A SURFACE-WATER – GROUNDWATER MODEL TO EVALUATE AQUIFER SUSTAINABILITY IN WASHINGTON COUNTY, MINNESOTA

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Acknowledgements

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Consortium of Sponsors include:

Washington County
City of Afton
City of Woodbury
Valley Branch Watershed District
South Washington Watershed District

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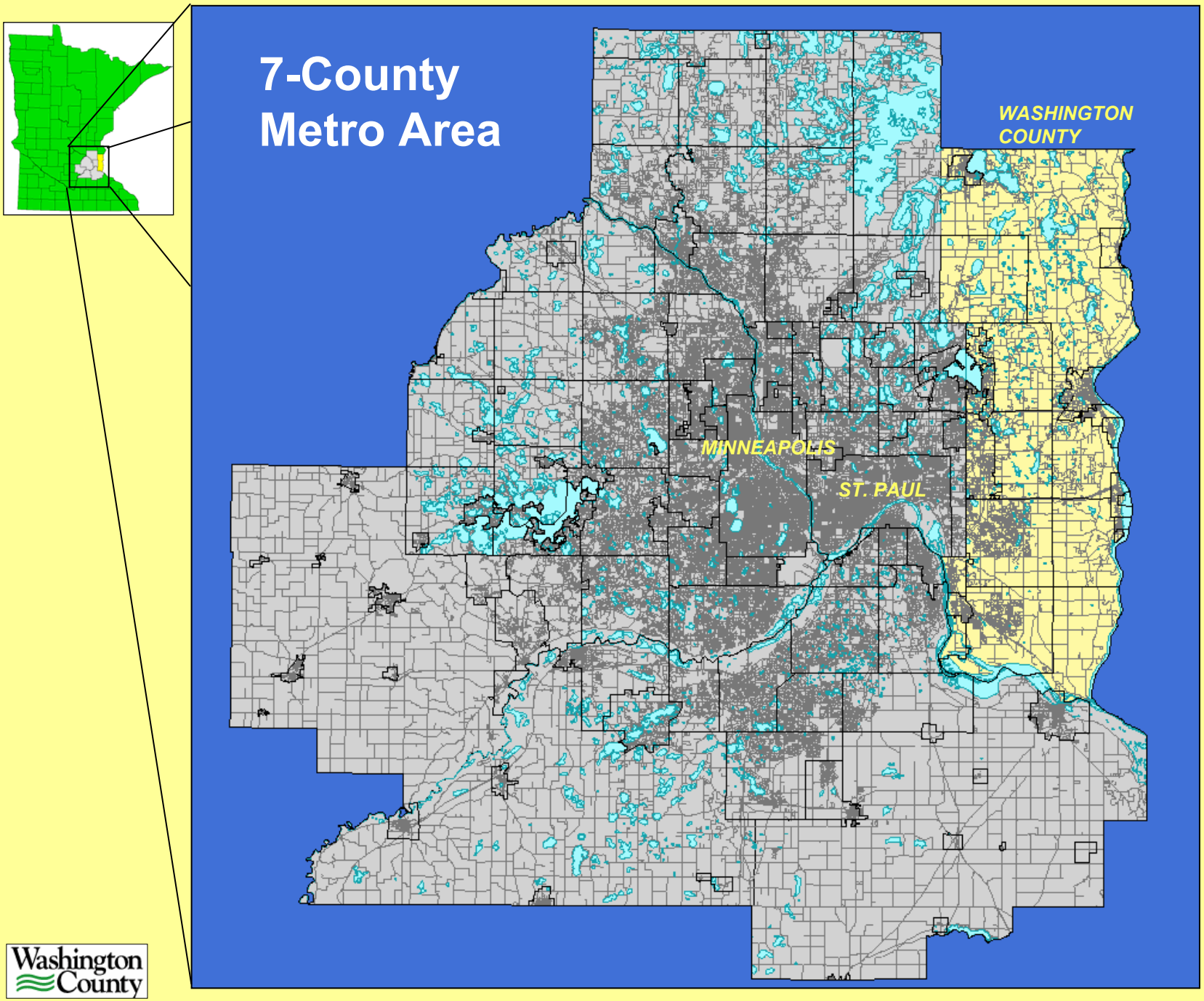

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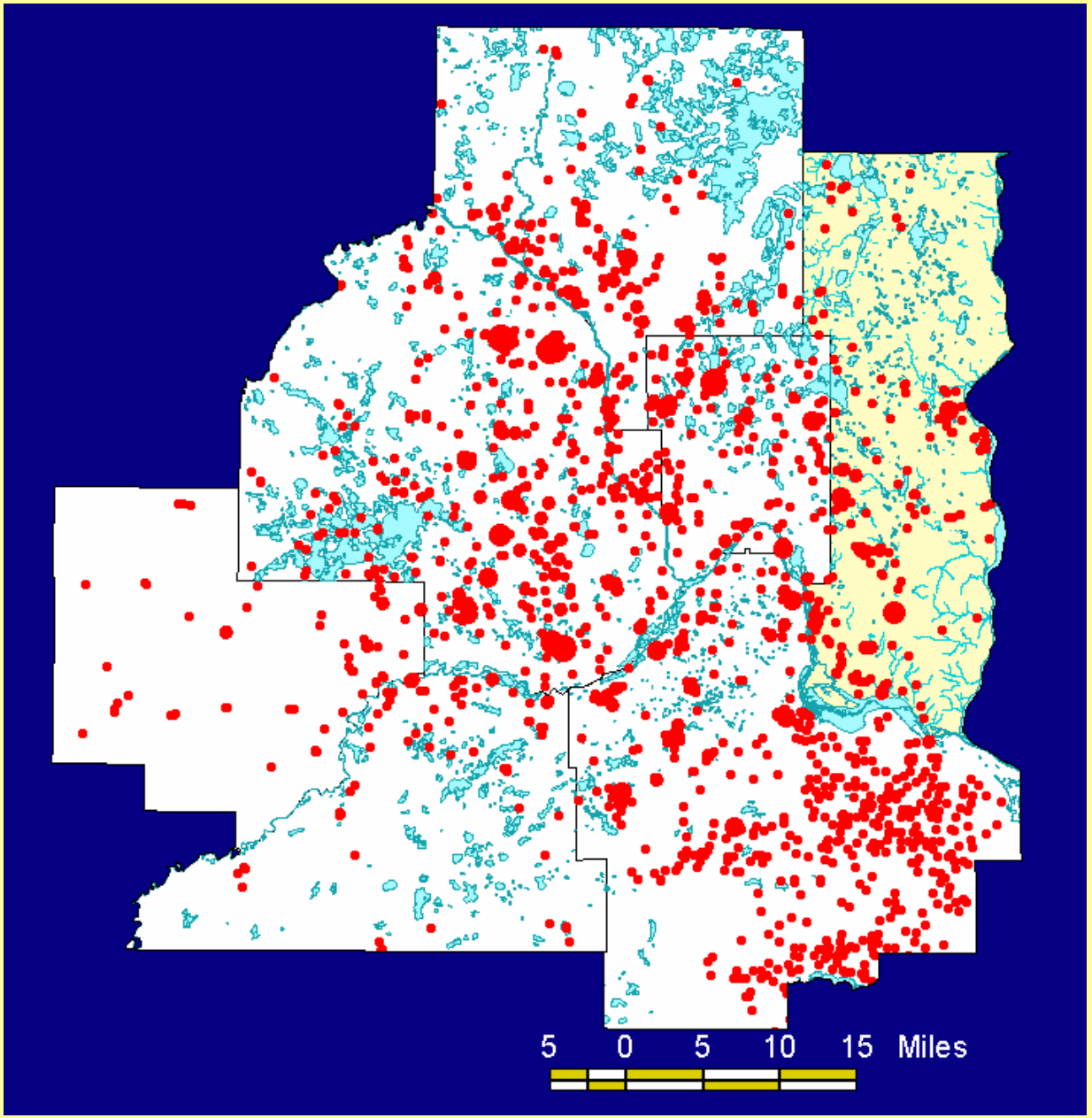
Reported Groundwater Withdrawals - 2003



Source: Minnesota Dept. of Natural Resources SWUDS database

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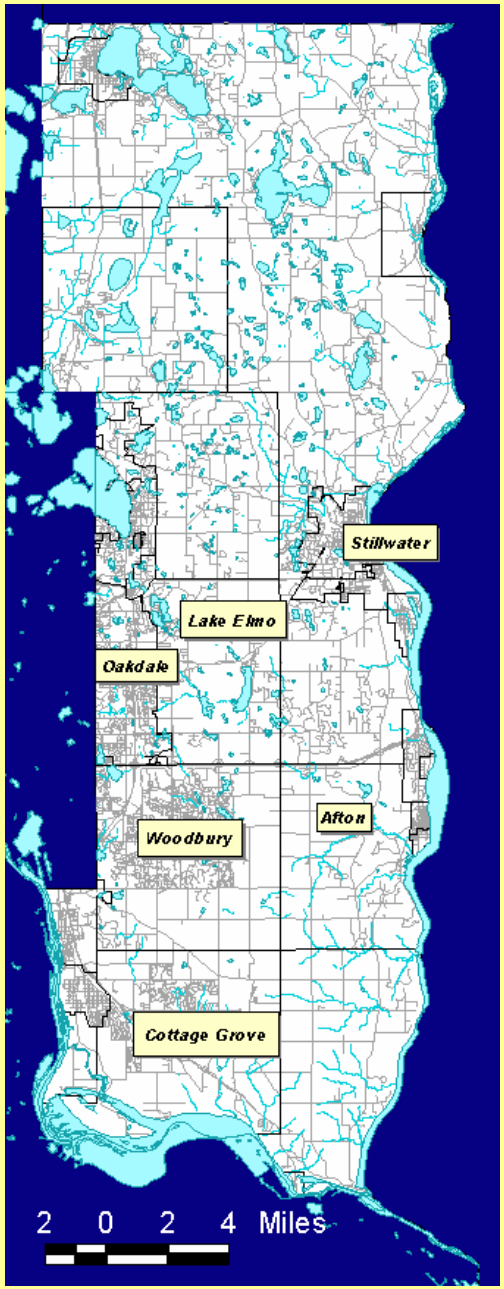

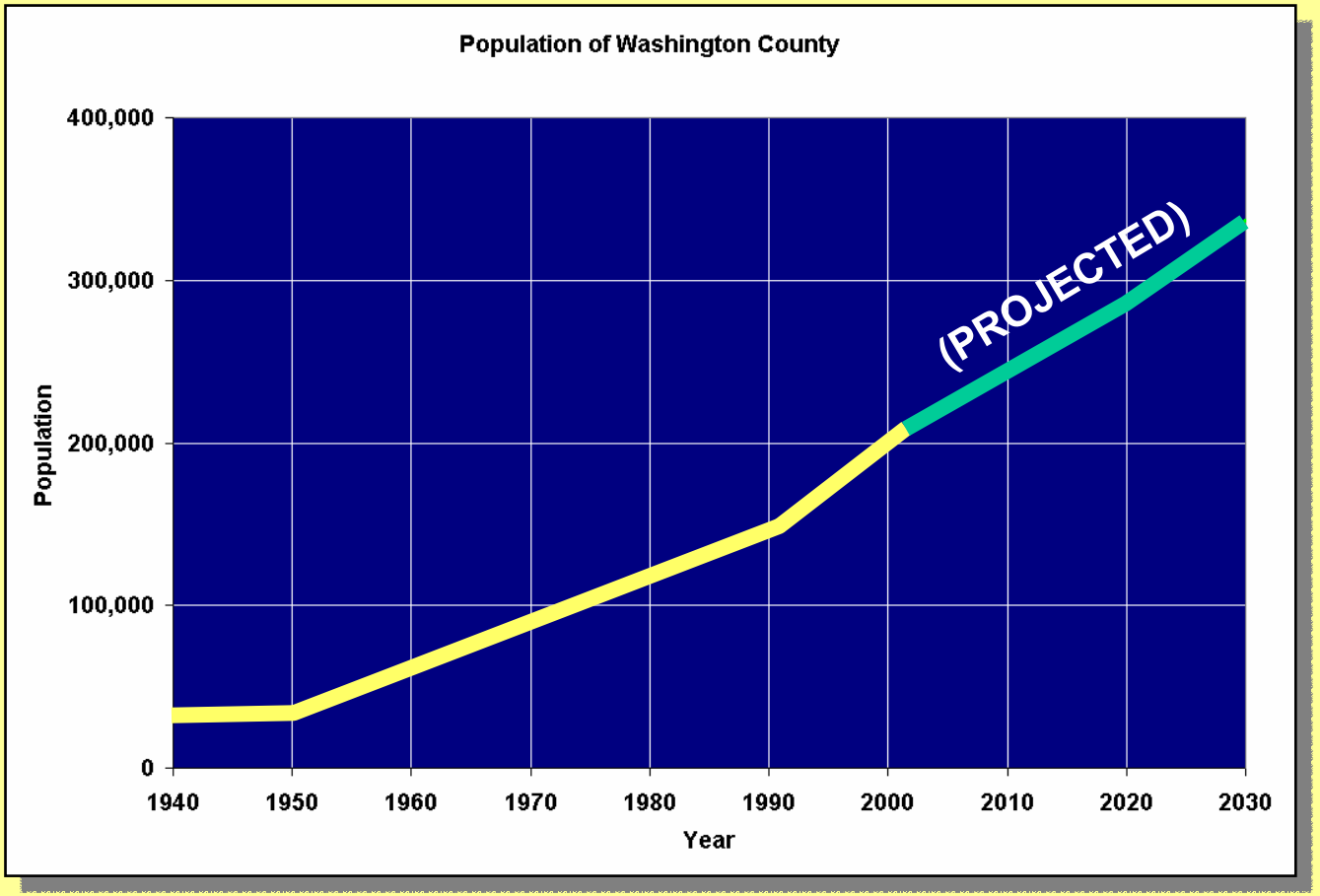

Source: U.S. Census Bureau

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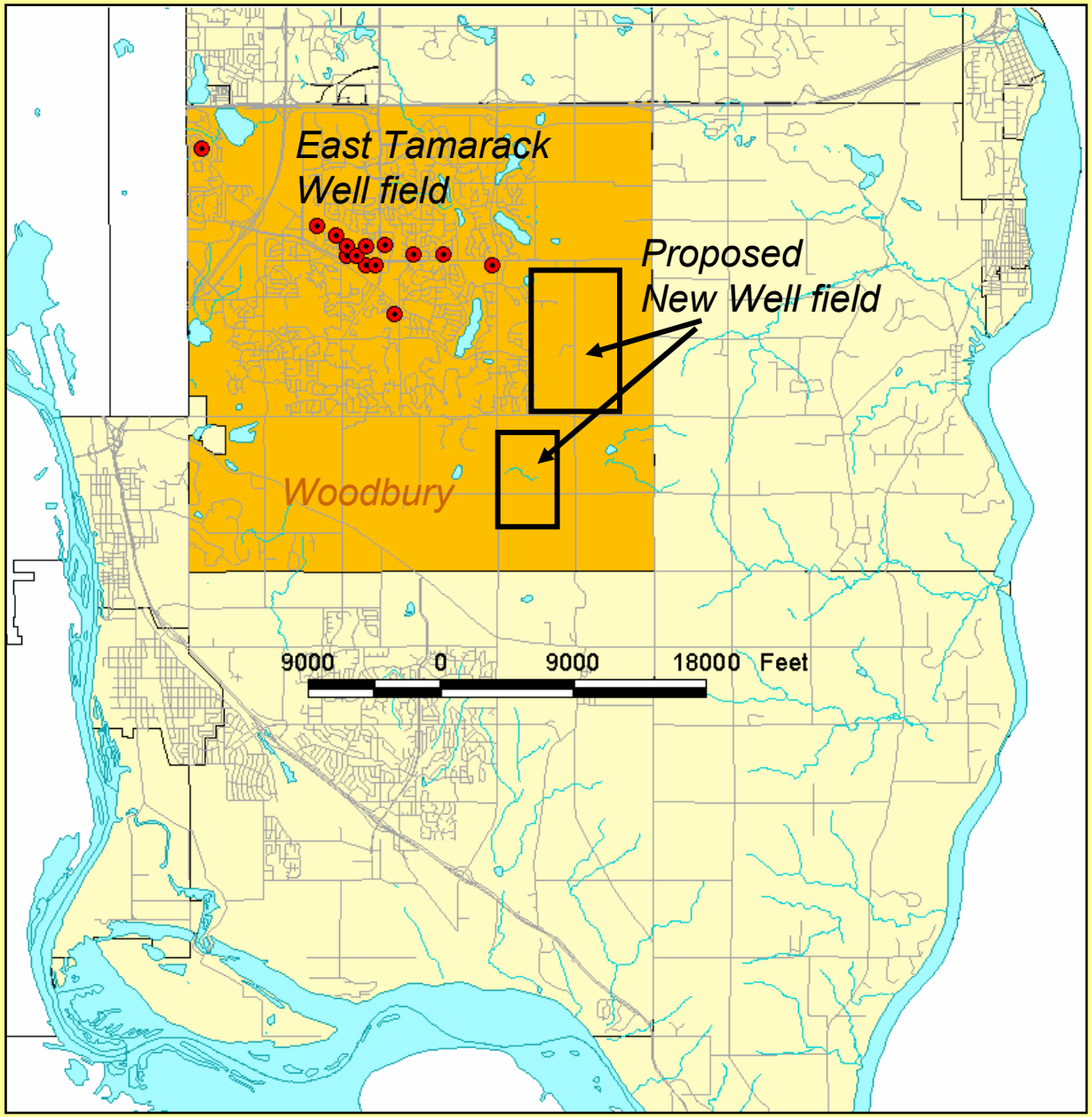

Alternative Urban Area-wide Review (AUAR)

-3 new wells to serve area to 2009

-Additional wells for subsequent years (as many as 12 more)

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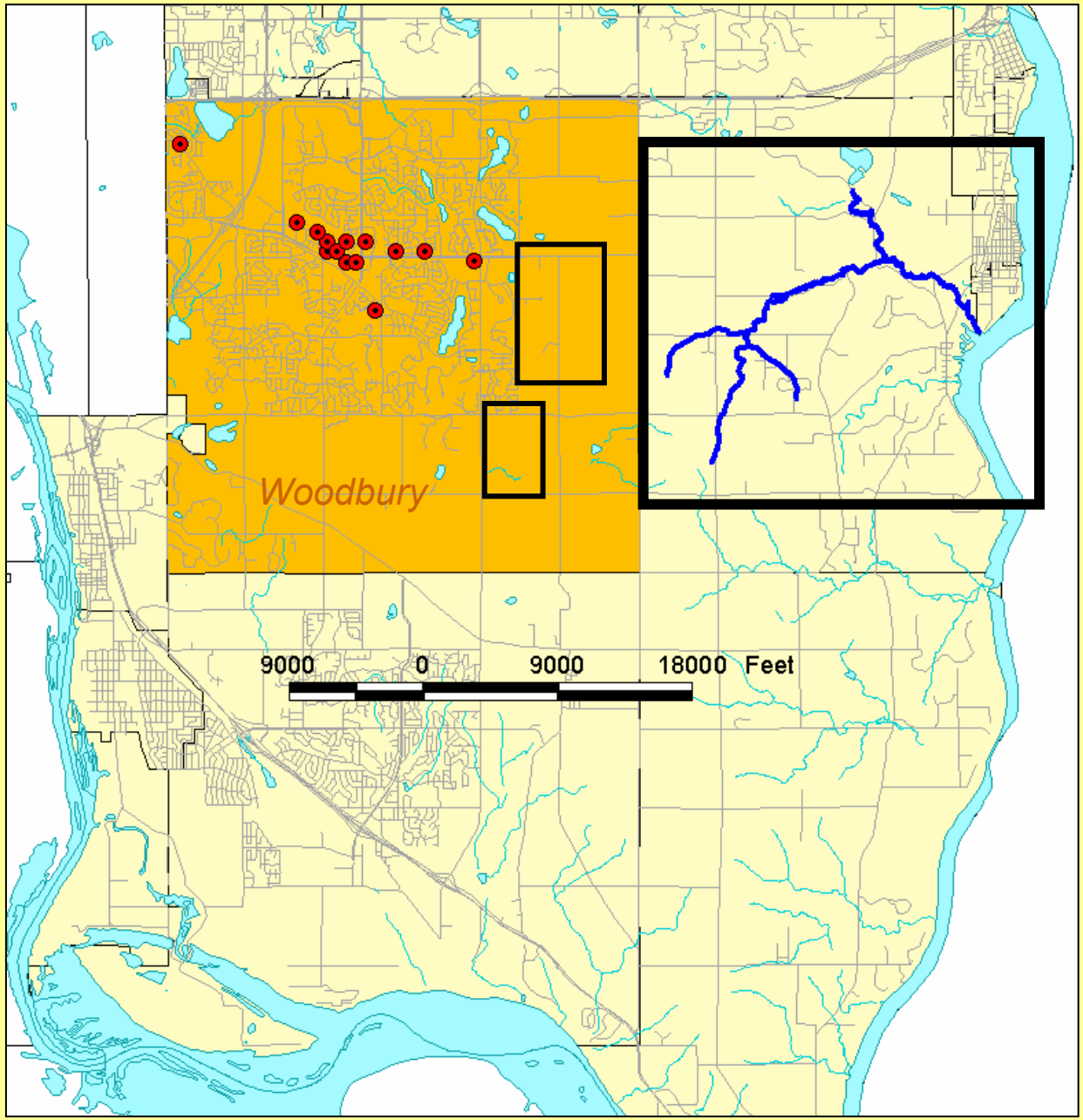

Valley Creek: Designated Trout Stream in City of Afton

A highly valued resource

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Mn. Rule 6115.016: the "current, course, or cross section" of a designated trout stream cannot be altered

Valley Creek

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The key question of "sustainability"

How will Woodbury's future pumping affect base flows in Valley Creek? ("scientific interest")

How many wells can Woodbury put in and how much can they be pumped? (City's interest)

How and where should we monitor to measure adverse effects? (regulatory interest)

Can groundwater resources support future growth in Washington County? (County and planning interest)

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Preliminary modeling suggested that the new wells would be a problem

- Pre-existing model used
- Steady-state pumping predictions indicated significant reductions in base flows of Valley Creek
- Extensive cone of depression

Questions arose about the applicability of the models for the problem at hand

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The agreed-upon approach:

- Woodbury would be allowed to construct a new well (Well 15) and conduct an extensive aquifer test
- A new groundwater flow model would be constructed and calibrated *to specifically address the issues of sustainability*
- Simulations would be performed to evaluated 3 new wells
- Re-evaluation of understanding would be on-going

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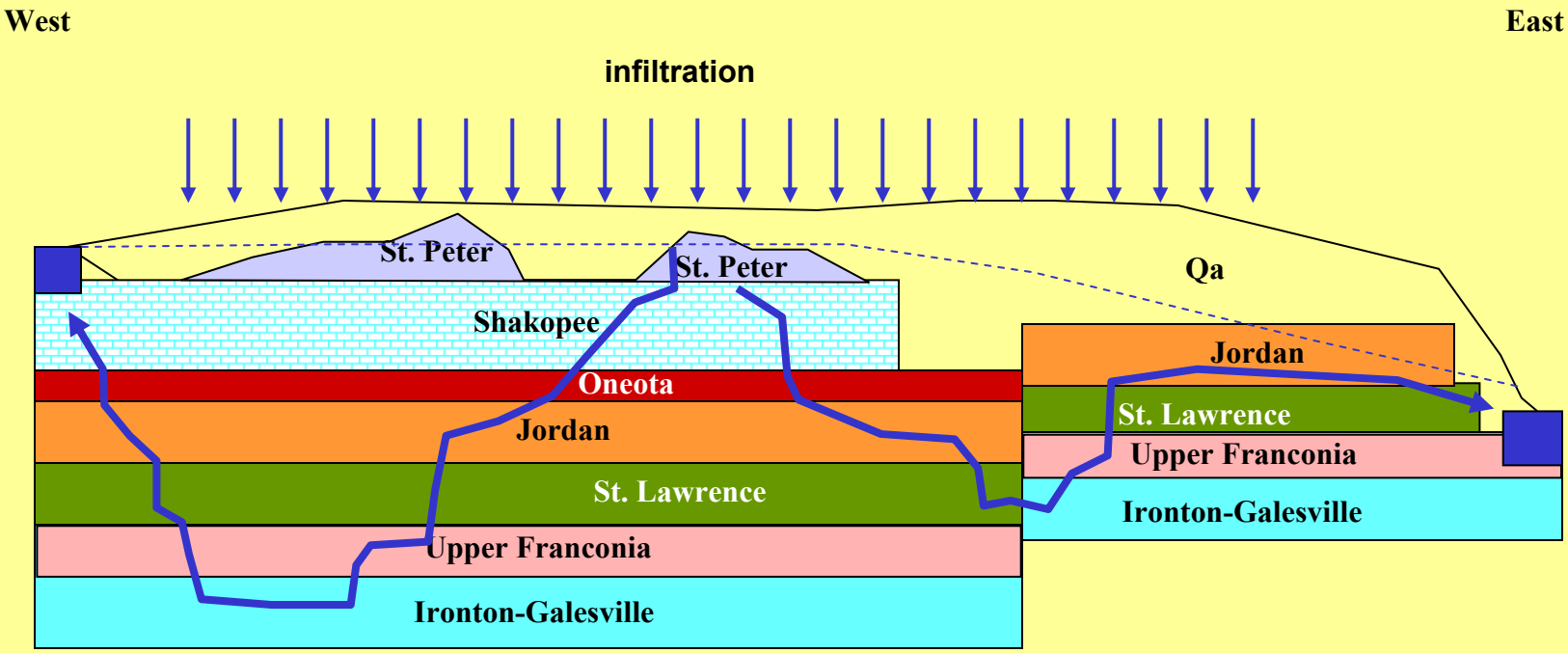
Schematic Hydrogeologic Cross Section



assumes no interaction with Eau Claire Fm. or Mt. Simon-Hinckley aquifer

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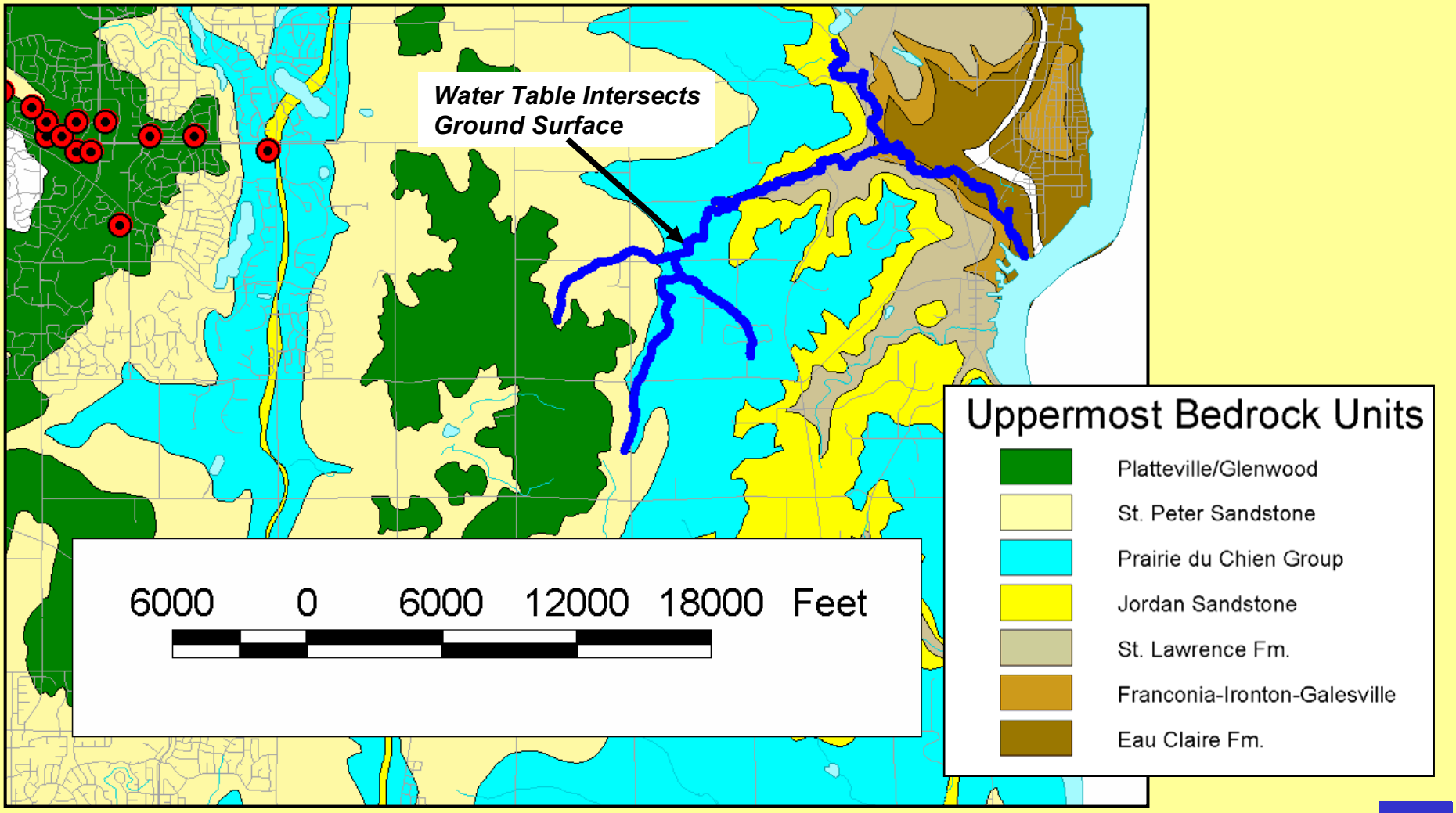
Valley Creek Intersects Several Bedrock Aquifers



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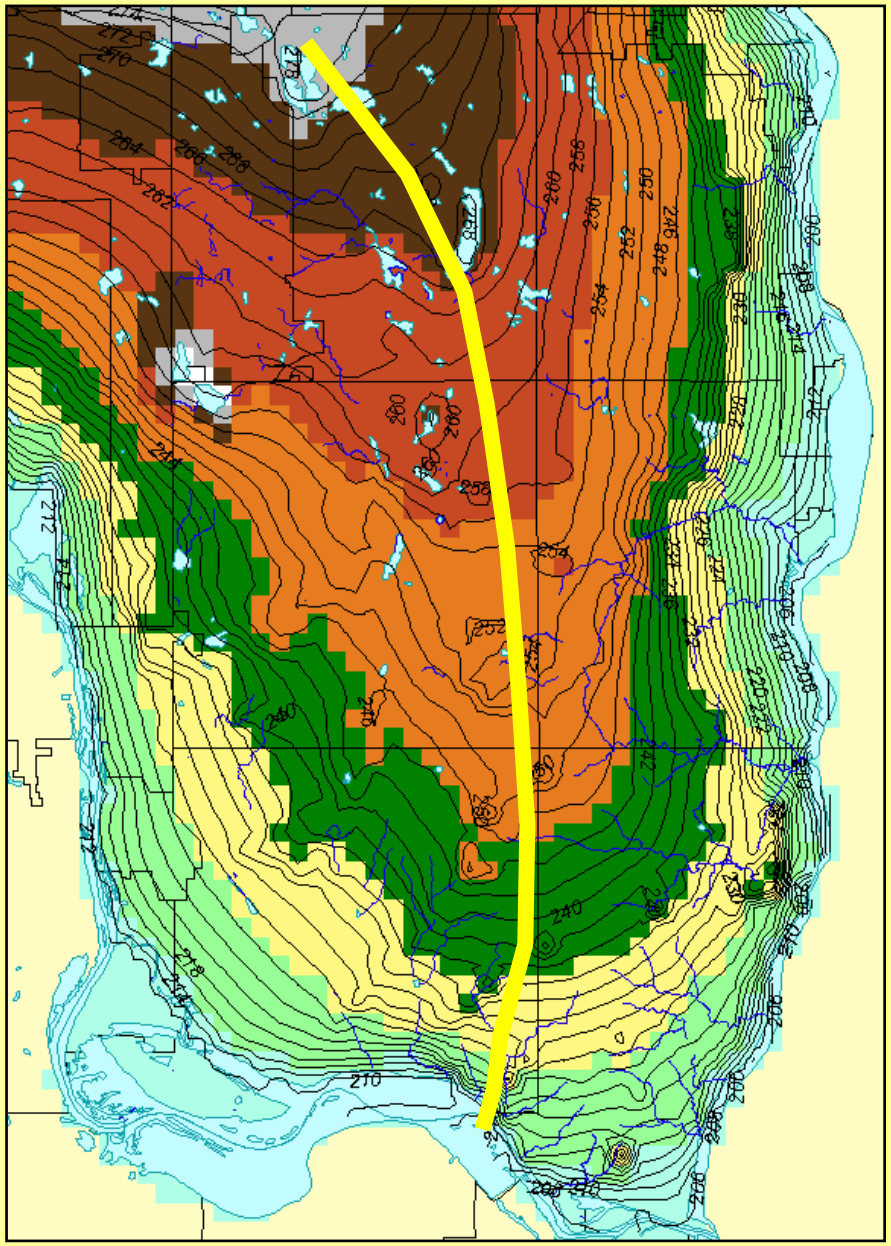

Potentiometric Surfaces Reflect Groundwater Divide Along Axis of County

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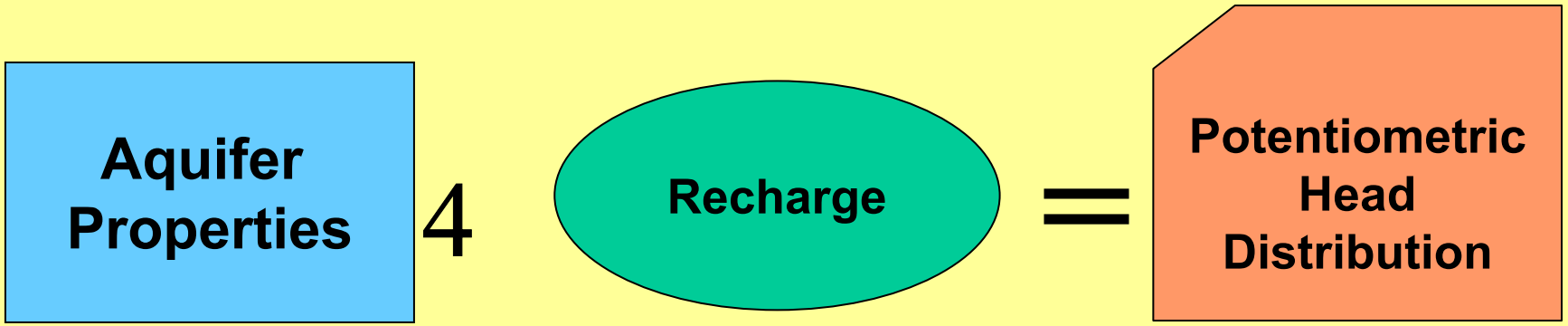
Estimating Recharge by the "Inverse Problem" Approach



I "know" this from Aquifer Tests

I vary this between 0 and annual precipitation

Results in a large range of "calibrated" recharge values – not a unique solution

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Our goal was to attempt to better estimate recharge

- First, optimize groundwater model in conventional manner
- Then, deterministically model surface hydrology processes that lead to infiltration
- Constrain Recharge and re-optimize model

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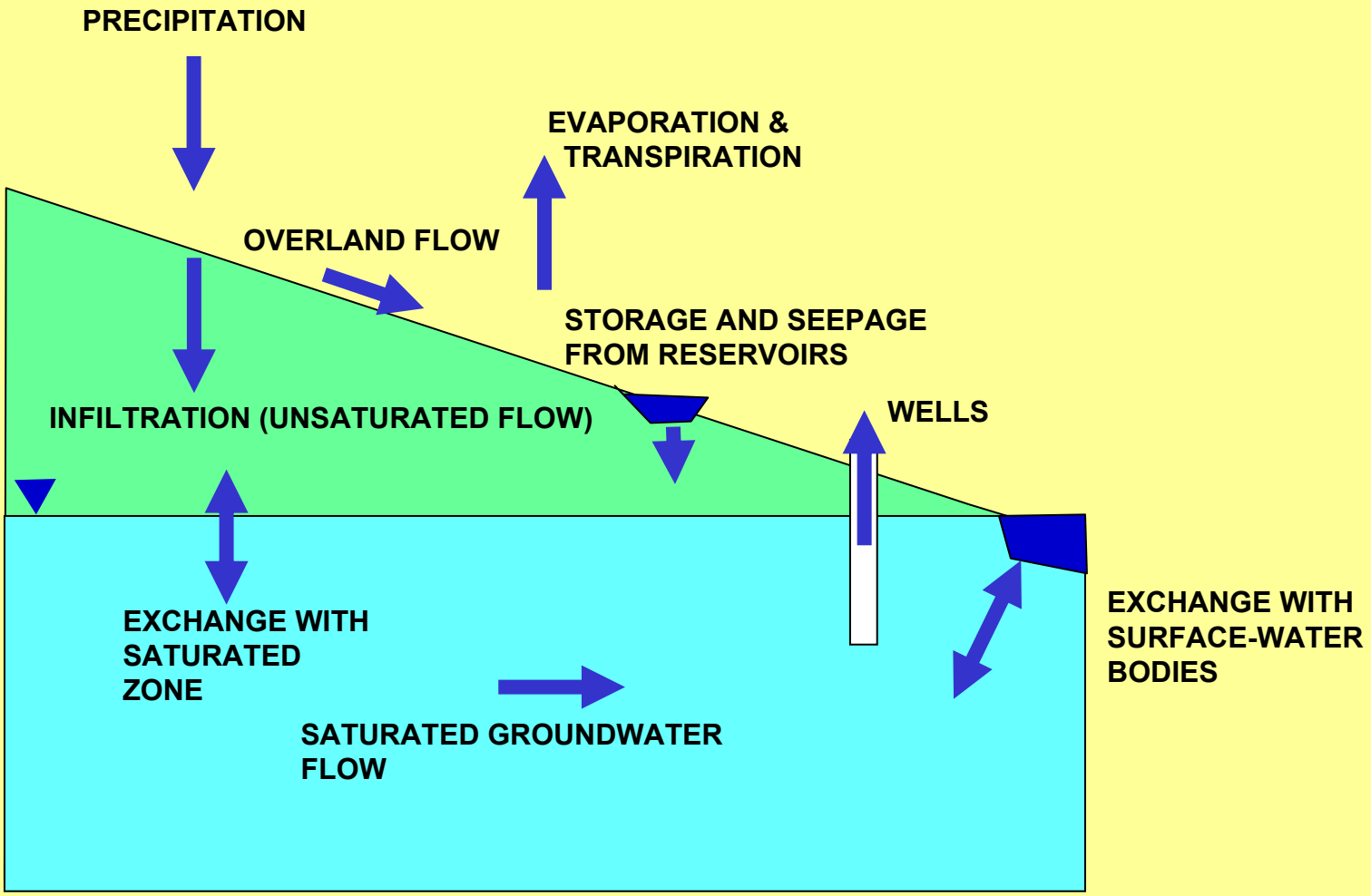
Conceptual Model of Processes



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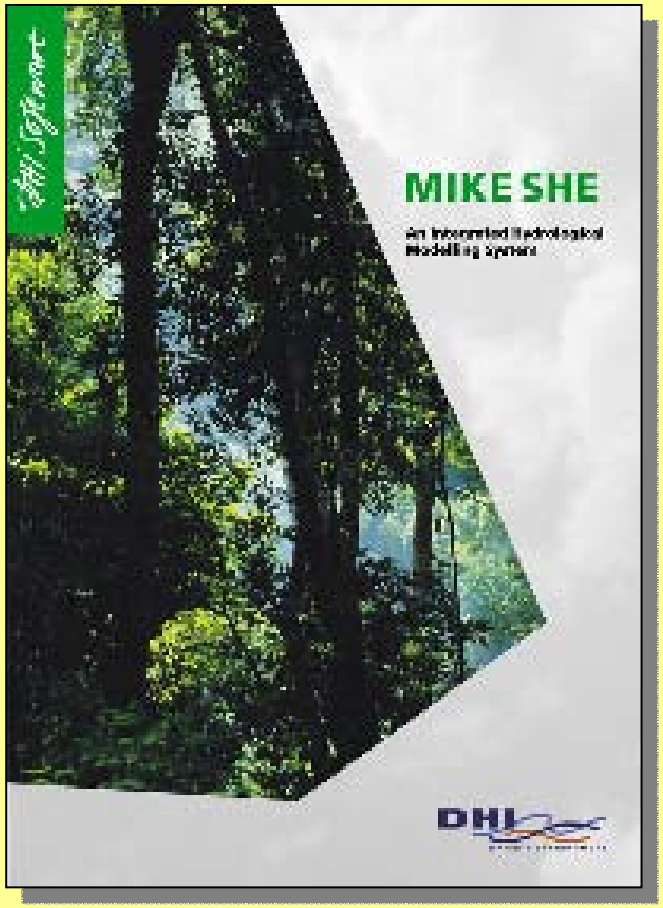
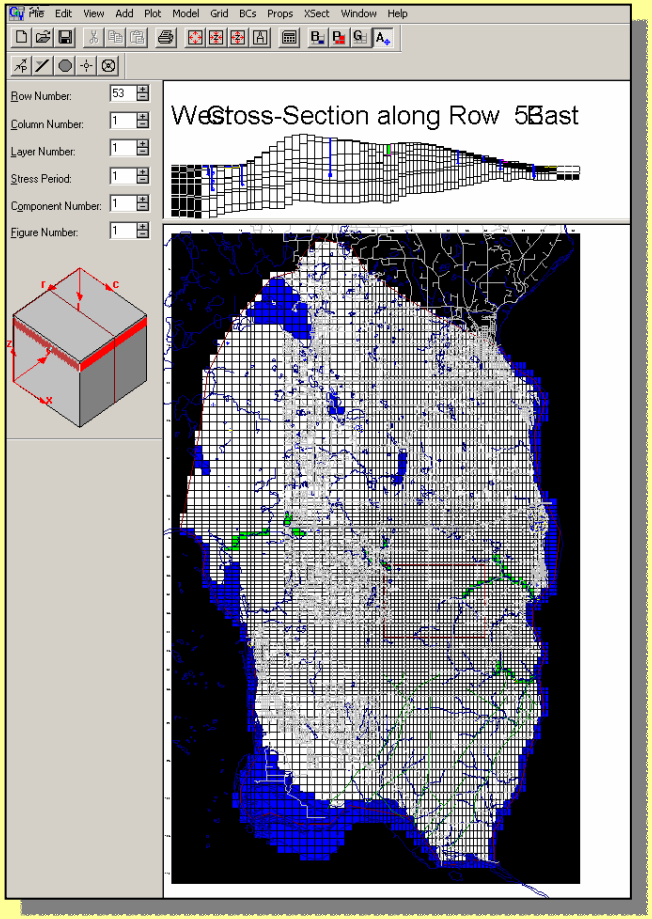
Two Modeling "Codes" Used: MIKE SHE and MODFLOW





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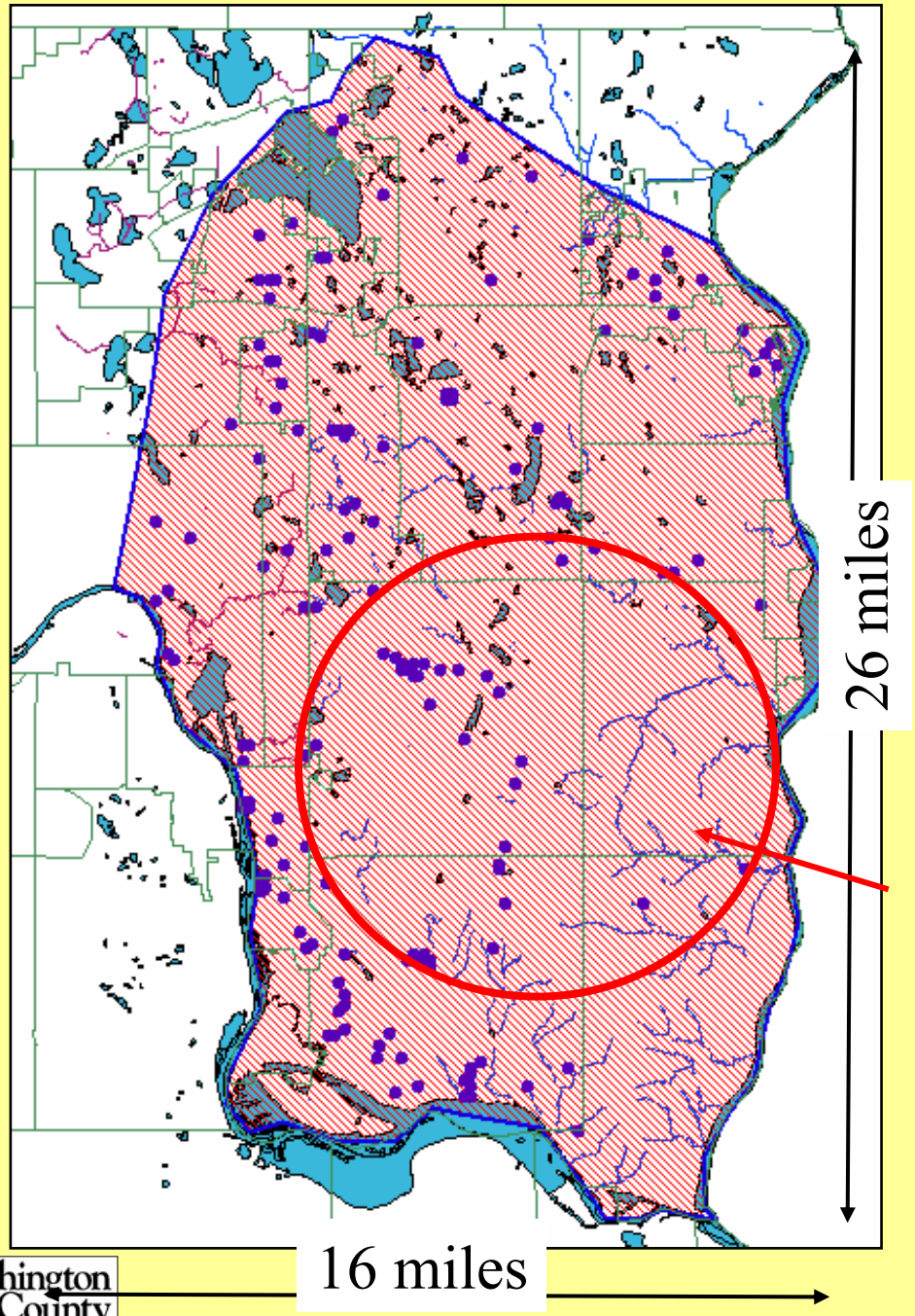

Model Domain:

The Areas of interest

primary area of interest

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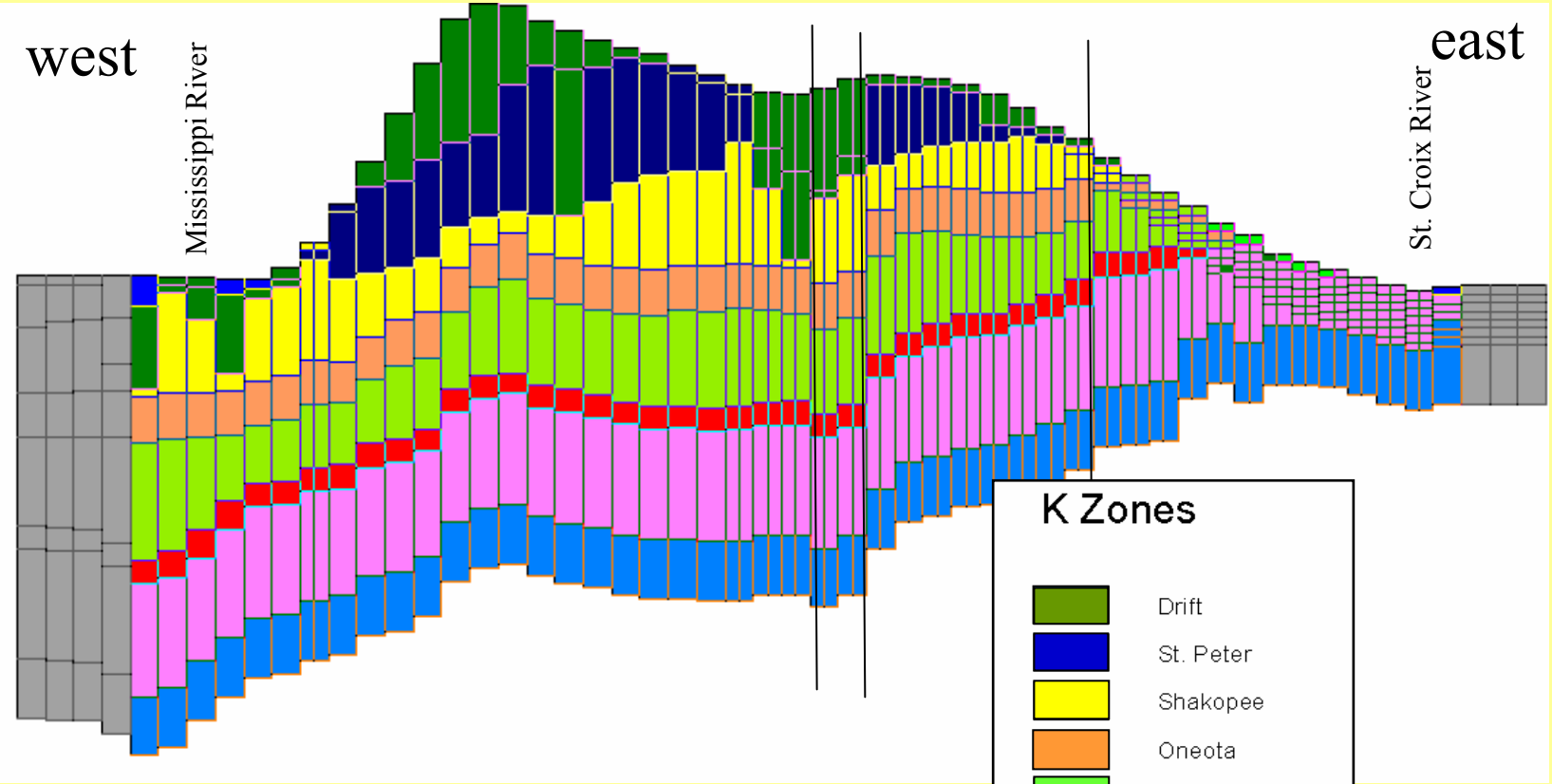
East-West Cross Section Thru Valley Creek Area, Showing Parameter Zones



(inactive cells are gray)

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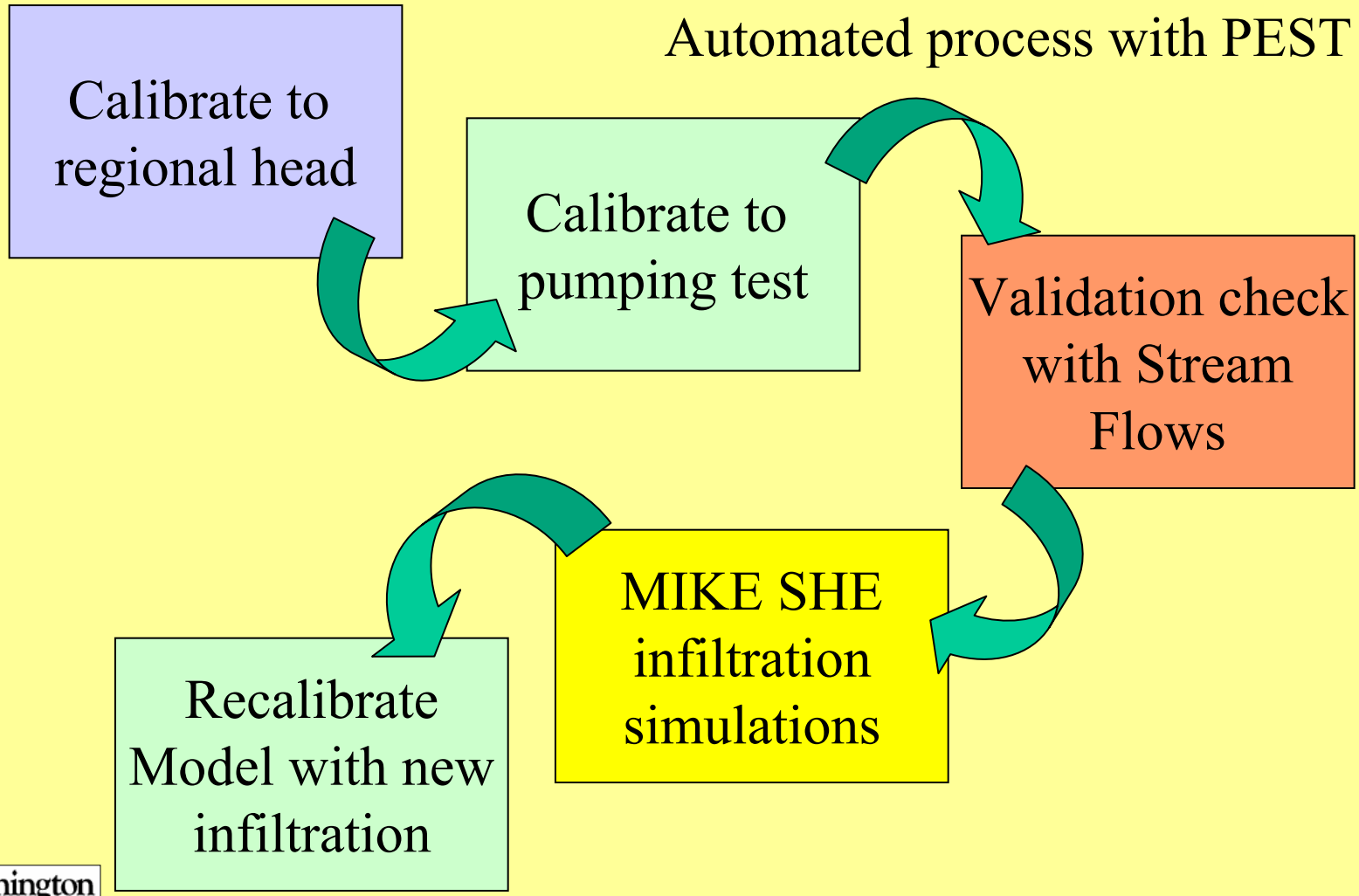
The groundwater model calibration process



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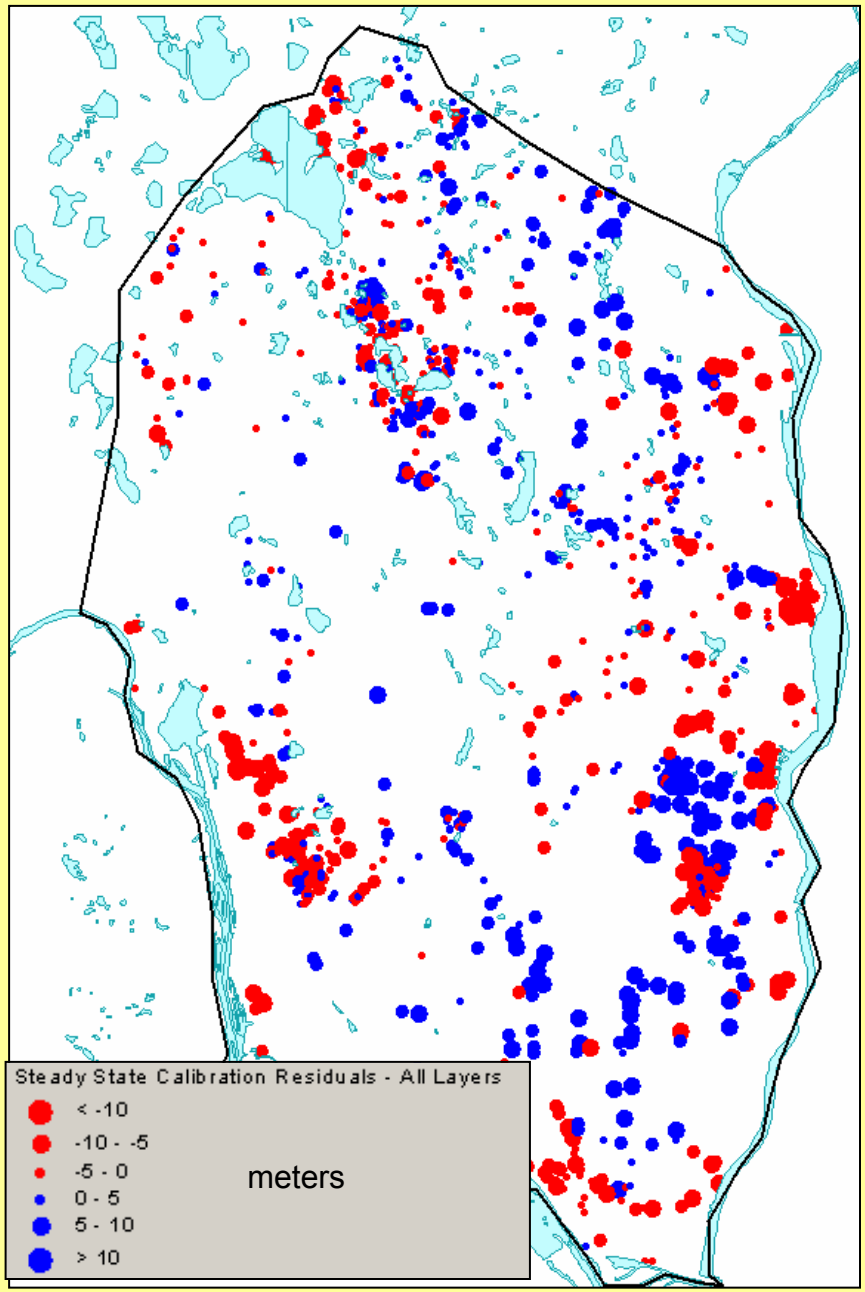

Steady-State Calibration Targets

- 1,132 Steady-State Head Targets (equally weighted)
- 32 parameters (later reduced to 18) – primarily Kx and Kz (zones, not pilot points)

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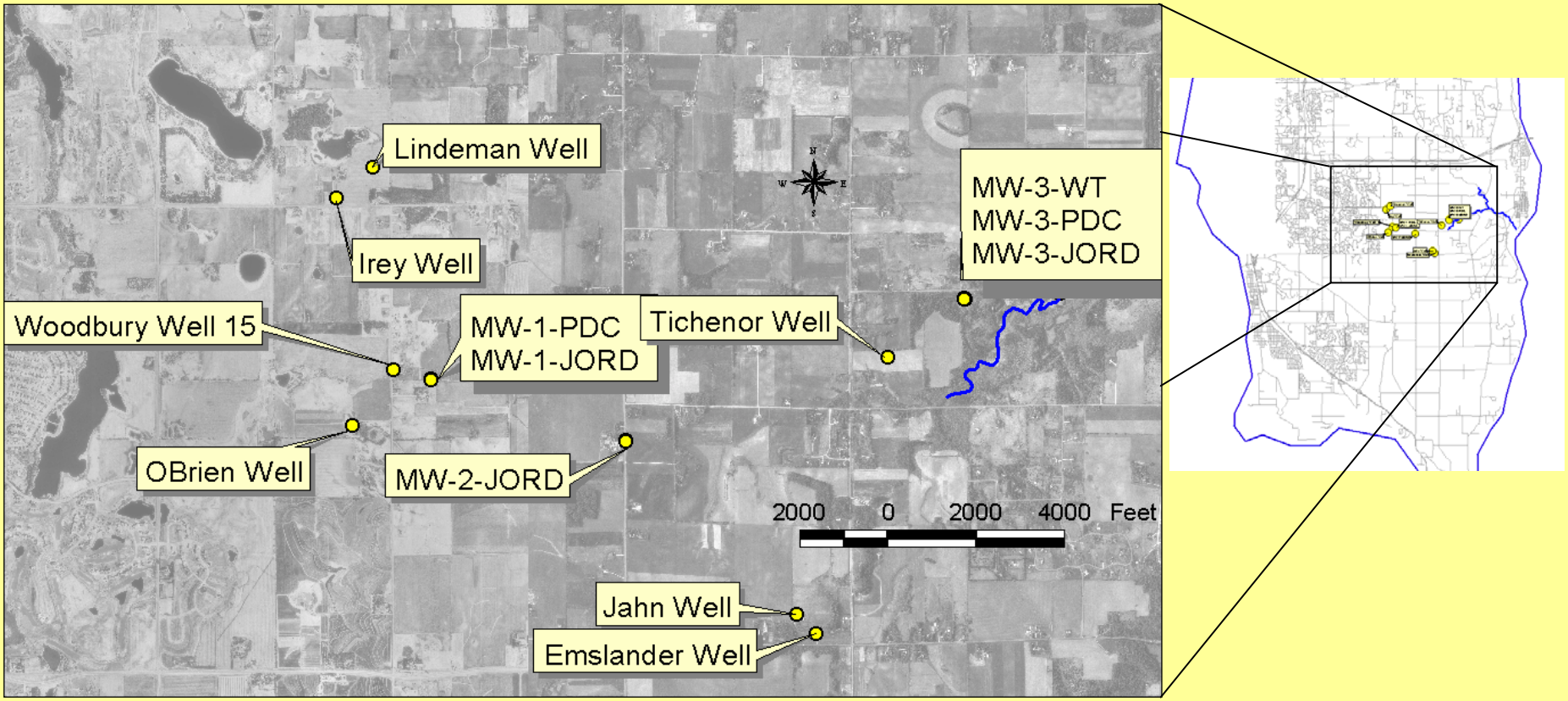
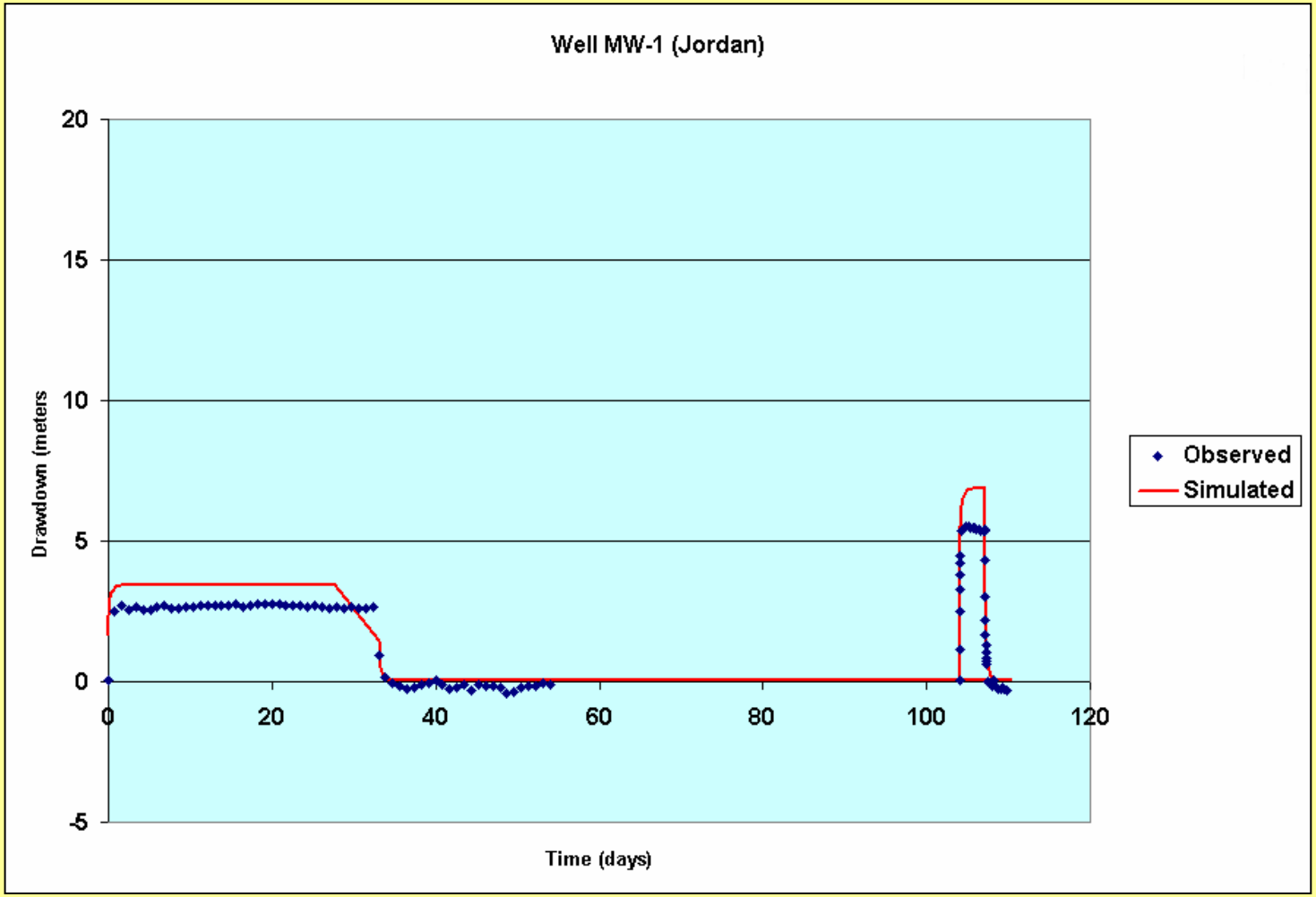
Optimization to Woodbury Well 15 Pumping Tests



72 hr test and 30 day test (Bonestroo Rosene Anderlik & Assoc.)

MW-1 (Jordan) Drawdown – simulated and observed



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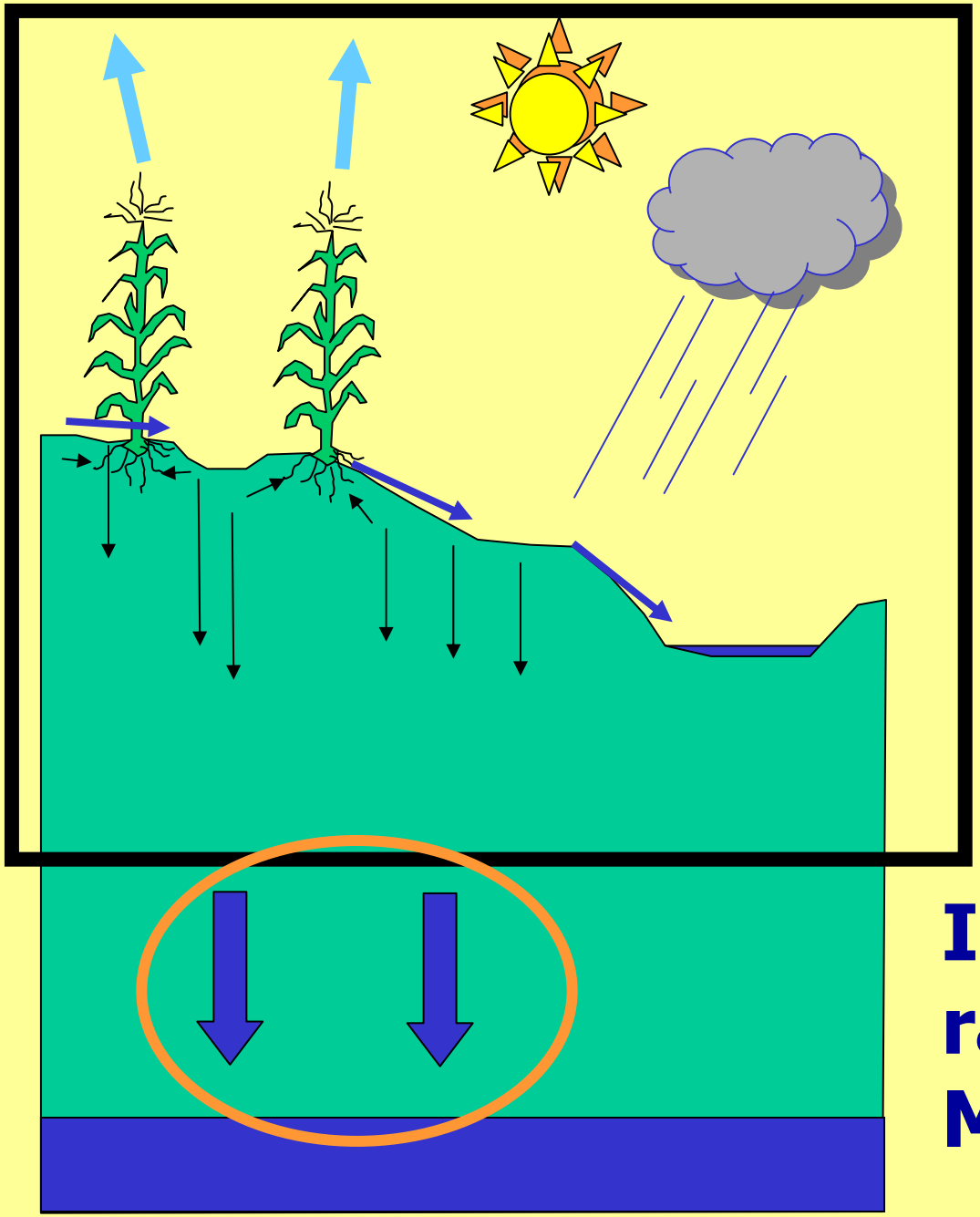

MIKE SHE Processes

Infiltration rates to MODFLOW

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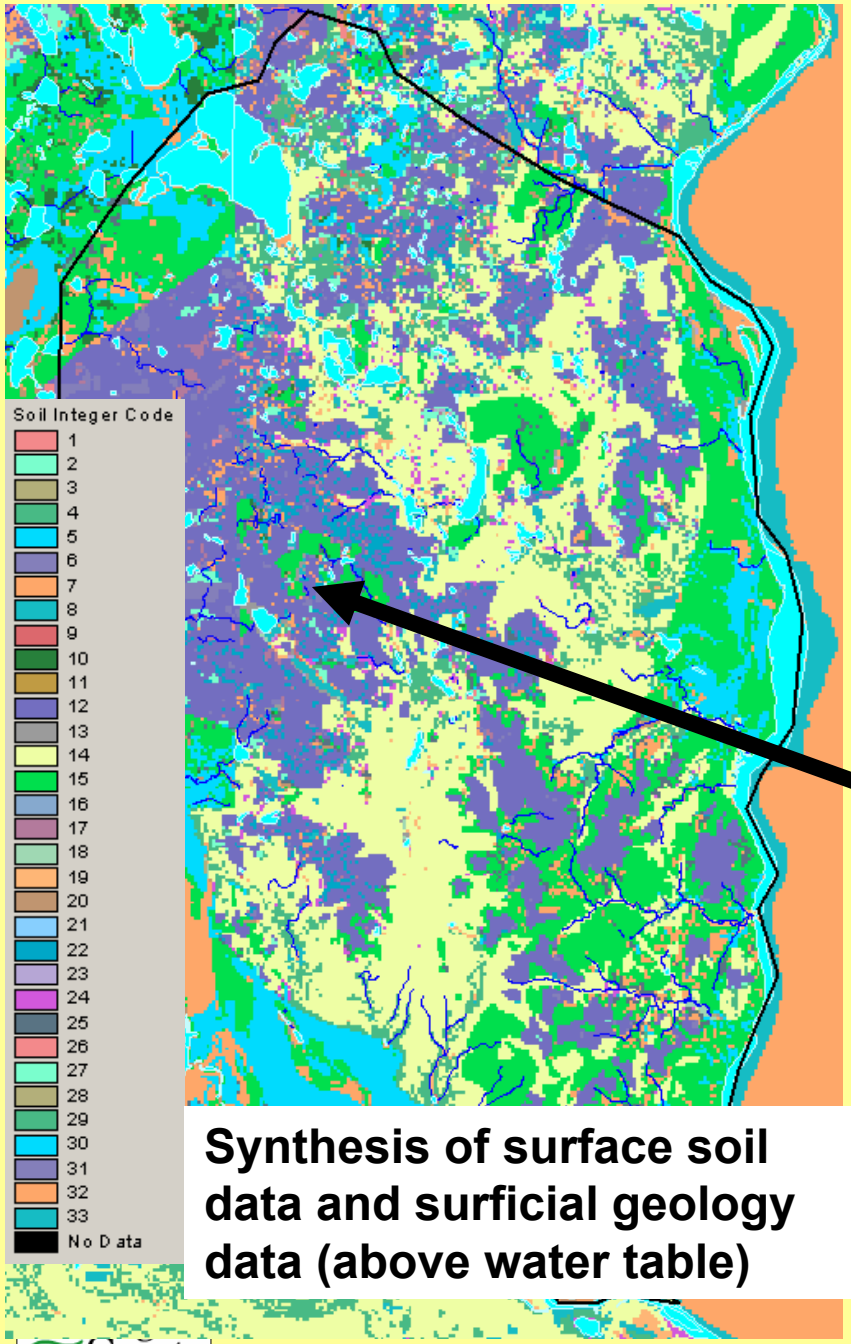
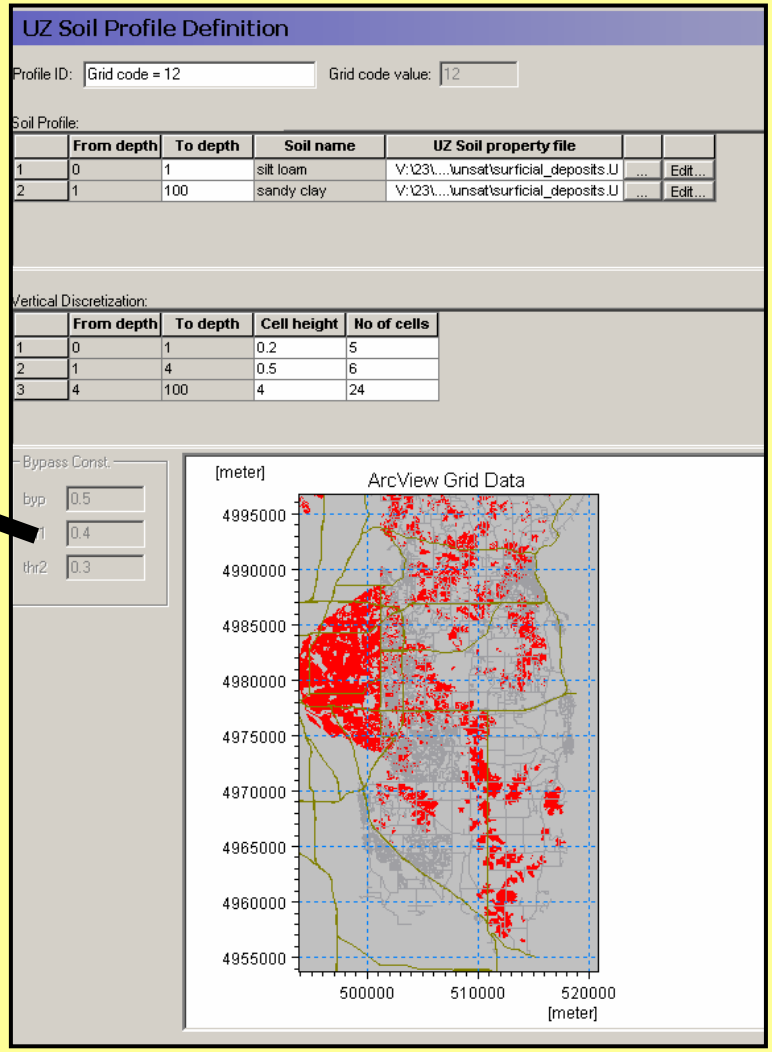
Soil Grid Integer Code



Synthesis of surface soil data and surficial geology data (above water table)



(for Unsaturated Flow)

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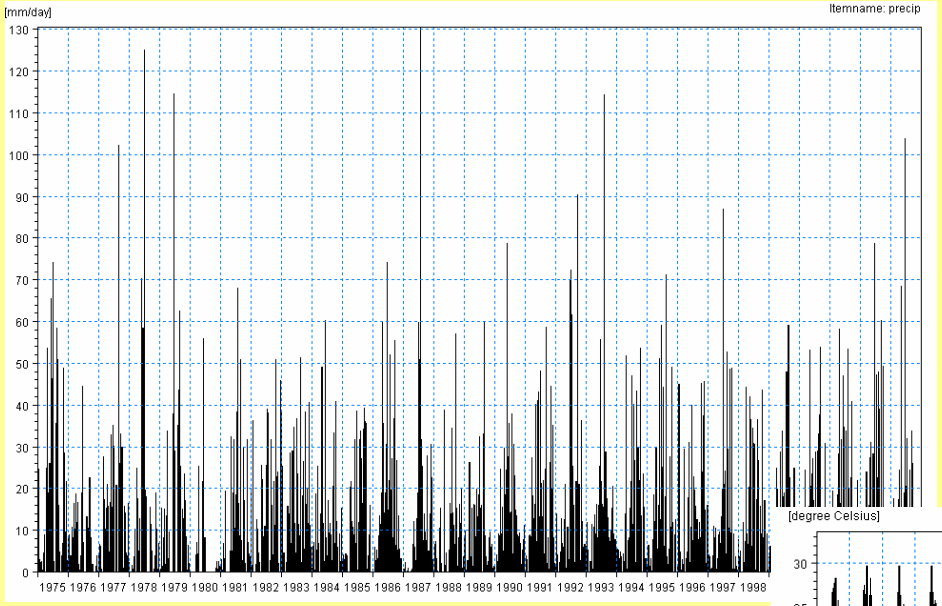
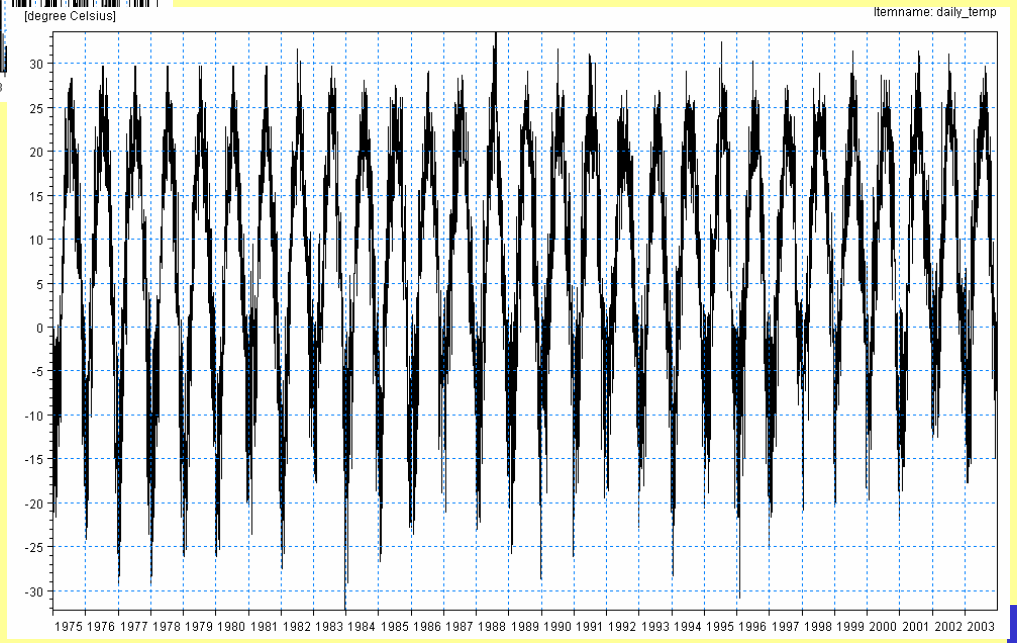
Daily Precipitation & Temperature Data from St. Paul Metro Site (1975-2003)



precipitation



temperature

(for Evaporation, Transpiration, and Snow Storage)

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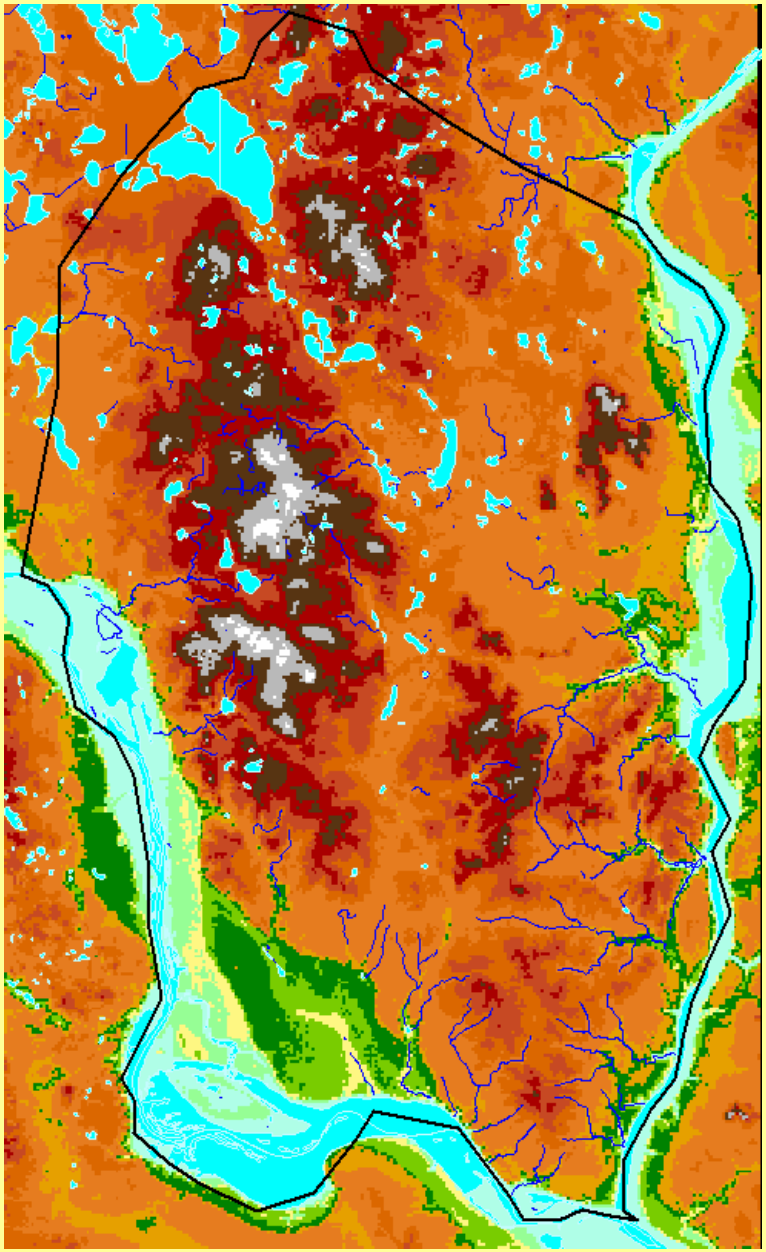
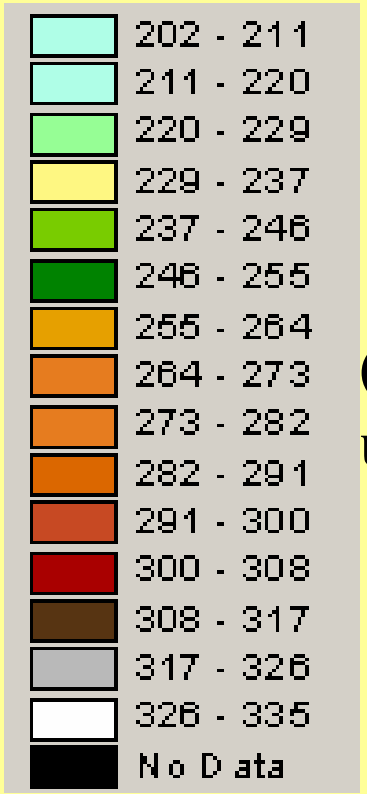


100-m grid ground surface elevation (m, MSL)



Calculated from:

1. 20-m grid of Washington Co.
2. DEM (30-m)

(for overland flow and unsaturated flow)

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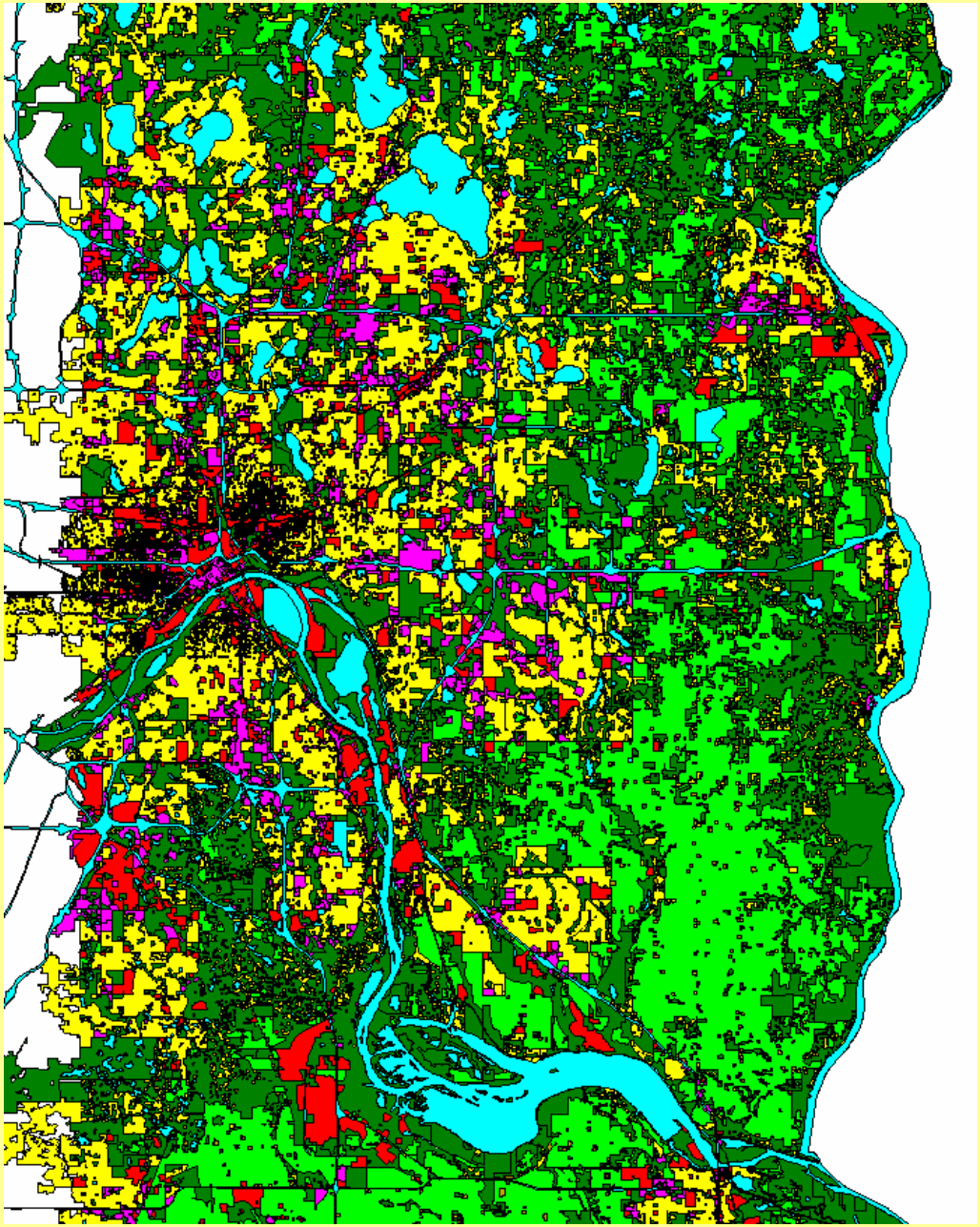

7 Main Land-Use Types for Identifying Vegetation

- CORN/SOY BEAN
- SINGLE FAMILY RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- FARMSTEADS
- PARK LAND
- OPEN WATER & PAVED

(for calculating evapotranspiration)

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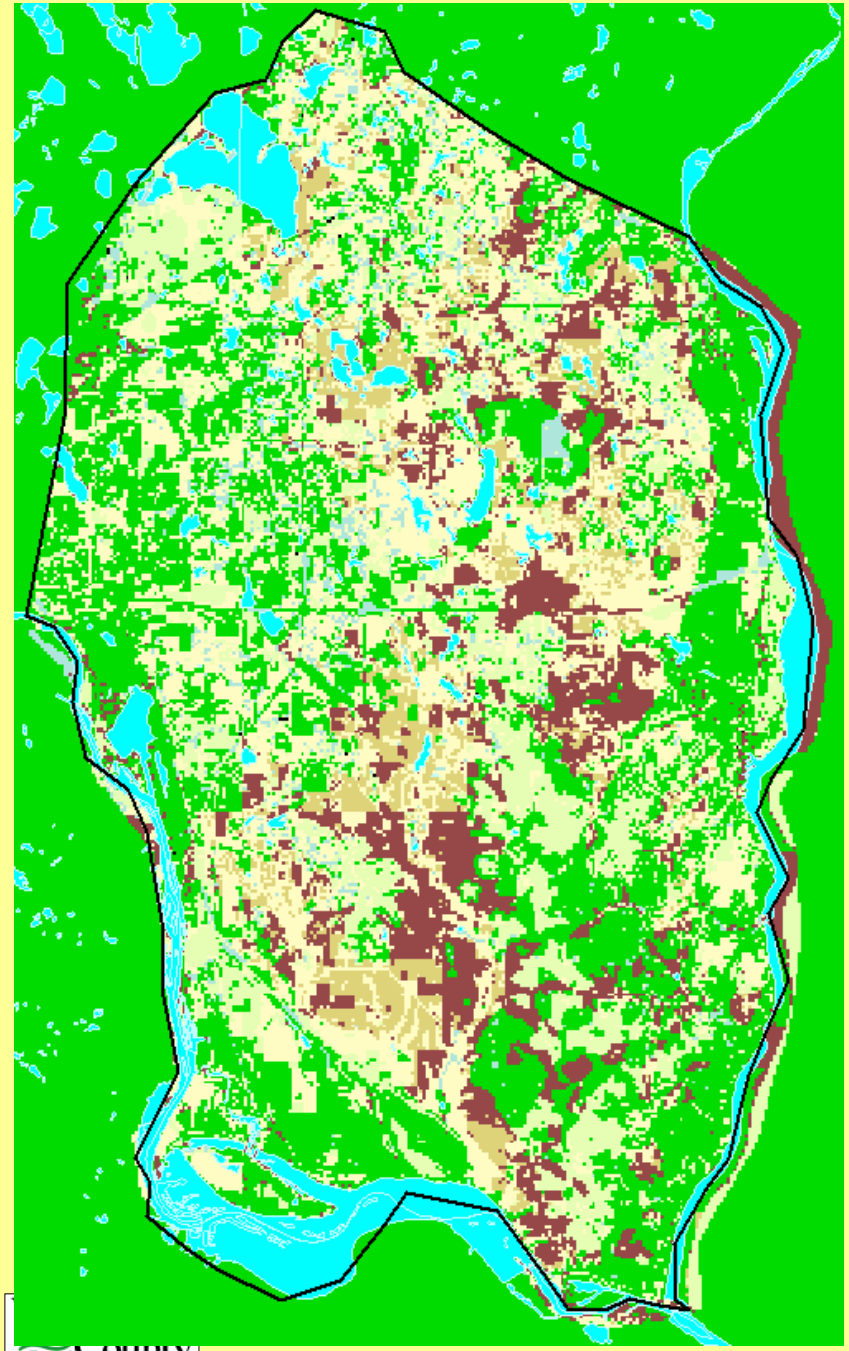
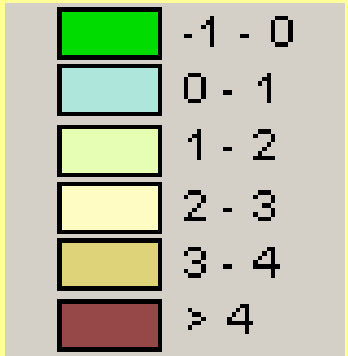


Difference in Annual Infiltration: Typical Year vs 1988

1988 Annual total/model domain = 6.67 in/yr

Typical Year Annual total/model domain = 8.67 in/yr

in/year



positive values indicate more infiltration during typical year

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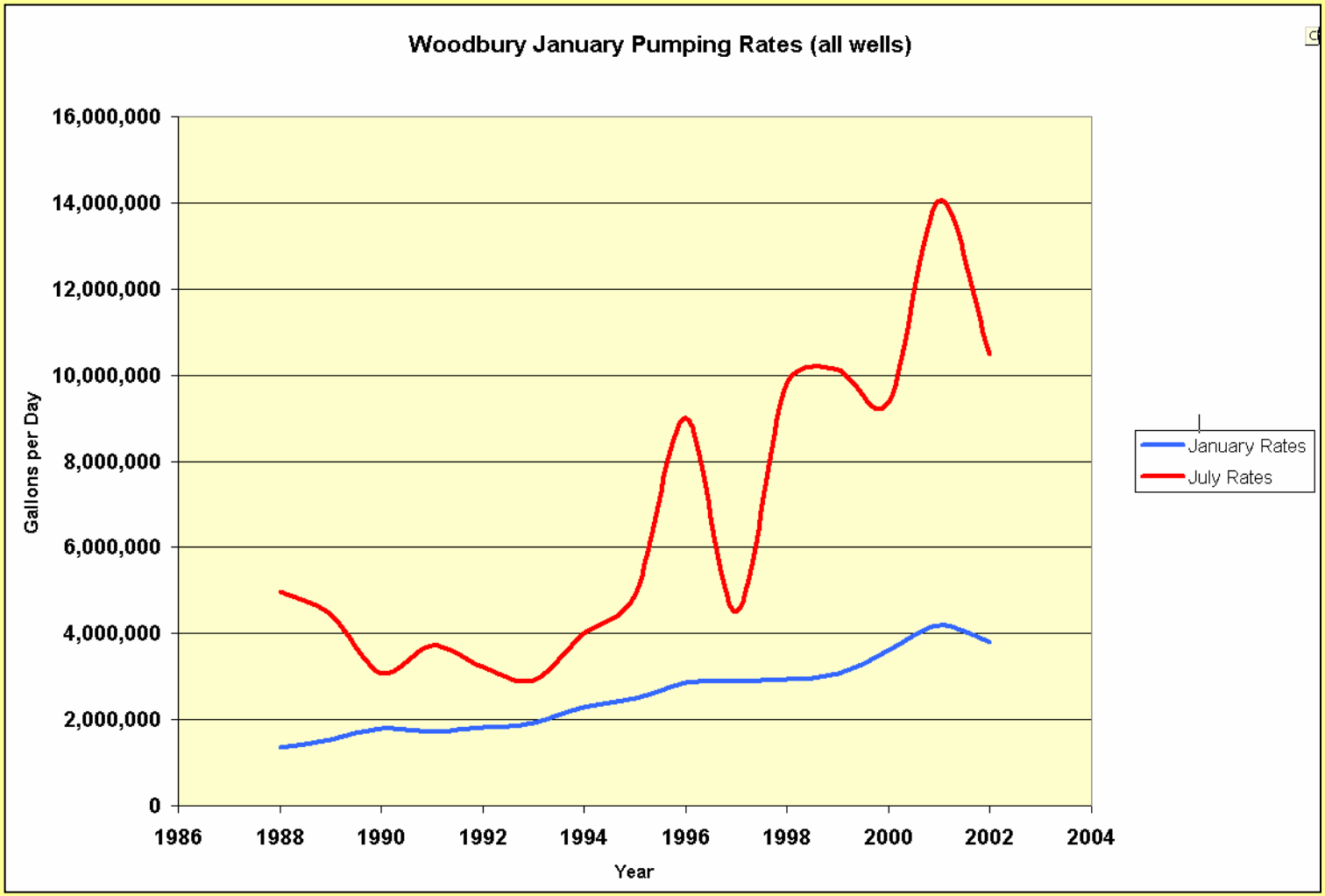
Seasonal Pumping Highly Dependent Upon Weather



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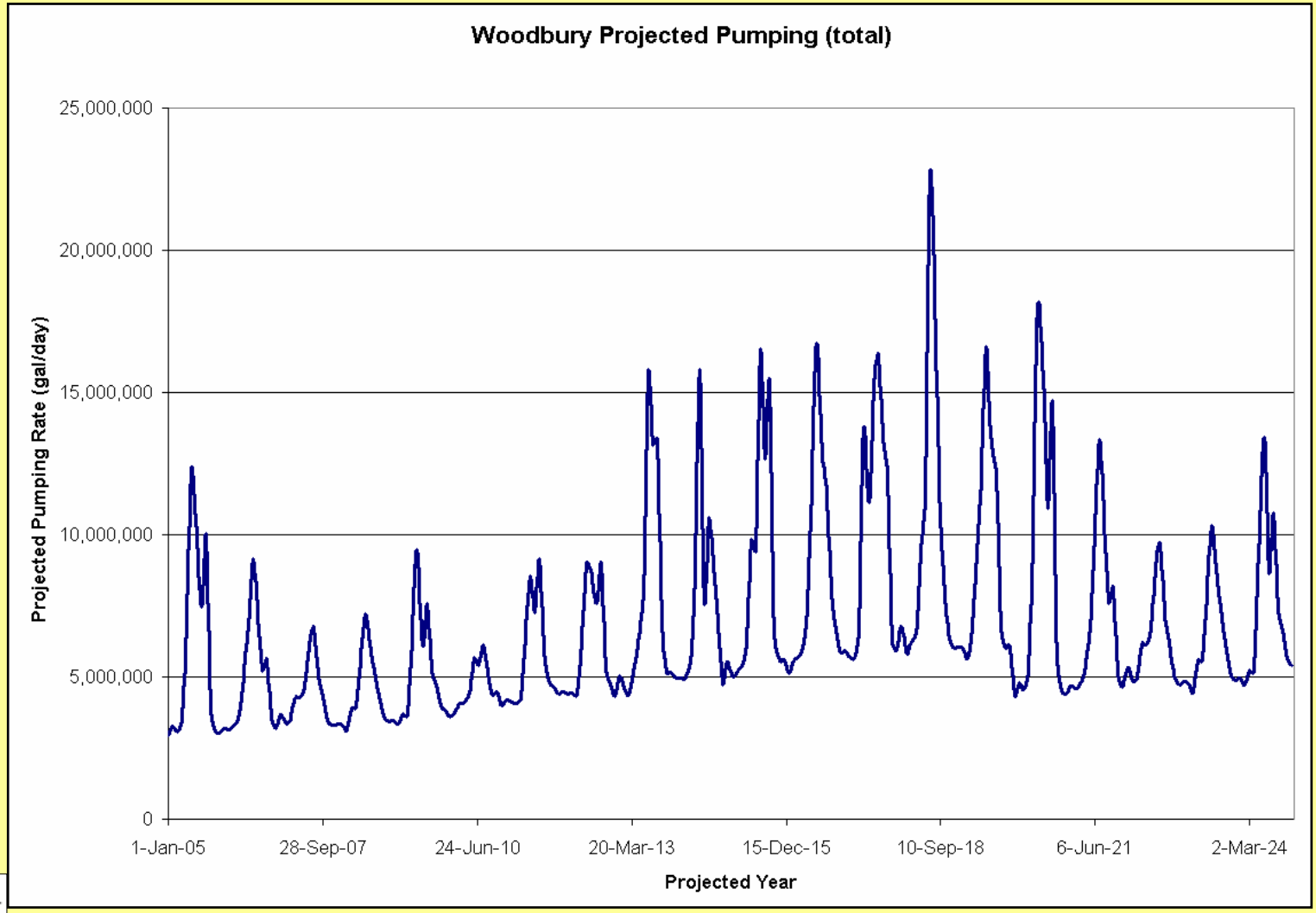
Future Pumping Projected on Basis of 1988-2002 Climate Data



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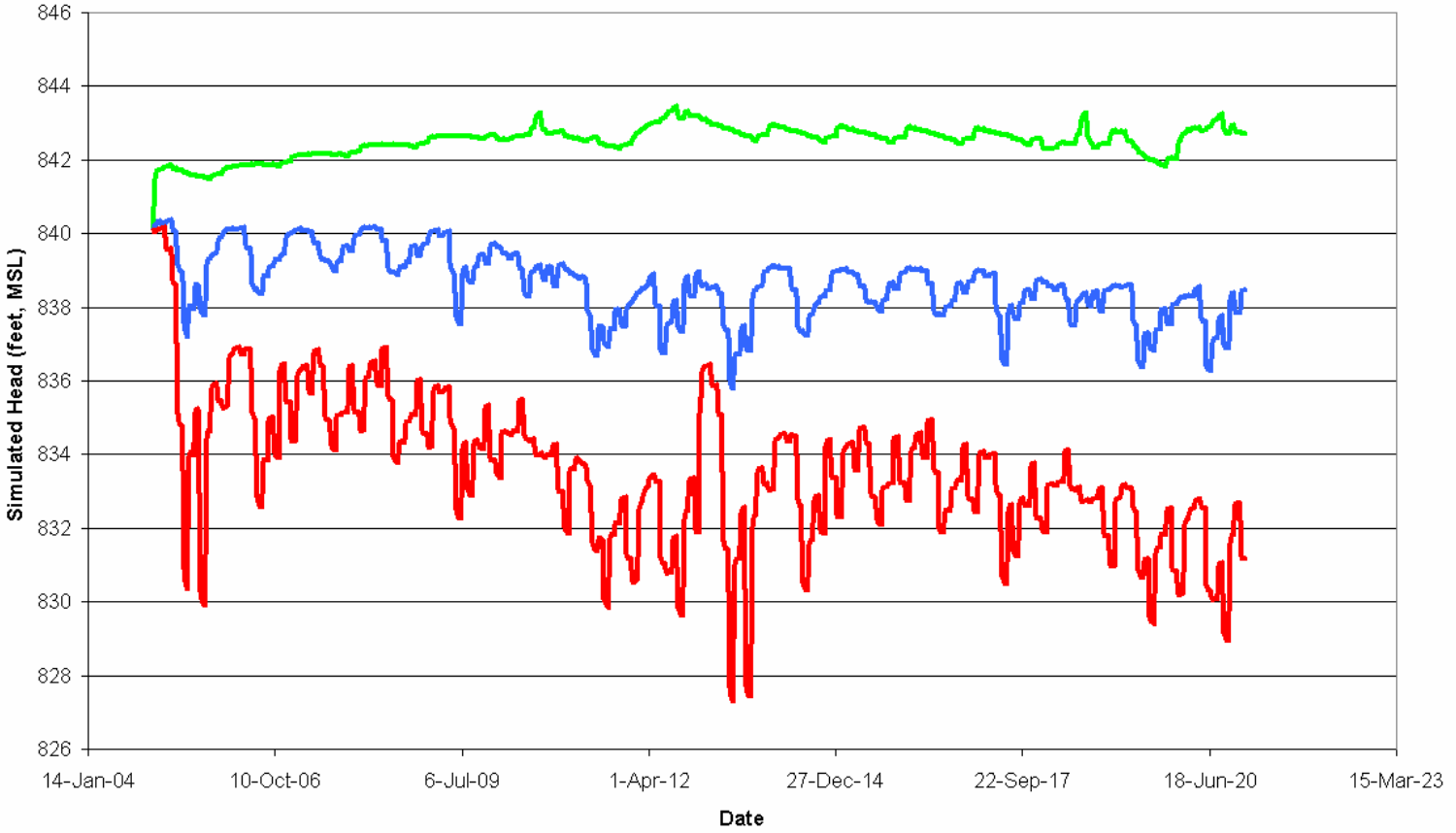
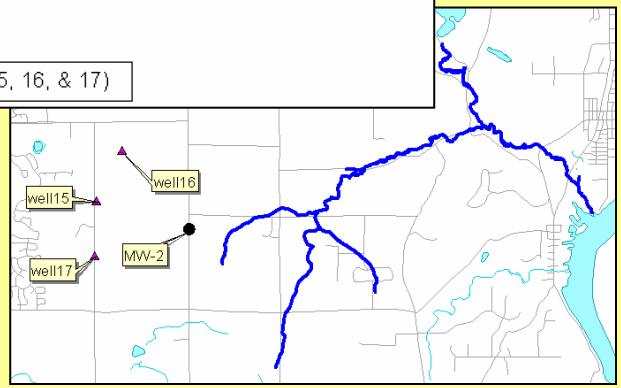
Projected Head in Jordan Sandstone at MW-2





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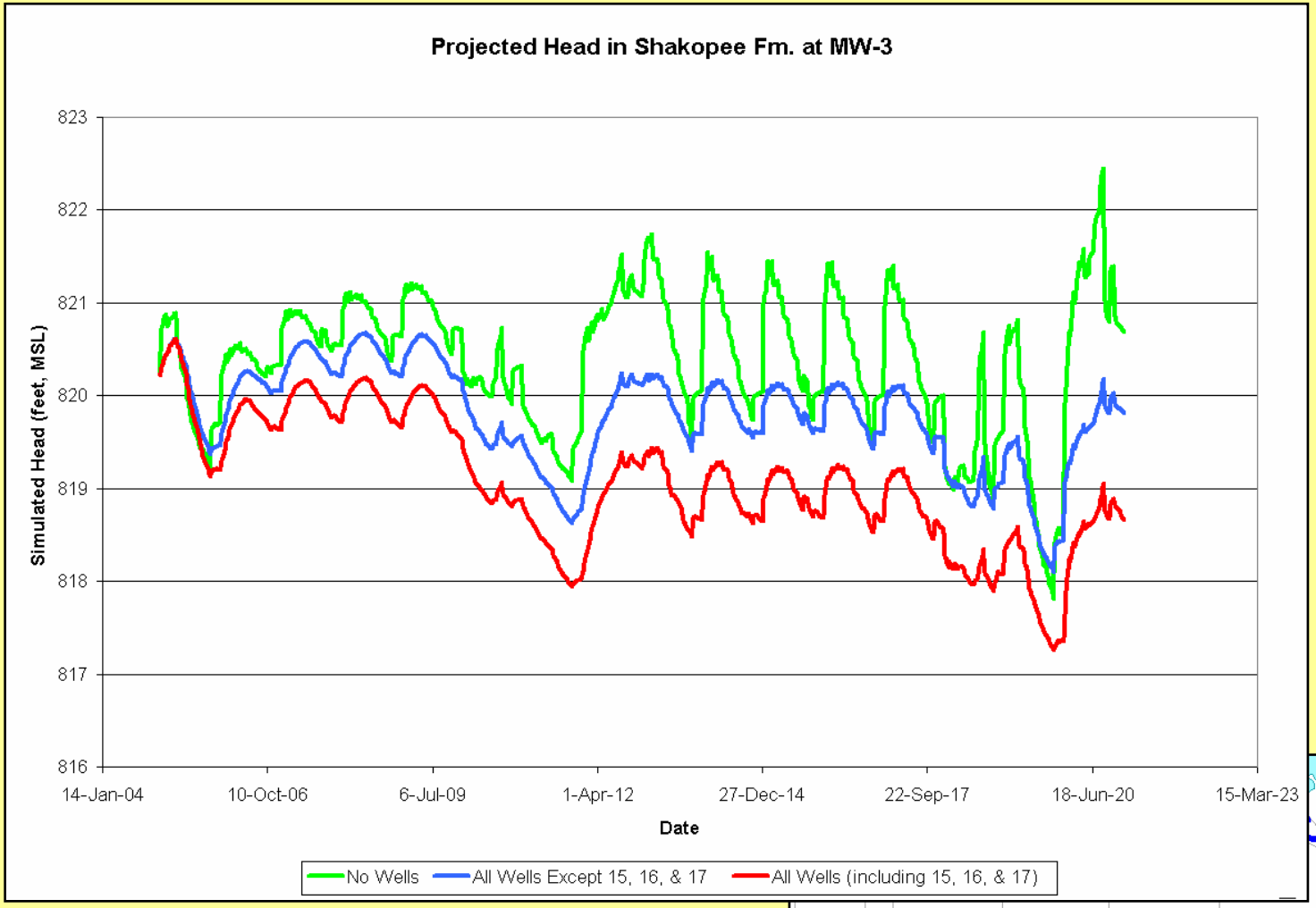

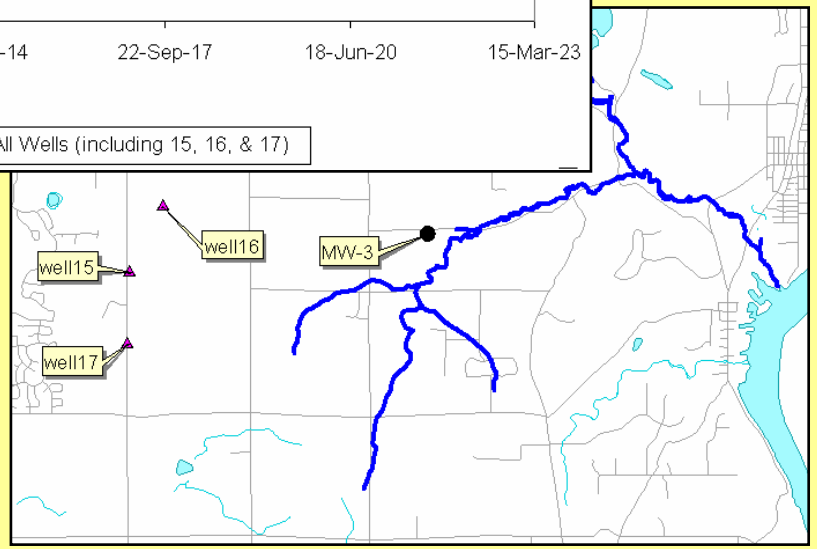

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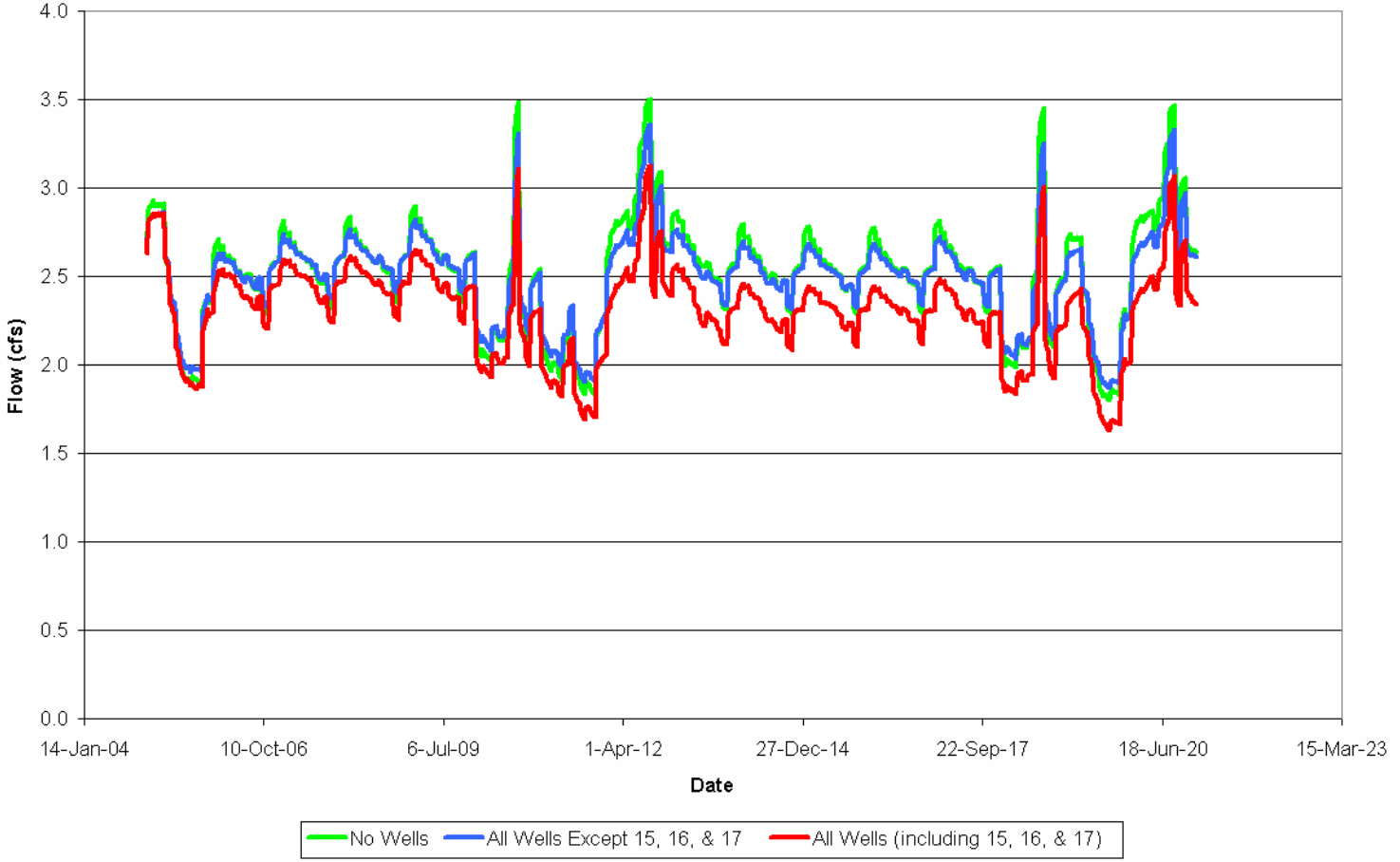
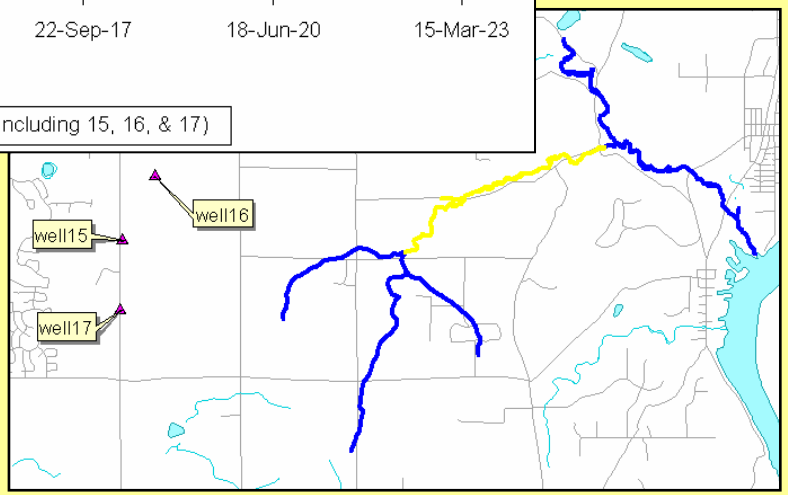
Projected Base Flows in Valley Creek - South Branch





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What are these model results saying?

- Effects of 3 new Woodbury Wells on Valley Creek Base flows will be unmeasurable
- Base flow fluctuations from seasonal and climatic conditions are far more important
- Fluctuations in hydraulic head near Valley Creek will not be diagnostic for determining effects (with 3 wells)

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What *might* this be saying about using models to evaluate sustainability?

- Conservative assumptions = wrong assumptions
- Water demand is important – consider pumping schedules, rather than averages
- Be careful about using partial flow systems – recharge affects deep aquifers

Sustainability is a Value Judgment

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