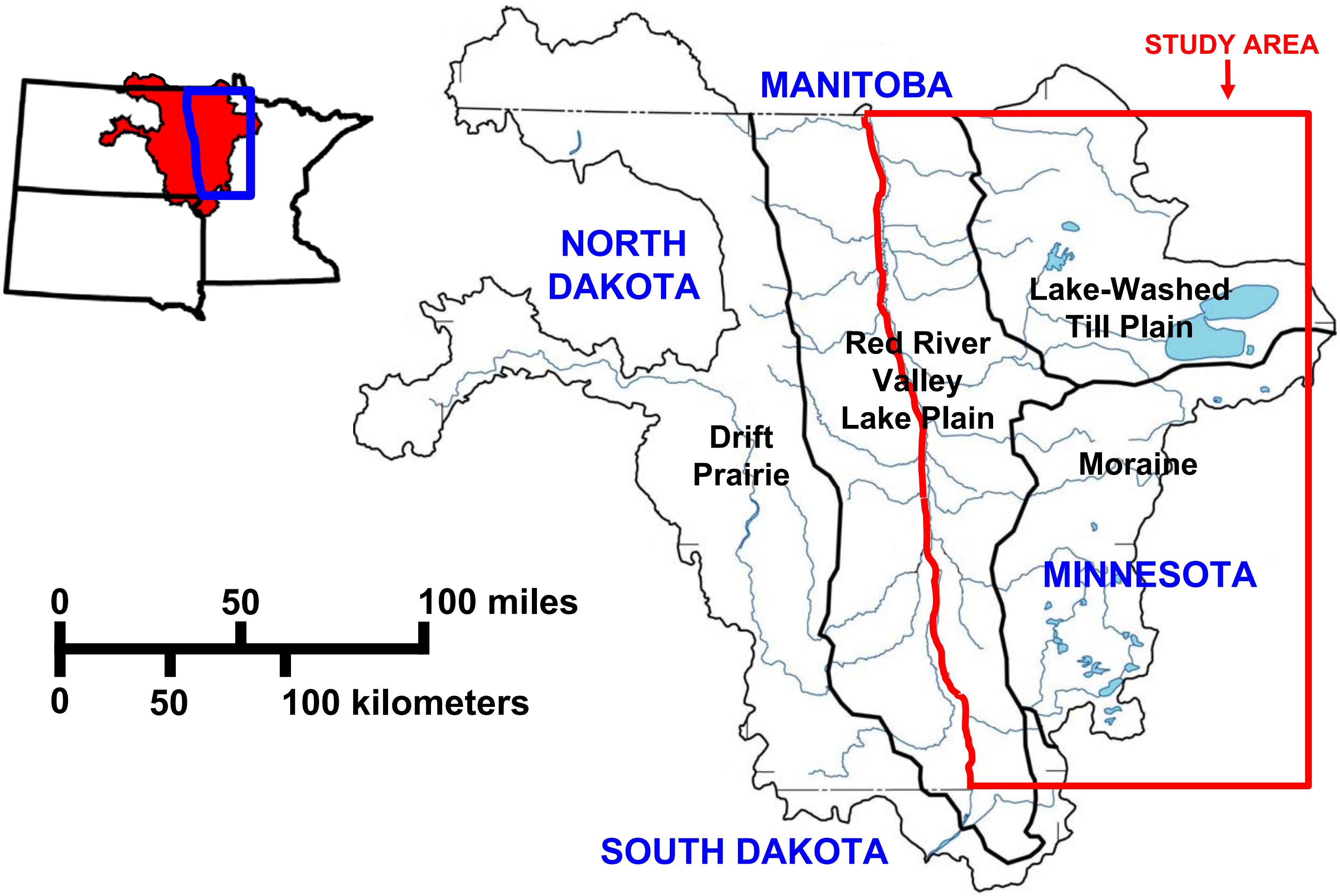
Availability of ground water from the surficial aquifers in the Red River of the North Basin, Minnesota

by Thomas H.C. Reppe
U.S. Geological Survey
Water Science Center of Minnesota

Prepared in cooperation with the Minnesota Geological Survey and the U.S. Department of the Interior, Bureau of Reclamation

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

Red River Basin and Study Area



Physiographic Areas

USGS


Lake-Washed Till Plain


Moraine

OBJECTIVES

Estimate the availability of ground water in nine selected surficial aquifers located within and adjacent to the Minnesota portion of the Basin

Compile water-quality data for the aquifers

Evaluate potential effects of ground-water development on surface waters connected to the aquifers

USGS

What factors affect the "availability of ground water"?

Aquifer Location, Thickness, and Extent

Ground-Water Storage

Water Sources and Discharges

Withdrawal Rates

Historic (and Planned) Water Use

Water Quality

USGS

What defines "availability of ground-water"?

Location – where is it (in relation to need)?

Volume – how much is present (max. vs. actual)?

Removal Rate – recharge rates and sources?

Interactions – other unaccounted for discharges?

Intended Use – for whom / what purpose?

Quality – how "good" is it – what is the use?

Cost – consequences and other water sources?

USGS

METHODS OF STUDY

- Compiled and reviewed information from published studies, hydrologic atlases, and regional hydrogeologic assessments
- Generated aquifer maps (including GW flow and saturated thickness contours)
- Compared and contrasted aquifers' hydraulic characteristics and properties, ground-water quality, and recent (2003) ground-water use

USGS

METHODS OF STUDY - continued

- Described ground water - surface water interactions, including simulated scenarios and actual ground-water pumping
- Estimated ground water storage in each aquifer using saturated thickness data (when available)
- Determined which aquifers have the greatest potential for additional ground-water development (i.e. availability of ground-water)

USGS

What factors influence ground-water availability?

- Water budget (recharge vs. discharge)
- Ability (or inability) to withdraw ground water (theoretical well yields and hydraulic properties)
- Volume of stored ground water relative to aquifer recharge (flux)

USGS

What factors influence ground-water availability?

- Intended uses of water and necessary quality
- Hydraulic connection between the aquifers and surface waters (streams, lakes, wetlands)
- Acceptance of adverse impacts on the system from increased ground-water pumping

USGS

Assumptions and (or) Complications with Study Methods

- **Data reported as originally published**
  - *With few modifications and (or) interpretations*

- **Data compiled from different sources, with varying levels of details and scales**
  - *Reported most recent and comprehensive data, with acceptance of minor mapping discrepancies*

- **Much of the original data were in paper format, with little to no GIS-based data**
  - *Conversion of data into digital-format was a tedious and piecemeal process*

USGS

Factors Affecting Ground-Water Availability

- Aquifer Location, Thickness, and Extent – relative to current uses and future needs

USGS

Surficial Aquifers of the Study Area

Red River Basin boundary

Major rivers and streams

0 50 miles

0 50 kilometers

Beach Ridge Aquifers

Buffalo Aquifer

Middle River Surficial

Two Rivers Surficial

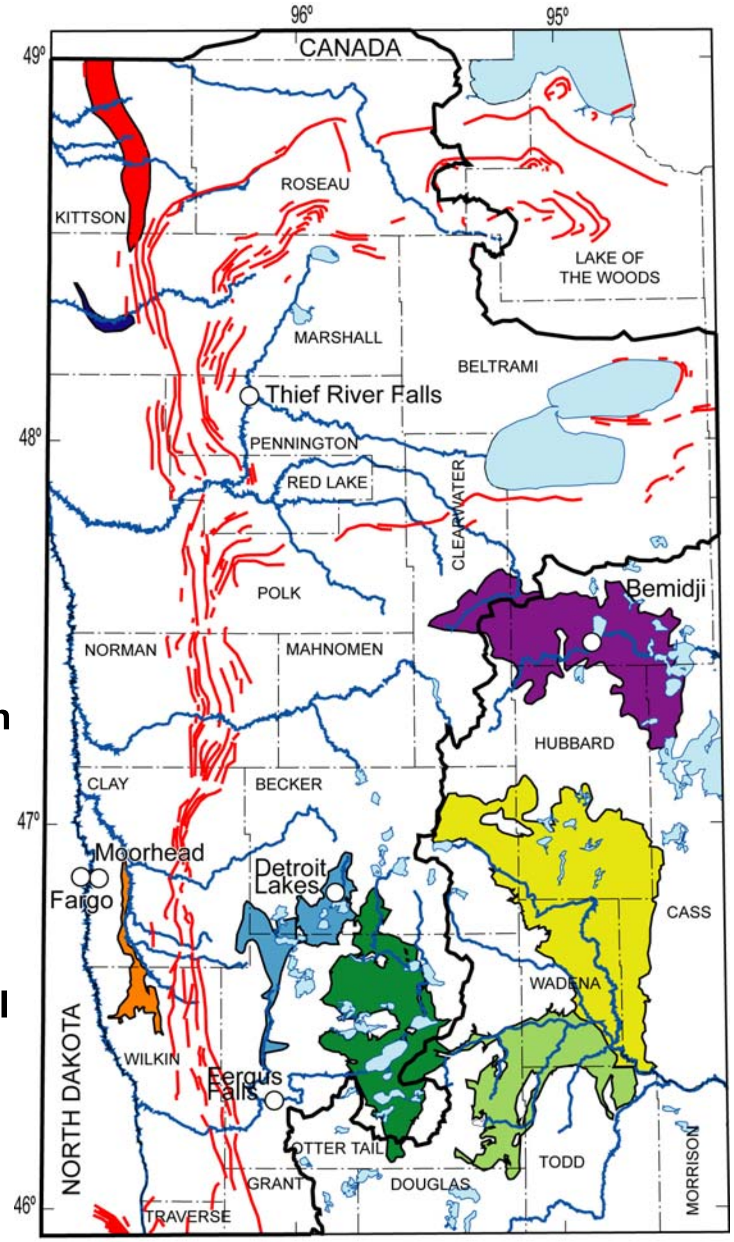
Pelican River Sand-Plain

Otter Tail Surficial

Wadena Surficial

Pineland Sands Surficial

Bemidji-Bagley Surficial



Buffalo Aquifer (saturated thickness data not available)

Saturated Thickness

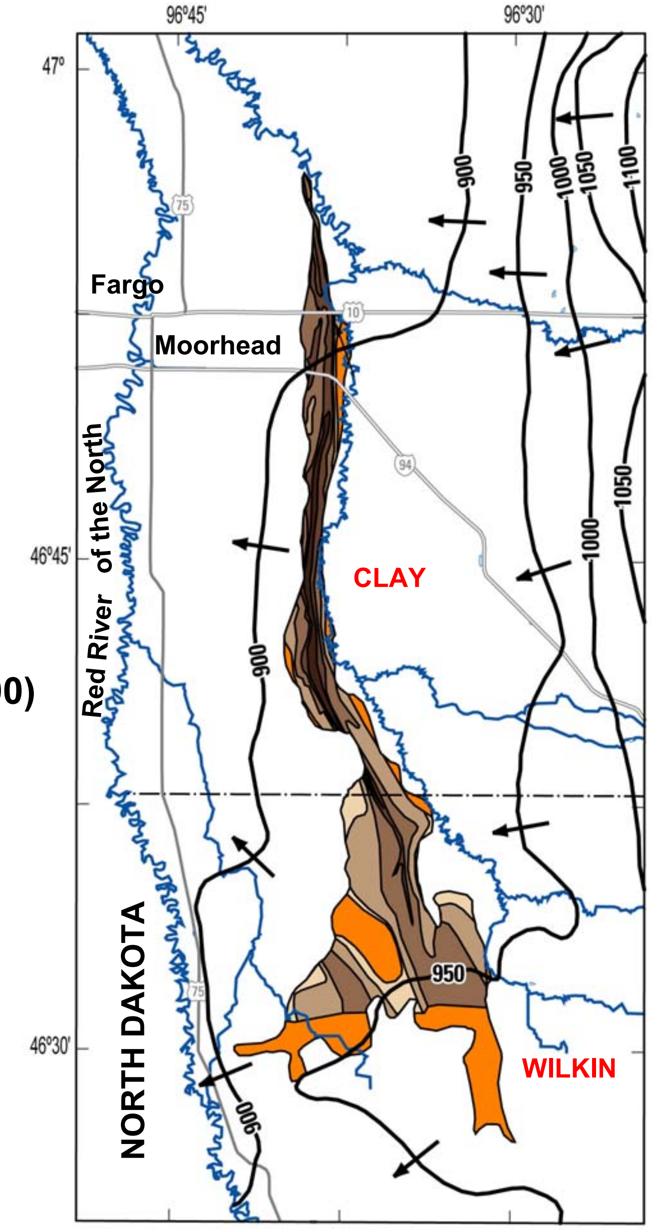
- >0 to <25 ft
- 25 to <50 ft
- 50 to <100 ft
- 100 to <150 ft
- 150 to <200 ft

—900— Regional water-table contour (MDNR, 2000)

← Direction of ground-water flow

0 10 miles

0 10 kilometers



USGS

Otter Tail Surficial (unsaturated portions or saturated thickness data not available)

Saturated Thickness
- >0 to <20 ft
- 20 to <40 ft
- 40 to <60 ft
- 60 to <80 ft
- 80 to <100 ft
- 100 to <120 ft

Pelican River Sand-Plain

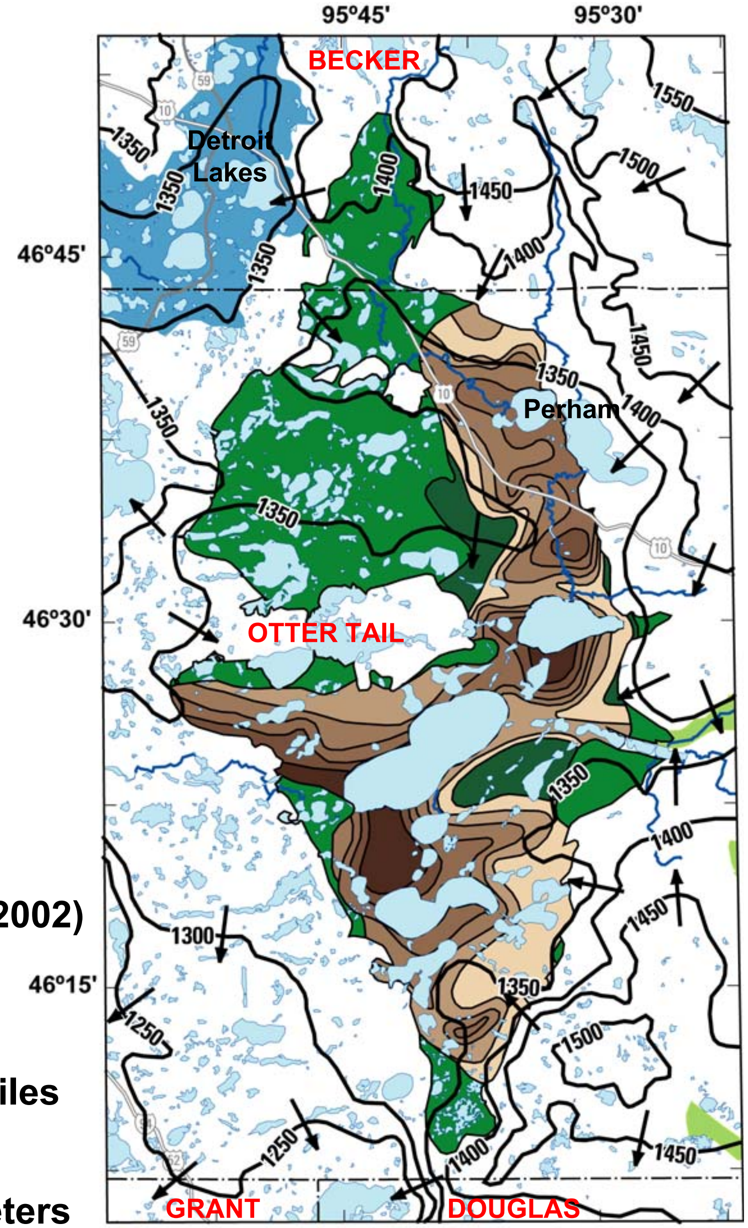
Wadena Surficial

—1300— Regional water-table contour (MDNR, 2002)

← Direction of ground-water flow

0 10 miles

0 10 kilometers



USGS

Pineland Sands Surficial (saturated thickness data not available)

Saturated Thickness

- >0 to <20 ft
- 20 to <40 ft
- 40 to <60 ft
- 60 to <80 ft
- 80 to <100 ft
- 100 to <120 ft
- 120 to <140 ft

Otter Tail Surficial

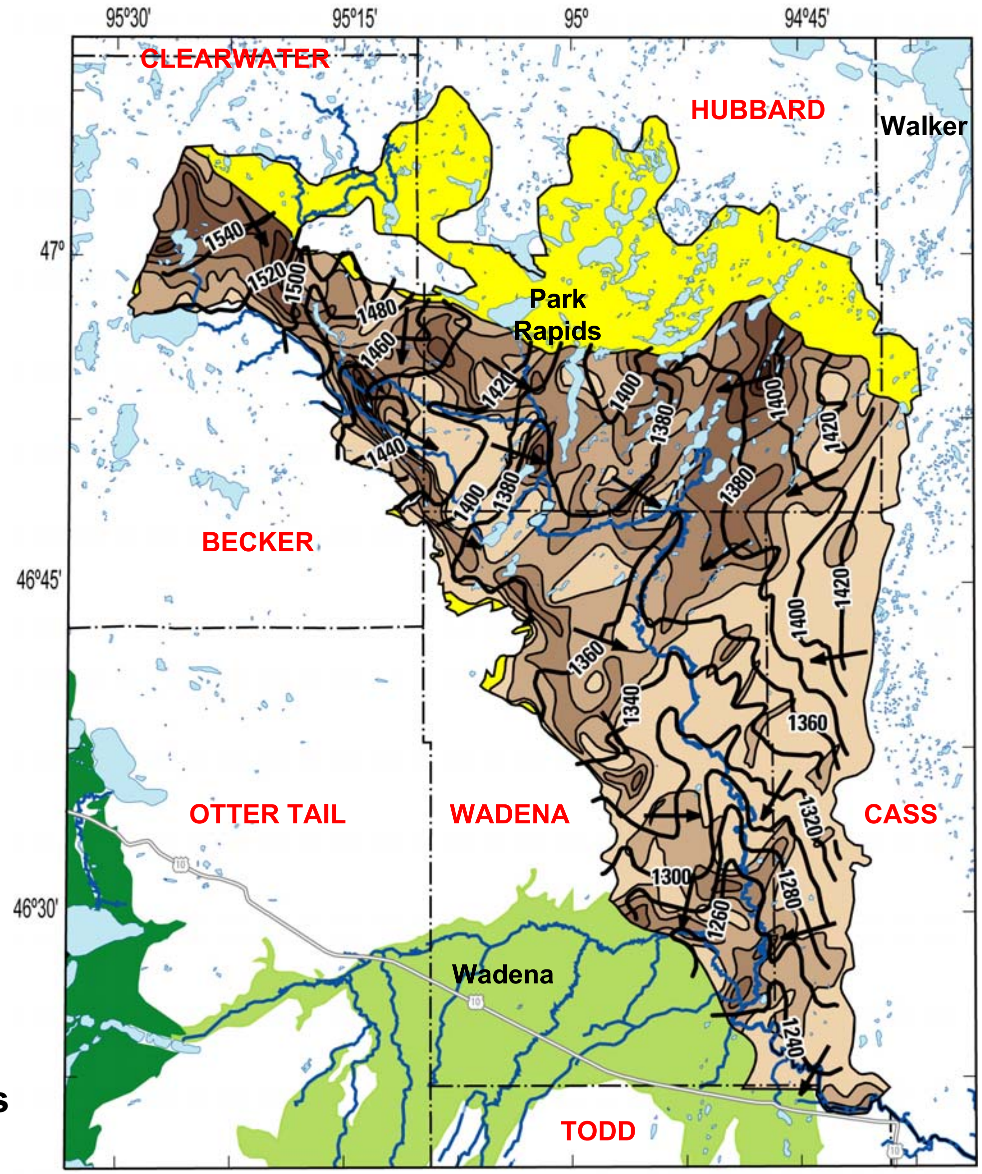
Wadena Surficial

—1300— Water-table contour

← Direction of ground-water flow

0 10 miles

0 10 kilometers



Factors Affecting Ground-Water Availability

- Aquifer Location, Thickness, and Extent – relative to current uses and future needs
- Maximum volume of ground water capable of being stored in each aquifer

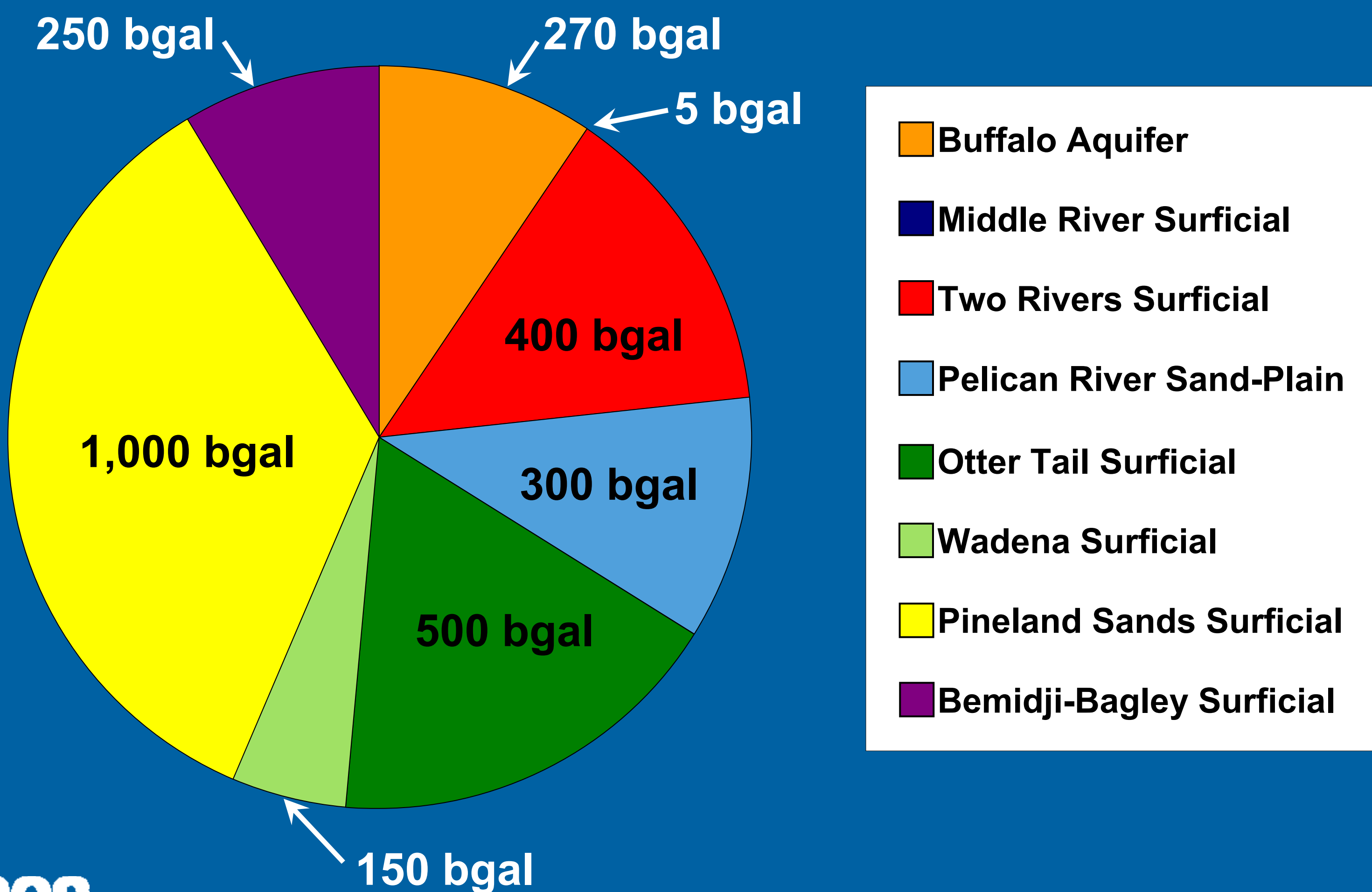
USGS

Estimating Maximum Volumes of Ground-Water Storage

- Compiled from aquifer studies, or calculated using aquifer areas (A), and published saturated thickness and porosity (n) data
- Storage = $\sum$ (A * median sat. thick. * n)
- “Storage” represents a maximum volume of water the aquifer is capable of holding

USGS

Maximum Ground-Water Storage (~2,900 bgal total)



USGS

Factors Affecting Ground-Water Availability

- Aquifer Location, Thickness, and Extent – relative to current uses and future needs
- Maximum volume of ground water capable of being stored in each aquifer
- Water sources and discharges – determined from water budget estimations

USGS

Water Budget Estimation Methods

- Steady-state simulations from published aquifer studies
- Published estimations of recharge and discharge components based on precipitation data and hydrograph analysis

USGS

Evaluating Ground-Water Availability Using Water Budget Estimates

- Water budgets varied based on methods and provided a range of values for the components
- Water budgets were influenced most by recharge components and aquifer storage
- “Availability” was evaluated by comparing and contrasting recharge sources and total

USGS

Comparison of Recharge to Evaluate Ground-Water Availability

- **Recharge was greatest in Otter Tail, Pineland Sands, Wadena Surficial Aquifers, and Pelican River Sand-Plain Aquifer - due to greater mean areal recharge (5-8 in./yr) and large aquifer areas**

- **Smallest recharge in Middle River and Two Rivers Surficial Aquifers – mean areal recharge of only 3 in./yr; small aquifer areas**

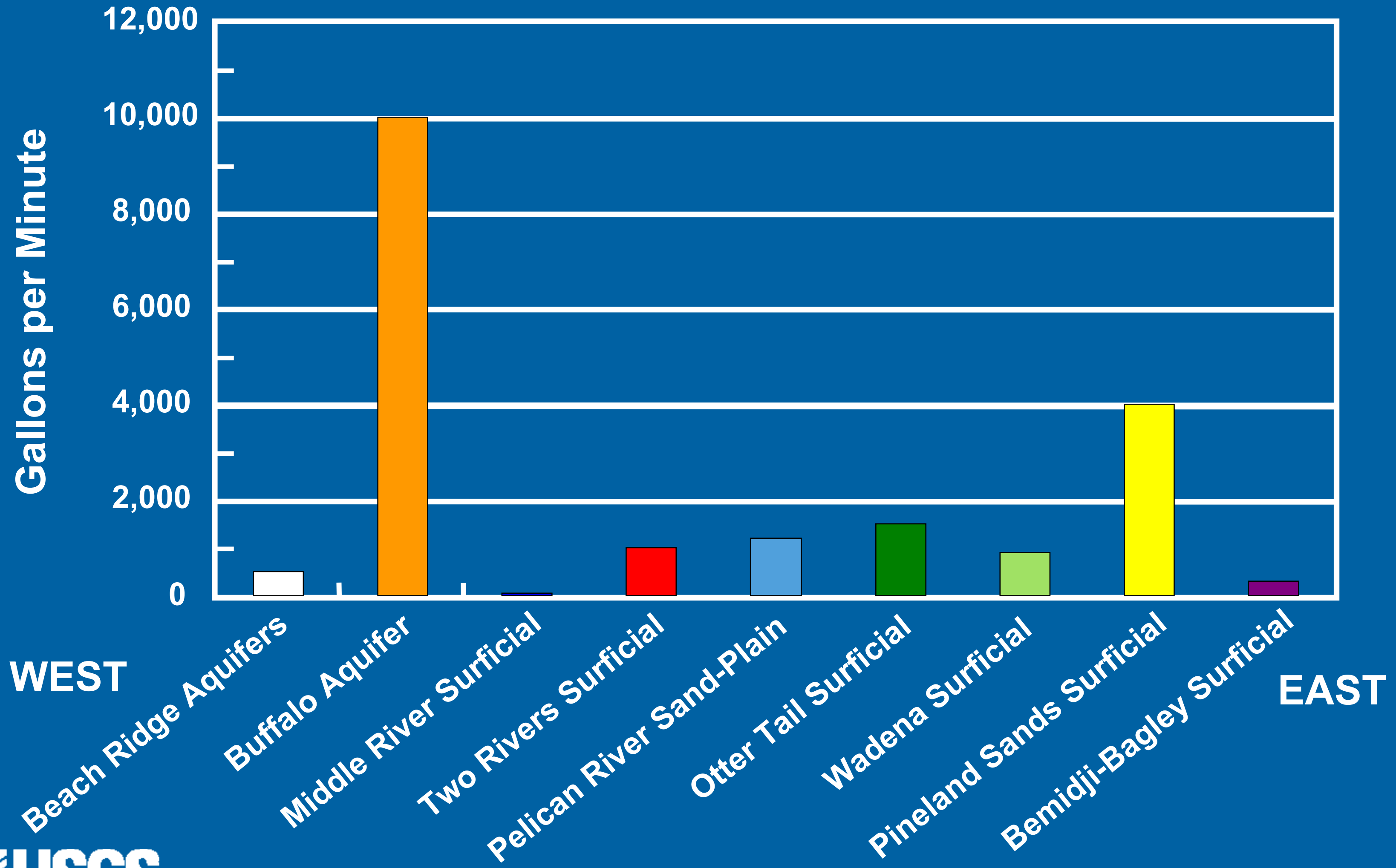
USGS

Factors Affecting Ground-Water Availability – cont.

- Rate that ground water can be withdrawn from the aquifer (comparison of theoretical well yields and actual pumping data)

USGS

Maximum Theoretical Well Yields



USGS

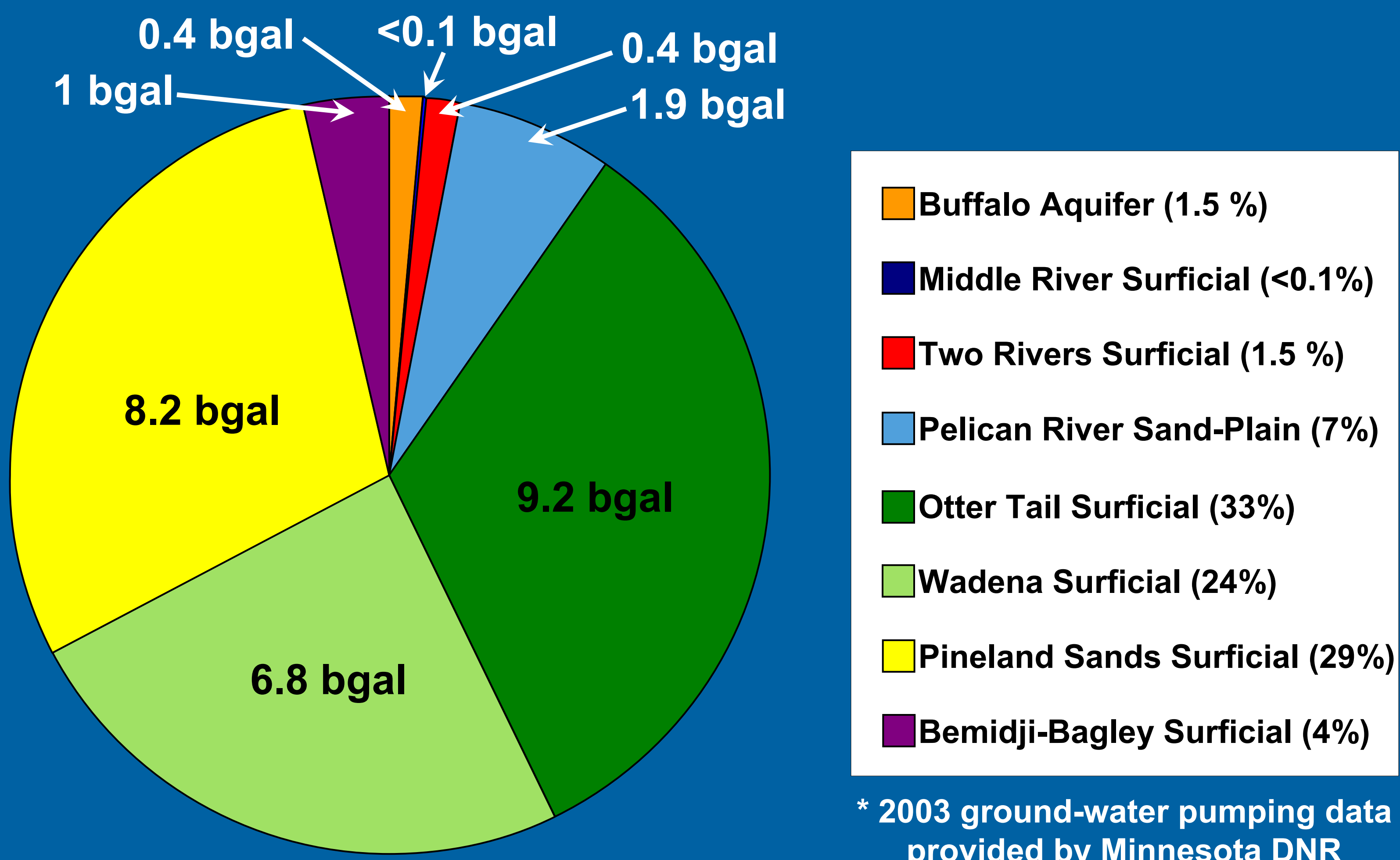
Factors Affecting Ground-Water Availability – cont.

- Rate that ground water can be withdrawn from the aquifer (comparison of theoretical well yields and actual pumping data)

- Historic (and planned) use of the ground water

USGS

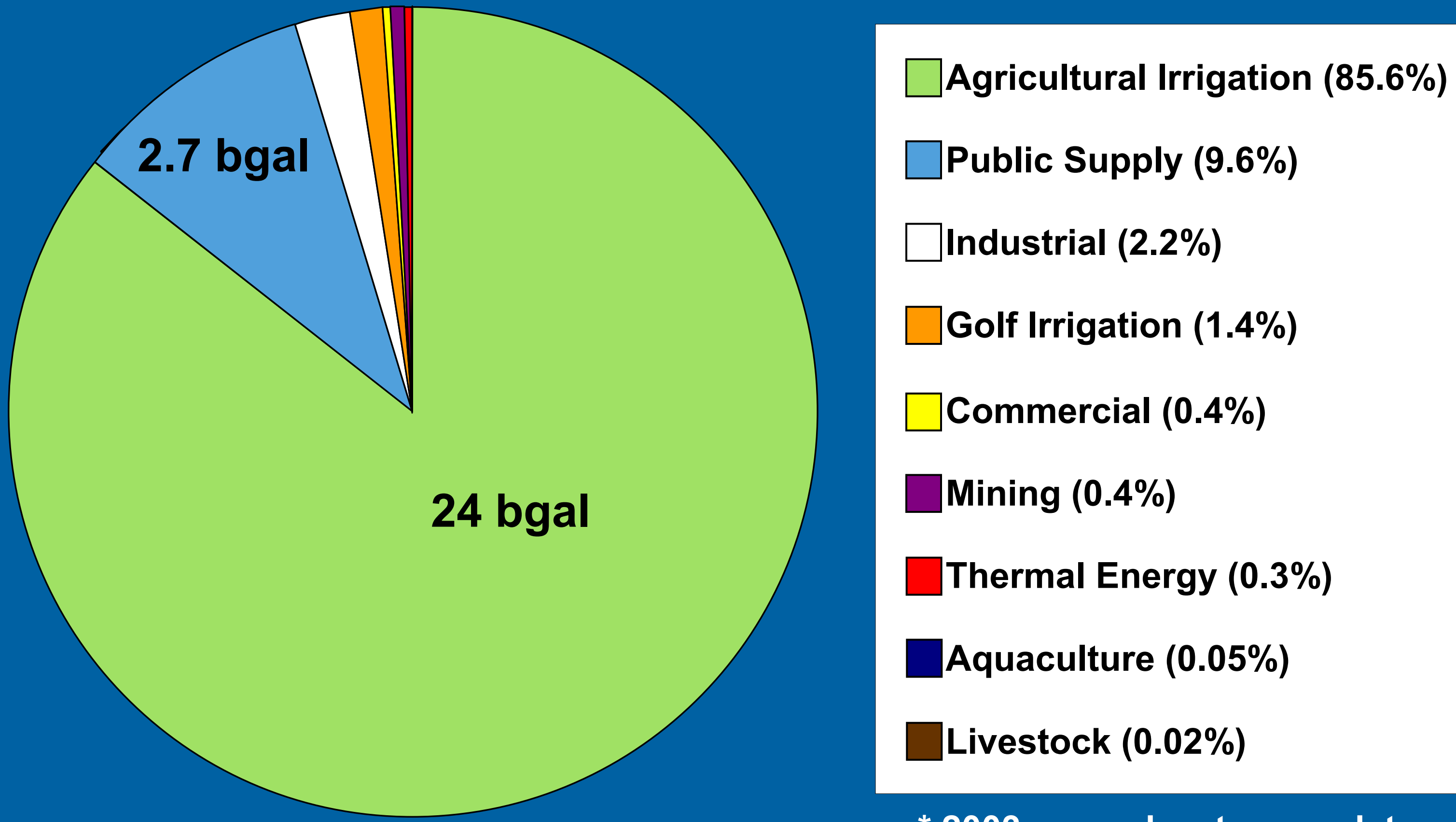
Ground-Water Withdrawals in 2003*
(~28 bgal total)



* 2003 ground-water pumping data provided by Minnesota DNR

USGS

Uses of Ground Water in 2003* (~28 bgal total)



* 2003 ground-water use data provided by Minnesota DNR

USGS

Factors Affecting Ground-Water Availability – cont.

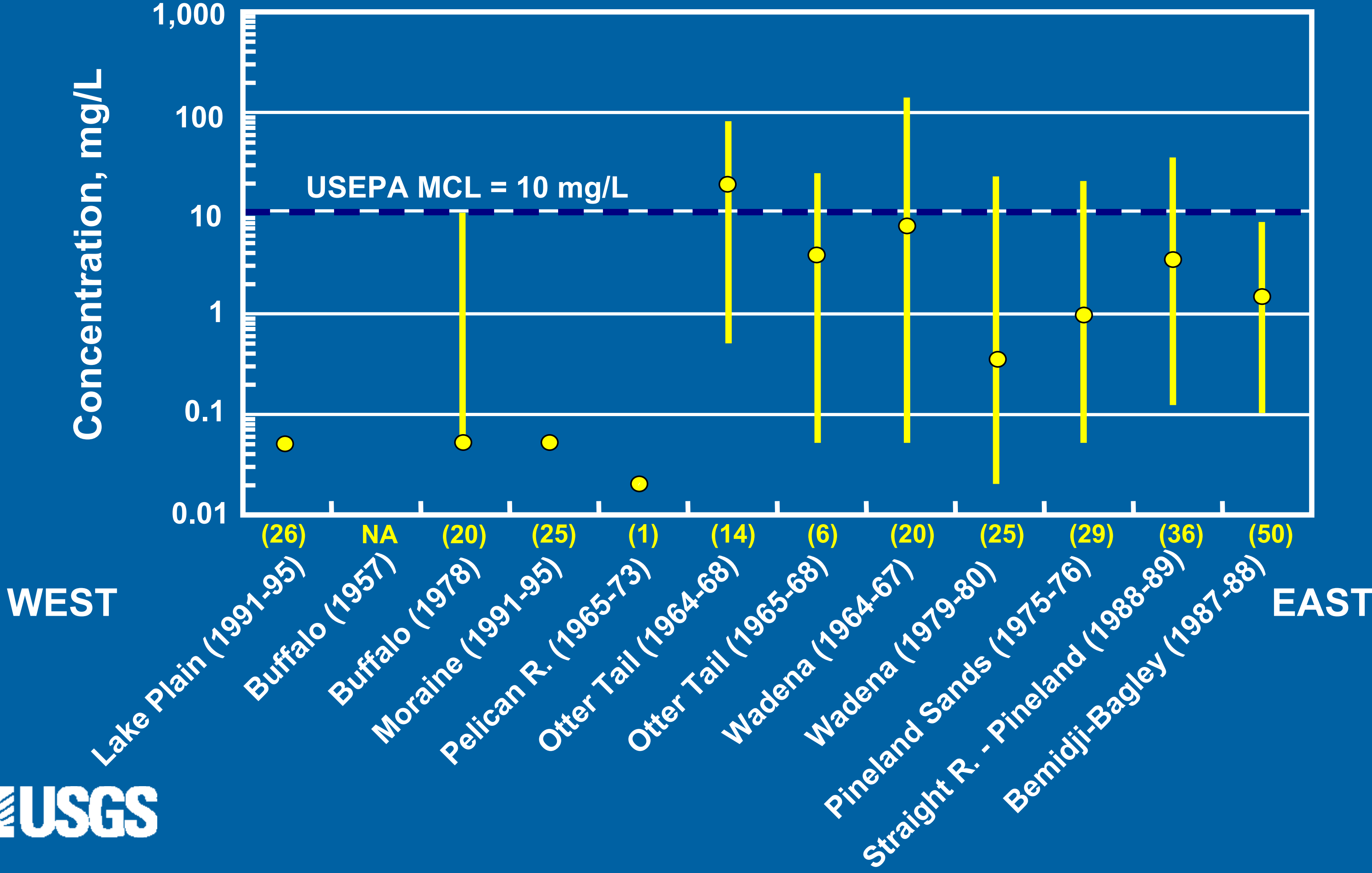
- Rate that ground water can be withdrawn from the aquifer (comparison of theoretical well yields and actual pumping data)

- Historic (and planned) use of the ground water

- Quality of the water (relative to the use)

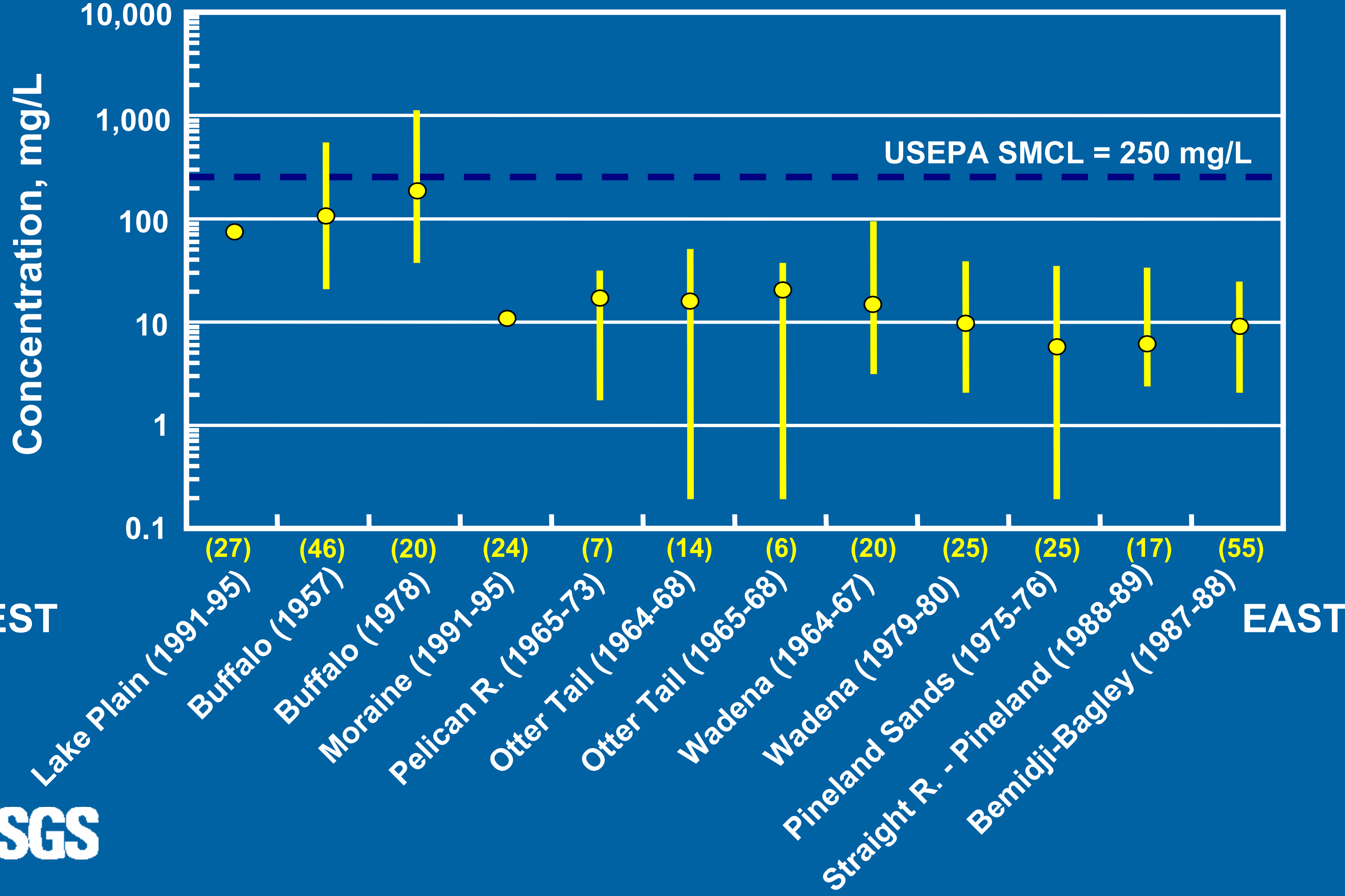
USGS

Concentration of Nitrate (as Nitrogen) from Surficial Aquifers



USGS

Concentration of Sulfate from Surficial Aquifers



USGS

OTHER CONSIDERATIONS

("less quantifiable factors of ground-water availability")

- **Hydraulic connection between the surficial aquifers and adjacent ground waters and surface waters, and the effects of increased ground-water pumping**
- **Implications to sustainable use and the acceptance of potential adverse results due to increased ground-water development**

USGS

CONCLUSIONS

- Otter Tail and Pineland Sands Surficial, and Pelican River Sand-Plain Aquifers have the greatest potential for development among the surficial aquifers studied

- Water levels and storage in Middle River Surficial Aquifer and Buffalo Aquifer are the most sensitive to increased pumping and the most susceptible to decline

USGS

Secondary Study Findings

- Surficial aquifers vary in hydraulic properties, water quality, and sources and rates of recharge and discharge

- Actual and simulated ground-water pumping indicate that aquifers can be hydraulically connected to surface waters

- Water-budget estimates may indicate aquifers that can be susceptible to ground-water losses due to increased withdrawals

USGS

USGS