Water-Use Modeling and Water Availability

Mid-Atlantic Area
Water Availability Workshop

Susan Hutson
U.S. Geological Survey
June 7-8, 2005

USGS

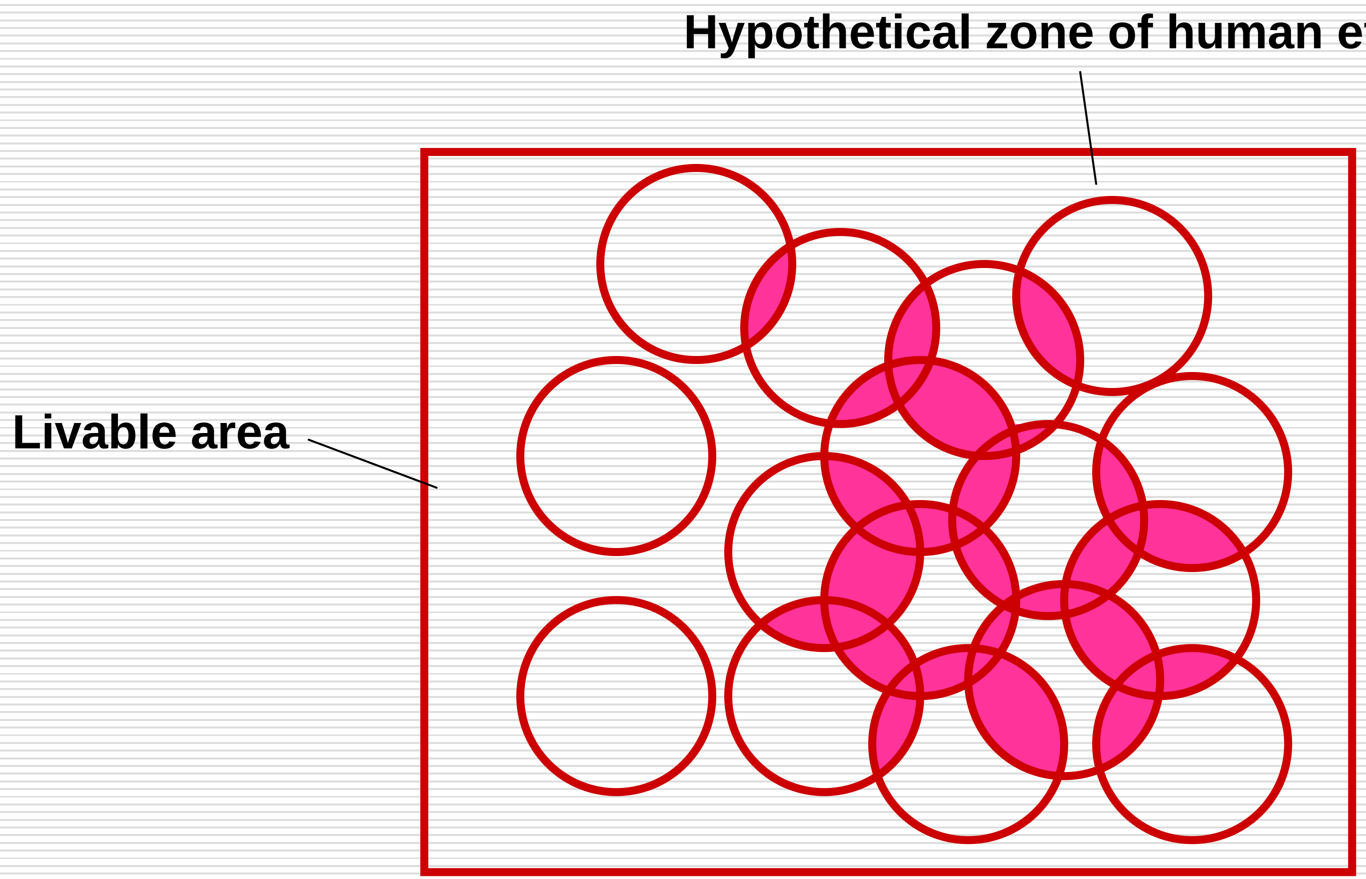
Water availability—
another definition

- Water availability and use are a function of the total flow of water through a basin, its quality, and the structures, laws, regulations, and economic factors that control its use.

Water use—
another definition

Water Use $\int$ water availability, demographic, cultural, and economic factors, and laws and regulations

Water Issues Increase out of Proportion to Growth



Purpose of presentation

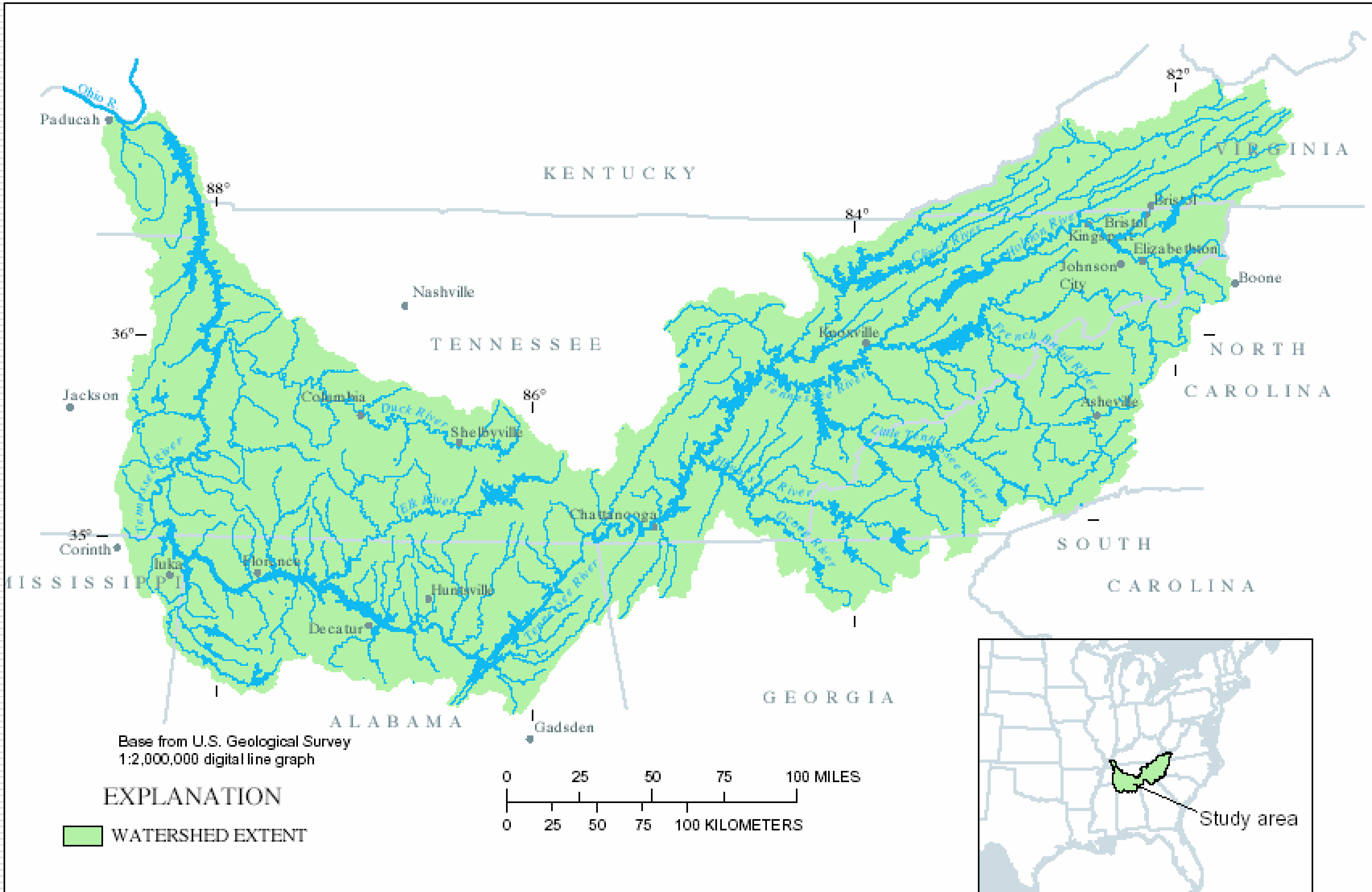
- How water-use models and hydrologic models have been used *in combination* to evaluate the impact of changing water demand on water availability.
- 3 case studies

USGS

Water availability and use

- Tennessee River watershed, 7-state region
  - Spatial accounting model--WU
  - Reservoir optimization model—pool management
- Duck River watershed, Tennessee
  - IWR-MAIN water-demand analysis software
  - Surface-water hydrologic model, OASIS
- Eutaw-McShan and Coffee Sands aquifers, Union County Mississippi
  - IWR-MAIN water-demand analysis software
  - MODFLOW ground-water finite-difference model

Tennessee River watershed—TVA reservoir operations study



Each reservoir has individual water demand needs

- Instream uses
  - Aesthetics
  - Navigation
  - Flood Control
  - Interbasin transfers
  - Water quality & waste assimilation

USGS

Reservoir optimization model—optimizing a water use choice

- Offstream uses
  - Public water supply
  - Cooling water for power & industry
  - Irrigation and livestock

USGS

New reservoir operations policy

Tennessee River watershed

- Within the “flood guide level” adjust summer pool and summer pool season to meet summertime recreational needs and downstream requirements

Consumptive use
Cumulative consumptive use
2000 to 2030

- Water that is withdrawn that is not immediately available for use within the watershed

- CU = water withdrawal – return flow
- CU = net water demand

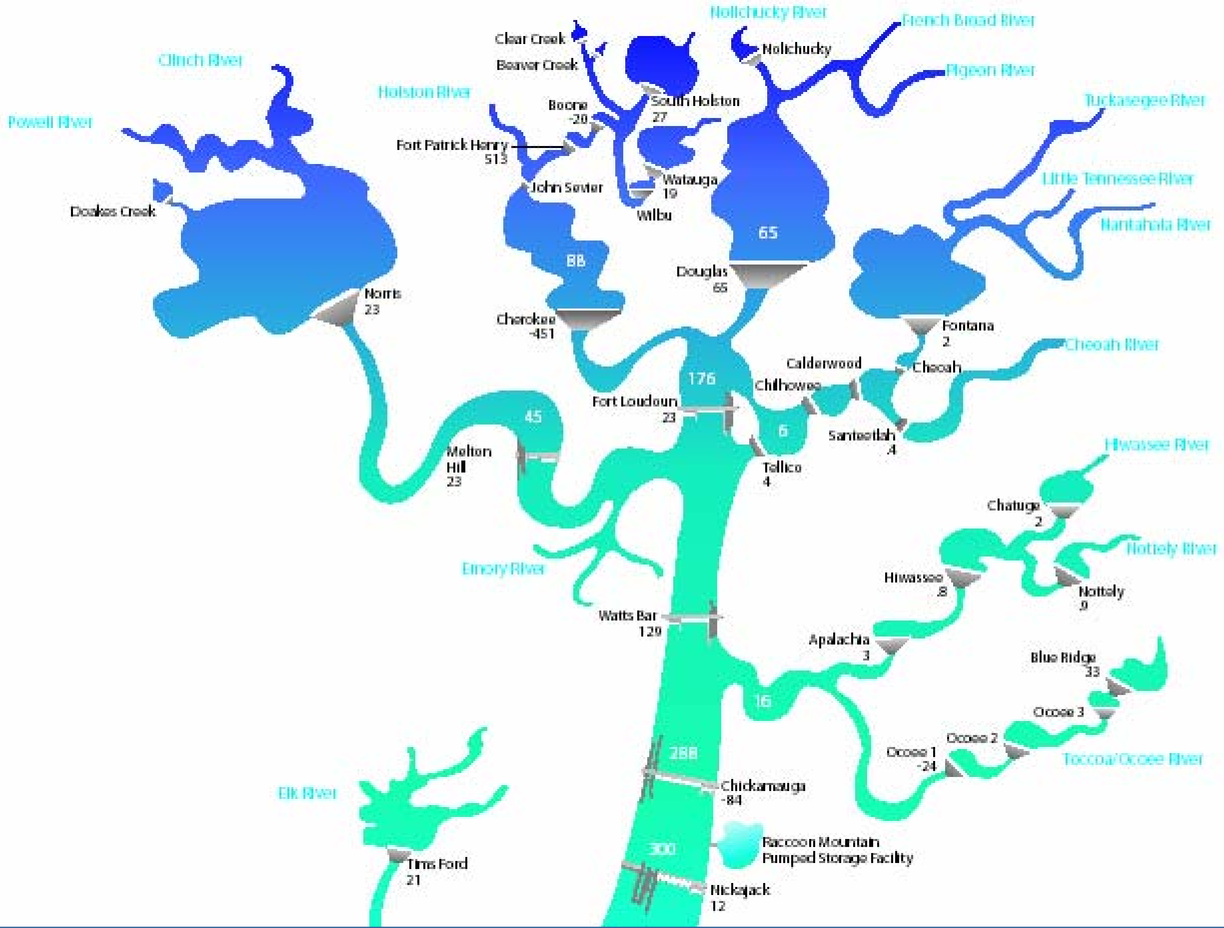
Spatial accounting model Reservoir Catchment Area

- RCAs
  - Spatial accounting unit
  - Net water demand determined for each RCA
  - Natural area truncated by a dam
  - Accounts for precipitation, runoff, evapotranspiration, shallow and deep infiltration & discharge from soil, and subsurface storage

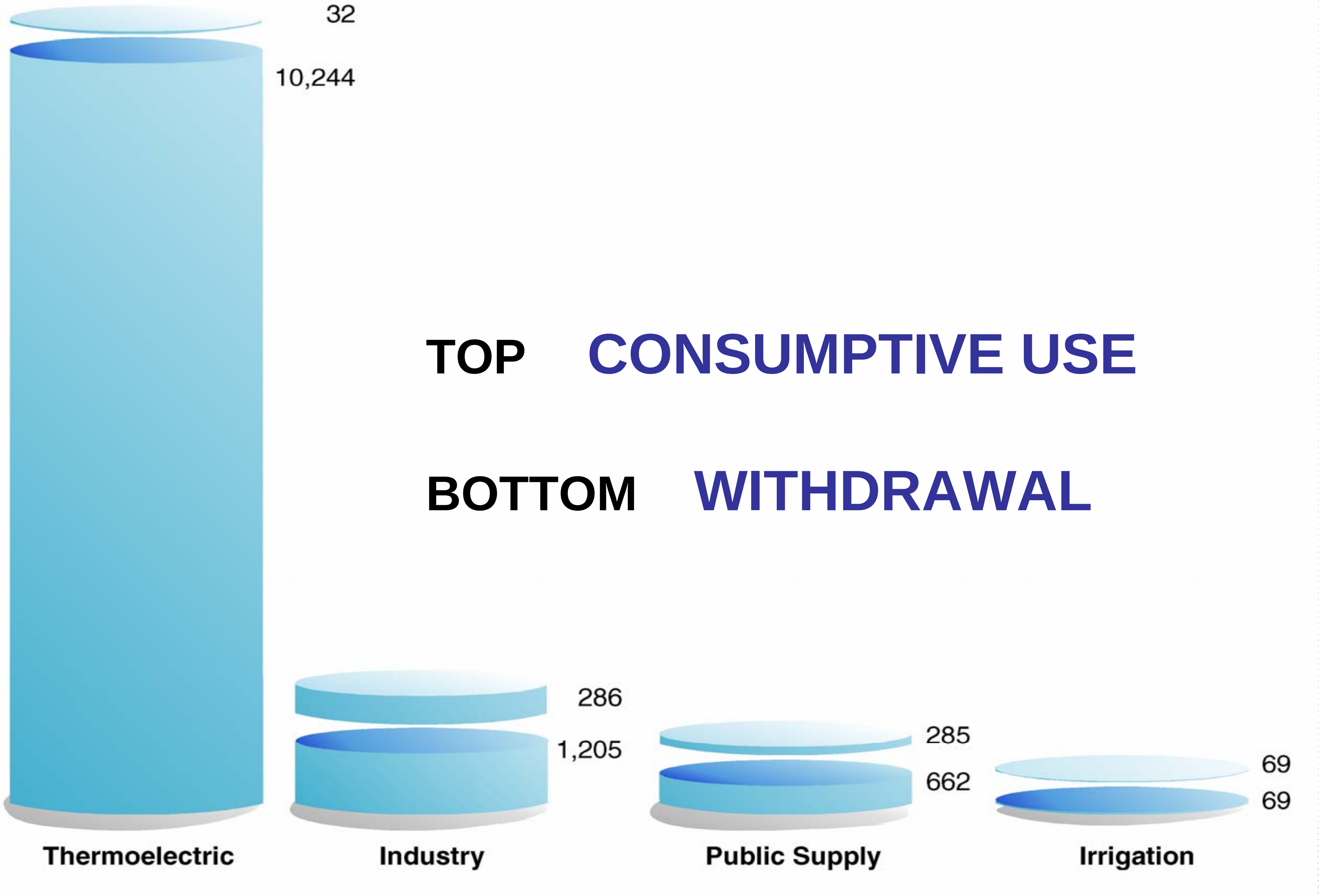
Spatial accounting units
Water Use Tabulation Area

- WUTA
  - RCAs aggregated to WUTA
  - Functional--dynamic area
  - Accounts for complete WU transaction from a water-use site
    - Water withdrawal
    - Return flow

Upstream reservoirs in the Tennessee River watershed



Withdrawal & Consumptive Use

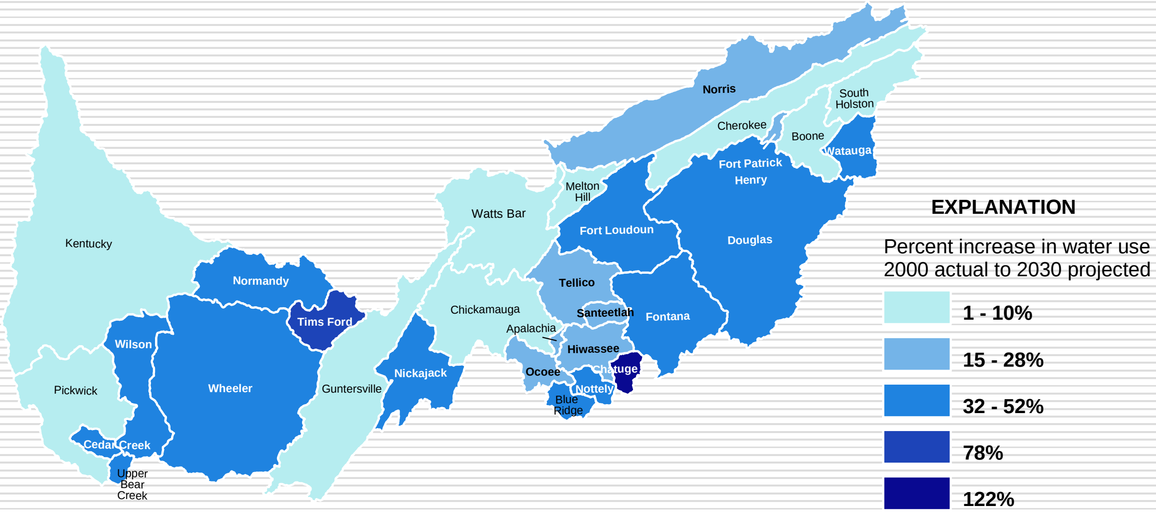


Projecting water demand to 2030

- Base year 2000
- Applied a constant growth rate factor developed by Woods & Poole for population, industry, and farm production
- TVA plans for power production

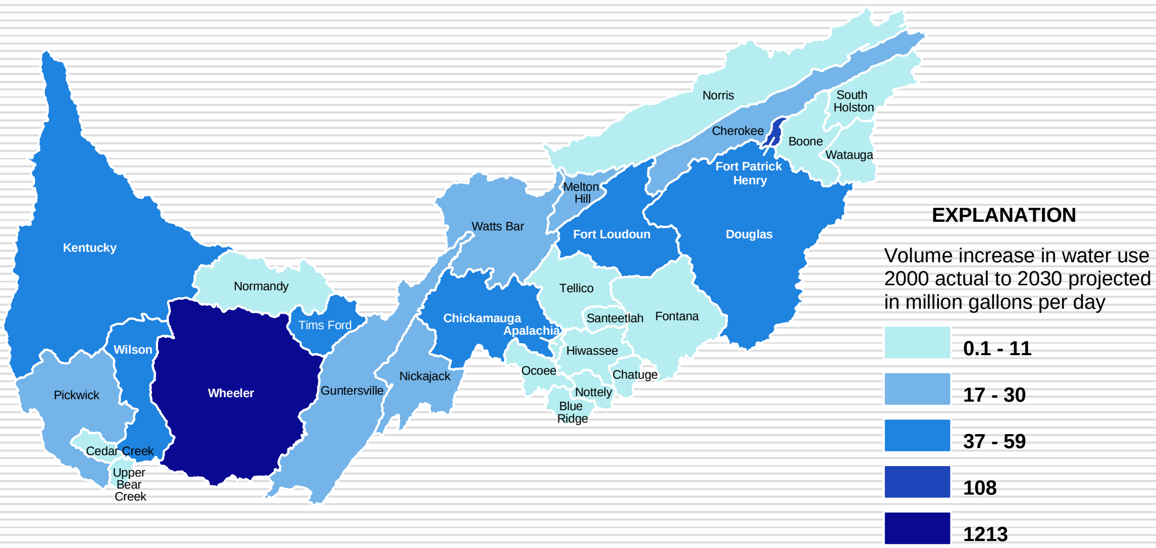
Percent increase

Chatuge



Volume increase

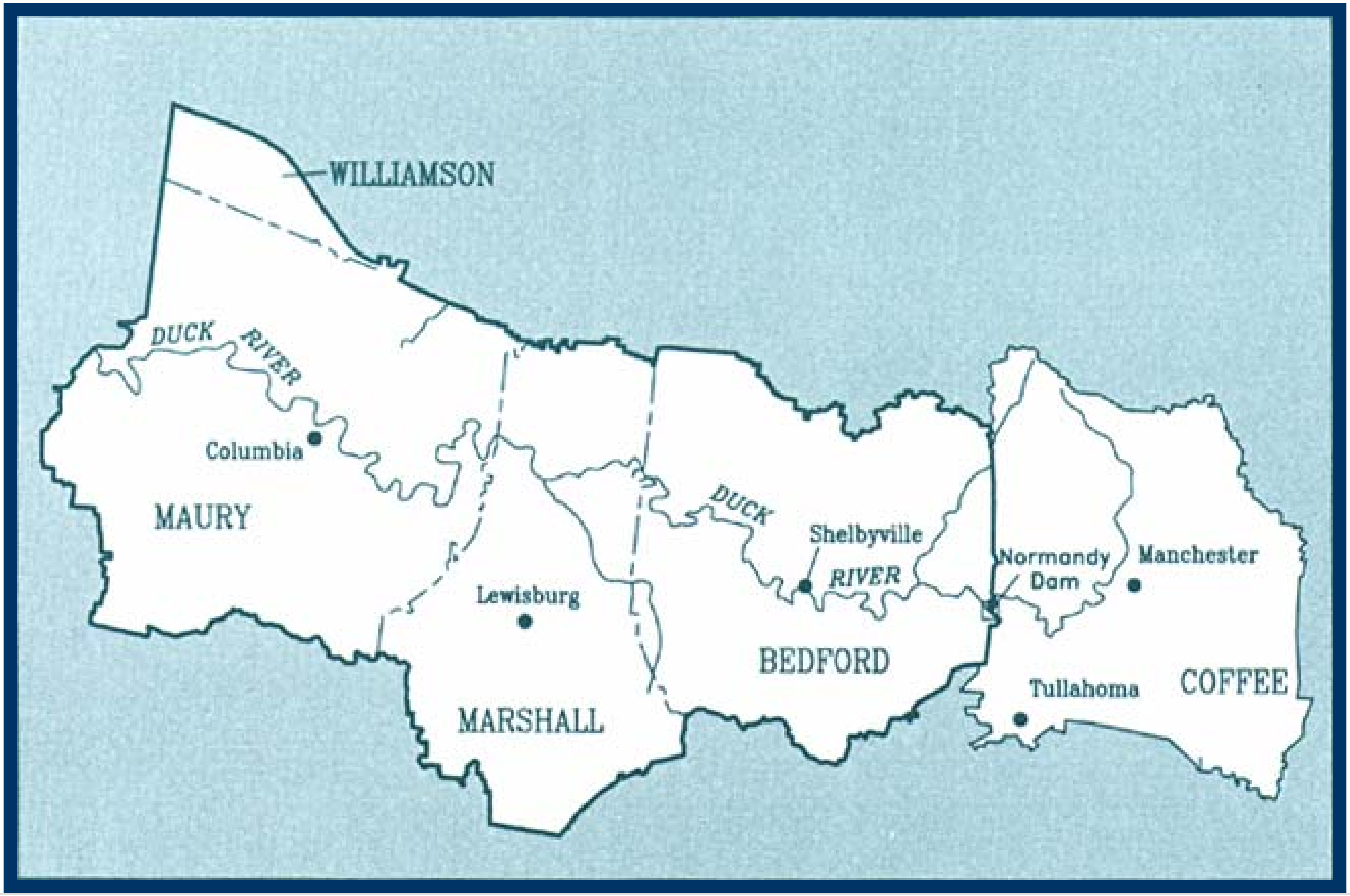
Wheeler



Cumulative Consumptive Use

WUTA	2000	2030	% change
Fort Loudoun	176	242	**38**
Watts Barr-Chickamauga	288	414	**44**
Nickajack	300	469	**56**
Guntersville	317	469	**48**
Wheeler-Wilson	533	806	**51**
Pickwick	563	863	**62**
Kentucky	649	983	**51**

upper Duck River, Tennessee River watershed



USGS

Water-supply alternatives
upper Duck River watershed

- Raise the height of Normandy Dam
- Develop Fountain Creek reservoir
- Build water intake downstream of Columbia
- Build pipeline to Tims Ford reservoir

IWR-MAIN water-demand analysis software *Institute* of Water Resources—Municipal and Industrial Needs

- **Billing accounts**
  - **Residential**
  - **commercial**
  - **industrial**
  - **other**

- **Housing & employee types**
- **Housing & employee counts**
- **Median household income**
- **Marginal price**
- **Water conservation practices**
- **Long-term precip & temp**

Residential Water Demand
Per-household water use/d

1. **Regression model**
   - **X variables**
     - **Monthly Temperature**
     - **Monthly Precipitation**
     - **Median income**
     - **Price of water**
   - **Y value**
     - **Monthly residential water use**

Approach
Residential regression equation

- $q = a + bt + cp + dm + ei$

- q = rate of daily use per single family household
- a = inelastic demand
- b,c,d, and e are linear coefficients of elasticity for temperature, precipitation, marginal price, and median income

Surface-water hydrologic model, OASIS

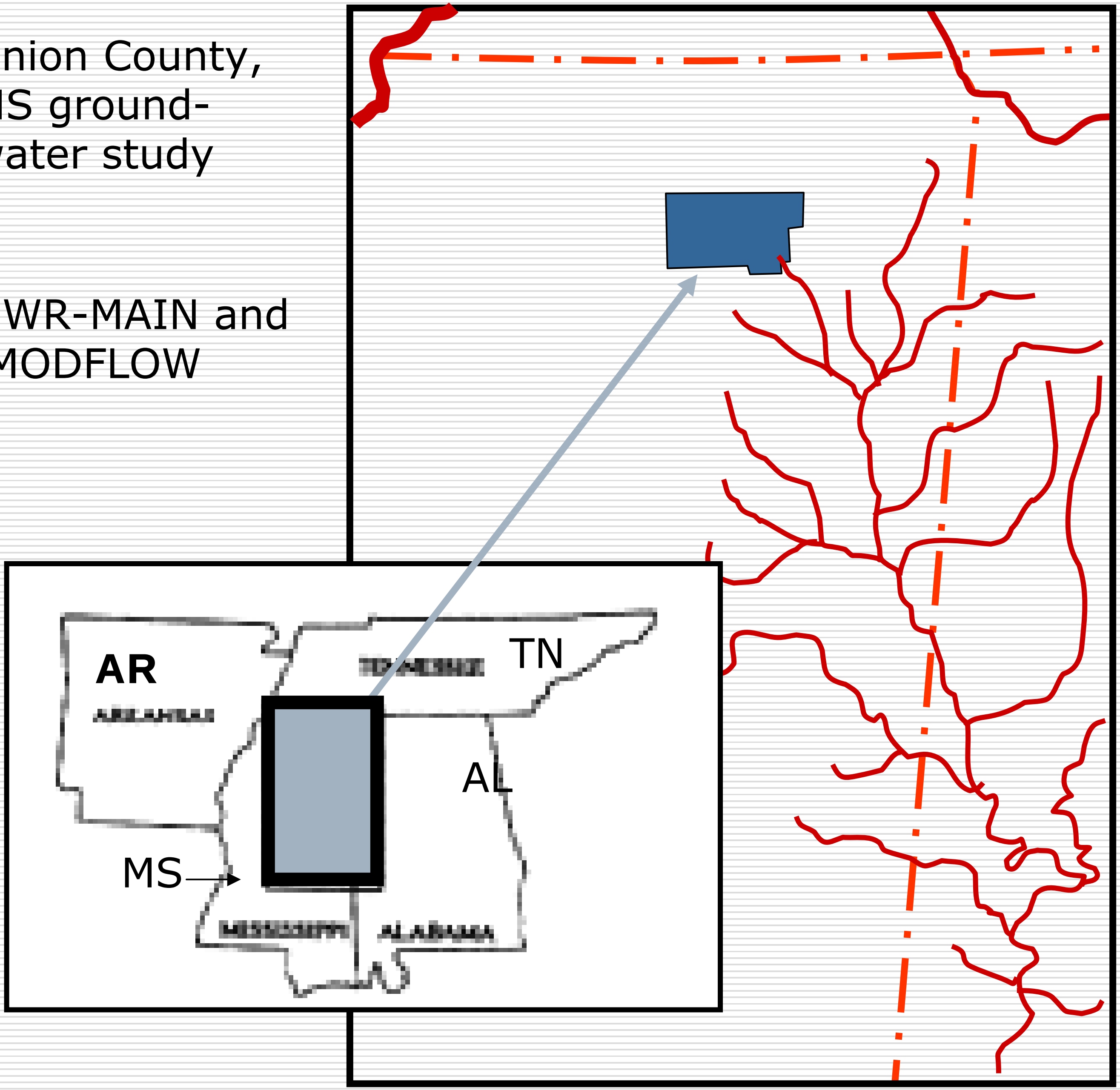
- Changes in withdrawals and return flows (demand projections)
- Long-term record
- Timing of the peaks
- Lowest years on record
- Storage within the system
- Worked in the reservoir storage

Result
upper Duck River watershed

Intervening recharge between the 2 dam sites was sufficient to augment releases and meet downstream water needs to 2050

Union County, MS ground-water study

IWR-MAIN and MODFLOW



Simulate changes in ground-water levels

- Major water-supply aquifers
  - Eutaw-McShan
  - Coffee Sands
- Water demand model
  - Multivariate approach
  - IWR-MAIN water-demand management suite
- GW model
  - MODFLOW finite-difference

Water-Supply Alternatives

- Drill more ground-water wells
- Purchase water from a regional supplier
  - NE Mississippi Regional WSD
  - Tri-County Regional Water Supply District
- Construct reservoir on Cane Creek

Water Use
Base Year 1998

- Total Q 2.85 Mgal/d
  - 90% public supply
    - *59% residential*

USGS

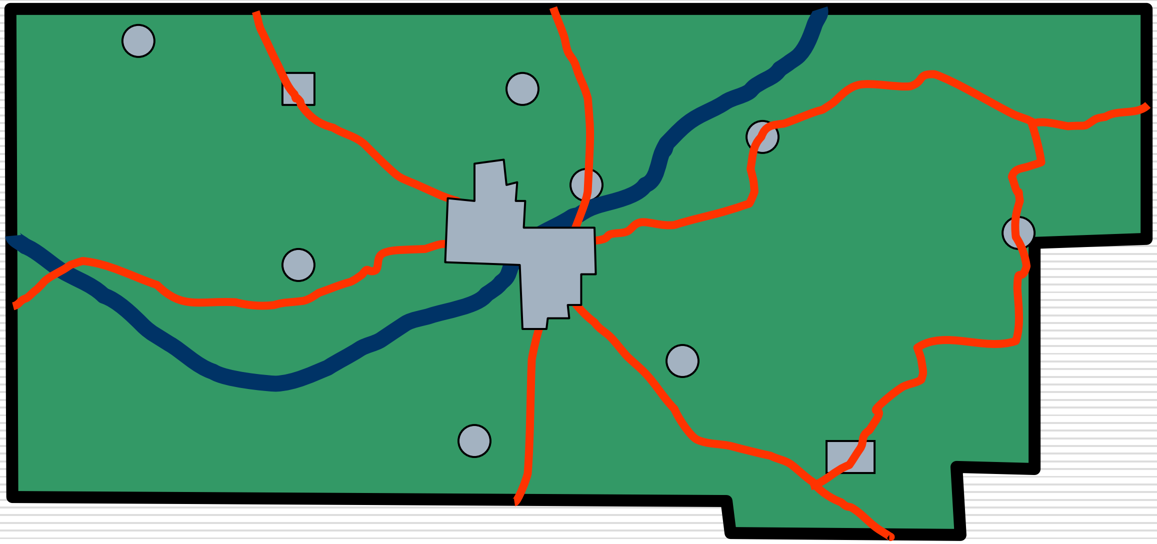
Ground-Water Assessment

Water Demand

- Years
  - 2010, ‘20, ‘30, ‘40, ‘50
- Scenarios
  - Normal-economic growth
  - High-economic growth

IWR-MAIN

USGS



Union County, Mississippi

Ground-Water Assessment

Water demand output

IWR-MAIN

PS 21 wells
Normal 1.18

High 1.77

→

Ground water input

MODFLOW

25 pumpage points

Ground-Water Model

- MODFLOW--calibrated
  - 34,960 SQ. MI.
  - 209,760 GRID CELLS
    - 230 ROWS
    - 152 COLUMNS
  - 6 LAYERS
  - HEAD-DEPENDENT FLUX BOUNDARIES
  - Annual rate of 1.03

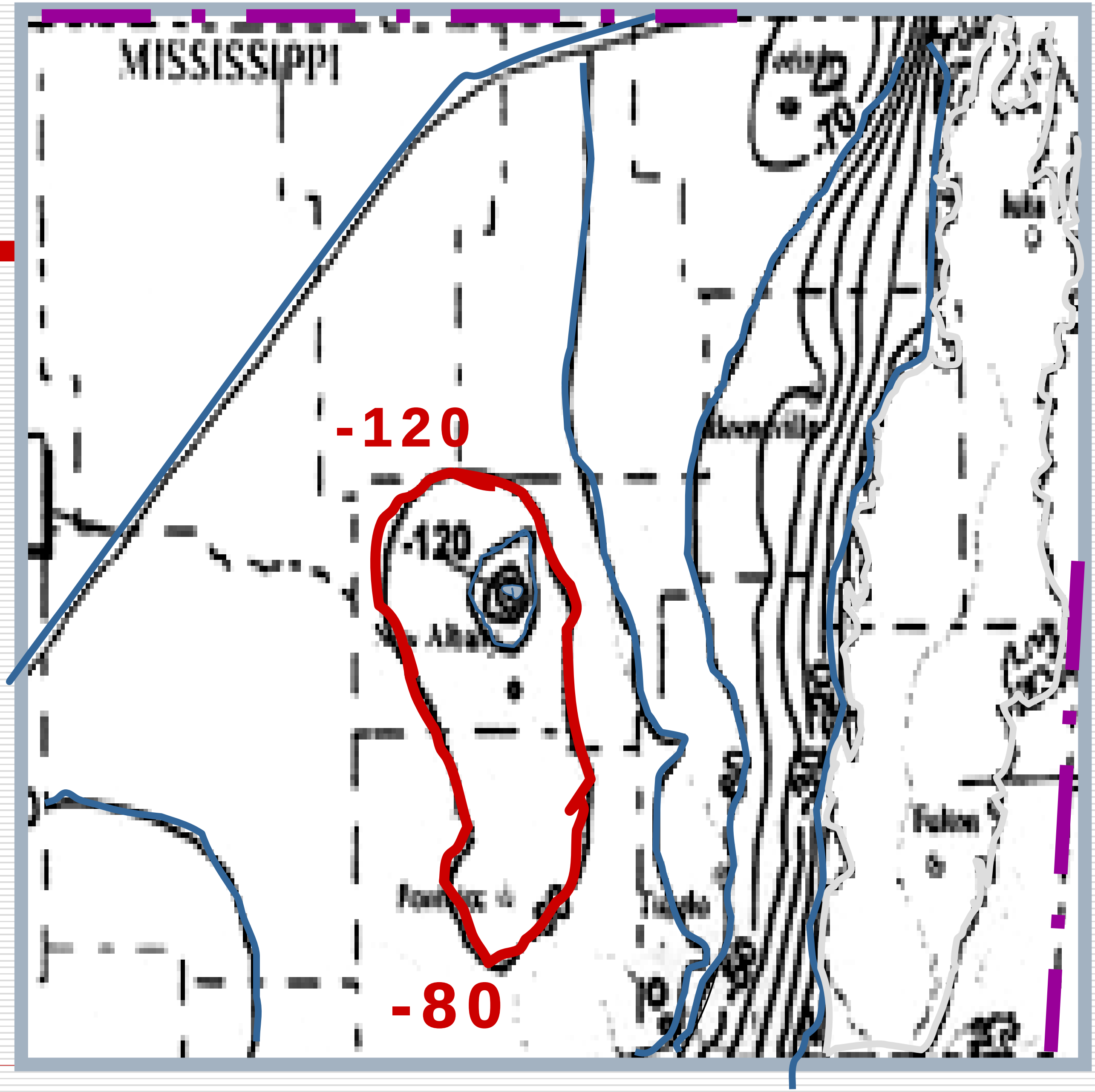
USGS

Coffee Sand

Coffee Sand

- Baseline and normal growth
  - 65 feet below 2000 levels at New Albany
- High growth
  - 75 feet below 2000 levels at New Albany

Eutaw-McShan



USGS

Eutaw-McShan

- Baseline —120 feet
- Normal growth —135 feet
- High growth —190 feet

Summary

- **Combining the water-demand models with the appropriate surface or ground-water models provide a systematic approach for analyzing water availability and water-supply alternatives**