquifer code.
Hydraulic Conductivity Control
TCEQ Hydraulic Conductivity Data

### Draft analysis

- Average is 3.6 ft/day
- Awaiting final structure for discrimination between aquifers and confined/unconfined

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**WELL GEOMETRY**

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**WELL TEST**

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**Graph:**

![Graph showing frequency distribution of hydraulic conductivity](https://via.placeholder.com/150)

- **Frequency**
- **Hydraulic Conductivity (ft/d)**
- **Measured**
- **Theory**
Vertical Hydraulic Conductivity ($K_v$)

- $K_v$ values for the Northern and Southern Carrizo-Wilcox models were set using constant $K_h/K_v$ ratios over large zones.

- $K_v$ values for the Central Carrizo-Wilcox model were calculated as the harmonic mean assuming and calibrating a clay conductivity.

- We propose to use clay fraction and an assumed clay conductivity to define $K_v$ zones which would then be varied within limits during calibration.
Regional Groundwater Flow

- In the northern portion of the study area, groundwater flows locally in the Queen City aquifer rather than regionally due to topographic controls (Fogg and Kreitler, 1982)

- In the central and southern portions of the study area, groundwater flows regionally in the Queen City and Sparta aquifers from topographic highs in the outcrop areas to topographic lows down dip of the outcrop
Water Levels

Objectives

- Develop water-level elevation contours of predevelopment conditions
- Develop water-level elevation contours for
  - The start of model calibration (1980)
  - The end of model calibration (1990)
  - The end of model verification (1999)
- Evaluate transient water-level conditions and select hydrographs for use as calibration targets
- Evaluate cross-formational flow
Water-Level Data

Development of Water-Level Elevation Contours

- Used data from the TWDB website
- Averaged data from two years before and two years after the year of interest
- Created contours for the Queen City and Sparta aquifers separately
Water-Levels

Challenges

– Identification of predevelopment conditions
– Inconsistent data coverage from year to year and county to county
– Little well control down dip of the outcrop
– Irregular topography in northern portion of the study area resulting in complex water-table surfaces for the Queen City and Sparta aquifers
Queen City Water Level Control
Sparta Aquifer Water Level Control
Queen City 1980 Water Level Elevation

Contour Interval = 50 feet

- Model Boundary
- Downdip Edge of Queen City Outcrop
- Downdip Edge of Sparta Outcrop
- Water-Level Elevation (feet)
- Measurement Point
Sparta 1980 Water Level Elevation

Contour Interval = 50 feet

- Model Boundary
- Downdip Edge of Queen City Outcrop
- Downdip Edge of Sparta Outcrop
- Water-Level Elevation (feet)
- Measurement Point
Queen City Hydrograph Locations
Sparta Hydrograph Locations
Recharge

Recharge – The addition of water to the water table. Recharge equals water inputs at ground surface (precipitation + irrigation + stream loss) minus water losses (runoff + evapotranspiration)

Recharge is a complex function of
- Precipitation (rate, volume, distribution),
- Evapotranspiration (ET)
- Runoff
- Soil moisture, soil type
- Runoff
- Depth to water

Recharge is not directly measurable on a model scale

Recharge varies as a function of time and space
Recharge

- **Northern and Southern Carrizo-Wilcox GAMs**
  - SWAT models used to predict recharge variation both temporally and spatially
  - Recharge based primarily on daily precipitation data, MRLC land use data, and STATSGO soil parameters.
  - SWAT recharge results in the Northern Carrizo-Wilcox model & northern part of the Southern model were decreased during calibration.

- **Limitations to Method as applied**
  - Rates too high in high precipitation regions
  - Method is decoupled from underlying aquifer properties
Recharge

Central Carrizo Wilcox Model

- *Estimated* minimum and maximum temporal recharge rates (corresponding to minimum and maximum precipitation) for each formation.
- Scaled the recharge spatially based on soil hydraulic conductivity, with maximum recharge occurring for a soil column vertical hydraulic conductivity greater than or equal to 1.75 ft/day.

Limitations to Method as applied

- Subjective specification of formation minimum and maximums
- Limits recharge areally which may tend to limit total recharge volumes
## Recharge Estimates – Muller and Price (79)

<table>
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<th>Zone</th>
<th>Region</th>
<th>M&amp;P 79</th>
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Total Recharge Estimates: 634700, 682100, 163800
Queen City-Sparta Recharge Estimates

- Chloride mass balance method
- BEG study in progress (Scanlon and Reedy)
- Based upon 1050 Cl measurements in the outcrop of QC/Sparta
Water Quality

Data on water quality were obtained from TWDB internet files and TCEQ’s public water supply section.

Data were requested from groundwater conservation districts.

Water-quality data from TWDB included:

- 289 wells with information for the Queen City and El Pico Formations
- 405 wells with data for the Sparta and Laredo Formations

Where repeated samples were reported, the most recent analysis was used for mapping.
Water Quality Results

- Average total dissolved solids (TDS) increases down dip in the aquifers:
  - Statistics confirms that average TDS in the confined aquifer is greater than in the unconfined parts of the Queen City and Sparta aquifers.

- Average TDS is greater south of Lee County than to the north, as previously reported in TWDB Hydrologic Atlases:
  - Statistical tests confirm findings for both the Queen City and Sparta aquifers.
  - Evaluation of the hydrogeologic control(s) of this regional difference is in progress.
Water Quality Results (cont.)

- Average TDS is greater south of Lee County than to the north, as previously reported in TWDB Hydrologic Atlases:
  - Statistical tests confirm findings for both the Queen City and Sparta aquifers.
  - Evaluation of the hydrogeologic control(s) of this regional difference is in progress.

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<th>Queen City</th>
<th>Sparta</th>
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TDS - Sparta Aquifer

Sparta TDS (mg/L)
0 - 500
500 - 1000
1000 - 3000
3000 - 12000
Carrizo-Wilcox Pumping (AFY)

Yearly Average Pumping Rate (AFY) 1980-1997

Reported Pumpage 1997 - 430,000 AF

Mean Annual Pumping (acre ft/yr) 1980-1997: Carrizo-Wilcox Aquifer

- 0-25
- 25-50
- 50-150
- 150-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- 50,000-100,000

Does not include rural/domestic
Queen City Pumping (AFY)

Yearly Average Pumping Rate (AFY) 1980-1997

Does not include rural/domestic

Reported Pumpage 1997 - 14,000 AF

Mean Annual Pumping (acre ft/yr) 1980-1997: Queen City Aquifer

- 0-25
- 25-50
- 50-150
- 150-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- 50,000-100,000

DRAFT
Sparta Aquifer Pumping (AFY)

Yearly Average Pumping Rate (AFY)
1980-1997

Does not include rural/domestic

Reported Pumpage
1997 - 6,800 AF

Mean Annual Pumping (acre ft/yr)
1980-1997: Sparta Aquifer

- 0 - 25
- 25-50
- 50-150
- 150-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- 50,000-100,000

Kilometers
Other Aquifer Pumping (AFY)

Yearly Average Pumping Rate (AFY) 1980-1997

Mean Annual Pumping (acre ft/yr) 1980-1997: Other Aquifer

- 0-25
- 25-50
- 50-150
- 150-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- 50,000-100,000

DRAFT
Streams – Prudic (1991)

- Stream length (1 mile)
- Stream width
- Streambed thickness
- Streambed hyd. K
- Streambed elevation
- Streambed slope
- Manning’s roughness
- Headwater reach Q for every stress period
- Segment connections
Streams

Queen City Sparta GAMs will require the addition of very few new reaches

- Each cell is a reach
- Reaches make up segments
Streams – Calibration

- Calibrate streambed conductivities to match losses/gains

Calibration targets:

- USGS low flow data (Slade et al. 2002) – 366 studies on 249 stream reaches
- Stream Gage Analysis (base flow)
- Published estimates from other models (Limited)
- Stream gage data – upper bound
Ongoing Efforts – Stream Routing

- Review the method(s) used to assign stream flow rates to ungauged headwaters and provide recommendations for improvement.
- Review of the calibration targets used to characterize stream/aquifer interaction.
- Development of additional gain/loss estimates (surface water calibration targets).
- Review and provide recommendations regarding approach for initialization and calibration of stream bed conductance in the completed Carrizo-Wilcox models.
Model Implementation

- We will begin with the same values in overlap areas.
  - Structure
  - Hydraulic Conductivity
  - Storage
  - Pumping
  - Recharge
  - Boundaries

- We will monitor parameter changes between models during calibration to insure consistency between models at the end of the day.
Proposed Approach:

- We will begin with the same values in overlap areas.
- We will monitor parameter changes between models during calibration to insure consistency between models.
- Complete SWAT simulations in remaining Central basins for ET.
- Further analyze what is driving SWAT results
- Monitor Dr. Scanlon’s research into controls on recharge.
- Develop calibration methodology based on our analyses and previous estimates.
Boundaries - Implementation

- **Top boundary (above Sparta)**
  - N & S C/W GAMs used GHBs with a conductance estimated from the Kv of overlying layers and a head estimated from ground surface correlation.
  - Central C/W GAM used a constant conductance of 100 ft2/d and heads determined from Queen City water levels.
  - **Proposed:** Use N & S GAM approach

- **Northeast and Southwest lateral boundaries**
  - N & S C/W GAMs used no flow boundaries.
  - Central C/W GAM used GHBs in the confined section.
  - **Proposed:** Boundary condition will be based on observed flow directions in historical period. We will use inter-model iteration for predictive period if drawdowns warrant.
Boundaries - Implementation (cont.)

- Downdip boundary
  - N & S C/W GAMs used a no flow boundary for the downdip boundary
  - Central C/W GAM used a GHB downdip boundary
  - Proposed: Use no-flow boundary for the downdip boundary in the Queen City and Sparta. Keep the GHB in the Central C/W model (no effect).
GAM Schedule

2003

SAF 1 — Feb 28
Stakeholder - Apr 31
Data

SAF 2 — June 12

SAF 3 — Nov

2004

SAF 4 — Mar

SAF 5 — June

Stakeholder Comments

Jan 23 — Kickoff Meeting

Jan

Feb

Mar 1

June

Jan 31 — Draft Conceptual Model Report

draft concept

Steady-state model review

Steady-state model review

Transient model review

Predictions review

Draft report review

Final Report & Model

Complete database

Evaluate data

Preliminary model design
Meeting Wrap-Up

Next meeting – November

- Final conceptual model review
- Model implementation
- Draft Steady-state model calibration
- Pumping Distribution

Discussion / comments / questions
Who to Contact?

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- **Dr. Shirley Wade**
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  shirley.wade@twdb.state.tx.us
# ATTACHMENT A: SIGN-UP SHEET

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Contact Information (including email address, if available)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mike Mahoney</td>
<td>Evergreen UWCD</td>
<td></td>
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<tr>
<td>Barry Miller</td>
<td>Gonzales UWCD</td>
<td></td>
</tr>
<tr>
<td>Bob Kier</td>
<td>Lost Pines GCD/RSKC</td>
<td></td>
</tr>
<tr>
<td>Melissa Bryant</td>
<td>San Antonio River Authority</td>
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<td>Steve Raabe</td>
<td>San Antonio River Authority</td>
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<td>Ronnie Hernandez</td>
<td>San Antonio River Authority</td>
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<td>Rudy Farias</td>
<td>San Antonio River Authority</td>
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Meeting Minutes for the
Second Queen City/Sparta Groundwater Availability Model (GAM)
Stakeholder Advisory Forum (SAF) Meeting

June 12, 2003

San Antonio River Authority
San Antonio, Texas

The second Stakeholder Advisory Forum (SAF) Meeting for the Queen City/Sparta Groundwater Availability Model (GAM) was held on June 12th from 1:30 until 3:30 PM at the San Antonio River Authority in San Antonio, Texas. Attachment A of these meeting minutes provides a list of all participants who signed up as attending the meeting.

The purpose of the second SAF meeting was to provide an update on the progress for the Queen City/Sparta Aquifers GAM and provide an opportunity for feedback from stakeholders.

Meeting Introduction: Dr. Shirley Wade, TWDB

The meeting was initiated by Dr. Shirley Wade of the Texas Water Development Board (TWDB). She gave a brief introduction to the GAMs and discussed the current status of the GAM program. She then discussed groundwater availability and use of the GAMs, followed by a look at the future of the GAMs and opportunities for public involvement in GAM development.

SAF Presentation: Van Kelley, INTERA

Van Kelley, Project Manager for the INTERA Queen City/Sparta Team presented a prepared presentation. The presentation was structured according to the following outline:

1. GAM objectives and expectations
2. Hydrogeologic setting
   • Supporting database review
   • Preliminary conceptual model
3. Preliminary Approach to Model Implementation & Integration with Carrizo-Wilcox GAMs
4. Review of Project Milestones & Schedule
5. Expectations for the next SAF Meeting

The presentation is available on the GAM website (www.twdb.state.tx.us/gam).
Questions and Answers: Open Forum:

Q. What number SAF is this?
A: This is the second SAF meeting.

Q: When was the first SAF meeting held?

Q: Is INTERA doing all three model sections?
A: The INTERA team is responsible for all three model sections. The Bureau of Economic Geology (BEG) is working with INTERA in model development and will calibrate and run the central section. INTERA will calibrate and run the northern and southern sections.

Q: Is the Queen City aquifer under water table conditions throughout northeast Texas?
A: In the East Texas Basin, the Queen City is under water table conditions throughout, except for those areas that are overlain by isolated islands of Weches and Sparta.

Q: What does the note about rural/domestic on the pumping figures mean?
A: Rural/domestic pumping has not been assigned to individual aquifers at this time. The county volumes shown include only point specific volumes reported to the TWDB. Rural/domestic pumping will be assigned to individual aquifers and included in pumping for model runs.

Q: Will there be only one GAM in each area? Will there be a Carrizo-Wilcox model and a combined Queen City-Sparta and Carrizo-Wilcox model?
A: The Queen City and Sparta aquifers will be added to the existing Carrizo-Wilcox models, modifying the Carrizo-Wilcox data as needed to calibrate the models. Redesigning the Carrizo-Wilcox models was not the intention of this GAM, but some changes will be necessary.

Q: The limitations of the Carrizo-Wilcox models are fairly well documented, but the demand projections are not well documented. How were these developed? The Central model pumping estimates changed between the draft and final reports without an explanation. Procedures for developing pumping should be very well documented.
A: A detailed description of how pumping estimates from the TWDB were distributed is included in the Northern and Southern GAM Reports.

Q: In the Central/Southern model overlap zone, will the water balance change for the Central model or the Southern model when the new models are built?
A: We do not know at this time. This can only be answered after model development and calibration. Vertical hydraulic conductivity may be the most significant factor affecting the transient water balance in the confined section and it may require greater consistency in the overlap area to calibrate the Queen-City-Sparta GAM.