Water Supply Assessment for the Kaskaskia River Region

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We are halfway through our water supply assessment process

- Summary of work supported by ICCI – First phase of supply analysis and model preparation – January 2010 to May 2011 – 30-page report summary is available at www.icci.org (search report database by author = Knapp). Waiting for release of full report.
- Entering second phase of work – funded through IDNR – will center on evaluation of selected water demand planning scenarios and impact evaluation, primarily through application of models developed under the ICCI work.

Products of ICCI project

1. Compilation, Analysis, and Summary of Existing Information on Water Availability; Preparation of 150-page report

2. Model Development:

- Surface Water Accounting Model
- Watershed and Reservoir Simulation Models
- Groundwater Models

Compilation and Analysis of Existing Information

- Federal Reservoirs – Document water supply allocation process, existing contracts, and yield analysis (IDNR)
- Summarize and evaluate available information on drought impacts on streamflows and reservoir supplies, including yield analysis of water supply systems.
- Retrieve and summarize historical sets of water use and wastewater data as needed to support modeling
- Compile available groundwater data and analyze to determine if additional source locations exist

Evaluation of water supply availability in the region

ISWS models and analyses focus on the primary factors that define/limit water availability :

- Geology
- Climate – drought impacts on streamflows
- Impacts of water resource management
- Water allocations (input by IDNR)

Existing and Potential Water Sources in the Kaskaskia Region

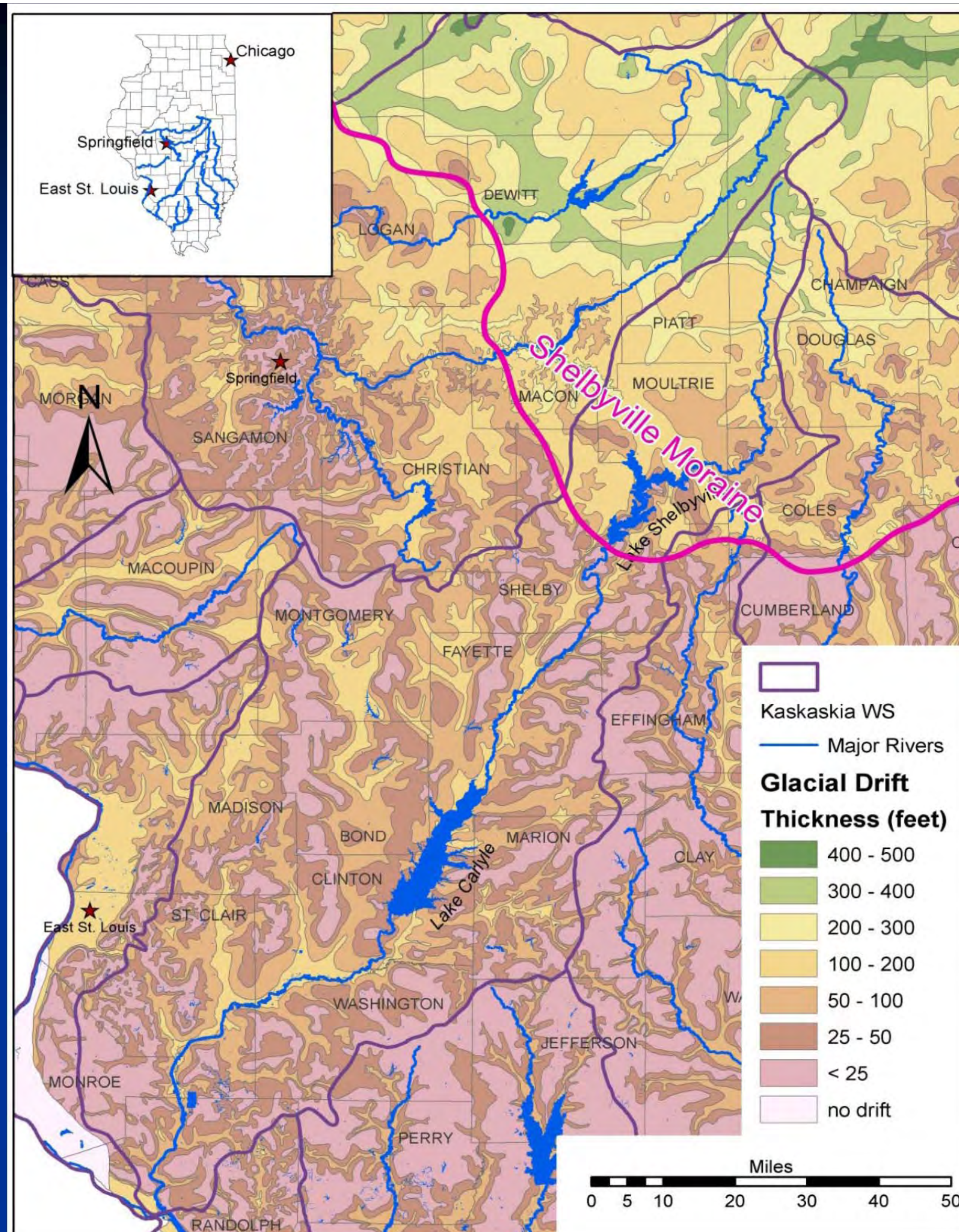
- Shallow Groundwater
- Direct River Withdrawals
- Federal Reservoirs
- Water Supply Reservoirs
- Importing water from outside the basin
- Wastewater effluents

Analysis of Groundwater Data

- Existing documents and reports
- Groundwater model files
- Extent of sand and gravel deposits
- Bedrock geology
- Soil types
- Location of observation wells
- Location of springs
- Aquifer test locations and results
- Locations of community wells
- Distribution and depth of private wells

Glacial Drift Thickness

The Shelbyville Moraine marks the furthest advance of the last glaciation



Source: ISGS

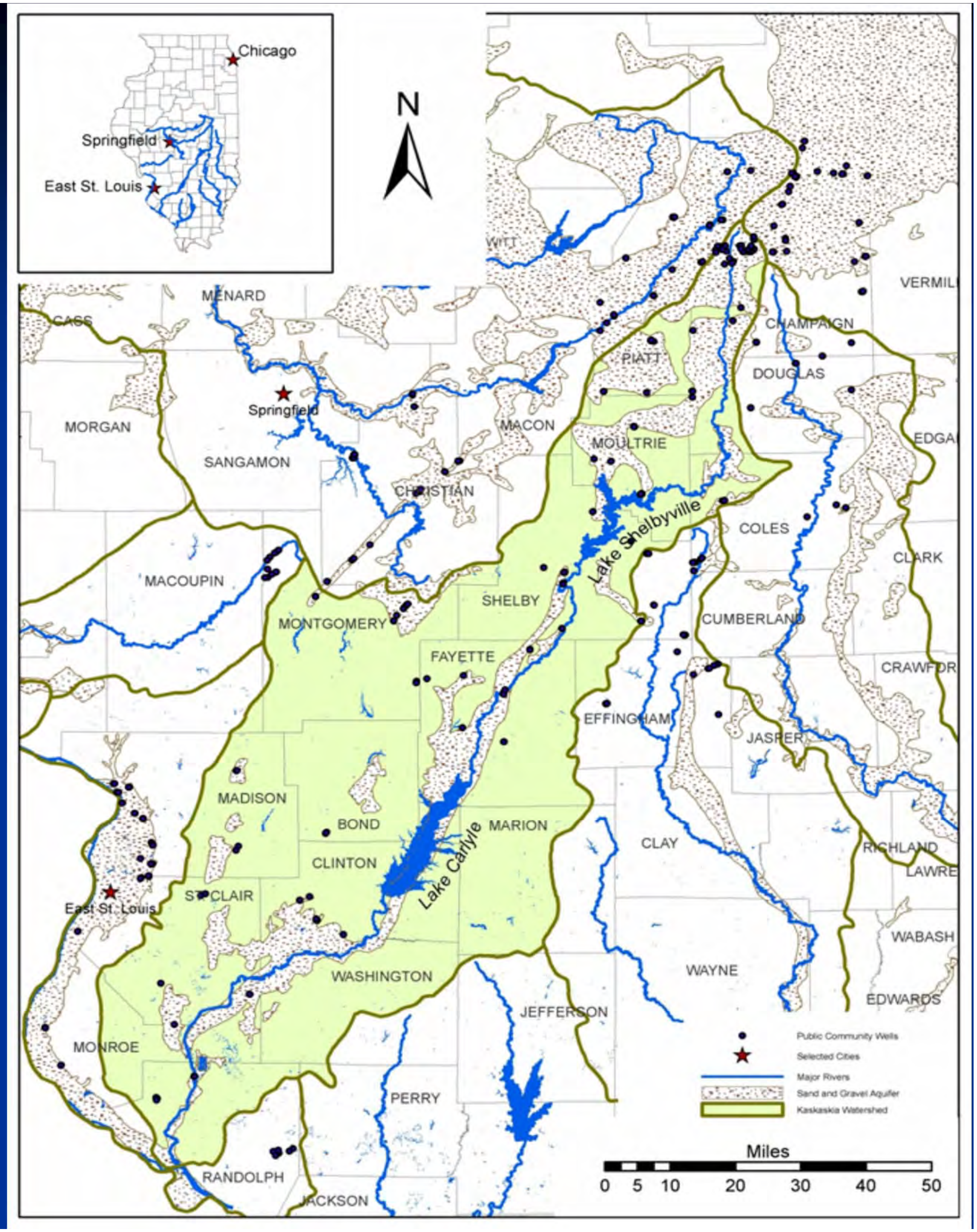
Extent of Sand and Gravel Aquifers

● Active Public Supply Wells

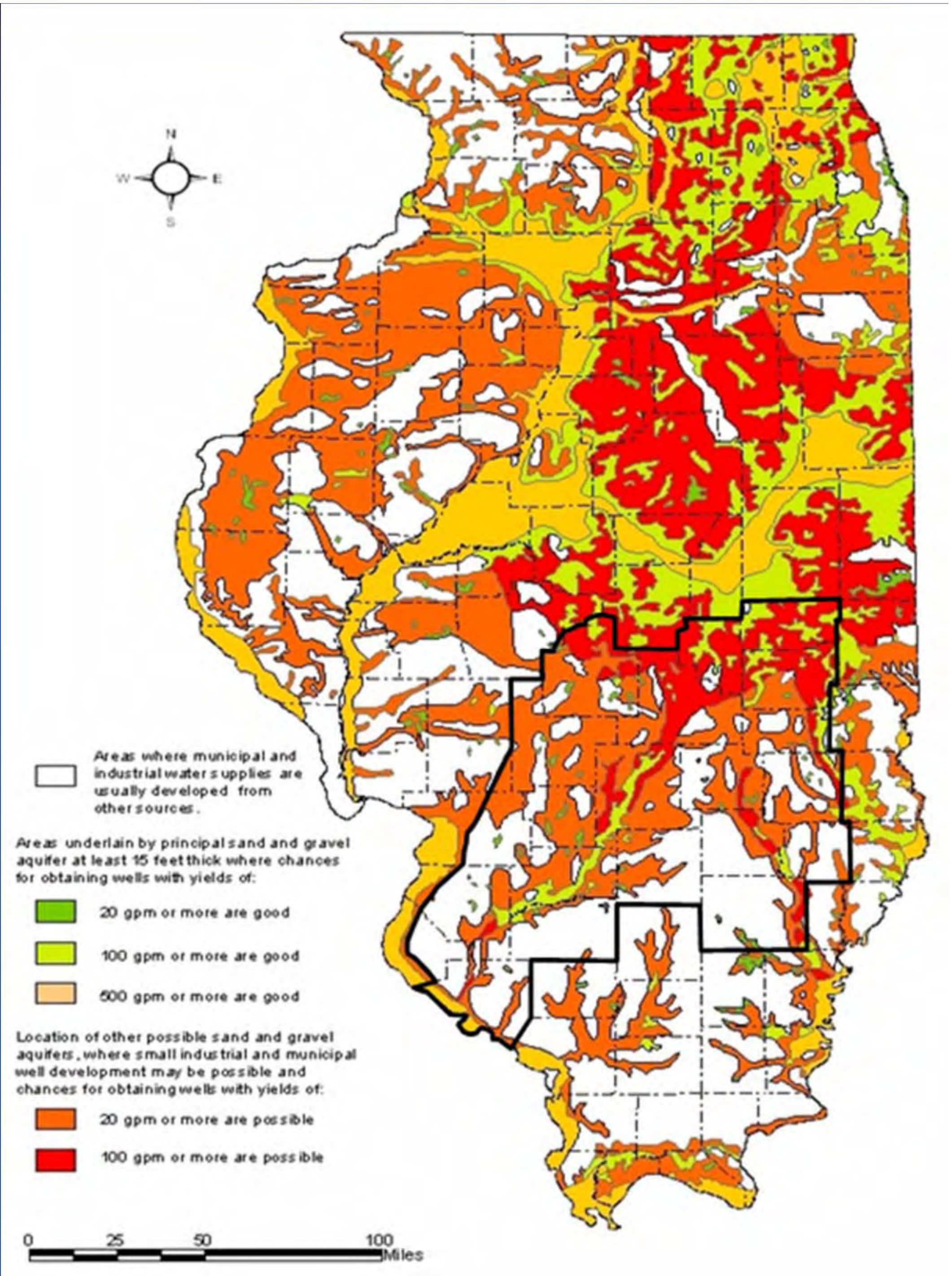
Sand and gravel aquifers are the primary source of groundwater

Many domestic supplies use shallow large-diameter dug wells

Limited freshwater available from the bedrock

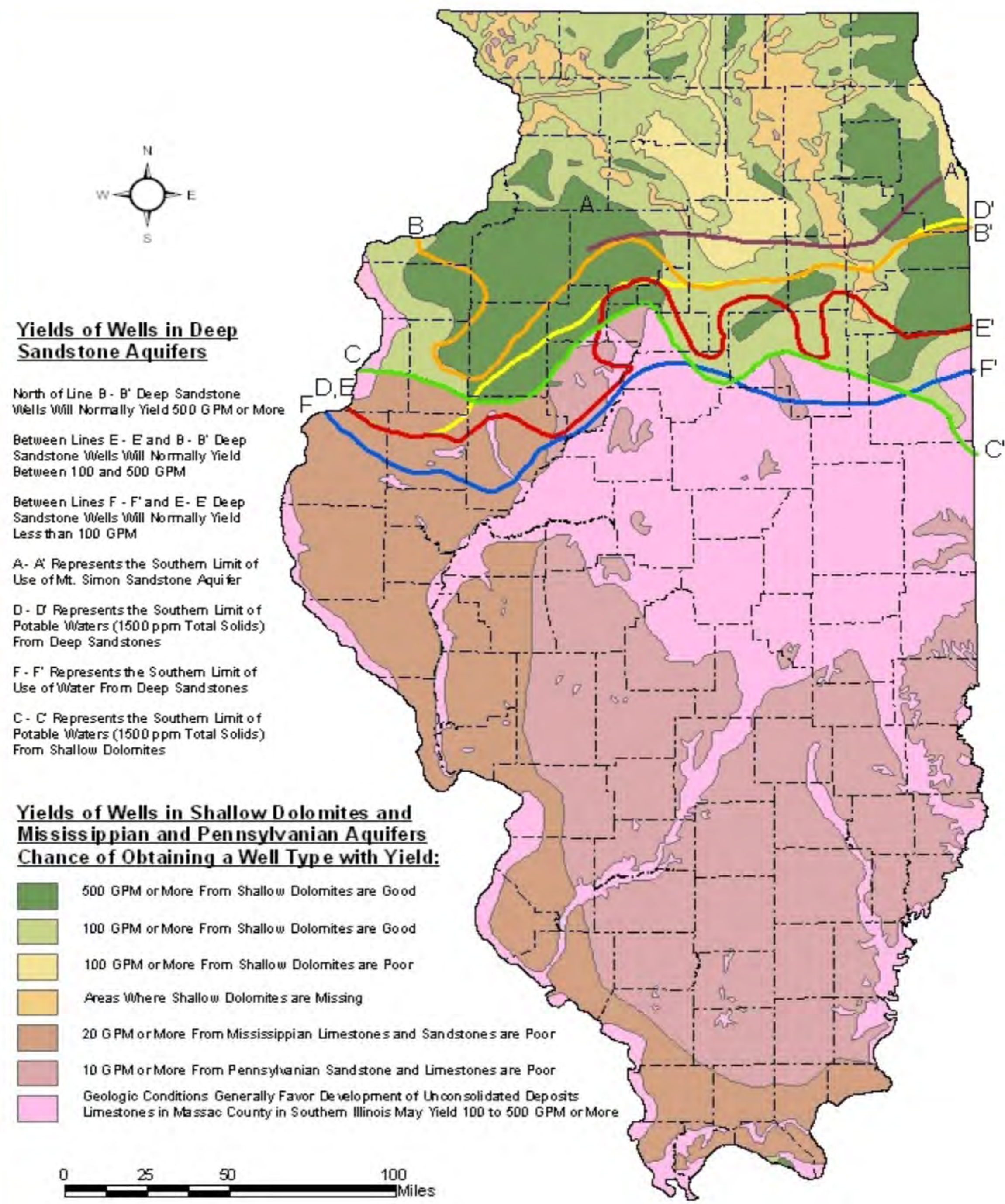


Expected Well Yields - Sand and Gravel Aquifers



Source: Illinois Technical Advisory Committee on Water Resources (1967)

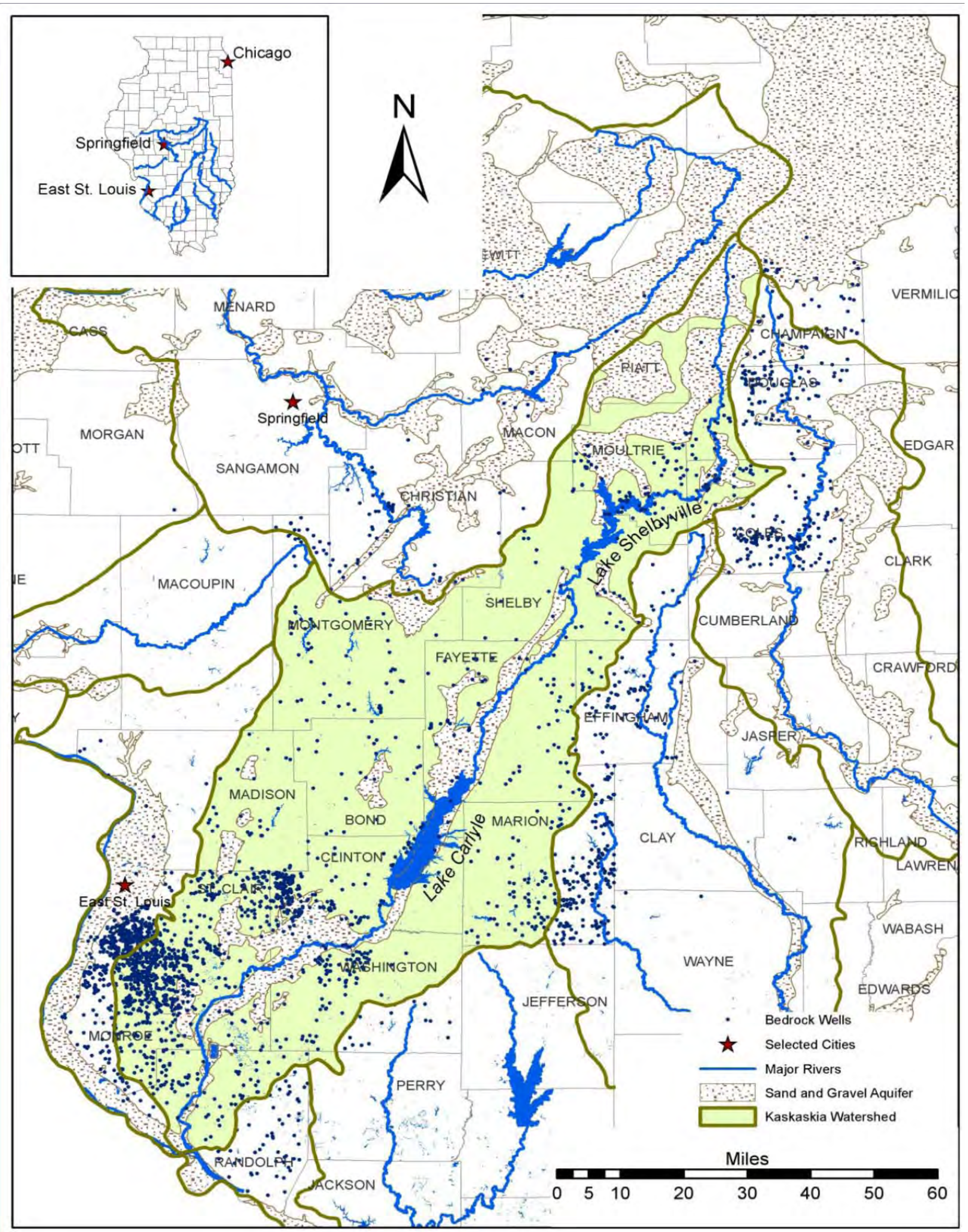
Expected Well Yields - Bedrock Aquifers



Source: Illinois Technical Advisory Committee on Water Resources (1967)

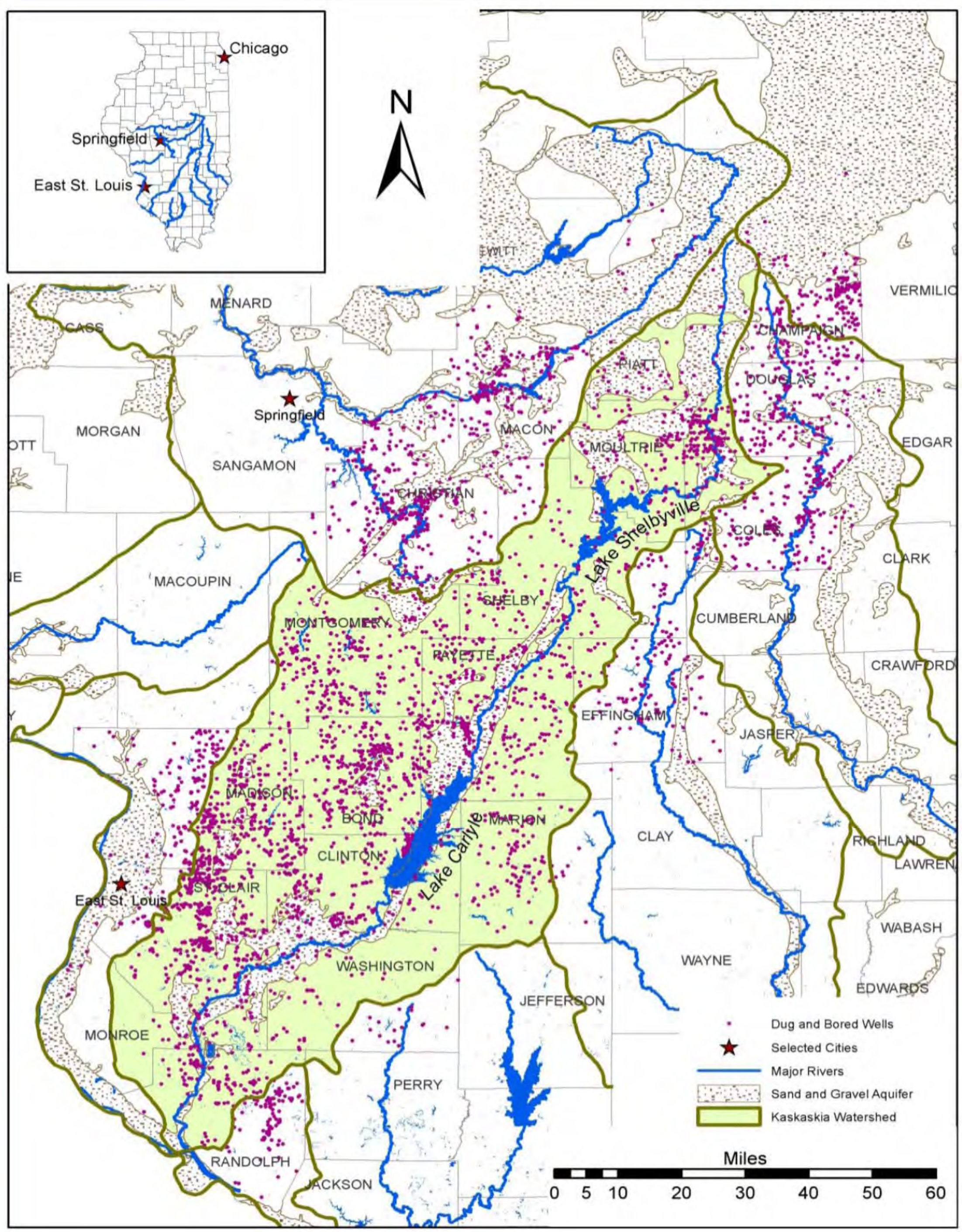
Location of Wells Completed into Bedrock

Private and public wells in ISWS database



Location of Dug and Bored Wells

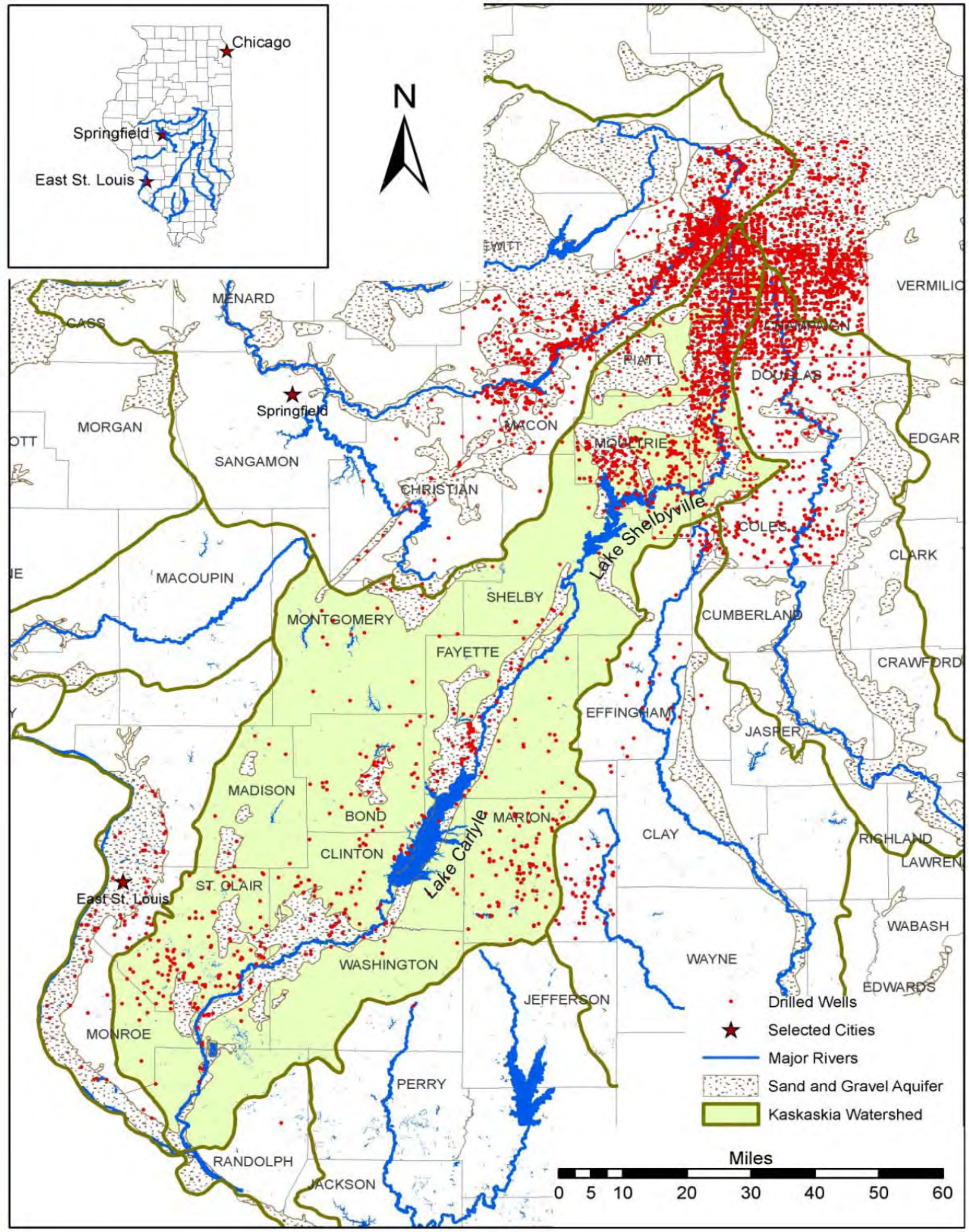
Private and public wells in ISWS database



Location of Dilled Wells Completed in the Glacial Deposits

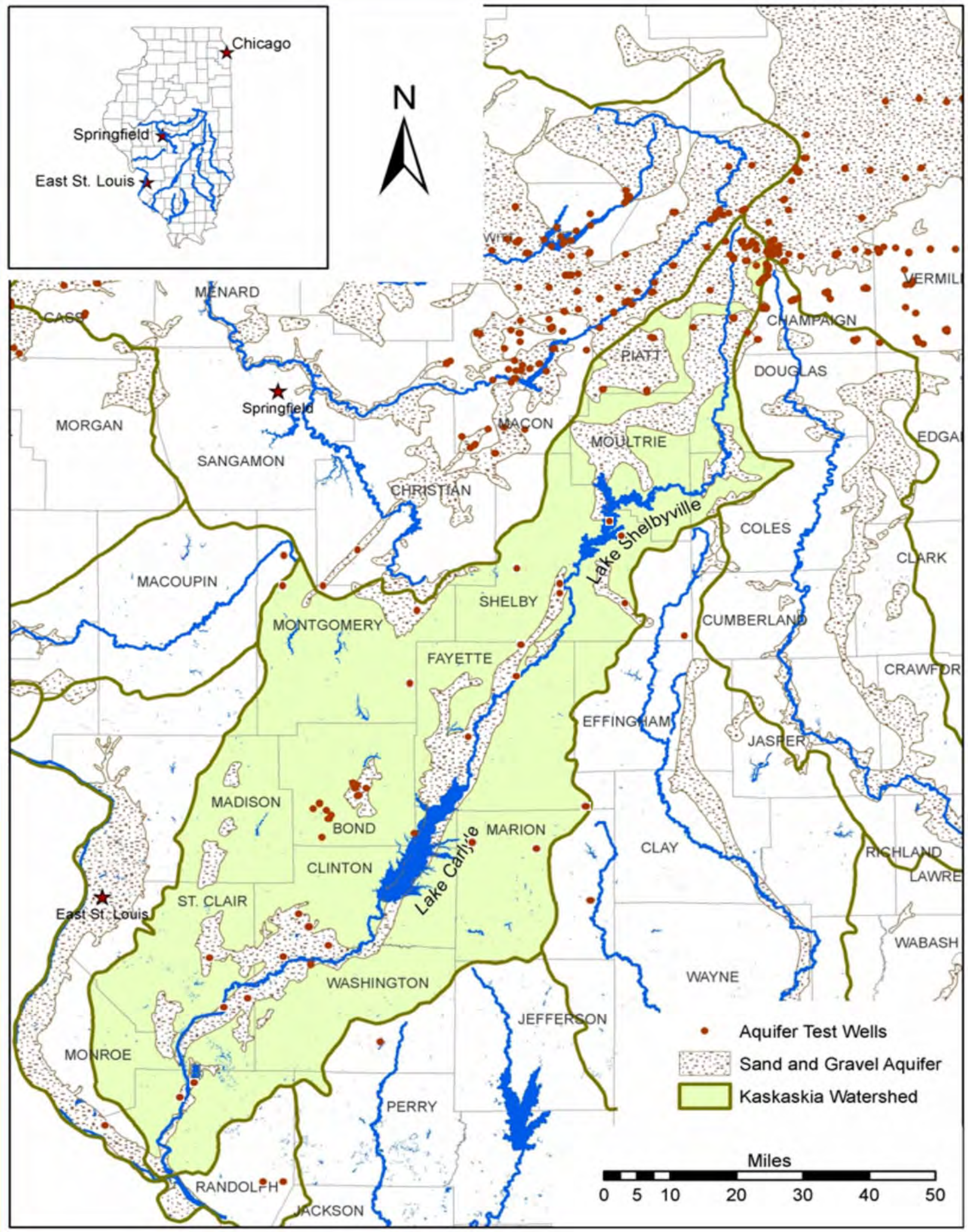
Private and public wells in ISWS database

Data mining used to look for any thicker sand aquifers that have not been previously identified



Locations of Aquifer Tests

ISWS database



Groundwater Availability in Southern Illinois

- Limited availability – major aquifers confined to major river valleys (e.g., Kaskaskia, Embarras)
- Shallow bedrock with thin overburden, limiting thickness of potential sand/gravel deposits
- Bedrock is principally Pennsylvanian shales with very limited groundwater development potential
- Away from the river valleys, sand/gravel deposits will be shallow & areally-limited, making them sensitive to drought and incapable of major additional development

Previous Groundwater Reports

- With respect to groundwater supply, most information is on public supplies
- Three ISWS studies assessed 22 PWS within the Kaskaskia Basin study area:
  - *Assessment of Public Groundwater Supplies in Illinois*, Visocky et al., 1978, ISWS Contract Report 209
  - *Assessment of Public Groundwater Supplies in Illinois*, Visocky et al., 1980, ISWS Circular 144
  - *Assessment of Eighteen Public Groundwater Supplies in Illinois*, Wehrmann et al., 1980, ISWS Contract Report 237
- 11 of those 22 PWS supplies now purchase their water

Modeling Groundwater Availability

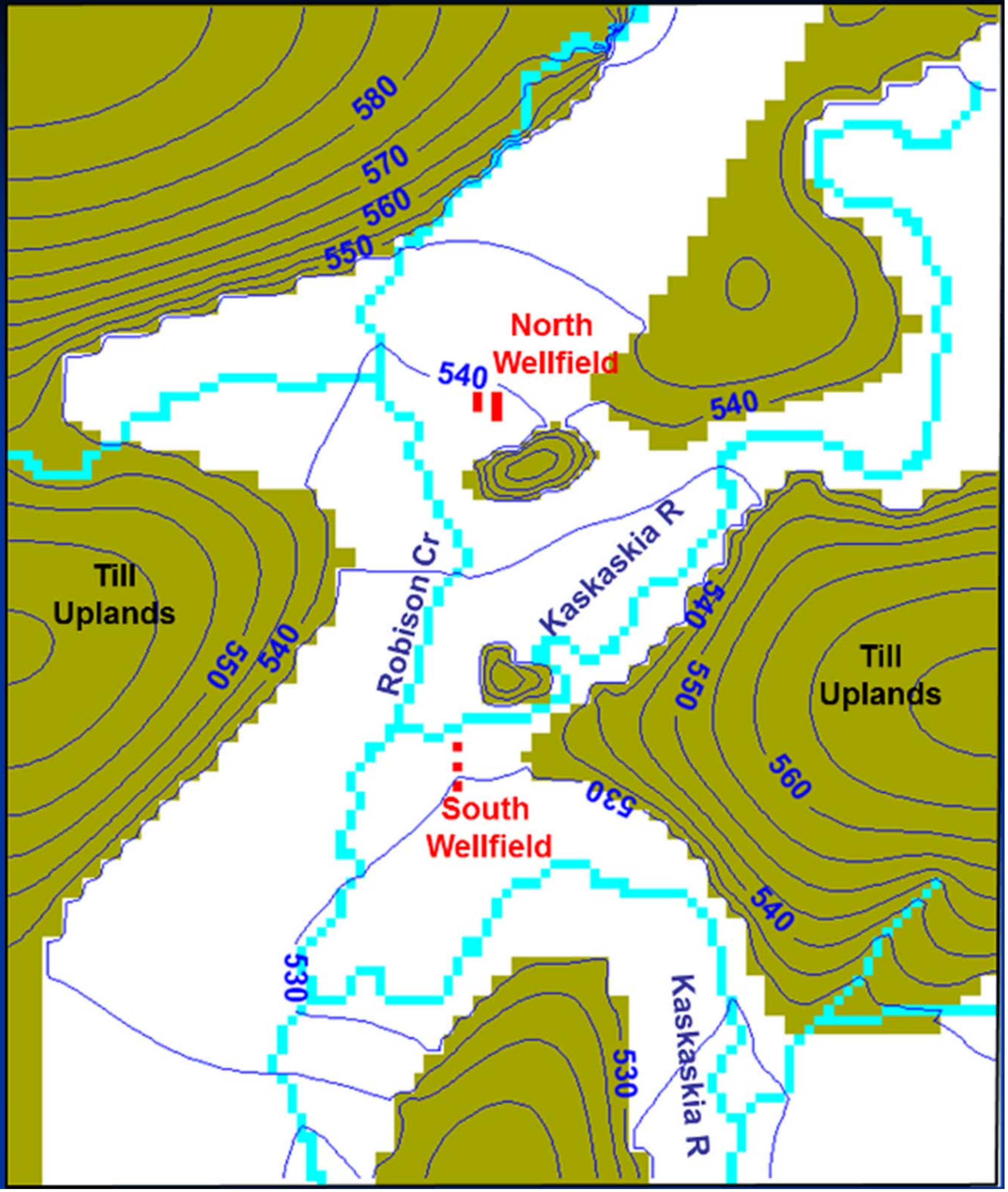
Analytical Modeling and Digital Modeling

- Analytic models make several assumptions about the aquifer-of-interest to simplify calculations of drawdown:
  - Assume the aquifers are isotropic and homogenous
  - If possible, assume aquifers are laterally extensive
  - If not possible, aquifer boundaries are assumed to be linear and either recharge or barrier boundaries; then use image well theory to calculate drawdowns
- Such techniques are very useful for assessing relatively small aquifers where available data are limited and the expense of collecting such data are not merited
- Where aquifer is complex and data can support the use of more sophisticated models, digital computer models are preferred, such as at Shelbyville, Taylorville, and Vandalia

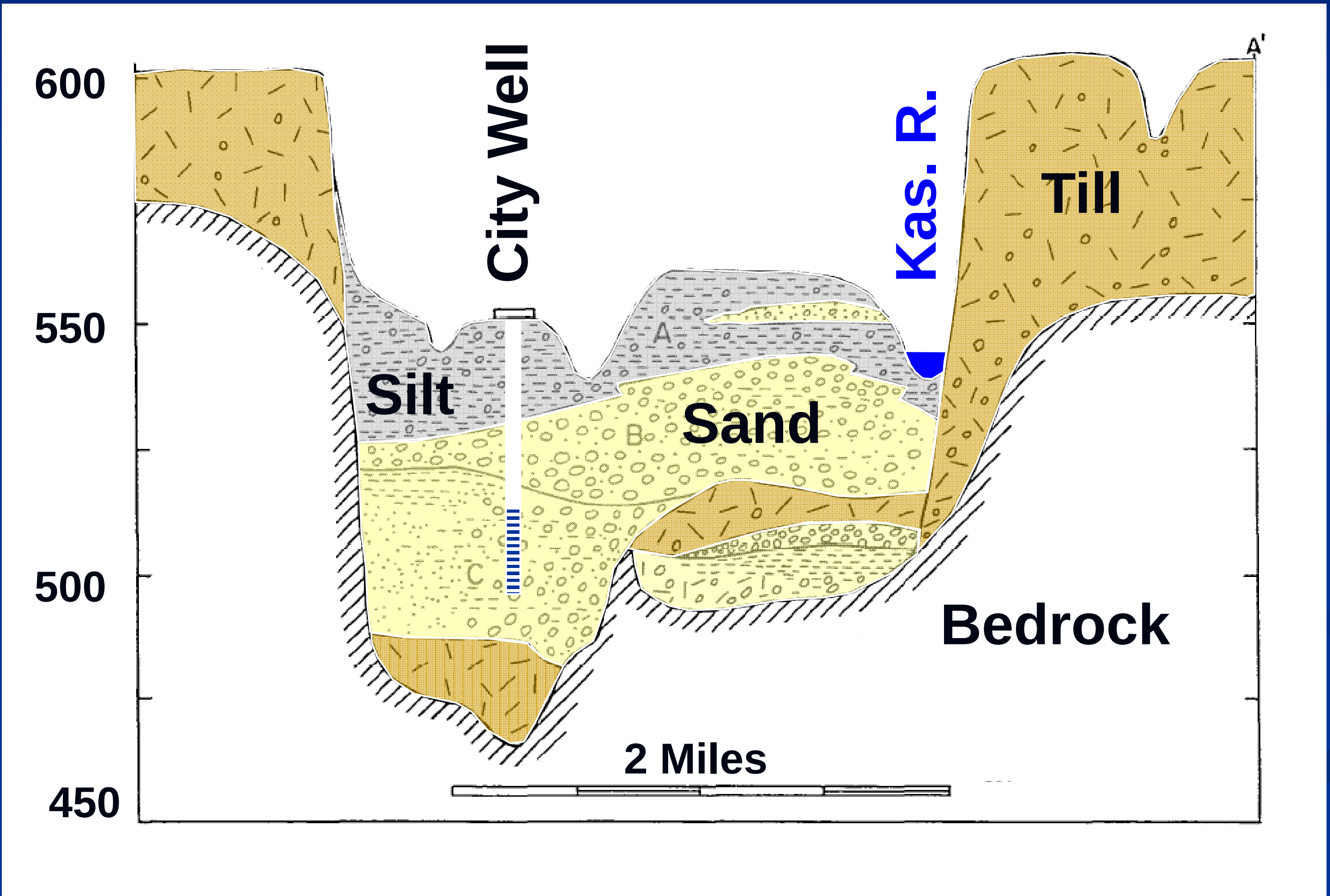
Small Town Aquifer PWS Adequacy

PWS	County	Est. Aquifer Yield, in gpd	Latest Q, in gpd (year)	Use/Yield
Dieterich	Effingham	45,000	21,700 (2008)	0.48
Edinburg	Christian	110,000	112,000 (2004)	1.02
Farmersville	Montgomery	none	92,000 (2004)	?
Fillmore	Montgomery	33,000	29,000 (2007)	0.88
Nokomis	Montgomery	216,000	261,000 (2002)	1.21
Oreana	Macon	75-85,000	100,200 (2008)	1.25
Percy	Randolph	100,000	82,500 (2009)	0.82
Red Bud	Randolph	500,000	390,000 (2007)	0.78
Toledo	Cumberland	129,000	101,300 (2008)	0.78
Willow Hill	Jasper	43,000	19,100 (2009)	0.44
Windsor	Shelby	140,000	91,600 (2007)	0.65

Predicted Water Levels from the Shelbyville Model

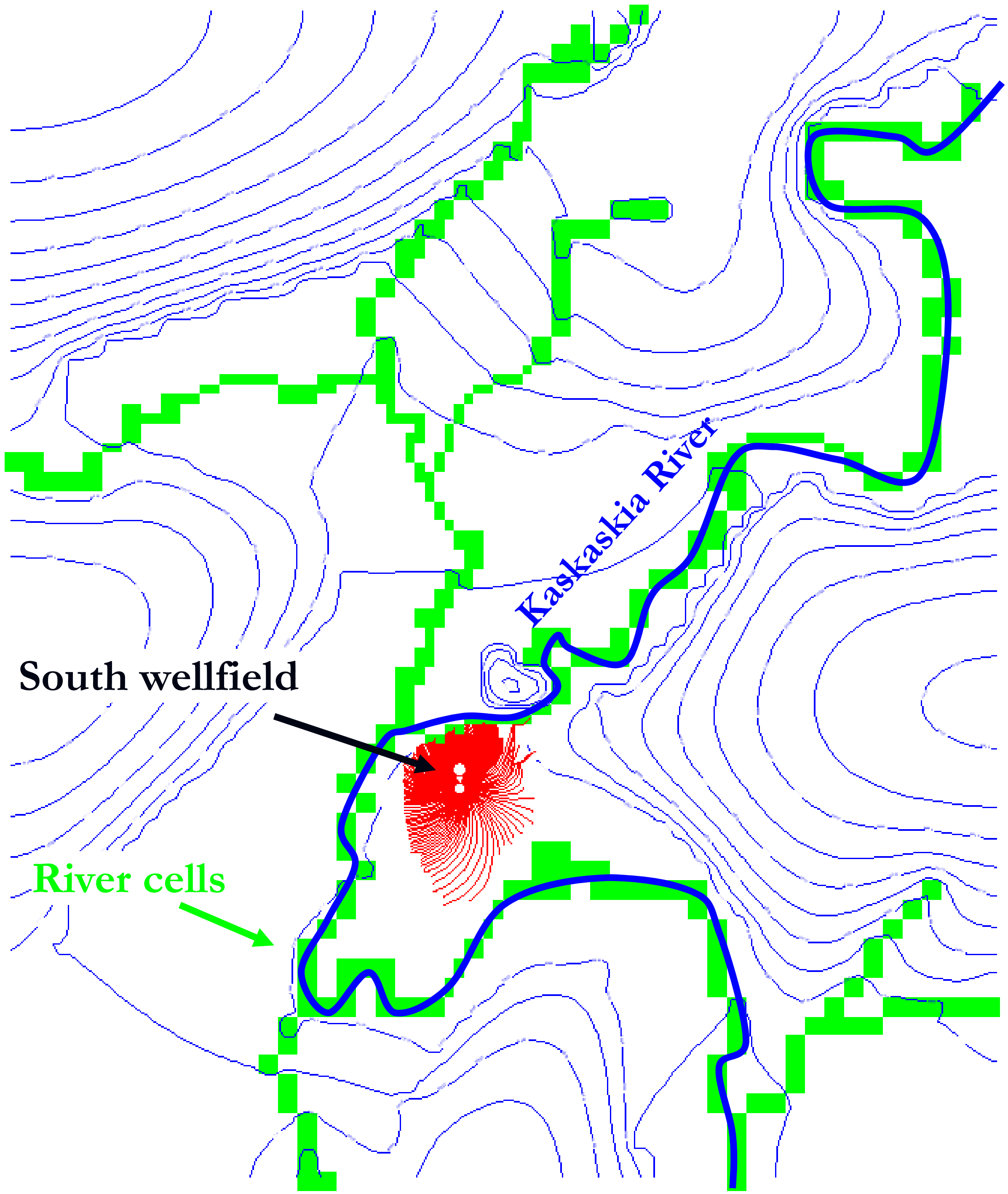


Example of Digital Modeling - Shelbyville

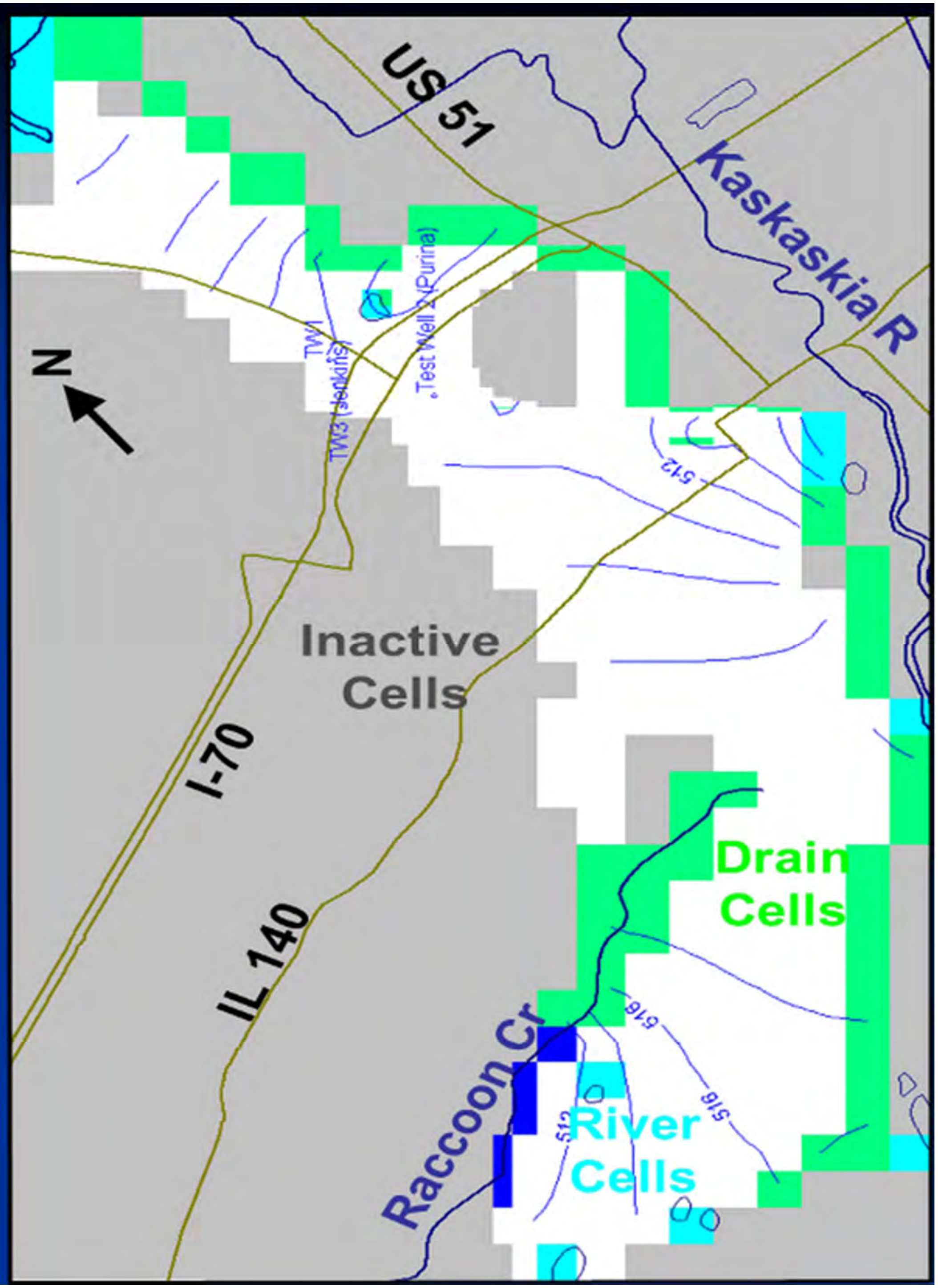


Shelbyville Model Output

Red lines show groundwater flow paths from the river to the wells



Predicted water levels from the Vandalia Model



Digital Groundwater Modeling

- Results of digital groundwater modeling to date suggest that groundwater extracted from wells in or near the Kaskaskia River valley essentially are either taking flow indirectly from the river, or are otherwise reducing the flux of natural groundwater flow to the stream.

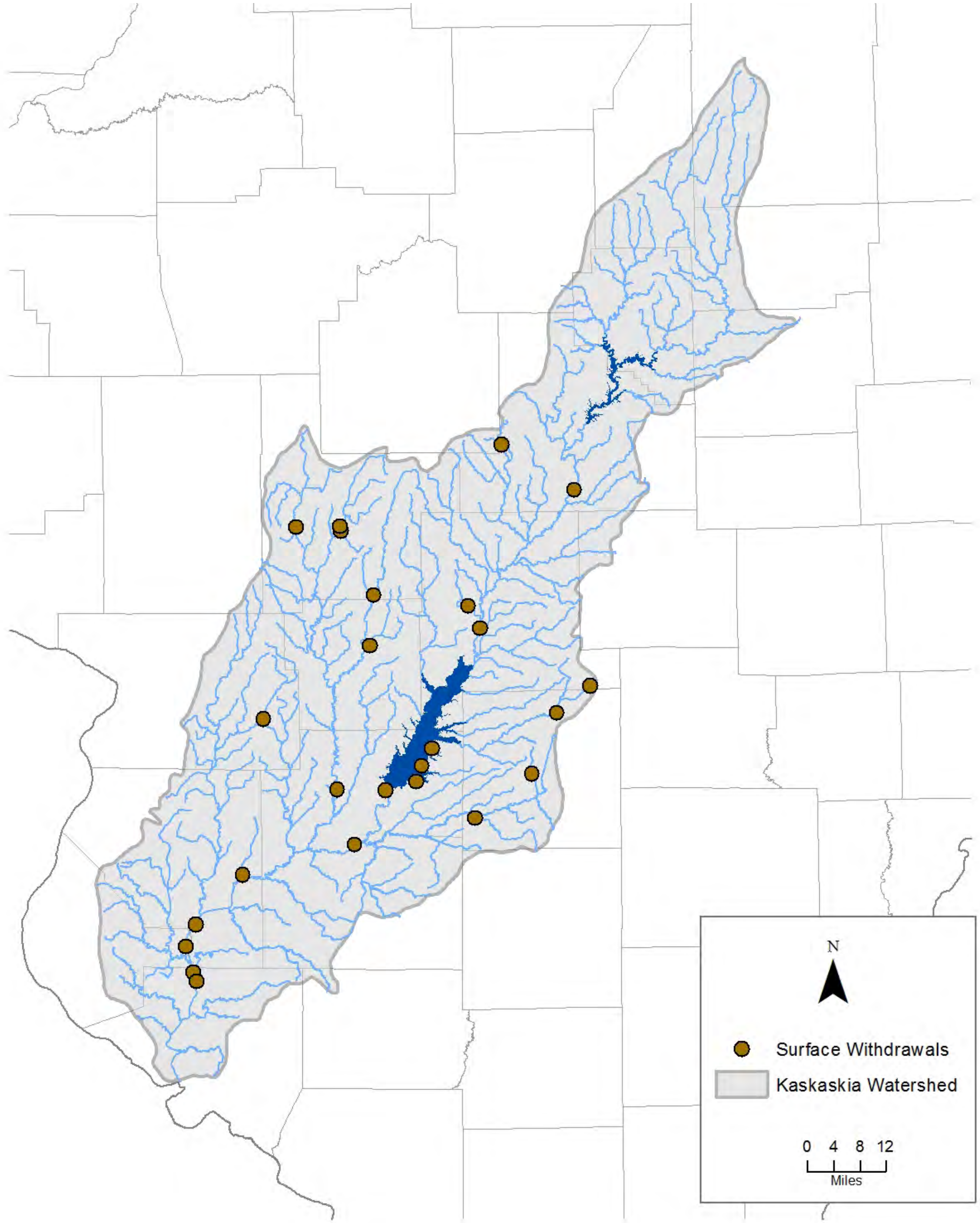
Existing and Potential Water Sources in the Kaskaskia Region

- Shallow Groundwater
- Direct River Withdrawals
- Federal Reservoirs
- Water Supply Reservoirs
- Importing water from outside the basin
- Wastewater effluents

Surface Water Withdrawal Locations

With the exception of withdrawals from the Kaskaskia River, all surface water systems in the region require reservoir storage.

Most streams go dry during extended dry periods.



Direct River Withdrawals

- Only the Kaskaskia River is capable of providing a sustained water supply for communities
  - Vandalia
  - Carlyle
  - Nashville
  - KWD
  - SLM
  - Sparta
  - Evansville
- Richland and Silver Creeks are sustained with effluents (possible industrial supply)

Federal Reservoirs

- Information on the allocation of water supply storage from Carlyle Lake and Lake Shelbyville will be presented next month by Frank Pisani.
- 14% of the storage in both reservoirs has been designated for water supply (managed by IDNR), providing a combined 50-yr yield of roughly 41.5 mgd (estimated in 2001 by ISWS)
- The ISWS will be reexamining the yield analysis in the upcoming year.

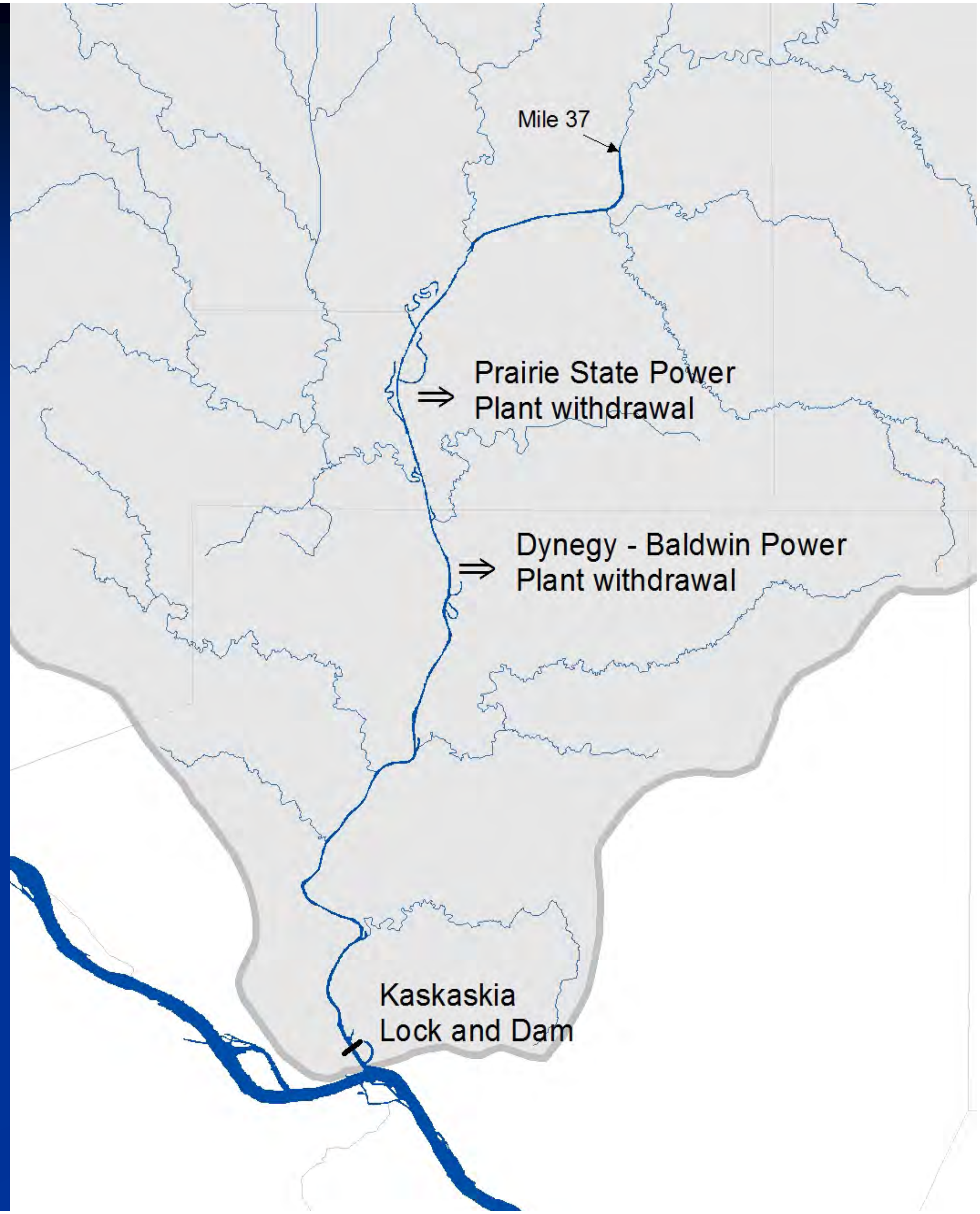
Kaskaskia Navigation Channel

The "third" federal reservoir in the region – developed originally for coal transportation

Lockages use considerable water

Need to analyze impact of 1950s drought on the need for Carlyle releases

Mississippi River as an additional source of water?



Impacts of drought: Difference between moderate and severe droughts in the Kaskaskia Region:

Runoff / inflow during historical droughts (total inches)

	12 months	18 months
Average years	9.0”	12.0”
Moderate droughts (1976-1977 & 1988-1989)	1.0-1.5”	3.5-4.0”
1953-1954 drought	0.1-0.3”	0.4-0.8”

Difference in yields for federal reservoirs:
1950s drought = 42 mgd, moderate droughts > 90 mgd

New reservoirs built after the 1953-1955 drought

- Lou Yeager (Litchfield)
- Glenn Shoals (Hillsboro)
- Governor Bond (Greenville)
- Vandalia Lake
- Highland Silver Lake
- Lake Mattoon
- Lake Sara (Effingham)
- Lake Taylorville

*Centralia connected to the Kaskaskia River

The storage in these reservoirs exceeds Carlyle & Shelbyville WS storage

Comparison of demand & yield (drought of record) for larger community systems

	Demand (mgd)	Yield* (mgd)
Charleston	1.5	4.6
Effingham	2.1	5.7
Greenville	1.4	3.0
Highland	1.3	2.0
Hillsboro	1.3	3.3
Litchfield	1.0	3.4
Mattoon	2.4	5.0
Olney	1.3	2.1
Taylorville	2.4	3.1

Comparison of demand & yield (drought of record) for smaller community systems

	Demand	Yield*	
Altamont	0.25	0.12	Inadequate
Breese	0.74	0.65	At Risk
Coulterville	0.14	0.01	Inadequate
Farina	0.14	0.05	Inadequate
Kinmundy	0.08	0.26	
Mt. Olive	0.21	0.19	At Risk
Pana	0.61	0.82	
Wayne City	0.30	0.26	At Risk

Full results of drought vulnerability analysis are given at:
www.isws.illinois.edu/hilites/drought

Estimating Surface Water Yield

Yield is the maximum uniform rate of withdrawal that can be taken out of a reservoir during a drought without experiencing shortages or reaching critically low water levels

For a reservoir withdrawal, the yield is determined using a "water budget" of the lake storage during drought, accounting for inflows and losses over the course of a drought.

Drought yields have always been considered to be "firm" numbers; however in reality they are far from being exact.

However, all of the data used in the water budget analysis have errors in measurement or estimation, some considerable in magnitude

*Uncertainties in Yield Estimates – Use of a Lower Confidence Limit

- Our biggest concern is that reservoir storage and inflow data may <u>overestimate</u> the amount of available water
- The traditional "best" estimate do not address uncertainties and there is roughly a 50% chance of overestimation
- The ISWS now calculates probabilistic estimates of yield. With a 90% confidence yield value (lowest 10th percentile) …
- …we are 90% confident that the "true" yield is equal to or greater than the 90% yield estimate
- …we are 90% confident that a community's system will have sufficient water during a severe drought

What drought severity to plan for?

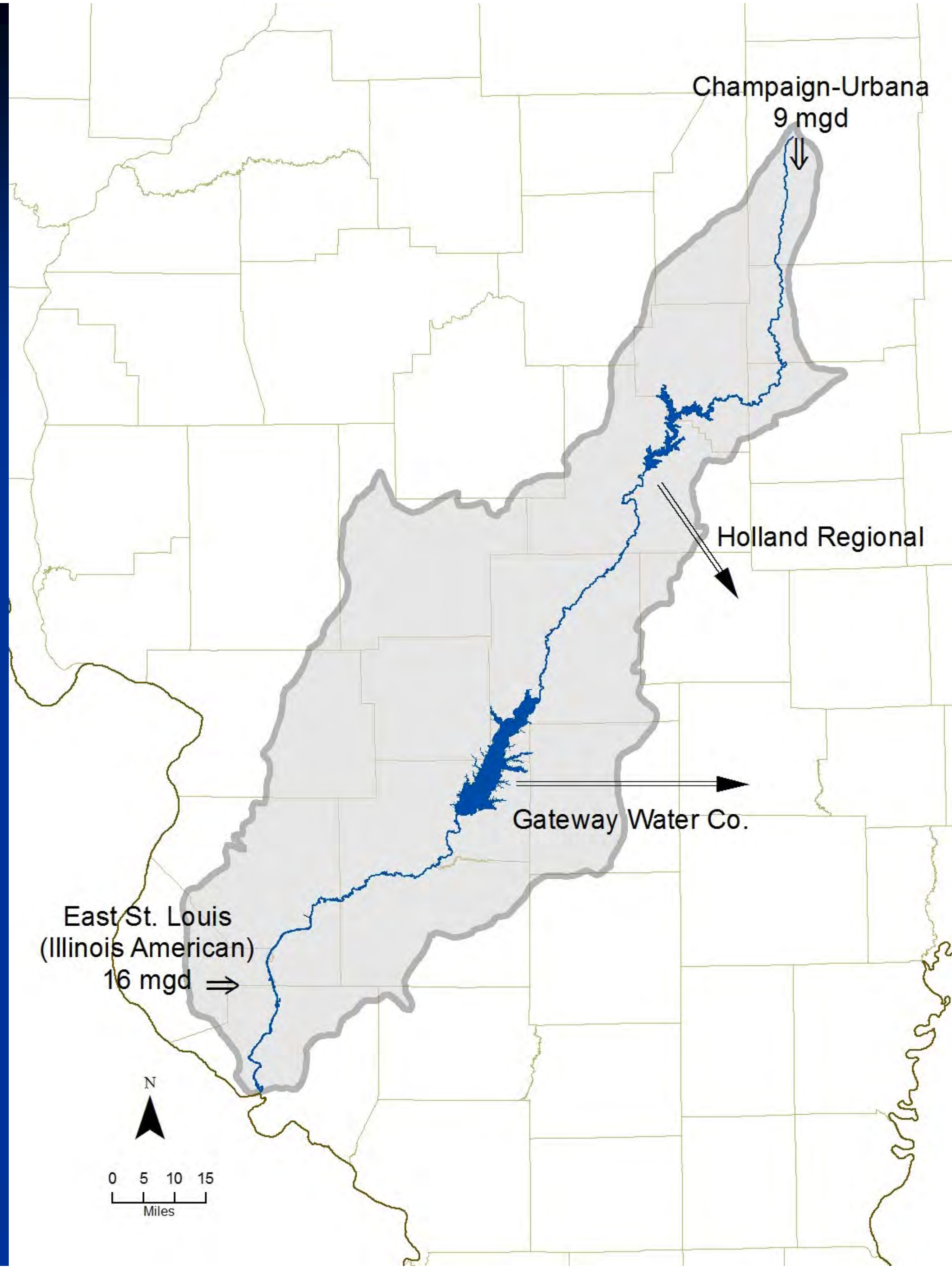
- Benefits to using the historical drought of record:
  - Greater accuracy in estimating yields using actual hydrologic and climatic observations rather than for a synthesized drought such as the 50- or 100-year drought
  - Provides for better communication to the public

- We should not ignore potential impacts of a worst-case drought. It is possible that the next severe drought could be the new drought of record. (Case in point: the Georgia drought of 2007-2008)
  - The problem here is in defining the parameters of a worst-case drought – beyond our scope of study.

Interbasin transfers: Importing and exporting water for community supplies

Effluent discharges from East St. Louis and Champaign-Urbana areas add additional low flows to the streams, increasing water availability

There are interbasin transfers with virtually every major system on the watershed divide



Additional surface-water models to be used in the impacts analysis

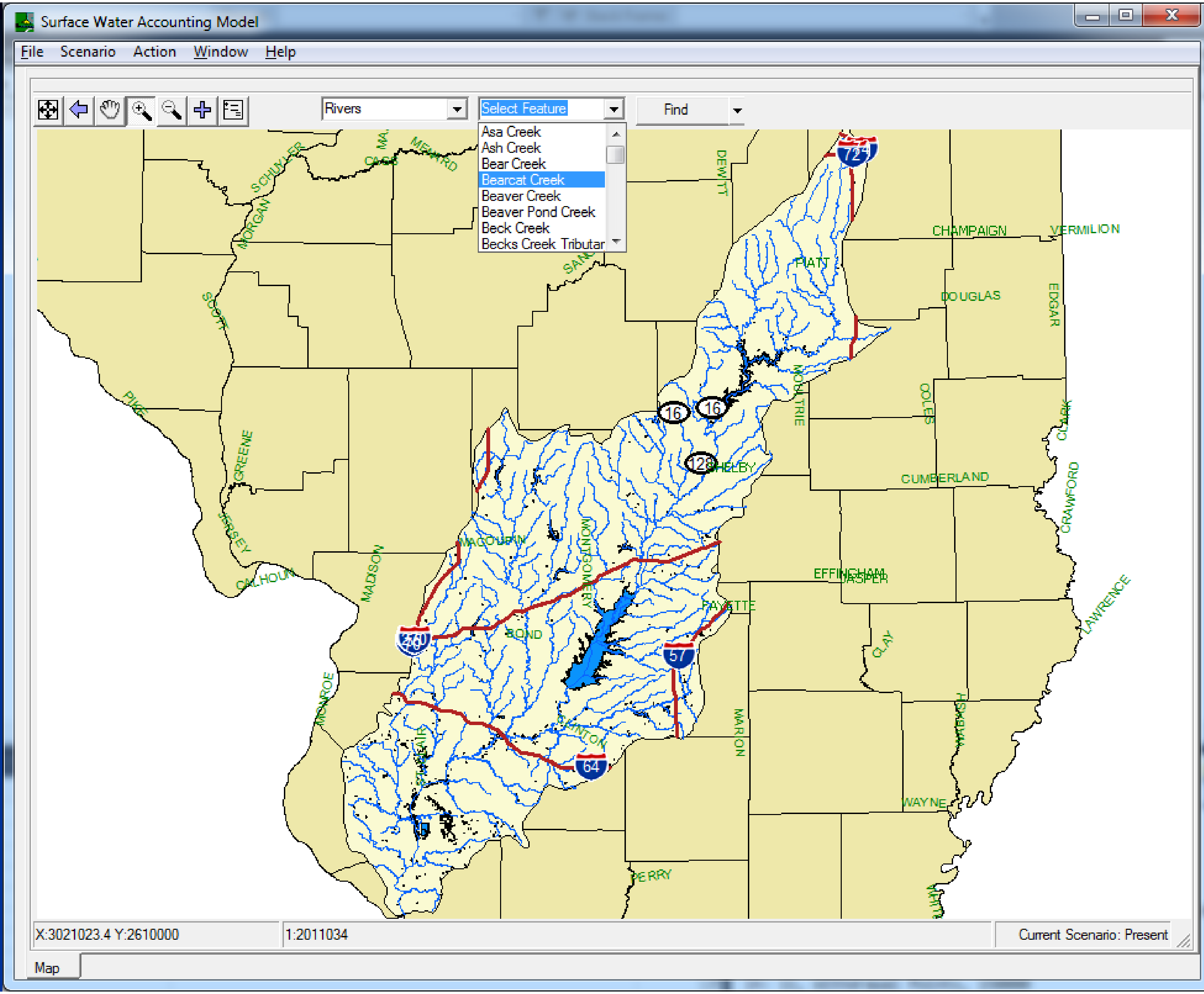
- Surface Water Accounting Model – change in future streamflows caused by projected increases in water use and full utilization of allocations
- Kaskaskia Watershed Simulation Model – to identify impacts of potential climate changes on streamflows and water availability
- Reservoir routing models of the federal reservoirs – to estimate impacts of full allocation on reservoir levels and outflow during drought, climate change impacts

Surface Water Accounting Model

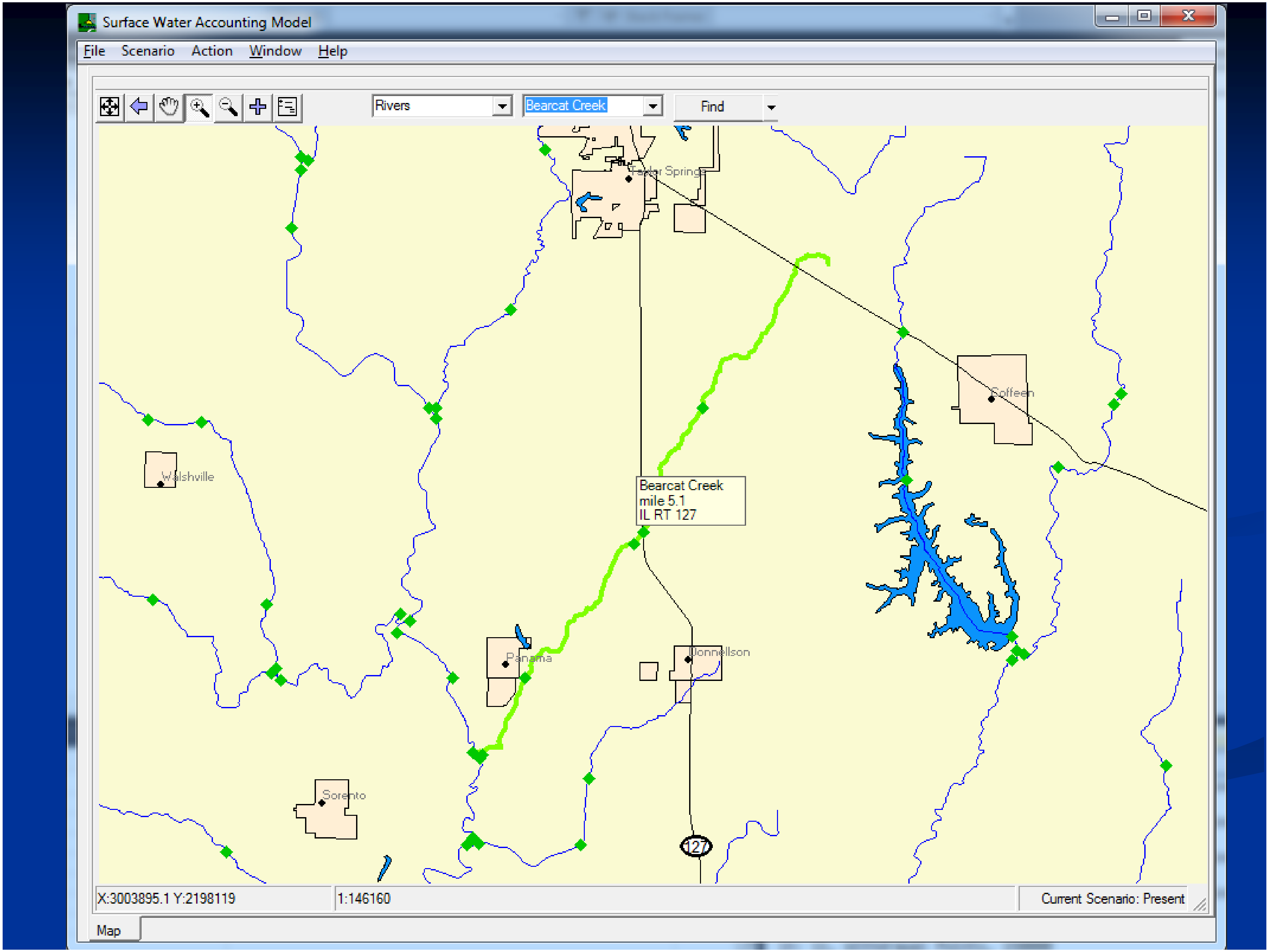
- Analyses of historical streamflow, water use, and wastewater effluent records and reservoir simulation models were used to determine how human modifications have changed streamflow over the years.
- The goal is to estimate what the flow conditions are under the current state of water development, as well as in the future using projected 2050 levels of water use.
- A GIS mapping interface to the database serves as both as an information system and scenario evaluation tool.

Surface Water Accounring Model

- For each streamflow record, estimates of estimated "unaltered" flows are developed and put in a database table.
- A second database table is developed that includes estimated impacts of existing hydrologic modifications (water withdrawals, effluents and reservoirs).
- The impact of future water demands can be evaluated by making changes to this second database.
- Present (and future) flows are estimated by layering the impacts of modification onto the unaltered flow estimates.



Surface Water Accounting Model
File
Scenario
Action
Window
Help
Rivers
Select Feature
Find
Asa Creek
Ash Creek
Bear Creek
Bearcat Creek
Beaver Creek
Beaver Pond Creek
Beck Creek
Becks Creek Tributar
CHAMPAIGN
VERMILION
PIATT
DOUGLAS
EDGAR
COLES
CUMBERLAND
CLARK
CRAWFORD
EFFINGHAM
JASPER
FAYETTE
CLAY
LAWRENCE
WAYNE
MARION
PERRY
BOND
MACOUPIN
MONTGOMERY
MADISON
GREENE
JERSEY
CALHOUN
PIKE
SCOTT
MORGAN
SCHUYLER
CASS
MENARD
DEWITT
MOULTRIE
SHELBY
MONROE
CLINTON
X:3021023.4 Y:2610000
1:2011034
Current Scenario: Present
Map



Surface Water Accounting Model
File Scenario Action Window Help
Rivers
Bearcat Creek
Find
Taylor Springs
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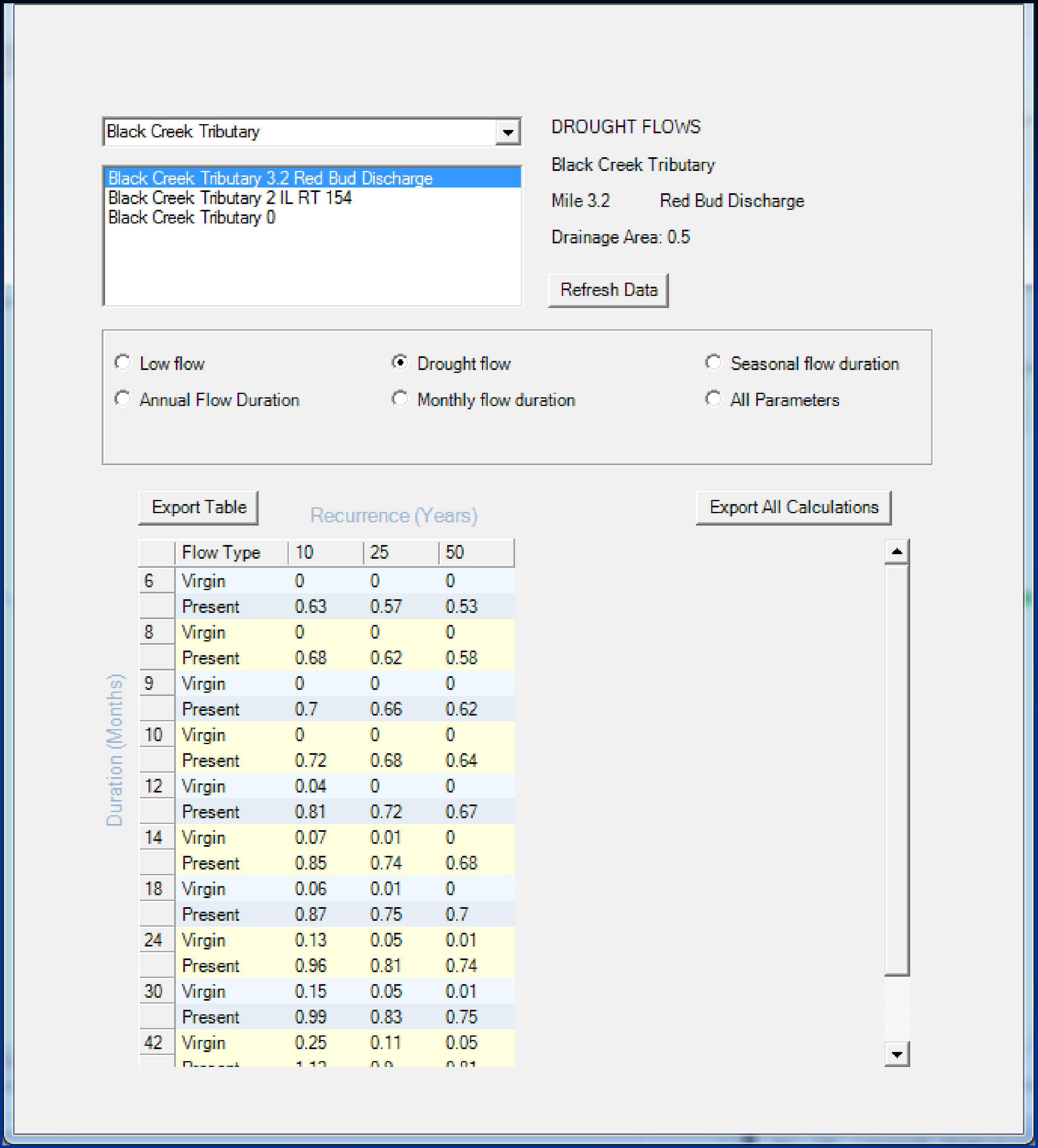
Sorento
127
X:3003895.1 Y:2198119
1:146160
Current Scenario: Present
Map



	Flow Type	10	25	50
6	Virgin	0	0	0
	Present	0.63	0.57	0.53
8	Virgin	0	0	0
	Present	0.68	0.62	0.58
9	Virgin	0	0	0
	Present	0.7	0.66	0.62
10	Virgin	0	0	0
	Present	0.72	0.68	0.64
12	Virgin	0.04	0	0
	Present	0.81	0.72	0.67
14	Virgin	0.07	0.01	0
	Present	0.85	0.74	0.68
18	Virgin	0.06	0.01	0
	Present	0.87	0.75	0.7
24	Virgin	0.13	0.05	0.01
	Present	0.96	0.81	0.74
30	Virgin	0.15	0.05	0.01
	Present	0.99	0.83	0.75
42	Virgin	0.25	0.11	0.05

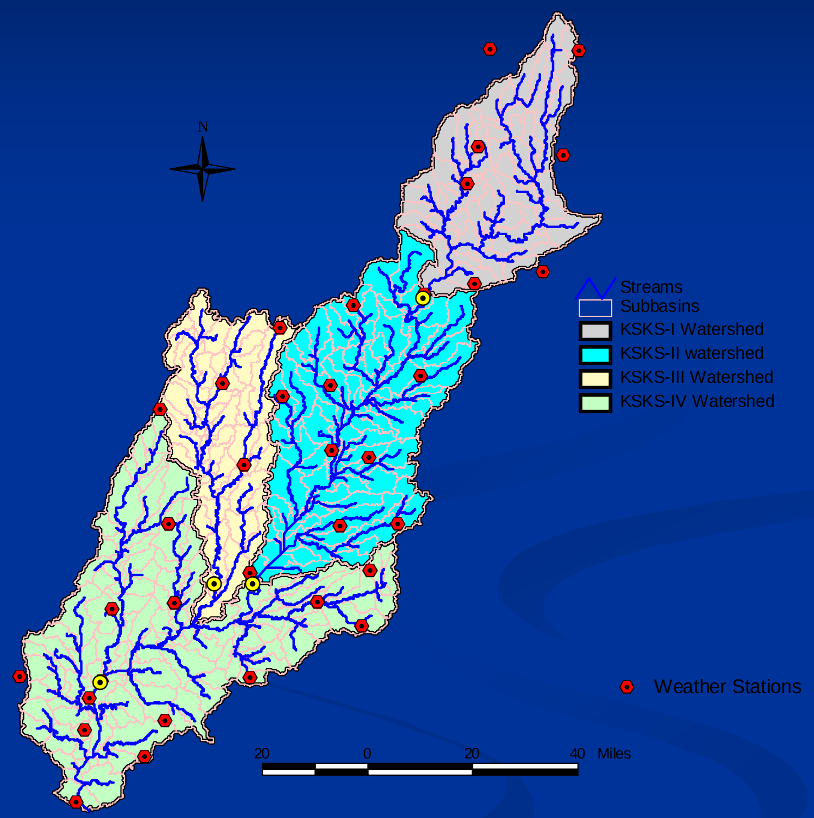
Kaskaskia Watershed Simulation Model

- **Watershed (Hydrologic Simulation) Model**
  - Developed using Soil and Water Assessement Tool (SWAT) a physically-based, distributed watershed scale model capable of directly simulating processes such as water and sediment movement, crop growth, nutrient cycling and others
  - In simulating these processes, SWAT requires watershed-specific information about topography, weather, soil properties, vegetation and land management practices
  - The model's ArcGIS Interface was used to generate data files that make up the watershed model from topography, land use, soil and climate inputs (can also be used for simulation and/or calibration)

KASKASKIA RIVER WATERSHED MODEL

- **Kaskaskia River Watershed**
  - Delineated into 348 subbasins to capture heterogeneity in land use, soil and climate inputs
  - Partitioned into four larger subwatersheds for calibration purposes (i.e., KSKS-I, -II, -III, and -IV)

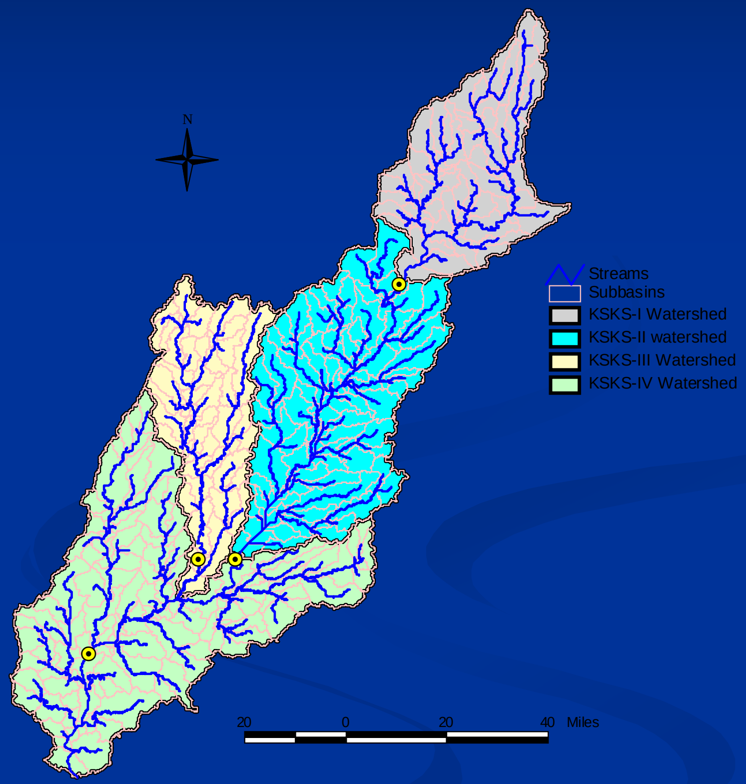
Subwatersheds	Area (Sq. Mi.)	No. of subbasins
KSKS-I	1053	65
KSKS-II	1663	101
KSKS-III	915	50
KSKS-IV	2174	132



  - Data from 35 Weather stations incorporated into model simulations

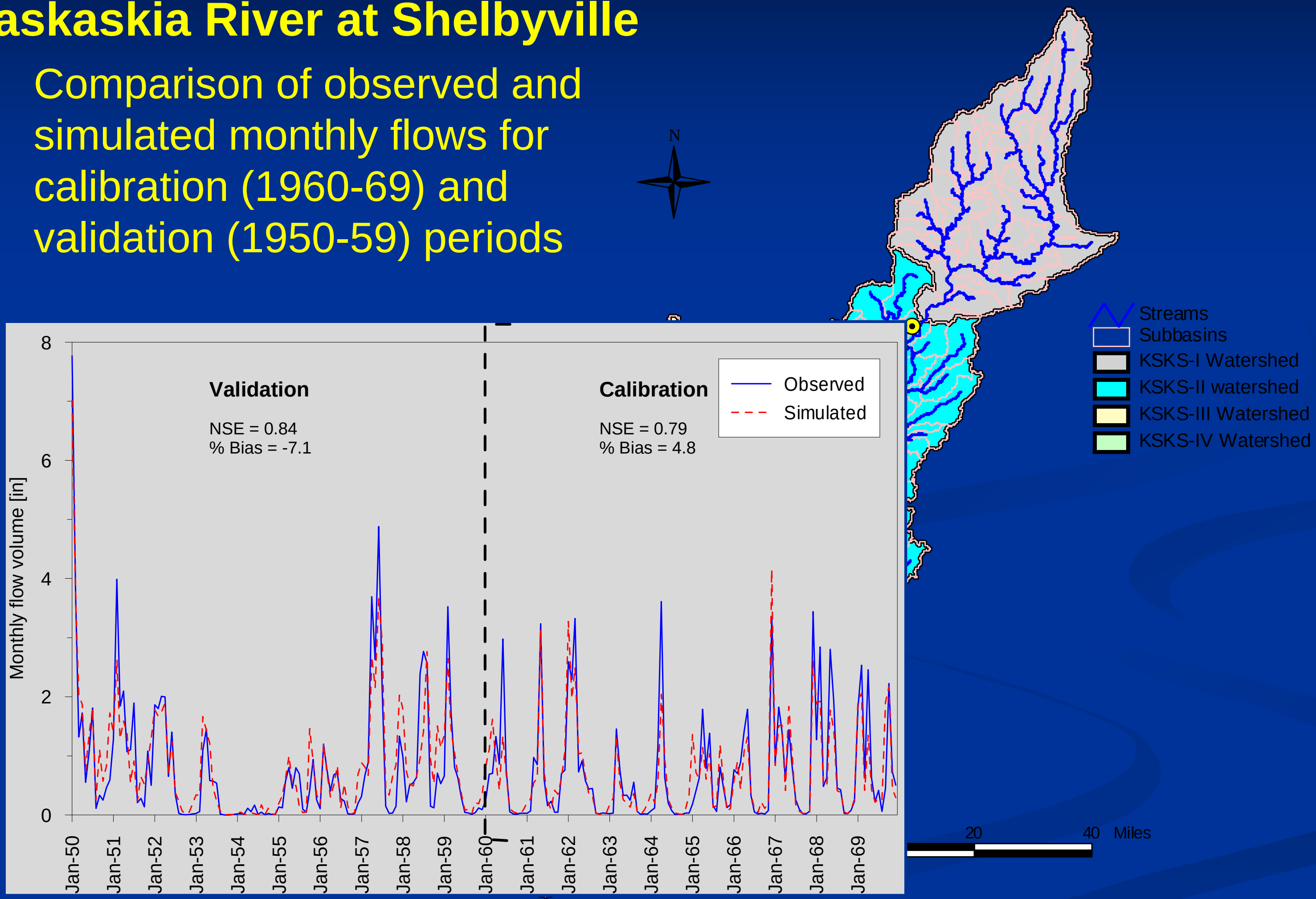
KASKASKIA RIVER WATERSHED MODEL

- **Calibration and Validation**
  - Observed flows at four USGS gauging stations were used for calibration and validation
  - Relatively dry periods were chosen for model calibration (1960-69) and validation (1950-59)
  - Optimization algorithms were used to calibrate model parameters of the four subwatersheds
  - Manual fine-tuning of the model parameters were done while incorporating them into the complete Kaskaskia River Watershed model



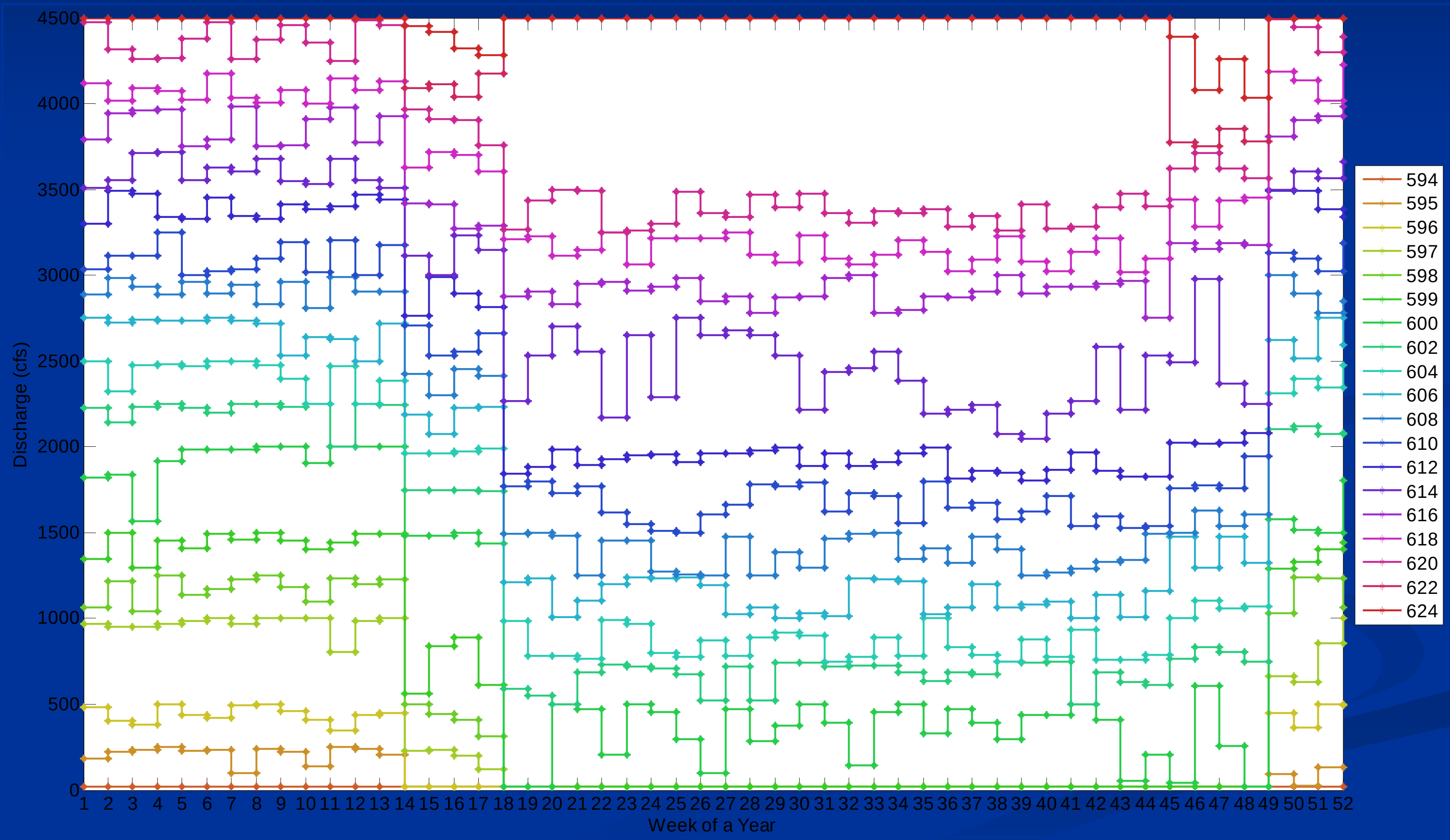
KASKASKIA RIVER WATERSHED MODEL

- **Kaskaskia River at Shelbyville**
  - Comparison of observed and simulated monthly flows for calibration (1960-69) and validation (1950-59) periods

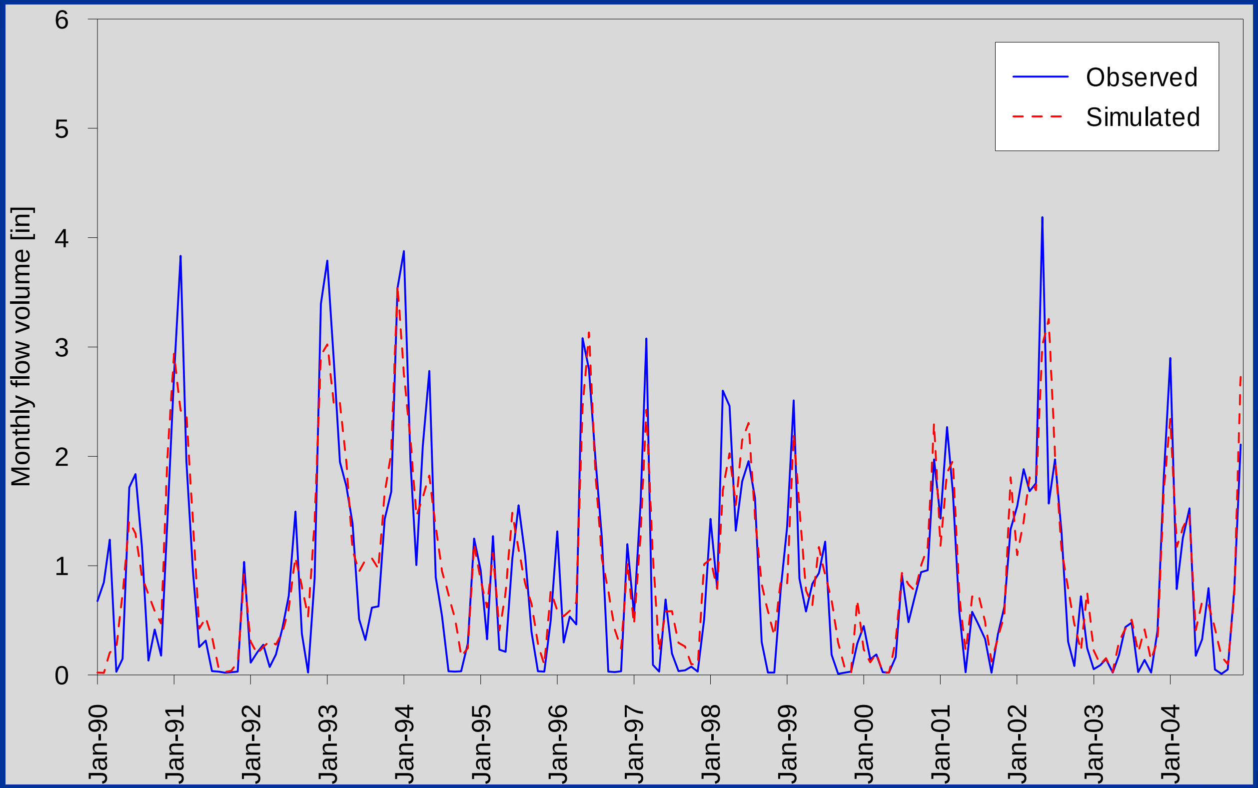


Reservoir Routing Models

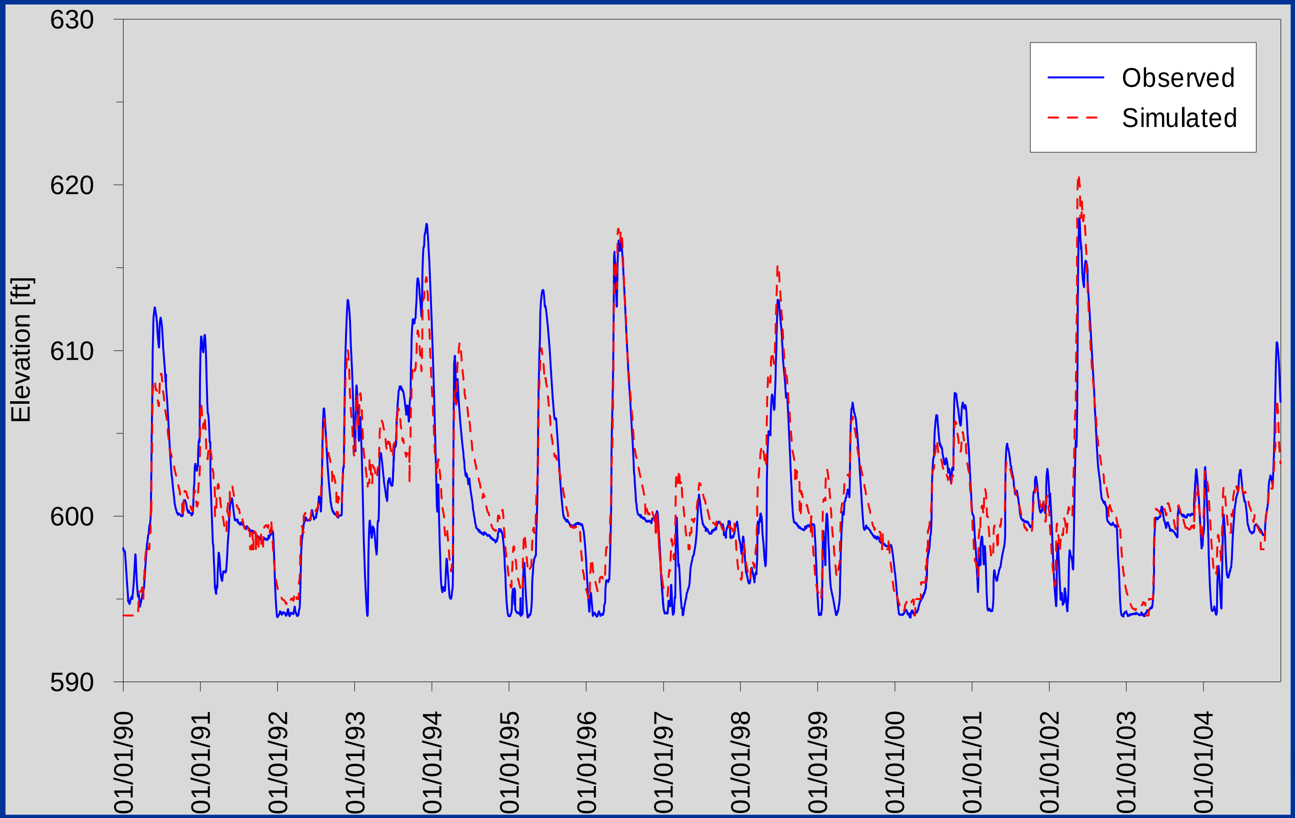
- **The routing models are trained to** simulated the reservoir release schedule of the federal reservoirs on a weekly basis



- **Lake Shelbyville**
  - Comparison of simulated and observed monthly outflows for 1990-2004)

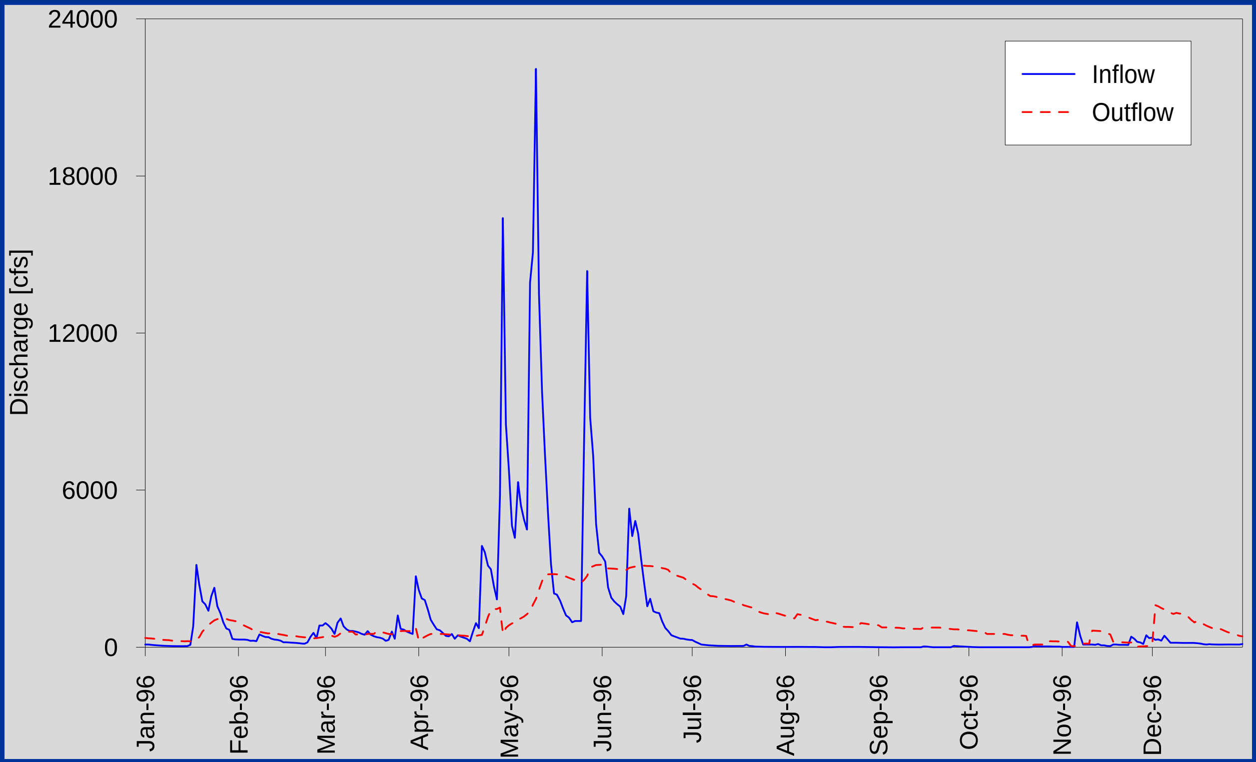


- **Lake Shelbyville**
  - Comparison of simulated and observed daily Pool Elevations for 1990-2004



RESERVOIR ROUTING MODEL

- **Lake Shelbyville**
  - Comparison of inflow and outflow hydrographs showing both the attenuating and lagging effects of the reservoir on the inflow hydrograph (e.g.,1996)



Findings and Future Work

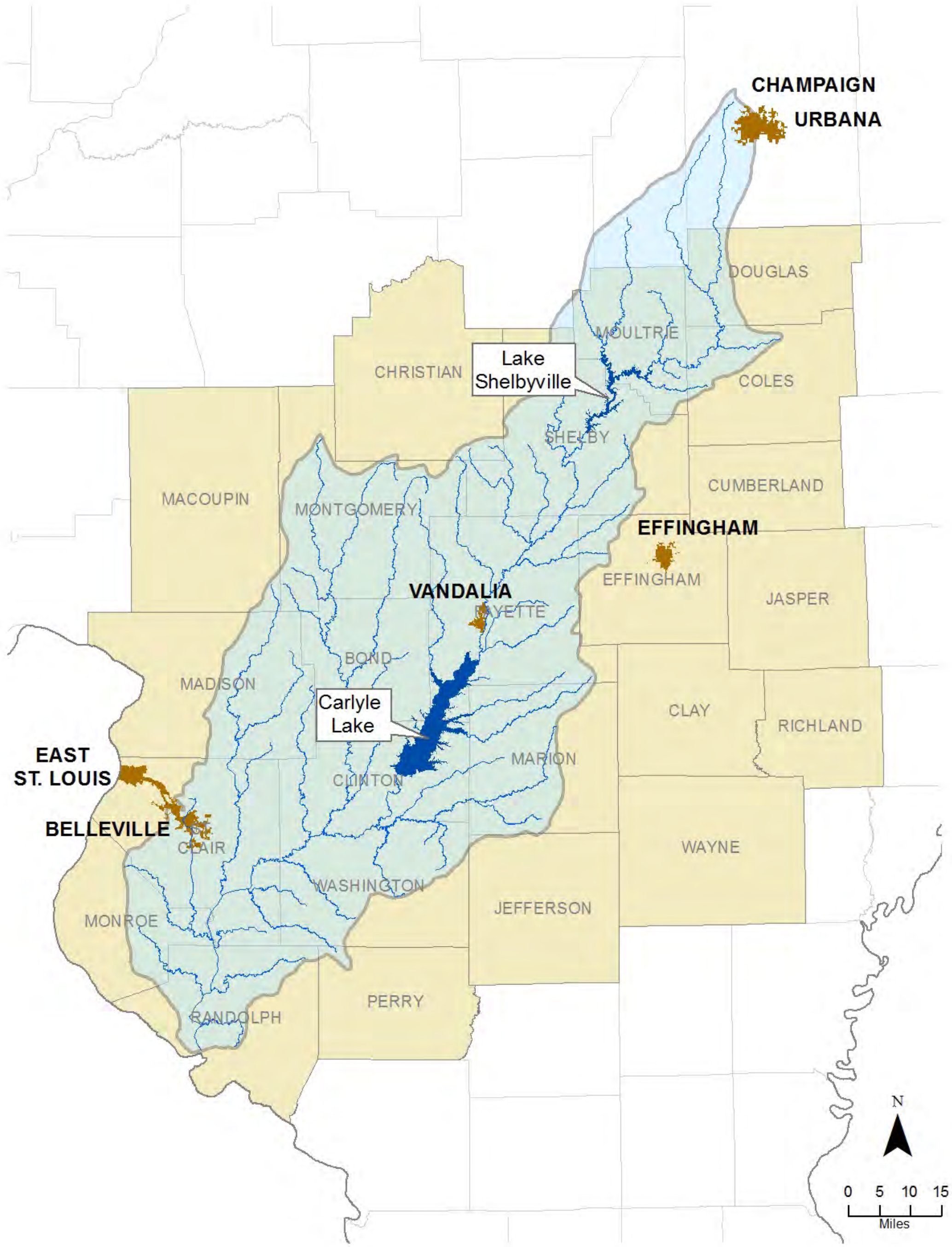
- Models have been developed, but the process of model application for simulating future water use and climate change scenarios has not yet been undertaken.
- Data on public water supplies indicates a clear trend of smaller users interconnecting to larger systems and thus putting greater demand on those larger systems. At this time, most of these larger systems appear to have sufficient surplus yield.
- A number of small systems are considered inadequate or at-risk. During the next severe drought, these systems may likely need to interconnect (or haul water).

Findings and Future Work

- There is a gradual increase of water being imported to the watershed from nearby urban areas (E St. Louis and Champaign-Urbana), increasing low flows (and water availability) in those portions of the Kaskaskia River.
- Data mining of groundwater data does not identify new areas of potential sources of supply.
- Modeling indicates that many of the groundwater supply systems are actually diverting water away from rivers, thus reducing surface water availability.

Findings and Future Work
conclusion

- Available water in the Kaskaskia Navigation Channel during a severe drought (such as the 1950s) needs to be evaluated in order to have a better understanding of the timing and impacts associated with releases from Carlyle Lake.
- Reexamination of yield assessments for the federal reservoirs might also consider scenarios of periodic reservoir releases as expected during drought (not simply the traditional assumption of constant withdrawal).


CHAMPAIGN
URBANA
DOUGLAS
MOULTRIE
Lake
Shelbyville
CHRISTIAN
COLES
SHELBY
CUMBERLAND
MACOUPIN
MONTGOMERY
EFFINGHAM
EFFINGHAM
VANDALIA
FAYETTE
JASPER
BOND
MADISON
Carlyle
Lake
CLAY
RICHLAND
EAST
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MARION
CLINTON
BELLEVILLE
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