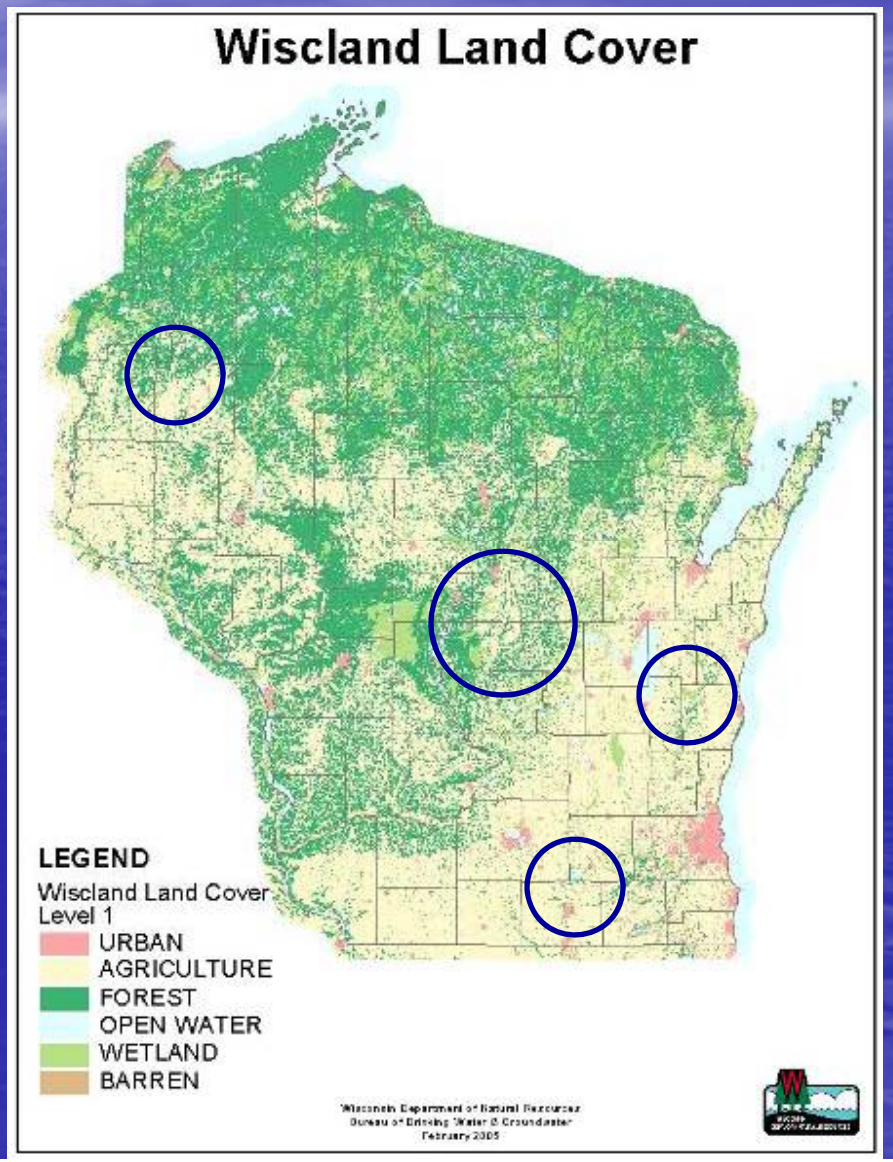
Case Studies for Understanding Groundwater and Lake Interactions

Wisconsin Lakes Convention 2008

Case Studies

- Silver Lake, Barron Co
- Middle Genesee, Walworth Co
- Crystal Lake, Sheboygan Co
- Central sand plains

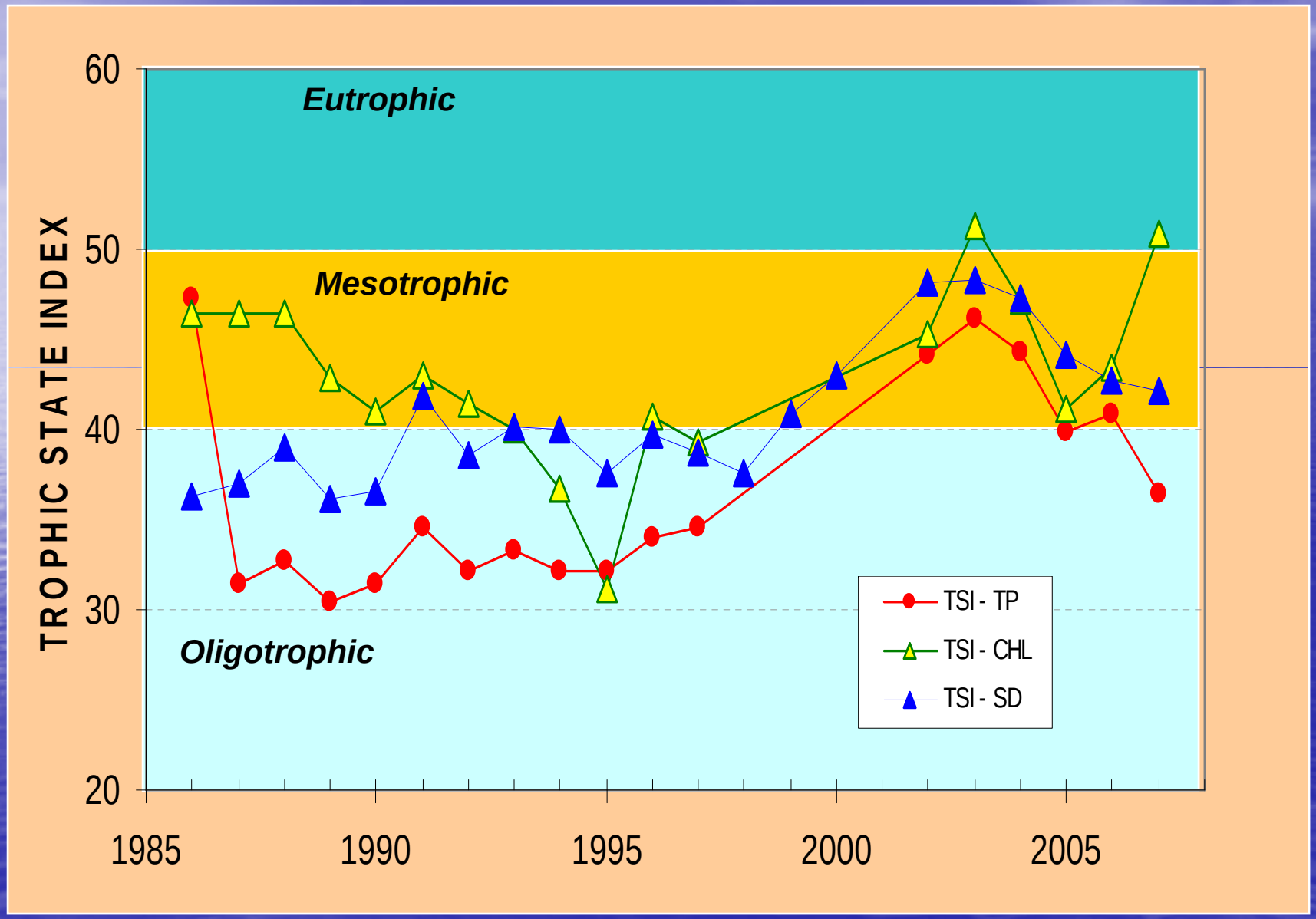


The effects of changes in water level on the water quality of Silver Lake, Barron County, Wisconsin

Dale Robertson and Bill Rose

U.S. Geological Survey,
Wisconsin WSC

Average Summer Trophic State of Silver Lake



Water Budget

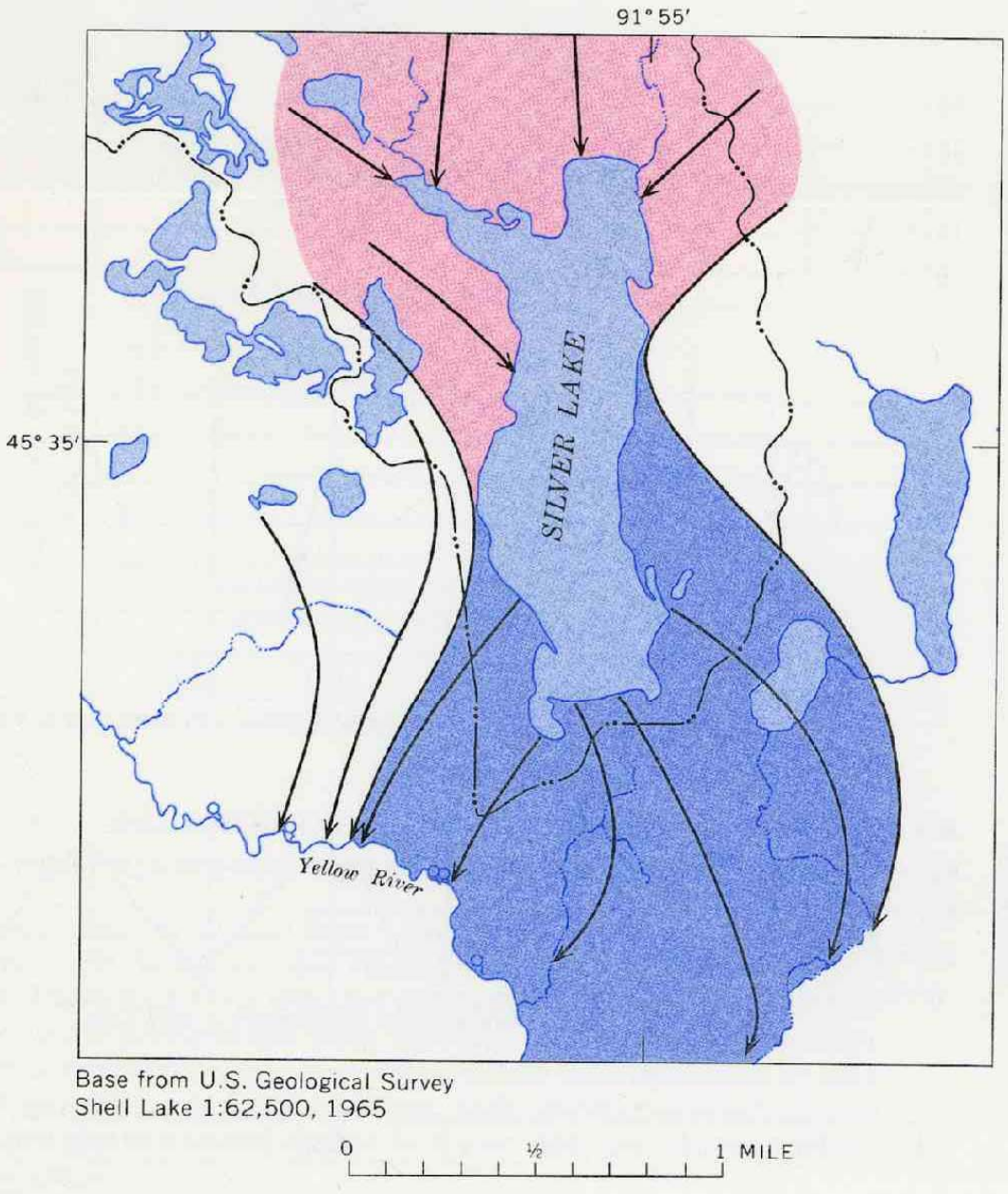
Change in Storage = Inputs – Outputs

Ground water

$$\Delta S = P + Q_I + G_I - E - G_o$$

Precipitation Surface water Evaporation

Original Description of Ground-water Flow



EXPLANATION

Area contributing ground water to Silver Lake

Area receiving ground water from Silver Lake

Direction of ground-water movement

Spring

Silver Lake drainage divide

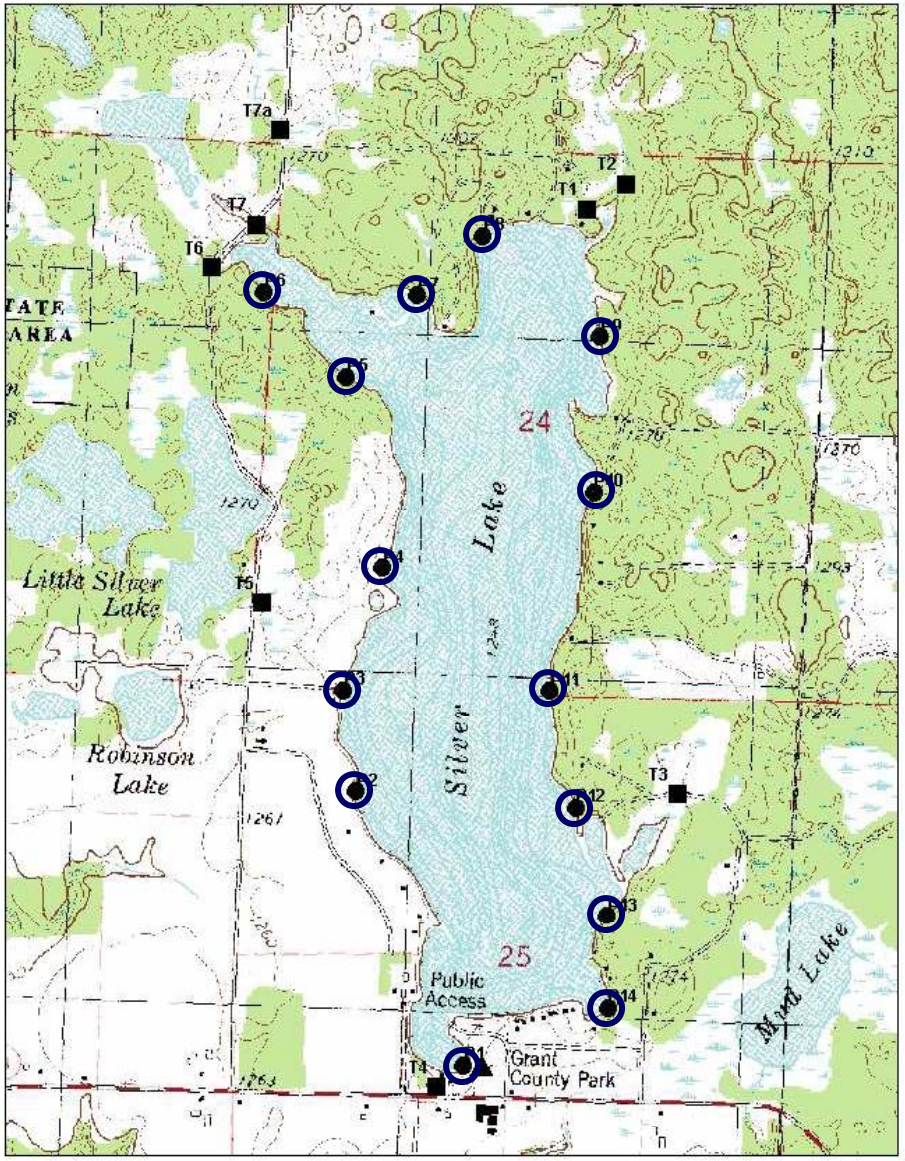


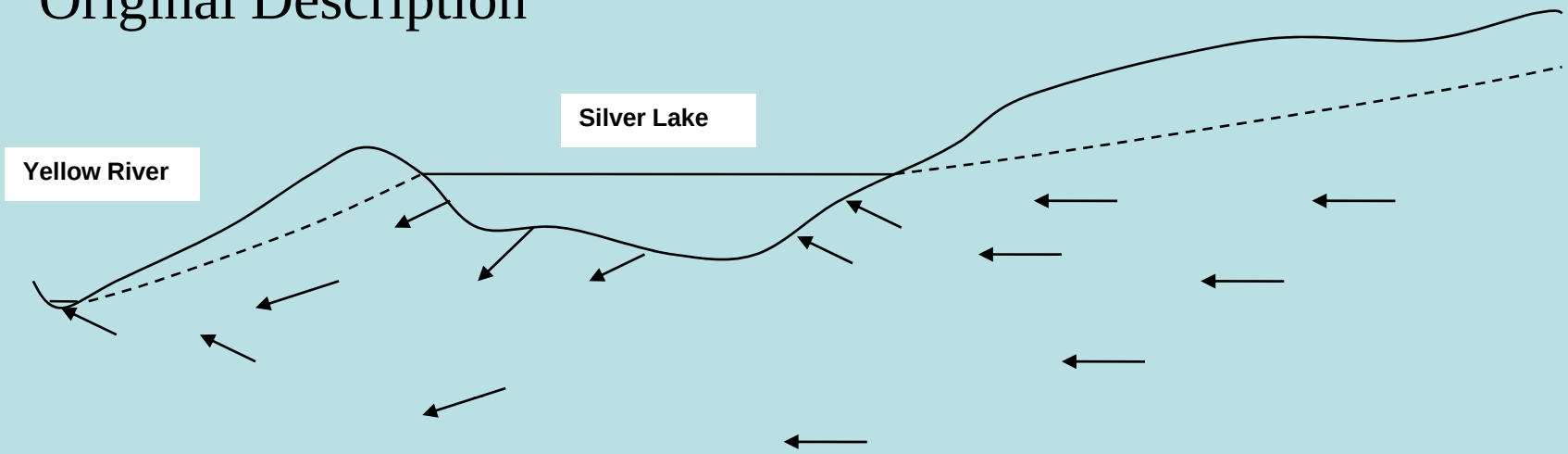
Figure 1. Locations of monitoring sites at Silver Lake near Cumberland, Wisconsin.

Installation and measurement of piezometers

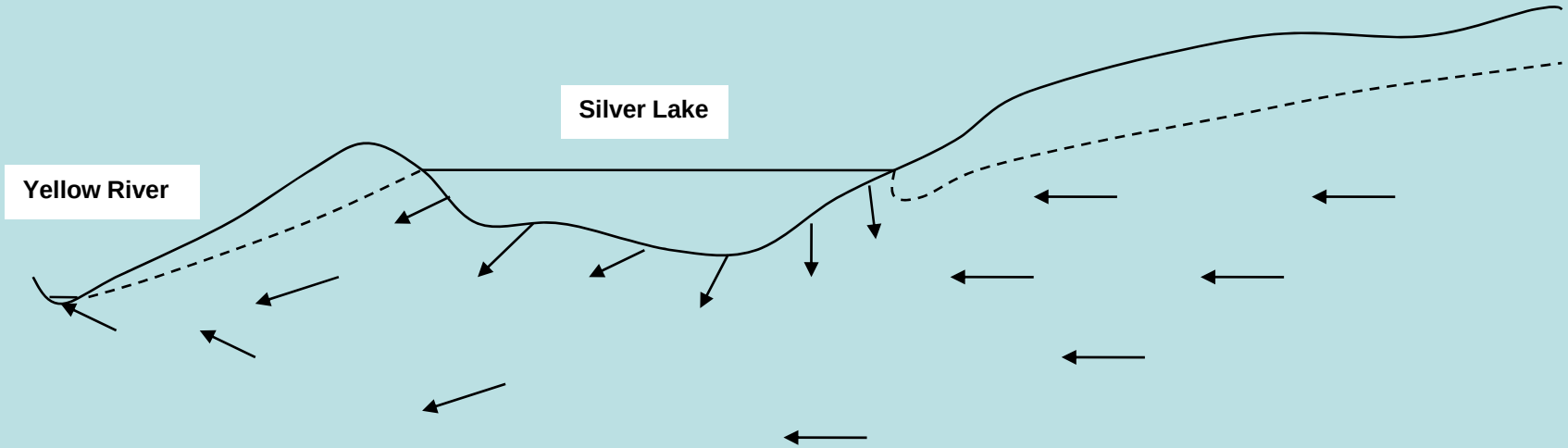
Lake
water level
recording
gage and
rain gage

Ground-water flow near Silver Lake

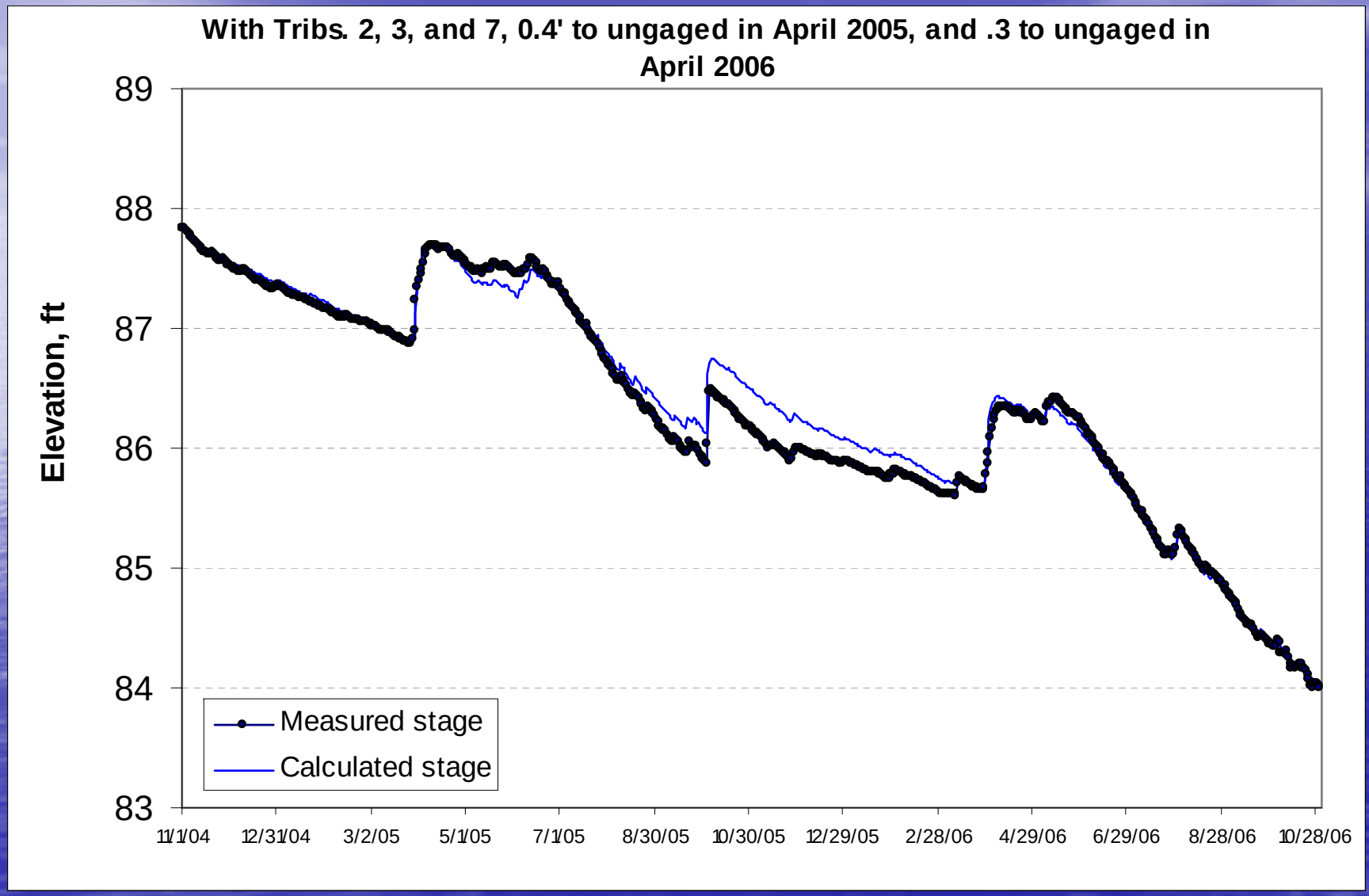
Original Description



New Description

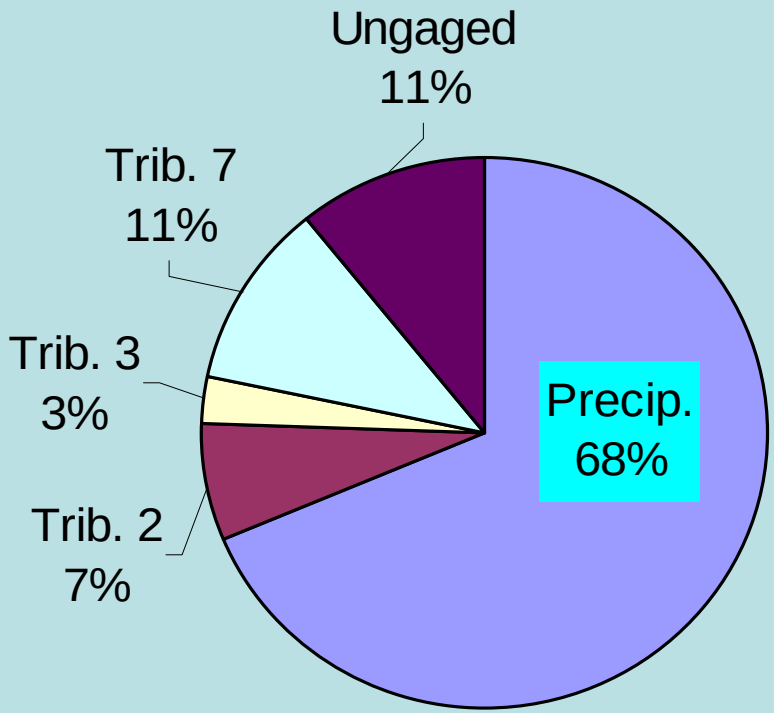


Estimated Ground-water Output – 0.1 inches/day

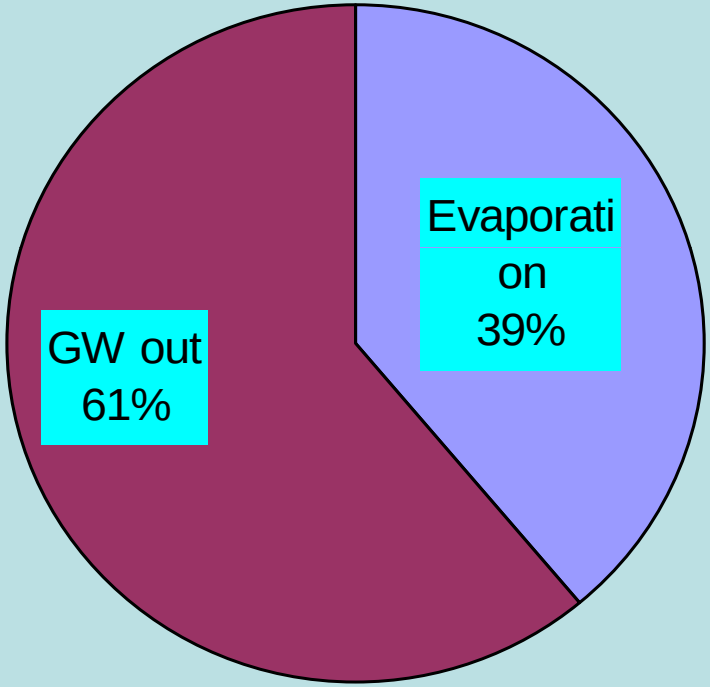

With Tribs. 2, 3, and 7, 0.4' to ungaged in April 2005, and .3 to ungaged in April 2006
Elevation, ft
89
88
87
86
85
84
83
11/1/04
12/31/04
3/2/05
5/1/05
7/1/05
8/30/05
10/30/05
12/29/05
2/28/06
4/29/06
6/29/06
8/28/06
10/28/06
Measured stage
Calculated stage

MY2005

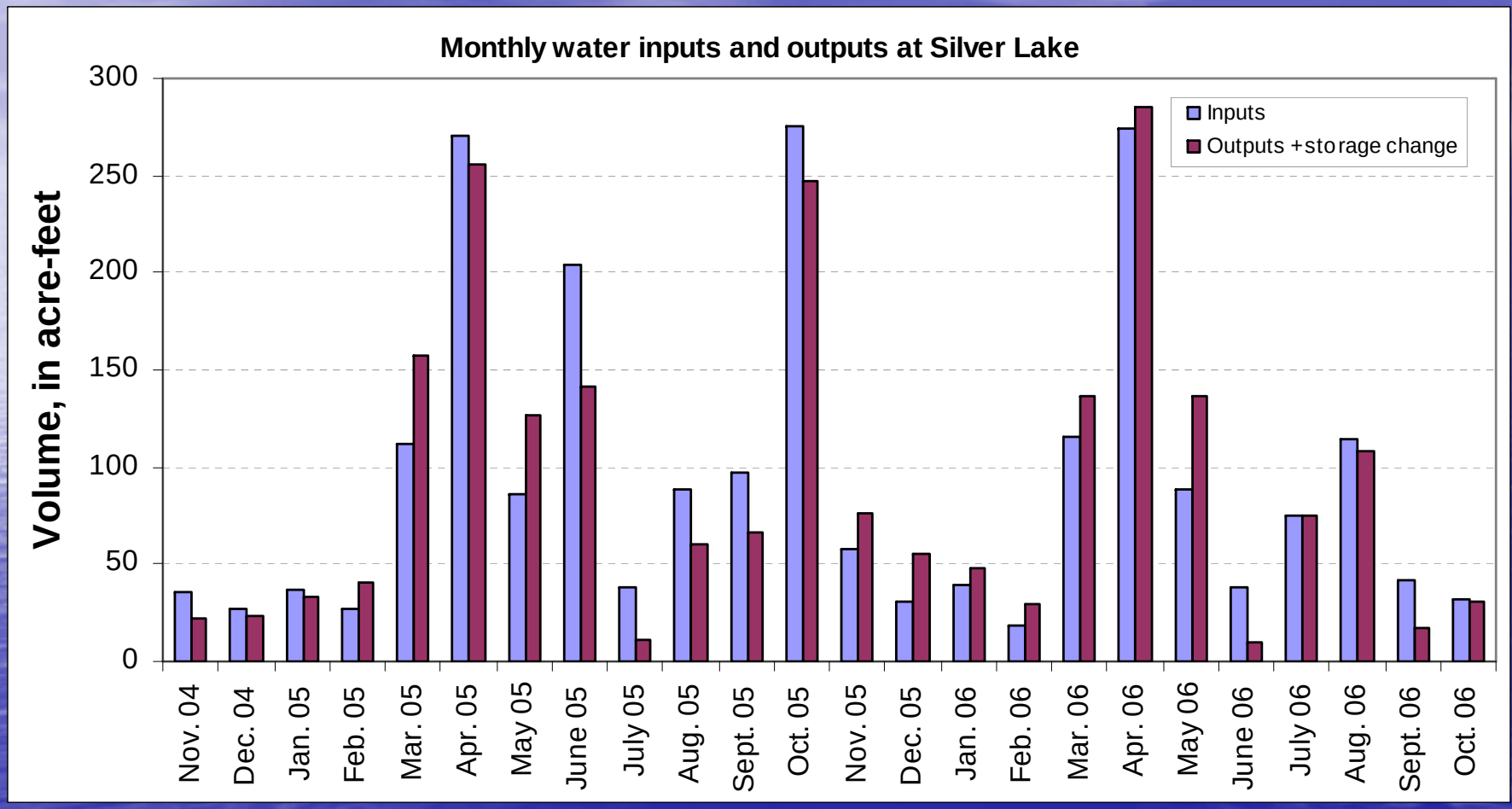
Water inputs = 1297 acre-ft



Water outputs = 1777 acre-ft



Accuracy of the Estimated Water Budget



Results Can Now Be Used To:

1. Understand changes in water quality
2. Estimate how the lake should respond to various management alternatives
3. Develop a Management Plan for the lake
4. Better able to predict changes in other lakes

Middle Genesee Lake

Waukesha County

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

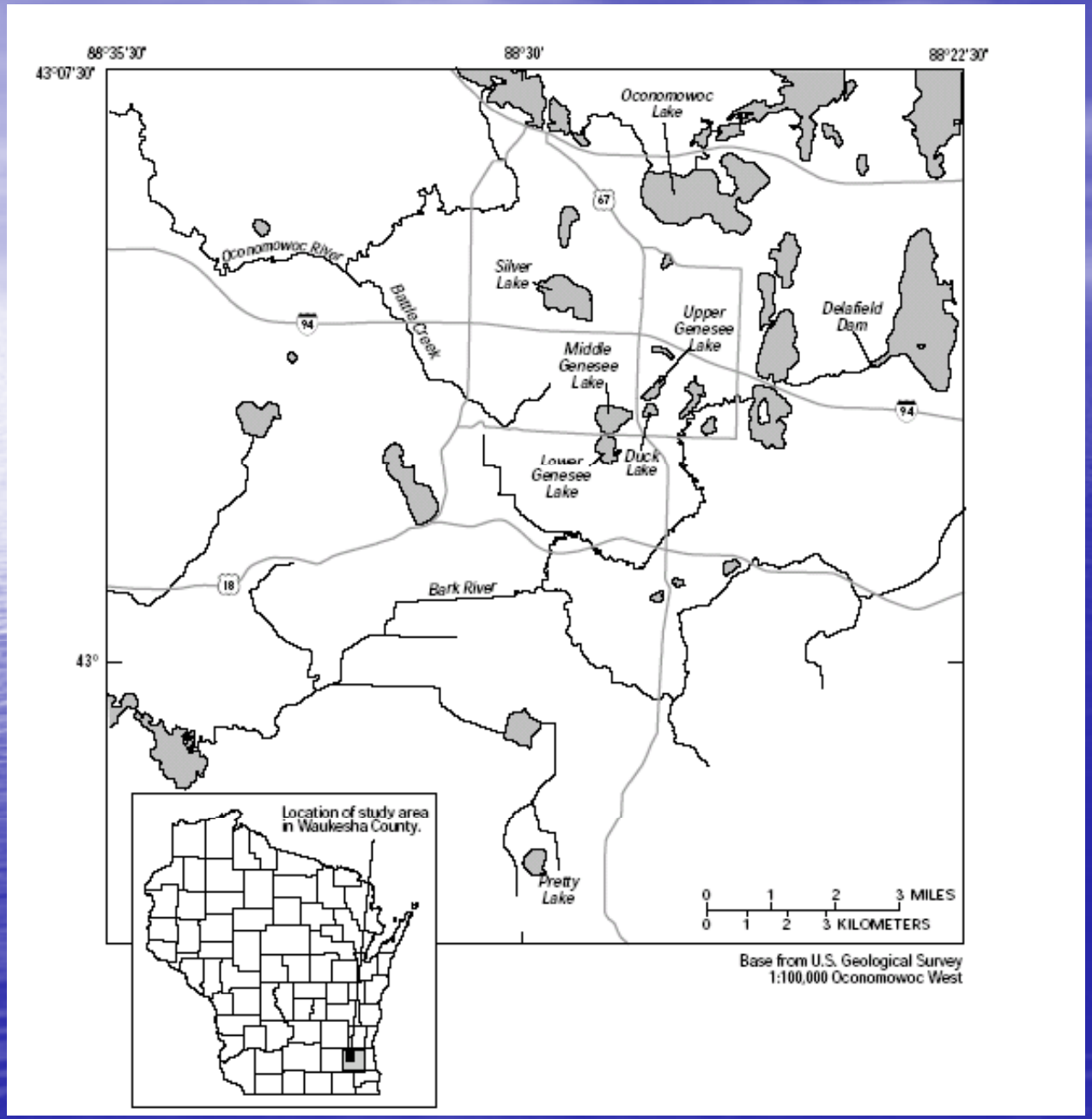
Simulation of the Shallow Hydrologic System in the Vicinity of Middle Genesee Lake, Wisconsin, Using Analytic Elements and Parameter Estimation

Water-Resources Investigations Report 00–4136

Prepared in cooperation with the
Middle Genesee Lake Management District
Wisconsin Department of Natural Resources

USGS
science for a changing world

Middle Genesee Study, Waukesha County



USGS
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Middle Genesee Study, Waukesha County

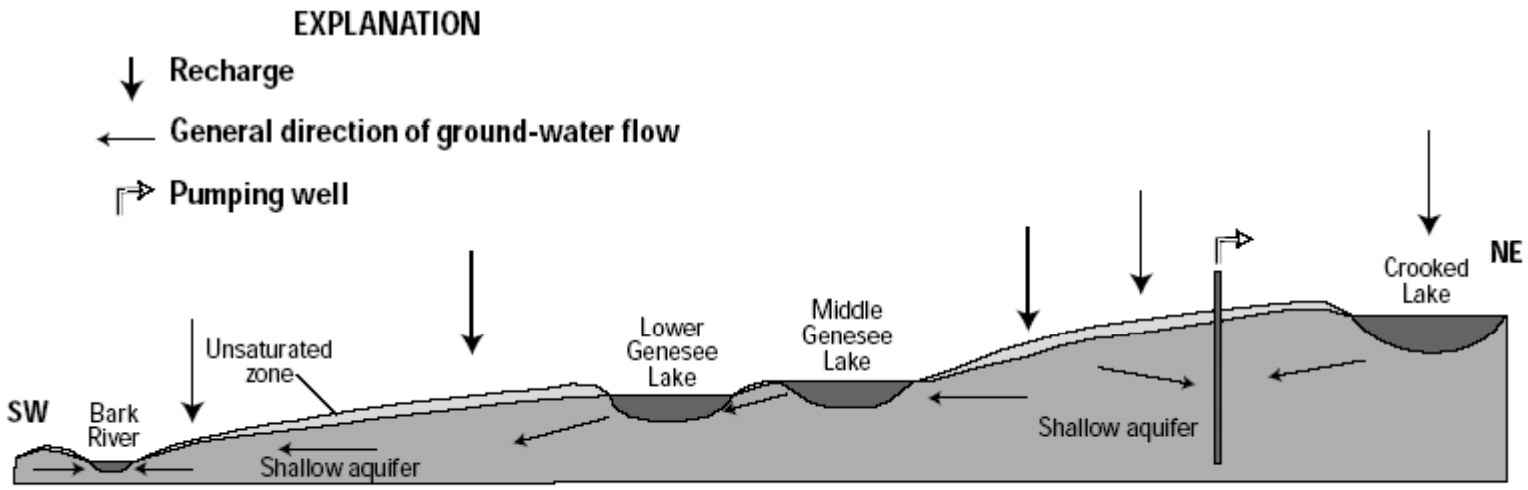
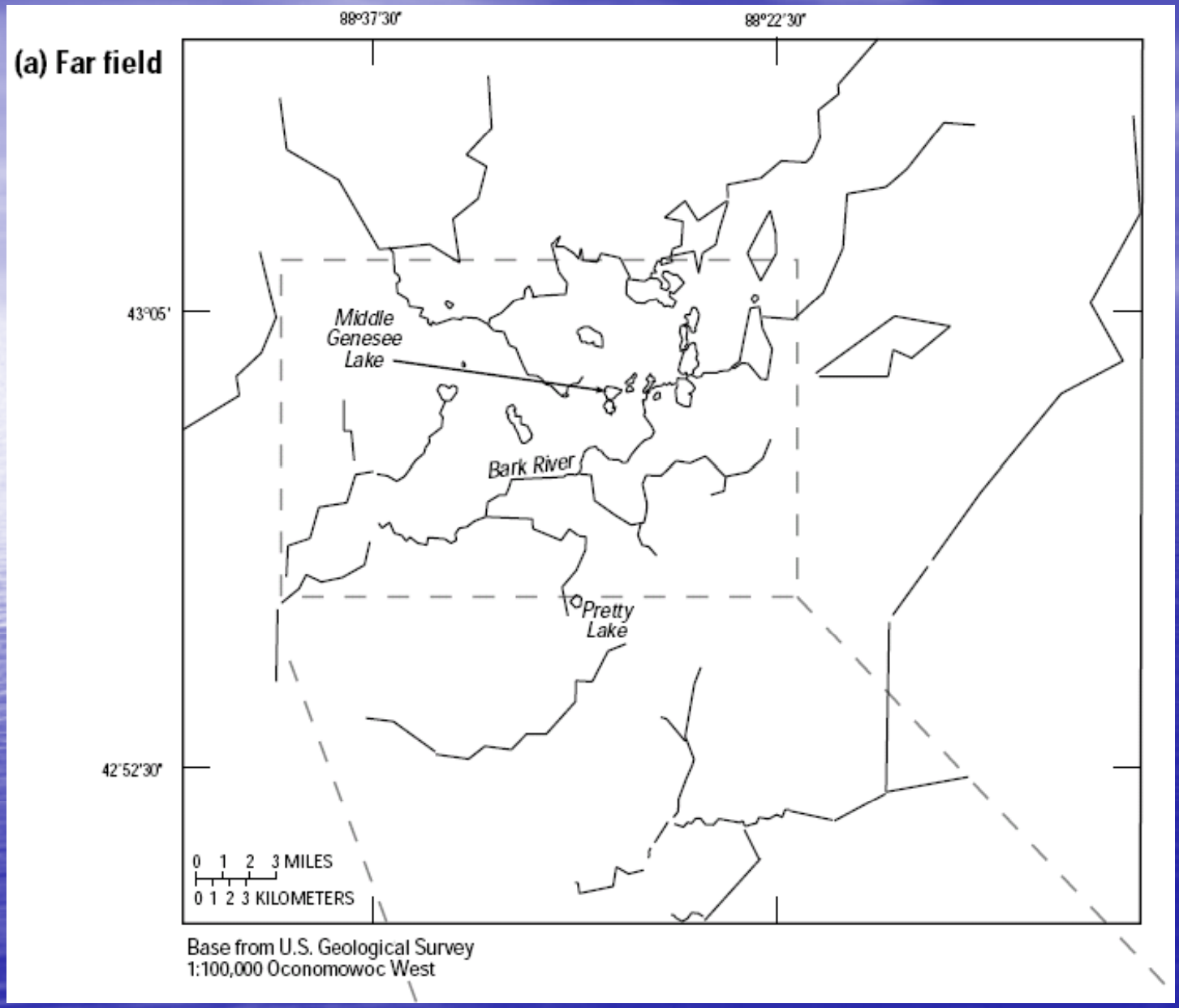


Figure 2. Conceptual model of shallow hydrologic system in the vicinity of Middle Genesee Lake, Waukesha County, Wisconsin.

USGS science for a changing world



Middle Genesee Study,
Waukesha County

USGS
science for a changing world

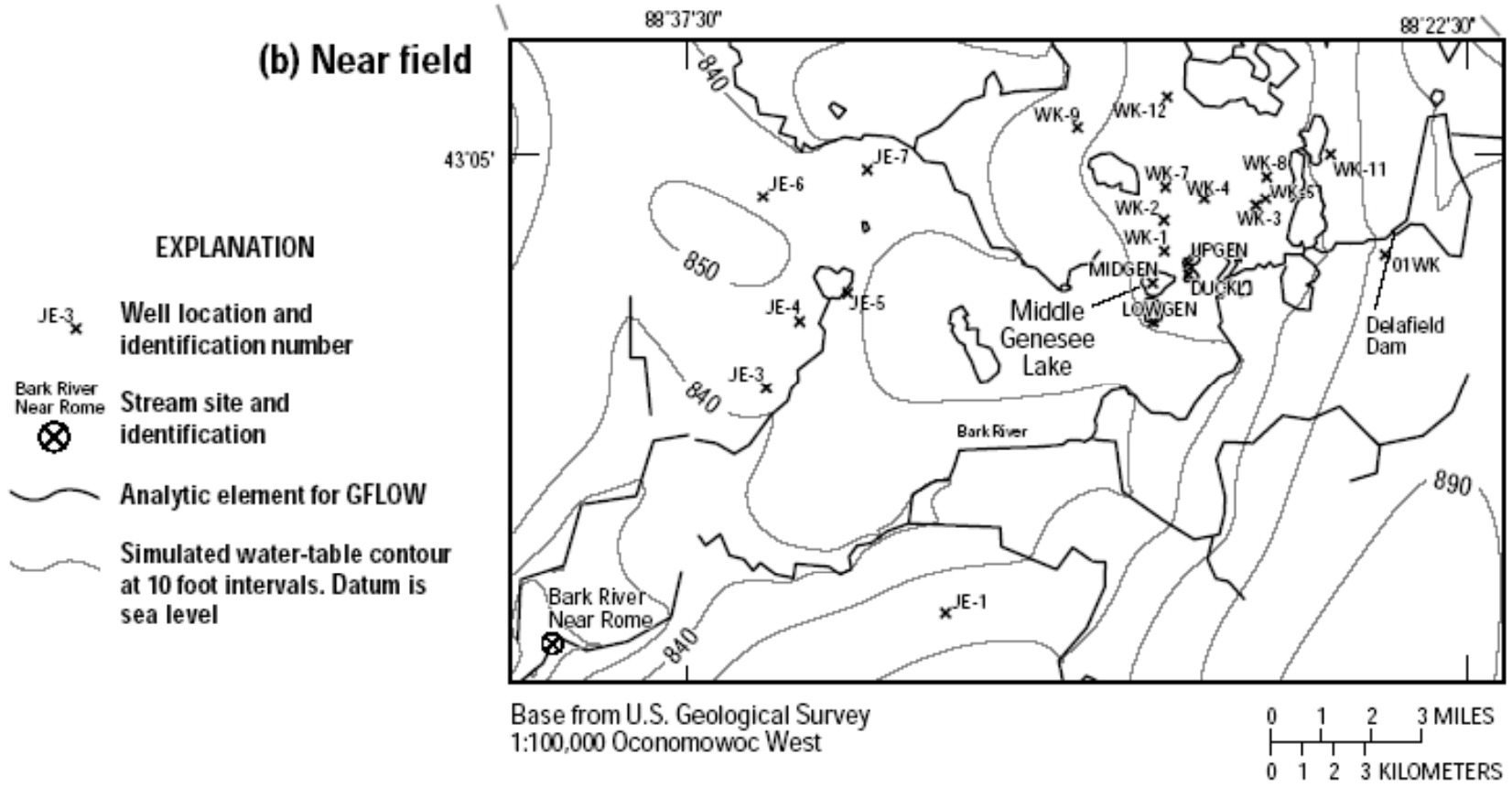


Figure 4. Simulated hydrologic features with analytic elements, initial water-table elevation and calibration targets, (a) far field elements (Global recharge is applied for the entire far field); (b) near field elements.

USGS science for a changing world

HYDROLOGIC BUDGET

Middle Genesee Study, Waukesha County

An annual hydrologic budget for Middle Genesee Lake can be described by

$$\Delta S = P - E + GW_{in} - GW_{out},$$

where

ΔS is change in lake storage,

P is volume of precipitation falling directly on the lake,

E is volume of water evaporated from the lake surface,

GW_{in} is volume of ground-water flow into lake, and

GW_{out} is volume of flow out of the lake to the ground-water system.

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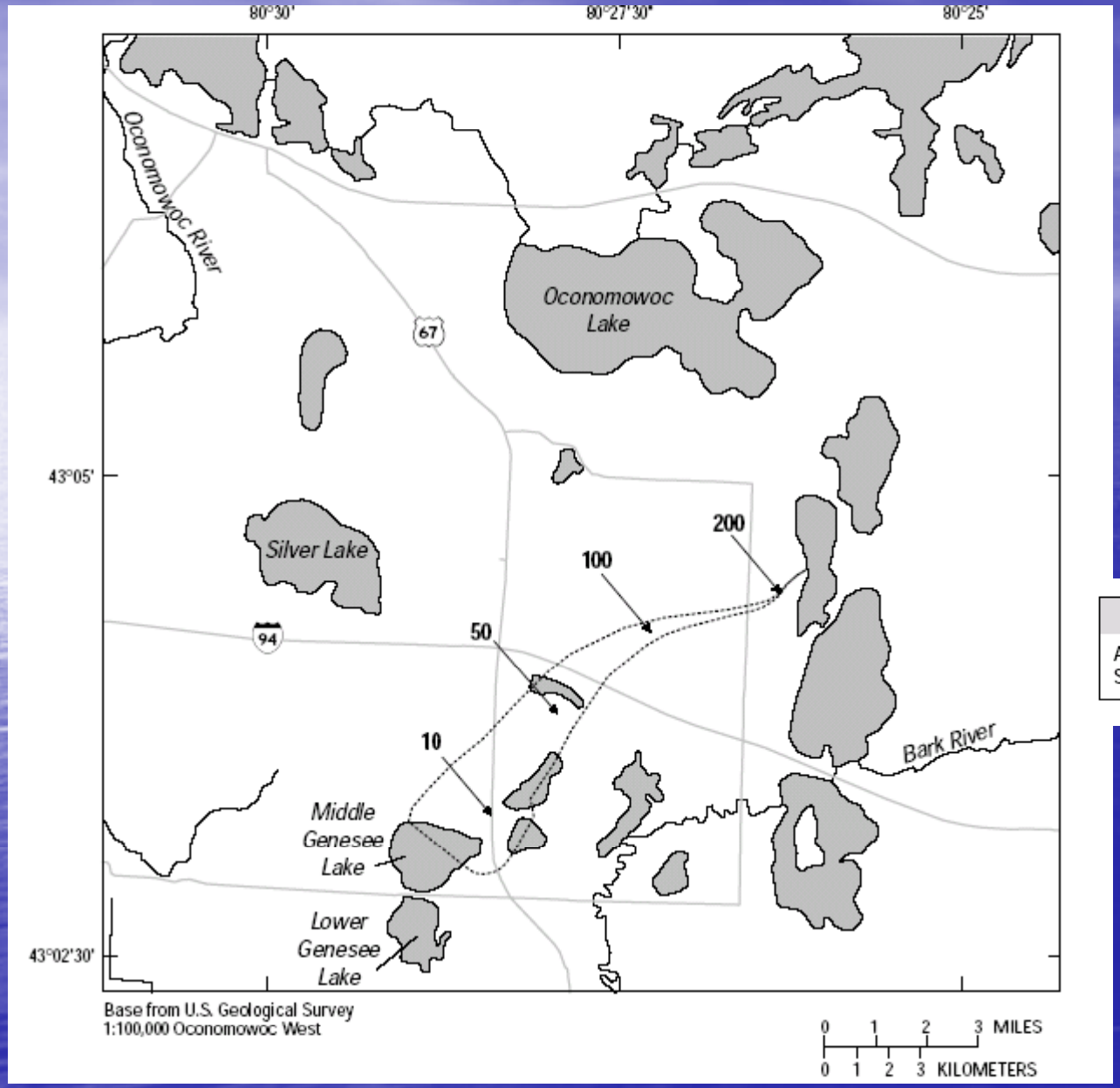
Middle Genesee Study, Waukesha County



EXPLANATION

Undeveloped capture zone

10 Travel time, in years

MIDDLE GENESEE LAKE LEVEL	
Average measured lake level:	863.00 feet above sea level
Simulated level:	862.62 feet above sea level

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Middle Genesee Study, Waukesha County

The calibrated model can be used to estimate GW_{in} ➔

$P = 32$ in/yr,

$E = 30$ in/yr,

$GW_{in} = 25.2$ in/yr, and

$GW_{out} = P - E + GW_{in} = 27.2$ in/yr.

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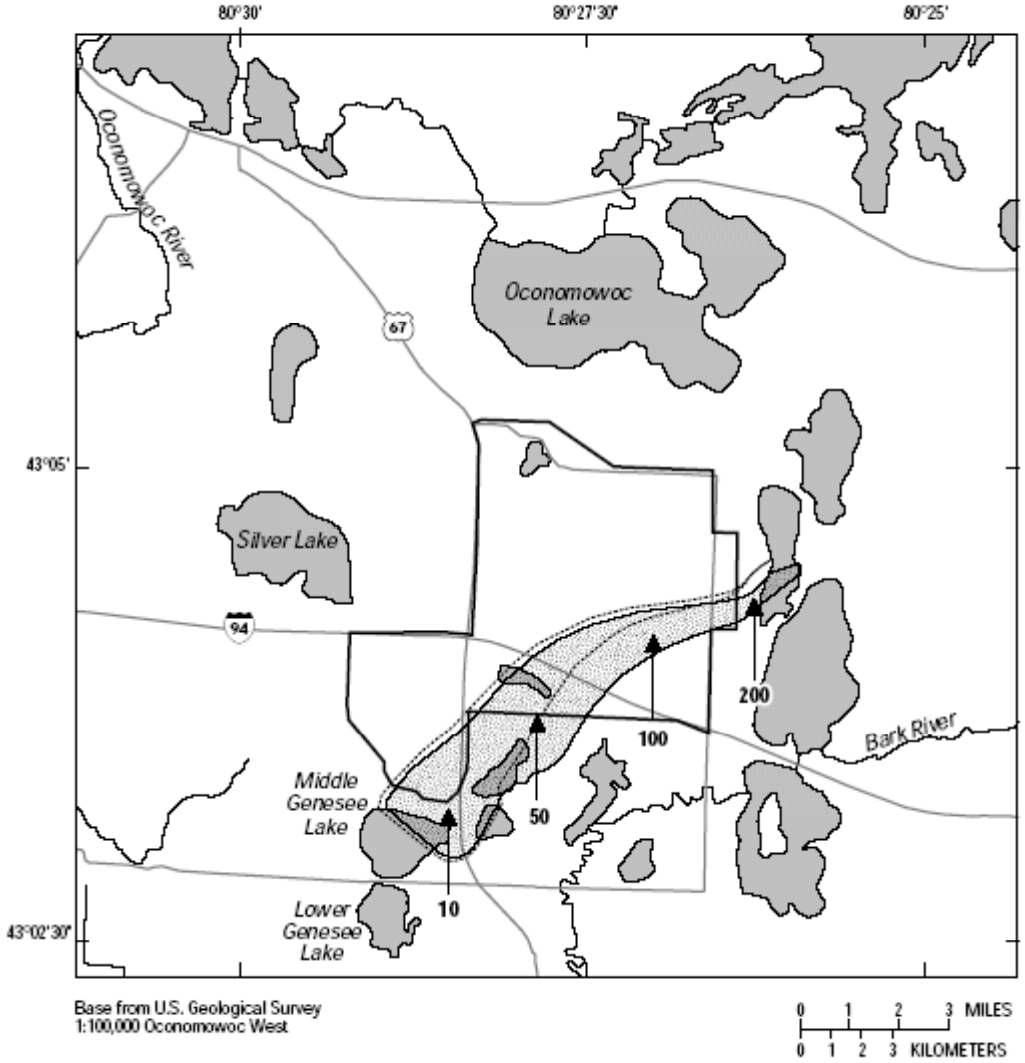
Middle Genesee Study, Waukesha County



EXPLANATION

- Original capture zone
- Developed capture zone
- 10 — Travel time, in years
- Recharge reduced area

MIDDLE GENESEE LAKE LEVEL CHANGE	
Original lake level:	862.6 feet
Developed lake level:	862.5 feet (Δh = 0.1 feet)
95% C.I. (+)lake level:	864.4 feet (Δh = 0.0 feet)
95% C.I. (-) lake level:	860.6 feet (Δh = 2.0 feet)

Δh is change in lake stage;
95% C.I. is 95-percent confidence interval

The ground-water capture zone under a "development" scenario

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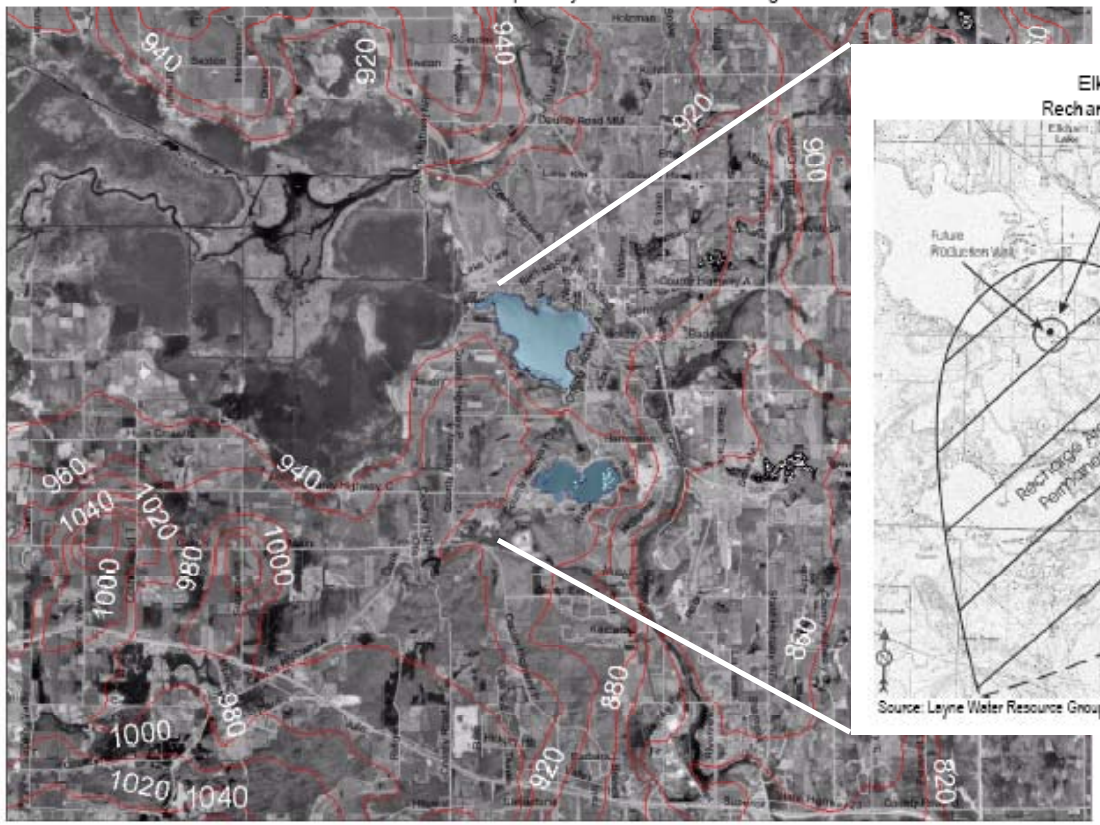
CASE STUDIES: CRYSTAL LAKE

Bob Nauta, RSV Engineering

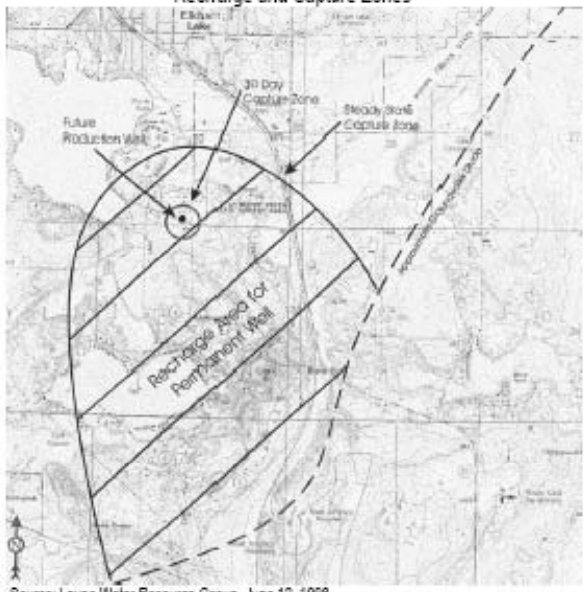
Figure 2.2
Groundwater Contour Map of Crystal Lake & Surrounding Area



Hey and Associates, Inc.

Not to Scale

Figure 3.1
Elkhart Lake Well #3
Recharge and Capture Zones



Source: Layne Water Resource Group, June 12, 1998.

Are the wells affecting Crystal Lake?

Figure 3.9
Depth of Crystal and Elkhart Lakes Compared to
Four High Capacity Wells Located Near the Lakes with Known Depth Information

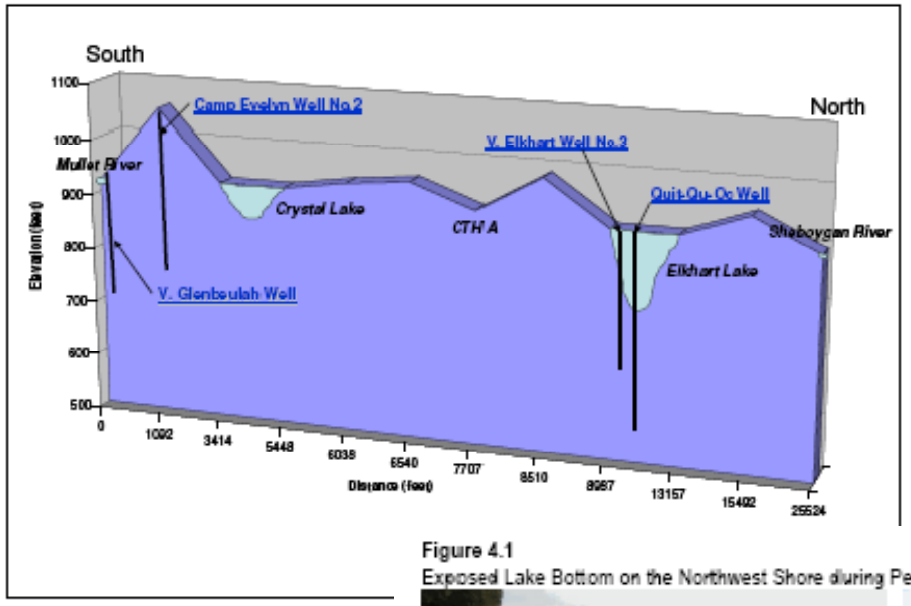


Figure 3.10
Relationship of Date of High Capacity Well Installation
To Changes in Crystal Lake Level

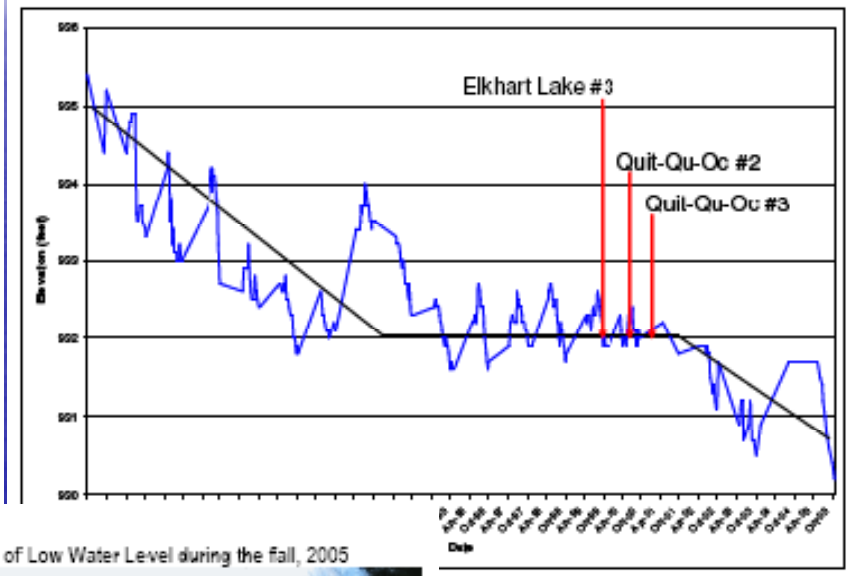


Figure 4.1
Exposed Lake Bottom on the Northwest Shore during Period of Low Water Level during the fall, 2005

Source: Sanitary District No. 1 Towns of Rhine and Plymouth, 2005.

Figures from Hey and Associates, 2007

CASE STUDIES: CRYSTAL LAKE

- **STATISTICAL ANALYSES**
- **WATER CHEMISTRY ANALYSES**
- **GROUNDWATER MONITORING**

CASE STUDIES: CRYSTAL LAKE
GROUNDWATER MONITORING

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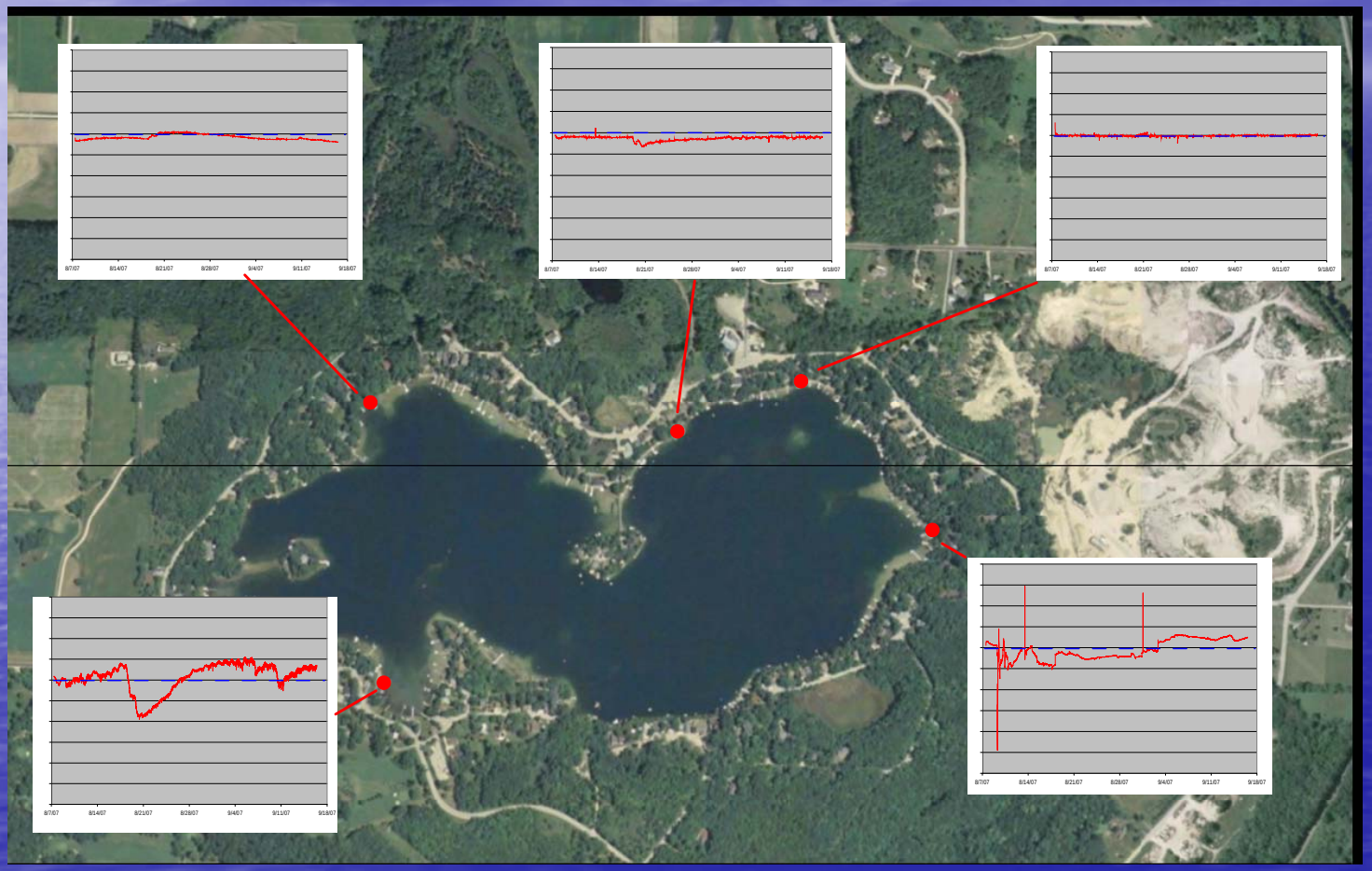
GROUNDWATER MONITORING



CASE STUDIES: CRYSTAL LAKE

- **STATISTICAL ANALYSES**
- **WATER CHEMISTRY ANALYSES**
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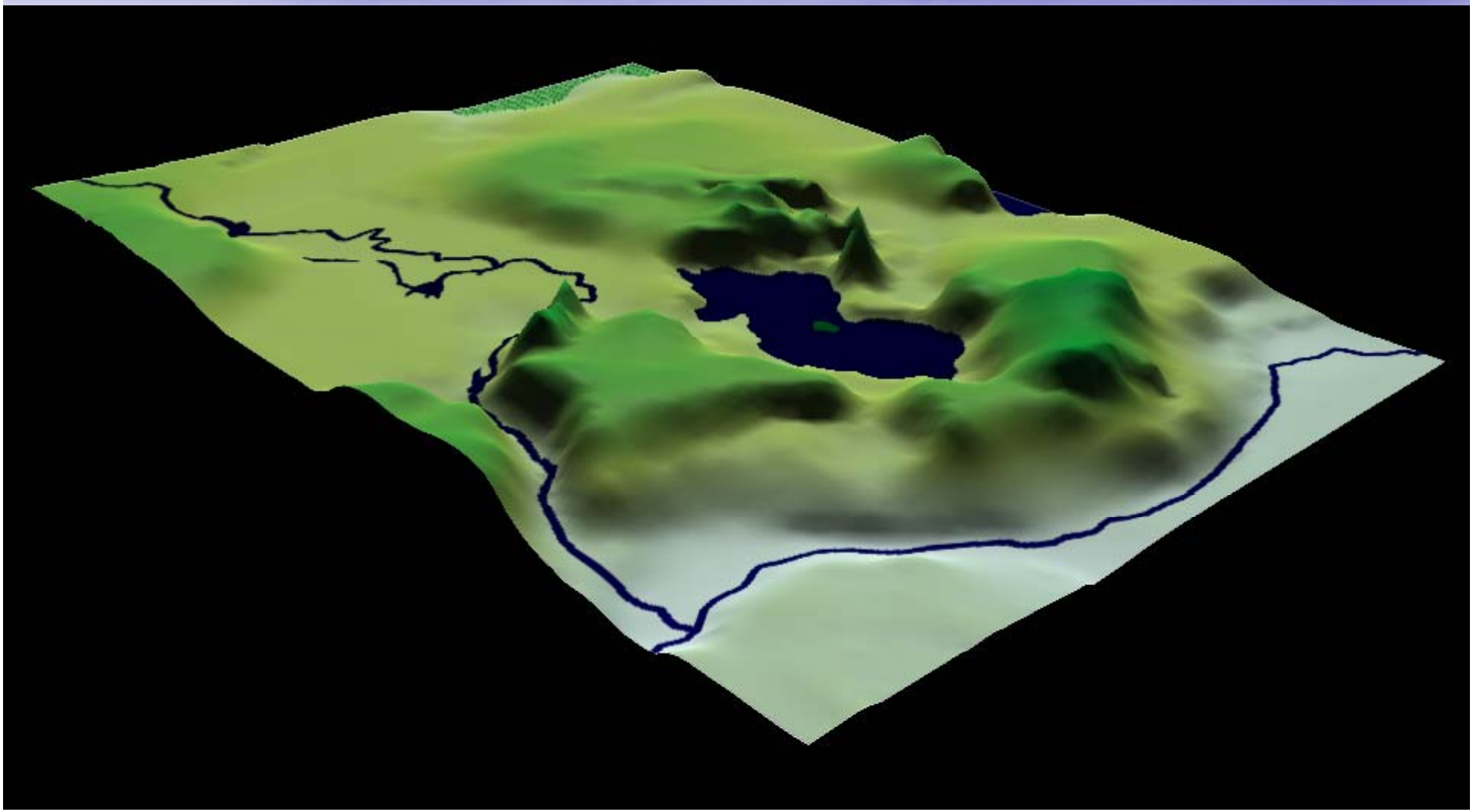
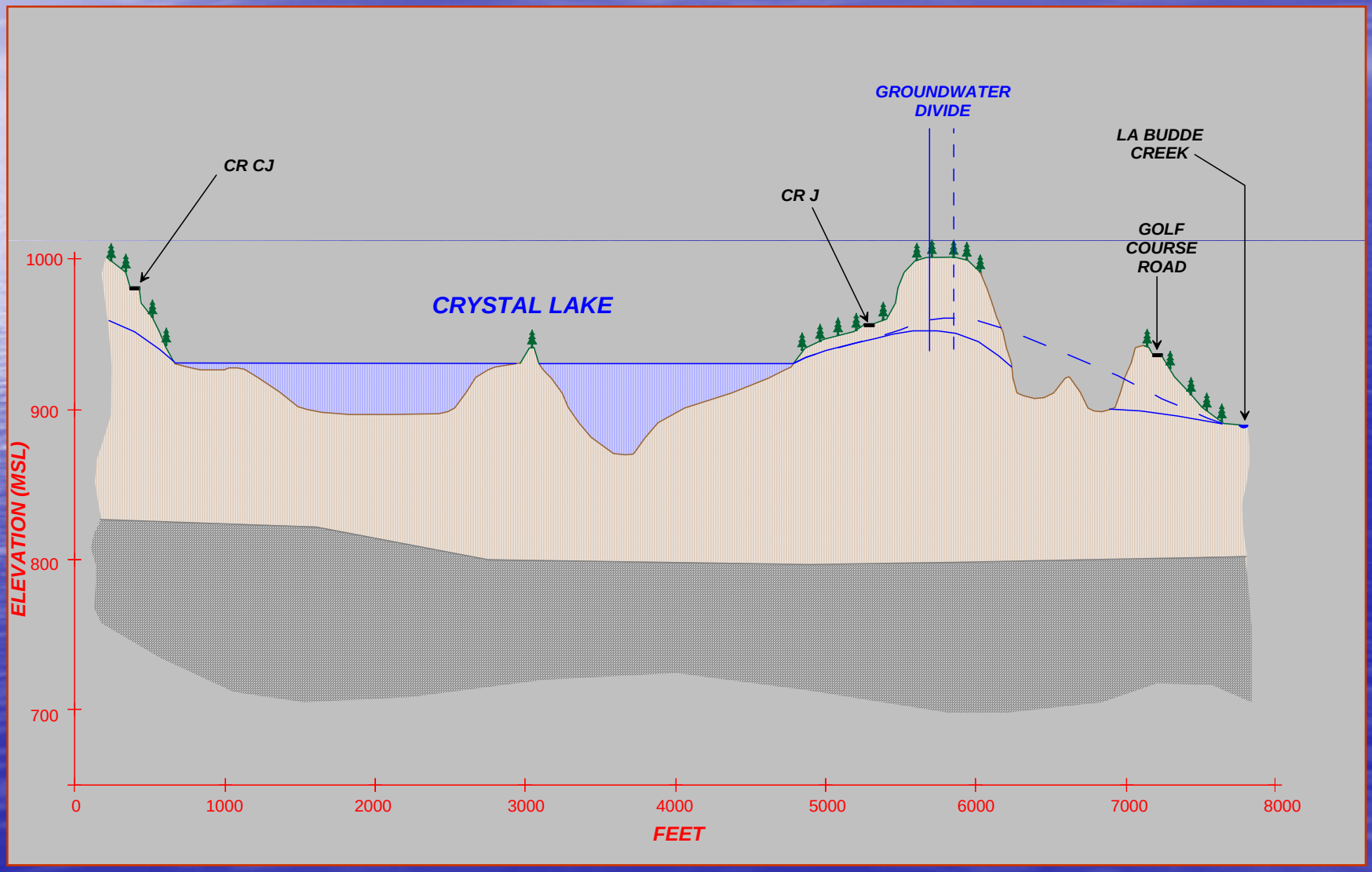
- **GROUNDWATER MODELING**

CASE STUDIES: CRYSTAL LAKE
GROUNDWATER MODELING



CASE STUDIES: CRYSTAL LAKE
GROUNDWATER MODELING



CASE STUDIES: CRYSTAL LAKE

- STATISTICAL ANALYSES
- WATER CHEMISTRY ANALYSES
- GROUNDWATER MONITORING
- GROUNDWATER MODELING
- ORGANIZE REGIONAL STUDY
- GRANT ASSISTANCE

CASE STUDIES: CRYSTAL LAKE
REGIONAL STUDY

- **SANITARY DISTRICT #1 – TOWNS OF RHINE & PLYMOUTH**
- **TOWN OF RHINE**
- **LITTLE ELKHART LAKE REHABILITATION DISTRICT**
- **SHEBOYGAN COUNTY**

CASE STUDIES: CRYSTAL LAKE
REGIONAL STUDY

- **CITIZENS ADVISORY COMMITTEE**
- **TECHNICAL WORKING GROUP**

CASE STUDIES: CRYSTAL LAKE

- STATISTICAL ANALYSES
- WATER CHEMISTRY ANALYSES
- GROUNDWATER MONITORING
- GROUNDWATER MODELING
- ORGANIZE REGIONAL STUDY
- GRANT ASSISTANCE

CASE STUDIES: CRYSTAL LAKE
GRANT ASSISTANCE

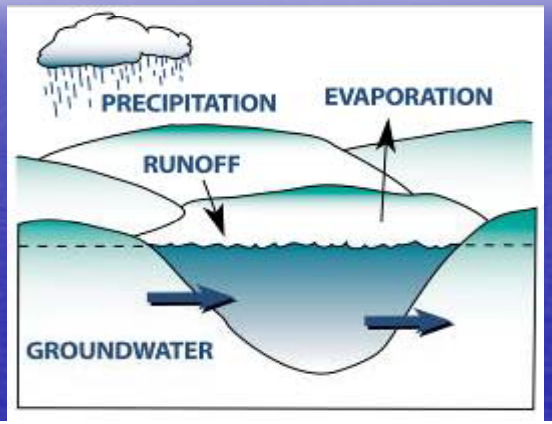
- **SUBMITTED BY SHEBOYGAN COUNTY**
- **FIRST STEP IN REGIONAL STUDY – ORGANIZE EXISTING DATA**
- **PROCEED TO NEXT PHASE**

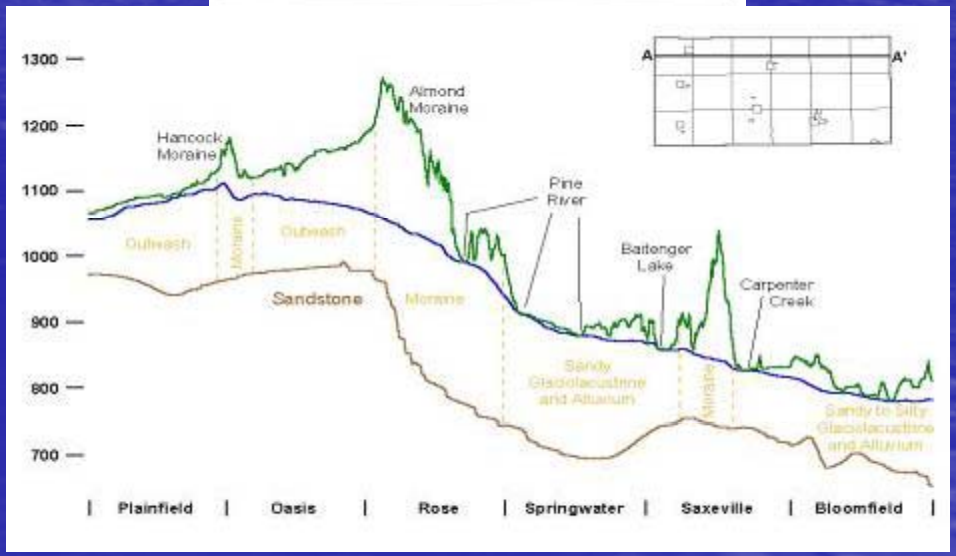
Central Sands Lakes

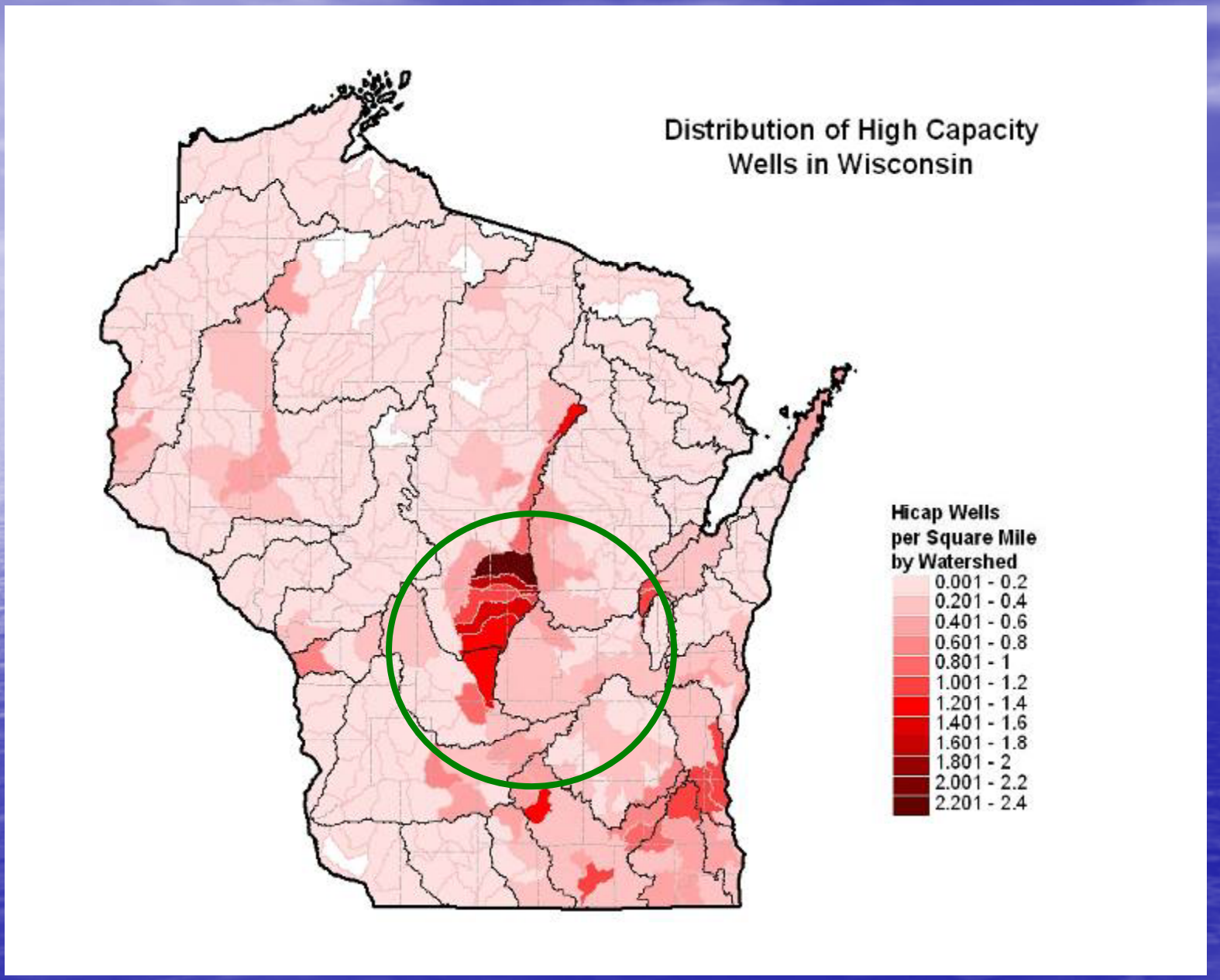
Tim Asplund, WDNR
and George Kraft (UWSP)

NW Waushara County Lakes

- Landlocked lakes, no outlet
- Sandy soils
- Lakes near major regional groundwater divide
- Recent declines after unusually high period in the 1990s
- Short-term drought in Central WI
- Major pumping center

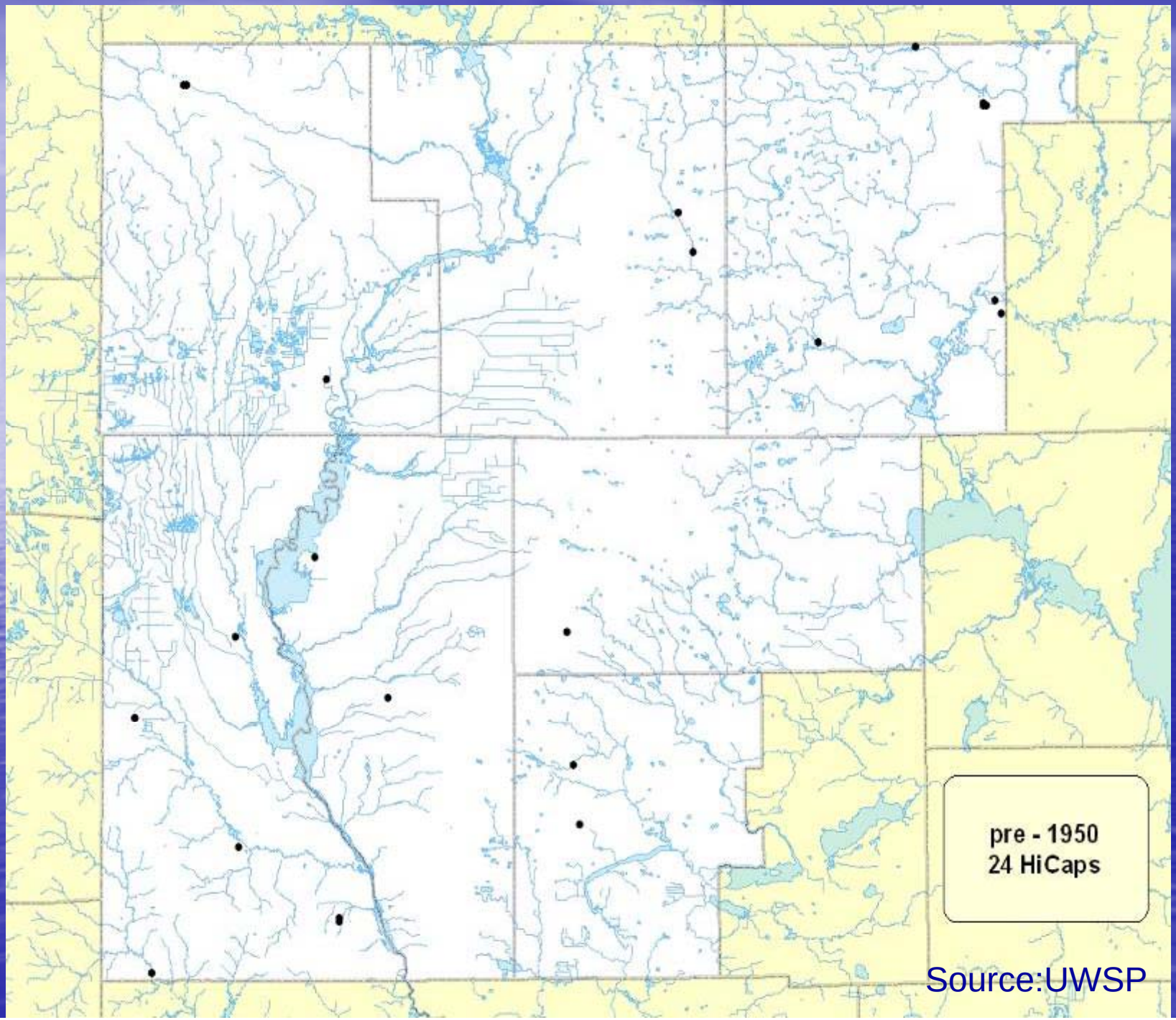




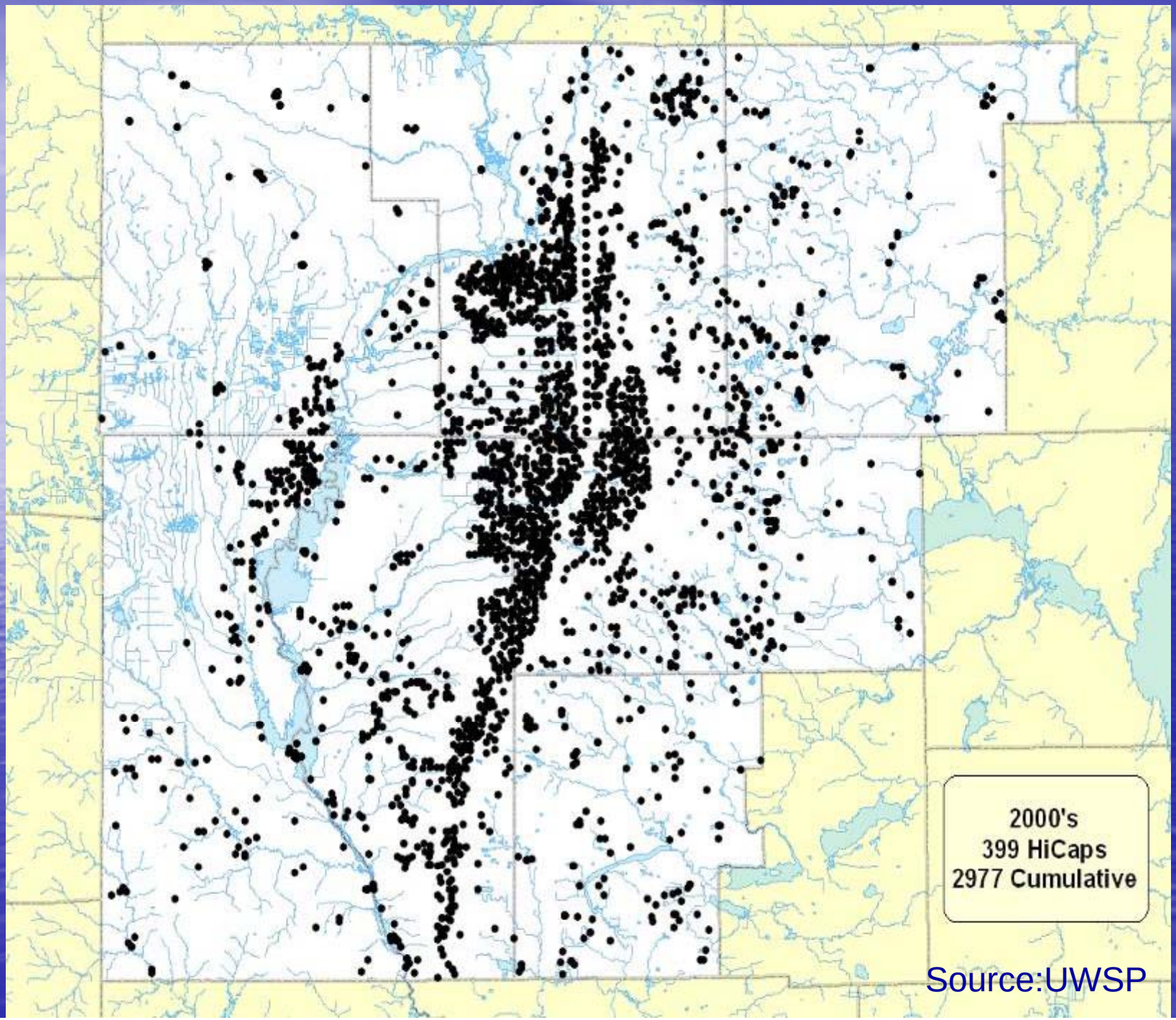

Distribution of High Capacity Wells in Wisconsin
Hicap Wells per Square Mile by Watershed
0.001 - 0.2
0.201 - 0.4
0.401 - 0.6
0.601 - 0.8
0.801 - 1
1.001 - 1.2
1.201 - 1.4
1.401 - 1.6
1.601 - 1.8
1.801 - 2
2.001 - 2.2
2.201 - 2.4

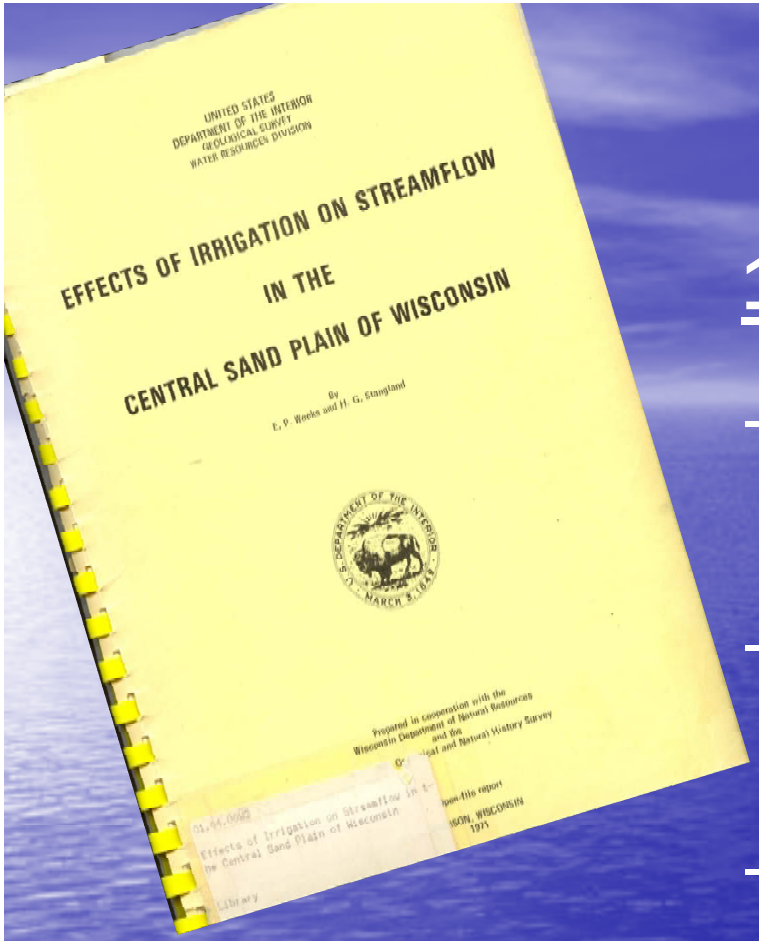
Source: UWSP


IPMENT
WISCONSIN



Source:UWSP

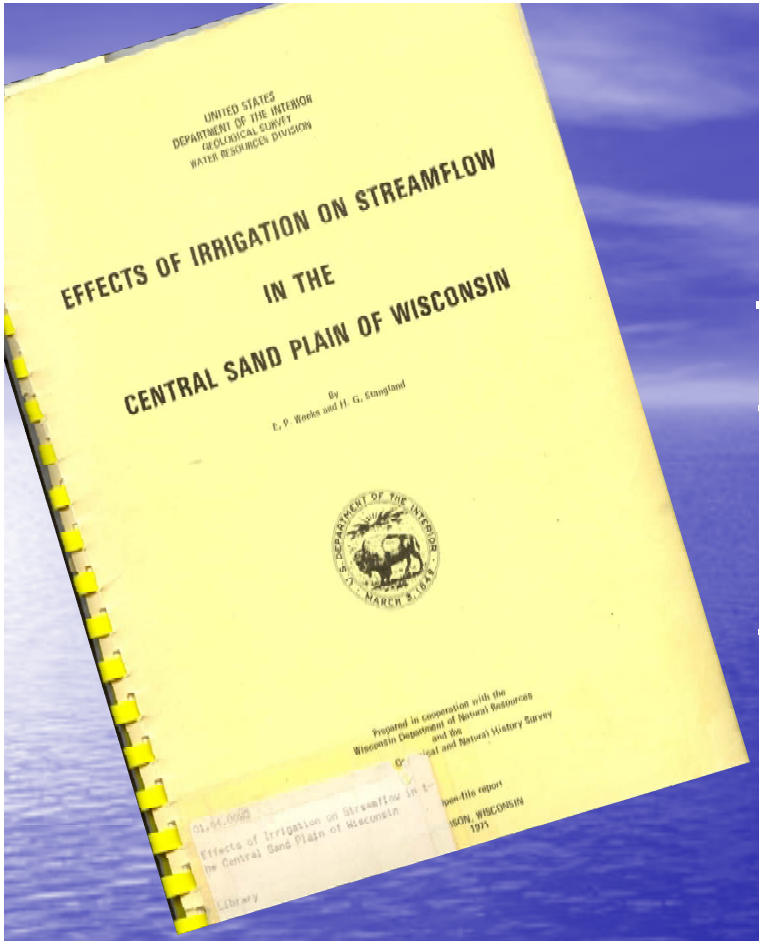

2000's
399 HiCaps
2977 Cumulative
Source:UWSP



Effects of irrigation

1970 –1/4 of the area irrigated

- **normal summer stream loss: 25-30%**
- **normal summer water decline: ½ foot**
- **drought stream loss: 70-90%**
- **drought water decline: 2-3 feet**



Effects of irrigation

<u>If 50% of area irrigated</u>

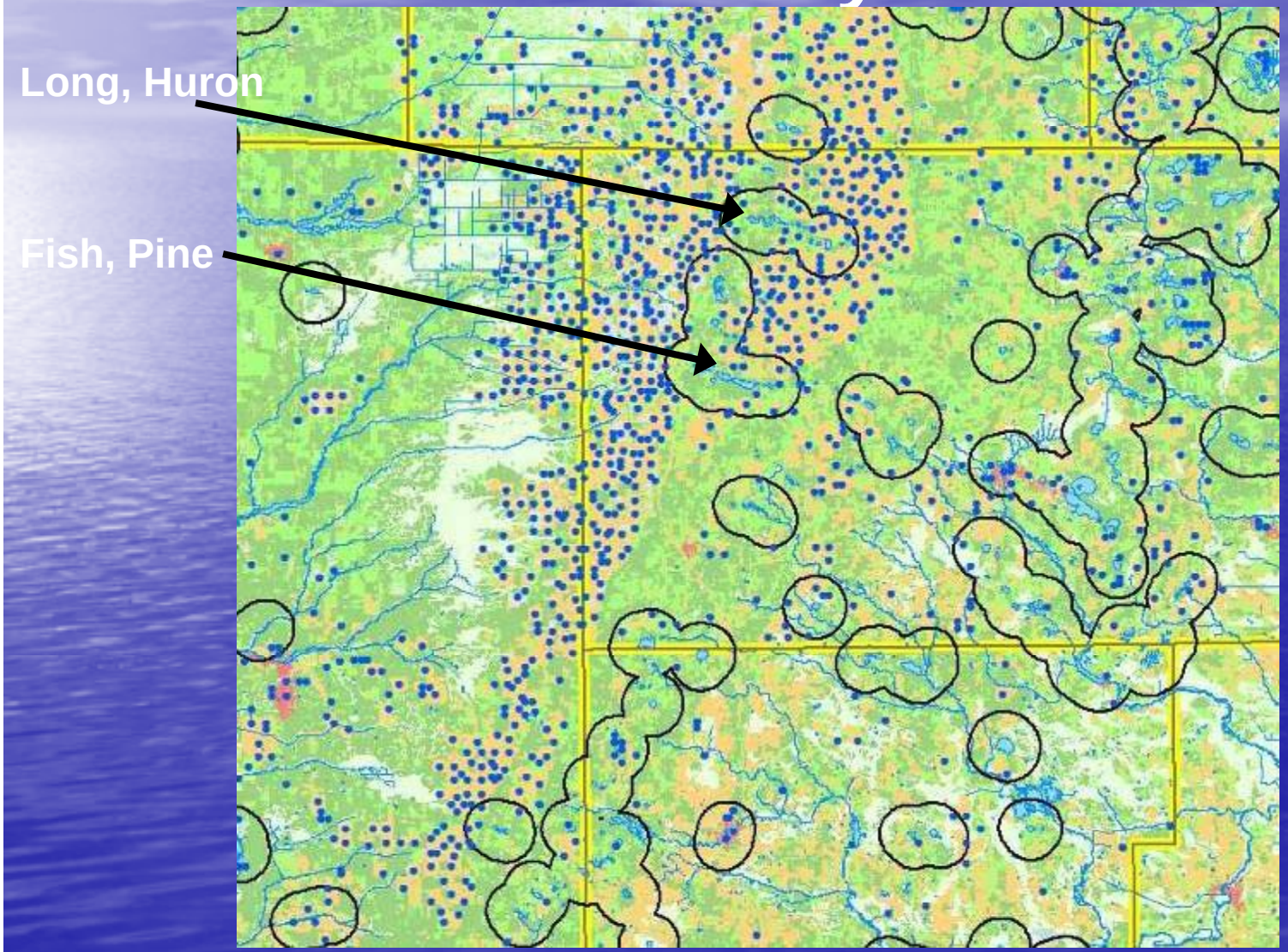
-drought stream loss:
100%

- drought water decline:
4 - 5 feet

<u>2007:</u>

>75% of area irrigated

Waushara County Lakes

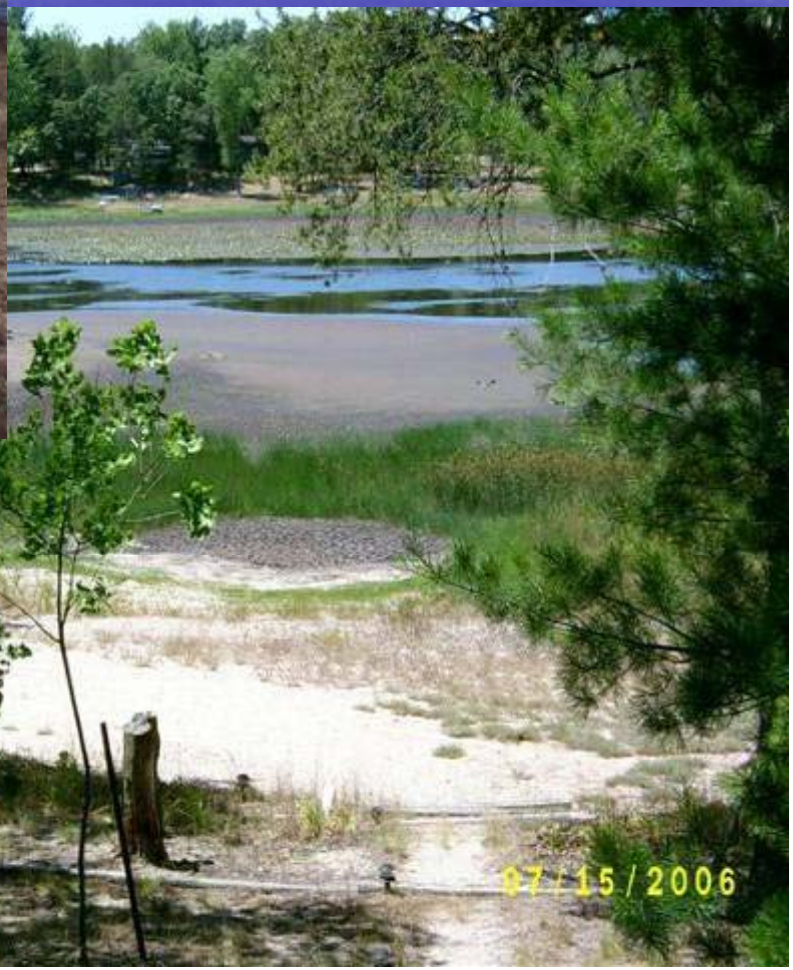


Source: UWSP

1950s

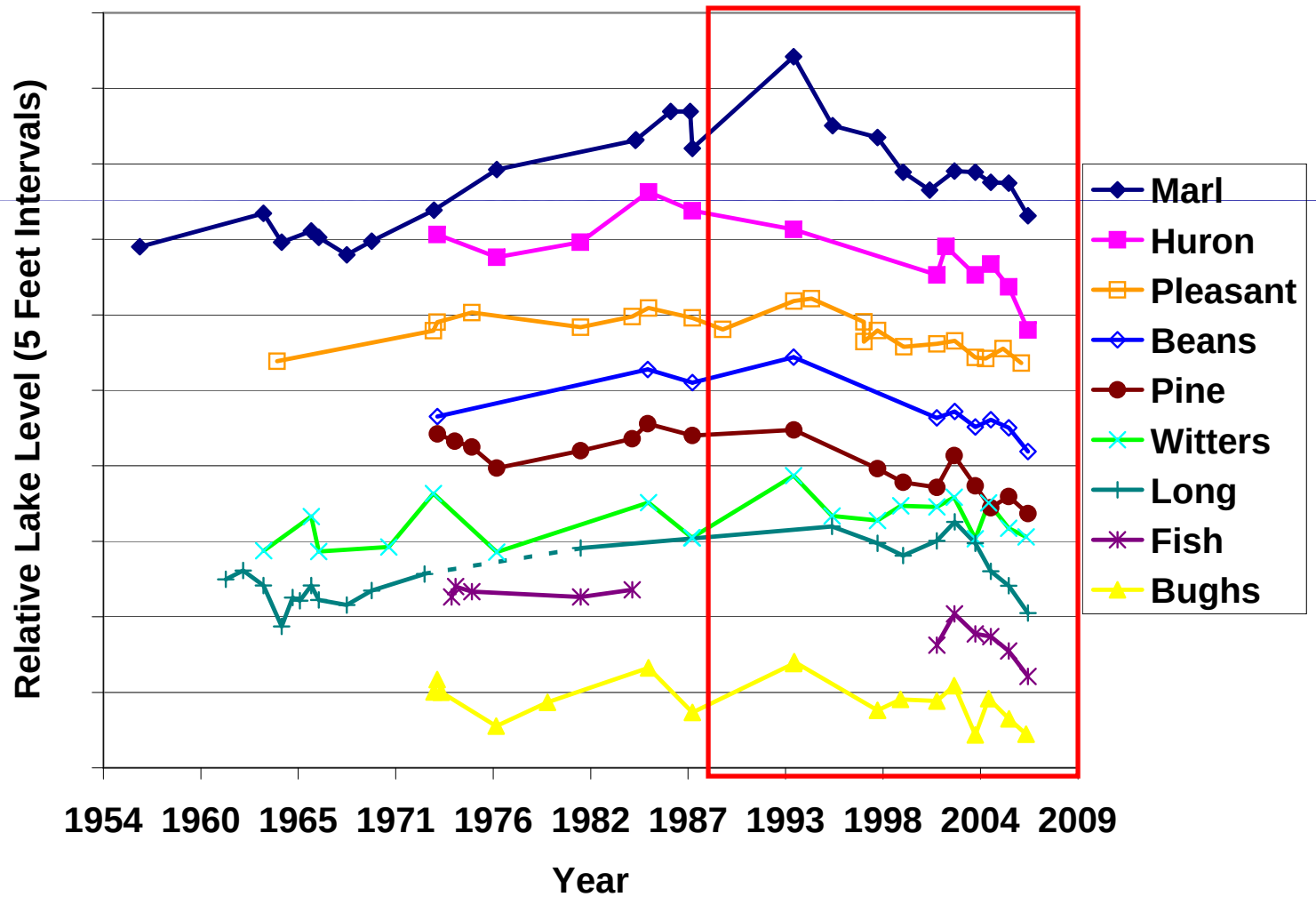
1994

Spring 2006

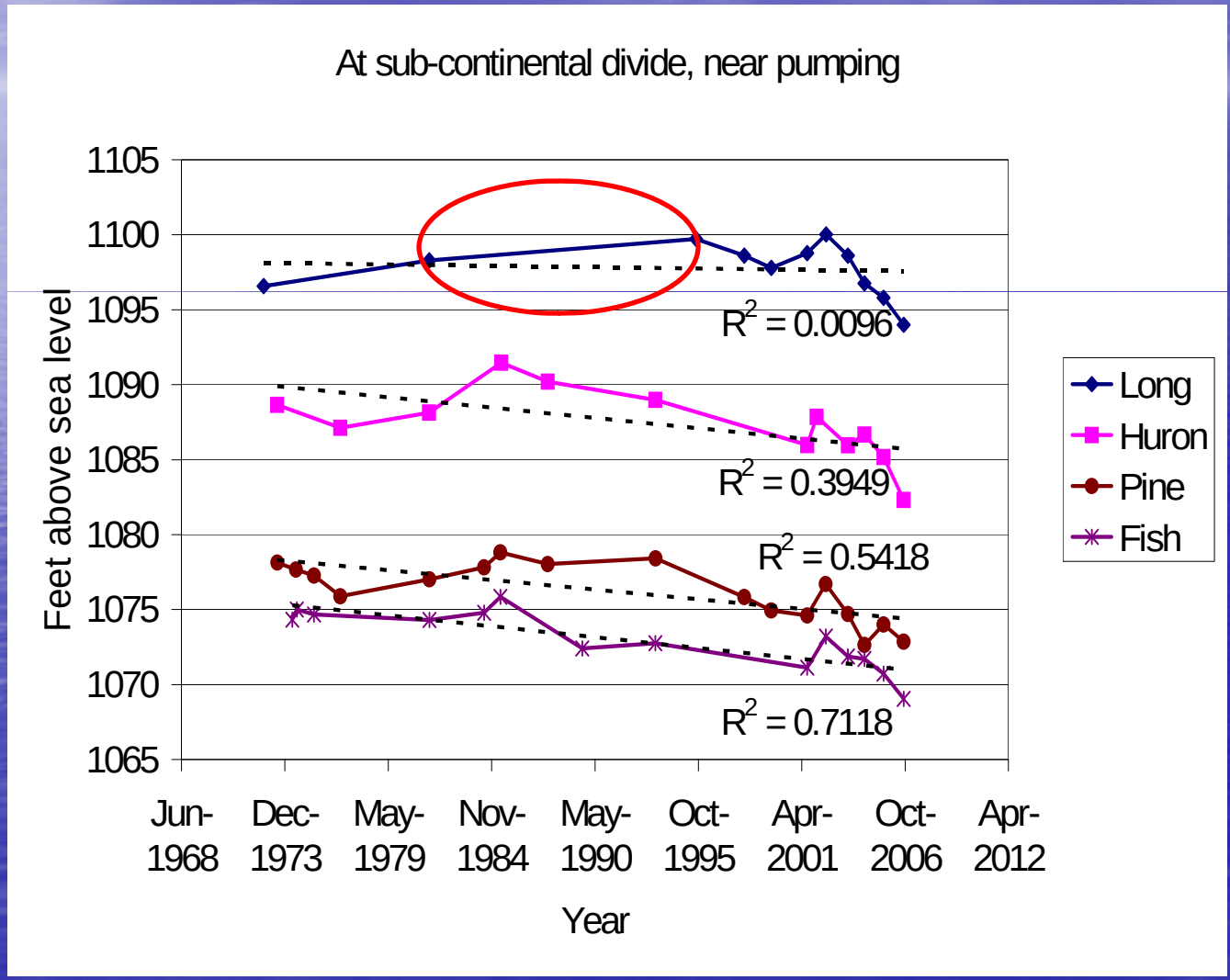


July 2006

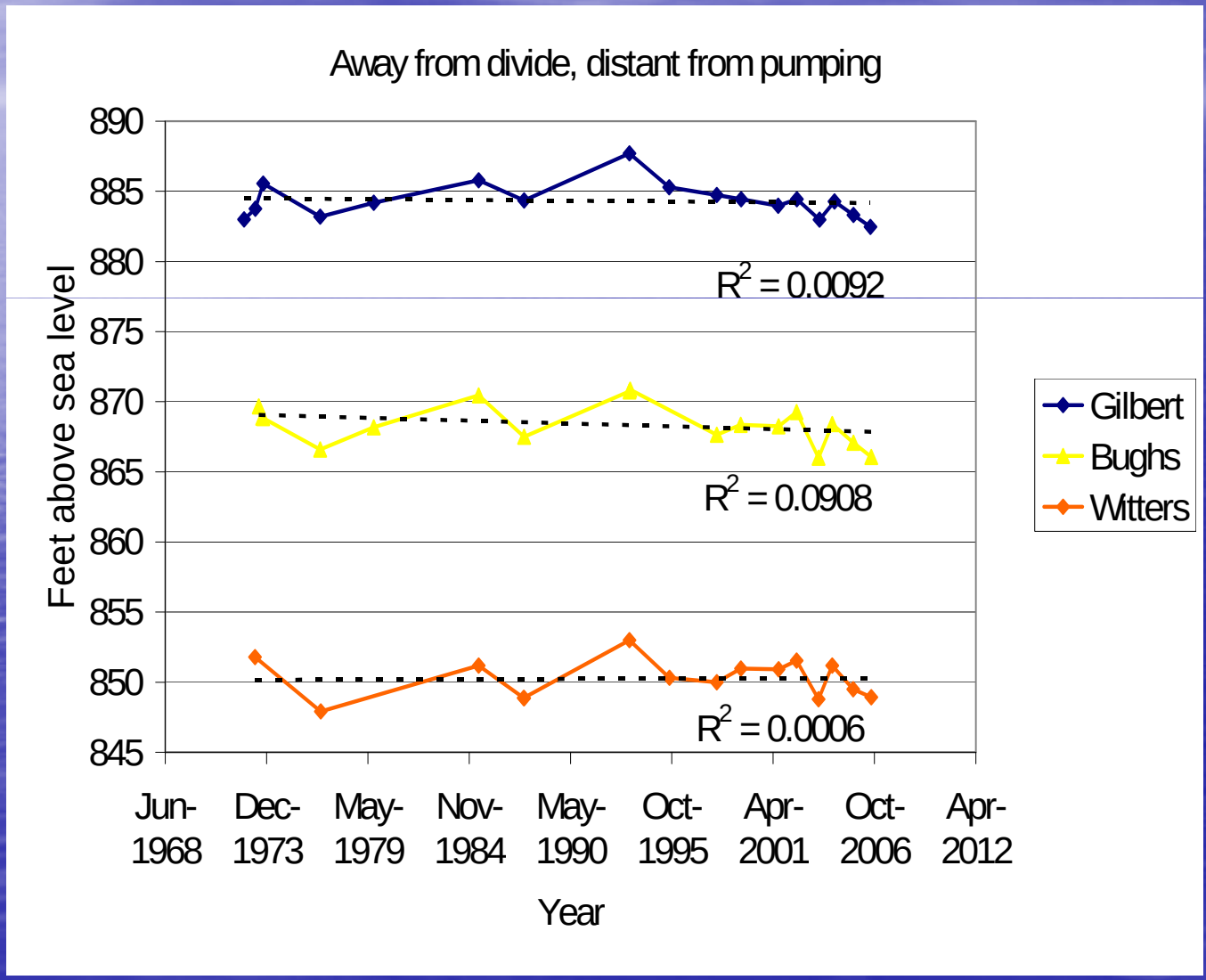
Waushara Co Lakes

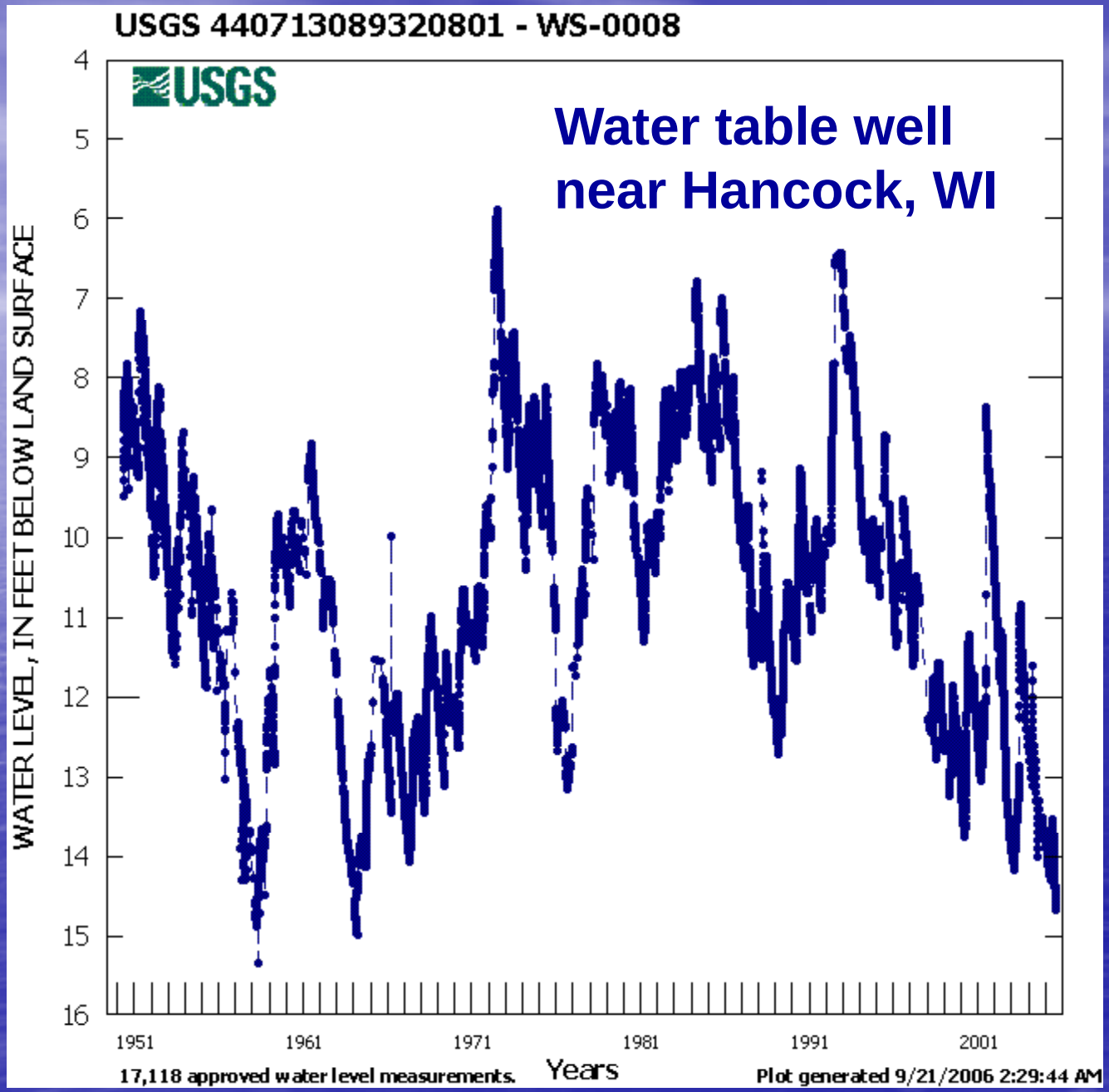


Waushara Co. Lakes

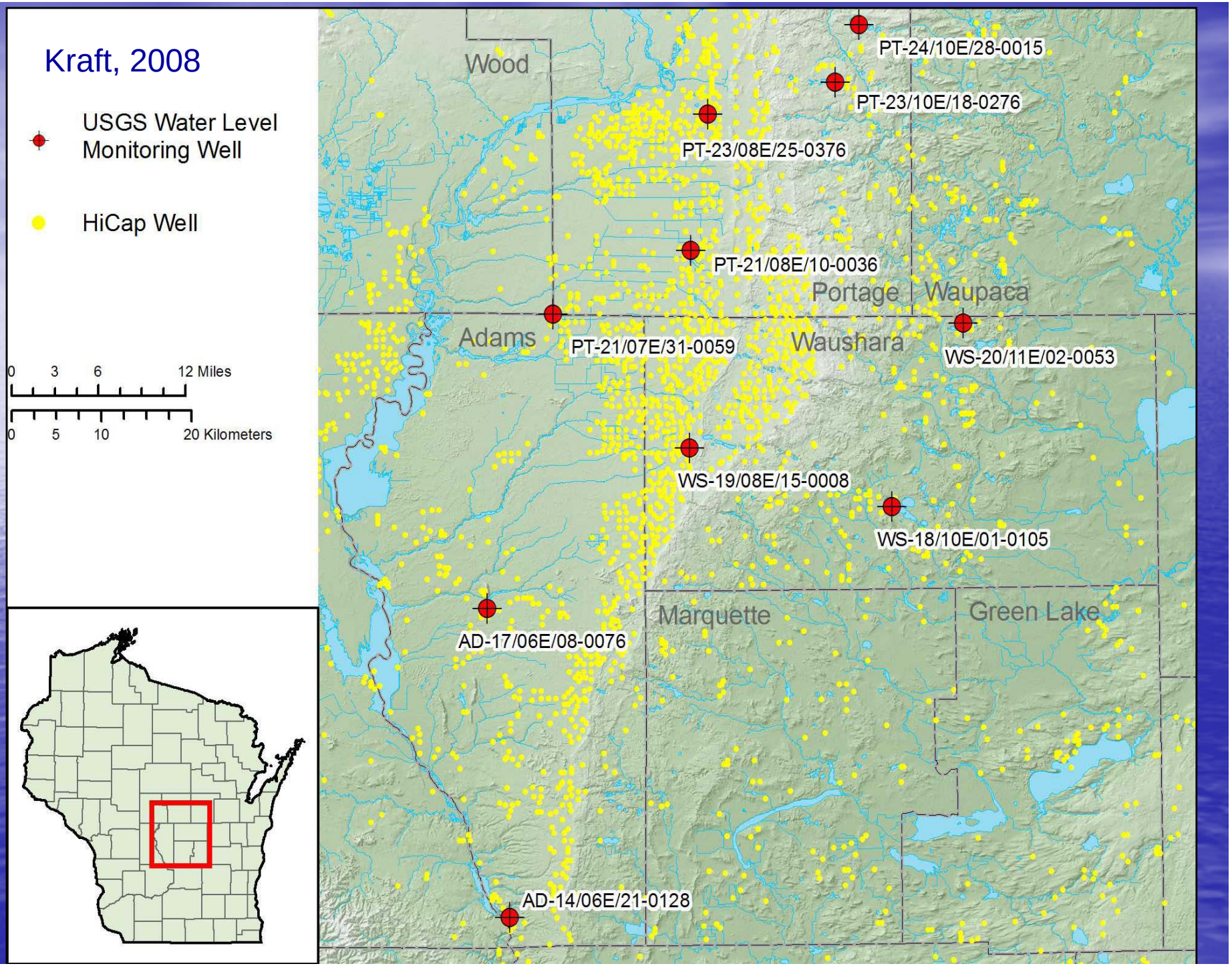


Waushara Co. Lakes

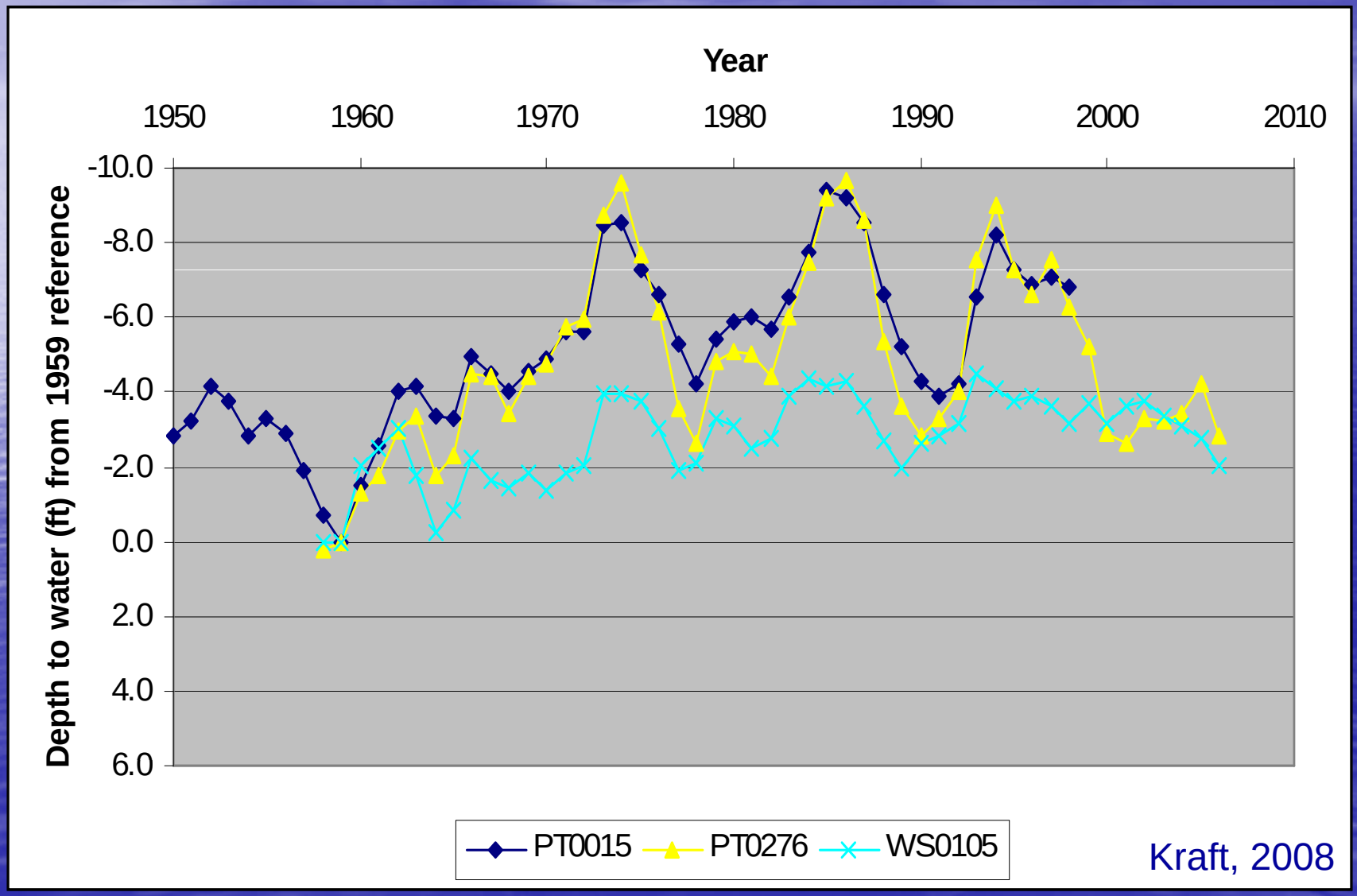




source: US Geological Survey - http://groundwaterwatch.usgs.gov

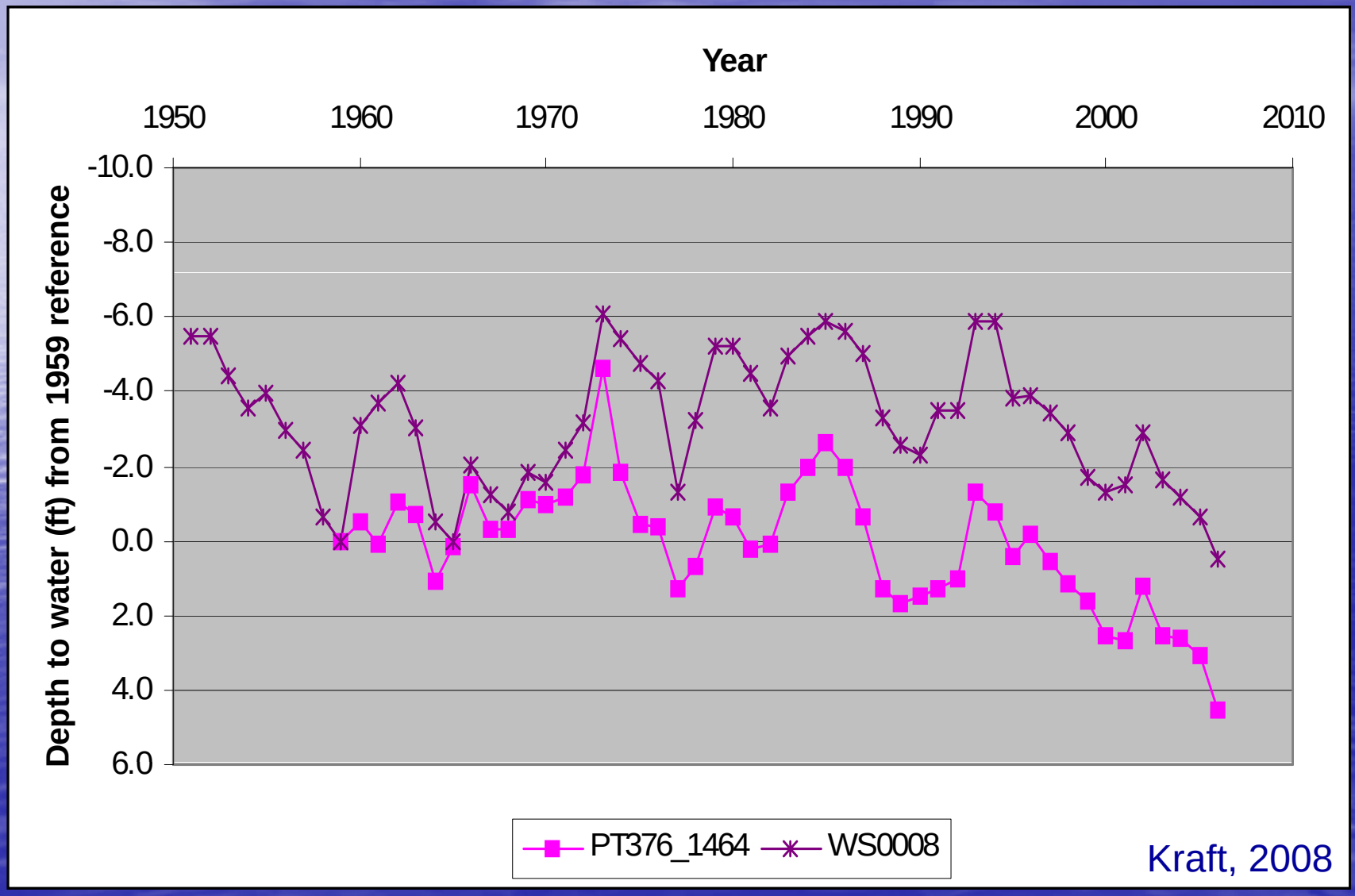

Kraft, 2008
USGS Water Level Monitoring Well
HiCap Well
0 3 6 12 Miles
0 5 10 20 Kilometers
Wood
PT-24/10E/28-0015
PT-23/10E/18-0276
PT-23/08E/25-0376
PT-21/08E/10-0036
Portage
Waupaca
Adams
PT-21/07E/31-0059
Waushara
WS-20/11E/02-0053
WS-19/08E/15-0008
WS-18/10E/01-0105
Marquette
Green Lake
AD-17/06E/08-0076
AD-14/06E/21-0128

Water levels unaffected by pumping

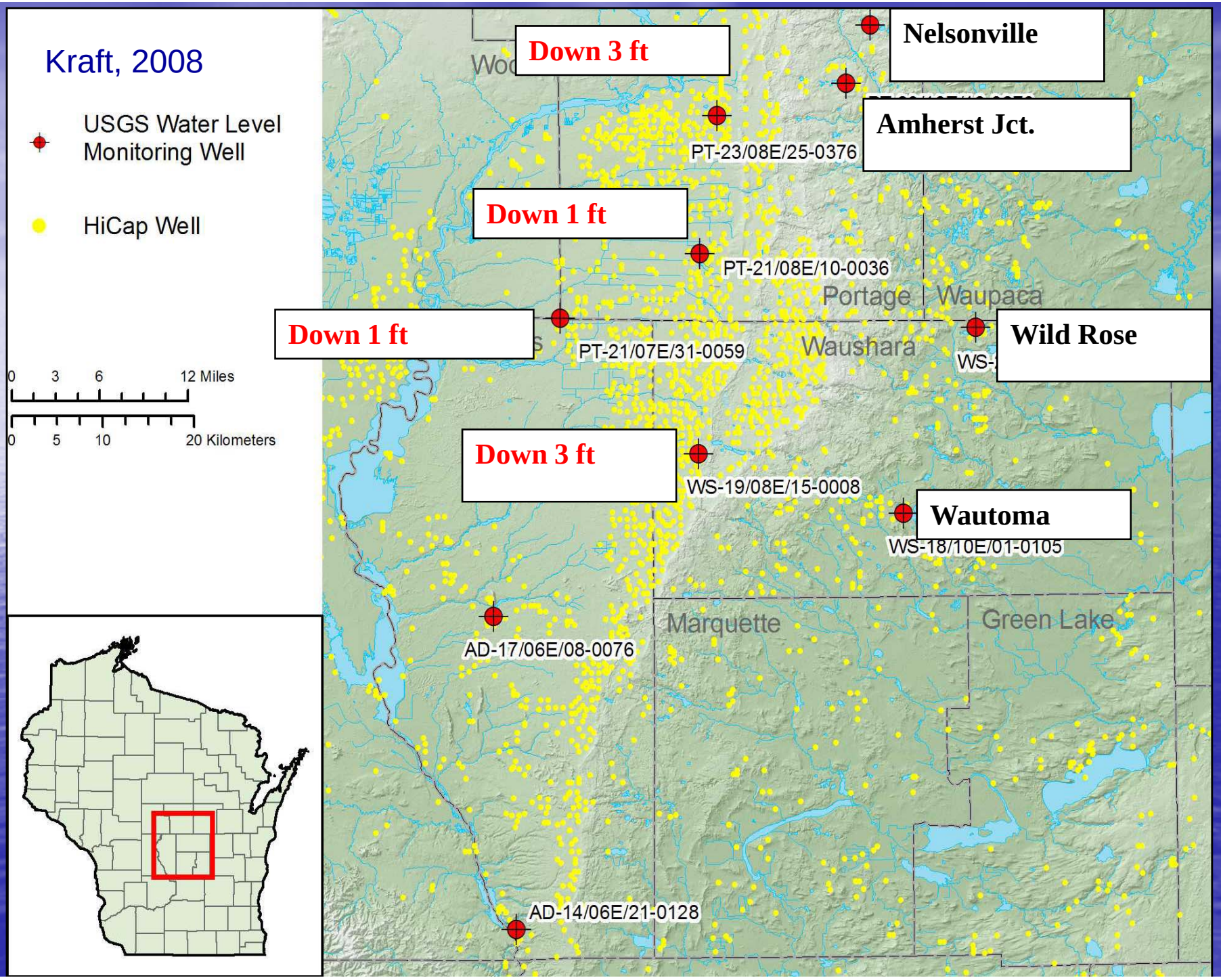


Kraft, 2008

Water levels affected by pumping



Kraft, 2008


Kraft, 2008
USGS Water Level Monitoring Well
HiCap Well
0 3 6 12 Miles
0 5 10 20 Kilometers
Down 3 ft
Nelsonville
Amherst Jct.
PT-23/08E/25-0376
Down 1 ft
PT-21/08E/10-0036
Portage
Waupaca
Down 1 ft
PT-21/07E/31-0059
Waushara
Wild Rose
Down 3 ft
WS-19/08E/15-0008
Wautoma
WS-18/10E/01-0105
Marquette
Green Lake
AD-17/06E/08-0076
AD-14/06E/21-0128