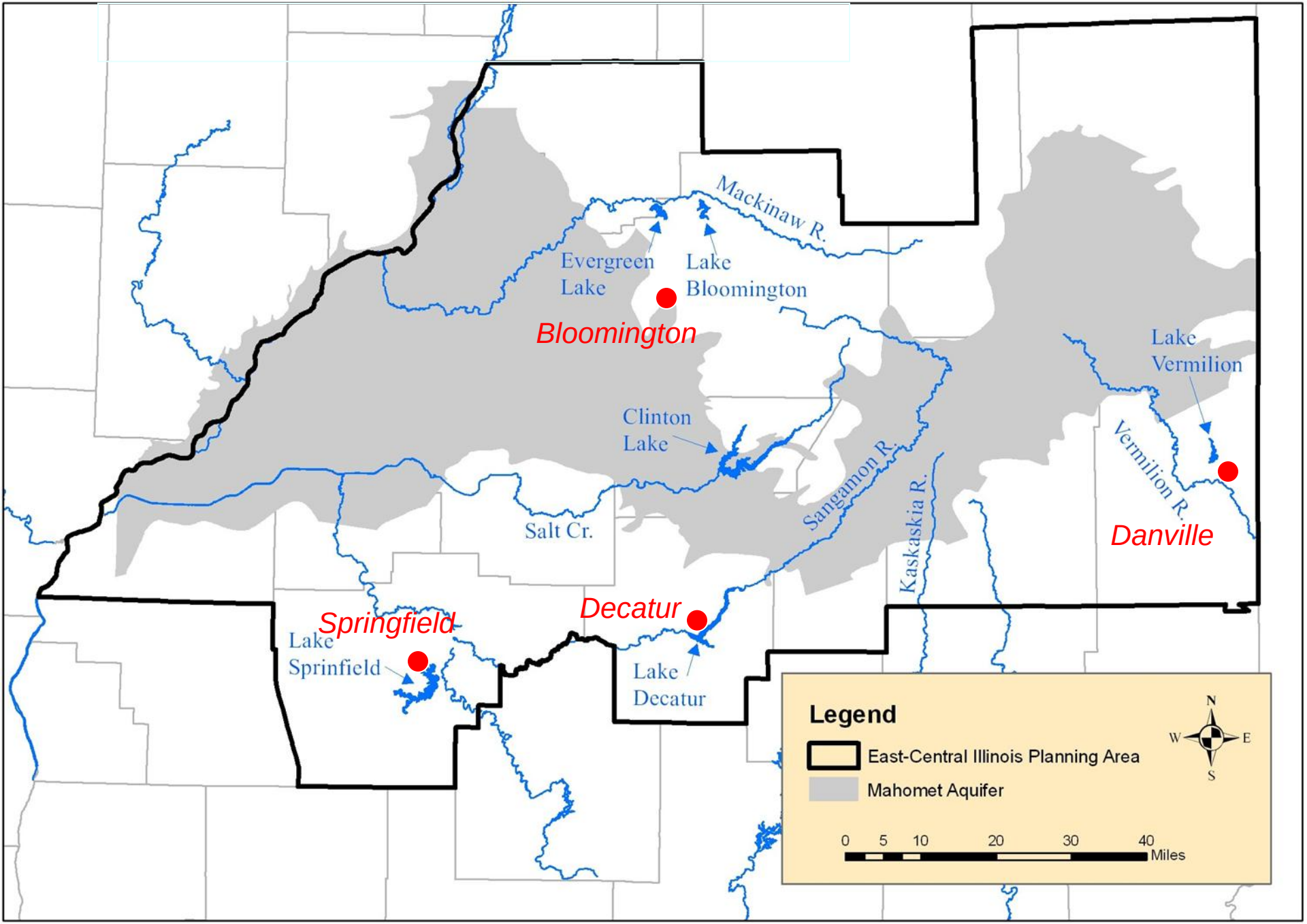
Drought Vulnerability of Community Surface Water Supply Systems in East-Central Illinois *(A Tale of Four Cities)*

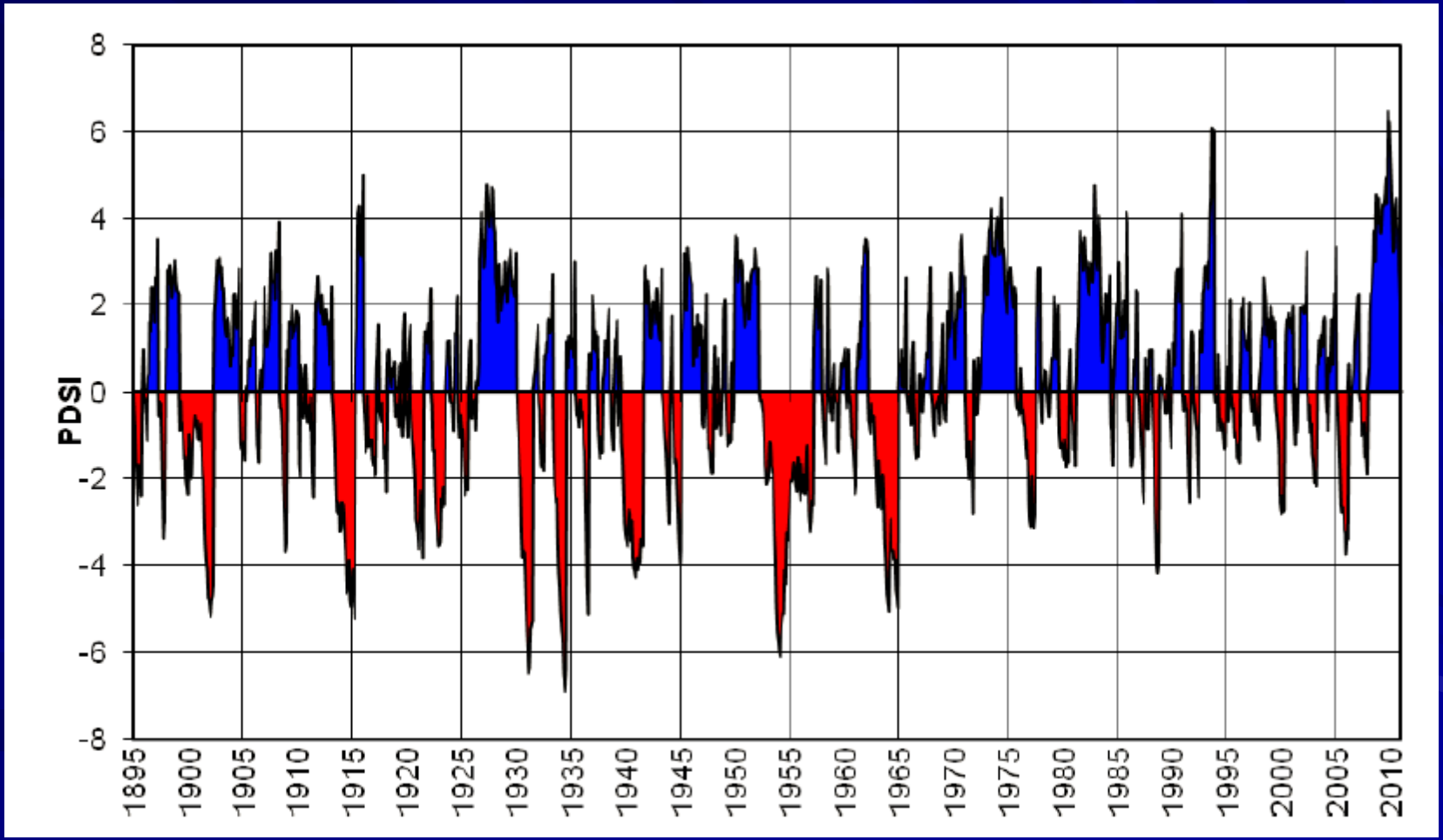
H. Vernon Knapp
Illinois State Water Survey
Prairie Research Institute
University of Illinois


Mackinaw R.
Evergreen Lake
Lake Bloomington
Bloomington
Lake Vermilion
Clinton Lake
Sangamon R.
Vermilion R.
Danville
Salt Cr.
Kaskaskia R.
Springfield
Lake Sprinfield
Decatur
Lake Decatur
Legend
East-Central Illinois Planning Area
Mahomet Aquifer
0 5 10 20 30 40
Miles
N
W
E
S

Drought Vulnerability of Surface Water Supplies

- With groundwater supplies we focus on the sustainability and replenishment of the supply.
- In contrast, surface water systems in Illinois are highly replenishable in all but the driest years. Surface water supply analysis thus focuses on the adequacy of the supply during the most extreme droughts.
- With the exception of Bloomington in 1988-1989, East-Central Illinois water supplies have not experienced an extreme drought (capable of limiting available supply) since the 1950s.

Palmer Drought Severity Index for Illinois



What type of drought should our planning consider?

- Because multi-decadal shifts in Illinois precipitation have been recorded in the past, both towards wetter and drier conditions at various times in the record, it is reasonable to assume that similar shifts will occur in the future.
- Absent long-term climate change, it is expected that drought conditions similar to the worst historic droughts (1930s-1950s) will occur again, with the possibility that a more extreme droughts might also occur infrequently.
- Thus, it is sensible that Illinois water supply systems should plan for the recurrence of the worst historic droughts, with specific focus on the *drought of record*.
- Long-term climate change is uncertain, but could lead to warmer/drier conditions than those recorded in the past.

Community Surface Water Systems

- Analysis focuses on the four largest community surface water systems in the region: Bloomington, Danville, Decatur, and Springfield
- A water budget for each community's system is created to estimate how the current system would react when faced with climatic and hydrologic conditions similar to what was experienced during the drought of record and other severe droughts
- Estimates of the water supply yield for each system are probabilistic in nature, to account for uncertainties in the data used to derive the yield estimates.
- The drought vulnerability for each system is based on the estimated probability that the system would experience shortages if a drought similar to the drought of record were to recur.

Data Uncertainties in Estimating Reservoir Yields

- Reservoir capacity measurements
- Streamflow into the reservoir during drought
- Evaporation & precipitation over the lake

- For most data there is roughly a 50% probability that the measurement (or estimate) is too high. Thus, there is also a 50% probability that the resulting yield is too high.
- Our biggest concern is that reservoir storage and inflow data may overestimate the amount of available water (producing a false positive)
- Our analysis examines the possibility that streamflow and reservoir capacity could be less than measured, and evaporation greater than its estimated value.

Uncertainties in Yield Estimates – Producing a Yield having Higher Confidence

- The traditional "best" estimates of yield (that do not address data uncertainties) provide roughly a 50% confidence value (equal chance that it could be over- or under-estimated)
- We suggest most communities should have systems that provide an adequate supply during extreme drought with much higher level of confidence (than 50%).
- For this reason, we now also calculate a 90% confidence yield value (lowest 10^{th} percentile) …
  - …we are 90% confident that the "true" yield is equal to or greater than the 90% yield value
  - …we are 90% confident that a community's system will have sufficient water during a severe drought

The classification of vulnerability also considers likely changes in water demand during a drought

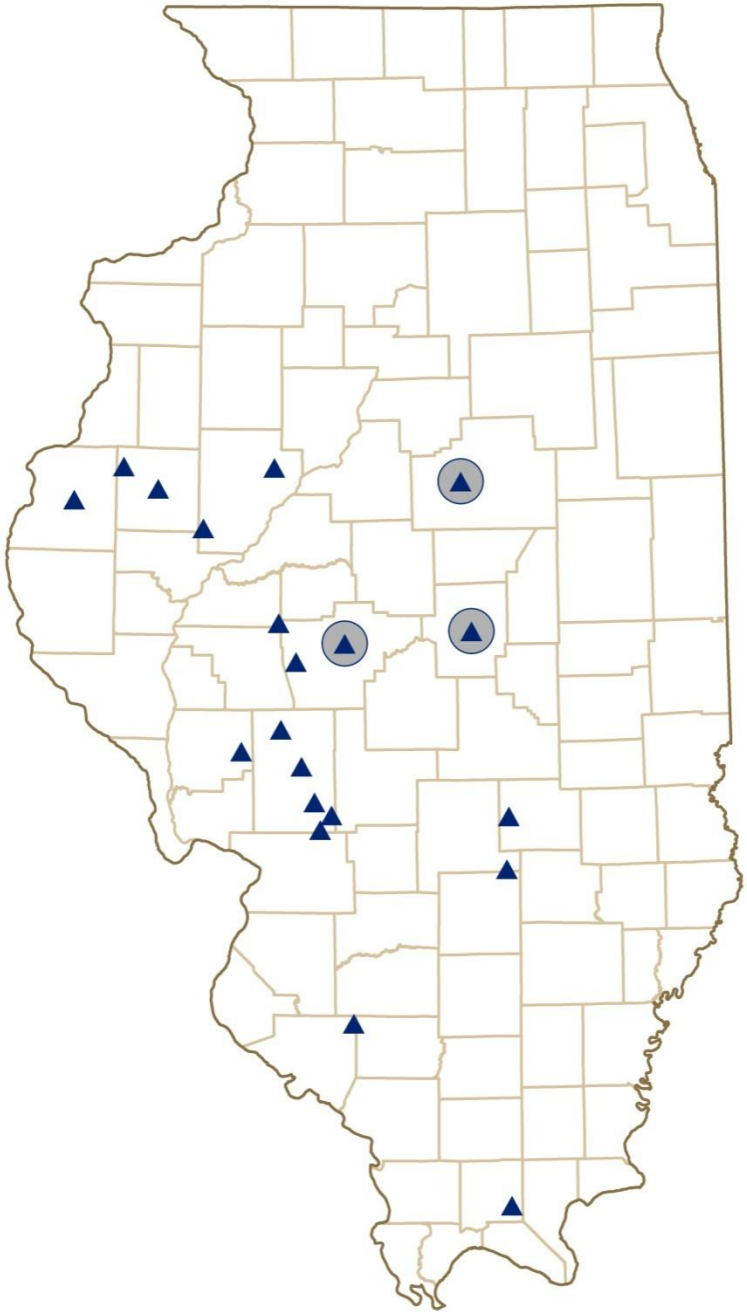
- Water supply droughts almost always start during the summer; in these early stages of drought, community water demands are often 20-30% higher than normal summer water use
- At some point, voluntary and/or mandatory restrictions will be invoked that will reduce use, but may be insufficient to fully counterbalance the initial high demand rates at the start of the drought
- We interpret that a system shortage would occur if measures beyond typical mandatory restrictions would be necessary

Drought Vulnerability of Surface Water Supplies

- A shortage is considered to occur if the estimated available water is insufficient to meet expected demands during a drought of record, including consideration of water restrictions that are likely to occur as outlined in each community's Drought Action/Response Plan.
- Inadequate supply – there is greater than a 50% probability that shortages would occur during a drought of record condition.
- At Risk supply – greater than a 10% probability that shortages would occur during a drought of record (in other words, less than 90% confidence in the supply).
- Marginal supply – there may be sufficient water to avoid a shortage, but the community would likely be taking extraordinary measures based on the drought threat.

Currently At Risk and Inadequate Systems (21)

These 21 systems provide water to over 400,000 Illinois residents



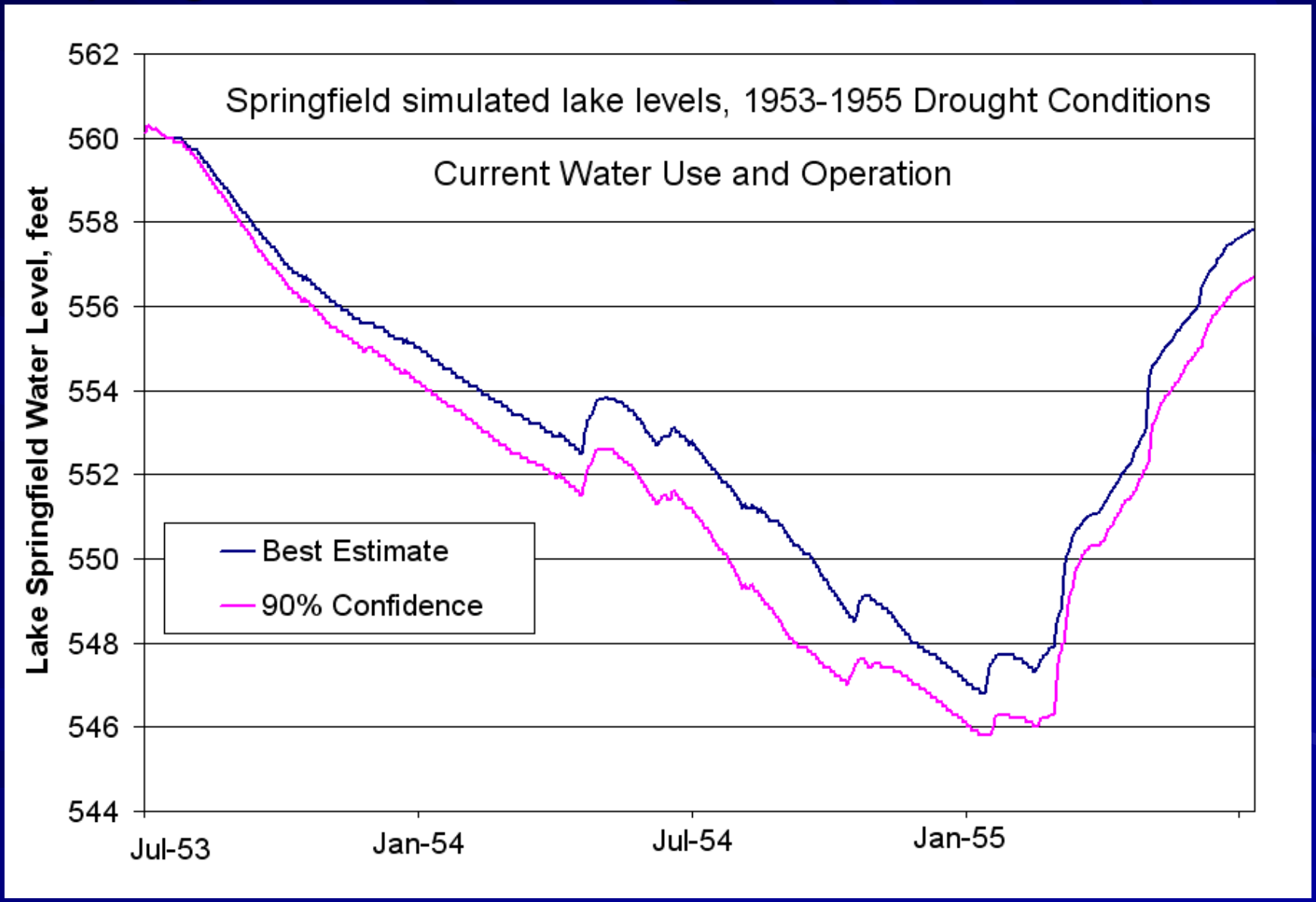
Surface Water Sources Considered in the Yield Analysis

- Bloomington
  - Lake Bloomington, Evergreen Lake, Mackinaw River Pumping Station
- Danville – Lake Vermilion
- Decatur
  - Lake Decatur, DeWitt Well Field, & former gravel pit
- Springfield
  - Lake Springfield, South Fork Pumping Station

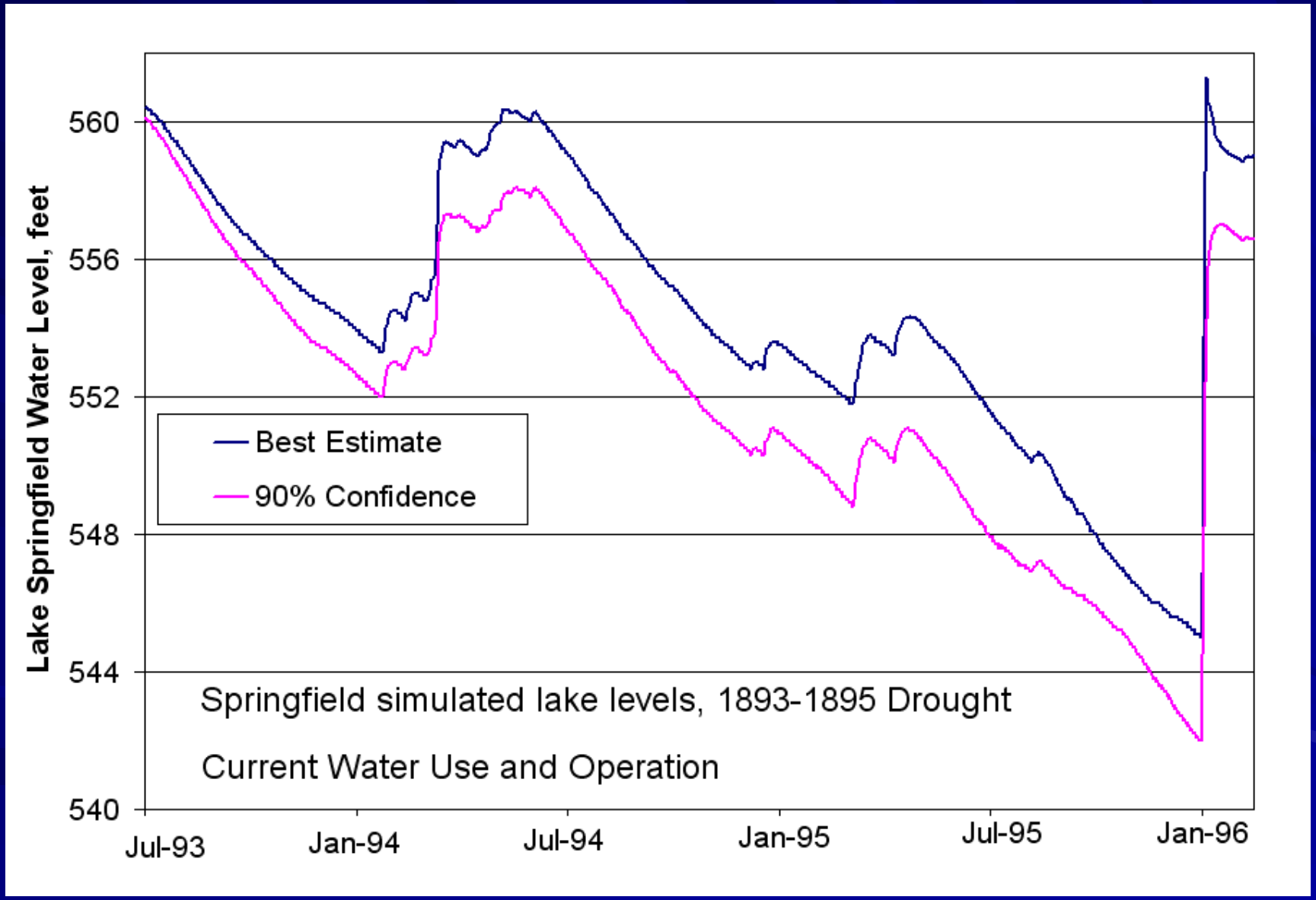
Springfield – Inadequate Supply

- Drought vulnerability is based on the use of the lake for both potable supply and for power plant cooling
  - Current use = 32 mgd (9 mgd power consumption)
  - WHPA baseline projected use by 2050 = 40 mgd
  - Yield @ 50% confidence = 27.8 mgd
  - Yield @ 90% confidence = 25.7 mgd
  - By 2050, yield will have been reduced by 1.6 mgd
- Most of the City's power-plant units would need to shut down during a >40 year drought (@ elevation 548')
- Once the power plant is shut down, the lake would still have 6 months of water available for potable supply
- Examined separately, the potable supply is categorized as marginal, but with projected baseline growth will be at risk by 2020.

Springfield 1953-55 drought w/ current water use



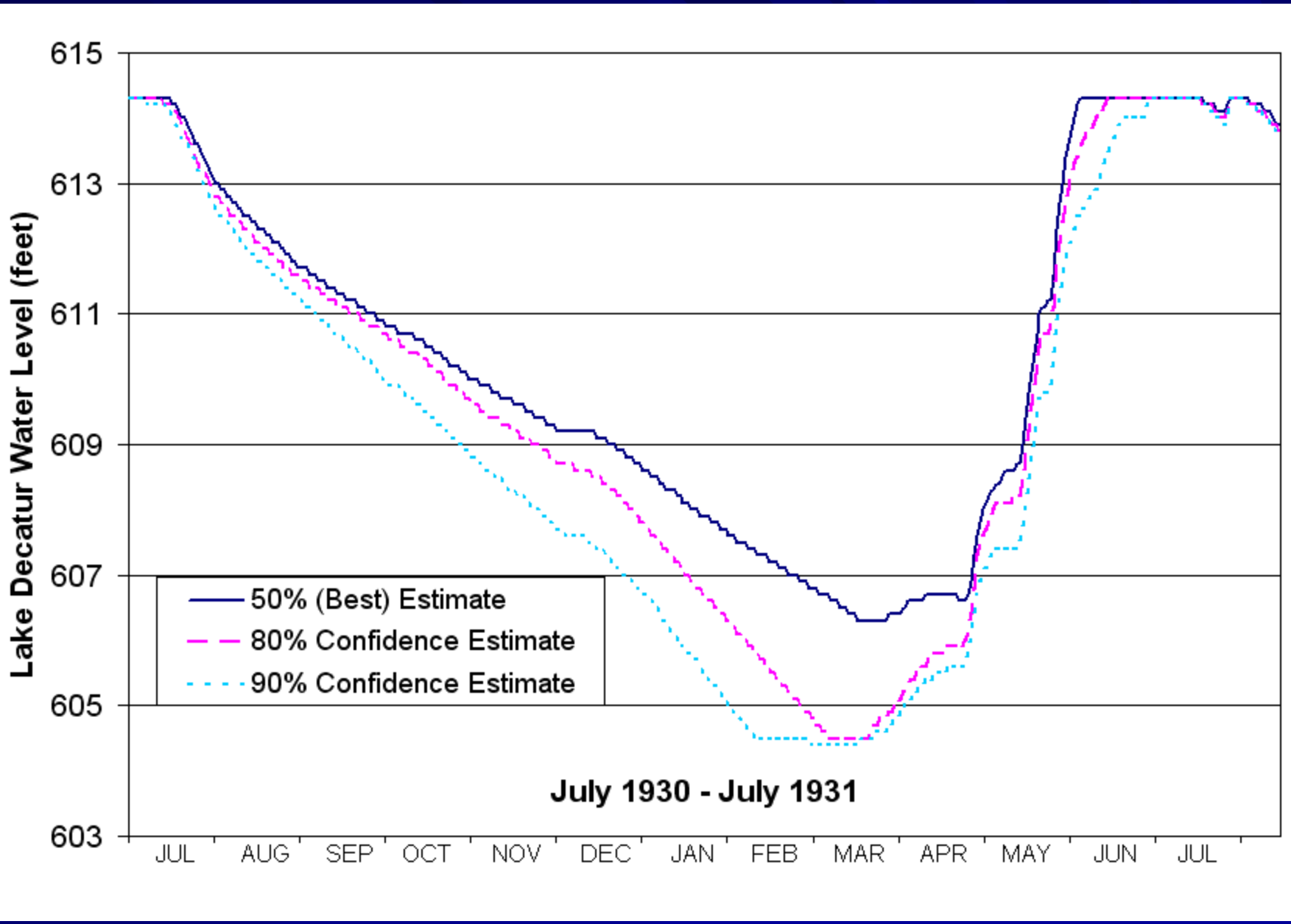
Springfield 1893-95 drought w/ current water use



Decatur – At Risk Supply

- Drought vulnerability is based on the use of the lake for withdrawals by both City and ADM
  - Current use = 35-36 mgd total (14 mgd)
  - WHPA baseline projected use by 2050 = 52 mgd
  - Yield @ 50% probability = 38.1 mgd
  - Yield @ 90% probability = 32.8 mgd
- Without additional supplies, based on projected baseline growth the system will be inadequate by 2020.
- Possibility that the yield could be increased up to 3 mgd with ongoing dredging contract.
- If lake storage is completely consumed in an extreme drought, lake inflow and well field pumping could still provide roughly 15-17 mgd until recovery occurs.

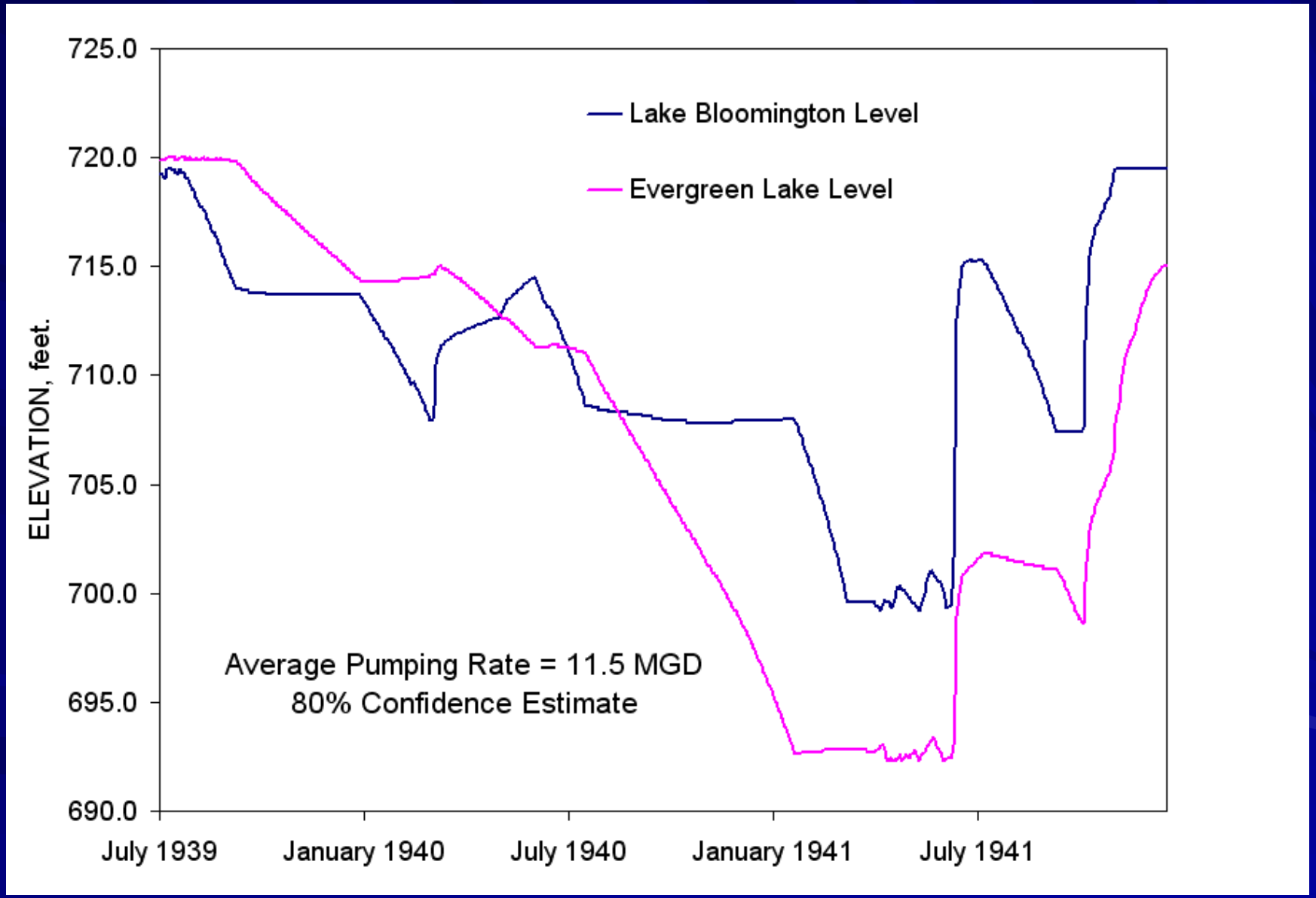
Decatur: 1930-31 drought with current water use



Bloomington – At Risk Supply

- Drought vulnerability
  - Current use = 12 mgd
  - WHPA baseline projected use by 2050 = 17 mgd
  - Yield @ 50% probability = 12.7 mgd
  - Yield @ 90% probability = 10.6 mgd
  - By 2050, yield will have been reduced by 1.1 mgd
- Without additional supplies, based on the projected baseline growth the system will be classified as inadequate by 2020.

Bloomington 1939-41 – 80% confidence



Danville – Adequate Supply

- Drought vulnerability
  - Current use = 8.4 mgd
  - WHPA baseline projected use by 2050 = 9.0 mgd
  - Yield @ 50% probability = 12.7 mgd
  - Yield @ 90% probability = 9.5 mgd
  - By 2050, yield will have been reduced by 1.8 mgd
- Without additional supplies, with projected baseline growth the system will be at risk by 2040.

Summary: Best (50%) Yield Estimates compared to 90% Confidence Estimates

- Bloomington (current use = 12 mgd)
  - Best estimate = 12.7 mgd (1939-1941)
  - 90% estimate = 10.6 mgd Deficit = 1.4 mgd
- Decatur (current use = 36 mgd)
  - Best estimate = 38.1 mgd (1930-1931)
  - 90% estimate = 32.8 mgd Deficit = 3.2 mgd
- Springfield (current use = 40 mgd)
  - Best estimate = 27.8 mgd (1953-55)
  - 90% estimate = 25.7 mgd Deficit = 6.3 mgd
- Danville (current use = 8.4 mgd)
  - Best estimate = 14.1 mgd (1930-31)
  - 90% estimate = 10.5 mgd No Deficit

Projecting into the future – 2050 baseline scenario assuming no changes to the system

- Bloomington (projected use = 17 mgd)
  - Best estimate = 11.6 mgd (1939-1941)
  - 90% estimate = 9.5 mgd Deficit = 7.5 mgd
- Decatur (projected use = 52 mgd)
  - Best estimate = 38.1 mgd (1930-1931)
  - 90% estimate = 32.8 mgd Deficit = 19 mgd
- Springfield (projected use = 40 mgd)
  - Best estimate = 26.1 mgd (1953-55)
  - 90% estimate = 24.0 mgd Deficit = 16 mgd
- Danville (projected use = 9.0 mgd)
  - Best estimate = 11.8 mgd (1930-31)
  - 90% estimate = 8.5 mgd Deficit = 0.5 mgd

Projecting Future Drought Conditions

- Absent significant shifts in climate, it is reasonable to expect that drought conditions similar to the historic droughts of the 1930s and 1950s will occur again, with the possibility that worse droughts might also occur on an infrequent basis.
- A hydrologic simulation model of the Sangamon River basin was used to identify possible changes in stream flows related to selected climate change scenarios for Illinois. Flow reduction associated with the driest scenario (95^{th} percentile of all GCM model predictions) produced estimated yield reductions in the Decatur and Bloomington systems of 16 and 19%, respectively.

Addressing Drought Vulnerability

- Demand Management. Changing community water use habits and updating older fixtures and infrastructure has the potential to reduce the probability of potential shortages during drought, but by itself is not expected to drastically change the overall drought vulnerability status of these communities.
- Source Development. Development of additional water sources is essential if these communities are to avoid water shortages (or the threat thereof) during an extreme drought similar to the historical drought of record.