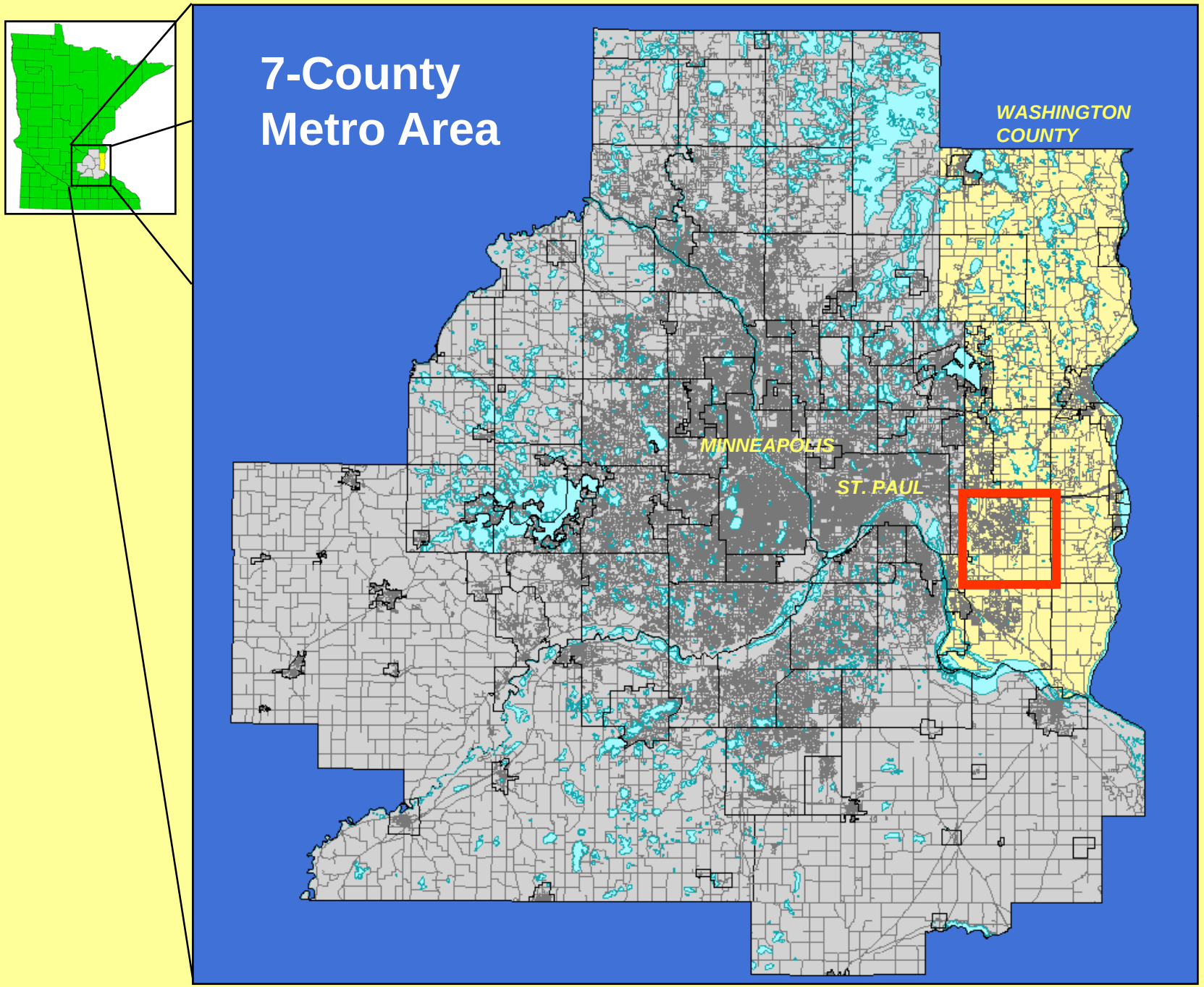
Predicting Response of Baseflow in Valley Creek to Proposed Pumping in Woodbury, MN

Ray W. Wuolo

Barr Engineering Company, Minneapolis

May 2009

BARR



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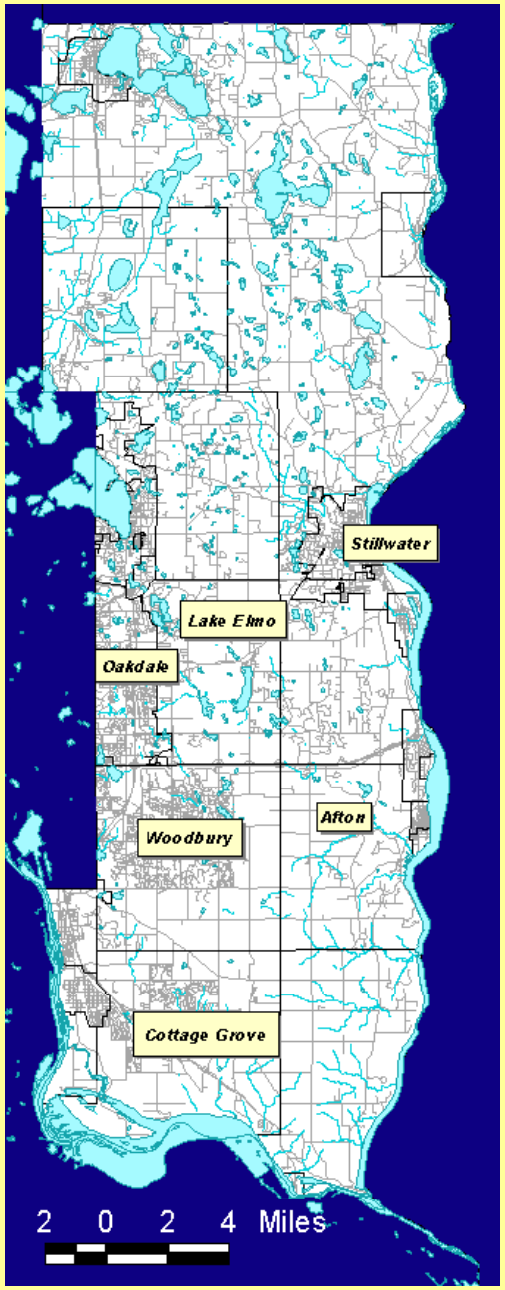

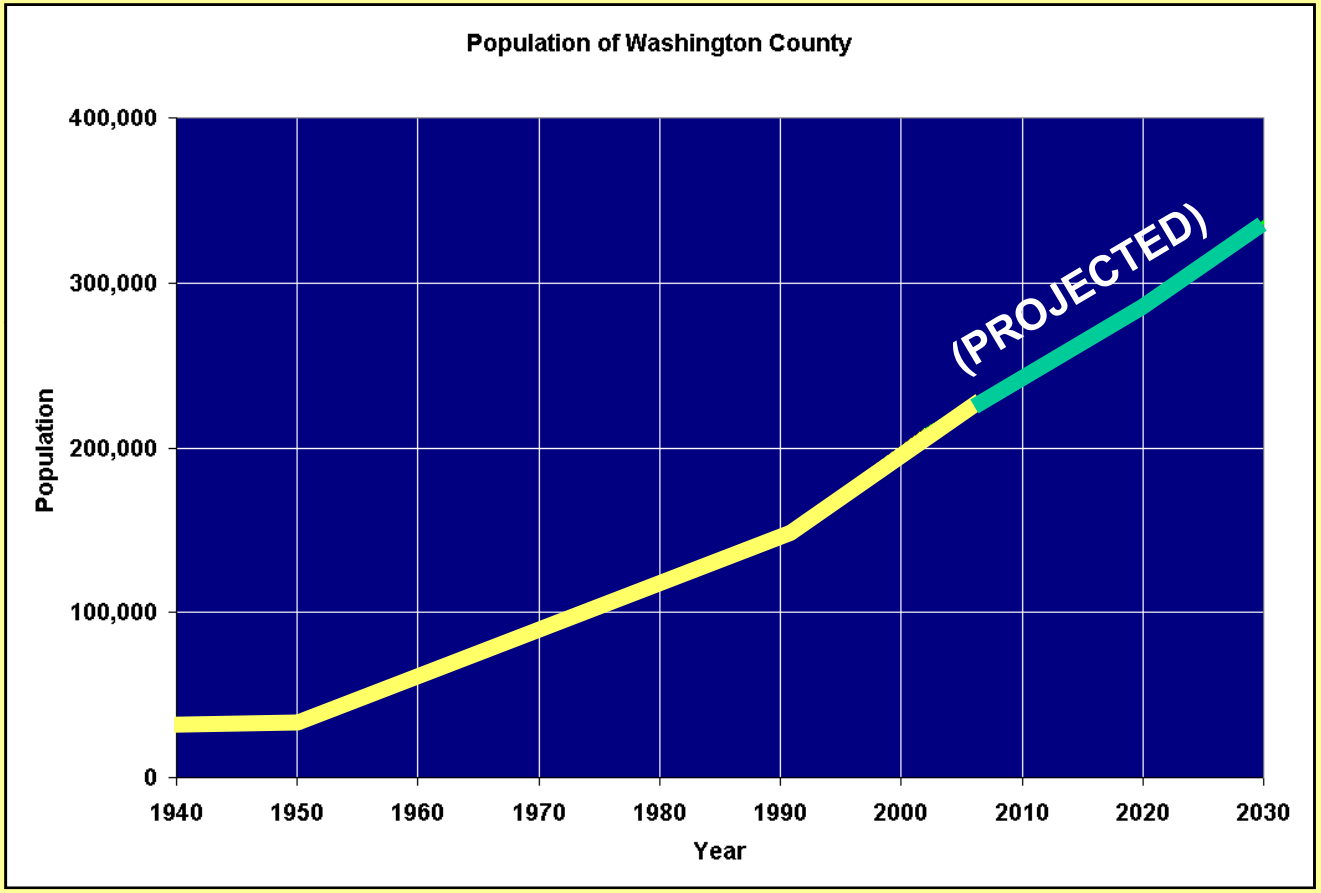

Source: U.S. Census Bureau

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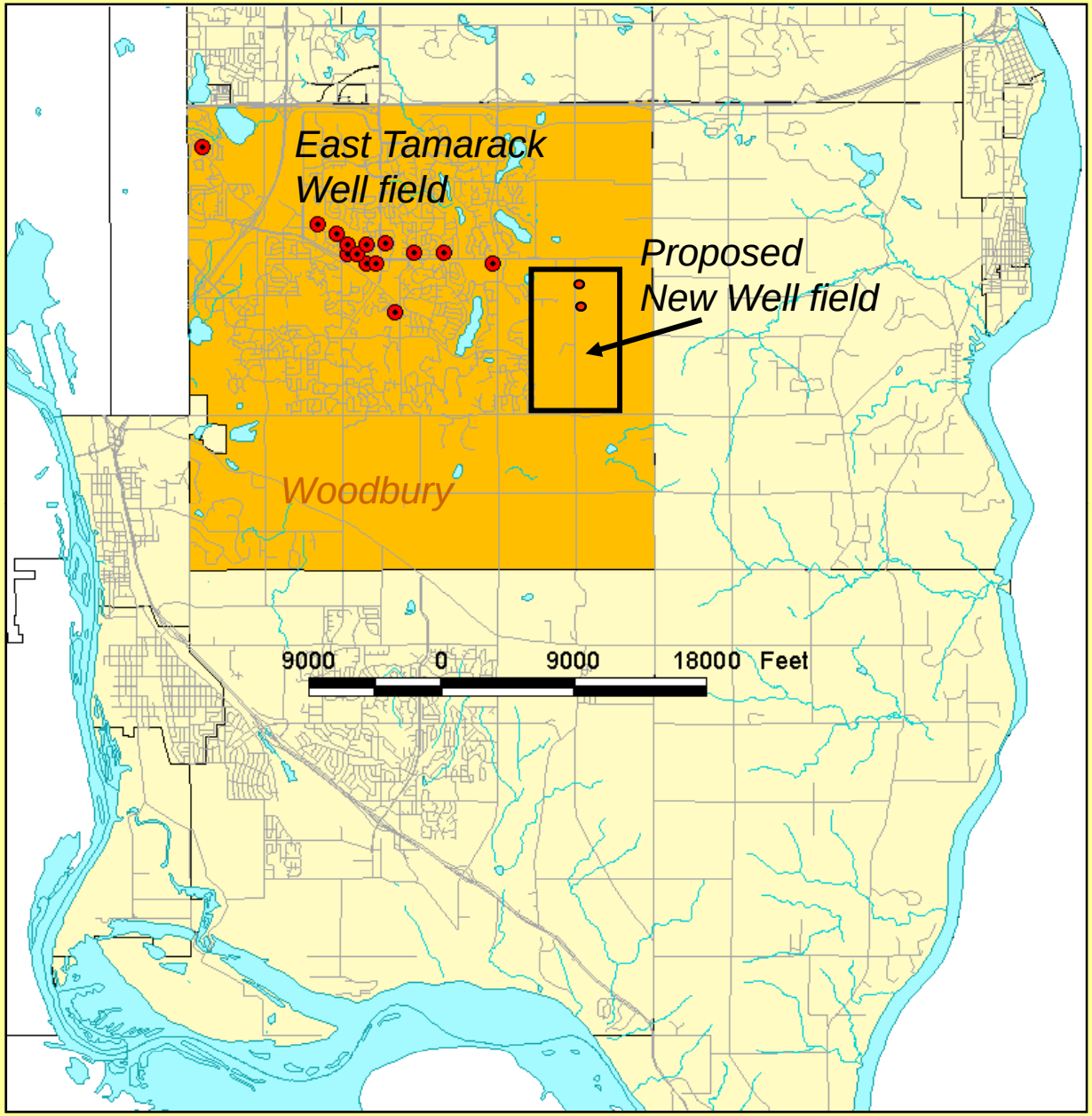

Alternative Urban Area-wide Review (AUAR) -2003

-3 new wells to serve area to 2009

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

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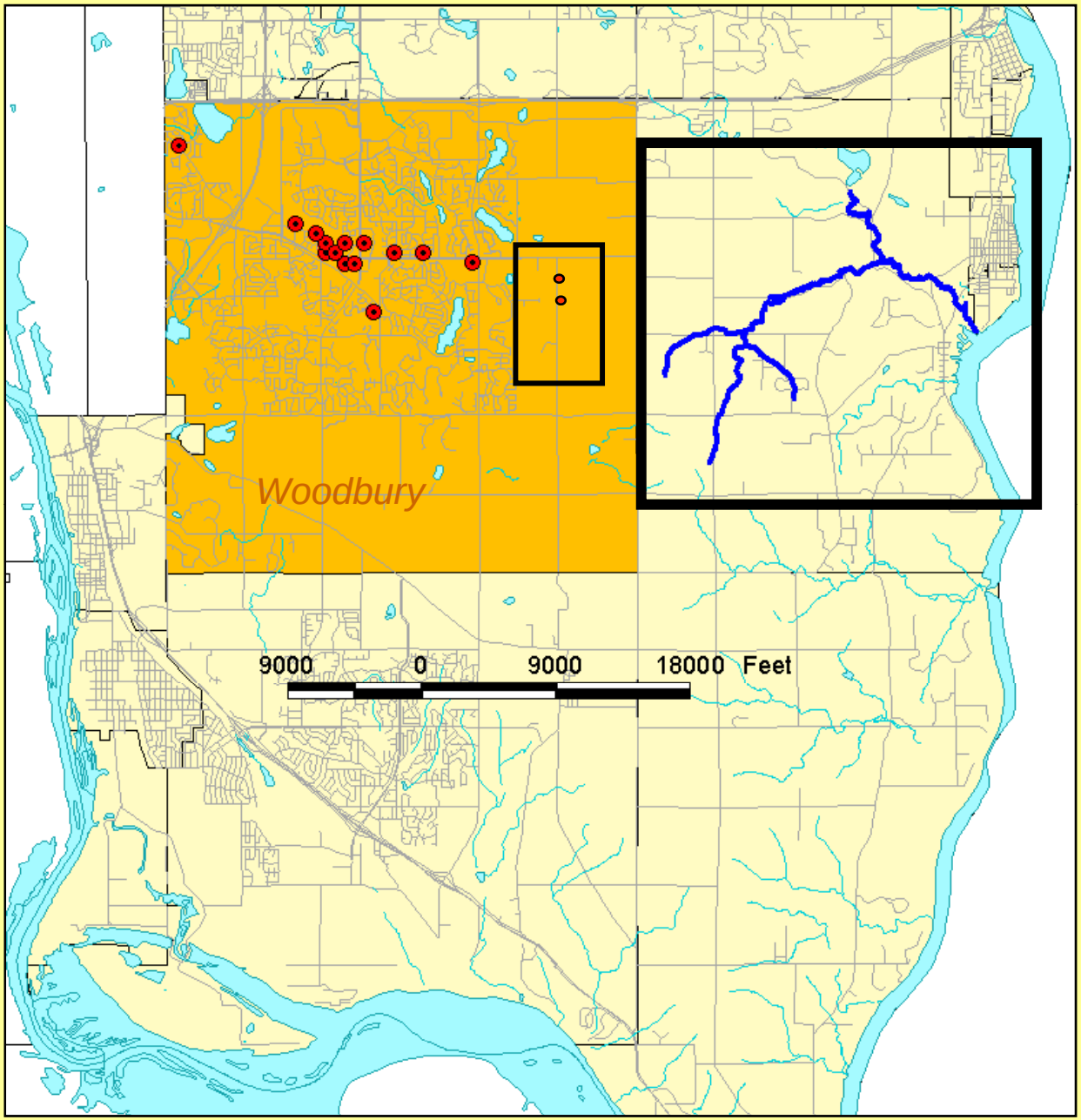

Valley Creek: Designated Trout Stream in City of Afton

A highly valued resource

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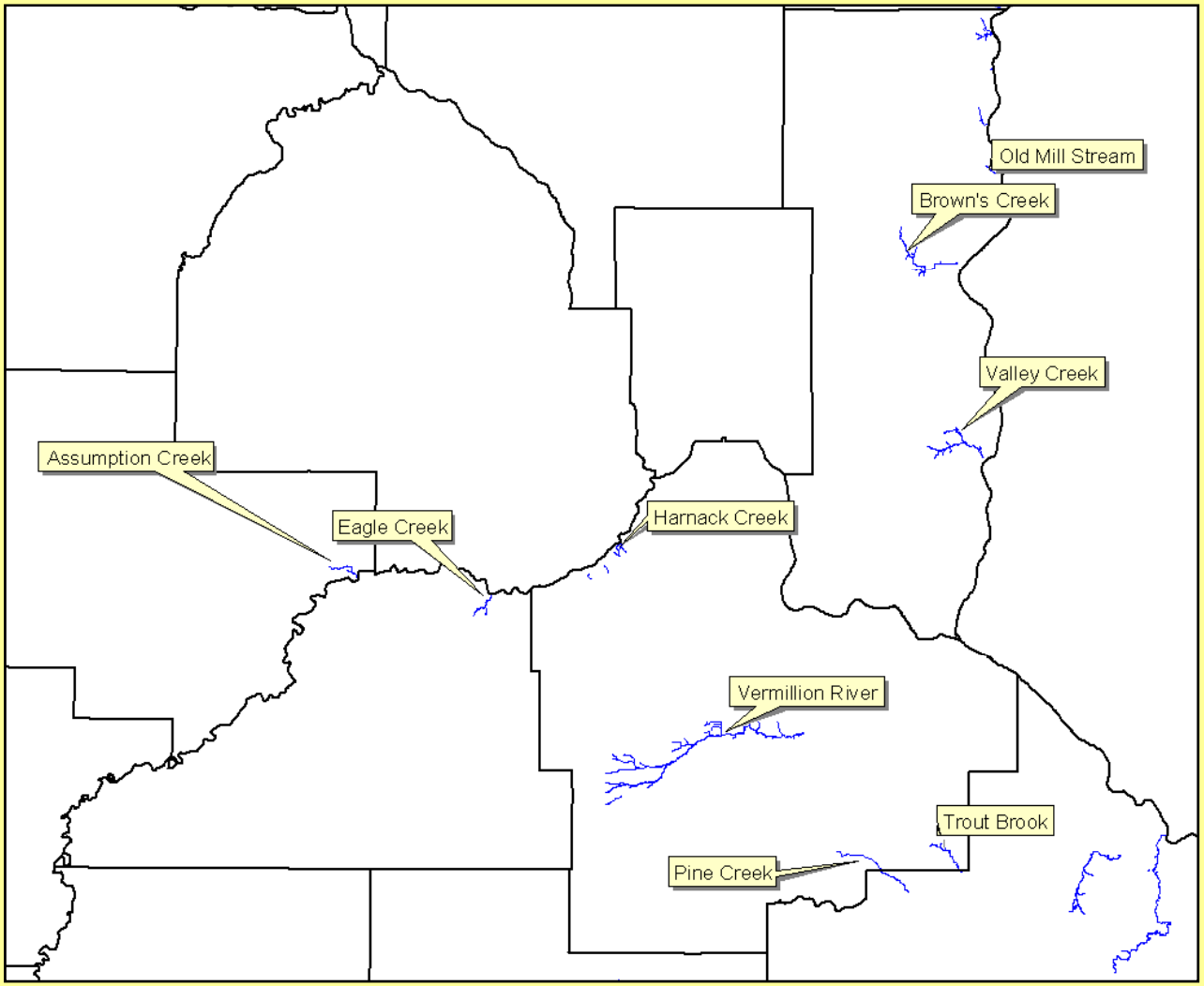
Desigated Trout Streams in the Metro Area



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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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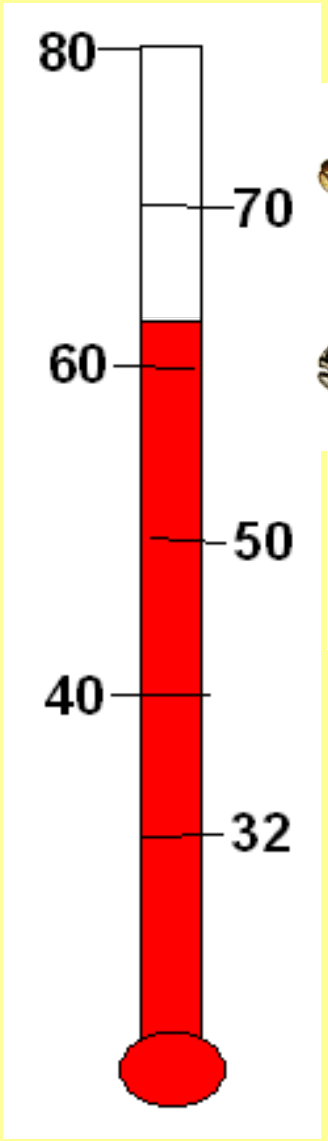

BROWN TROUT
44º - 80ºF

RAINBOW TROUT
44º - 75ºF

BROOK TROUT
44º - 56º F

TROUT NEED COLD, CLEAR WATER TO LIVE AND SPAWN - COLD WATER HOLDS MORE OXYGEN

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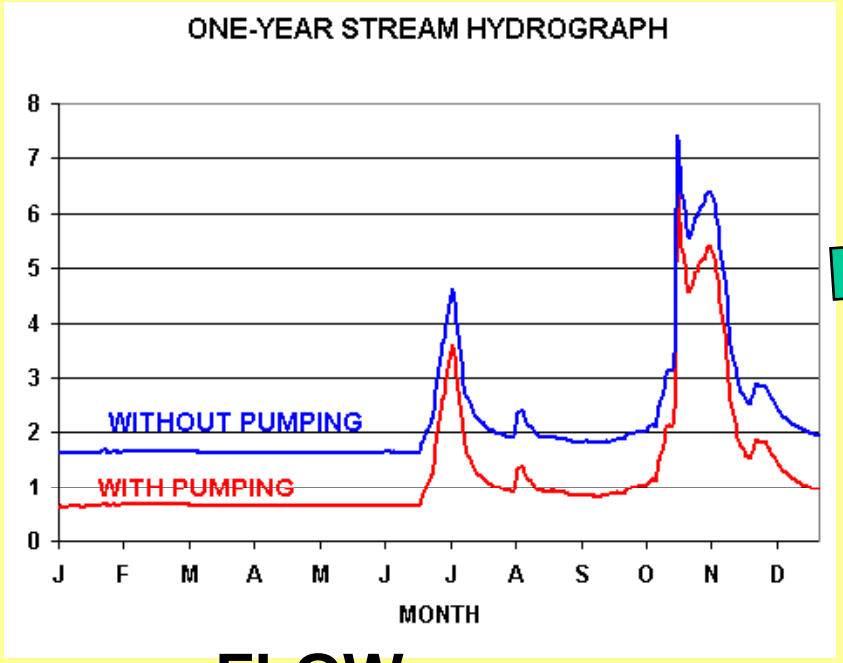
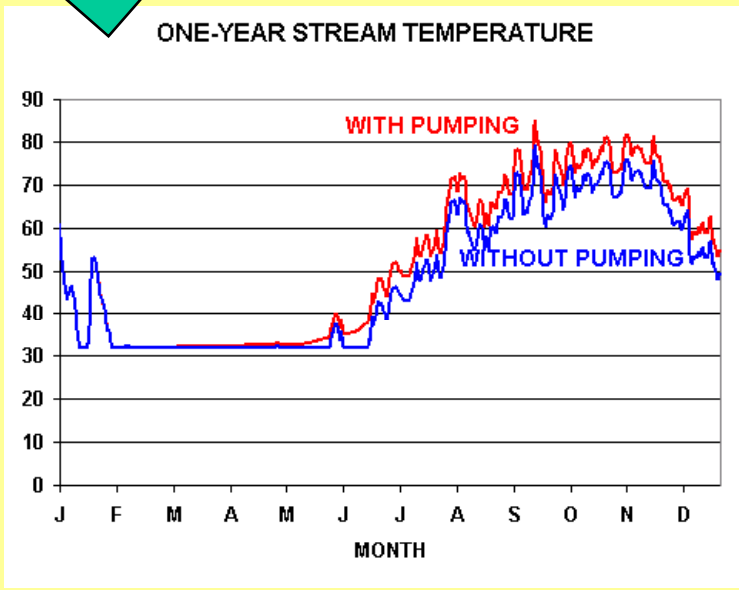
REDUCED BASE FLOW RAISES STREAM TEMPERATURE



FLOW

example

TEMPERATURE



AVERAGE TEMP. INCREASES BY 4.5ºF

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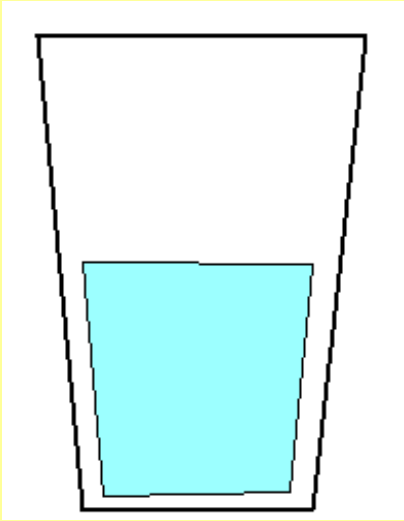
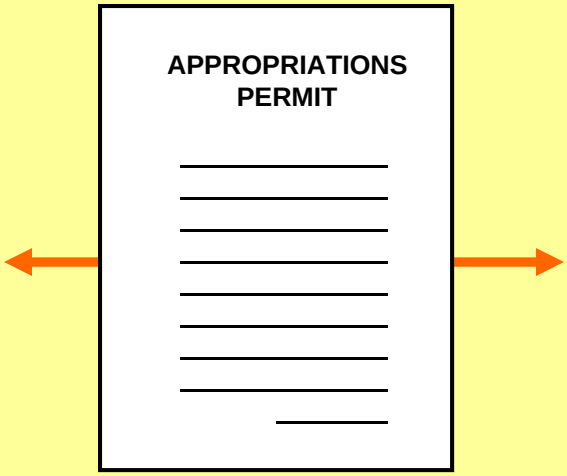
THE REGULATORY VEHICLE THAT TIES WELLS TO TROUT STREAMS IS THE APPROPRIATIONS PERMIT

WATER SUPPLIES





TROUT STREAMS

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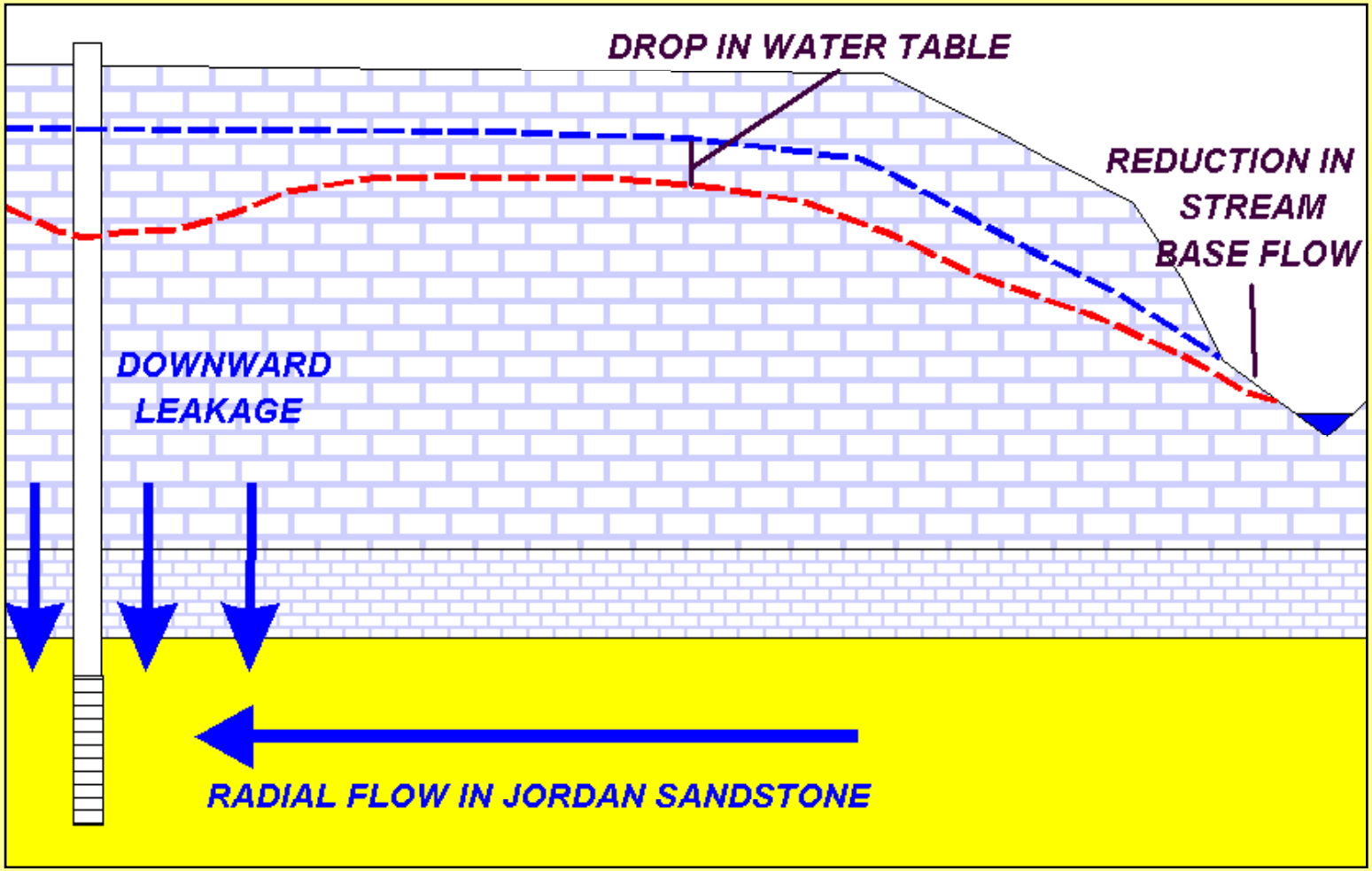
PUMPING WILL CAUSE DROP IN WATER TABLE



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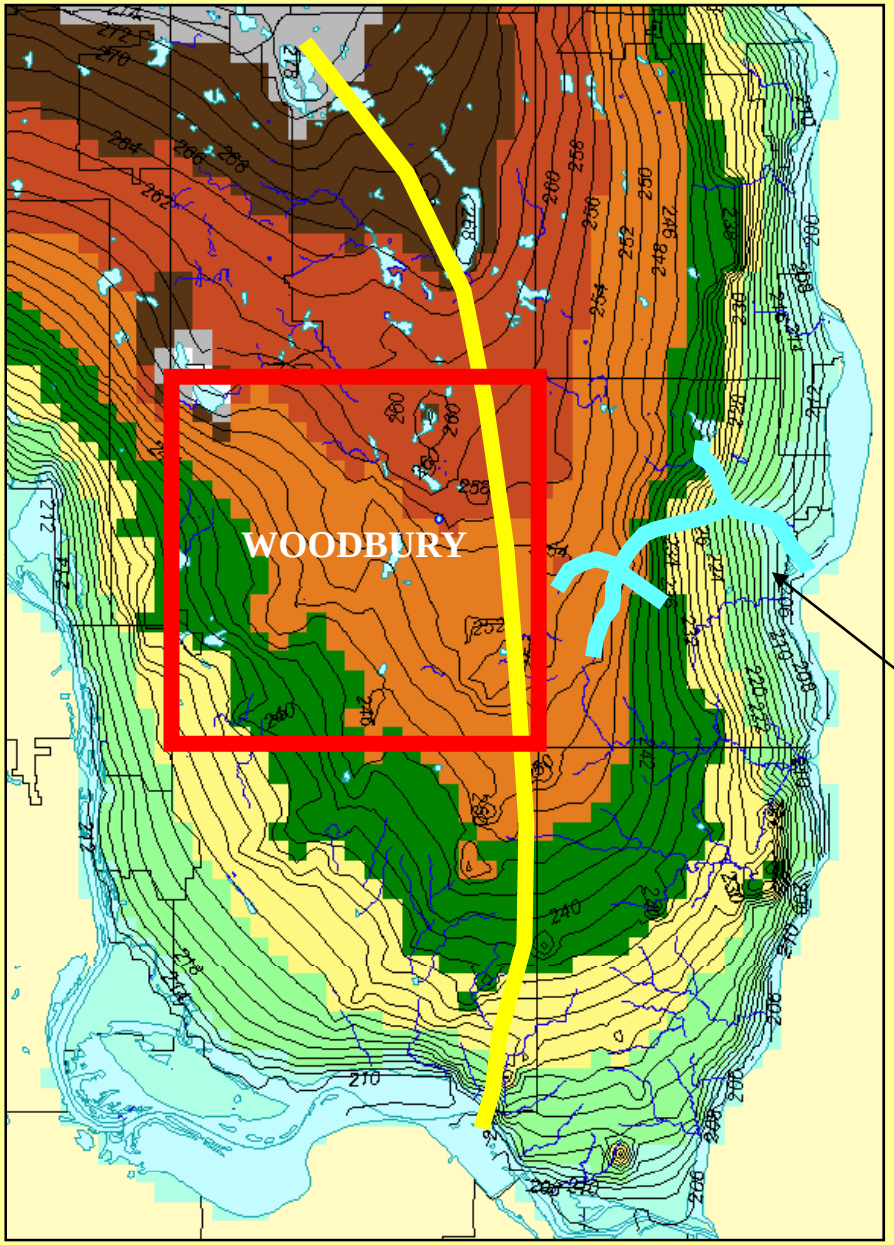

Potentiometric Surfaces Reflect Groundwater Divide Along Axis of County

Valley Creek

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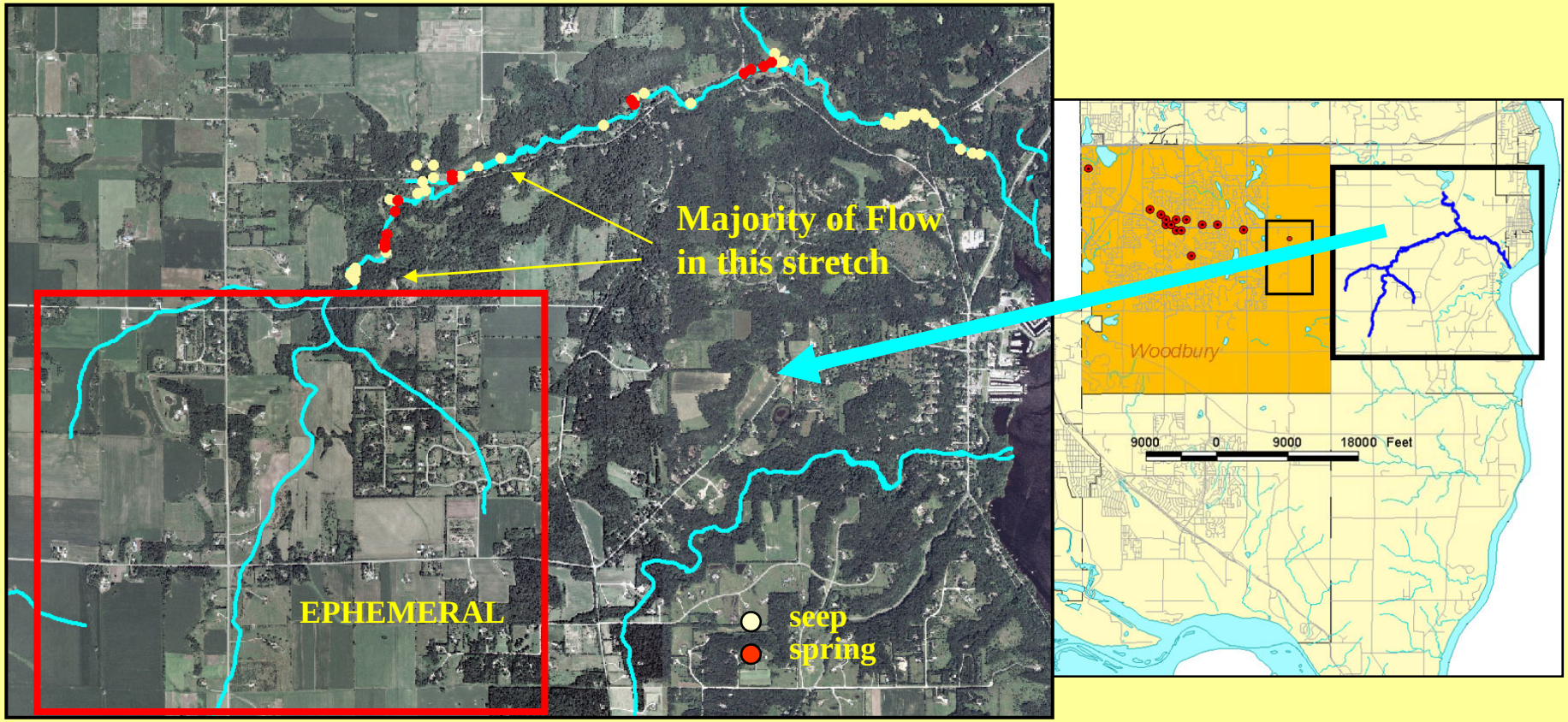
South Branch of Valley Creek originates as series of springs and seeps



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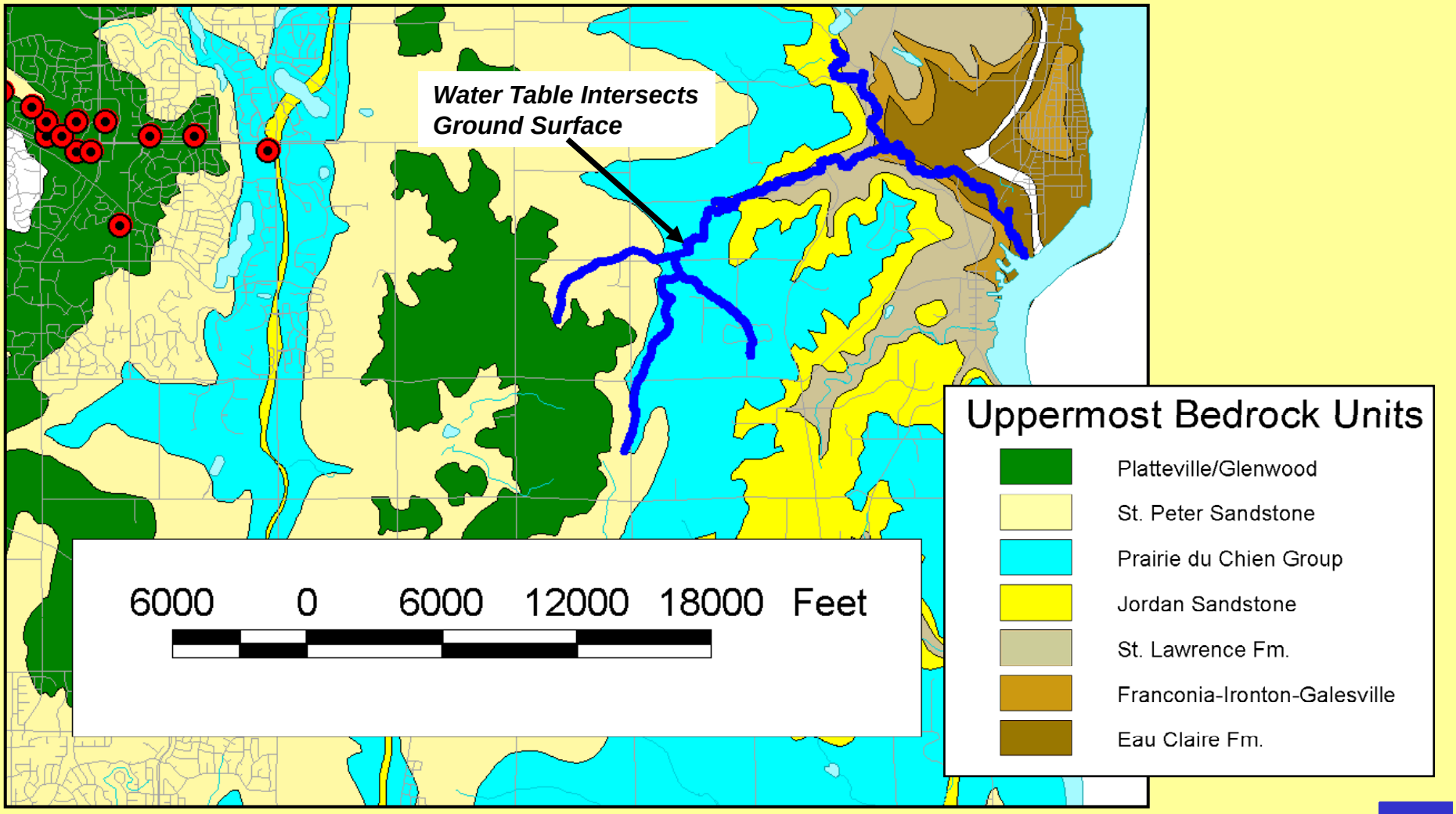
Valley Creek Intersects Several Bedrock Aquifers



(older geologic map)

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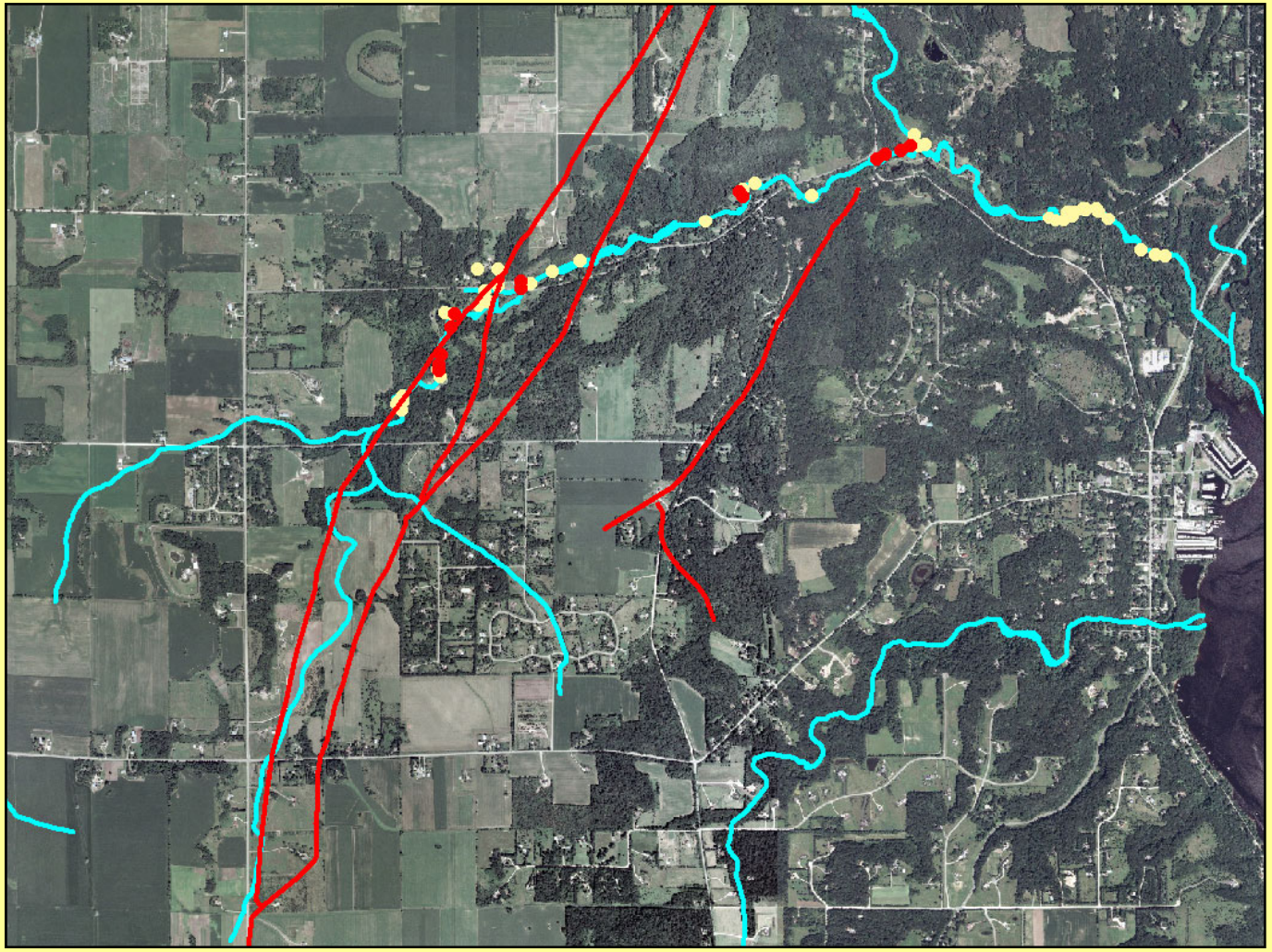
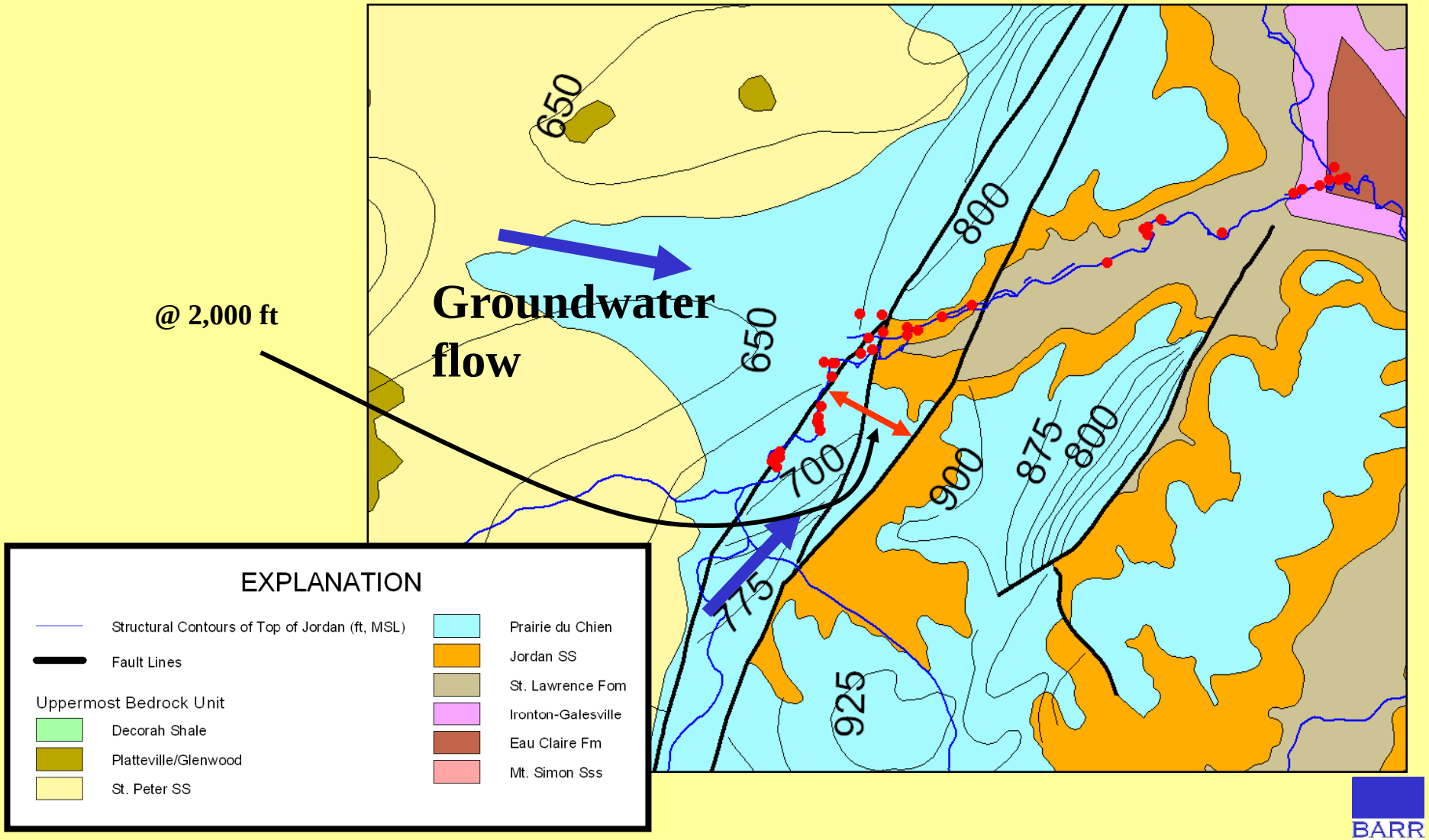
Faults mapped by MGS



Step Faults – 250 feet of displacement over short distance



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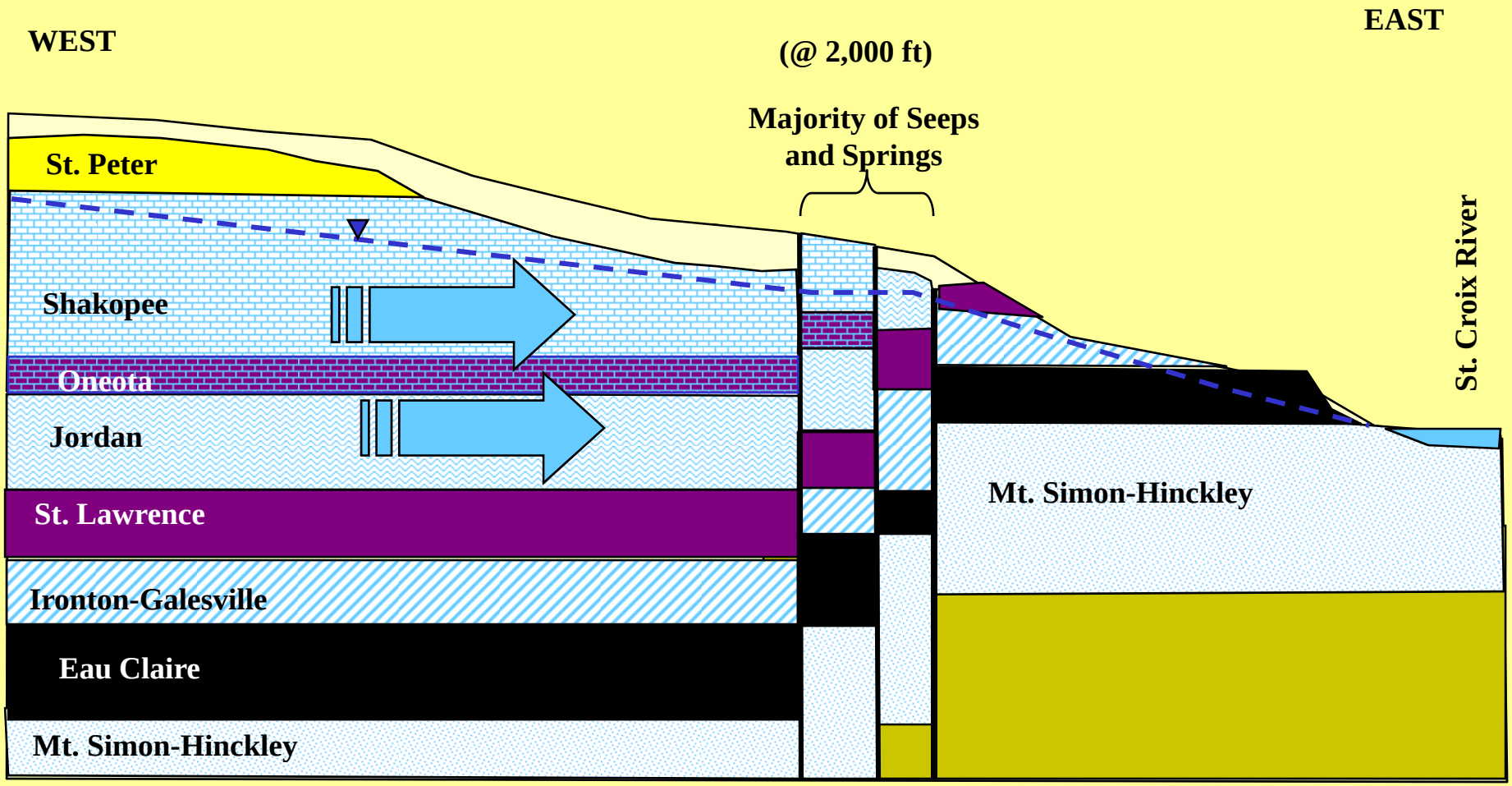
Schematic Cross Section of Faulting



(darker units indicate aquitards)

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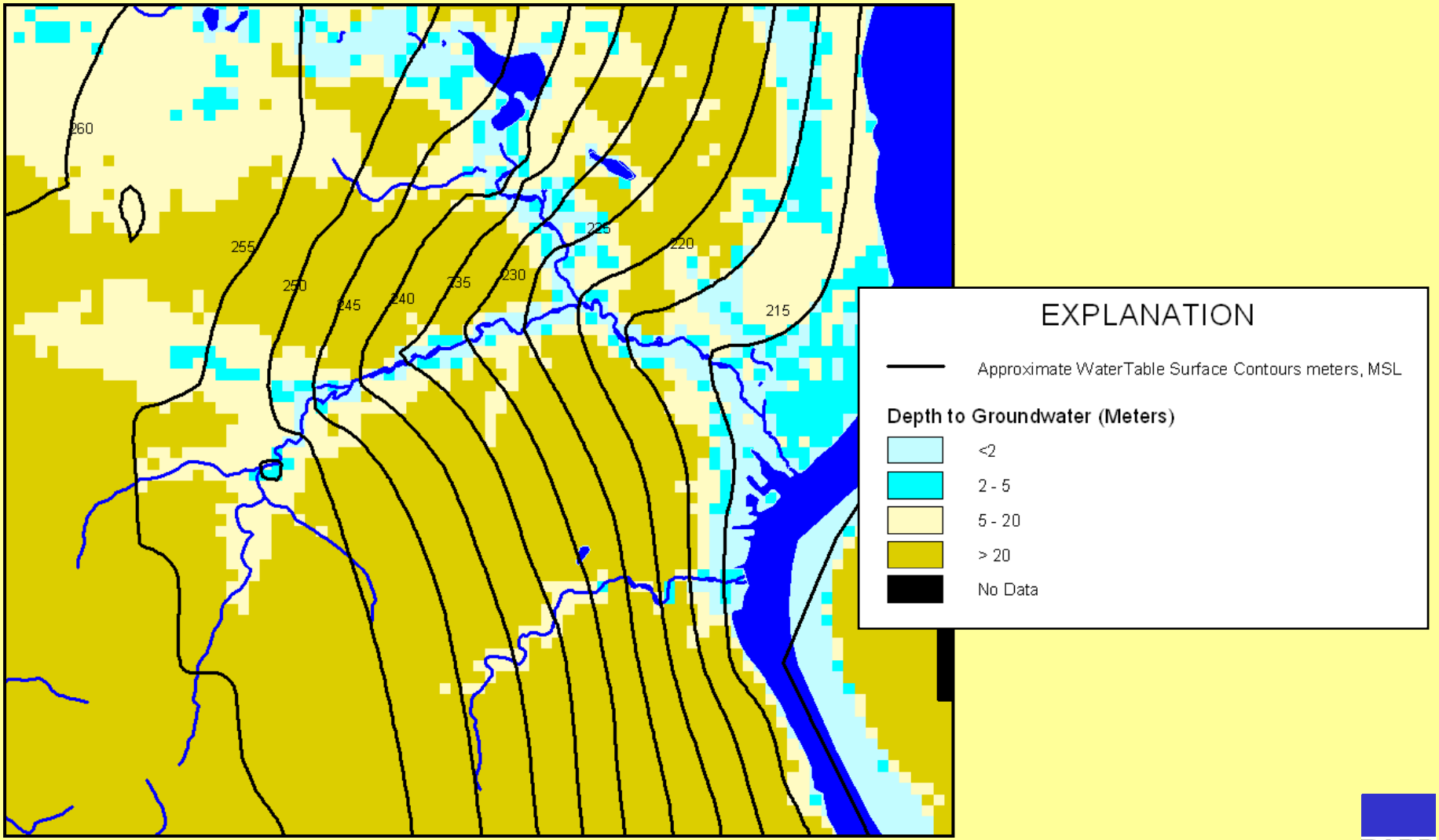
Water Table and Depth to Water Table



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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? (planning interest)

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Initial analyses 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

Are the limiting assumptions associated with this screening approach predicting "overly pessimistic" outcomes?

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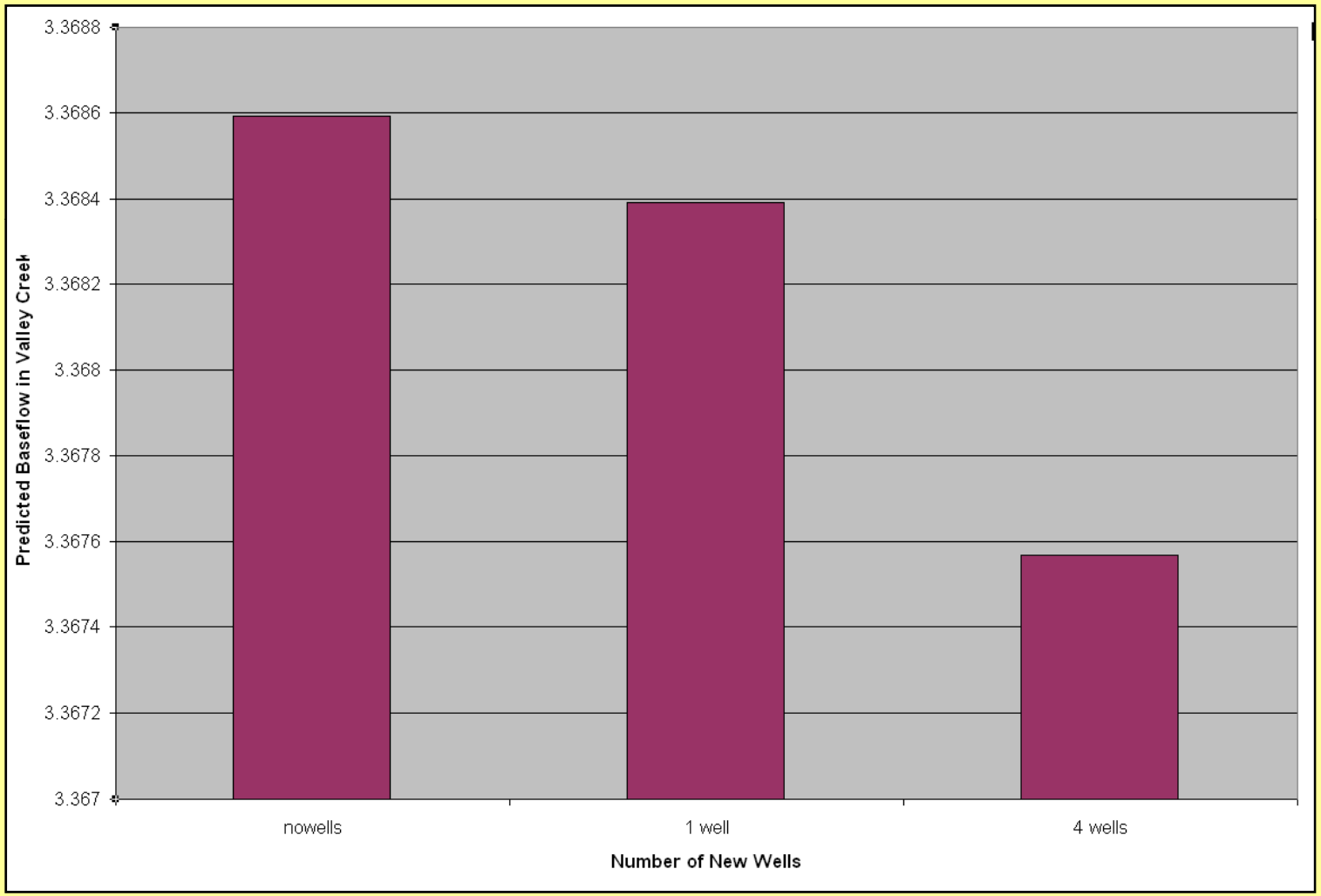
“Groundwater Model Predicts Drop in Baseflow to Valley Creek”



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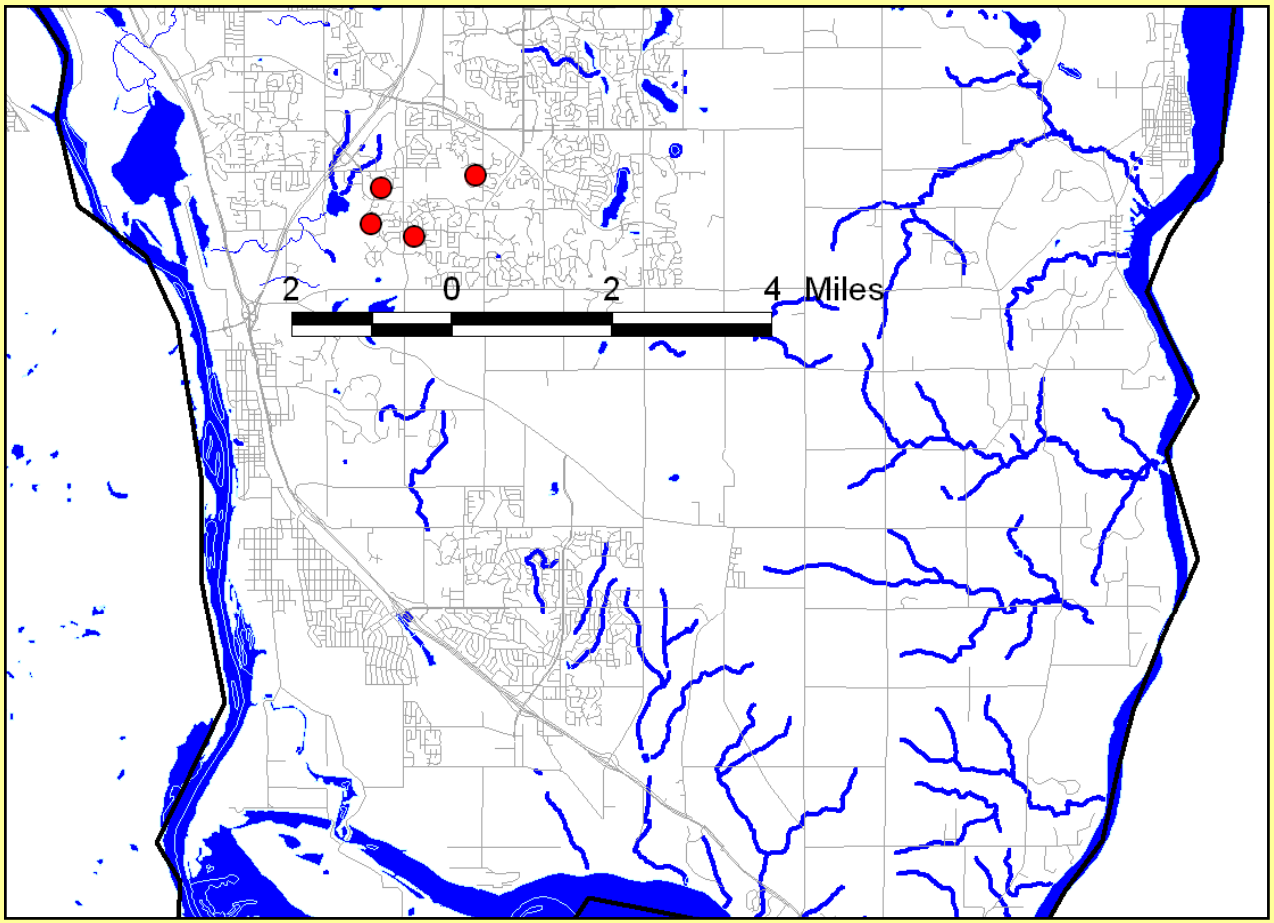
Domestic wells – located over 4 miles away



Each well pumps at 2.2 gpm

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Pumping always results in a reduction in groundwater flow to streams (even outside of the so-called "groundwater-shed")

- Any amount of pumping will result in a predicted decrease in baseflow
- Wells can be anywhere in the model domain
- Don't blame this on groundwater modeling
  - blame it on Sir Isaac Newton

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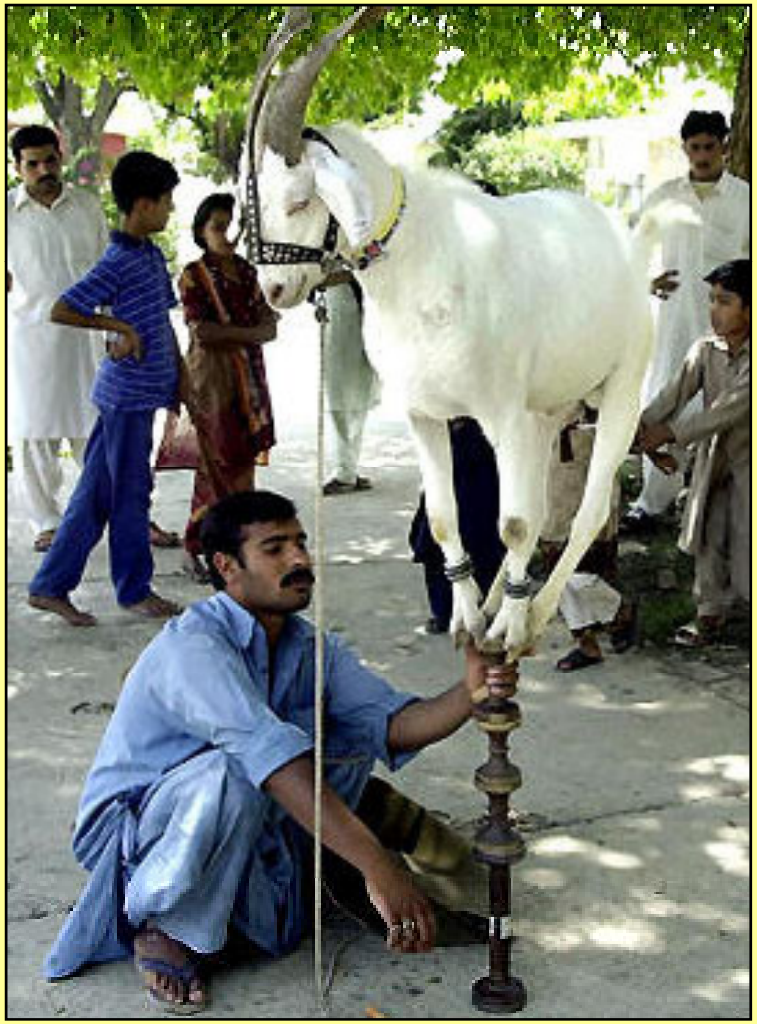
If we are unwilling to accept some reduction in baseflow, then we might as well "go out and heard goats"



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

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If some reduction in baseflow is acceptable, then how much and on what basis?

- Ecologically based levels?
- Predicted or measured natural fluctuations?
- Measureable changes?

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The agreed-upon approach:

- Woodbury would be allowed to construct two new well (Wells 15 & 16) 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 new wells
- Re-evaluation of understanding would be on-going

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Evolution of Study

- 2002: Woodbury AUAR – steady-state AEM model predictions
- 2003-2005: LCCMR-funded MODFLOW-MIKE SHE model of south Washington Co.
- 2003: 30-day pumping test using Well 15
- 2006: 90-day pumping test using Wells 15 & 16
- 2007: Recalibration of MODFLOW model
- 2009: Additional recalibration and incorporation of Metro Model information (SWB model)

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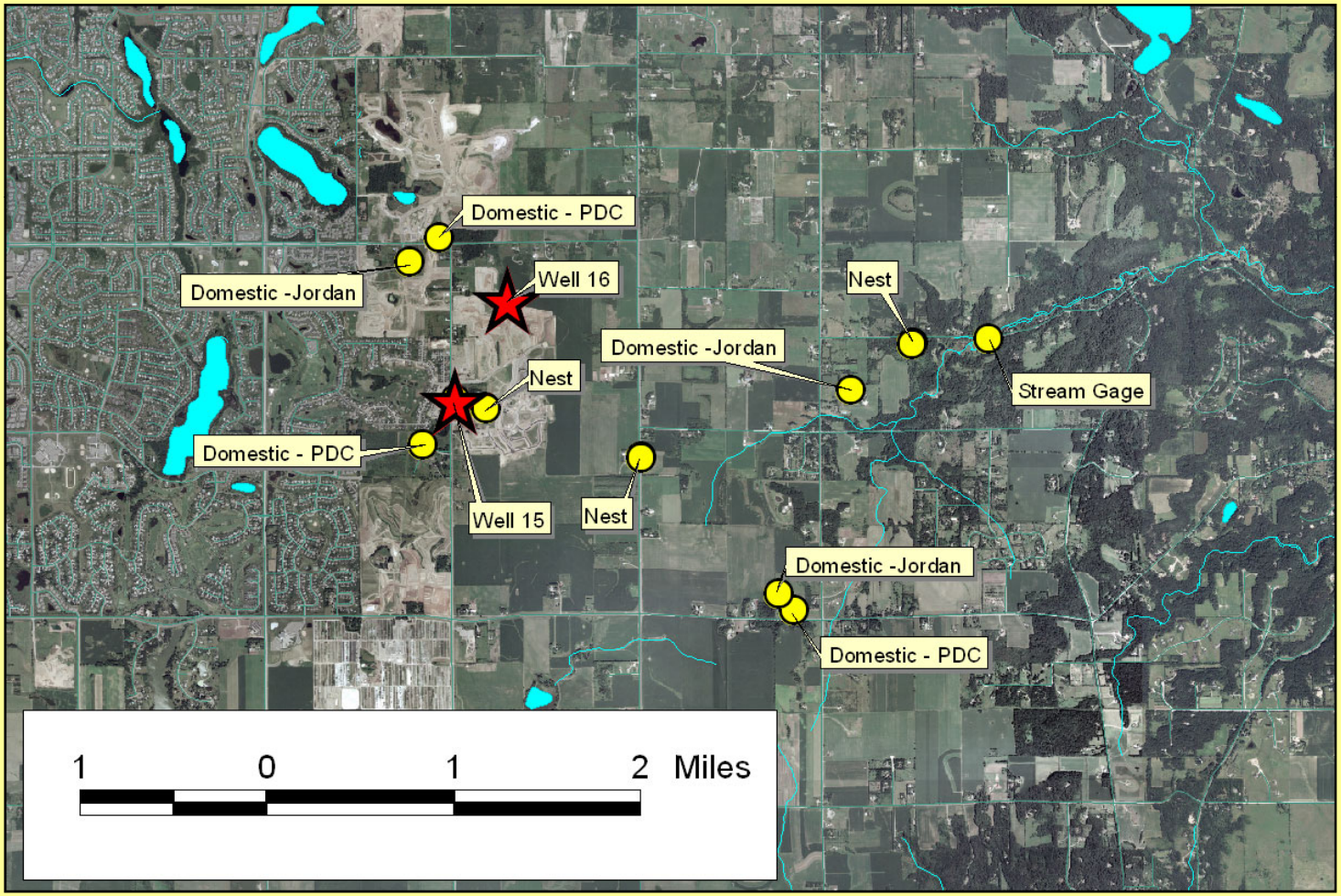
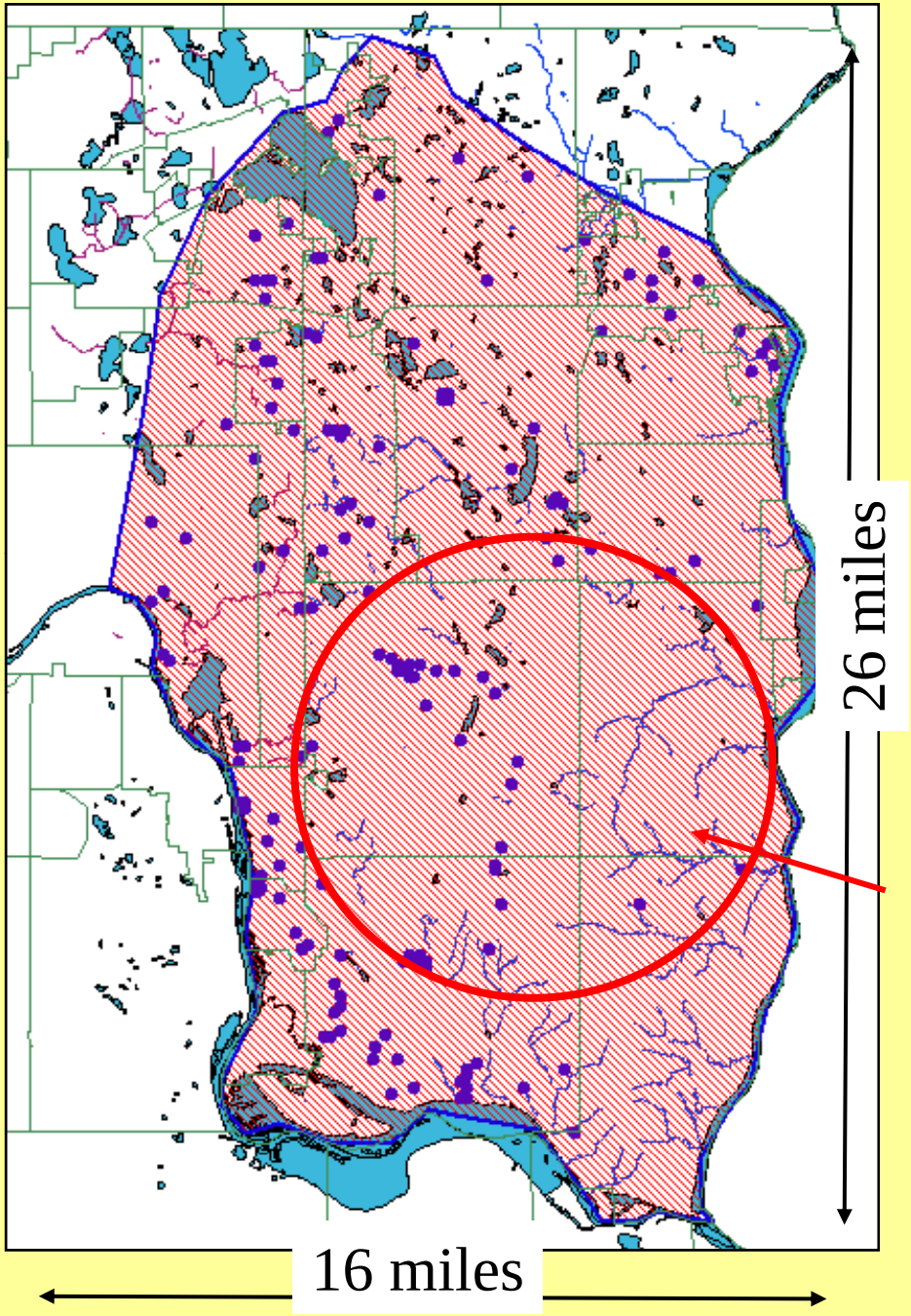
Aquifer Test Layout



Aquifer tests performed by Mark Janovec of Bonestroo

BARR

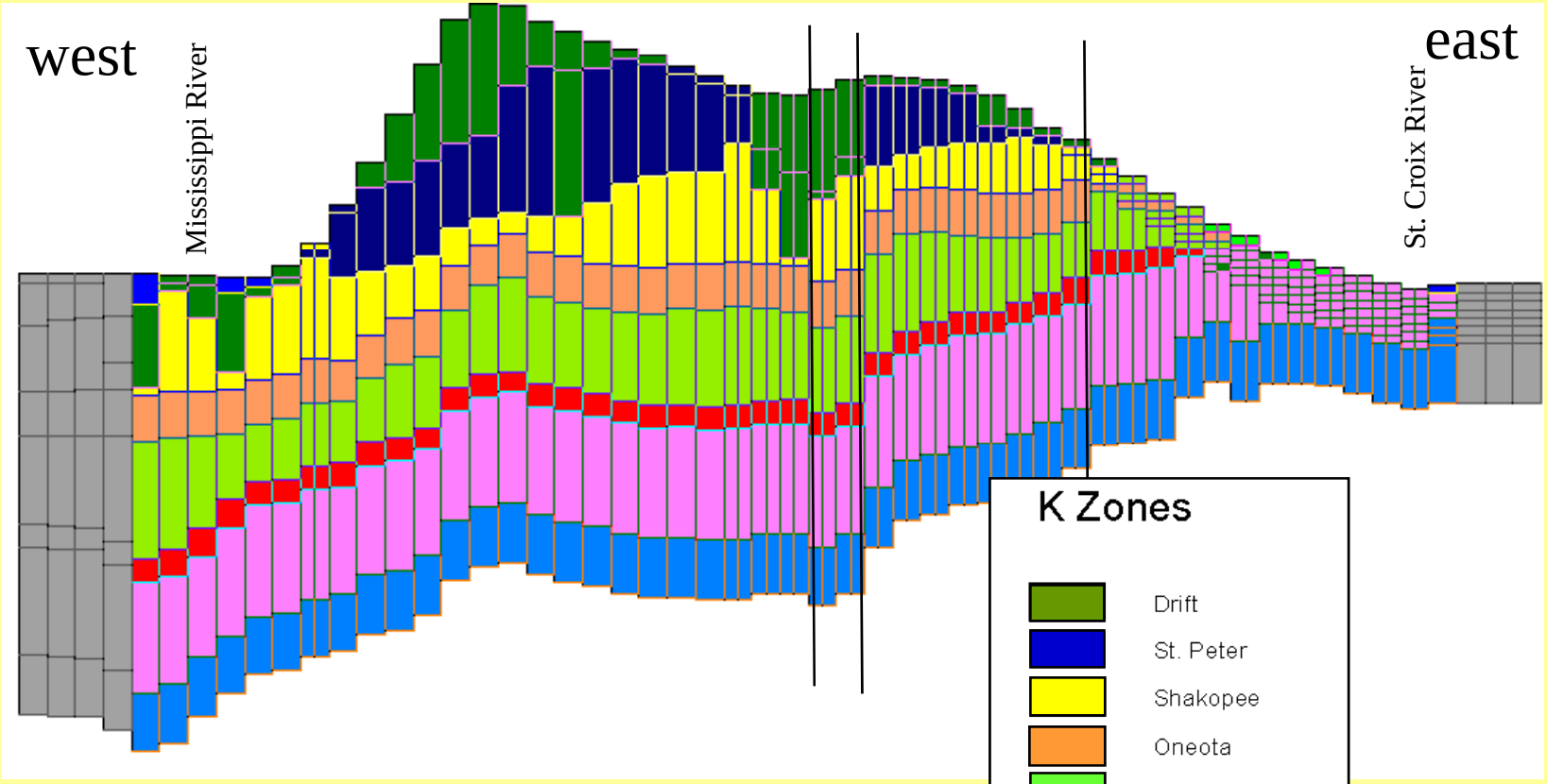


Model Domain:

The Areas of interest

primary area of interest

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



(inactive cells are gray)

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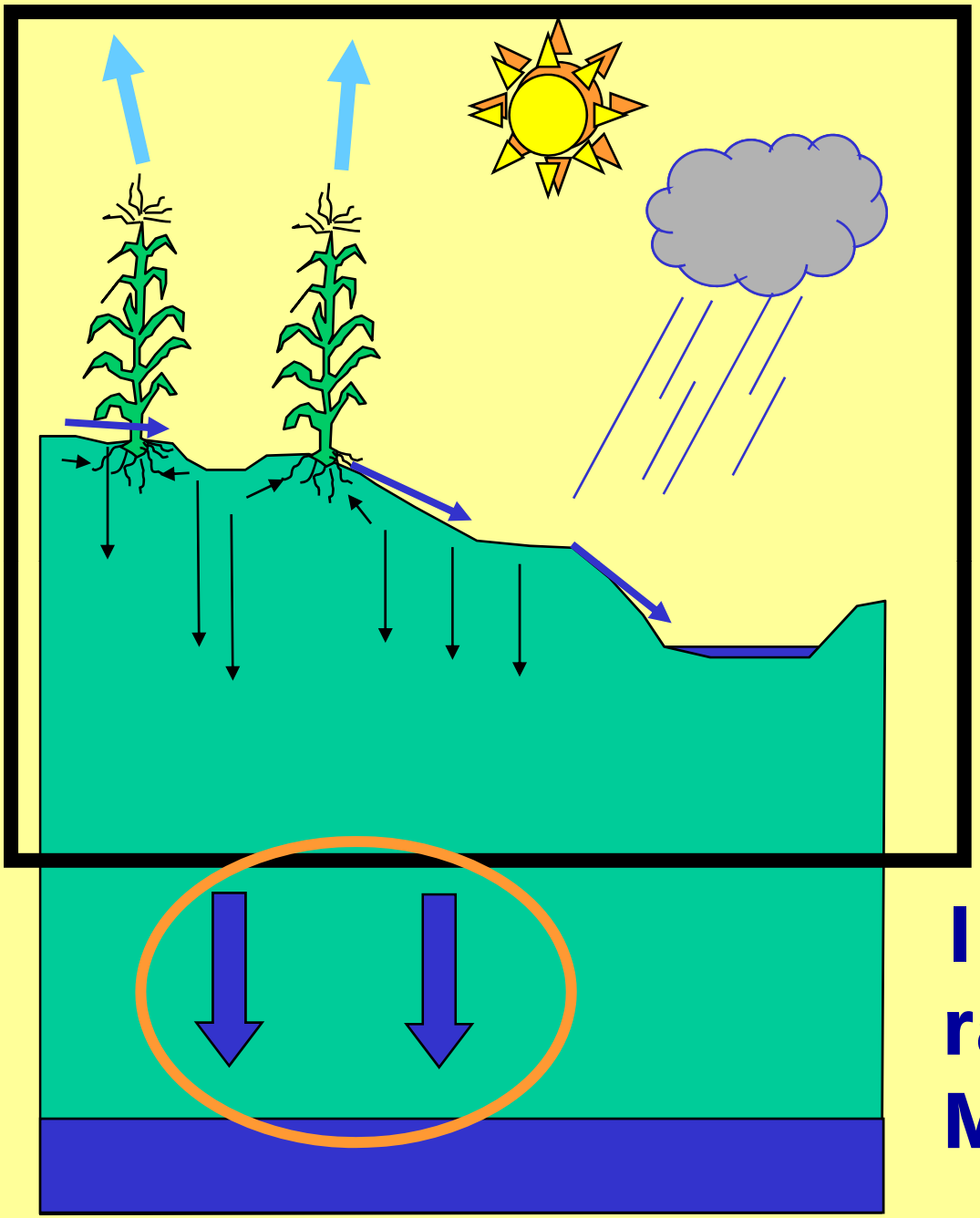

MIKE SHE Processes

SWB Processes

Infiltration rates to MODFLOW

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Evolution of Model

- Zoned-based parameter distribution with grid-based MIKE SHE recharge
  - TMR approach used in calibration to Well 15 pumping test
- Pilot-point based parameter distribution with MIKE SHE recharge
  - Refined grid of regional model to calibrate to Well 15-16 pumping test
- Hybrid pilot-point & zone model – parameter values from Metro Model
  - Grid-based recharge from SWB model (Metro Model)

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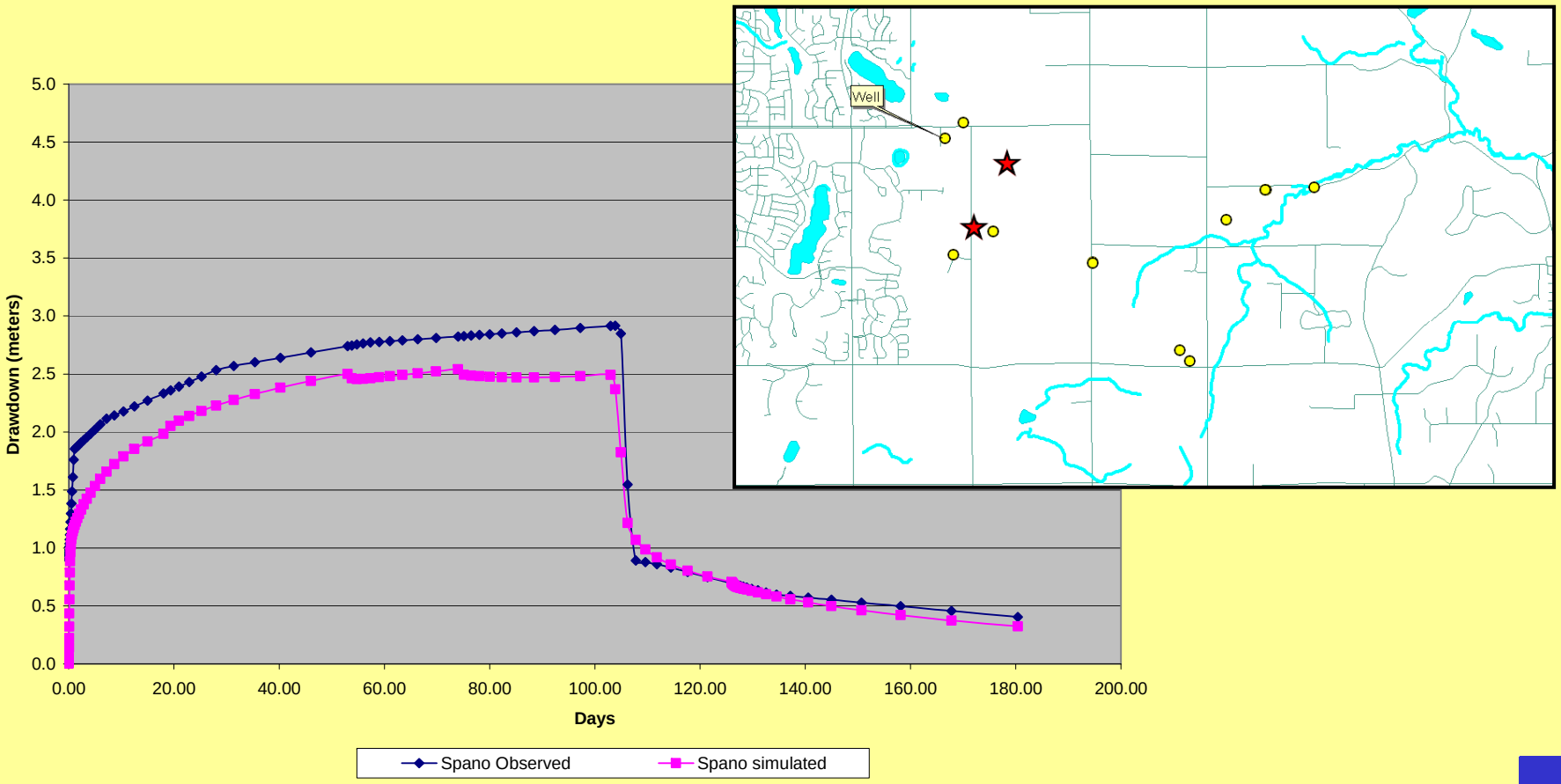
Calibration Targets

- Regional head values (mostly from CWI)
- Drawdown and residual drawdown data from well nests and domestic wells
- Head data from well nests and domestic wells during pumping & recovery
- Head difference data in well nests during pumping & recovery
- Flow measurements downstream of major spring area in Valley Creek

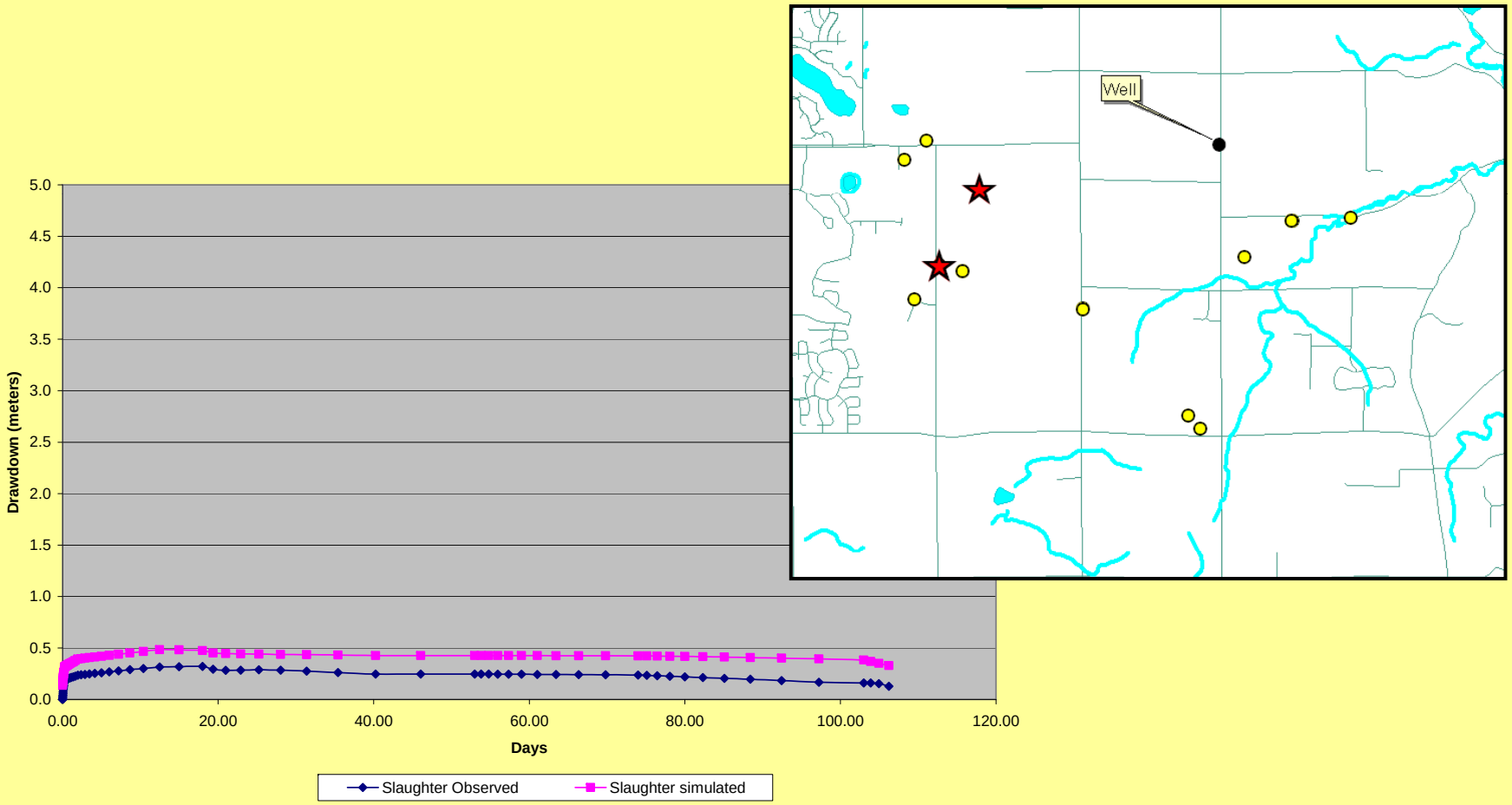
BARR

Observed vs Simulated Drawdown



BARR

Observed vs Simulated Drawdown



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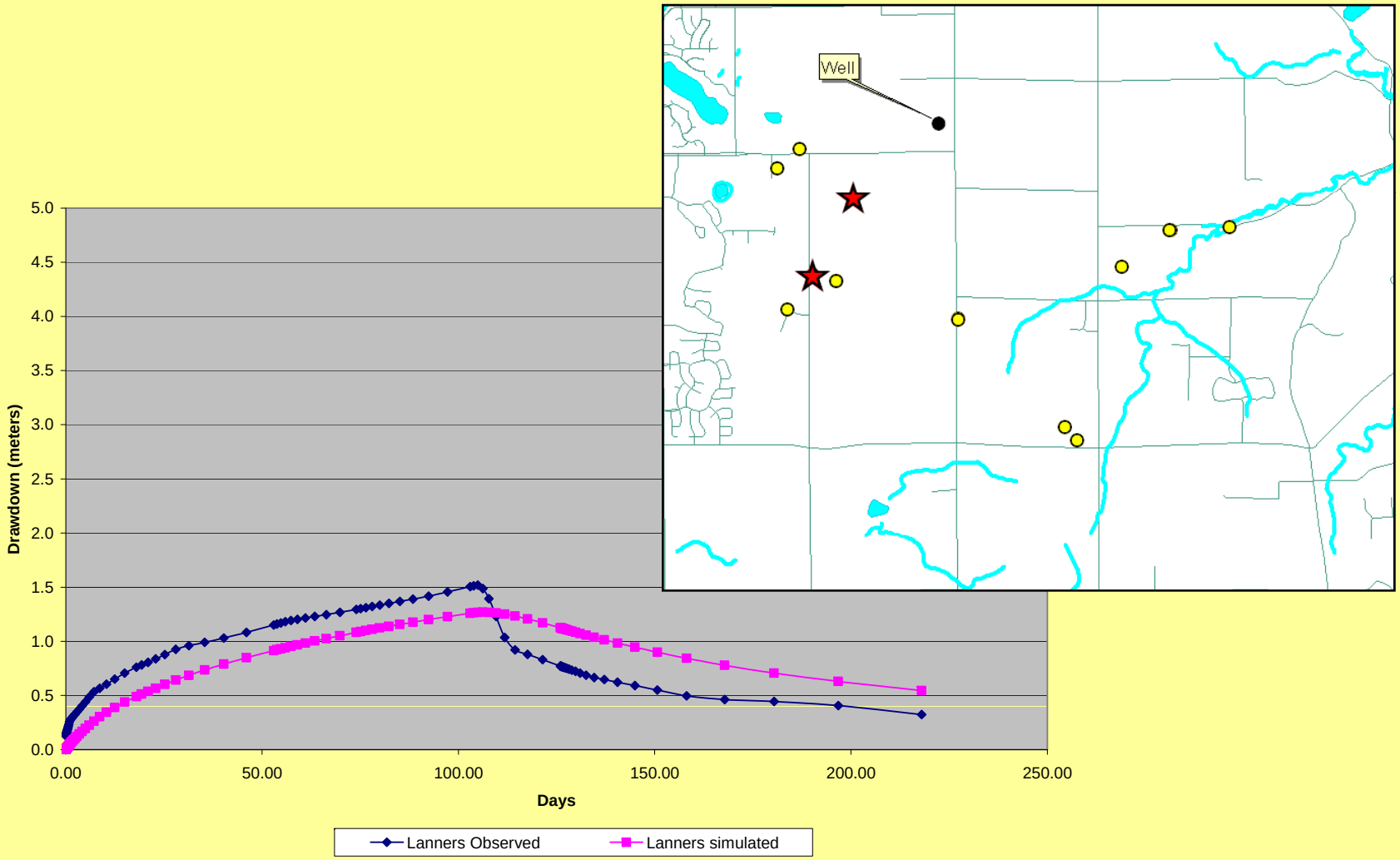
Observed vs Simulated Drawdown



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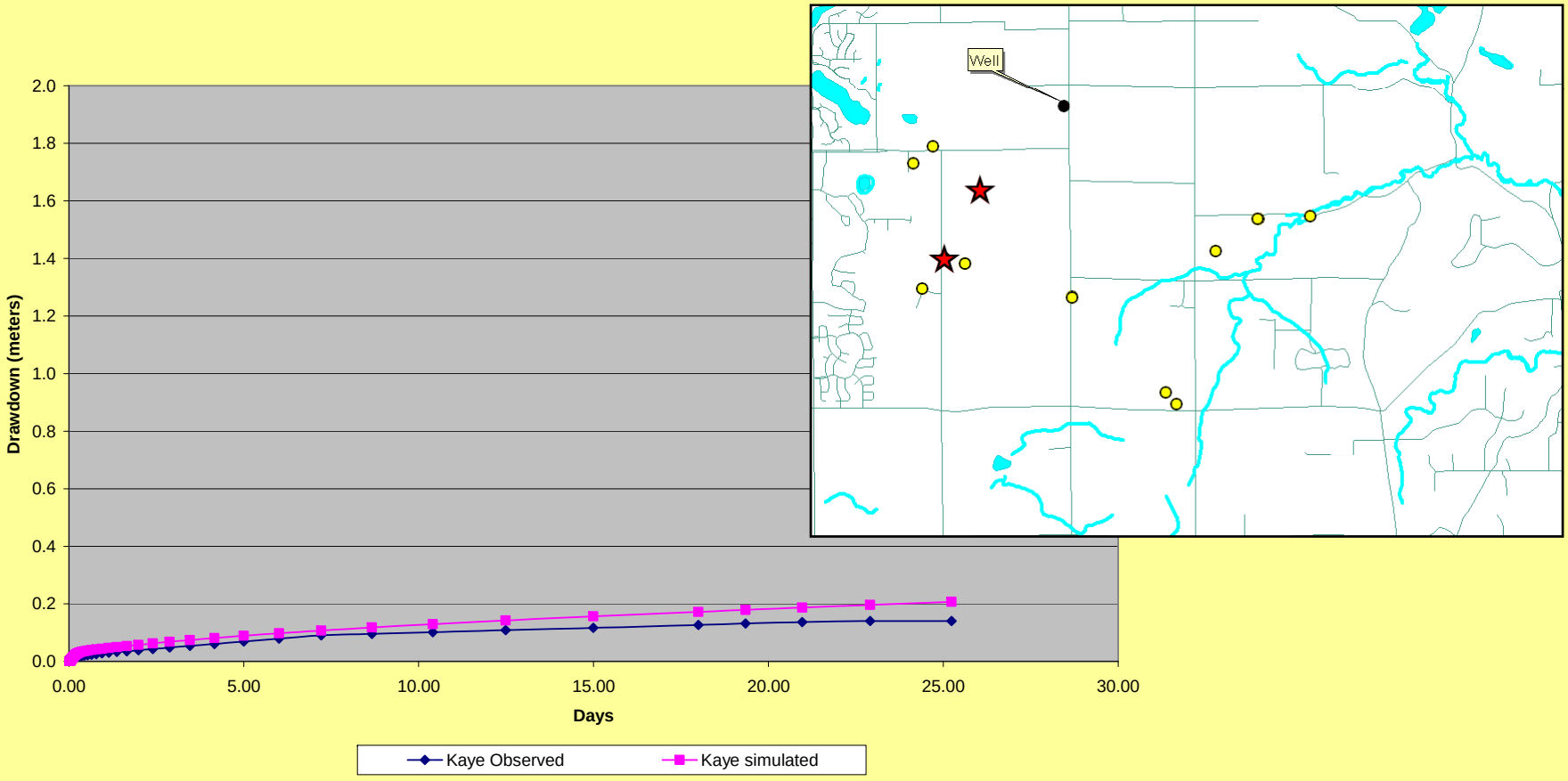
Observed vs Simulated Drawdown



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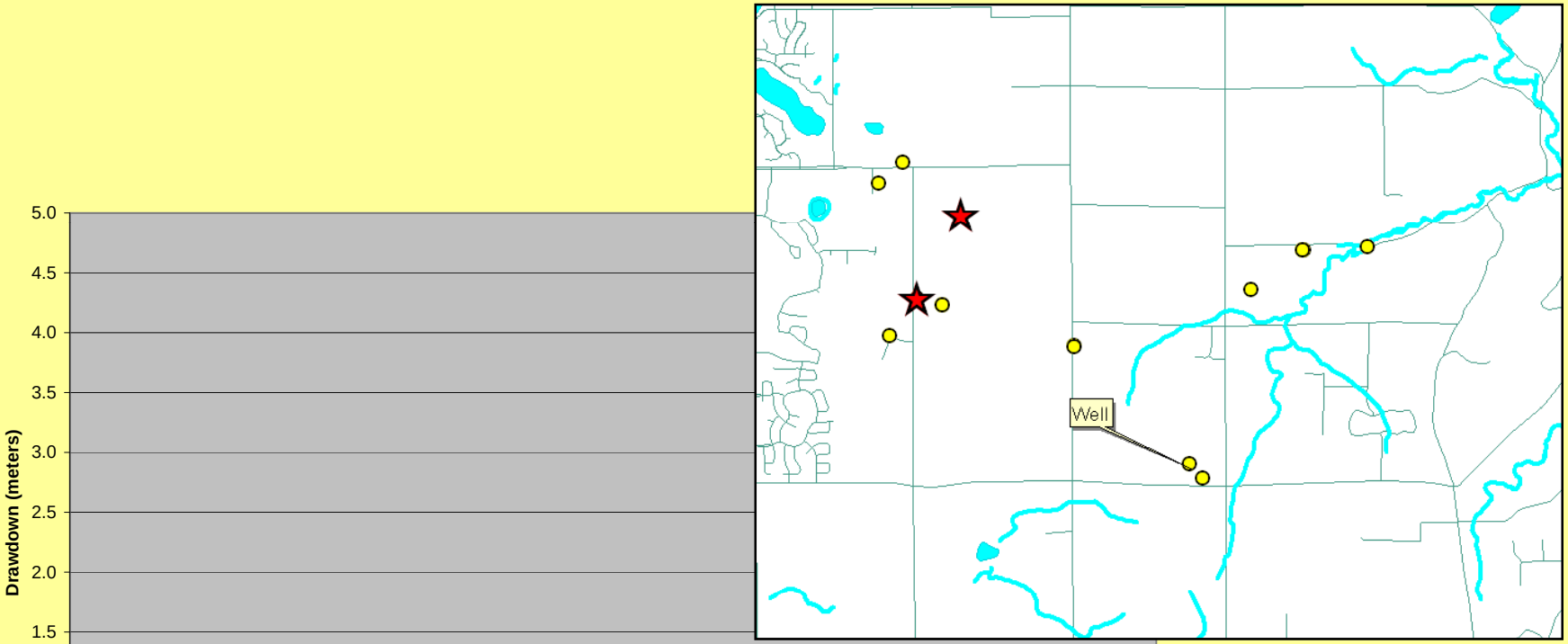
Observed vs Simulated Drawdown



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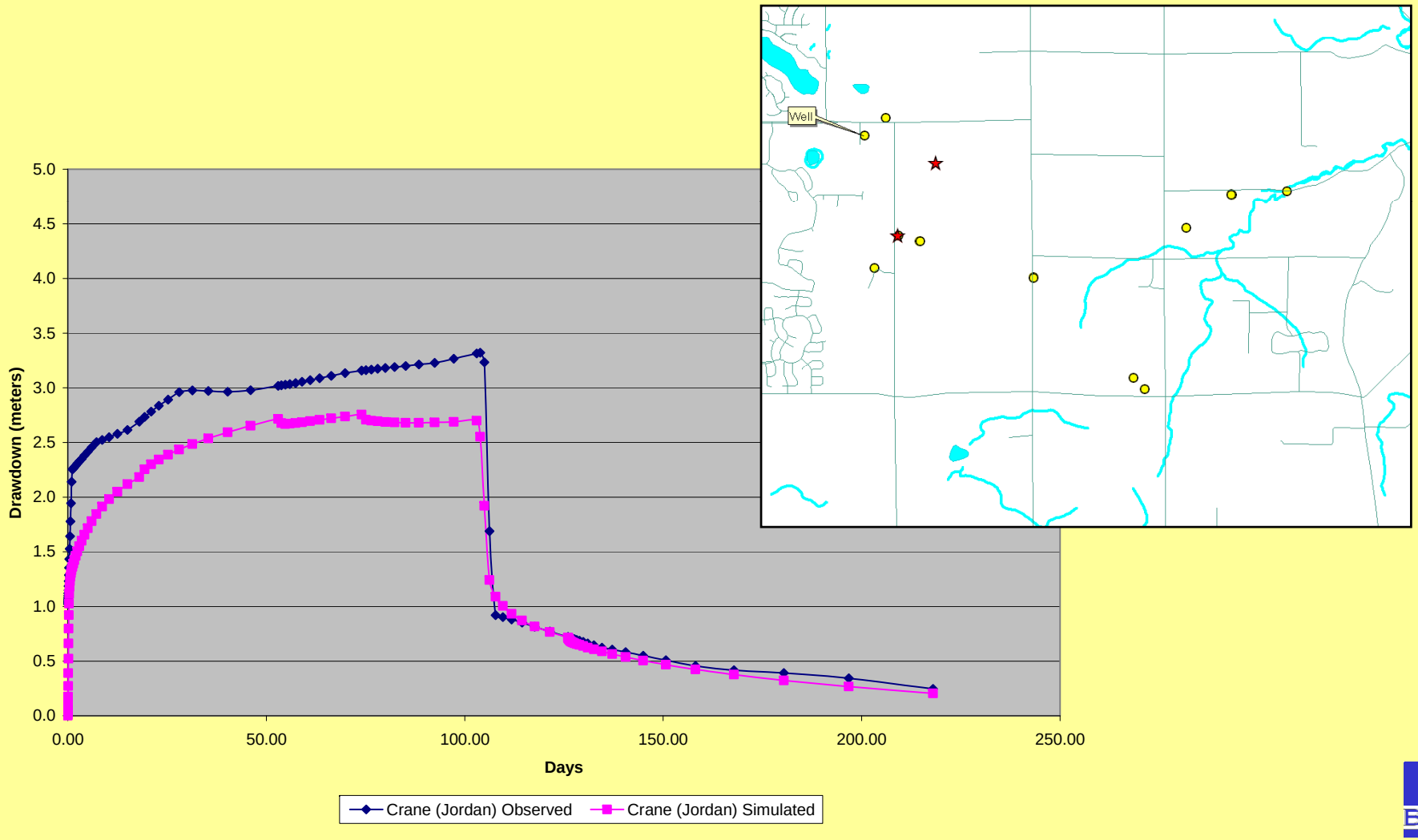
Observed vs Simulated Drawdown



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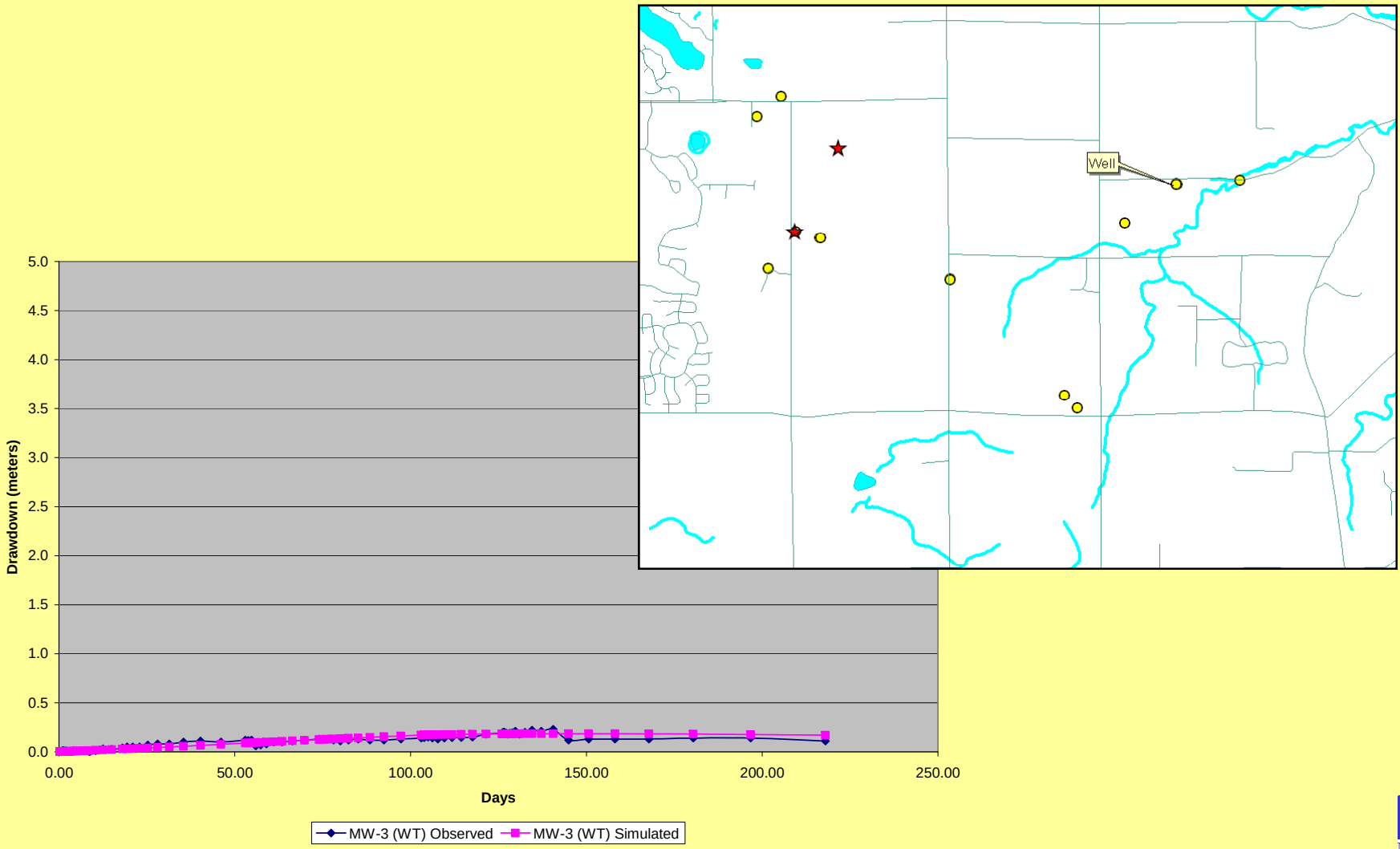
Observed vs Simulated Drawdown



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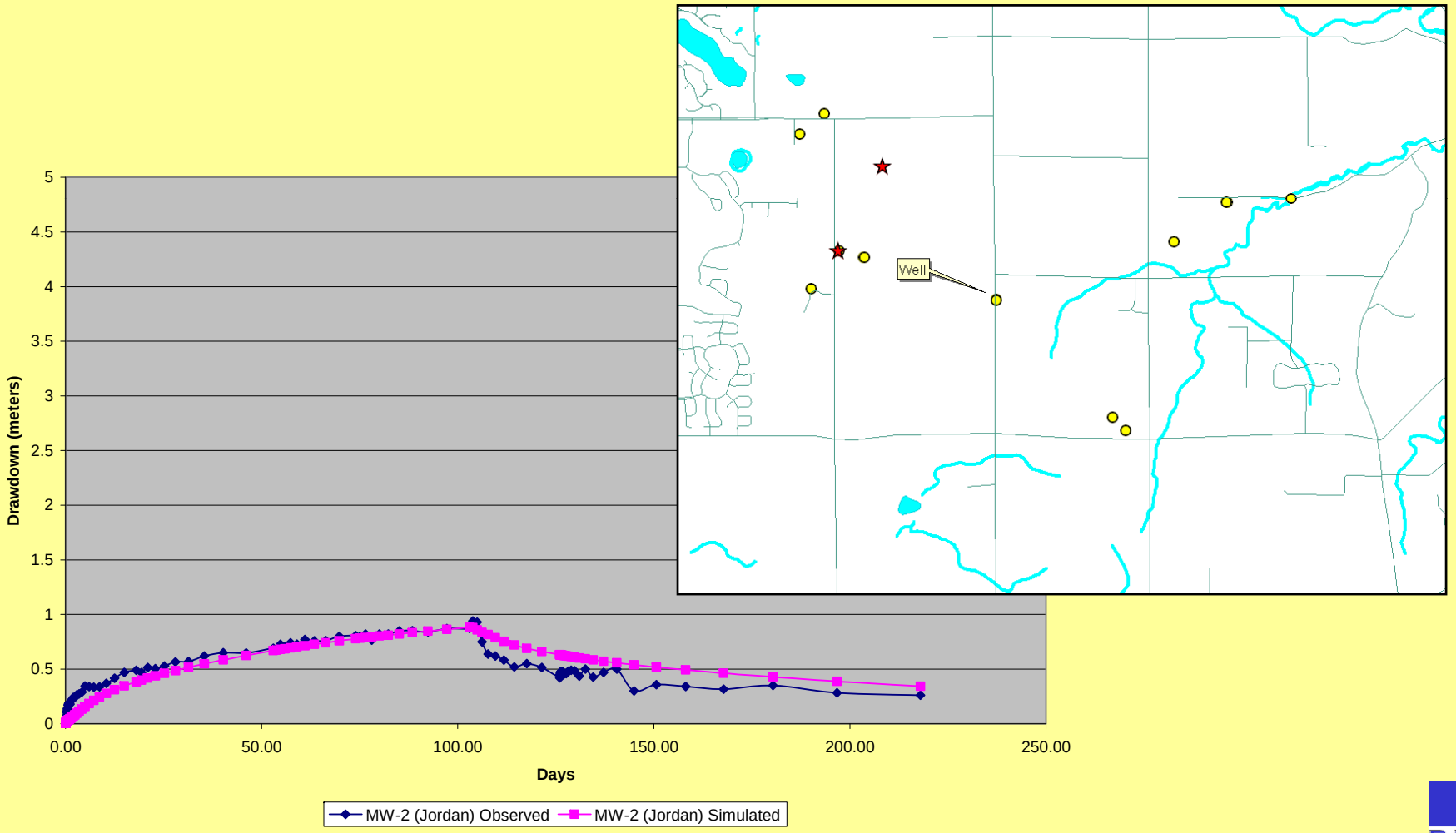

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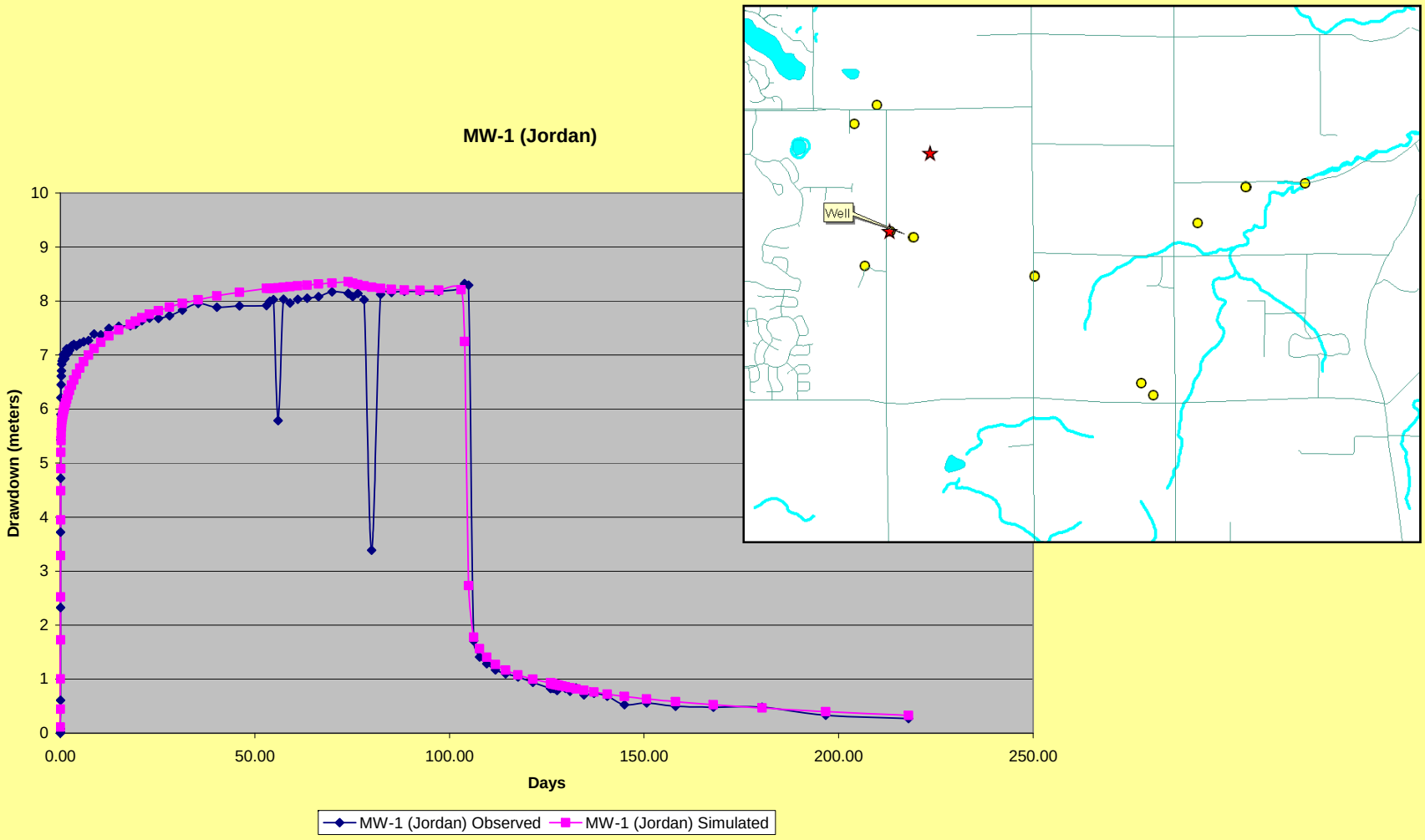
Observed vs Simulated Drawdown



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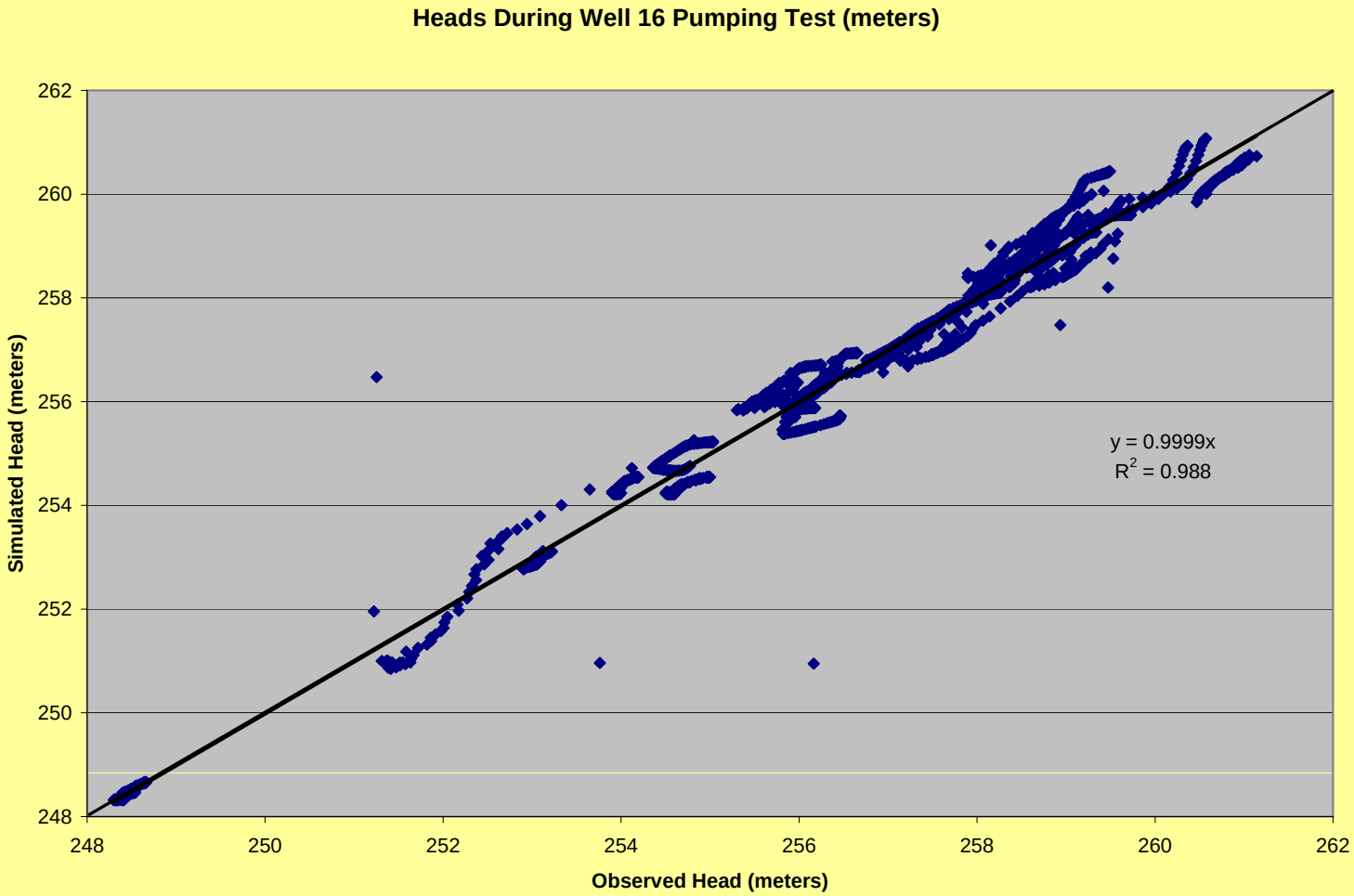
Heads (m, msl): Observed and Simulated in observation wells during aquifer test



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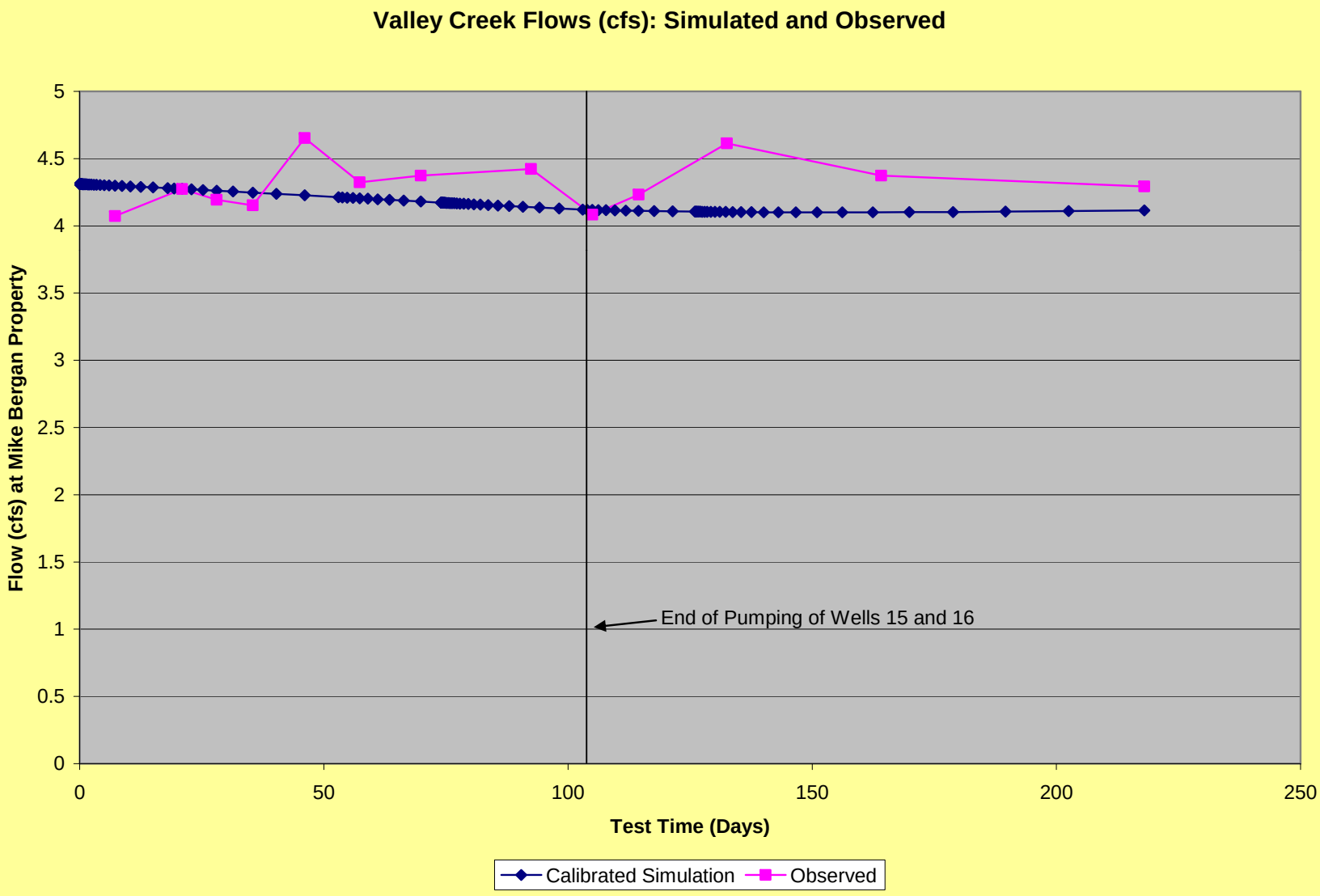
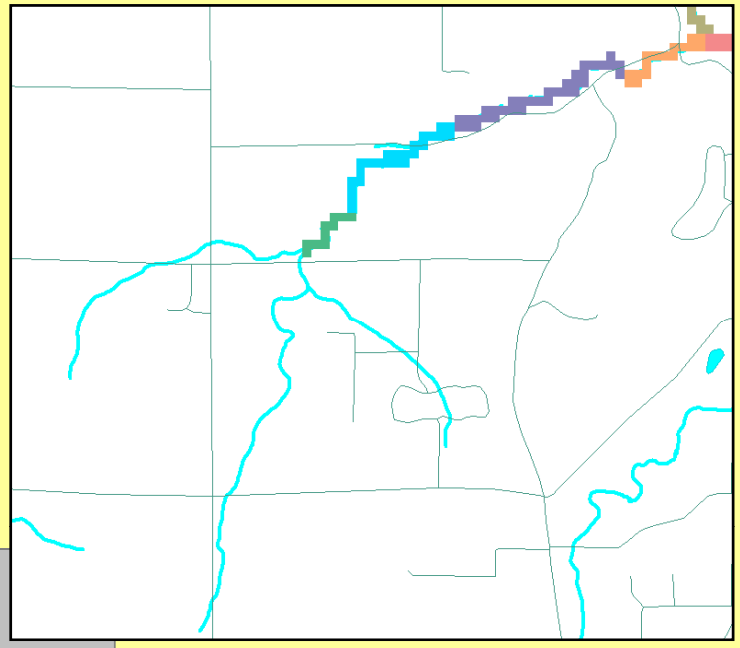
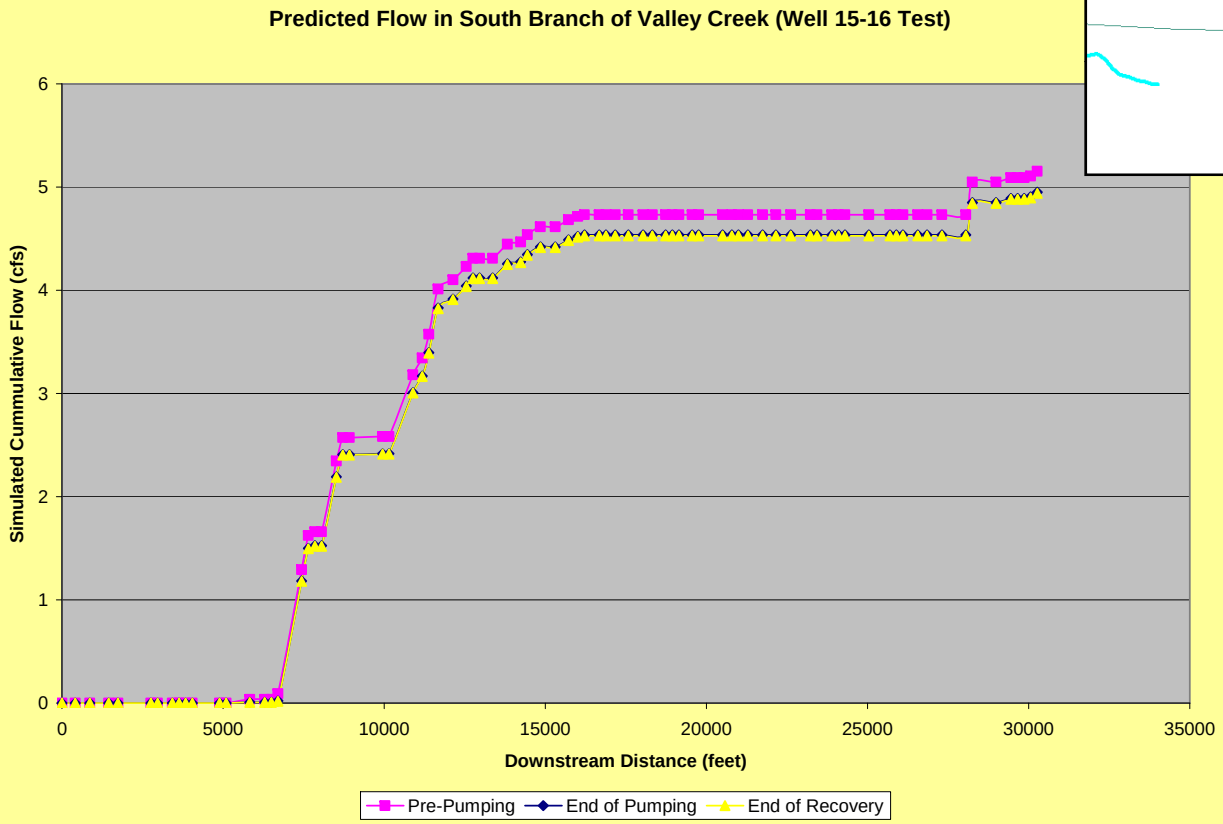
Flow in Valley Creek: Predicted vs. Observed



Predicted Cummulative Flow in Valley Creek





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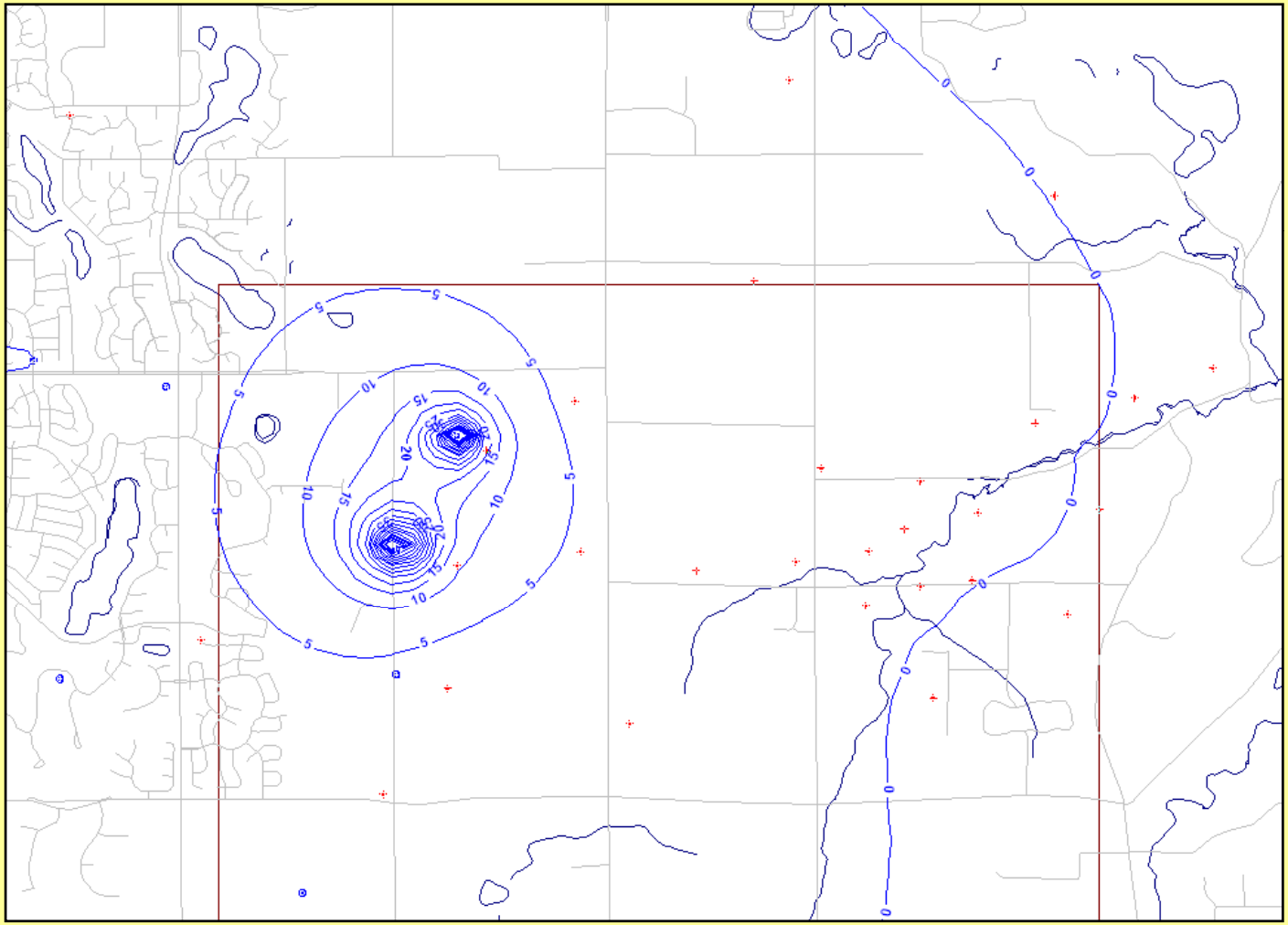
Predicted Drawdown (ft) at End of Pumping Phase: Jordan Sandstone



5 ft contour interval

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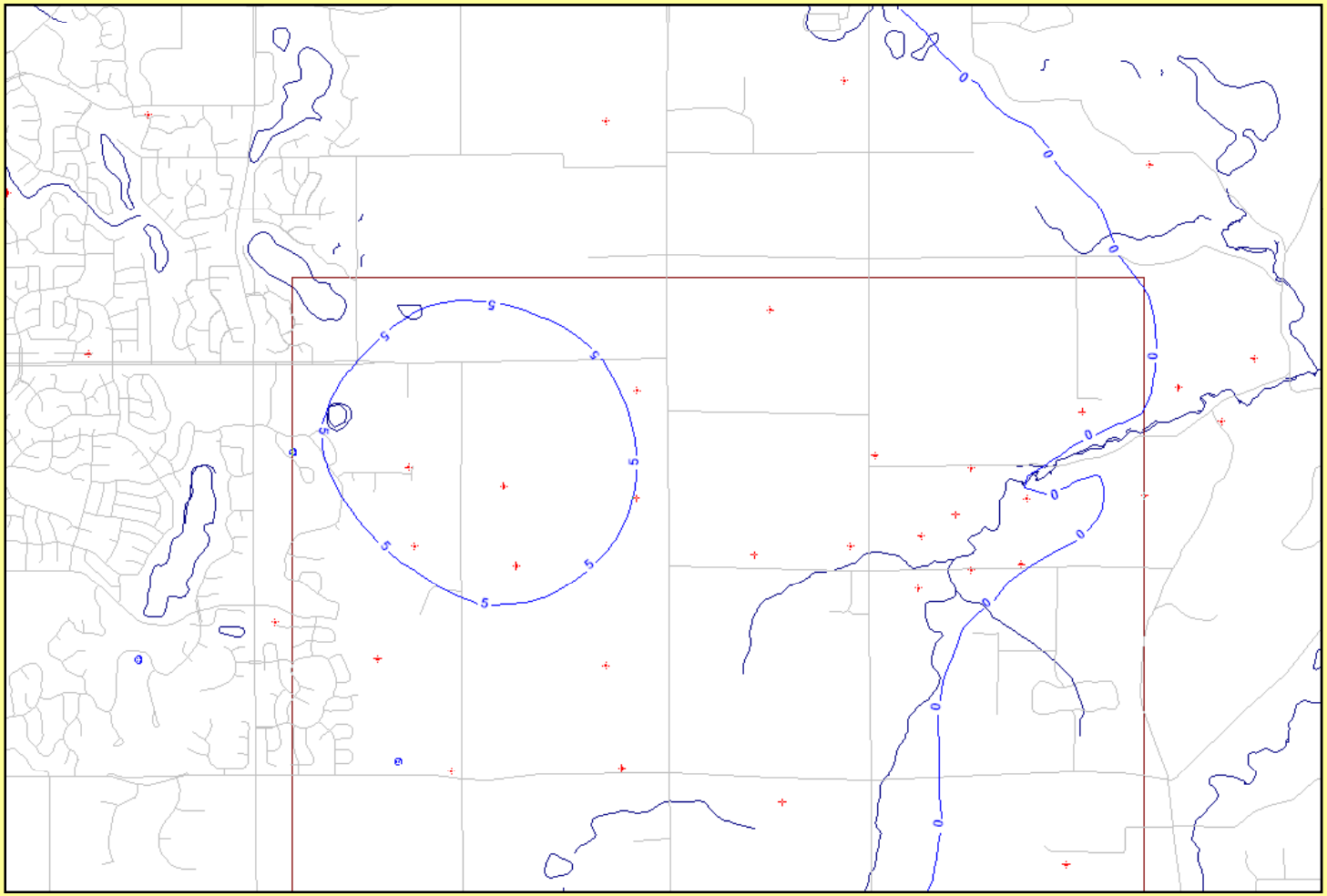
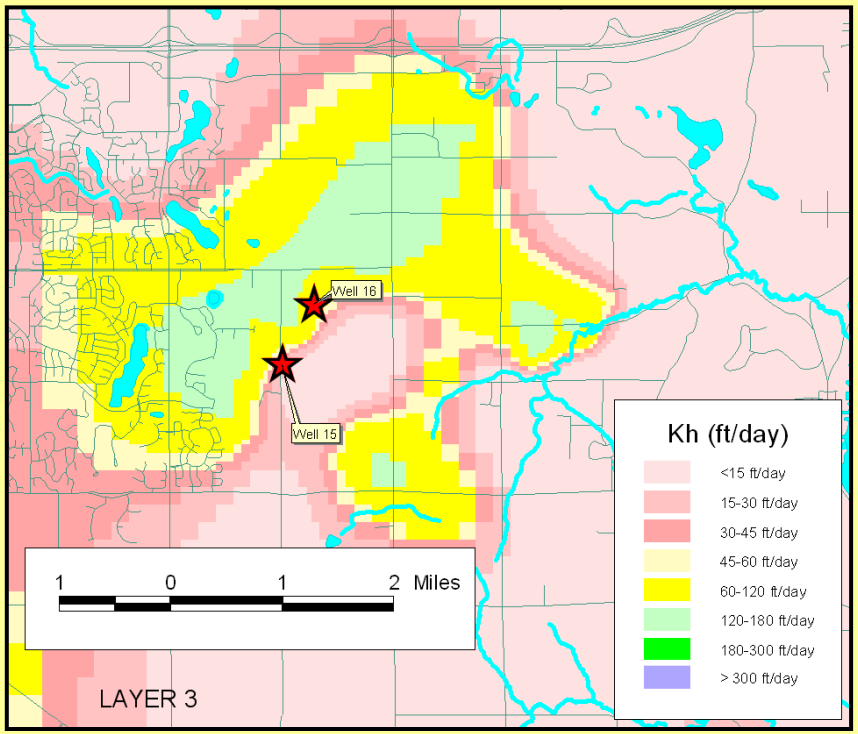
Predicted Drawdown (ft) at End of Pumping Phase: Shakopee Formation



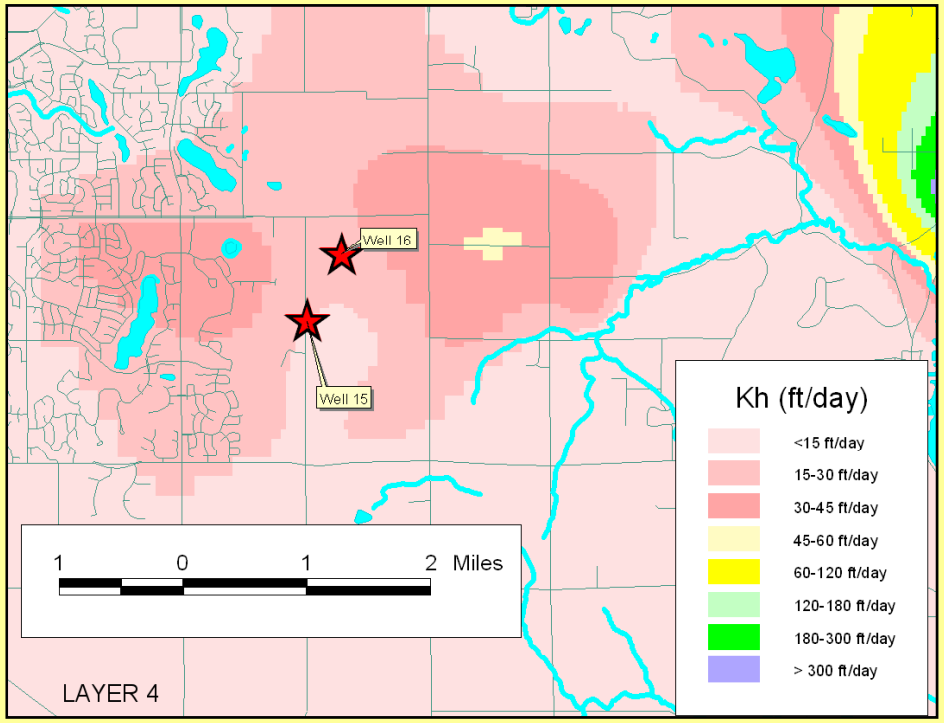
5 ft contour interval

BARR

Calibrated Horizontal Hydraulic Conductivity Values



Mostly Shakopee



Mostly Oneota

BARR

Future Well Field Simulations

- Two future well fields – East and Southwest in the City of Woodbury
- Transient simulations through 2029
  - Monthly pumping schedules for existing & future wells
  - New wells brought “on-line” sequentially every 3 years
  - Monthly variations in recharge (used SWB results for climate conditions from 1975-2005)
  - Changes in land use in Woodbury

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Why use a transient simulation?

- To place the effects of future pumping on baseflow in context with the effects of other “model-able” phenomena

- To more accurately reflect the way existing and future wells will be used

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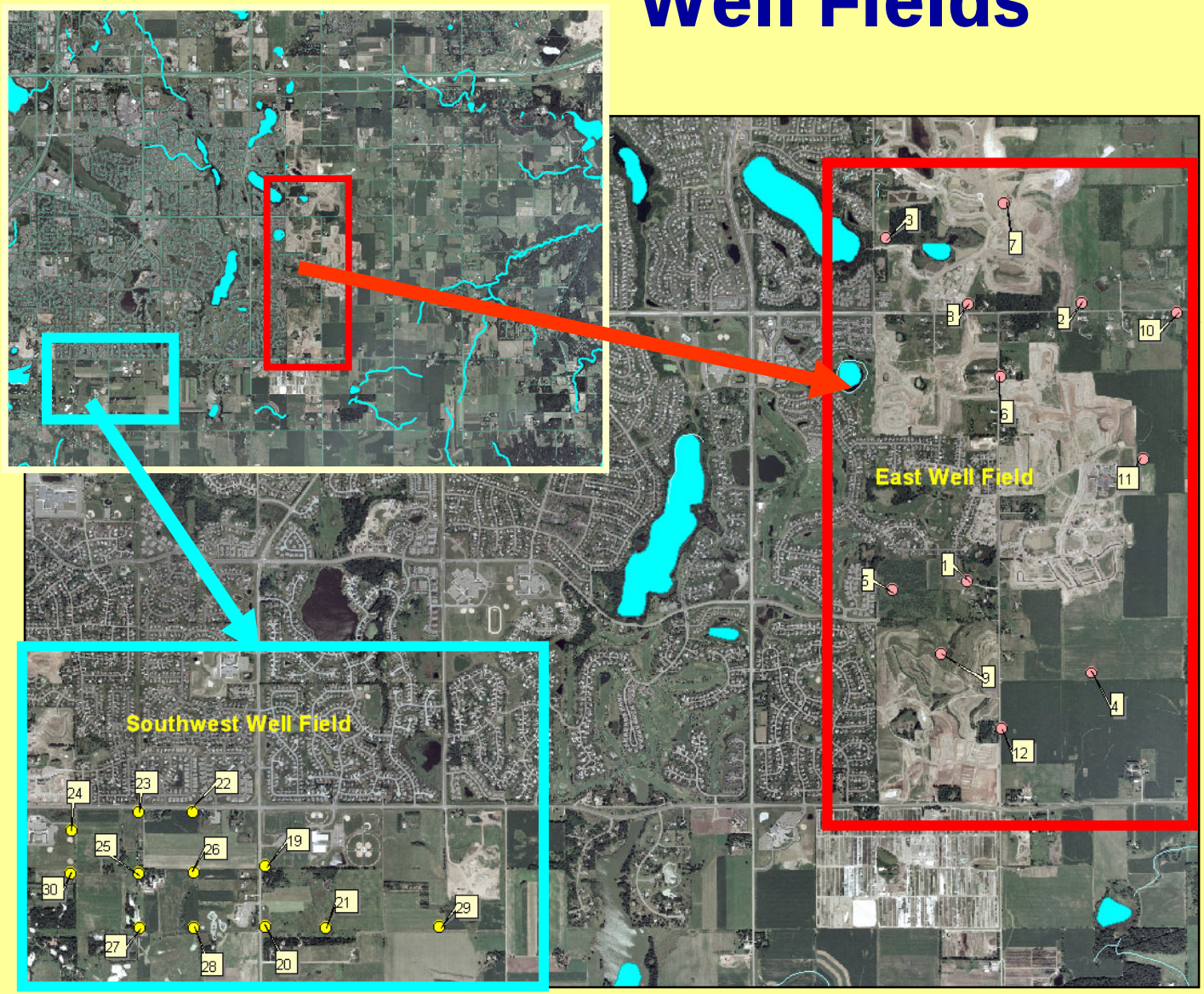
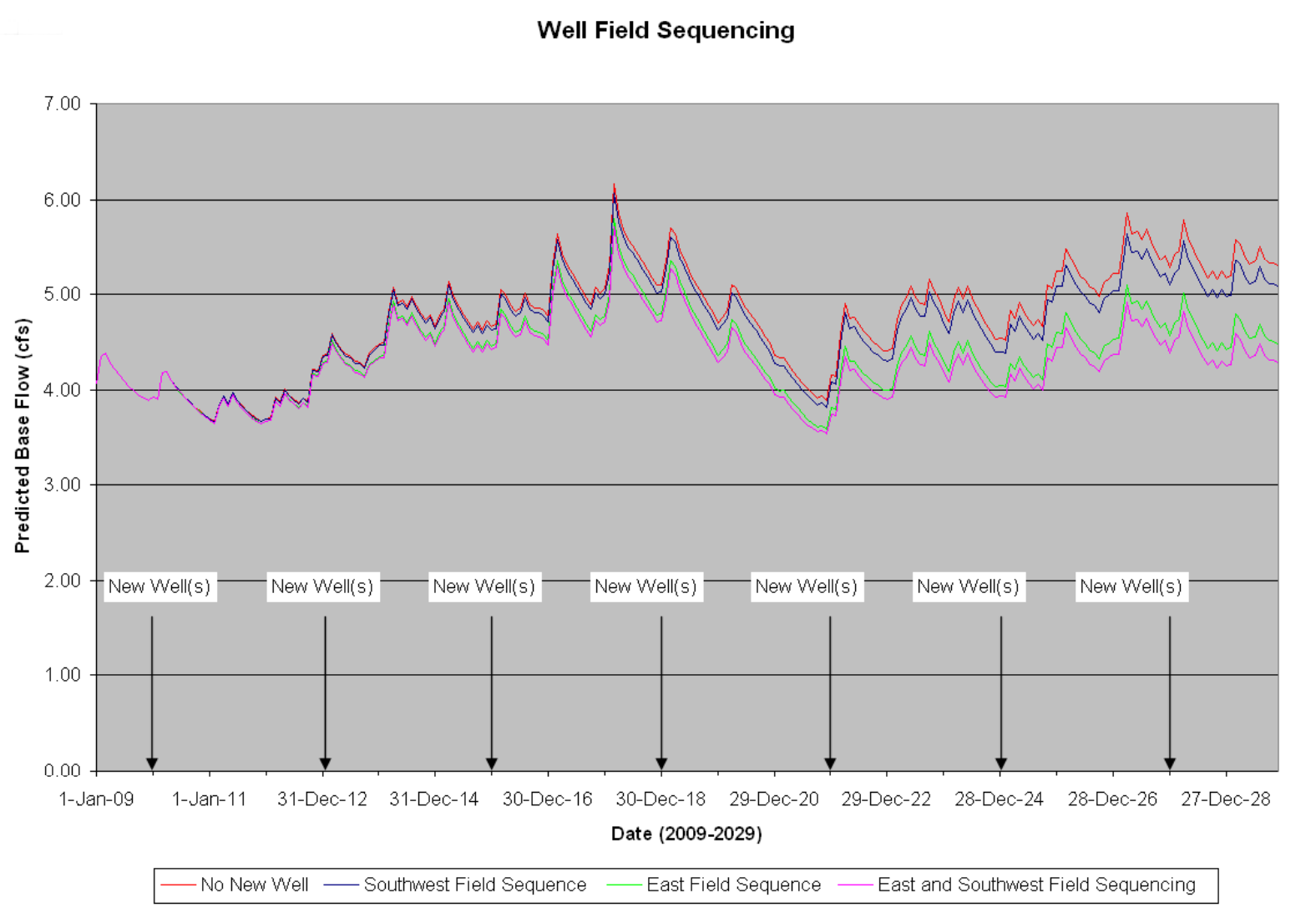
East and Southwest Well Fields



BARR

Predicted Effects on Baseflow



Predicted Sources of Baseflow Changes – compared to yearly fluctuations

	East Well Field	Southwest Well Field	East & Southwest Well Fields	Climatic-Related Year-to-Year Fluctuations
Mean Base Flow Change	0.35 cfs	0.08 cfs	0.41 cfs	0.69 cfs
Maximum Base Flow Change	0.66 cfs	0.18 cfs	0.81 cfs	1.47 cfs

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Predicted Sources of Baseflow Changes – compared to monthly fluctuations

	East Well Field	Southwest Well Field	East & Southwest Well Fields	Climatic-Related Month-to-Month Fluctuations
Mean Base Flow Change	0.35 cfs	0.08 cfs	0.41 cfs	0.11 cfs
Maximum Base Flow Change	0.66 cfs	0.18 cfs	0.81 cfs	1.00 cfs

BARR

A cautionary word on the predictive tool that we have created

“The Wax Key”

Conclusions

- Pumping in Woodbury will cause a reduction in baseflow of Valley Creek (we didn't need a model to figure that out)
- We may not ever be able to tease out pumping effects from climatic (or other) fluctuations in *stream* flow data
- We are continually learning new things about hydraulic connections in this area

BARR

Some interesting questions (sources of continuing uncertainty)

- What is the role of the fault system (and other conduit flow) on stream flow?
- What is the stream flow? What is the accuracy of stream-flow measurements?
- What is the role of changing land use on recharge and baseflow? How will infiltration measures affect stream flow?
- How much induced leakage takes place from the F-I-G when wells are pumped?

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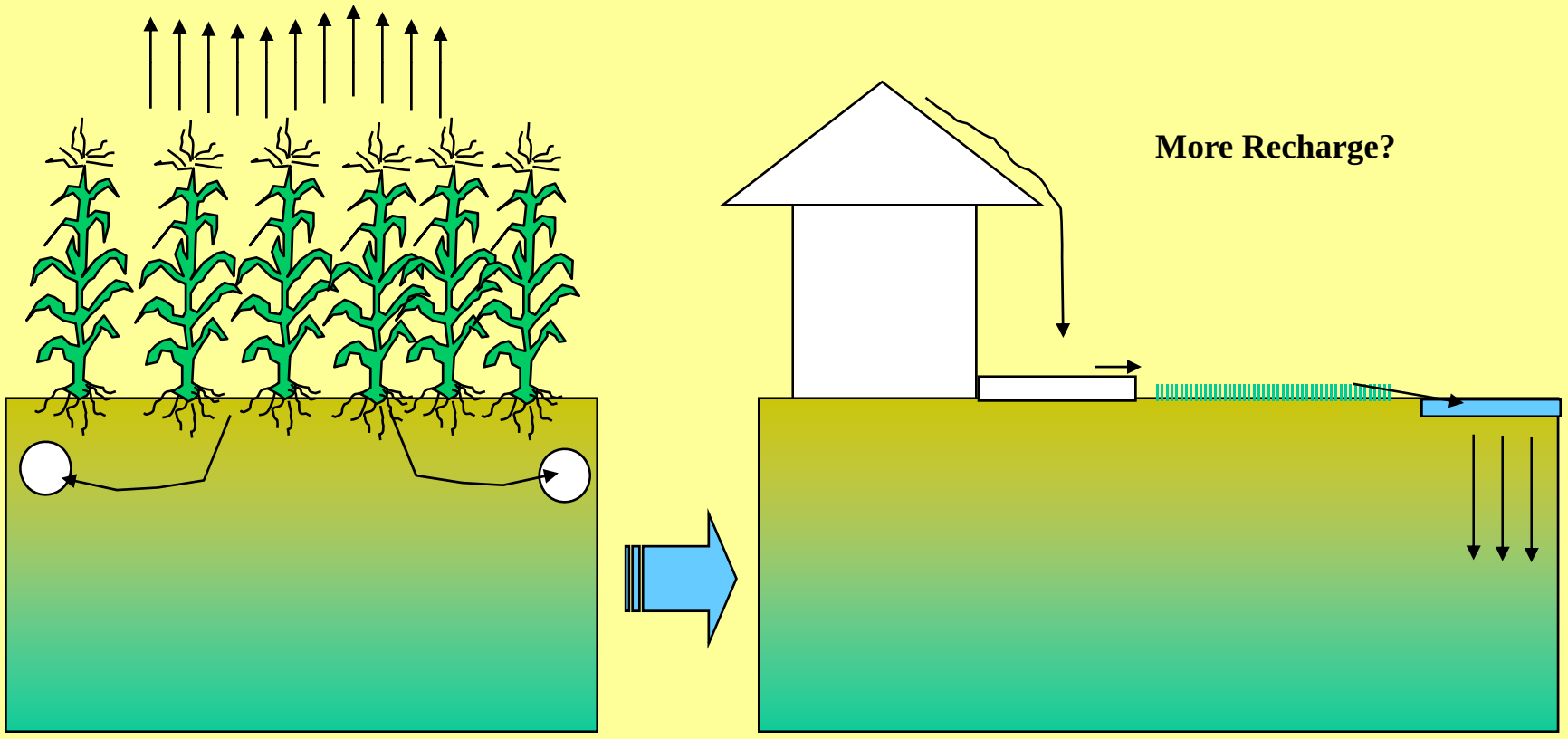
Changing land use and recharge…

IS THIS HAPPENING AND BY HOW MUCH?



BARR

What will the policy be concerning pumping effects on (trout) streams going forward?

- Will we acknowledge that baseflow reductions will occur? Will we single out some users of groundwater but not others?
- Will we look at cummulative (basin-wide) effects?
- Will we find some quantitative measure for acceptable reduction?
- Can we get creative on mitigative measures?
- How will we operate in an uncertain world?

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