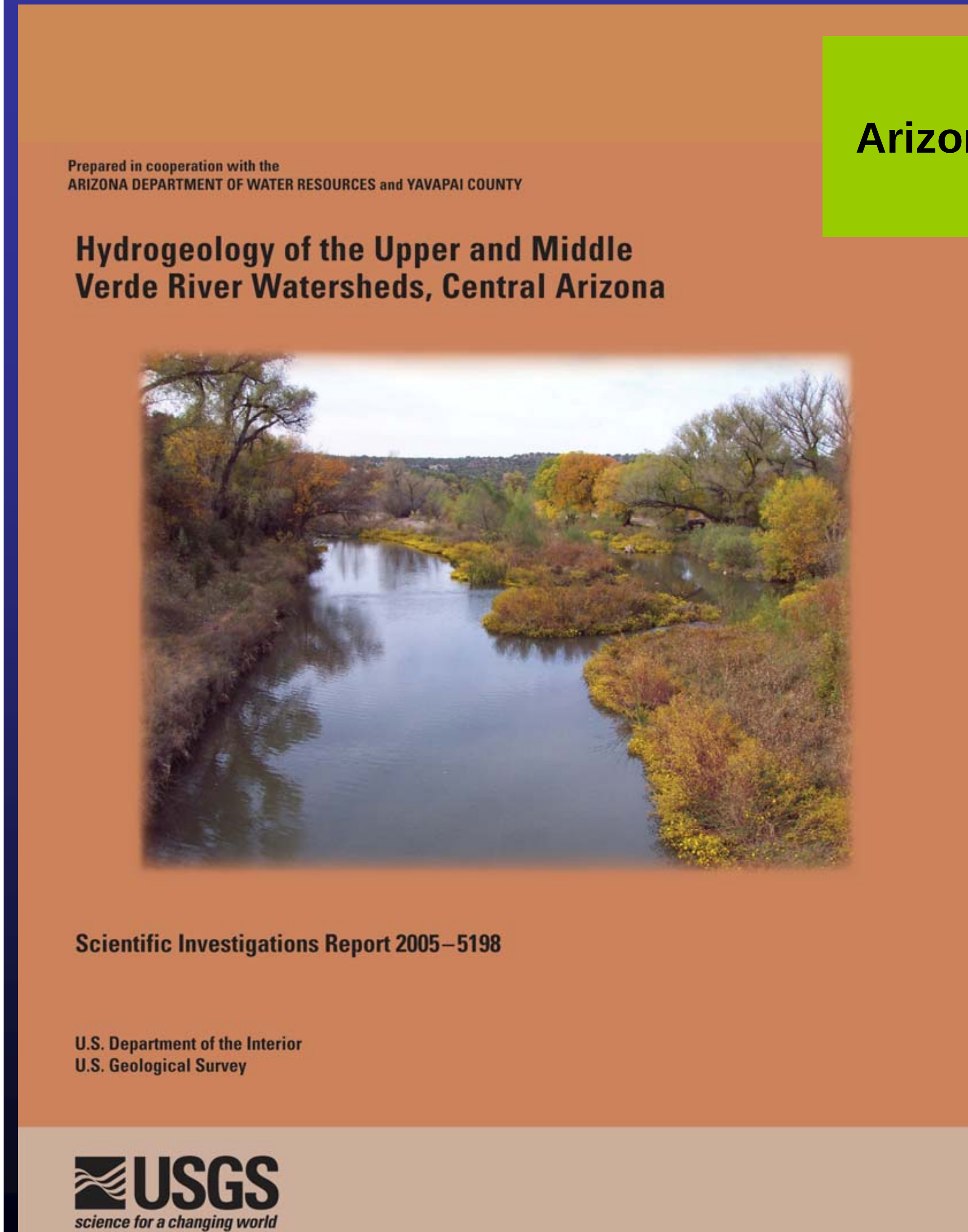
Prepared in cooperation with the
ARIZONA DEPARTMENT OF WATER RESOURCES and YAVAPAI COUNTY

Hydrogeology of the Upper and Middle Verde River Watersheds, Central Arizona

Scientific Investigations Report 2005–5198

U.S. Department of the Interior
U.S. Geological Survey

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Arizona Department of Water Resources
Yavapai County

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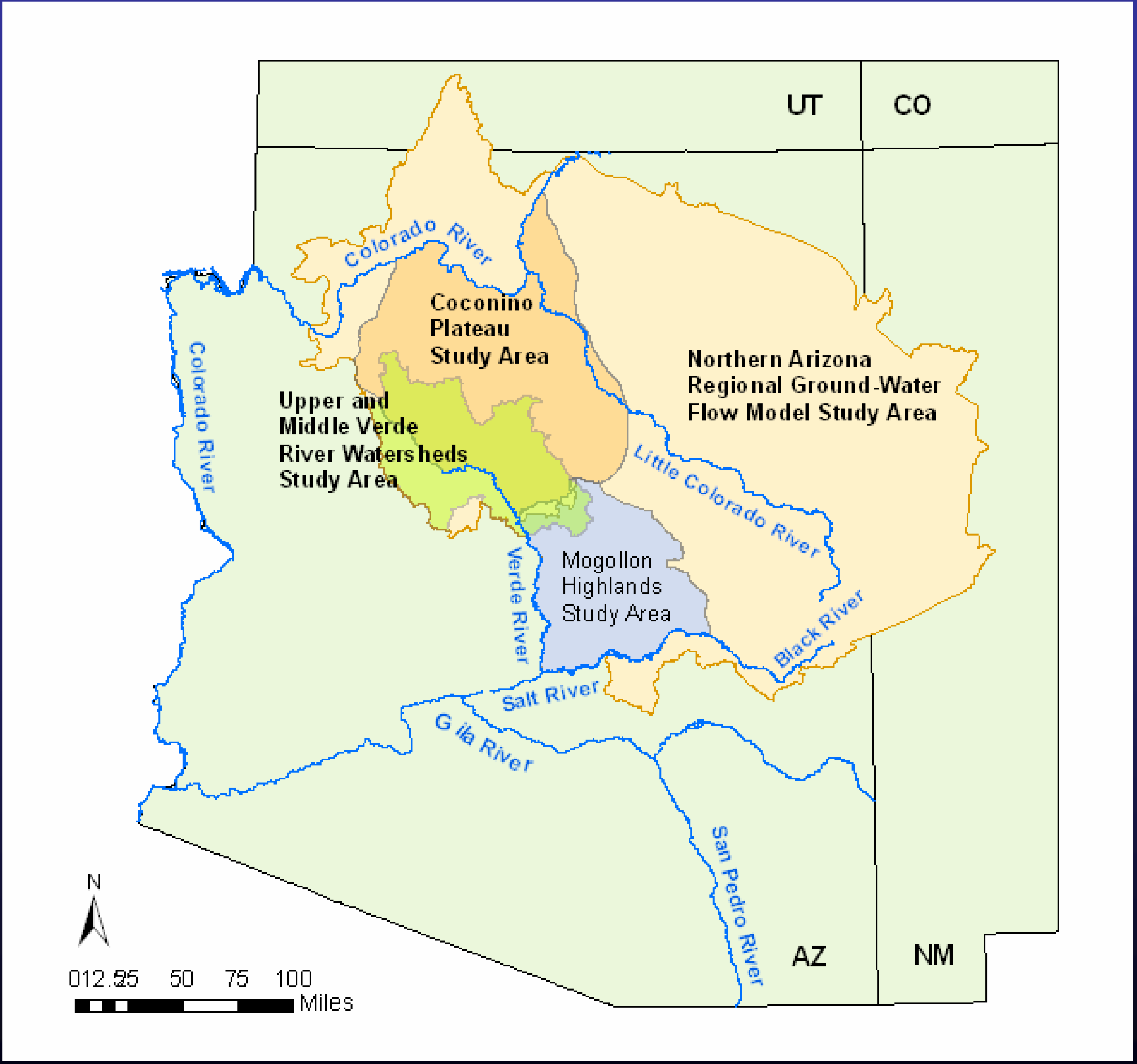
Part III

Introduction to Numerical Modeling

Outline

- Definitions
  - Conceptual Model
  - Numerical Model
- Objectives of Numerical Model
- Features of Numerical Model
- Examples From the San Pedro Regional Model
- Introduction to the Model Area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Coconino Plateau Study Area
Northern Arizona Regional Ground-Water Flow Model Study Area
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Colorado River
Little Colorado River
Mogollon Highlands Study Area
Verde River
Black River
Salt River
Gila River
San Pedro River
N
0 12.5 25 50 75 100
Miles
AZ
NM

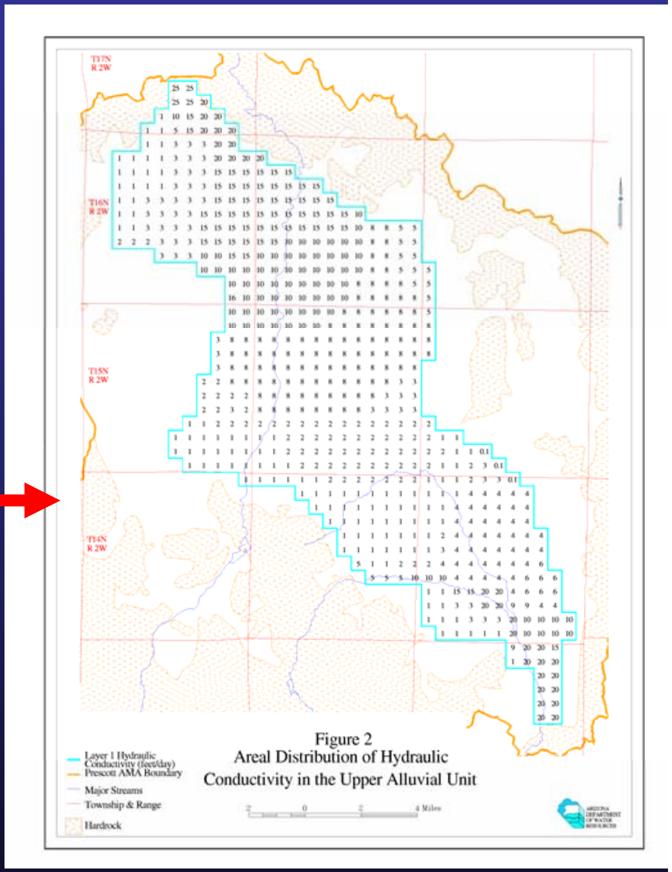
Geohydrologic conceptual model: ***A conceptual model is simply a physical explanation of how a system is thought to work.*** The development of conceptual models is a necessary step in developing more detailed quantitative models.

Numerical Modeling: The conversion of the conceptual model to a numerical representation of the ground-water system, its components, and interactions with the surface-water system.

Why do we need to translate conceptual models to numerical models?

1. The best tool available to quantify the hydrologic system
2. To test our understanding of the conceptual model
3. To evaluate data gaps and guide data collection procedures
4. To predict impacts of climate fluctuations and development scenarios on system

How does a numerical model work?



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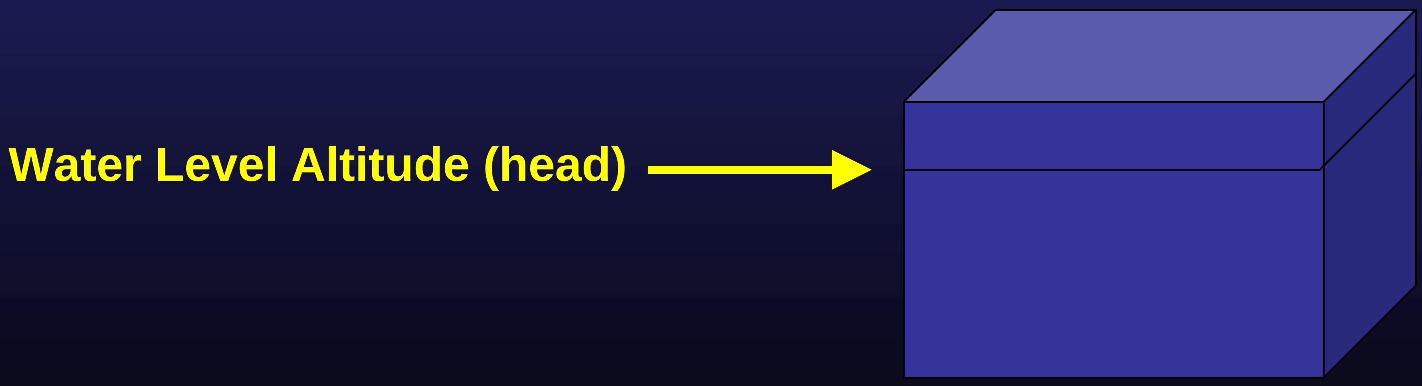
Model Inputs, Outputs, and Storage

- Inflows
  - Recharge (natural and artificial)
- Outflows
  - Base flow, evapotranspiration, withdrawals
- Maintains accounting of water volumes in grid cells
  - By grid cell, aquifer, layer
- Calculates water level altitudes (heads) for each cell



Objectives of Numerical Model

1. Improve understanding of hydrologic processes on a regional scale
   - Recharge locations and annual rates
   - Ground-water flow paths
   - Aquifer extent and connectivity

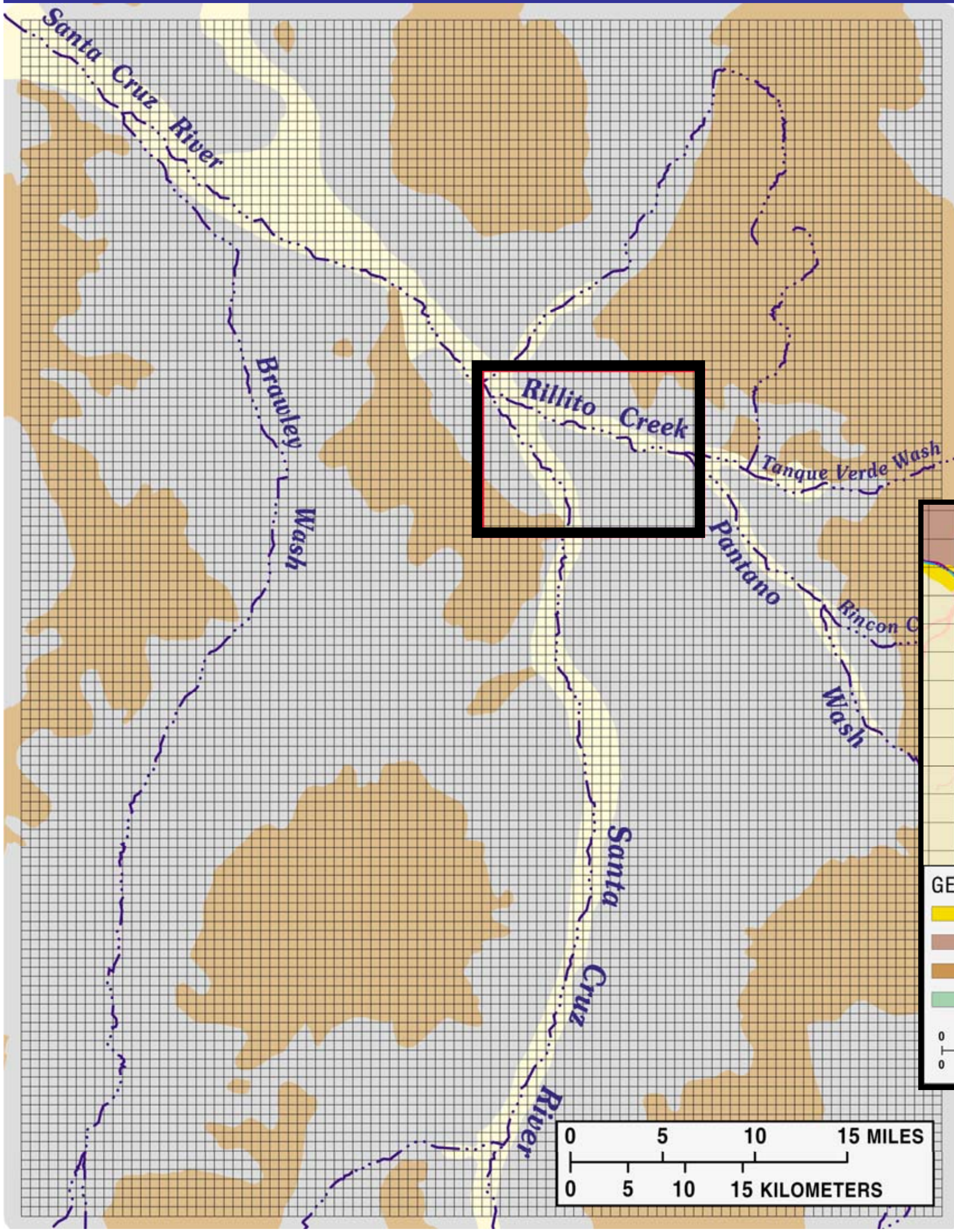
2. Provide boundary conditions for local, nested models

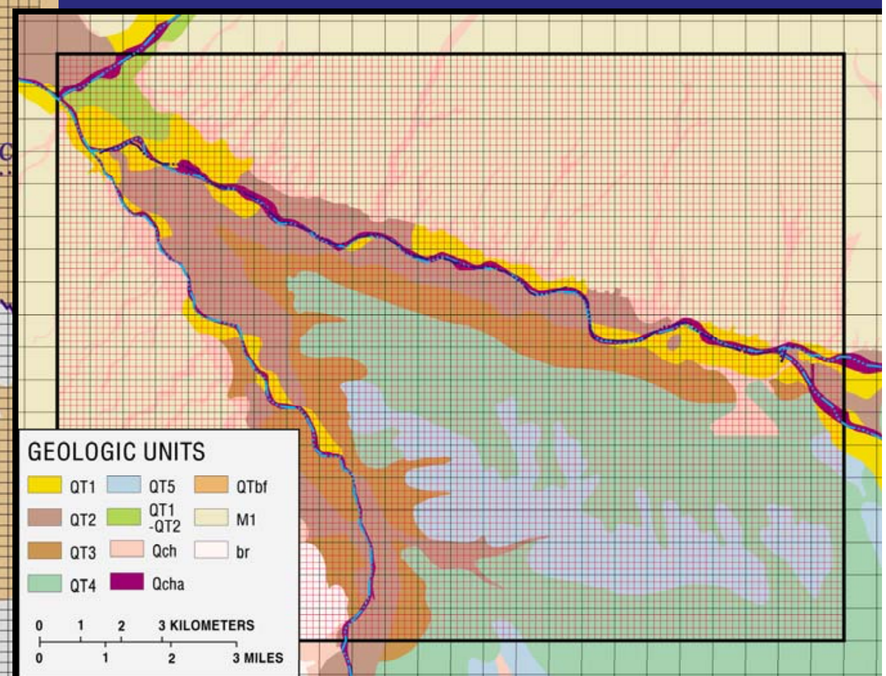
3. Provide a numerical information tool for management and protection of water resources

4. Provide a numerical tool to identify data collection needs

5. Provide a tool to examine hydrologic consequences of various scenarios
   Climate fluctuations
   Development of watersheds

Local or nested model –
Finer scale
Increased detail





Scenario Development for Numerical Model (TAC and WAC Responsibility)

- Scenario development
  - Evaluate scenarios at 1-2 mile grid scales
    - Natural scenarios - Climate fluctuations
    - Anthropogenic scenarios - Withdrawals
  - Evaluate interbasin interactions
    - Big Chino Subbasin – Verde Valley Subbasin
    - Verde Valley Subbasin – Coconino Plateau
  - Evaluate some intrabasin interactions
    - Large withdrawal centers – Aquifer Storage
    - Large withdrawal centers – Baseflow

NOTE: Regional model is not the optimal tool for all development scenarios; Local/nested models will provide greater detail and more accurate answers

Scenario Development Recommendations and Considerations

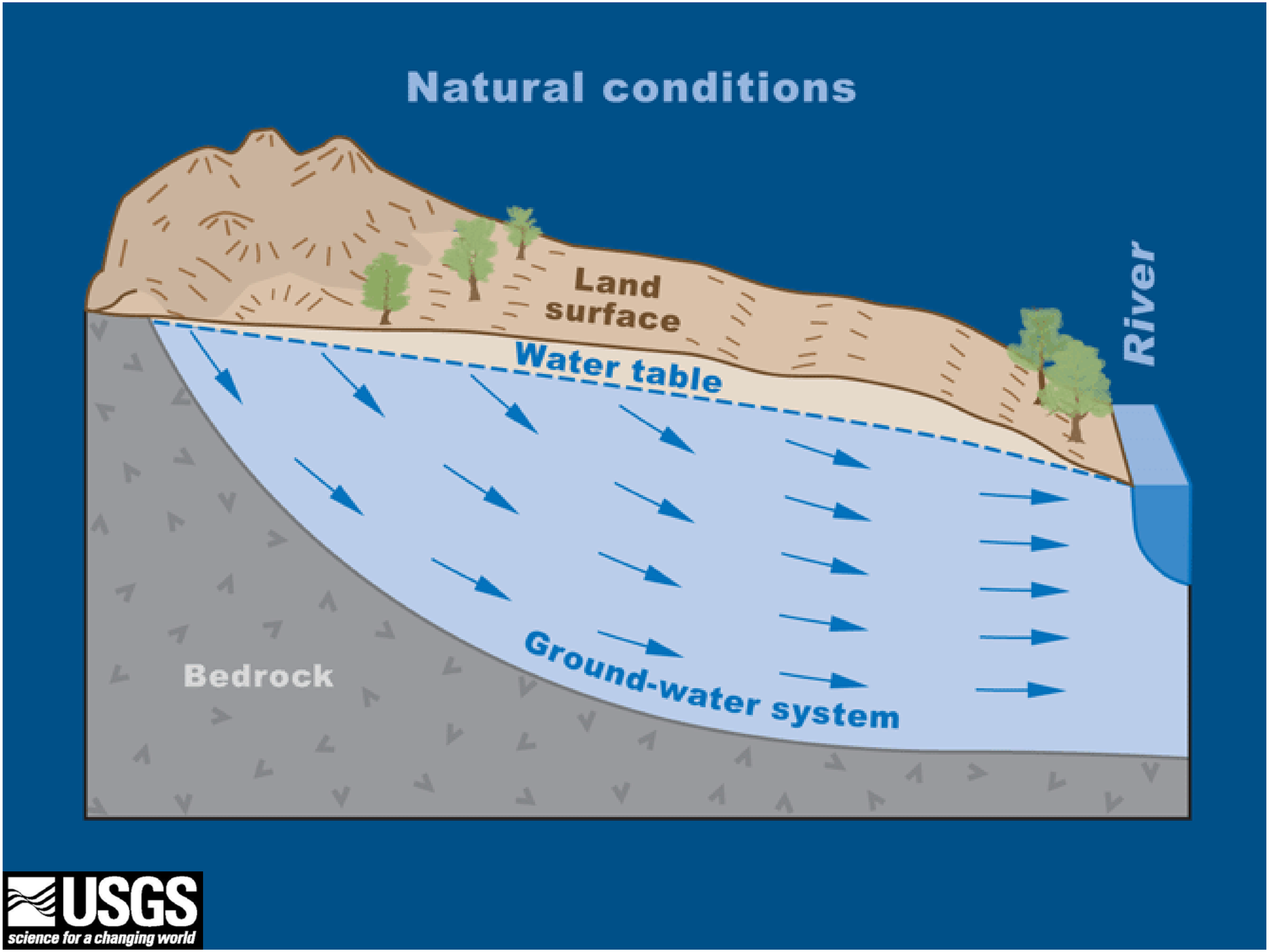
- Development/Projection; required information
  - Location of withdrawals
  - Depth of screened interval for wells (aquifer)
  - Rate of withdrawal
  - Time periods of withdrawals

- Incidental and artificial recharge
  - Location
  - Recharge rate
  - Incidental recharge factors

- Scale Considerations
  - Mile by mile grid cell size
  - Center of the grid cell is the point of calculation
- Broad ex: Impact of pumping on Verde River base flow
- Fine ex: Drawdown impact within Holocene alluvium near the river

Additional Features

- Particle tracking
- Sensitivity of model features
- Residence time of water
- Zone budgets
- Parcel between changes in storage and reductions in base flow


Natural conditions
Land surface
River
Water table
Bedrock
Ground-water system
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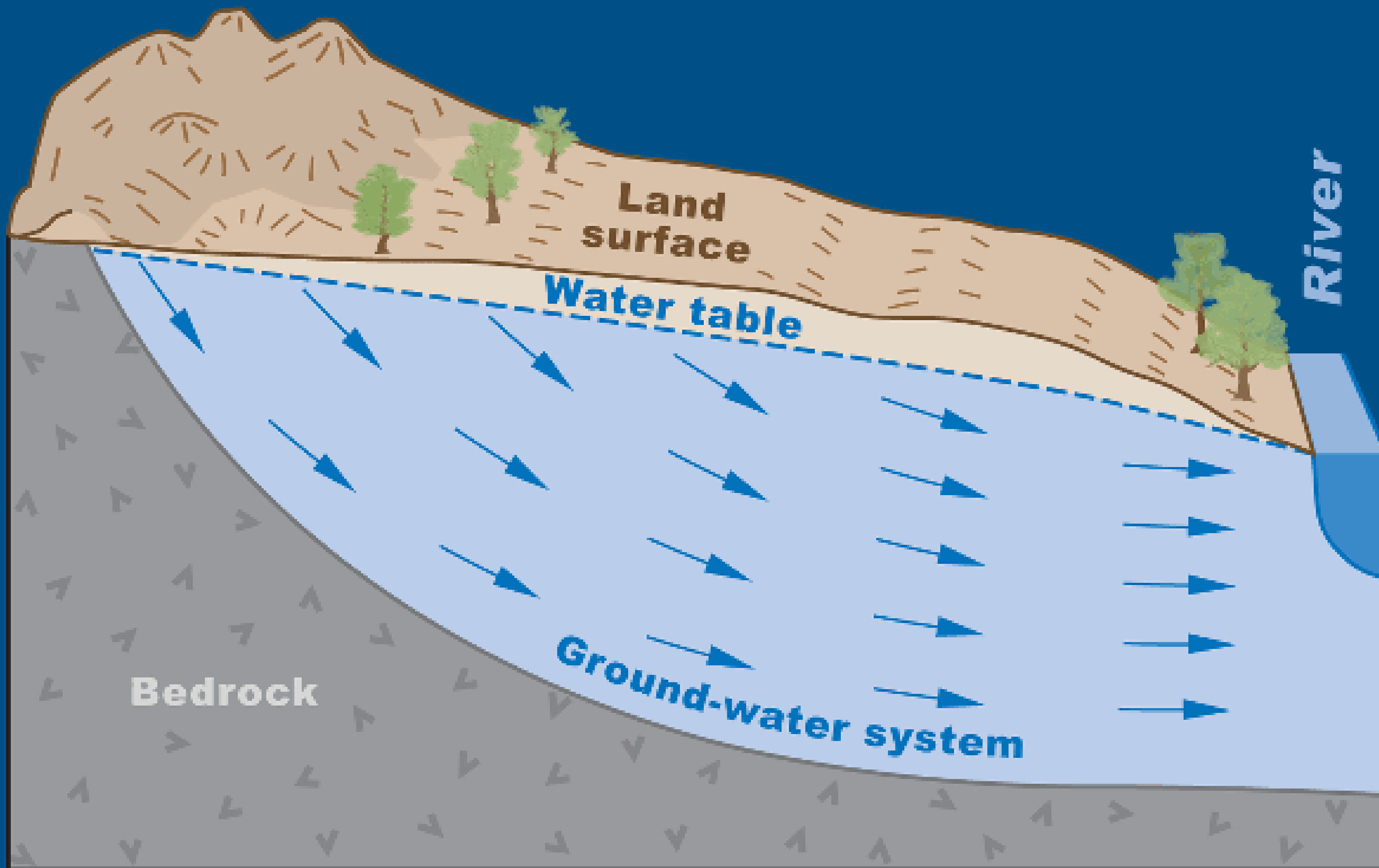
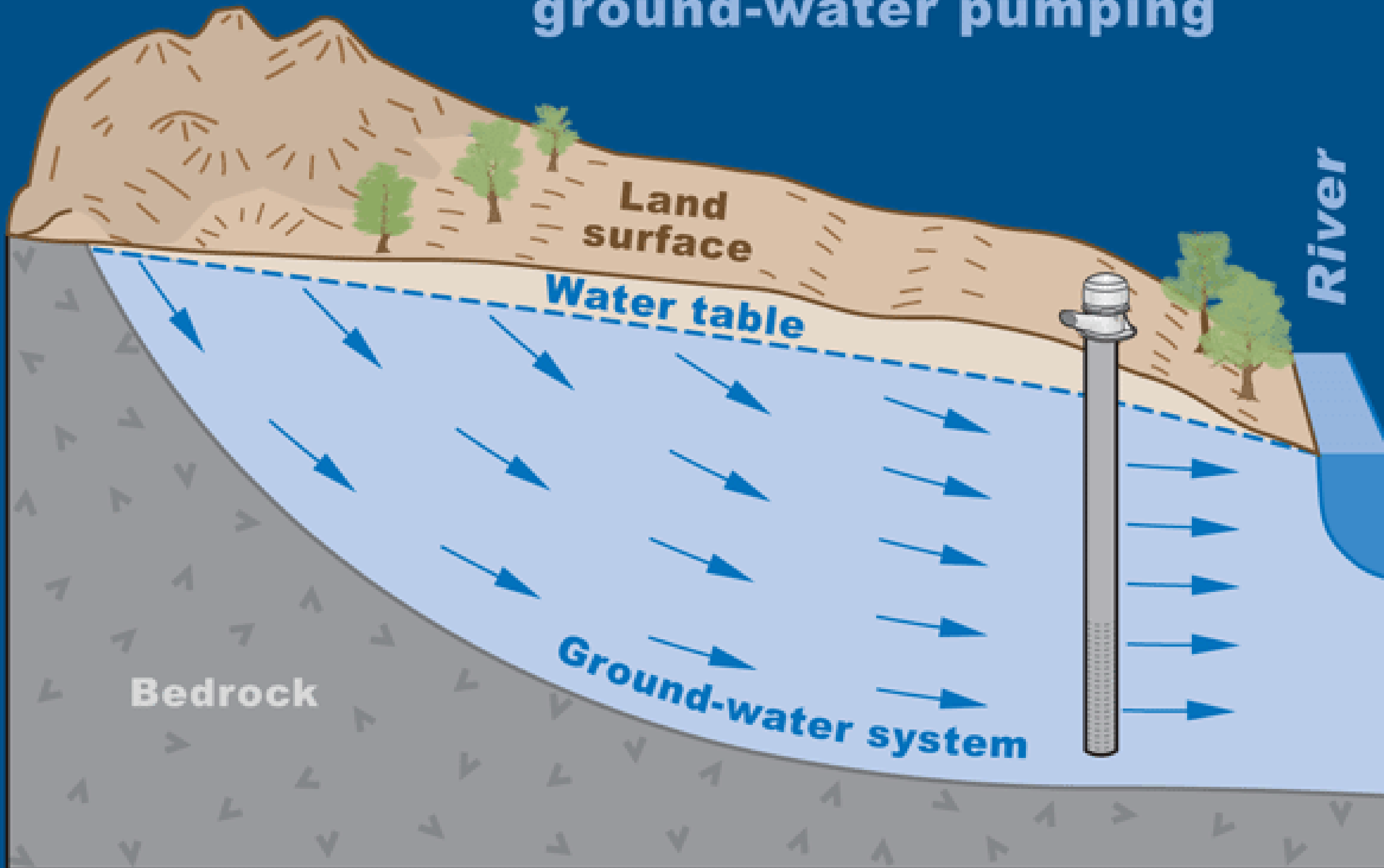
Natural conditions



Equilibrium change caused by ground-water pumping



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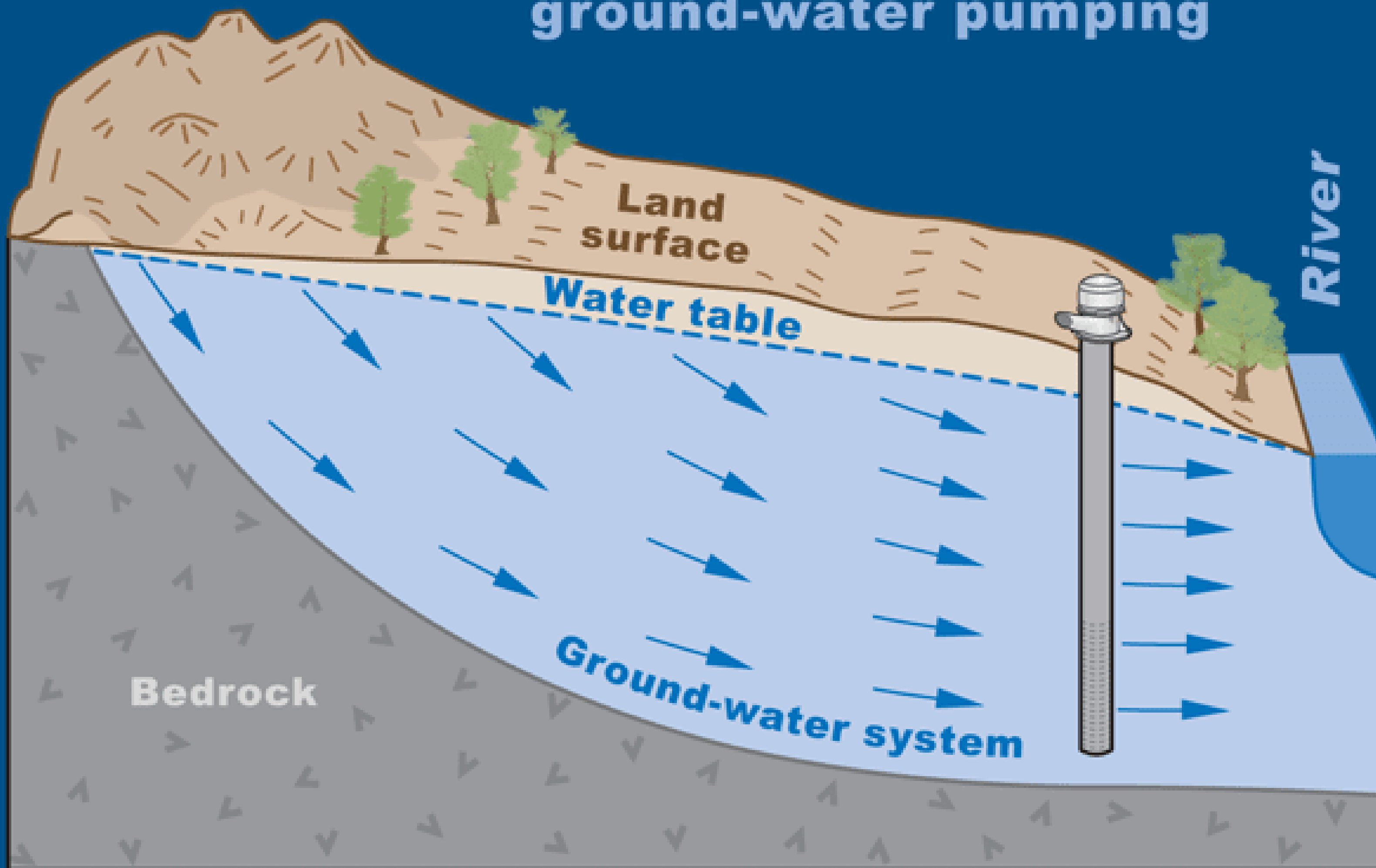
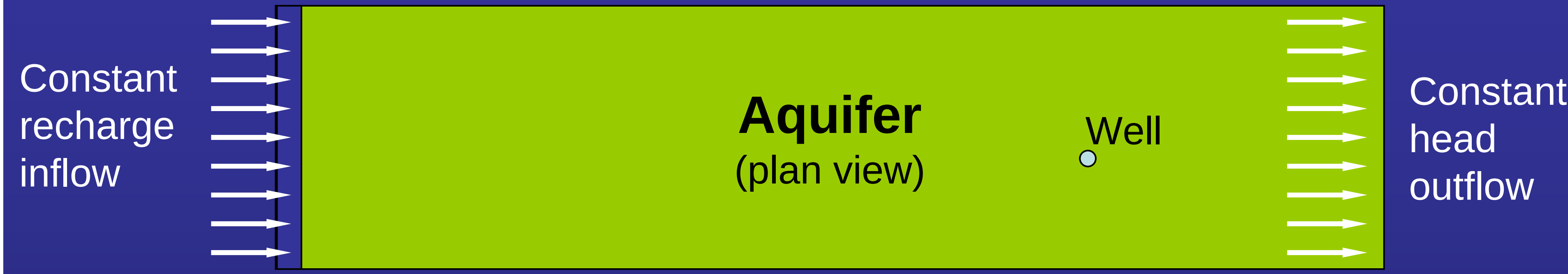
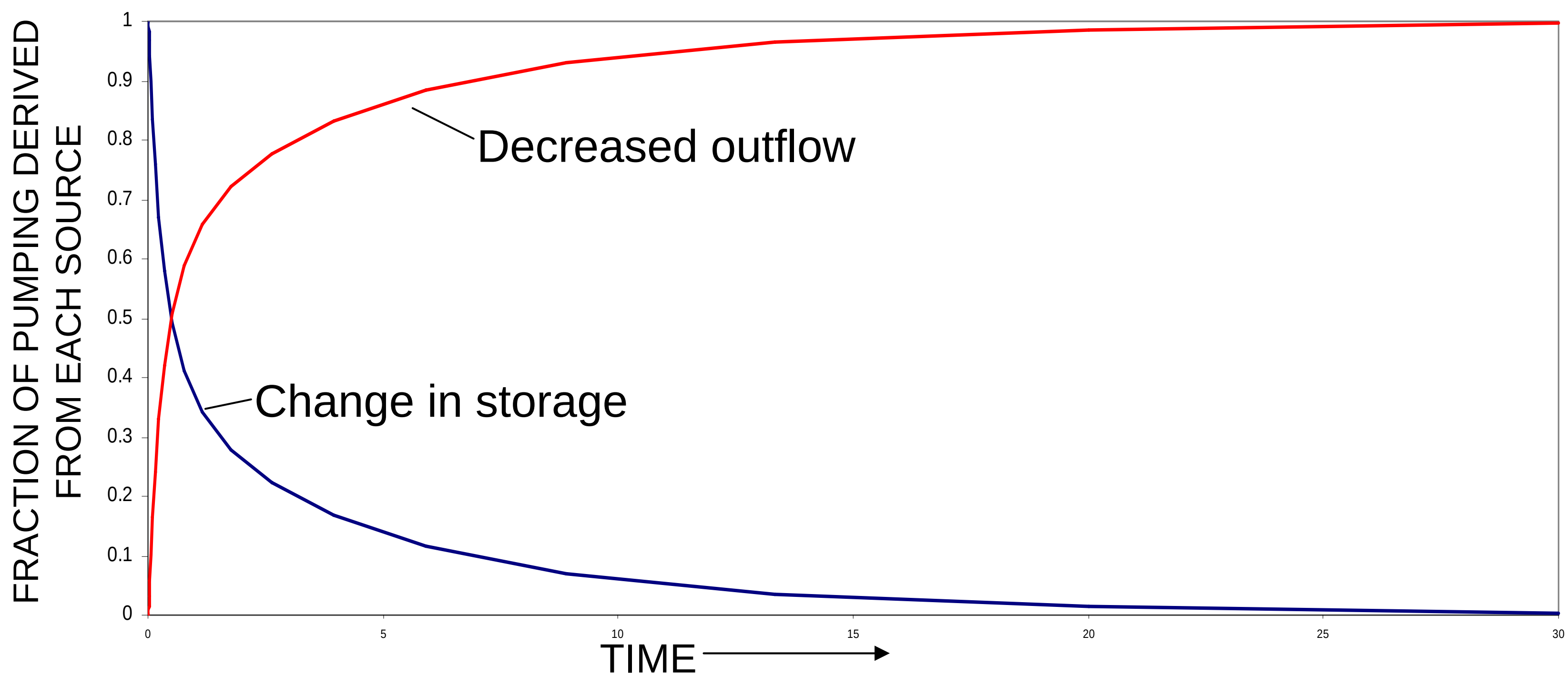
Equilibrium change caused by ground-water pumping



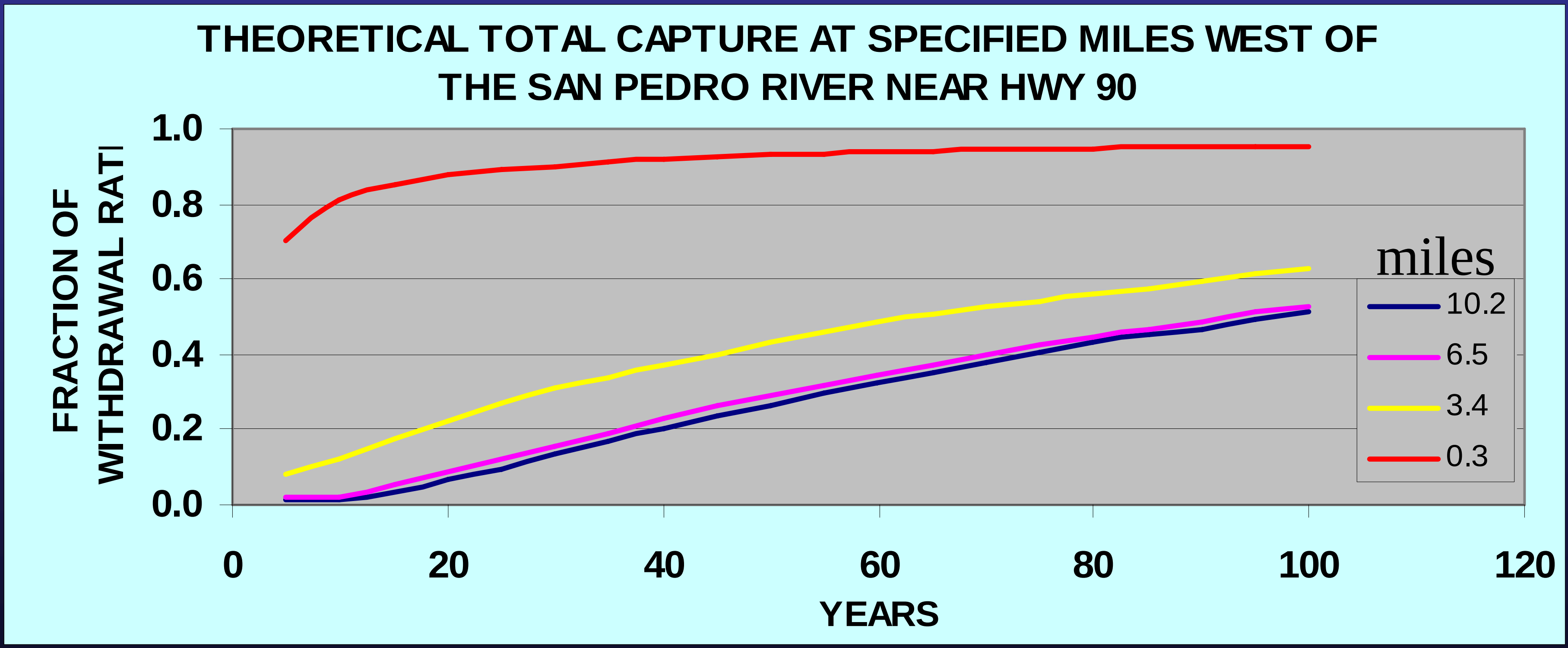
Basics of "Capture"





Theoretical Capture of Ground-Water Discharge at Hypothetical Well Sites

JML1



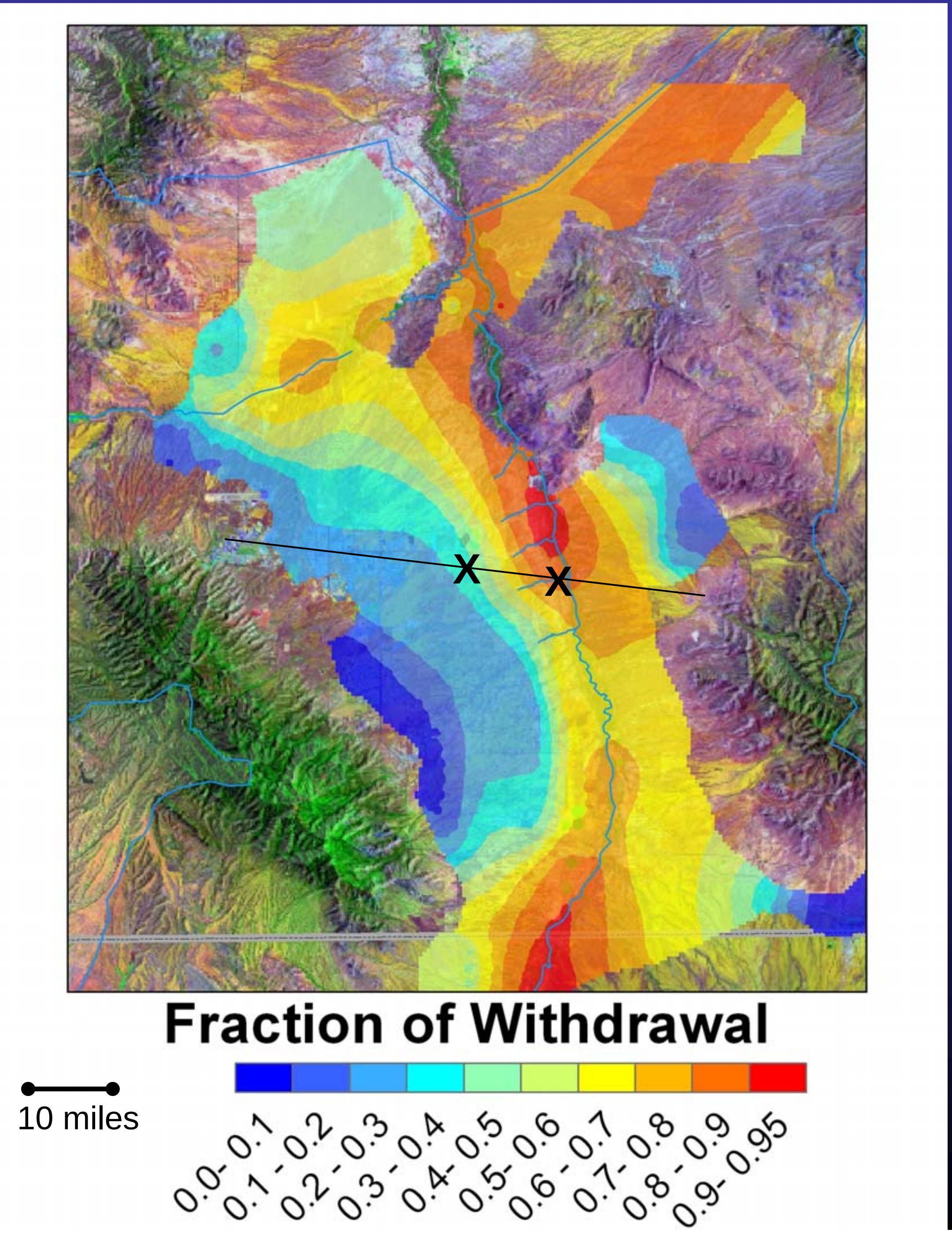
Slide 18

JML1 Y-axis label runs off chart

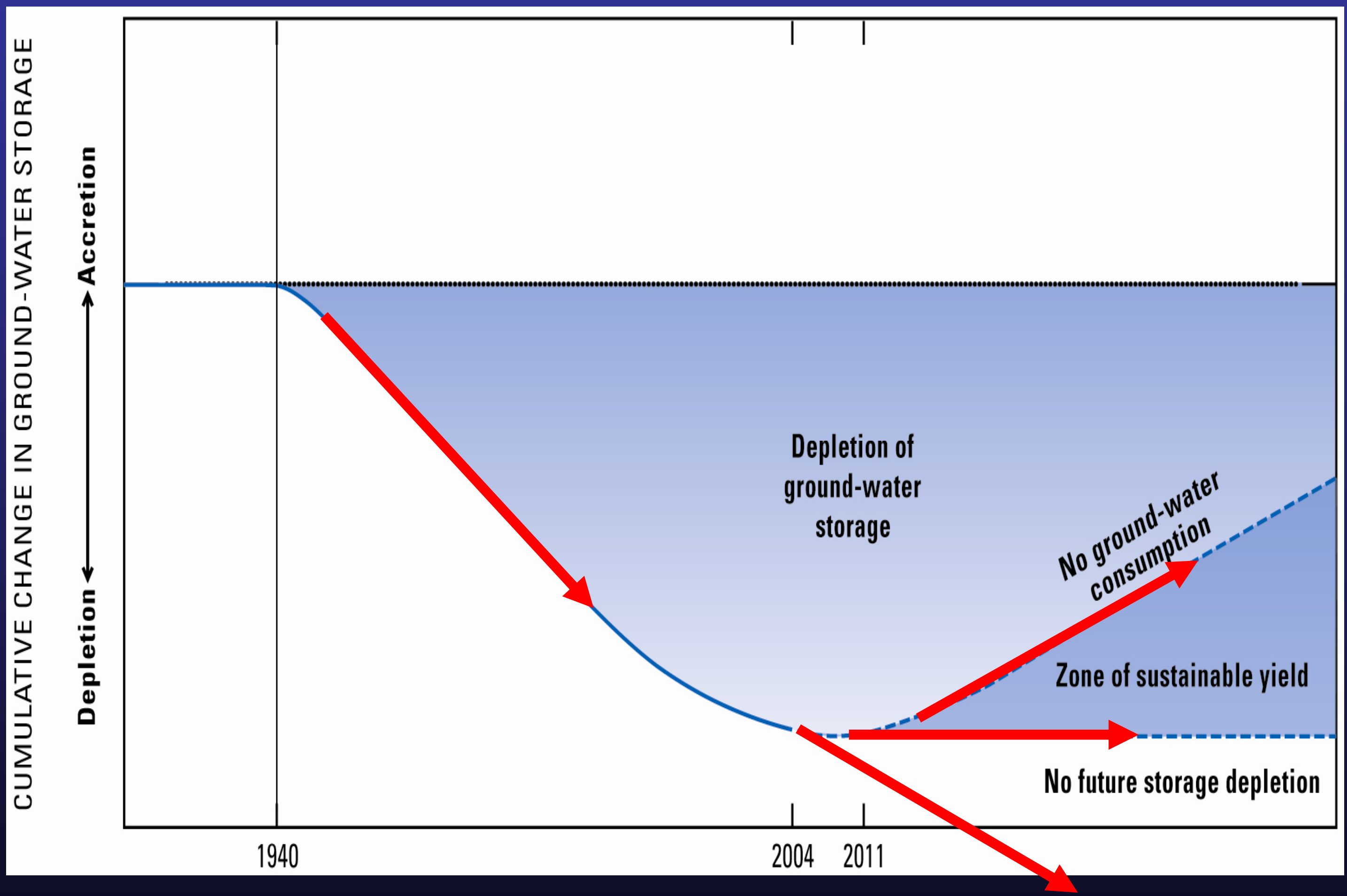
Jim Leenhouts, 2/24/2006

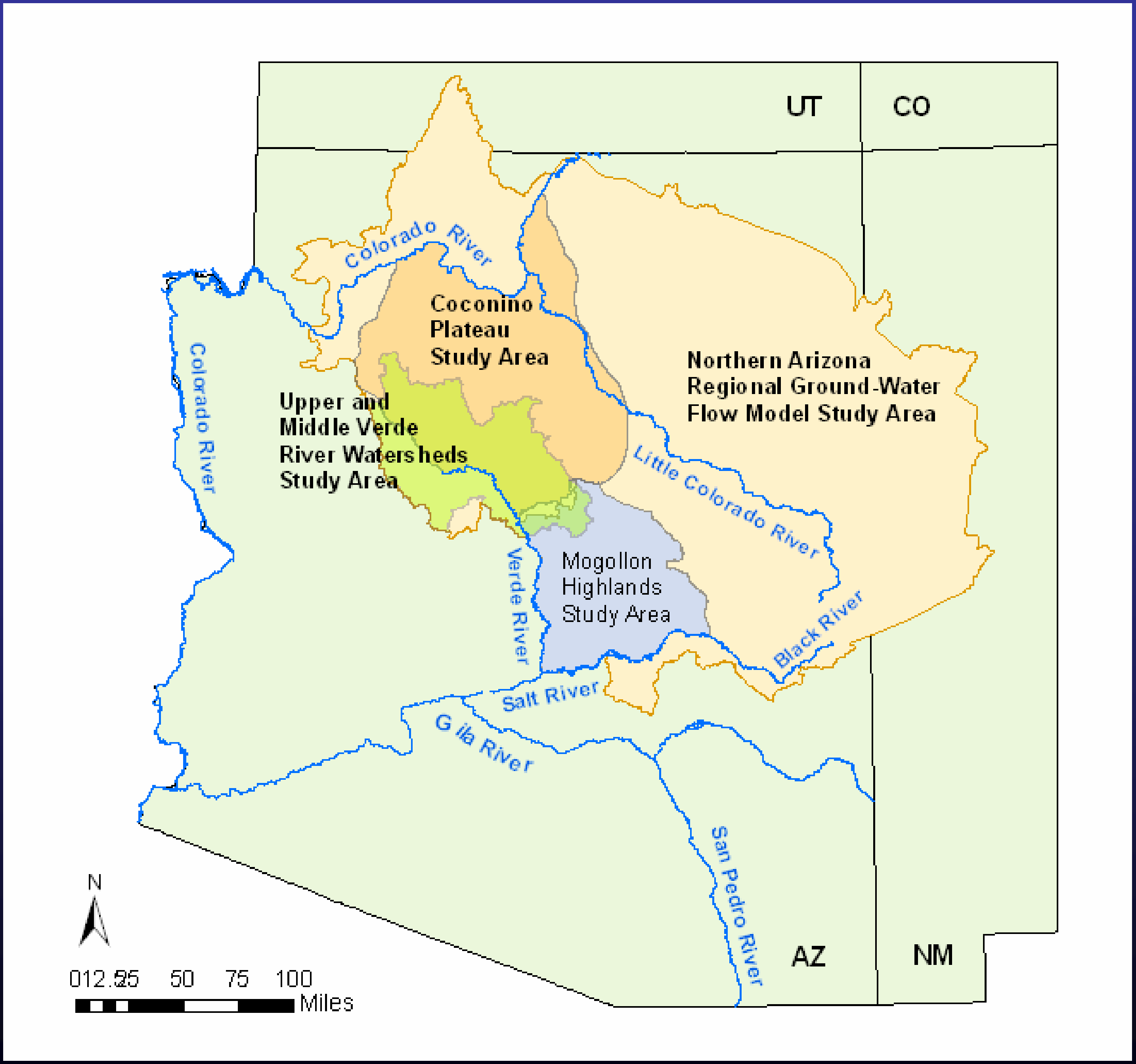
Theoretical Capture of Ground-Water Discharge at 50 yrs

For example: Pumping at point X at a rate of 100 AF/yr would result in a decline of 30-40 AF/yr in discharge to streams, ET, springs, and ground-water flow.



Sustainable yield – initial goal
An Aquifer-Storage Approach

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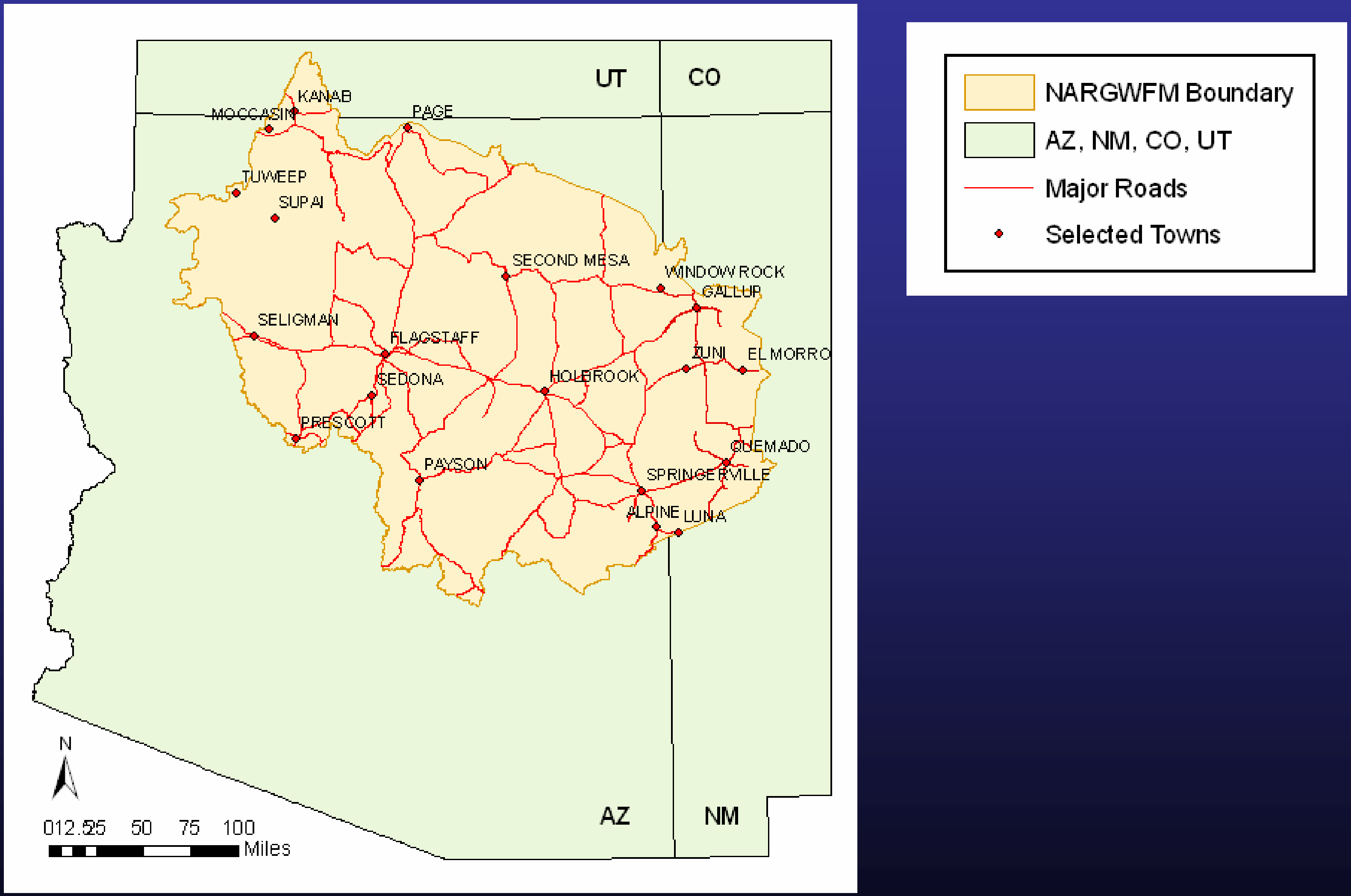
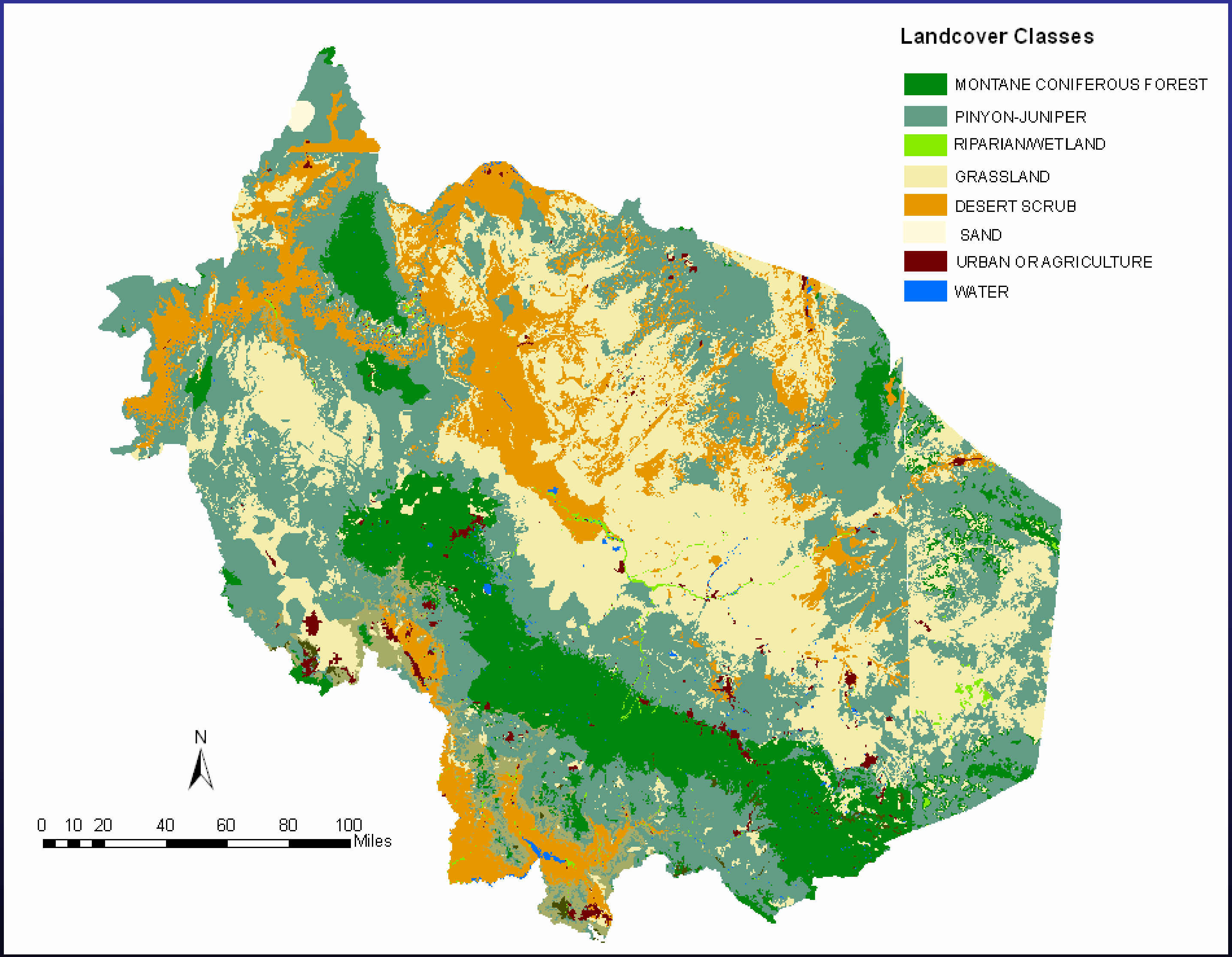
Miles
AZ
NM

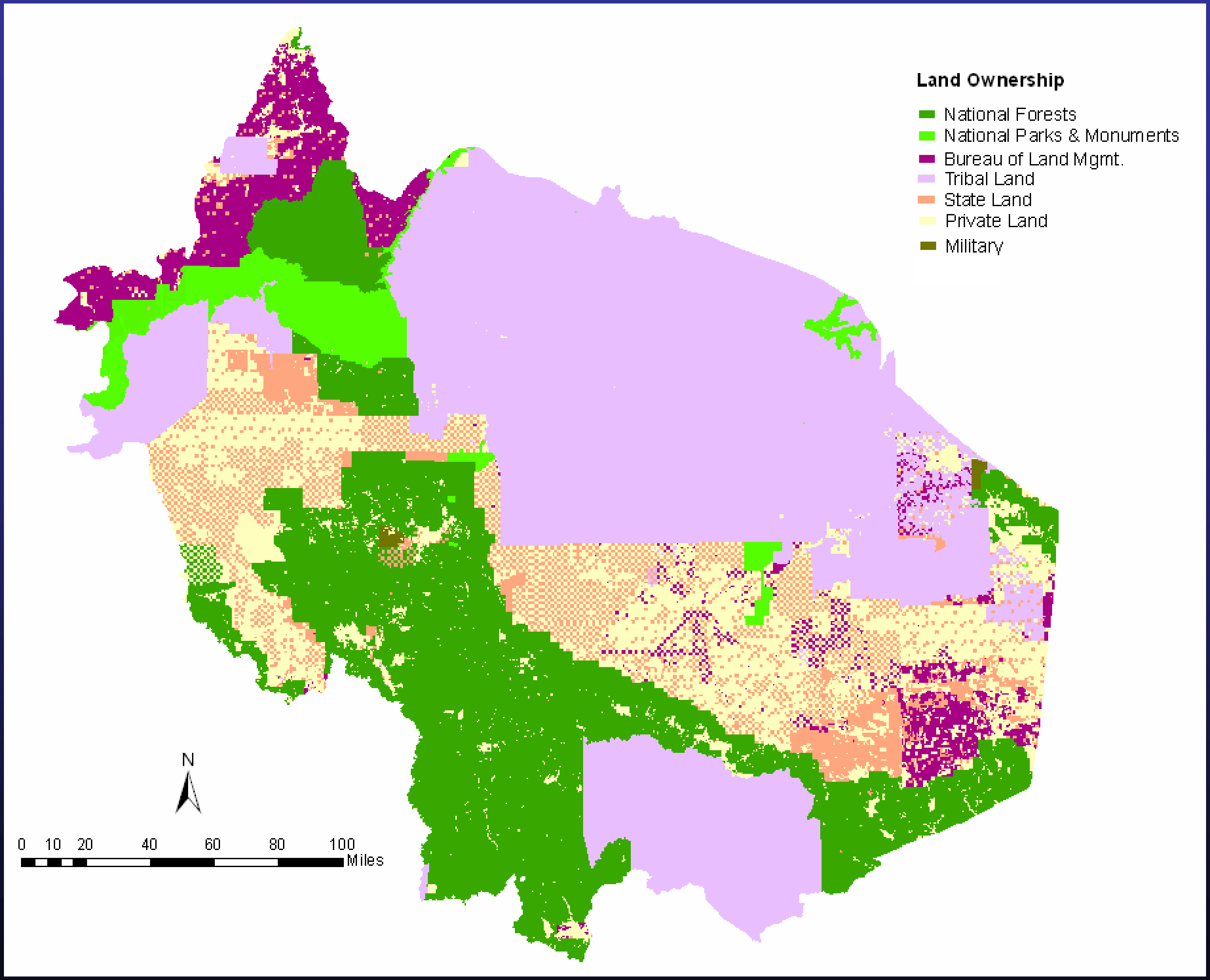
N AZ Regional Ground-Water Flow Model
Geographic Extent of Model



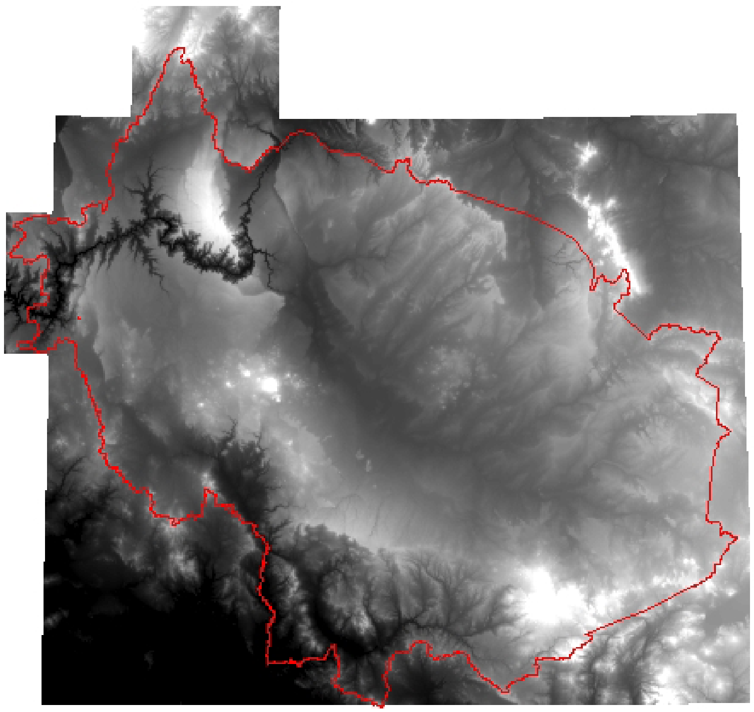
N AZ Regional Ground-Water Flow Model
Landcover



N AZ Regional Ground-Water Flow Model
Land Ownership



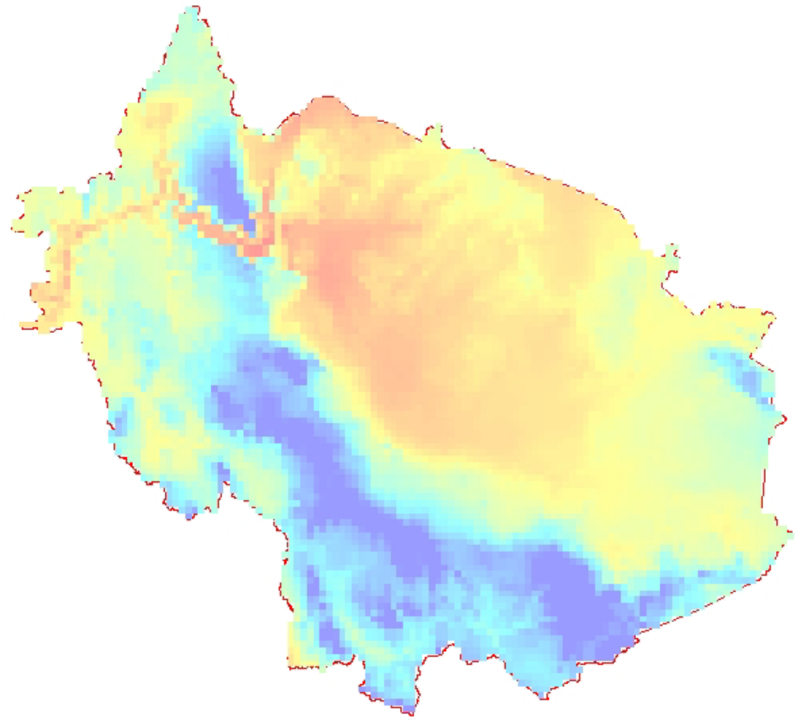
Top Layer Surface Elevation



Higher Elevation

Lower Elevation

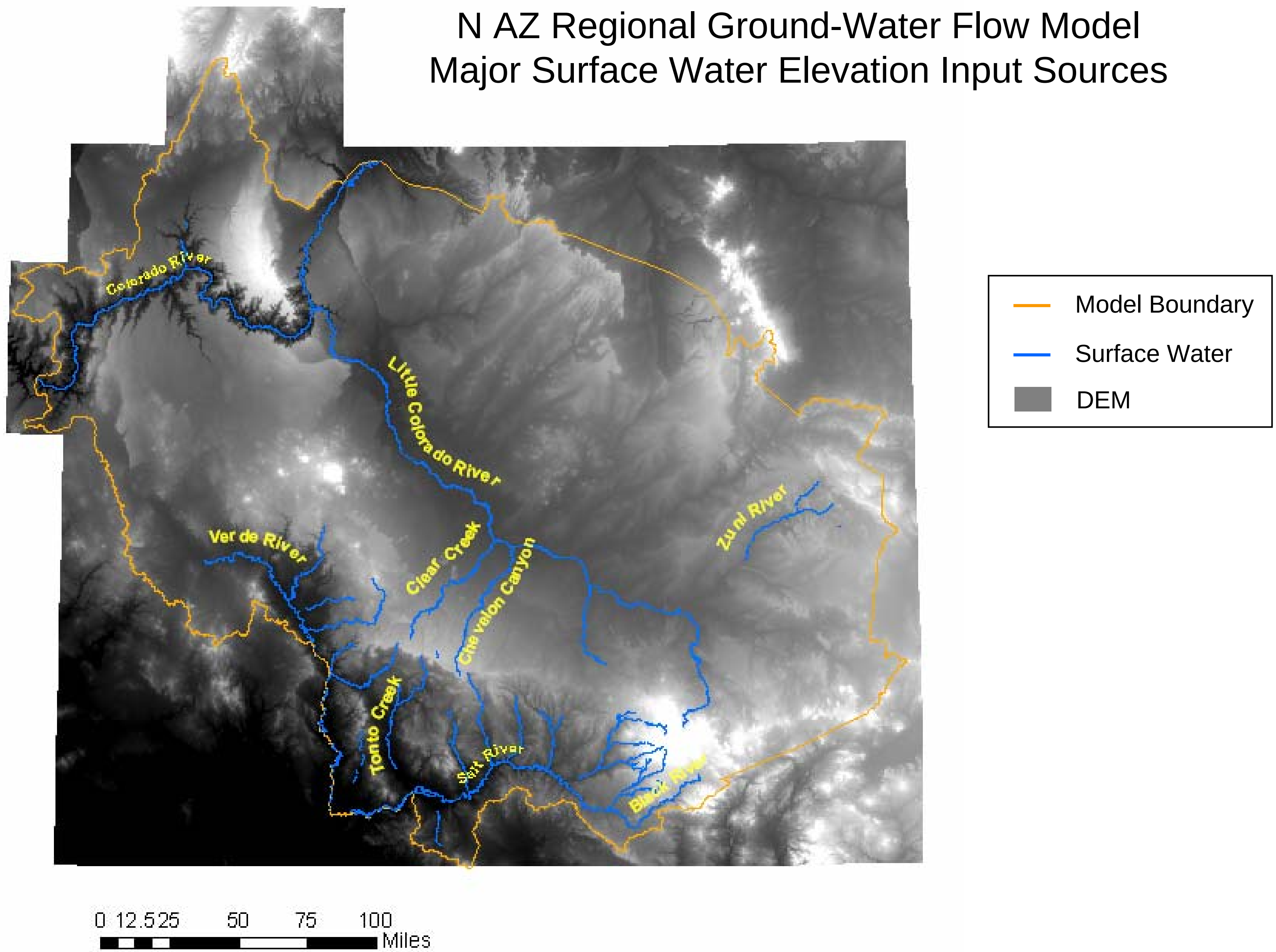
Precipitation/Recharge



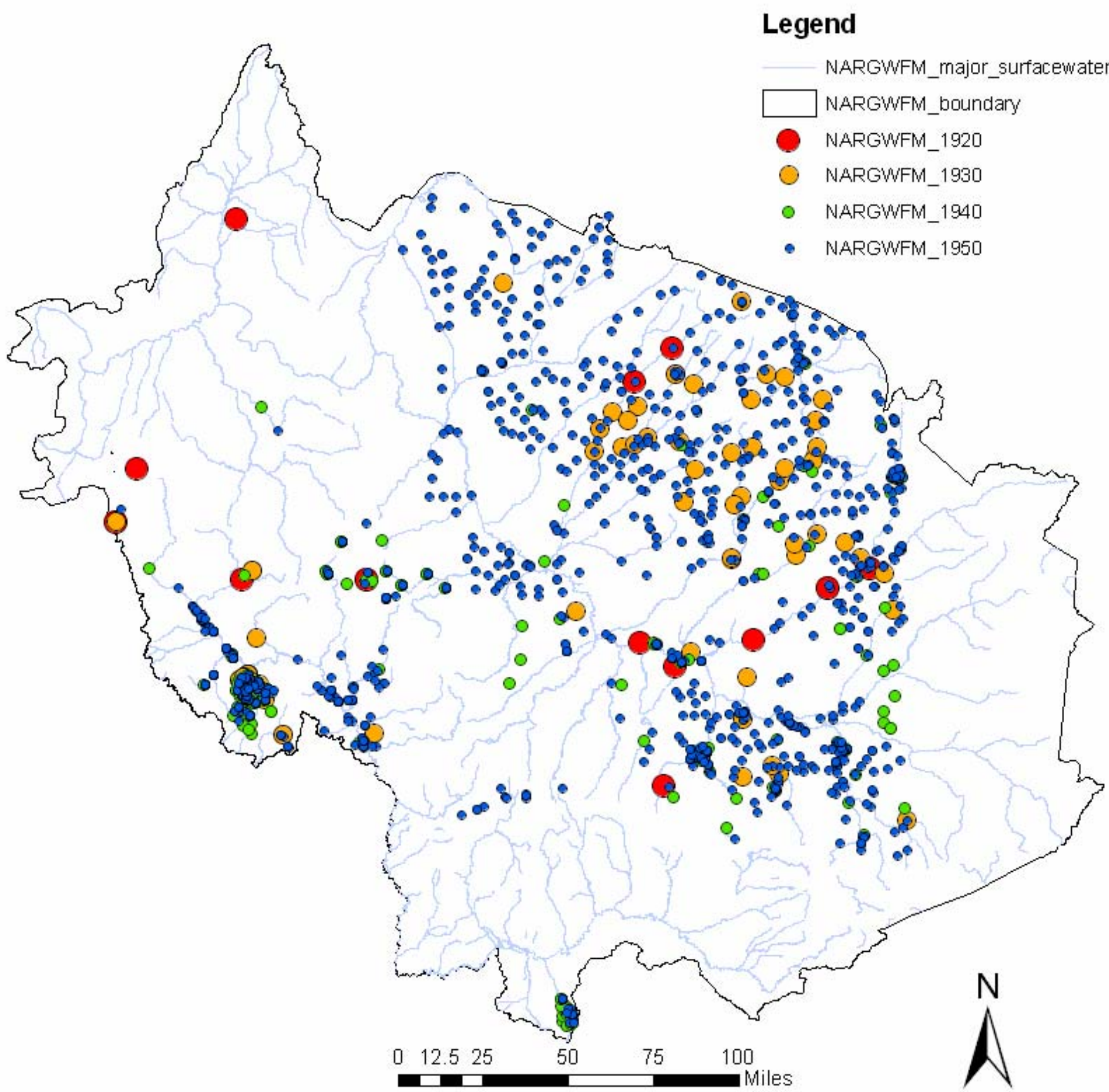
Higher Precipitation

Lower Precipitation

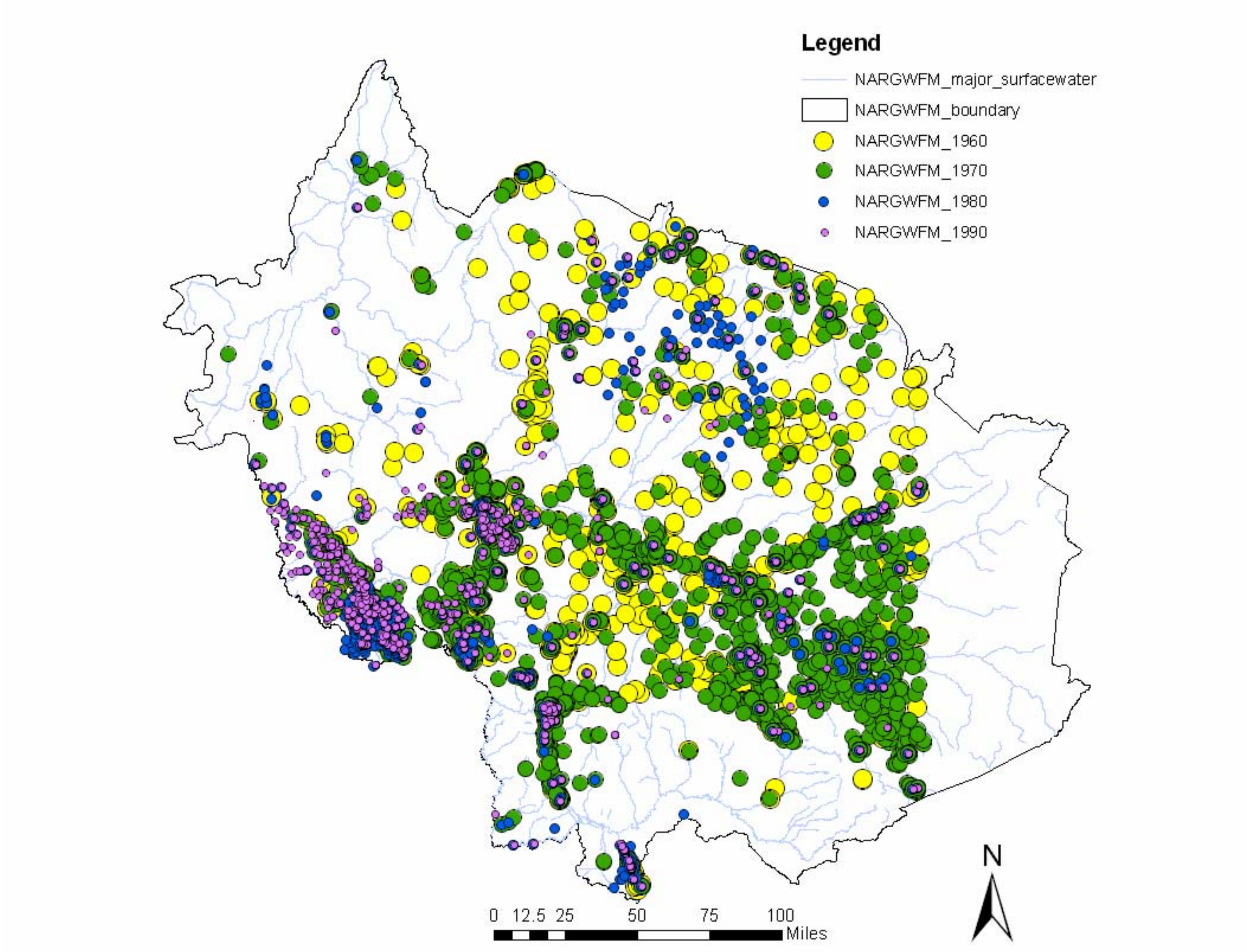
N AZ Regional Ground-Water Flow Model
Major Surface Water Elevation Input Sources



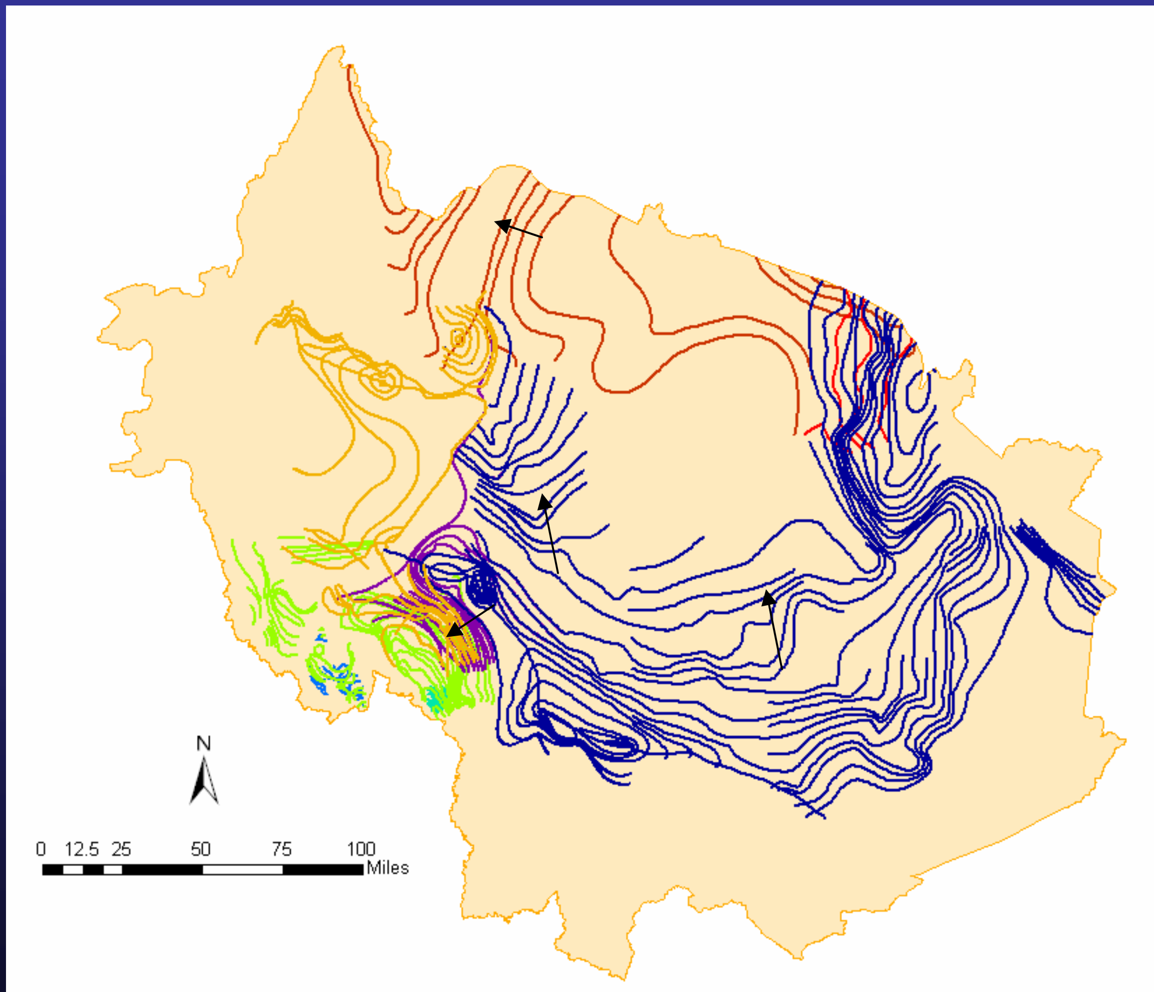
N AZ Regional Ground-Water Flow Model
New Well Locations by Decade: 1920-1959



N AZ Regional Ground-Water Flow Model
New Well Locations by Decade 1960-1999



N AZ Regional Ground-Water Flow Model
Water-Level Contours for Transient Conditions



Model Boundary

Water-Level Contours

Bills, D.J.; Flynn, M.E.; Monroe, S.A. 2005 (C Aquifer)

Bills, D.J.; Flynn, M.E.; Monroe, S.A. 2005 (Redwall-Muav Aquifer)

Bills, D.J.; Flynn, M.E.; Monroe, S.A. 2005 (C Aquifer – Little Colorado River Basin)

Blasch, K.W.: Hoffmann, J.P.; Graser, L.F.; Bryson, J.R.; Flint, A.F. 2006 (Verde Formation)

Geldon, A..L. 2002 (Madison Aquifer)

Geldon, A..L. 2002 (Canyonlands Aquifer)

Owens-Joyce, S.J. 1981

Remick, W.H 1982

Work in Progress
15 March 2006

Summary

- Conceptual and numerical model linked
- Regional scale and objectives for model
- Scenarios must consider scale and representation
- Multiple model products available for interpretation