FIGURE 1.6 The hydrologic cycle.
Cyclic salts and Weathering

Riparian Transpiration

Agricultural Evapotranspiration

Open Water Evaporation

Waste water

Consumptive use

Geothermal waters

Saline Groundwaters

Water & Salt Inputs/ Outputs

Courtesy F. Phillips and S. Mills
Conceptual Model of Water Dynamics

- Well pumping
- Irrigation
- Precipitation
- Transpiration
- Evaporation
- Drain
- LFCC (Loss of Freshwater Catchment)
- Rio Grande
- River flow
- Groundwater recharge and discharge
Numbers on map correspond to river names below.

Rivers shown are those whose average flow at the mouth is 17,000 cu ft/sec or more. Average flow of Yukon River, Alaska (not shown) is 240,000 cu ft/sec.

1 Columbia  8 Arkansas  15 Ohio  22 St. Lawrence
2 Willamette  9 White  16 Cumberland  23 Hudson
3 Pend Oreille  10 Red  17 Tennessee  24 Allegheny
4 Snake  11 Atchafalaya  18 Alabama
5 Sacramento  12 Mississippi  19 Tombigbee
6 Colorado  13 Illinois  20 Apalachicola
7 Missouri  14 Wabash  21 Mobile

FIGURE 1.7 Relative size and location of the largest rivers in the U.S.
FIGURE 1.8 Water use in the U.S.
Demands On Water Resources

AVERAGE CONSUMPTIVE USE FROM SAN ACACIA TO SAN MARCIAL

- 52% Groundwater Outflow
- 27% Riparian ET
- 12% Crop ET
- 8% Open Water Evap
- 1% M&I Depletion
<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Precise</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 1.11** Illustration of the difference between accuracy
FIGURE 1.13 Histogram of annual peak discharges for Example 1.3. Discharges are grouped by 1000-ft³/sec increments.
TABLE 1.12
Mean Trout Size vs. Mean Pool Depth Data for Example 1.4

<table>
<thead>
<tr>
<th>Mean Pool Depth (meters)</th>
<th>Mean Trout Size (g)</th>
<th>Calculated Size (g)</th>
<th>Residual (measured minus estimated grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>121</td>
<td>107.0</td>
<td>14.0</td>
</tr>
<tr>
<td>0.5</td>
<td>110</td>
<td>134.4</td>
<td>-24.4</td>
</tr>
<tr>
<td>0.6</td>
<td>152</td>
<td>161.8</td>
<td>-9.8</td>
</tr>
<tr>
<td>0.7</td>
<td>213</td>
<td>189.1</td>
<td>23.9</td>
</tr>
<tr>
<td>0.9</td>
<td>219</td>
<td>243.8</td>
<td>-24.8</td>
</tr>
<tr>
<td>1</td>
<td>302</td>
<td>271.2</td>
<td>30.8</td>
</tr>
<tr>
<td>1.1</td>
<td>281</td>
<td>298.6</td>
<td>-17.6</td>
</tr>
<tr>
<td>1.2</td>
<td>347</td>
<td>325.9</td>
<td>21.1</td>
</tr>
<tr>
<td>1.4</td>
<td>367</td>
<td>380.6</td>
<td>-13.6</td>
</tr>
</tbody>
</table>

FIGURE 1.14 Regression equation and plot of mean trout size vs. mean pool depth.
Area of Interest for High-Resolution Modeling

Telescopic model - smaller domain - refined grid - constant head from regional model
Key Data Collected

Geologic Data
• Stratigraphy (color, grain size, hydraulic conductivity)

Aquifer Data
• Hydraulic conductivities (aquifer testing)
• Water-elevation time series

Surface-Water Data
• Locations and elevations of river, canals, and drains
• Surface-water stage time series
Stratigraphy

Legend

- No Sample
- Clay, Sandy Clay
- Silt, Silt & Fine Sand
- Fine Sand
- Fine to Medium Sand, Medium Sand
- Fine to Coarse Sand, Coarse Sand
- Sand and Gravel, Gravel
- Clayey Gravel
- Santa Fe Group Bedrock
- Water Surface

Layer 1
Layer 2
Layer 3

Santa Fe Formation

Valley alluvium

HWY-W02
HWY-W03
HWY-W04
HWY-W07
HWY-W06
HWY-E01
HWY-E02
HWY-E03

Rio Grande

East

West
Aquifer Testing
Aquifer Test Instrumentation
0.5 miles north of Highway 380 in San Antonio

Legend
- Red: Well 0-20 feet
- Green: Well 40-50 feet
- Purple: Well 80-90 feet
- Yellow: Staff gage
- Black Star: Extraction well

Low-permeability zone
Time-drawdown of nested well W07A,B,C

Legend
- Well 0-20 feet
- Well 40-50 feet
- Well 80-90 feet

Drawdown (ft)

Elapsed Time (min)
Model Grid

Domain is 320 rows x 170 columns = 54400 grid cells
OR 6 miles x 3 miles = 18 miles²

Telescopic model grid is 100 feet x 100 feet

Regional model grid is 1000 feet x 1000 feet
Three-Layer Model

Layer 1 - sand
Layer 2 - clay/silt
Layer 3 - sand/gravel
Surface Water System

- Designation of grid cells to represent drains, LFCC, and river.

- Each cell has values for:
  - stage
  - conductance
  - bottom elevation
  - bed thickness
  - vertical hydraulic conductivity
Riverbed Conductance = \( \frac{K_{LW}}{M} \)

MODFLOW River Package:
- Riv1  (MODFLOW 83)
Estimation of River Stage

Gage reading at San Marcial
Stage height input for model

Stage (feet)

Oct Dec Jan Mar May Jul Sep Nov Jan Mar May Jul
Evapotranspiration

IKONOS – July 2000

Legend
- **Green**: Crop and pasture
- **Red**: Riparian
- **Yellow**: Sandbars
- **Other or inactive**

Image showing a map with the above legend.
Prescribed Head

- **Constant head boundary determined from regional model for every stress period**

**Diagram**

- **Regional model**
- **Telescopic model**

[Diagram showing the regional model and the telescopic model with the constant head boundary.]
Model Calibration

Groundwater Budget

<table>
<thead>
<tr>
<th></th>
<th>af/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td></td>
</tr>
<tr>
<td>River seepage</td>
<td>34,037</td>
</tr>
<tr>
<td>Net boundary influx</td>
<td>6,052</td>
</tr>
<tr>
<td>TOTAL IN</td>
<td>40,089</td>
</tr>
<tr>
<td>OUT</td>
<td></td>
</tr>
<tr>
<td>LFCC seepage</td>
<td>31,930</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>8,191</td>
</tr>
<tr>
<td>TOTAL OUT</td>
<td>40,121</td>
</tr>
<tr>
<td>IN - OUT</td>
<td>-33</td>
</tr>
</tbody>
</table>

Screen Depth
- 10 - 25 ft
- 40 - 70 ft

$R^2 = 0.97$

$RMS = 5.22$ ft