Outline

- General Introduction to the GAM program
- Introduction to the Rustler GAM team
- Rustler regional overview
- Basics of groundwater flow
- Overview of Rustler Aquifer
- Numerical groundwater modeling and the GAMs
- Data collection
- GAM schedule
Groundwater Availability Modeling

Wade Oliver
Contract Manager
Rustler Aquifer Groundwater Availability Model (GAM)

Texas Water Development Board
GAM Program

- **Purpose:** to develop tools that can be used to help GCDs, RWPGs, and others understand and manage their groundwater resources.

- **Public process:** you get to see how the model is put together.

- **Freely available:** models are standardized, thoroughly documented. Reports available over the internet.

- **Living tools:** periodically updated.
What is Groundwater Availability?

Science + Policy = Groundwater Availability

GAM or other tool + Desired Future Conditions = Managed Available Groundwater

Goal: informed decision-making
Major Aquifers
Minor Aquifers

MINOR AQUIFERS OF TEXAS

Legend

- Brazos River Aquifer
- Upper Trinity Aquifer
- Lower Trinity Aquifer
- Llano Estacado Aquifer
- Edwards Aquifer
- Gulf Coast Aquifer
- East Texas Aquifer
- West Texas Aquifer
- Rio Grande Valley Aquifer
- South Texas Aquifer
- Coastal Bend Aquifer
- Gulf Coast Aquifer
- South Texas Aquifer
- Edwards Aquifer
- East Texas Aquifer
- West Texas Aquifer
- Llano Estacado Aquifer
- Upper Trinity Aquifer
- Brazos River Aquifer

Map updated December 2006 by Mark Ayers, G.S.P.
How we use Groundwater Models

- Inform groundwater districts about historical conditions in the aquifer

<table>
<thead>
<tr>
<th>Management Plan requirement</th>
<th>Aquifer or confining unit</th>
<th>Results</th>
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<td>Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers</td>
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How we use Groundwater Models

- Assist districts and management areas in determining desired future conditions

**Drawdown vs. Pumping in Jeff Davis County UWCD**

Igneous Aquifer

- Requested Drawdown: 10 feet

- Scenario 1 Trendline
- Scenario 2 Trendline

**Decline in Water Levels**

- **Pumping (acre-feet per year)**

- **Drawdown (ft)**
How we use Groundwater Models

- Assist districts and management areas in determining desired future conditions

**Outflow to Springs**

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<td>2000</td>
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Stakeholder Advisory Forums

- Keep updated about progress of the model
- Understand how the groundwater model can, should, and should not be used
- Provide input and data to assist with model development
Contact Information

Wade Oliver
wade.oliver@twdb.state.tx.us
512-463-3132

Texas Water Development Board
1700 North Congress Avenue
P.O. Box 13231
Austin, Texas 78711-3231

Web information:
www.twdb.state.tx.us/gam
Project Team & Responsibilities

**INTEGRATED PROJECT TEAM**

- **Dr. John Sharp, PG**
  - 27 years of experience in Texas hydrogeology including specialized expertise in regional groundwater flow systems of Trans-Pecos region and west Texas
  - Conceptual model development
    - Trans-Pecos flow systems
    - aquifer boundaries
  - Model implementation review

- **Dr. Dennis Powers, PG**
  - 30 years of experience with west Texas and southeastern New Mexico hydrogeology including detailed geological and hydrogeological studies of the Rustler Formation
  - Rustler structure development
  - Conceptual model development
    - depositional environments
    - dissolution controls
  - Model implementation review

- **Dr. Robert Holt**
  - 25 years of experience with the Rustler Formation focusing on conceptual hydrogeological model development, geologic controls on hydrologic parameters, depositional systems, paleohydrology, and fracture system origin
  - Conceptual model development
    - depositional environments
    - aquifer properties
  - Model implementation review

**Project Team & Responsibilities**

- Project management
- Model development/calibration
- GIS
- Stakeholder communications

25 scientists and engineers in Texas specializing in development of quantitative modeling tools; proven experience on 10 GAMs for TWDB
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Groundwater Management Areas
Groundwater Conservation Districts

- Brewster County GCD
- Culberson County GCD
- Jeff Davis County UWCD
- Middle Pecos GCD
- Presidio County UWCD

State Boundary
County
Rustler - Texas
Rustler - New Mexico
Topography (meter above mean seal level)
Annual Average Precipitation 1971-2000
Annual Average Temperature
1971-2000
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Groundwater Flow - Definitions

- **Aquifer** – Water saturated permeable geologic unit that can transmit significant quantities of water (e.g., sands & gravels).
  - Unconfined – water table forms the upper boundary
  - Confined – has overlying/underlying lower permeability layers
- **Water table** – The top of the saturated zone.
- **Hydraulic head** – The water level in a well expressed as an elevation.
Groundwater Flow – Definitions (continued)

- **Hydraulic conductivity** (permeability) – A physical property of the geologic media representing its ability to transmit water.

- **Specific yield** – The volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in water table elevation.

- **Storativity** – The volume of water that a confined aquifer releases from storage per unit surface area of aquifer per unit decline in head.
Groundwater Flow – Definitions (cont’d)

- **Recharge** – The entry of water to the saturated zone at the water table:
  \[
  \text{Recharge} = (\text{precipitation} + \text{stream loss}) \quad \text{minus} \quad (\text{runoff} + \text{evapotranspiration}).
  \]

- **Cross-formational flow** – Groundwater flow between separate geologic formations.

- **Stream losses or gains** – The water that is either lost or gained through the base of the stream or river.
Basic Principles of GW Flow

- The primary observable quantity describing groundwater flow is the water level as measured in a well.
- The water level expressed as elevation is termed the hydraulic head.
- The difference in hydraulic head between adjacent wells determines the direction of GW flow (from higher heads towards lower heads).
- The water table is typically a subdued replica of the topography.
Basic Principles of GW Flow

- The thickness and hydraulic conductivity of the aquifer material define volumetric flow rates (e.g., for pumping)
  - The larger the hydraulic conductivity and thickness, the greater the flow.
Schematic Cross Section of Groundwater Flow
Confined/Unconfined Aquifer
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Structural Setting

Legend
- Rustler aquifer
- Outcrop
- Downdip

Map showing the structural setting with areas labeled as Delaware Basin, Central Basin Platform, Midland Basin, Val Verde Basin, and locations such as Van Horn, Alpine, Fort Stockton, Presidio, Sanderson, and Del Rio.
Conceptual Flow Systems

after Sharp (2001)
## Generalized Stratigraphy

<table>
<thead>
<tr>
<th>System</th>
<th>Culberson and Reeves Counties, TX</th>
<th>Pecos County, TX/Glass Mountains</th>
<th>Central Basin Platform</th>
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<tbody>
<tr>
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<td>Alluvium Volcanics</td>
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<td>Dockum</td>
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<tr>
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<td>Upper Member</td>
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<td>Middle Member</td>
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<td>Culebra Dolomite</td>
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<td></td>
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<tr>
<td></td>
<td>Lower Gypsum &amp; Mud</td>
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<td>Siltstone</td>
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<td>Salado</td>
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</table>
Structural Cross-Section

From Jones (2001)
Structural Cross-Section

From Ashworth (1990)
Model Structure

Challenges:
- Develop a base Rustler
- Develop internal Rustler stratigraphy
- Use Hiss (1976) as a starting point for the Top of Rustler
- Develop the Rustler lithology at select locations to develop an understanding of stratigraphy
- Younger units structure will be based upon GAMs, Literature, and interpretation (as needed)
- TGS Log Library (private)
- We will also look into RRC, BEG..
- Sandia
- Sulphur Mining
- Models:
  - Sandia
  - Davies
  - Boghici
Sandia Model

- Dr. Holt interpreted Rustler structure and stratigraphy into Texas
- We will attempt to access these original logs

Properties

- General lack of data
- High range in measured values in NM
Properties

- Properties of the Rustler members have been correlated to:
  - Depositional facies (halite presence)
  - Secondary porosity
  - Depth of burial

- We will attempt to use soft data in addition to measurements to upscale properties
### Rustler Wells with Water-Level Measurements

**Year of First and Last Measurement and Total Number of Measurements**

<table>
<thead>
<tr>
<th>State Well Number</th>
<th>County</th>
<th>Year of First Water-Level Measurement</th>
<th>Year of Last Water-Level Measurement</th>
<th>Number of Water-Level Measurements</th>
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Pumping will be estimated from PreD
Develop conceptual water balance as part of conceptual model development

- Outcrop water balance
- Boundary flows and spring flows will be an important part of conceptualization and implementation
- Water chemistry – flow paths
Stream-Aquifer Interaction
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Definition of a Model

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.
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 only means for integrating available data for the prediction of groundwater flow at the scale of interest.
A numerical groundwater flow model is the mathematical representation of an aquifer.

It uses basic laws of physics that govern groundwater flow.

In the model domain, the numerical model calculates the hydraulic head at discrete locations (determined by the grid).

The calculated model heads can be compared to hydraulic heads measured in wells.
Modeling Protocol

Define model objectives

Data compilation and analysis

Conceptual model

Model design

Calibration

Steady State*

Transient*

Verification

Prediction

Reporting

Future Water Strategies

Comparison with field data

*Includes sensitivity analysis

Field data

Future Water Strategies

Field data
Start with a conceptual model
Divide it up into cells

Irrigation
return flow

Spring

Dry spring

Enhanced recharge beneath agricultural area

Escarption spring

West
East
## Model Layering

<table>
<thead>
<tr>
<th>System</th>
<th>Culberson and Reeves Counties, TX</th>
<th>Pecos County, TX/Glass Mountains</th>
<th>Central Basin Platform</th>
<th>Model Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary/Tertiary</td>
<td>Pecos Alluvium</td>
<td>Alluvium</td>
<td>Alluvium</td>
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<tr>
<td></td>
<td></td>
<td>Volcanics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cretaceous</td>
<td></td>
<td>Edwards-Trinity</td>
<td>Edwards-Trinity</td>
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</tr>
<tr>
<td>Triassic</td>
<td>Dockum</td>
<td>Dockum</td>
<td>Dockum</td>
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</tr>
<tr>
<td>Permian</td>
<td>Dewey Lake</td>
<td>Dewey Lake</td>
<td>Dewey Lake</td>
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</tr>
<tr>
<td></td>
<td>Rustler</td>
<td>Rustler</td>
<td>Rustler</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forty-Niner</td>
<td>Upper Member</td>
<td>Upper Member</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Magenta Dolomite</td>
<td>Middle Member</td>
<td>Middle Member</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tamarisk</td>
<td>Lower Member</td>
<td>Lower Member</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culebra Dolomite</td>
<td>Tessey Limestone</td>
<td>Tessey Limestone</td>
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<tr>
<td></td>
<td>Lower Gypsum &amp; Mud</td>
<td></td>
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<tr>
<td></td>
<td>Siltstone</td>
<td></td>
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<tr>
<td></td>
<td>Salado</td>
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</tbody>
</table>

**Note:** The table represents different geological systems and their layers across various regions, with model layering indicated by shading and number.
GAM Model Specifications

- Three dimensional (MODFLOW-2000)
- Regional scale (1000’s of square miles)
- Grid spacing
  - Uniform grid – ¼ miles proposed
- Implement
  - recharge
  - groundwater/surface water interaction
  - pumping
- Calibration to observed water levels/fluxes
MODFLOW

- Code developed by the U.S. Geological Survey
- Selected by TWDB for all GAMs
- Handles the relevant processes
- Comprehensive documentation
- Public domain – non-proprietary
- Most widely used groundwater model
  - USGS had 12,261 downloads of MODFLOW computer code in 2000
- Supporting interface programs available
  - Groundwater Vistas to be used in all GAMs
Outline

- General Introduction to the GAM program
- Introduction to the Rustler GAM team
- Rustler regional overview
- Basics of groundwater flow
- Overview of Rustler Aquifer
- Numerical groundwater modeling and the GAMs
- Data collection
- GAM schedule
Data Collection

- Heads, Discharge & Water Quality Data
  - County Reports (predevelopment)
    - Evidence of artesian wells
    - Evidence of flowing springs
  - TWDB groundwater database
  - GCDs
  - Thesis work
  - Other literature
Data Collection

- Hydraulic Properties
  - County reports
  - Meyers
  - TCEQ Surface Casing Database
    - Typically specific capacity tests
  - GCD
  - Literature/Thesis
  - Stakeholders
Outline

- General Introduction to the GAM program
- Introduction to the Rustler GAM team
- Rustler regional overview
- Basics of groundwater flow
- Overview of Rustler Aquifer
- Numerical groundwater modeling and the GAMs
- Data collection
- GAM schedule
## Project Tasks and Proposed Schedule

<table>
<thead>
<tr>
<th>Project Task</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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<tbody>
<tr>
<td><strong>1.0 Project Management</strong></td>
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<td>1.1 Monthly Status Report</td>
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<tr>
<td>1.2 TWDB Review Meetings</td>
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<td>1.3 Senior Technical Review</td>
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<td><strong>2.0 Stakeholder Communication</strong></td>
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<tr>
<td>2.1 Stakeholder Interaction</td>
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<td>2.2 SAF Meeting</td>
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<tr>
<td>2.3 Stakeholder and TWDB Seminar</td>
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<tr>
<td><strong>3.0 Model Development</strong></td>
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<tr>
<td>3.1 Data Collection and Conceptual Model</td>
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<tr>
<td>3.2 Model Design</td>
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<td><strong>4.0 Model Calibration</strong></td>
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<td>4.1 Steady-State Calibration</td>
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<td>4.2 Transient Calibration</td>
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<tr>
<td>4.3 Sensitivity Analysis</td>
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<td><strong>5.0 Documentation &amp; Tech. Transfer</strong></td>
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<td>5.1 Data Model Documentation</td>
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<tr>
<td>5.2 Reporting</td>
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<table>
<thead>
<tr>
<th>Symbol</th>
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<tbody>
<tr>
<td>M</td>
<td>Monthly Report</td>
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<tr>
<td>CM</td>
<td>Conceptual Model Report</td>
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<tr>
<td>DM</td>
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<td>SAF Meeting</td>
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<td></td>
<td>TWDB &amp; Stakeholder Training</td>
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</tbody>
</table>
Data Request

Request:

- Any un-published data to support the model
  - Heads
  - Properties
  - Structural picks

- Date request by March 15, 2010
Thank You
Questions?

Van Kelley
512-425-2047
vkelley@intera.com
Meeting Minutes for the
First Rustler Groundwater Availability Model (GAM) Stakeholder Advisory Forum (SAF) Meeting
December 10th, 2009

Pecos County Courthouse, Ft. Stockton, Texas

The first Stakeholder Advisory Forum (SAF) Meeting for the Rustler Groundwater Availability Model (GAM) was held on Thursday, December 10th, 2009 at 9:00 AM at the Pecos County Courthouse located at 103 West Callaghan in Ft Stockton, 79735. A list of meeting participants is provided at the end of these meeting notes.

The primary purpose of the first SAF meeting is to provide an introduction to the Rustler GAM Team and the proposed approach to developing the model and to solicit input from stakeholders including any available data that could be made public. The meeting also provided a forum for discussing the project schedule and provided an opportunity for feedback from stakeholders.

Meeting Introduction: Wade Oliver, TWDB

The meeting was initiated by Mr. Wade Oliver of the Texas Water Development Board (TWDB). He gave a brief introduction to the GAM Program and discussed how GAMs are used in Texas water resources planning. He then discussed GAMs and how they relate to Managed Available Groundwater as well as the importance of the stakeholder process.

SAF Presentation: Van Kelley, INTERA Inc

Van Kelley (INTERA) presented a prepared presentation structured according to the following outline:

1. Introduction to the Rustler GAM Team
2. Rustler Regional Overview
4. Overview of the Rustler Aquifer
5. Numerical Groundwater Modeling and the GAMs
6. Data Collection/Data Needs
7. GAM Schedule

The presentation is available on the GAM website:

http://www.twdb.state.tx.us/GAM/rlsr/rlsr.htm
Questions and Answers: Wade Oliver (TWDB) Presentation:

Q: Does the TWDB publish any error bounds with their model predictions or are the GAMs always used purely deterministically?
A: Currently we do not calculate nor publish error bounds. This is a very difficult process given the model complexity. Ideally one would consider model error and how this translates to monitoring and the compliance with Desired Future Conditions.

Q: I ask the question because I have to wonder when mean error from portions of the Edwards-Trinity model is reduced from 256 ft to 80 ft. It seems there should be an error bound on the model predictions.
A: While your comment is true, complete and rigorous error analysis on these models is very involved and in the end the model error may be small in some cases relative to the assumptions in future resource use.

The following are a series of Stakeholder Comments in open discussion:

C: With the Cenozoic-Pecos Alluvium aquifer GAM a sensitivity analysis was run which gives one a good idea of the important parameters and which are unknown and those of those of us experienced in modeling already understand the uncertainties.

C: But the general public does not and they are the decision makers at the GMA.
A: Formal one-off sensitivity analyses are performed for all GAMs.

Questions and Answers: Van Kelley (INTERA) Presentation:

Q: Will your study extend into the regions of the Rustler which have TDS concentrations in excess of 5,000 ppm?
A: Yes, the study will go out past 5000 ppm to establish natural boundaries for the aquifer system. The TWDB defines the Rustler Aquifer to be that portion with TDS less than or equal to 5000 ppm.
## Attendance

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alyson McDonald</td>
<td>Texas AgriLife Extension</td>
</tr>
<tr>
<td>Gary Bryant</td>
<td>Texas AgriLife Extension</td>
</tr>
<tr>
<td>Paul Weatherby</td>
<td>General Mngr. - Middle Pecos GCD</td>
</tr>
<tr>
<td>Jim Duke</td>
<td>Representing: Williams Family</td>
</tr>
<tr>
<td>Wade Oliver</td>
<td>TWDB</td>
</tr>
<tr>
<td>Van Kelley</td>
<td>INTERA</td>
</tr>
</tbody>
</table>