Irrigation in the Midwest

Trends and potential issues

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Howard W. Reeves, USGS Michigan Water Science Center

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

Moisture Control to Improve Crop Yields

- Tile Drainage
- Irrigation

- Growth in both tile drainage and irrigation

Published Monday January 14, 2013

To help crops, Iowa farmers install more drainage tile

CEDAR RAPIDS, Iowa (AP) — Counterintuitive as it may seem, farm fields with the best tile drainage systems generally produced the highest yields during last year's drought, Iowa farmers and other experts say.

“I saw that right away in the first field I harvested this fall,” said Marion-area farmer Curt Zingula.

Zingula said he became “100 percent convinced” of the benefits of tile drainage in a dry year when he observed a disappointing harvest of soybeans on his traditionally wettest field. “My conclusion is that you have a better soil structure yielding better root growth in well-drained fields,” he said.

USGS

Illinois Agronomy Handbook

- Improving water management is an important way to increase crop yields. By minimizing crop-water stress, the producer obtains more benefits from improved cultural practices and realizes the full yield of the cultivars now available. Crops are particularly sensitive to water stress when they are undergoing reproductive growth.

Richard Cooke, Department of Agricultural and Biological Engineering, University of Illinois

USGS

Precipitation and potential moisture loss for 3 places in Illinois from the Illinois Agronomy Handbook

http://extension.cropsci.illinois.edu/handbook/pdfs/chapter11.pdf

Moisture deficit

Moisture surplus

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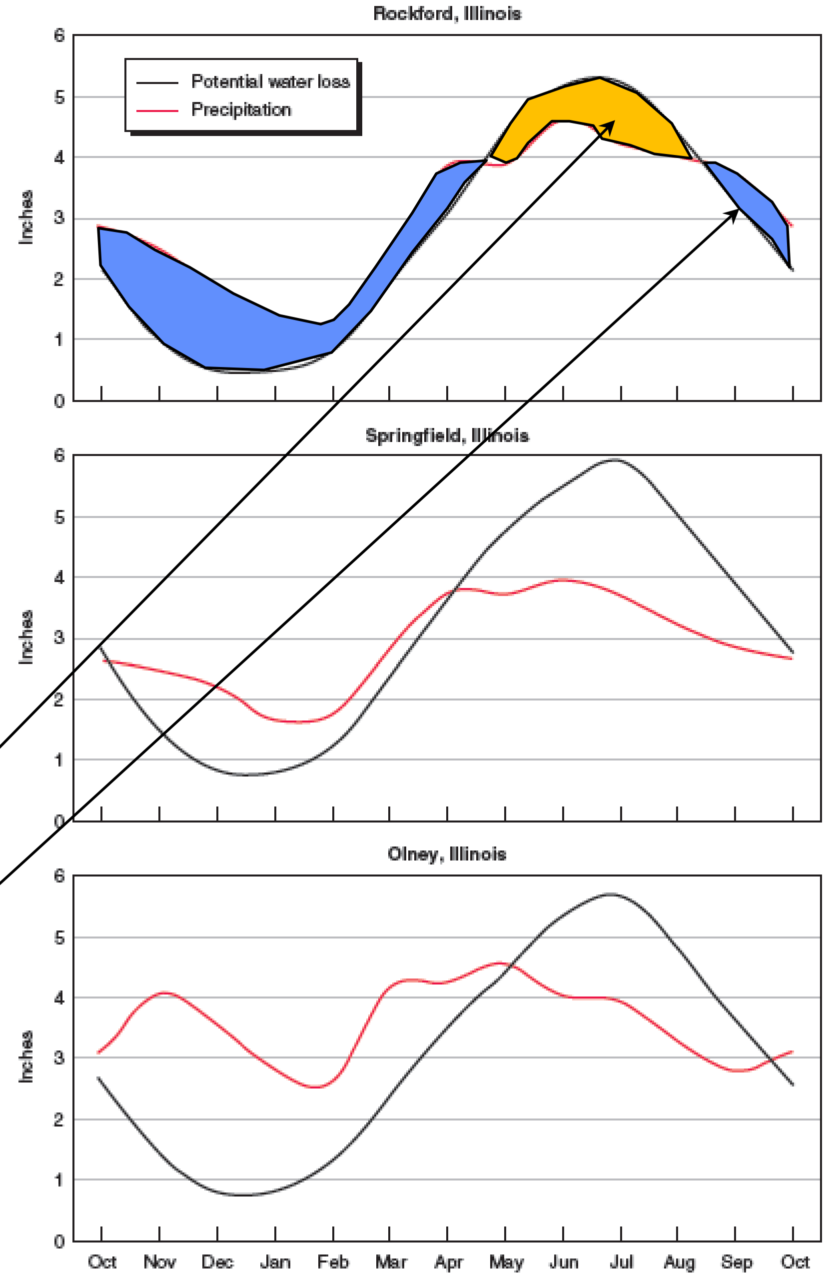


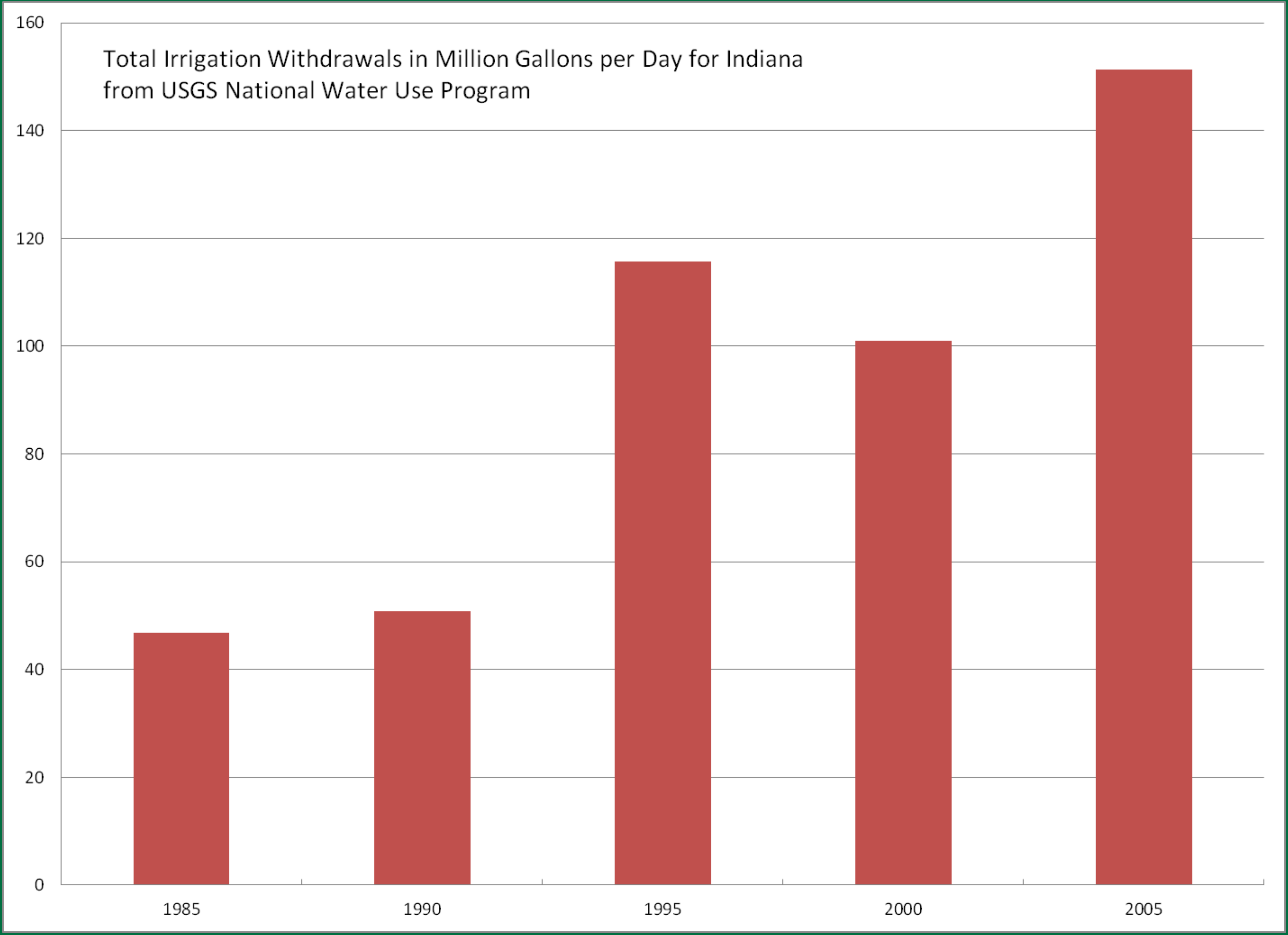
Figure 11.5. Average monthly precipitation and potential moisture loss from a growing crop in three regions of Illinois.

Trends

- Trends for some SW Michigan Counties, irrigated acres by county from Census of Agriculture

Year	Branch	Cass	Kalamazoo	St. Joseph
1964	358	603	571	2,021
1969	1,154	1,683	635	3,032
1974	4,060	2,795	769	7,540
1978	18,826	8,352	7,062	40,366
1982	24,365	11,870	13,196	56,881
1987	22,965	12,406	15,162	58,989
1992	26,506	13,540	20,336	85,009
1997	30,563	14,599	18,144	91,191
2002	39,315	25,437	29,615	103,980
2007	42,923	38,985	31,314	102,859

USGS


Total Irrigation Withdrawals in Million Gallons per Day for Indiana
from USGS National Water Use Program
160
140
120
100
80
60
40
20
0
1985
1990
1995
2000
2005

The Source of Water Derived from Wells

Essential Factors Controlling the Response of an Aquifer to Development

FROM A PAPER PRESENTED BEFORE THE ARIZONA SECTION

By CHARLES V. THEIS

GEOLOGIST IN CHARGE OF GROUND-WATER INVESTIGATIONS IN NEW MEXICO, U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR, ALBUQUERQUE, N.MEX. (PUBLISHED WITH THE PERMISSION OF THE DIRECTOR OF THE GEOLOGICAL SURVEY)

THIS paper discusses in a general way the essential factors that control the response of an aquifer to development by wells. A knowledge of these factors, including the role of time, is necessary for the interpretation of existing records of water levels, and can yield the only method of predicting the effect of ground-water development in an area where records of long duration are lacking. Some of these factors have been long recognized but others have come to light in the last few years, and the intensive work now being done in quantitative ground-water hydrology will doubtless still further refine our concepts.

CONTINUED increase in the use of ground water for municipal and industrial purposes, and for irrigation, makes more pressing the question as to the extent of reserves of ground water and the advisability and methods of regulating its use. Proper regulation, of course, is conditioned upon the ability to forecast with some degree of accuracy the future history of water levels in wells in a given area. Mr. Theis here gives a clear picture of the factors that must be taken into account in such forecasts, and concludes with a brief summary of recommendations for "the ideal development of any aquifer from the standpoint of maximum utilization of the supply."

The essential factors controlling the action of an aquifer appear to be (1) the distance to, and character of, the re-

water, or by movement vertically or laterally from another ground-water body. The latter process is more or less an incident in the movement of water underground, and will not be discussed here. Two possible conditions in the recharge area must be considered. The potential recharge rate may be so large in wet seasons or cycles, or even uniformly, as to exceed the rate at which water can flow laterally through the aquifer. In this case the aquifer becomes over-full and available recharge is rejected. The water table stands at or near the surface in the recharge area. There may be permanent or seasonal springs in low places discharging the excess water, or there may be marshes or other areas of vegetation draw-

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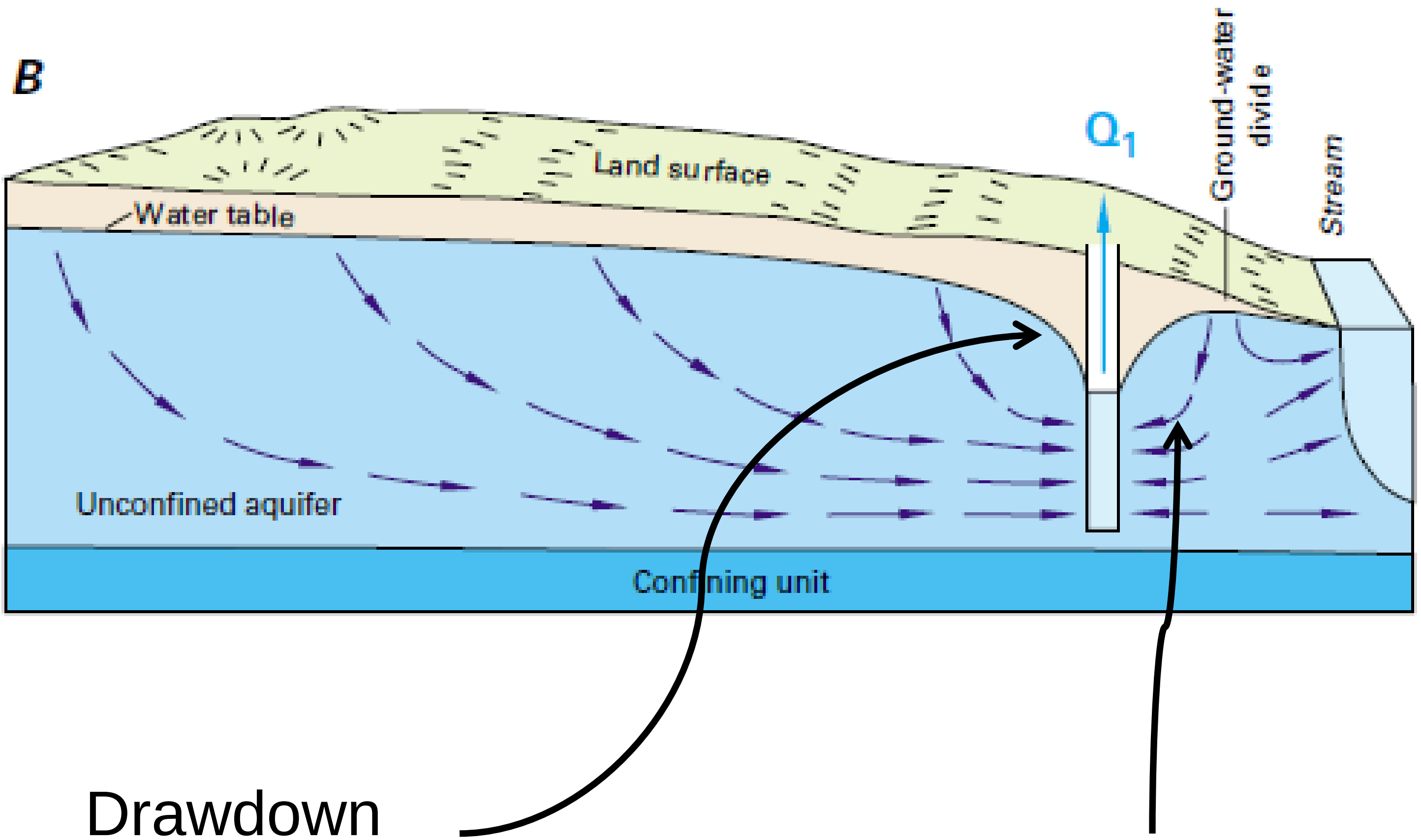
USGS

Source of water to wells

- Initially, water level near well decreases – water released from storage
- Cone of depression forms around well
- Cone expands until boundaries are encountered
- All water produced by a well is balanced by a loss of water somewhere
  - Loss of water from storage (water level declines)
  - Increase in recharge (decrease in runoff)
  - Decrease in discharge to surface water

From: Alley, W.M., Reilly, T.E., and Franke, O.L., 1999, Sustainability of groundwater resources: U.S.Geological Survey Circular 1186, 79 p.



Drawdown effecting other wells

Streamflow depletion

Potential for well-to-well conflict

- High-capacity irrigation wells can cause large drawdowns that extend far enough to interfere with neighbors wells
- Drawdown amount, extent, and timing depends on the pumping rate, geometry, and geologic setting of the system
- Be aware of areas where neighbors rely on shallow wells, especially jet wells, a couple feet of drawdown can make those wells ‘go dry’ by lowering the water level below the pump intake

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Example, Saginaw County, Michigan

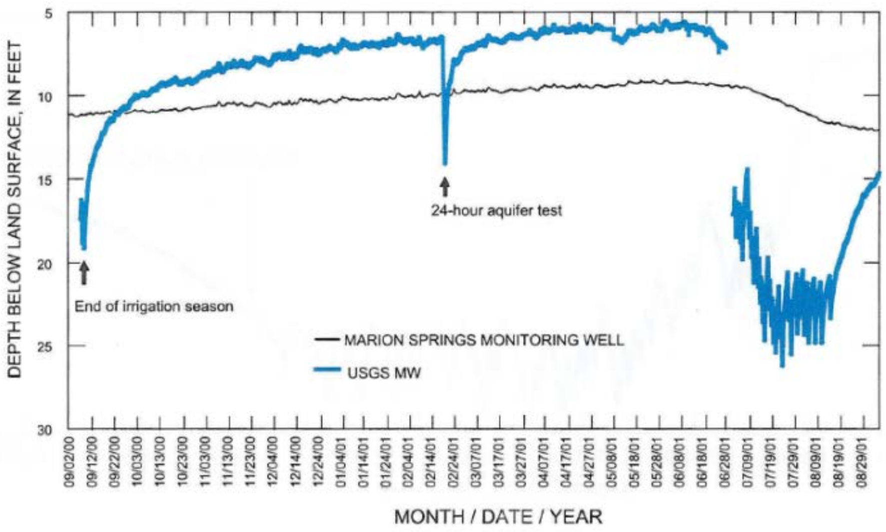


Figure 6. Depth to water in the Marion Springs monitoring well and the USGS MW, September 2000 through August 2001, western Saginaw County, Michigan.

~4.5 miles from Marion Springs to irrigation well

~0.5 miles from USGS MW to irrigation well

From USGS WRIR 01-4227

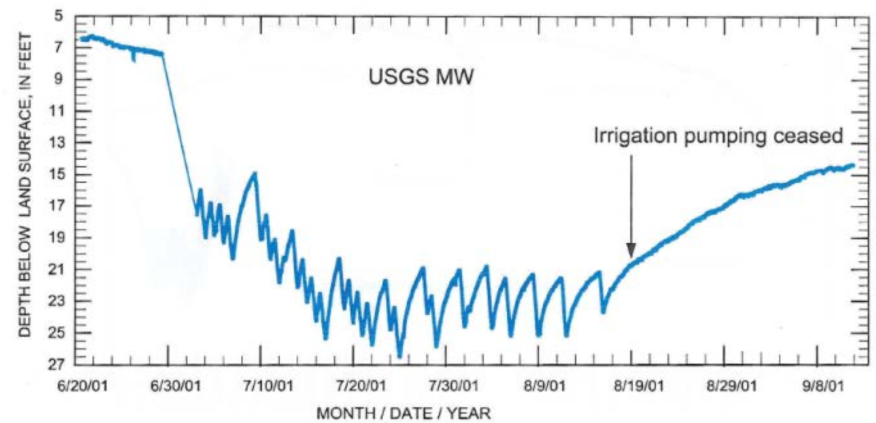
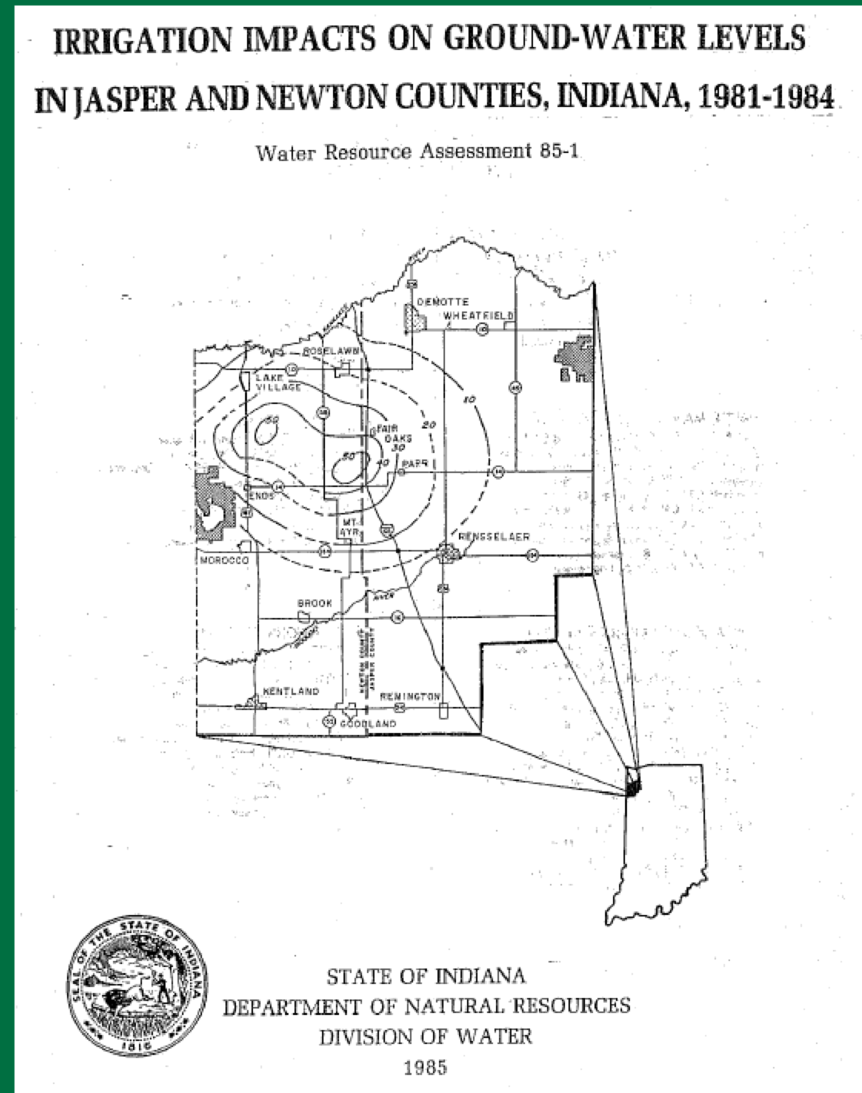


Figure 7. Depth to water at USGS MW, June through September 2001, western Saginaw County, Michigan.

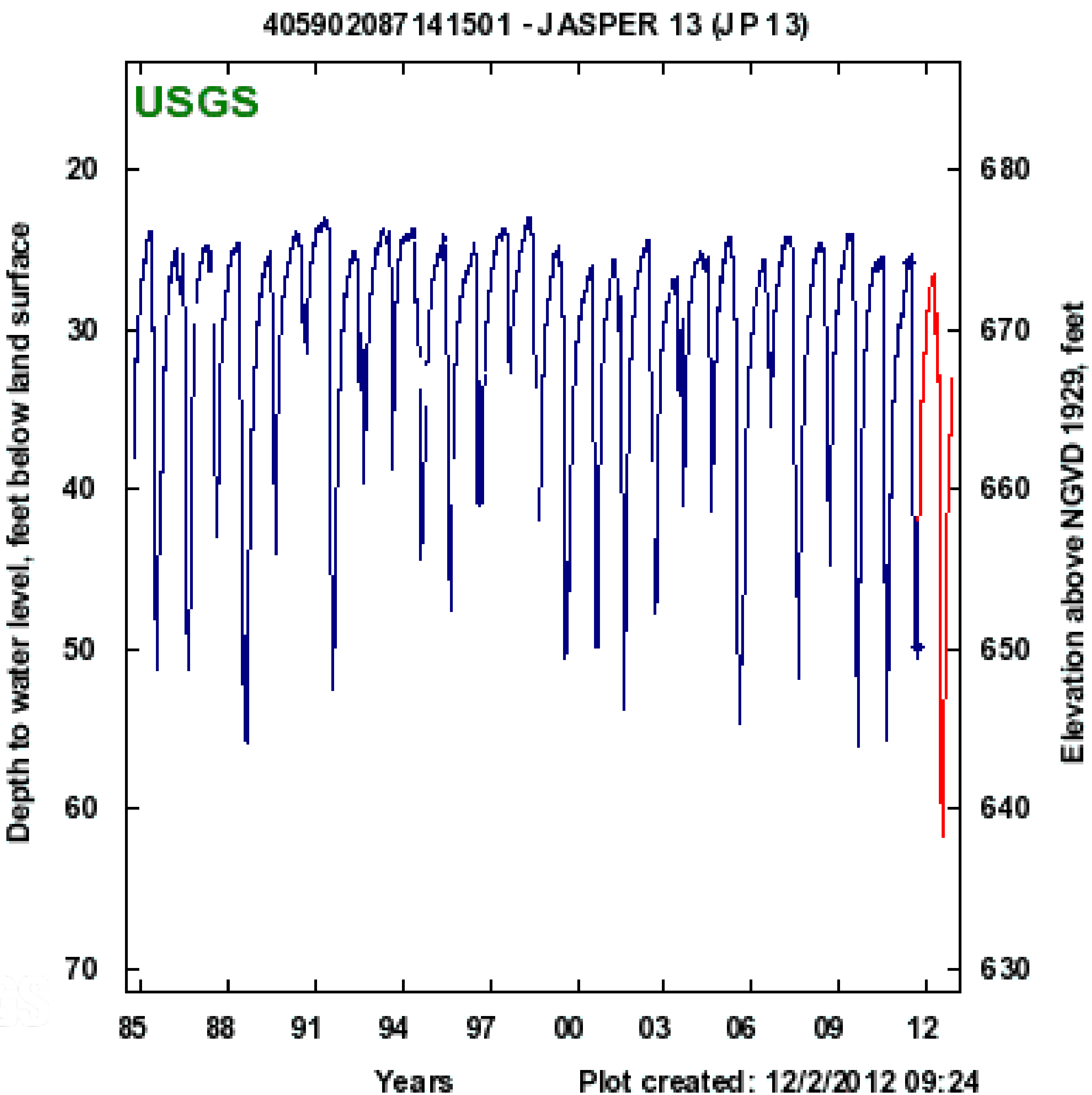
Jasper County, Indiana

- Installation of center pivot irrigation systems with 34 wells in a limestone aquifer
- 1981-84, nearly 130 household wells impacted
- 150-200 more wells impacted after this report, especially during 1988 drought
- Motivated water right and use legislation in Indiana to provide means for people with domestic wells to work through problems caused by high-capacity wells


IRRIGATION IMPACTS ON GROUND-WATER LEVELS IN JASPER AND NEWTON COUNTIES, INDIANA, 1981-1984

Water Resource Assessment 85-1

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER
1985



405902087141501 - JASPER 13 (JP 13)
USGS
Depth to water level, feet below land surface
Elevation above NGVD 1929, feet
20
30
40
50
60
70
680
670
660
650
640
630
85
88
91
94
97
00
03
06
09
12
Years
Plot created: 12/2/2012 09:24

Factors determining drawdown

- Local geology, aquifer type
  - Confined or unconfined
  - Fractured rock, unconsolidated material
- Geometry
  - Distance to boundaries
  - Configuration of aquifers
- Pumping rate and duration
- To minimize drawdowns (Theis):
  - Place wells near discharge areas
  - Spread demand over several wells

USGS

Groundwater/Surface-Water Interaction

Streamflow depletion by wells

- Methods to complement field data and analysis
- Recent report: Streamflow Depletion by Wells-Understanding and Managing the Effects of Groundwater Pumping on Streamflow, US Geological Survey Circular 1376, by P.M. Barlow and S.A. Leake
- http://pubs.usgs.gov/circ/1376/

USGS

Common Misconception from Leake and Barlow

- Total development of groundwater resources from an aquifer system is ‘safe’ or ‘sustainable’ up to the average rate of recharge
- If development = rate of recharge, rate of natural discharge will approach zero if recharge has not increased

USGS

Approaches to Estimating Groundwater/Surface-Water Interaction

- Field methods: installation of shallow monitoring wells paired with streamgage with addition of temperature measurement
- Analytical modeling
- Numerical modeling

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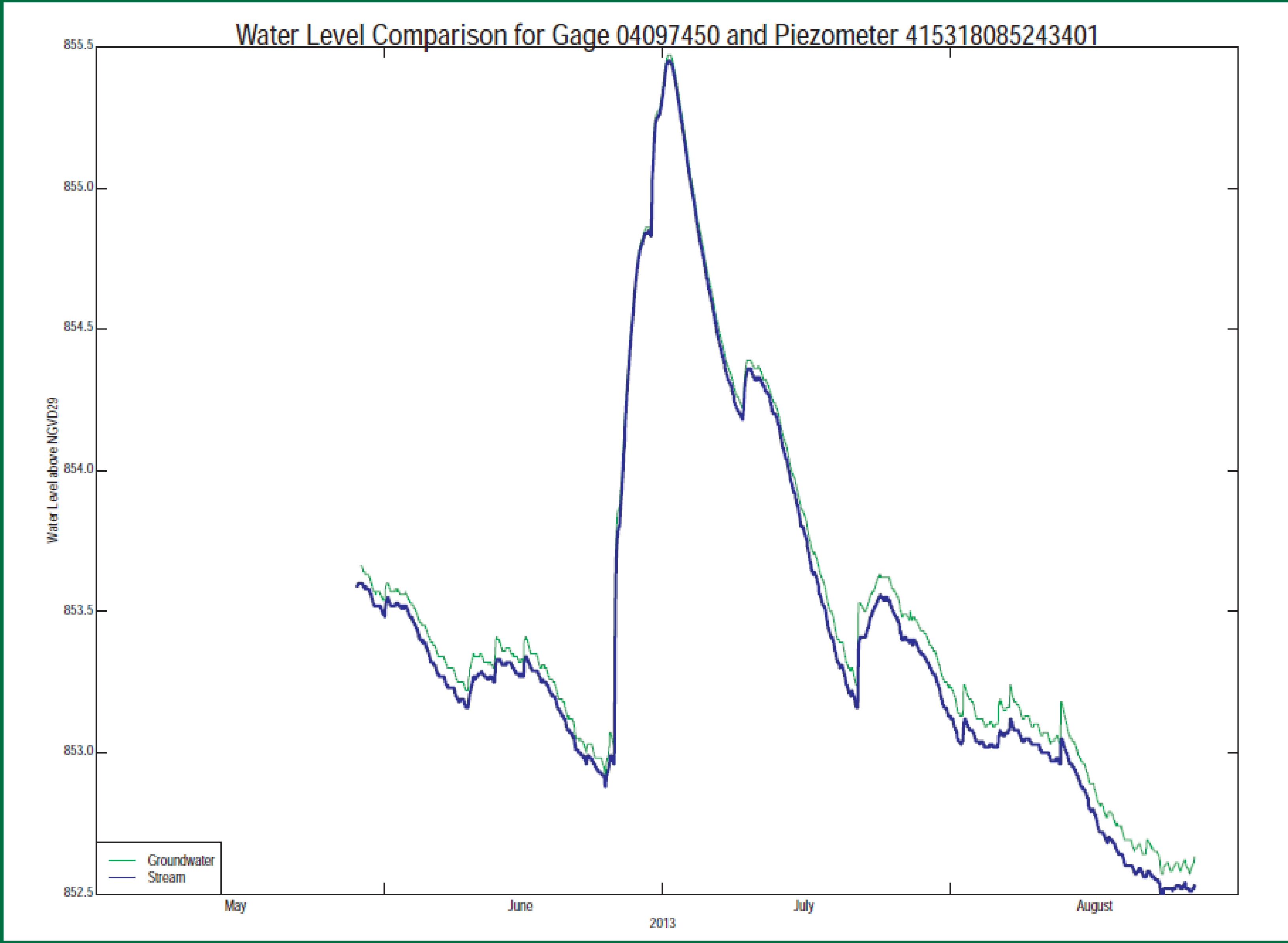
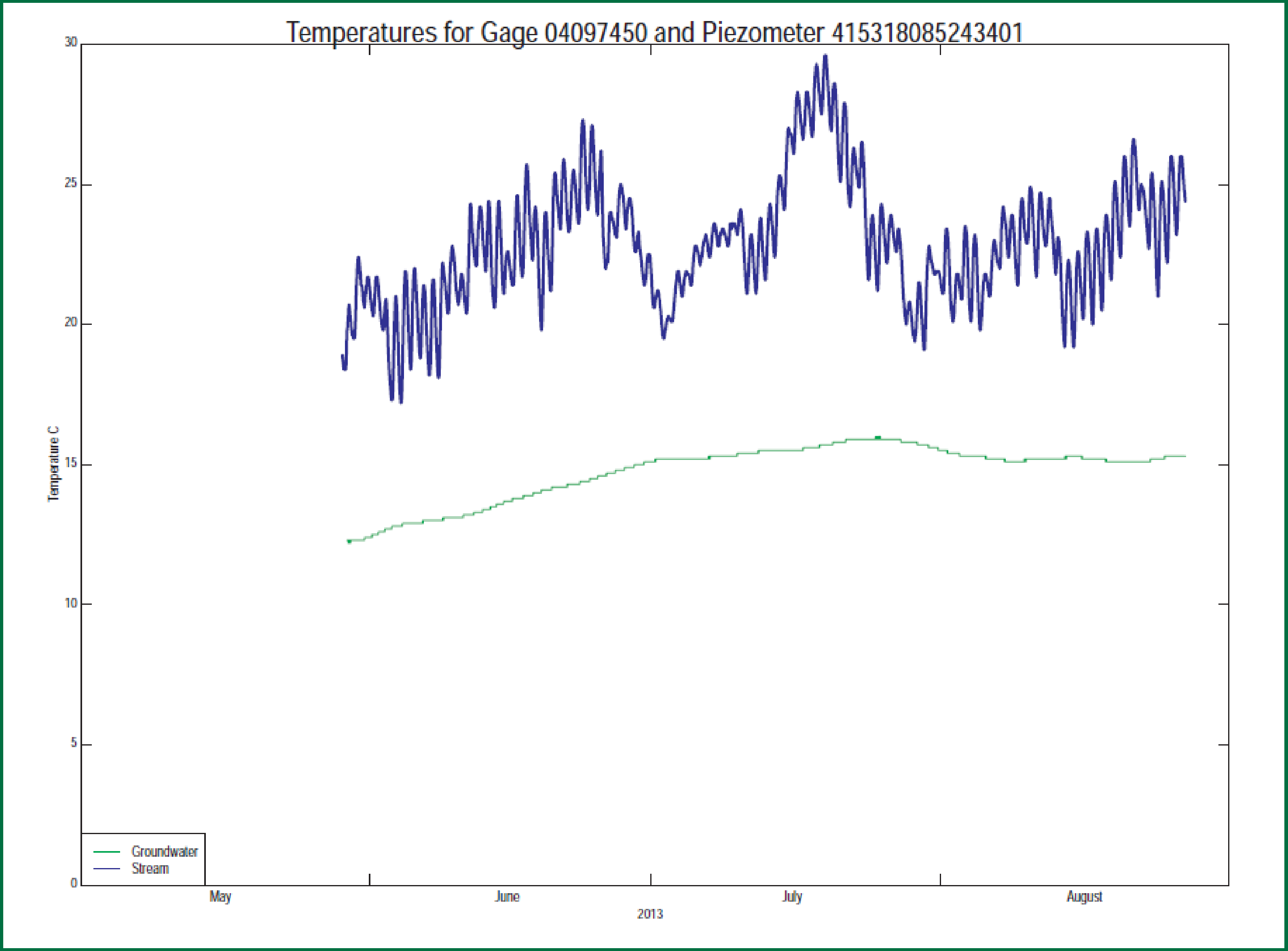


USGS

Provisional data subject to USGS revision



USGS

Provisional data subject to USGS revision

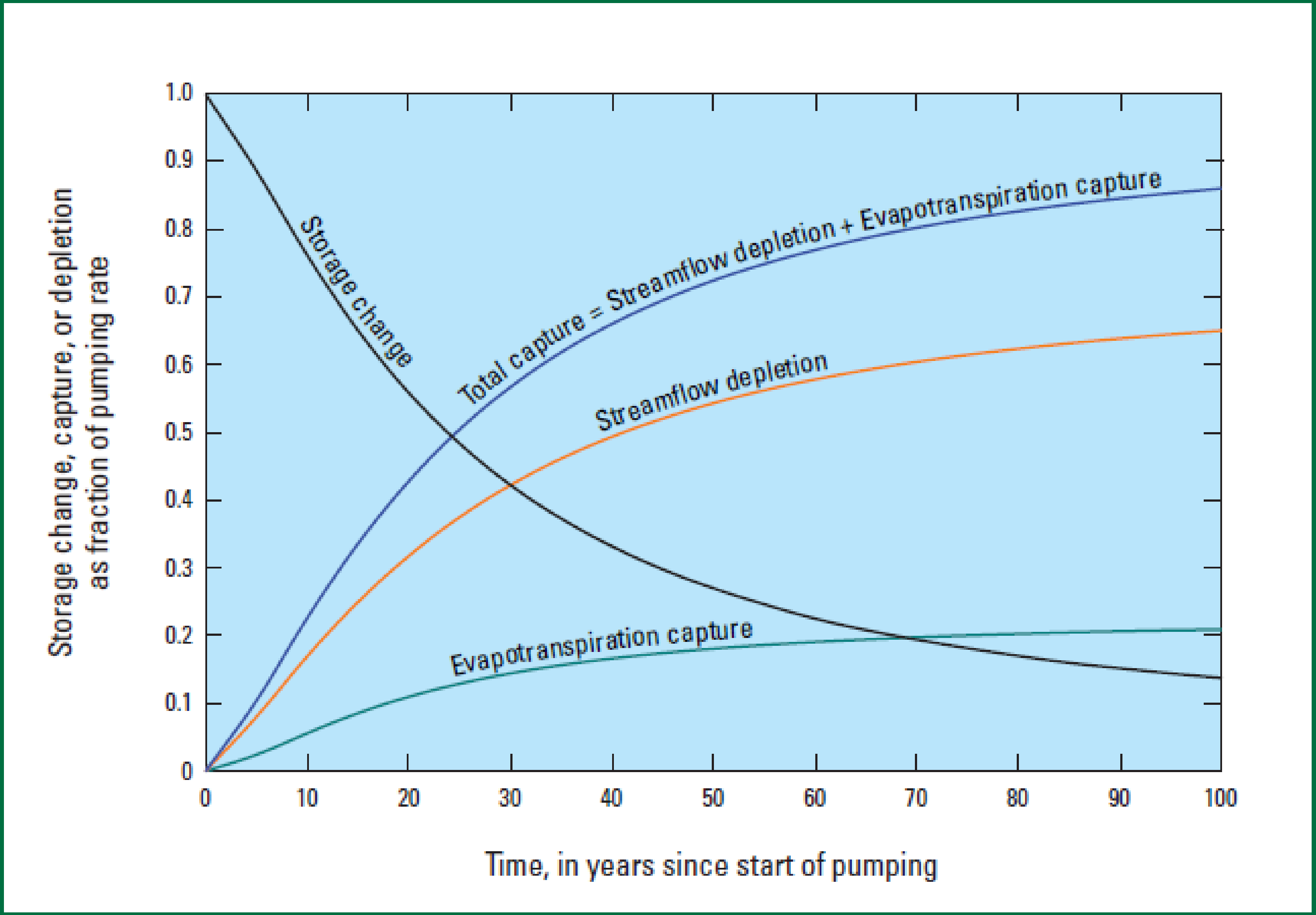
Analytical models

- Mathematical expressions relating streamflow depletion to pumping rate and aquifer characteristics
- Simple geometry, homogeneous aquifer
- Simple input requirements

Numerical Modeling

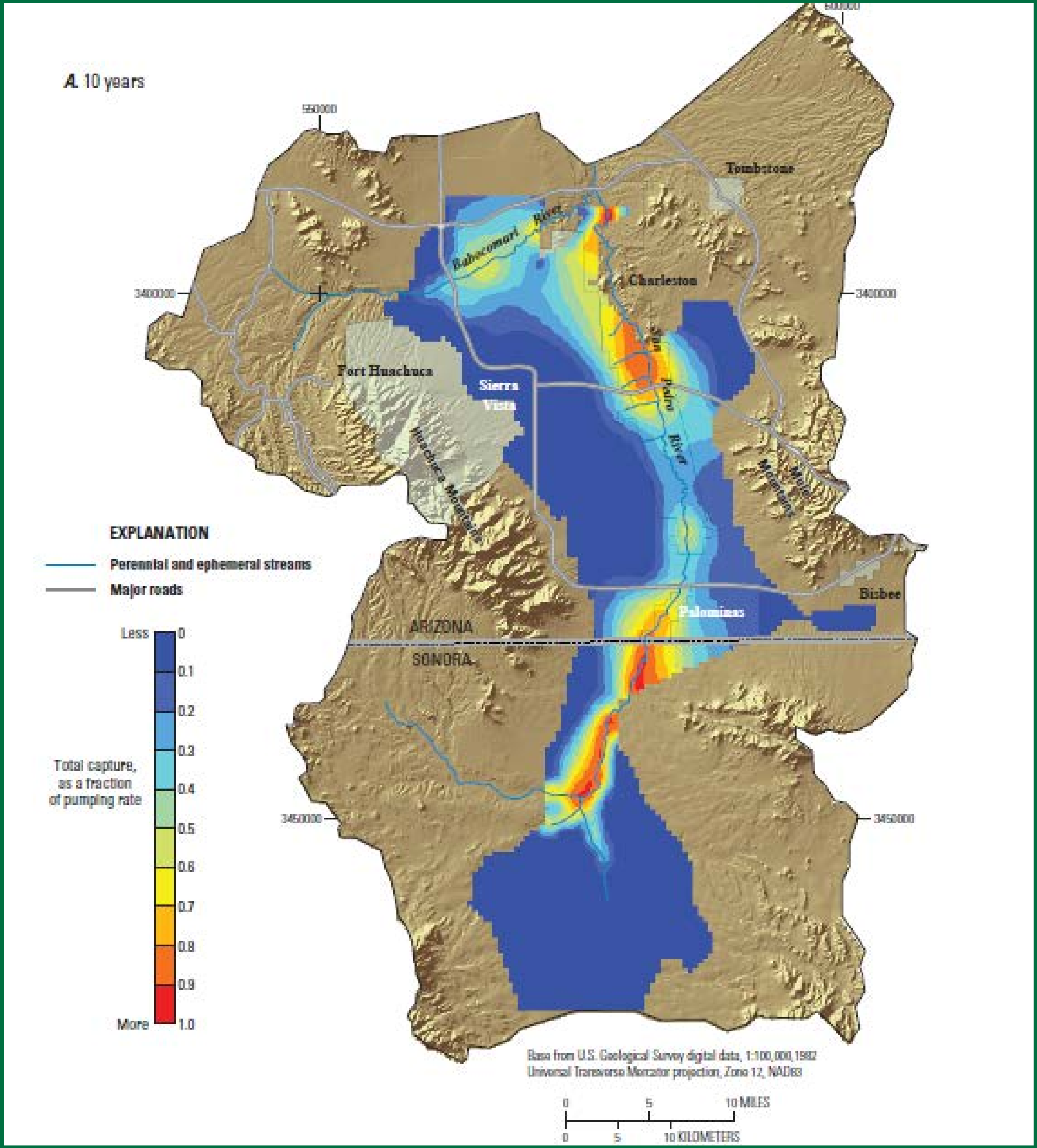
- Irregular geometry of aquifer or boundaries
- Irregular geometry of streams, lakes
- Non-uniform aquifer properties
- Complex pumping schedules and multiple wells
- Nonlinear conditions- properties change with aquifer condition
- Numerical models or approaches such as analytic element modeling

USGS



From USGS Circular 1376

From USGS Circular 1376



Final Comment

WATER RESOURCES RESEARCH, VOL. 48, W05301, doi:10.1029/2011WR011780, 2012

Coupling landscape water storage and supplemental irrigation to increase productivity and improve environmental stewardship in the U.S. Midwest

John M. Baker,[1,2] Timothy J. Griffis,[2] and Tyson E. Ochsner[3]

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Agriculture must increase production for a growing population while simultaneously reducing its environmental impacts. These goals need not be in tension with one another.

USGS

Resources

- Illinois Agricultural Extension, Agronomy Handbook: http://extension.cropsci.illinois.edu/handbook/
- MSUE St. Joseph County Portal Irrigation Resources page (Lyndon Kelley, MSU-Purdue Cooperative Extension) http://www.msue.msu.edu/portal/default.cfm?pageset_id=28706&page_id=361029
- Mark Basch, Water Rights and Use Section, Indiana Department of Natural Resources, Division of Water
- USDA http://go.usa.gov/Kow
- Kentucky Cooperative Extension Service
- Kentucky Geological Survey
  - Water wells and springs http://kgs.uky.edu/kgsmap/KGSWater/viewer.asp
- Kentucky Department of Agriculture
- USGS Kentucky Water Science Center

USGS