NORTHERN SEGMENT OF THE EDWARDS AQUIFER GROUNDWATER AVAILABILITY MODEL

GAM Stakeholder Training Nov. 2003
OUTLINE

• Introduction to finite-difference modeling
• Introduction to PMWIN
• Overview of Northern Edwards aquifer model
• Hands-on modeling exercise
INTRODUCTION TO GROUNDWATER FLOW MODELING
WHAT IS AN AQUIFER?

- Rock or sediment from which usable amounts of water can be extracted
WHAT IS A GROUNDWATER FLOW MODEL?

- Mathematical representation of an aquifer
- Uses basic laws of physics that govern groundwater flow
- Calculates the hydraulic head at discrete locations (grid)
- Calculated model heads can be compared to hydraulic heads measured in wells
WHY ARE GROUNDWATER FLOW MODELS NEEDED?

- Groundwater flow is difficult to observe
- Aquifers are typically complex in terms of spatial extent and hydrogeological characteristics
- Means of integrating available data for prediction of groundwater flow
MODEL INPUT DATA

- Geology
  - Stratigraphy
  - Structure
- Water levels
- Surface water
  - Spring discharge
  - Stream discharge
- Aquifer properties
- Water use
MODELING SKILLS

- GIS
- Programming
- Geology
- Groundwater hydrology
MODELING PROCESS

- Define model objectives
- Develop conceptual model
- Design model
- Calibration and verification modeling
  - Comparison with observed data
- Predictive modeling
  - Predict impacts of projected growth
    - 2000 - 2050
MODEL LIMITATIONS

• Approximation of the real system
  – Regional scale
• Uncertainty in the input data
  – Grid resolution
  – Incomplete data
Hydraulic head calculated by balancing water inflows and outflows

MODEL CELL

Aquifer properties:
- Hydraulic conductivity
- Storativity
- Aquifer thickness

Groundwater flow between cells

Recharge

Pumpage

Evapotranspiration

Springflow
Darcy’s Law

Hydraulic Gradient \( I = \frac{(h_1 - h_2)}{L} \)

\[
Q = KIA
\]

\[
Pore Water Velocity \quad v = \frac{KI}{porosity}
\]
Main Equations of Flow

\[ Q_{in} + Q_{out} = 0; \quad Q_{in} + Q_{out} = \text{Change in storage} \]

\[
\frac{\partial}{\partial x} \left( K_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial h}{\partial z} \right) = 0
\]

Steady-state modeling

\[
\frac{\partial}{\partial x} \left( K_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial h}{\partial z} \right) = S_s \frac{\partial h}{\partial t}
\]

Transient modeling
INTRODUCTION TO PMWIN
PROCESSING MODFLOW

- **PMWIN**
  - Pre/Post-processor (data entry/evaluation)
- **MODFLOW**
  - Modular 3-D groundwater flow model
- **MOC3D** - Solute-transport model
- **MT3D** - Solute-transport model
- **MT3DMS** - Solute-transport model
- **PEST** - Inverse model
- **UCODE** - Inverse model
- **PMPATH** - Advective transport model
PMWIN

- Grid
  - Grid size
  - Layer type - Unconfined or Confined/Unconfined
  - Boundary conditions - Active/Inactive cells
  - Top of layer
  - Base of layer
PMWIN (cont.)

- **Parameters**
  - Time units
  - Initial hydraulic heads
  - Boreholes/observations
  - Horizontal hydraulic conductivity
  - Vertical hydraulic conductivity
  - Specific storage
  - Transmissivity
  - Vertical leakance
  - Storage coefficient
  - Effective porosity
  - Specific yield
• Features
  – Density
  – Drains
  – Evapotranspiration
  – General-head boundary
  – Horizontal-flow barrier
  – Interbed storage
  – Recharge
  – Reservoir
• **Features**
  - River
  - Streamflow routing
  - Time-variant specified head
  - Well
  - Wetting capability
  - Output control
  - Solvers
  - Run
PMWIN (cont.)

• Post-processing tools
  – Presentation
    • View model output data
  – Water budget
  – Graphs
    • Head-time
    • Drawdown-time
    • Compaction-time ...
MODFLOW

• Modules
  – Basic Package
  – Block-Centered Flow Package
  – Density Package
  – Direct Solution Package (Solver)
  – Drain Package
  – Evapotranspiration Package
  – General-Head Boundary Package
  – Horizontal-Flow barrier Package
  – Interbed-Storage Package
  – Output Control
• Modules
  – Preconditioned Conjugate Gradient 2 Package
  – River Package
  – Recharge Package
  – Reservoir Package
  – Strongly Implicit Procedure Package (solver)
  – Slice-Successive Overrelaxation Package (solver)
  – Stream-Routing Flow Package
  – Time-Variant Specified-Head
  – Well Package
NORTHERN EDWARDS AQUIFER MODEL
STUDY AREA
SEASONAL PRECIPITATION

The graph shows the median monthly precipitation (in.) for different locations:
- Red line: AUSTIN MUNICIPAL AP
- Green line: JARRELL
- Blue line: TAYLOR
- Orange line: TEMPLE

The graph data is displayed from January (JAN) to December (DEC).
HISTORIC PRECIPITATION
EVAPORATION
HYDROGEOLOGY
<table>
<thead>
<tr>
<th>Series</th>
<th>Group</th>
<th>Stratigraphic Unit</th>
<th>Hydrologic Unit</th>
<th>Maximum Thickness (feet)</th>
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<tr>
<td>Gulf</td>
<td>Navarro</td>
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<td>Navarro and Taylor Group</td>
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<td></td>
<td>Taylor</td>
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<td></td>
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<td>Austin Chalk</td>
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<td>Washita</td>
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<td>Buda Limestone</td>
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<td>Del Rio Clay</td>
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<td></td>
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<td>Georgetown Formation</td>
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<td>Edwards Limestone</td>
<td>Edwards and associated limestones</td>
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<td>Walnut Formation</td>
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<td>Paluxy Formation</td>
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<td>Glen Rose</td>
<td>Upper Member</td>
<td>Upper Trinity</td>
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<td>Lower Member</td>
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<td>Travis Peak</td>
<td>Hensell Sand Member</td>
<td>Middle Trinity</td>
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<td>Cow Cr. Limestone Member</td>
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<td>Hammett Shale Member</td>
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<td>Sligo Member</td>
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<td>Hosston Member</td>
<td></td>
<td>850</td>
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HYDROSTRATIGRAPHY
SURFACE GEOLOGY
GEOLOGIC CROSS SECTIONS
HISTORIC PUMPAGE: TOTAL

- Rural Domestic (47%)
- Municipal (44%)
- Irrigation (6%)
- Manufacturing/Mining (8%)
- Livestock (1%)

HISTORIC PUMPAGE
RANGELAND
MODEL
DRAINS
(STREAMS)
MODEL RESULTS:
STEADY-STATE MODEL
MEASURED vs. SIMULATED WATER LEVELS
MEASURED vs. SIMULATED WATER LEVELS

RMSE = 32 ft
MEASURED vs. SIMULATED STREAM DISCHARGE
SENSITIVITY ANALYSIS: STEADY-STATE
MODEL RESULTS:
TRANSIENT MODEL
MEASURED vs. SIMULATED WATER LEVELS
MEASURED vs. SIMULATED WATER LEVELS
MEASURED vs. SIMULATED STREAM DISCHARGE
SENSITIVITY ANALYSIS: SPECIFIC STORAGE

Run 2: \( S_s = 0.0000050 \quad S_y = 0.0050 \)
Run 3: \( S_s = 0.0000100 \quad S_y = 0.0050 \)
Run 4: \( S_s = 0.0000025 \quad S_y = 0.0050 \)
SENSITIVITY ANALYSIS: SPECIFIC STORAGE
SENSITIVITY ANALYSIS: SPECIFIC YIELD

Run 2: $S_S = 0.00000050$  $S_Y = 0.0050$
Run 6: $S_S = 0.00000050$  $S_Y = 0.0500$
Run 8: $S_S = 0.00000050$  $S_Y = 0.0005$
SENSITIVITY ANALYSIS: SPECIFIC YIELD
MODEL RESULTS
PREDICTIVE MODEL
TOTAL PUMPAGE
WATER-LEVEL CHANGES:
DROUGHT RECHARGE
CONCLUSIONS

• Tool to evaluate groundwater resource management strategies
• Based on available geologic and hydrologic data
• Steady-state and transient runs
  – Average recharge of 20% annual precipitation
  – Approximately 50-70% of groundwater flow in unconfined part of aquifer
  – Groundwater extraction less than 20% of discharge
• Predictive model runs (2000-2050)
  – Average recharge conditions
    • Water-level rise throughout most of model area
  – Drought-of-record conditions
    • Water-level declines in unconfined part of aquifer
    • Water-level rise associated with lower pumping rates