Groundwater Availability Modeling (GAM):

- purpose: to provide reliable and timely information on groundwater availability
- assess adequacy or recognize inadequacy of supplies throughout 50 year planning horizon
- public process
- standardized, thoroughly documented, and available to public over Internet
Location of the Minor Aquifers in Texas for GAM

1. Blaine d
2. Blossum n
3. Bone Spring-Victorio Peak n
4. Brazos River alluvium n
5. Capitan Reef n
6. Dockum c,n
7. Edwards-Trinity (High Plains) c
8. Ellenburger-San Saba n
9. Hickory n
10. Igneous n
11. Lipan d
12. Marathon n
13. Marble Falls n
14. Nacatoch n
15. Queen City c
16. Rita Blanca d
17. Rustler n
18. Sparta c
19. West Texas Bosons d,n
20. Woodbine c
What is a groundwater model?

- a tool to estimate field conditions
- allows effective use of available data and account for complexities
- expands our ability to better understand and manage the water resources
- increases prediction accuracy of future events to a level far beyond “best judgement” decisions
Modeling Protocol

Purpose

Conceptual model

Numerical formulation

Model design

Calibration

Comparison with field data

Verification

Steady-state Model

Prediction

Prediction Runs (2000-2050)

Postaudit

Field data

Transient Model (1980-2000)
Conceptual model of the groundwater flow system, southern Gulf Coast aquifer

- Gulf of Mexico
- Evangeline aquifer
- Chicot aquifer
- Mesquite
- Rain
- Evapotranspiration (ET)
- Infiltration
- Runoff
- Water level

Flow paths:
- Rainwater infiltrates into the aquifers.
- Evapotranspiration (ET) from vegetation.
- Infiltration from surface water.
- Runoff from land to the aquifers.

Aquifers:
- Evangeline aquifer
- Chicot aquifer
- Jasper aquifer
- Burksville Confining System

Connections:
- Flow from the Gulf of Mexico to the Chicot aquifer.
A Model Cell

Recharge (Rainfall/River)

Pumping

Evapo-transpiration

Aquifer Thickness

Hydraulic Conductivity

Water Level
Recharge

- diffuse (direct) - precipitation or irrigation
- focused or localized - surface depressions, e.g. lakes or playas
- indirect recharge - beneath rivers, lakes

- recharge rate depends on rainfall, vegetation, soil type, topography
- recharge estimation - water budget, surface water techniques, numerical modeling, tracers

Average annual rainfall map
60 inches in the east to 8 inches in the west

Recharge due to connection between rivers and aquifers (Bouwer and Madock, 1997)
### Recharge for the Gulf Coast aquifer

<table>
<thead>
<tr>
<th>Source</th>
<th>Recharge (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groschen (1985)</td>
<td>0.06</td>
</tr>
<tr>
<td>Ryder (1988)</td>
<td>0 to 6</td>
</tr>
<tr>
<td>Dutton and Richter (1990)</td>
<td>0.1 to 0.4</td>
</tr>
<tr>
<td>Noble and others (1996)</td>
<td>6</td>
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<tr>
<td>Hay (1999)</td>
<td>.00004 to .04</td>
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<tr>
<td>Harden and Associates (2001)</td>
<td>3</td>
</tr>
</tbody>
</table>
Transmissivity

- transmission capability of the entire thickness of the aquifer
  \( T = KB \), hydraulic conductivity * aquifer thickness
- hydraulic conductivity (pump test, grain sizes and lab tests)
- specific capacity

Hydraulic conductivity is affected by degree of interconnection between pores

Unconfined aquifer

Confined aquifer
Pumping
- historical
- predictive

Categories
- municipal
- manufacturing
- domestic
- irrigation
- livestock
groundwater availability modeling

• ‘Like beauty, groundwater availability is in the eye of the beholder’

• it's a combination of policy and science
  – safe yield
  – as a percent of rainfall on outcrop
  – historical pumping
  – systematic depletion
Hydrogeology, Simulation of Ground-Water Flow, and Land-Surface Subsidence in the Chicot, Evangeline, and Jasper Aquifers, Houston Area, Texas

Mark C. Kasmarek & Eric W. Strom

In Cooperation with the Texas Water Development Board and the Harris-Galveston Coastal Subsidence District
Conceptual Chicot Aquifer Flow System

- Precipitation Recharge
- Runoff
- Stream
- Unsaturated Zone
- Saturated Zone
- Infiltration
- Ground-Water Recharge
- Potentiometric Surface
- Ground-Water Discharge
- Subsurface Flow System
- Equipotential Lines
- Flowlines
- Evapotranspiration
Conceptual Ground-Water Flow

The Evangeline is recharged directly by precipitation and surface runoff where it crops out north of Houston.

A weak hydraulic connection between shallow ground water, the Chicot aquifer, and the Evangeline aquifer allows the vertical movement of water into and between the aquifers.
Conceptual Ground-Water Flow

NORTWEST
AQUIFER OUTCROPS
Hydraulic Connection

HOUSTON-METRO

SOUTHEAST
Gulf of Texas

JASPER
EVANGELINE
CHICOT
FRESHWATER
SALINEWATER

Numerous Clay Lenses

Undifferentiated Sediments

Burkeville Confining System
TWDB Ground-Water Availability Models in Texas

Modified from TWDB website
Stratigraphic and Hydrologic Sections

Geologic cross section showing the northwest to southeast dip and relation of stratigraphic and hydrologic units (modified from Baker, 1986).
Preliminary Water-Table Contours
Contours Range from 0 to 541.5 feet
Contour Interval 10 feet
Preliminary Chicot Steady-State Heads

Contours Range from 0 to 421 feet
Contour Interval 10 feet
Preliminary Evangeline Steady-State Heads

Contours Range from 0 to 425 feet

Contour Interval 10 feet
Preliminary Burkeville Steady-State Heads
Contours Range from 52 to 426 feet
Contour Interval 10 feet
Preliminary Jasper Steady-State Heads

Contours Range from 77.6 to 541.5 feet

Contour Interval 10 feet
Preliminary Chicot Horizontal Hydraulic Conductivity
Preliminary Burkeville Vertical Hydraulic Conductivity
GAM Map View
GAM View From Gulf
GAM View From North
GAM Upper Gulf Coast Aquifer Outcrops
Water-Level Altitudes 2002 and Water-Level Changes in the Chicot, Evangeline, and Jasper Aquifers and Compaction 1973-2001 in the Chicot and Evangeline Aquifers, Houston-Galveston Region, Texas

In cooperation with the Harris-Galveston Coastal Subsidence District, City of Houston, and Fort Bend Subsidence District
1977-2002 Chicot Aquifer Water-Level Change
Chicot Aquifer Zero Water-Level Change
2002 Evangeline Aquifer
Water-Level Altitude
1977-2002 Evangeline Aquifer Water-Level Change
1990-2002 Evangeline Aquifer Water-Level Change
2002 Jasper Aquifer Water-Level Altitude

Map showing the water-level altitude of the Jasper Aquifer in 2002 with contour lines indicating water depth in meters.
1973-2001 Borehole Extensometer Cumulative Compaction
1973-2001 Borehole Extensometer Cumulative Compaction
Quality Scientific Data Collection and Analysis for the Long Term
Attendance list at the 4th Stakeholder Advisory Forum for the northern Gulf Coast aquifer Groundwater Availability Model, June 5, 2002

<table>
<thead>
<tr>
<th>Names</th>
<th>Affiliation</th>
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</thead>
<tbody>
<tr>
<td>Ali Chowdhury</td>
<td>Texas Water Development Board</td>
</tr>
<tr>
<td>David Huang</td>
<td>City of Houston</td>
</tr>
<tr>
<td>H.C. Clarke</td>
<td>Geology Consultant</td>
</tr>
<tr>
<td>David Dow</td>
<td>NHCRWA</td>
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<tr>
<td>Alan Hamilton</td>
<td>Ecologist</td>
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<tr>
<td>Bob Rodgers</td>
<td>RWR Associates</td>
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<tr>
<td>Ken Kramer</td>
<td>Sierra Club</td>
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<tr>
<td>David W. Minze</td>
<td>Bluebonnet GWCD</td>
</tr>
<tr>
<td>Eric Strom</td>
<td>US Geological Survey</td>
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<tr>
<td>Cary L. Betz</td>
<td>TNRCC</td>
</tr>
<tr>
<td>Haskell L. Simon</td>
<td>Region K - Regional Water Planning Group</td>
</tr>
<tr>
<td>Wes Meehan</td>
<td>USGS</td>
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<tr>
<td>Marl Lowry</td>
<td>Region K and P Consultant</td>
</tr>
<tr>
<td>Joe Broadus</td>
<td>US Geological Survey</td>
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<tr>
<td>John Nelson</td>
<td>LBG-Guyton Associates</td>
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<tr>
<td>Mark C. Kasmarek</td>
<td>US Geological Survey</td>
</tr>
<tr>
<td>Robert K. Gabrysch</td>
<td>Consultant Hydrogeologist</td>
</tr>
<tr>
<td>Ron Neighbors</td>
<td>Harris-Galveston Coastal Subsidence District</td>
</tr>
<tr>
<td>Phil Savoy</td>
<td>Murfee Engineering</td>
</tr>
<tr>
<td>David A. Van Dresar</td>
<td>City of Texas City</td>
</tr>
<tr>
<td>Tom Michel</td>
<td>Harris-Galveston Coastal Subsidence District</td>
</tr>
</tbody>
</table>
Q: Predictive-pumping distribution may not be that accurate and therefore, predictive water levels over the 50-year planning framework may not be valid. Population projection study is needed to estimate where the future population will migrate and where groundwater extraction will occur.

A: We are using the groundwater demand numbers as provided by the RWPGs for making predictive runs. New population projection study may not accurately locate well locations, as wells may not move with the population. We have to start somewhere and the model will be updated, as new data becomes available.

Q: The model may not accurately predict water levels in the areas outside the subsidence district where there is paucity of data. The new Groundwater Districts may not have the financial resources to use the model.

A: There is no denying that additional data can help improve the accuracy of the model. The model however includes the best information available today. On a regional basis, the model should be able to provide answers to various groundwater issues. Numerous wells may be needed to address local groundwater concerns.

The TWDB will help in making different scenario runs at the request of the Groundwater Districts. At this time, there will be no fees for these services and these requests will be handled on first come first served basis.

Q: Does the model include salt water?

A: No, the model does not simulate salt water. MT3D may be incorporated to simulate salt water.

Q: What are the salt concentrations at the down-dip boundaries of the Burkeville Confining System and the Jasper aquifer?

A: 10,000 PPM TDS based on geophysical logs.

Q: What is the steady-state head?

A: Water levels in an aquifer under pre-pumping conditions. Water levels for 1891 were used for constructing the pre-development model.

Q: Can you show recharge for the different outcrop areas?

A: We will report recharge-discharge values when we are done with calibrating the model.
Q: How dispersed is the clay data across the model area?

A: Away from the core, hardly any clay data is present.

Q: How much money is required to run a Groundwater District?

A: One stakeholder reported that TWDB said it might cost as little as $50,000. Another stakeholder reported that you might not be able to hire one professional staff for that amount.

Q: Chapter 376 states that the GW districts shall use the GAM models to estimate groundwater availability.

A: We are developing the GAM models as tools for predicting future water levels. Groundwater availability numbers for the aquifers are decided at the local levels.

Comment: The model is funded by the TWDB, the Harris-Galveston Coastal Subsidence District and the USGS. City of Houston and San Jacinto River Authority was ready to participate but did not make any financial contribution to the study.