



Water Resources & Irrigated Agriculture with an Emphasis on Biofuel Production

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



Overview

- **Water Budgets**

- **Effects of human activities**
- **Groundwater sustainability**
- **Climate change**

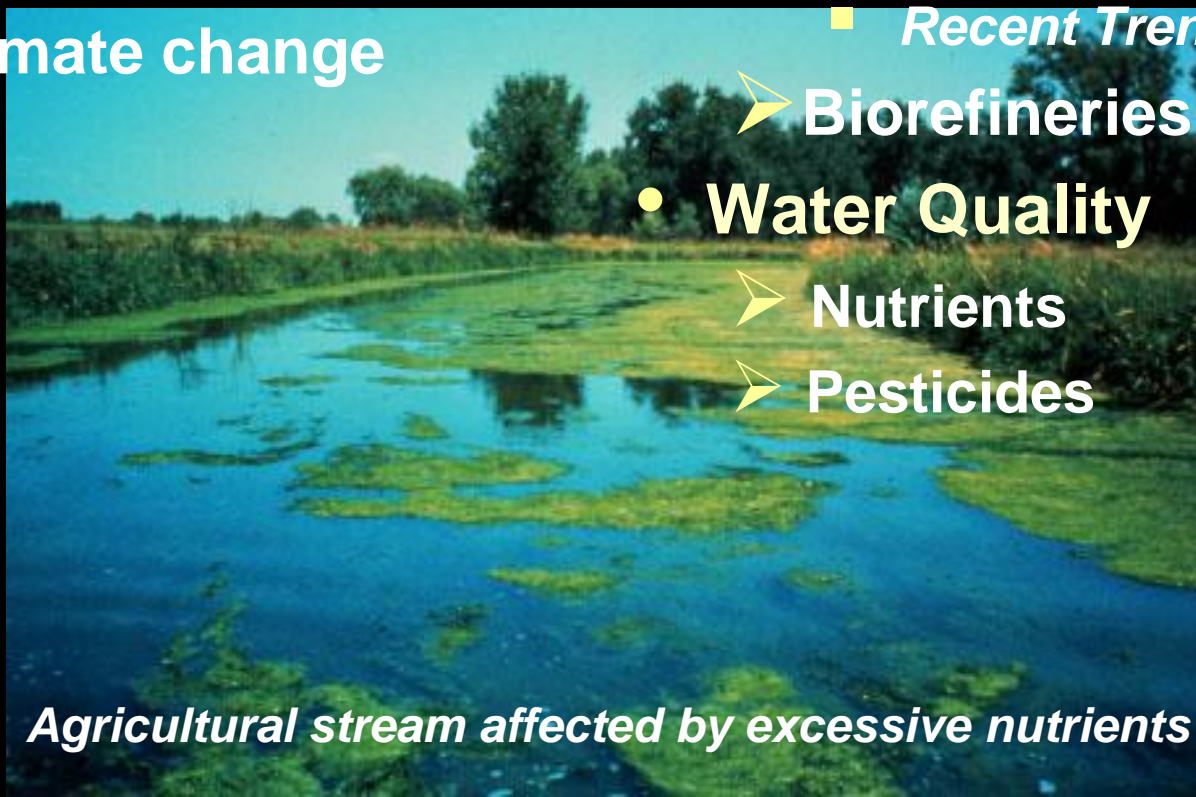
- **Water Use**

- **Irrigation**
 - *Weather and climate*
 - *Crop type*
 - *Energy*
 - *Recent Trends*

- **Biorefineries**

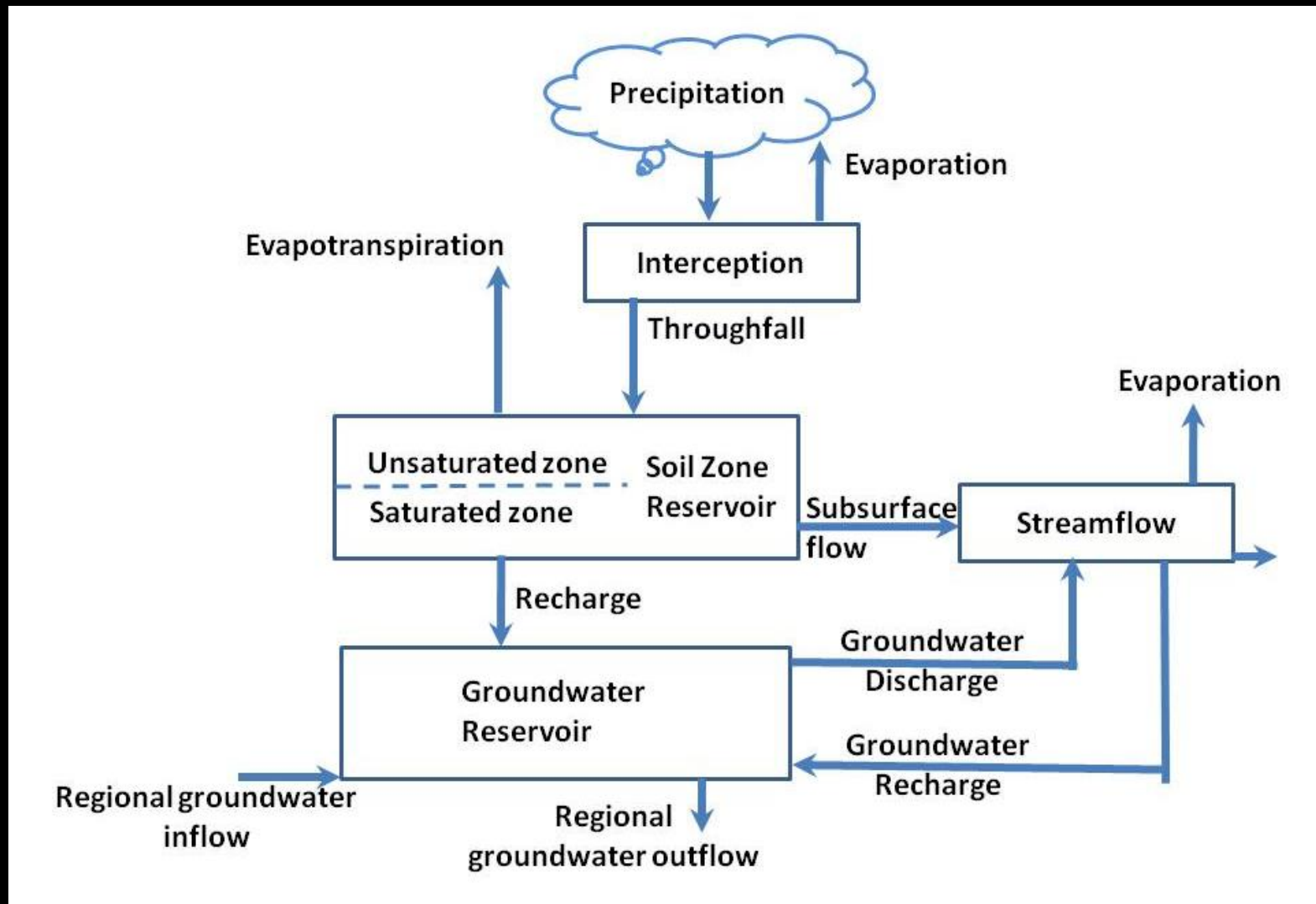
- **Water Quality**

- **Nutrients**
- **Pesticides**

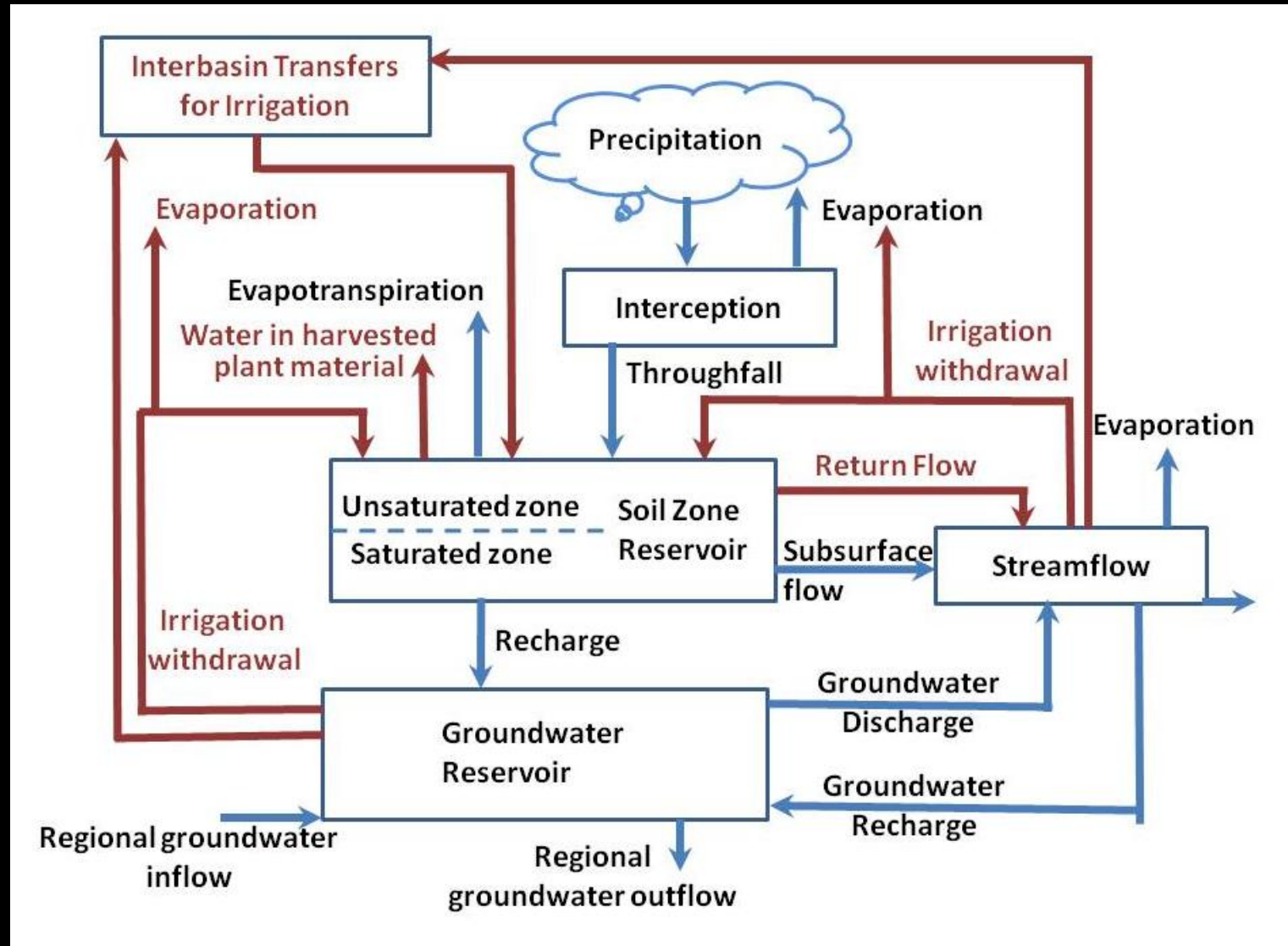


Agricultural stream affected by excessive nutrients

Water Budget—Undeveloped Basin

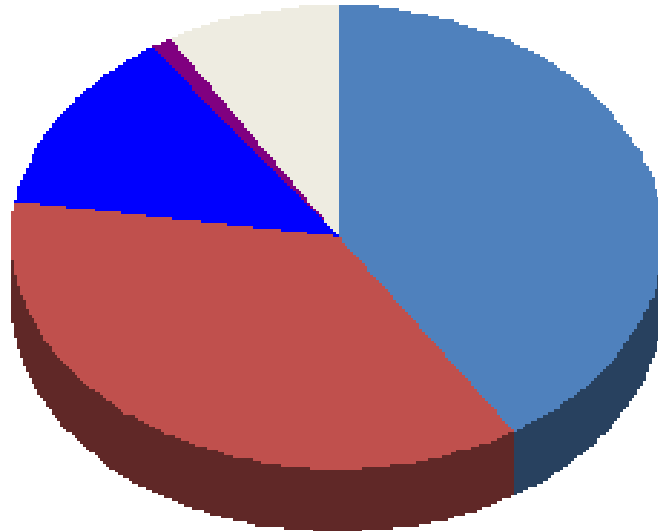


Water Budget—Developed Basin



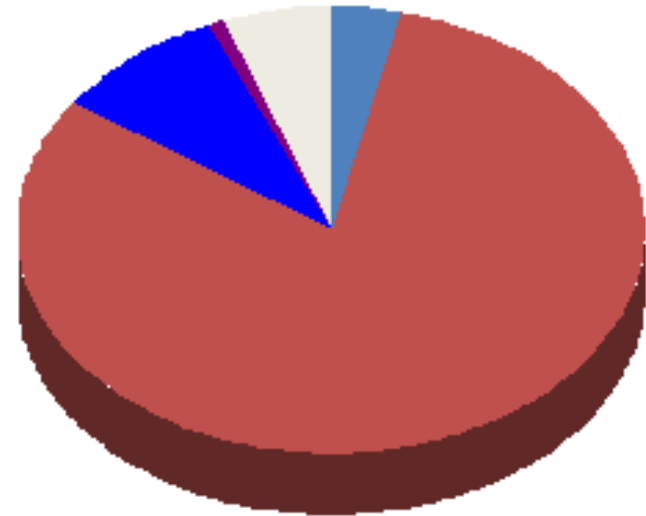
Water Withdrawals and Consumption

A. Withdrawals



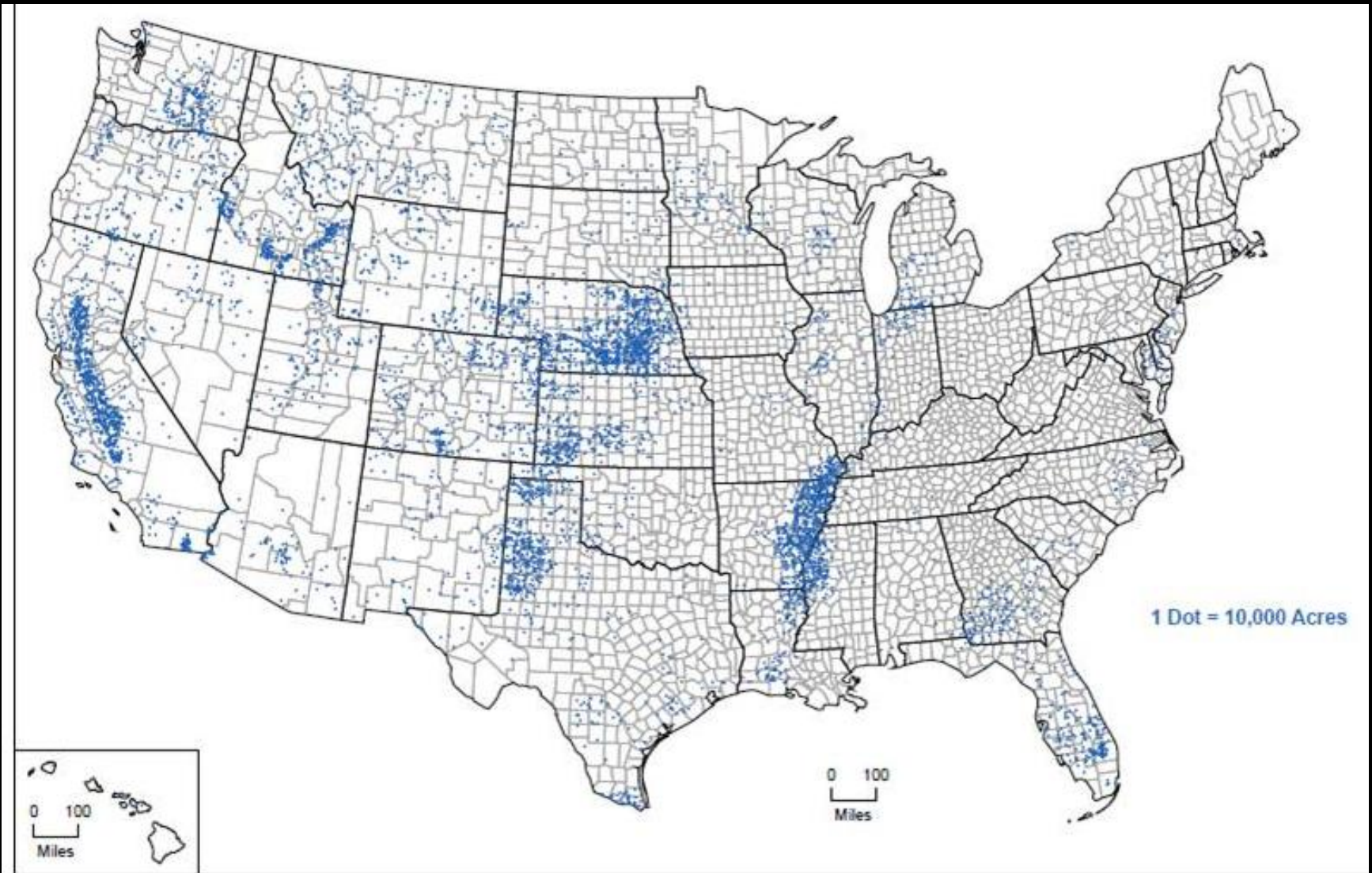
■ Thermoelectric Power
■ Irrigation
■ Public Supply
■ Domestic
■ Other

B. Estimated Consumptive Use



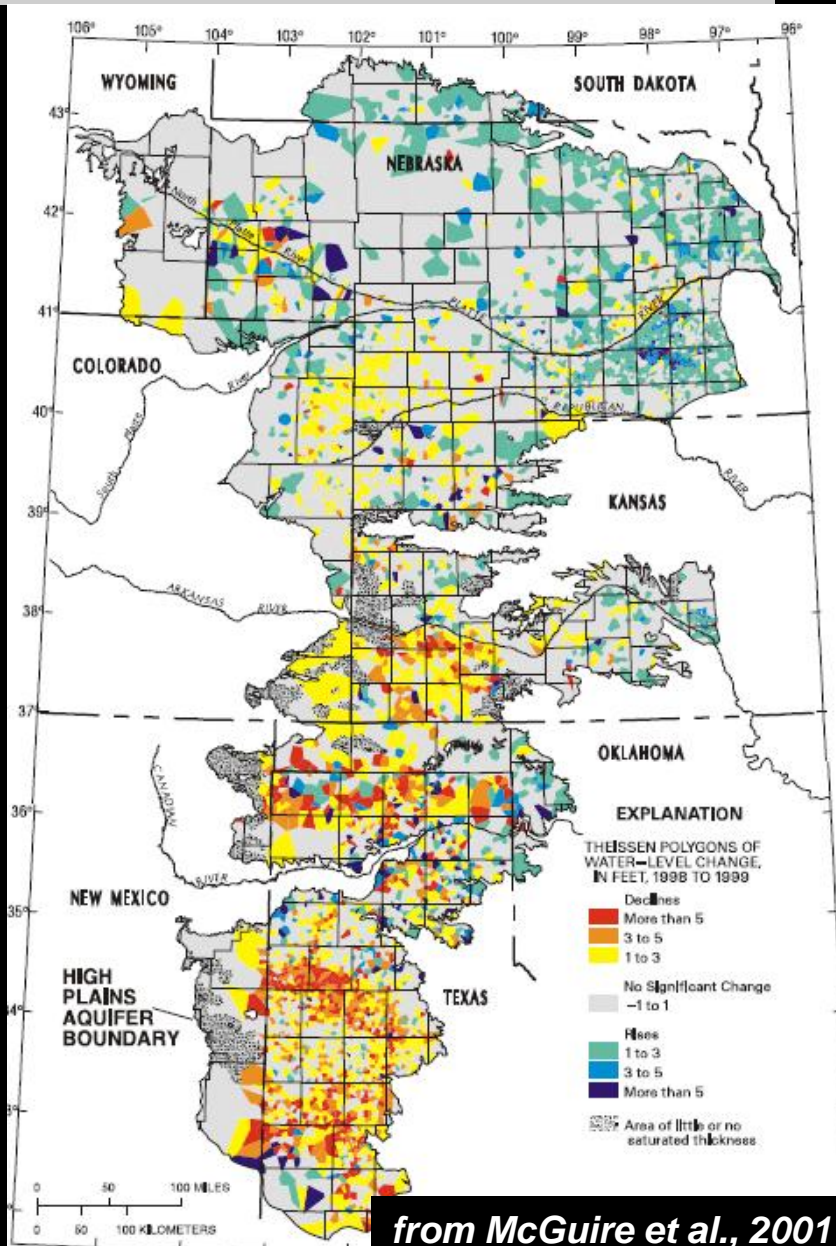
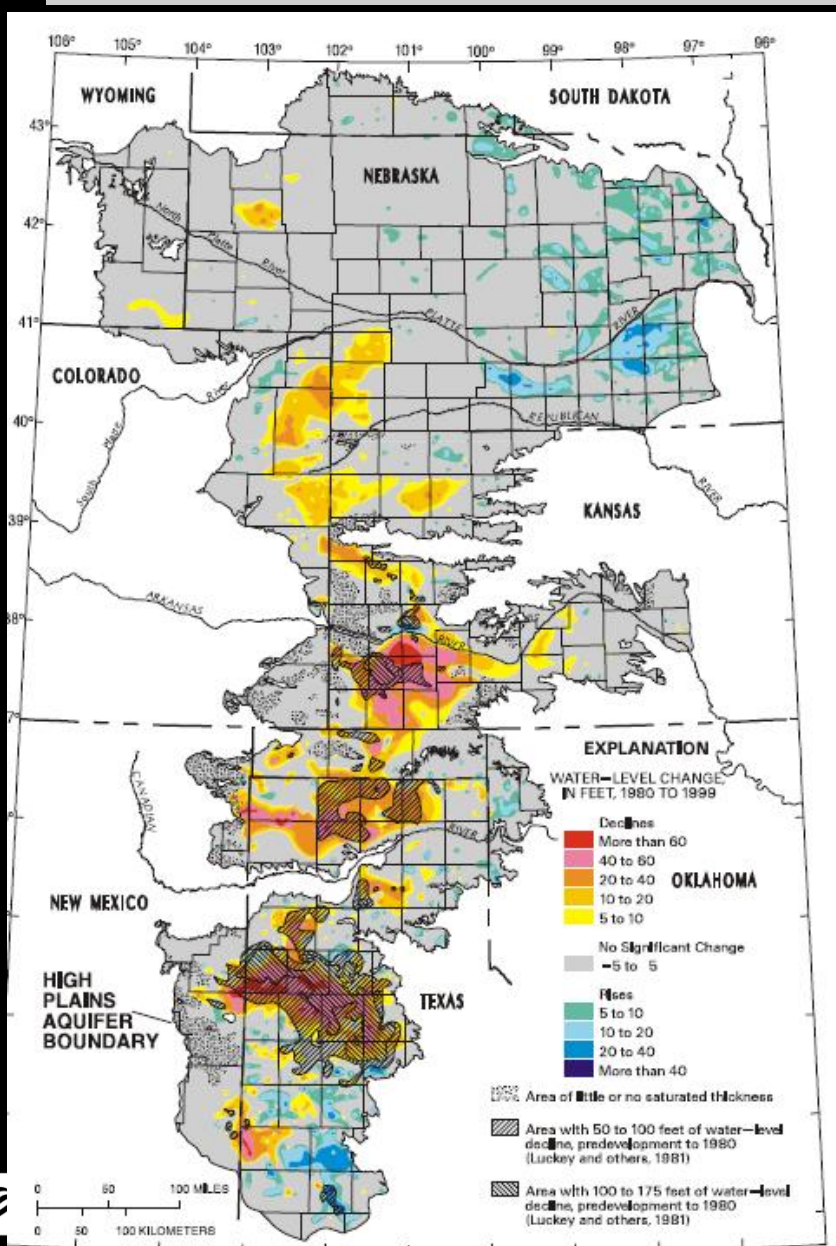
■ Thermoelectric Power
■ Irrigation
■ Public Supply
■ Domestic
■ Other

Irrigated Agriculture



1980 – 1998
red: 40 – 60 ft

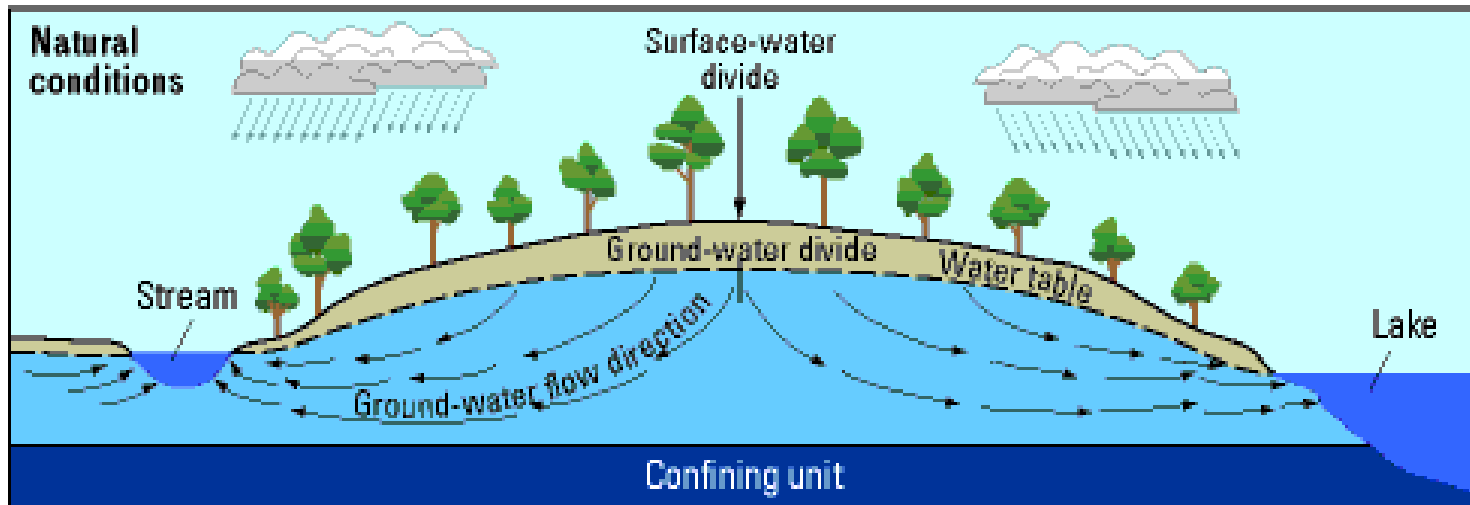
1997 – 1998
red: >5 ft



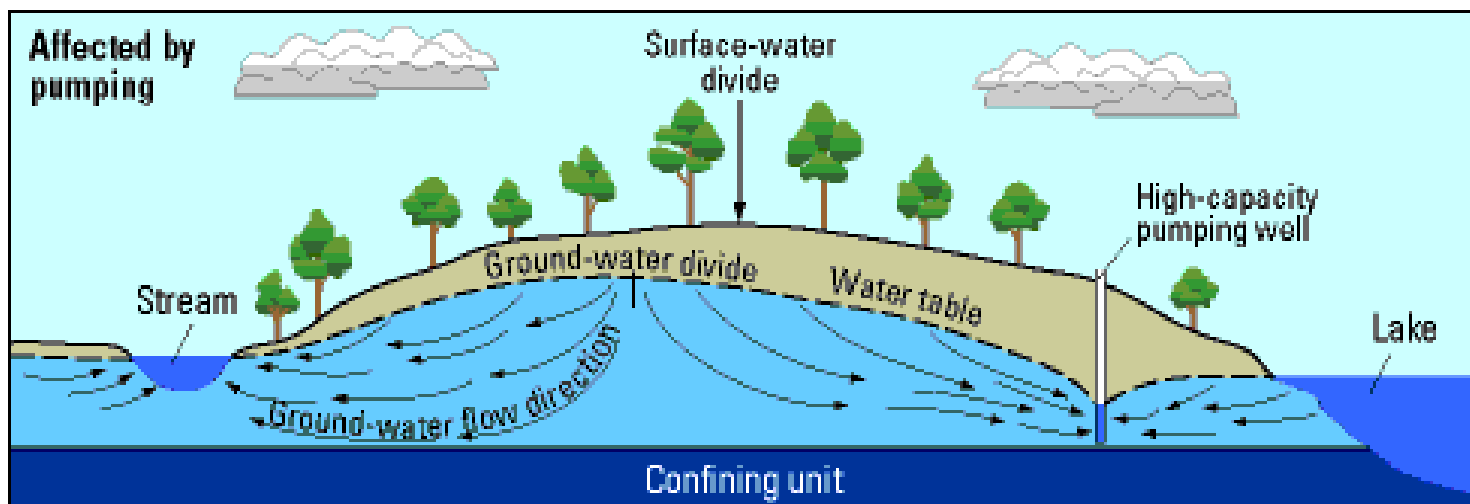
from McGuire et al., 2001

Groundwater Withdrawals

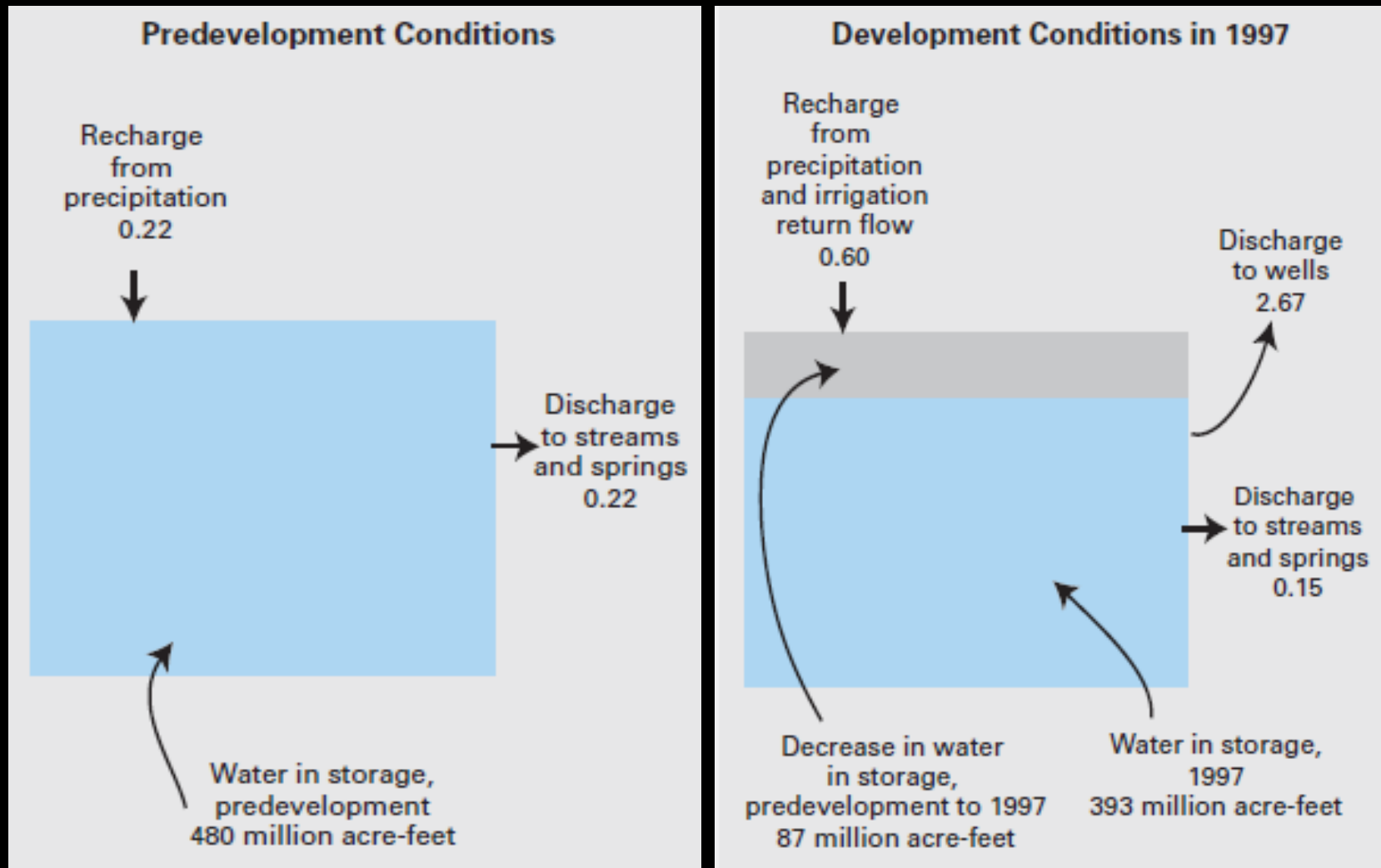
A



B



Example Change to Water Budget

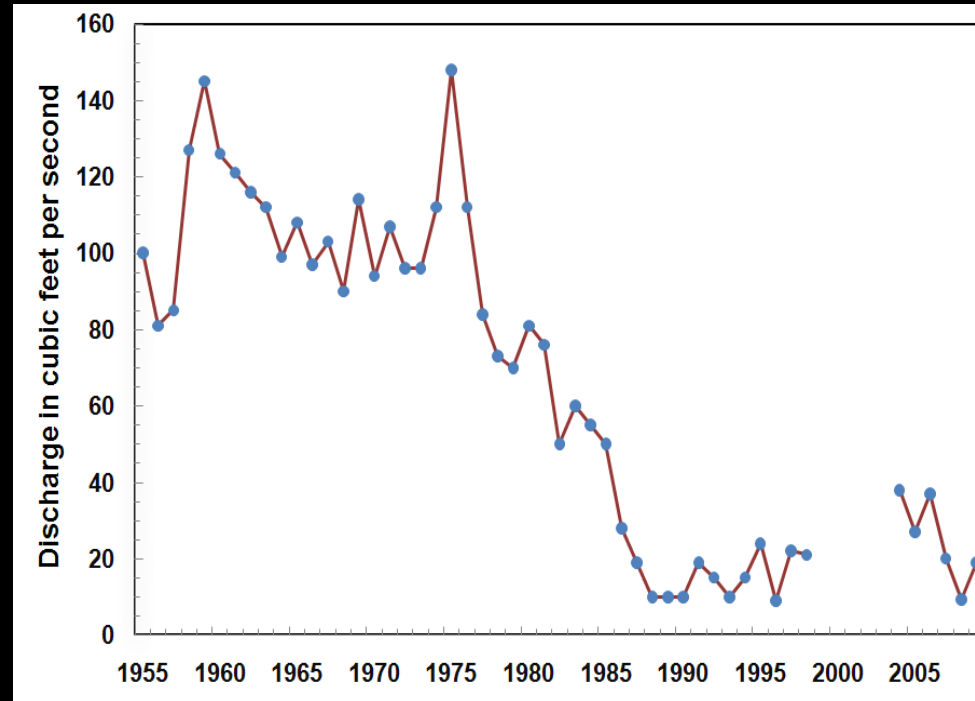
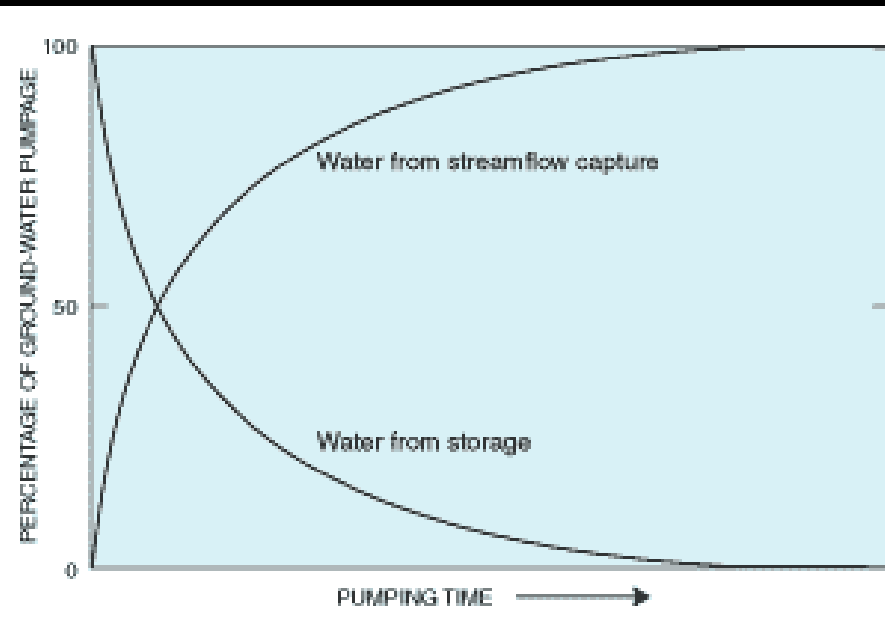


South Central High Plains; values in million acre-ft/yr

Groundwater Pumping and Streamflow

Initial withdrawals are from storage; at some point in the future (idealized), all of withdrawal will be from streamflow capture.

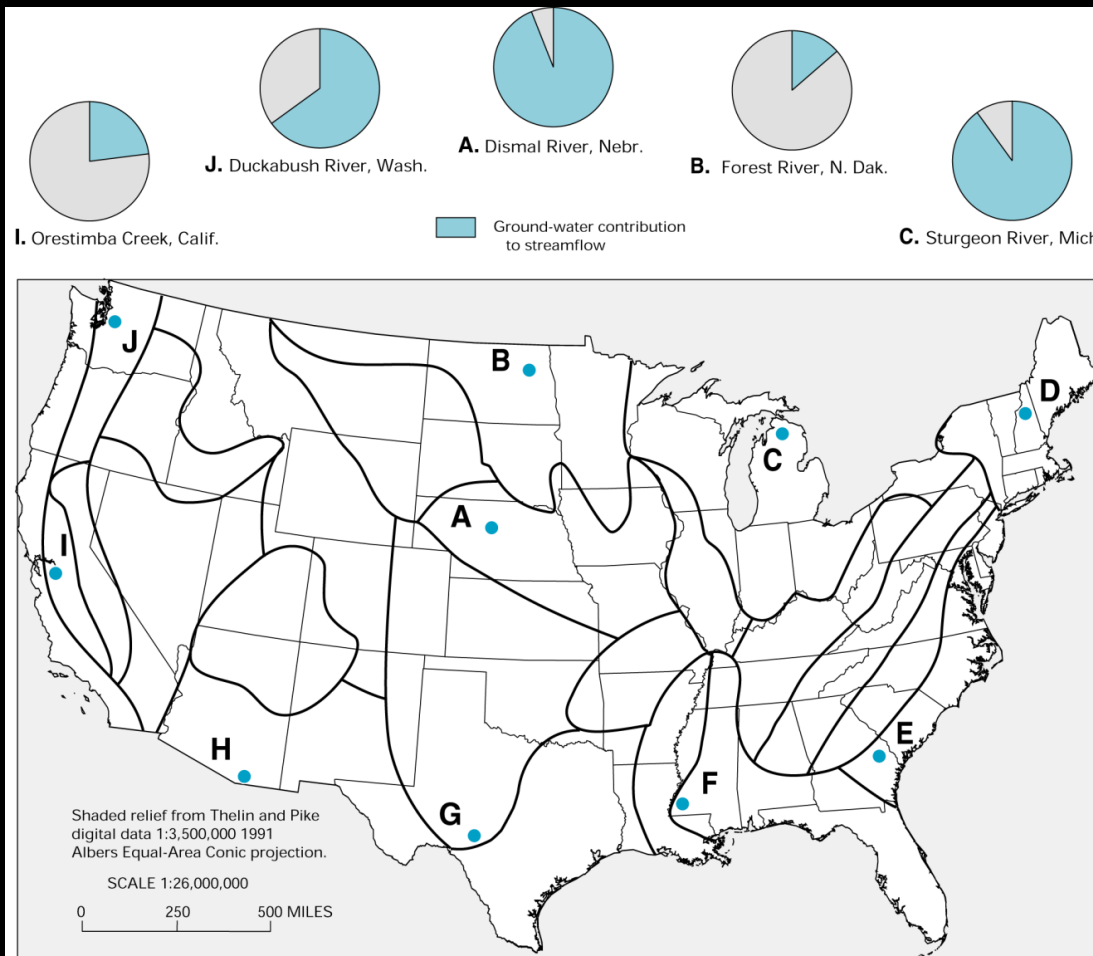
(Alley, et al., 1999)



Minimum annual streamflow for the Sunflower River, MS showing effects of withdrawals from the Mississippi River Valley alluvial aquifer on streamflow.

(Welch et al., 2010)

Groundwater Pumping and Streamflow

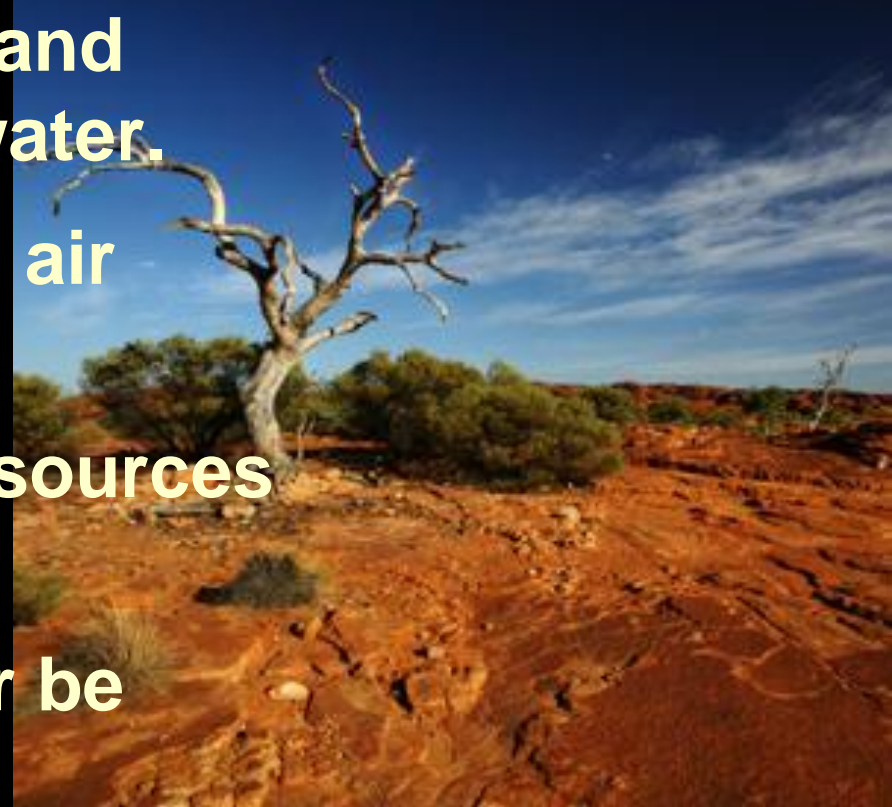


Groundwater contributions to total streamflow, by major aquifer.

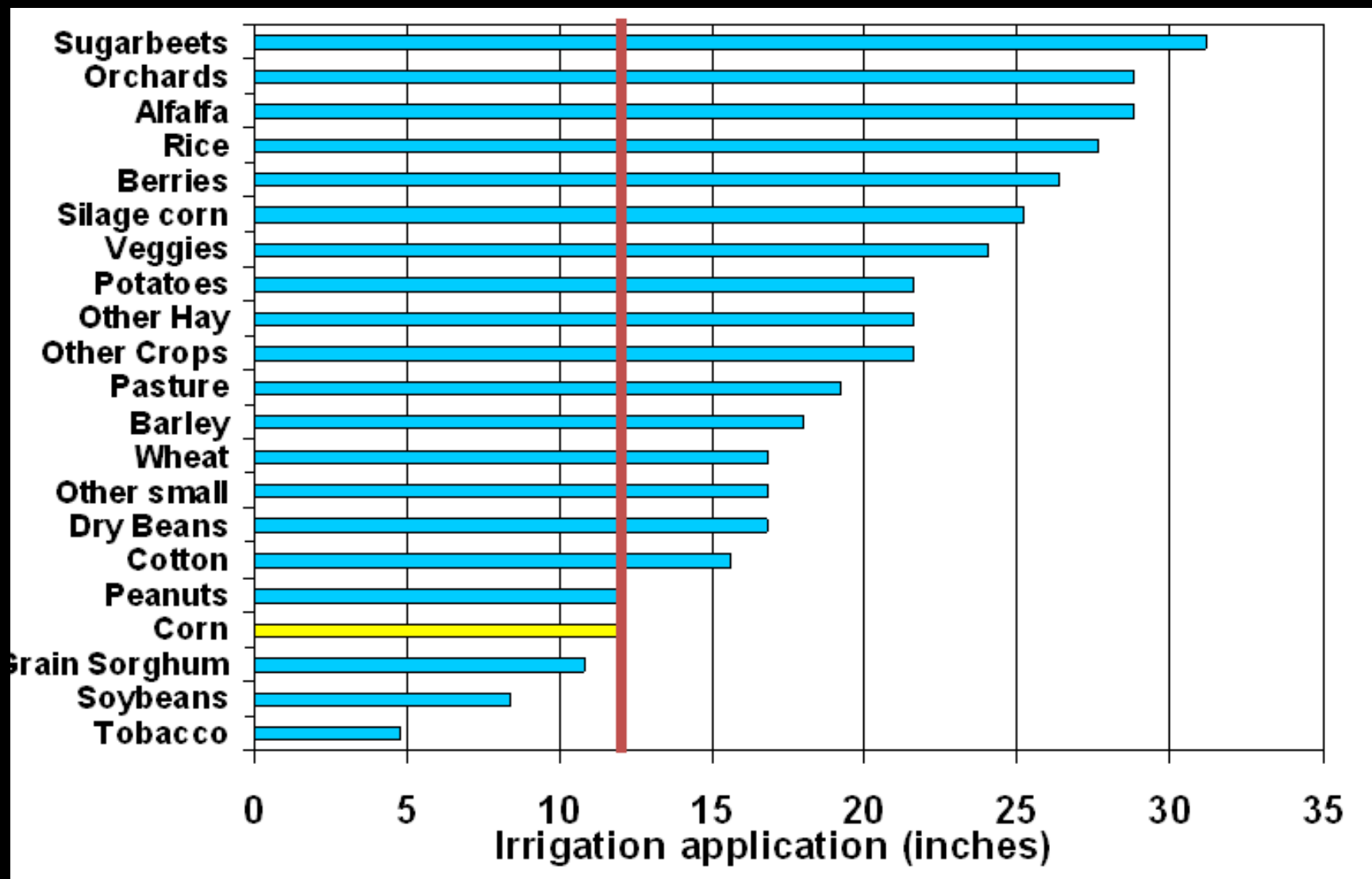
(Winter, et al., 1998)

Factors Affecting Irrigation—Climate

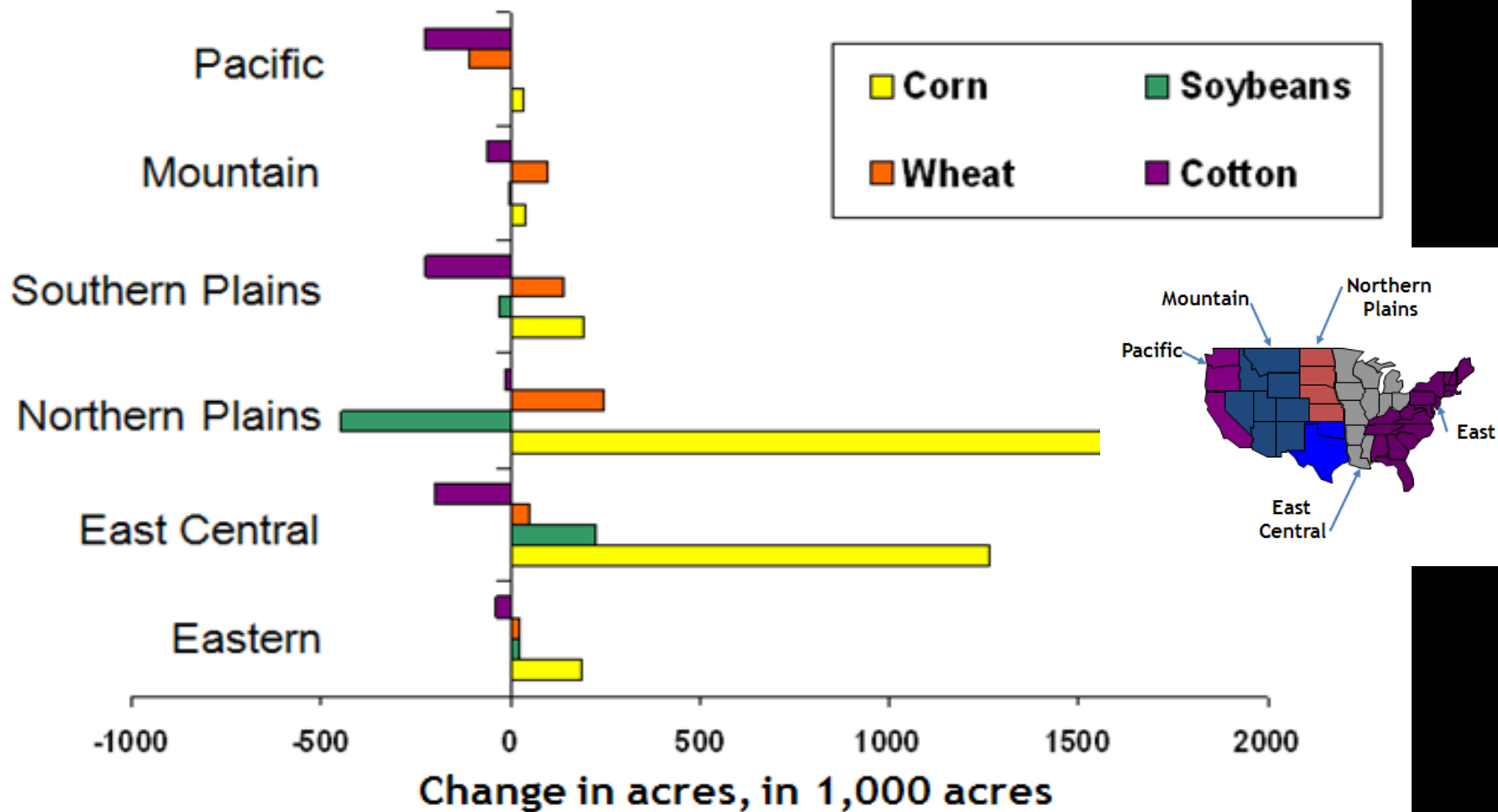
- **Effects of climate change on agriculture, ecosystems, and energy are mediated by water.**
- **Unambiguous increase in air temperature.**
- **Direct effects on water resources less evident.**
- **Stationarity can no longer be assumed.**



Factors Affecting Irrigation—Crop



Factors Affecting Irrigation—Crop



Factors Affecting Irrigation—Energy

- **9 – 11 percent of purchased agricultural input is for energy.**
- **Disconnect between energy costs and water use:**
 - **Not all irrigation required energy**
 - **Irrigation may lead to a more profitable crop**
 - **Water prices not set in market and do not reflect scarcity.**

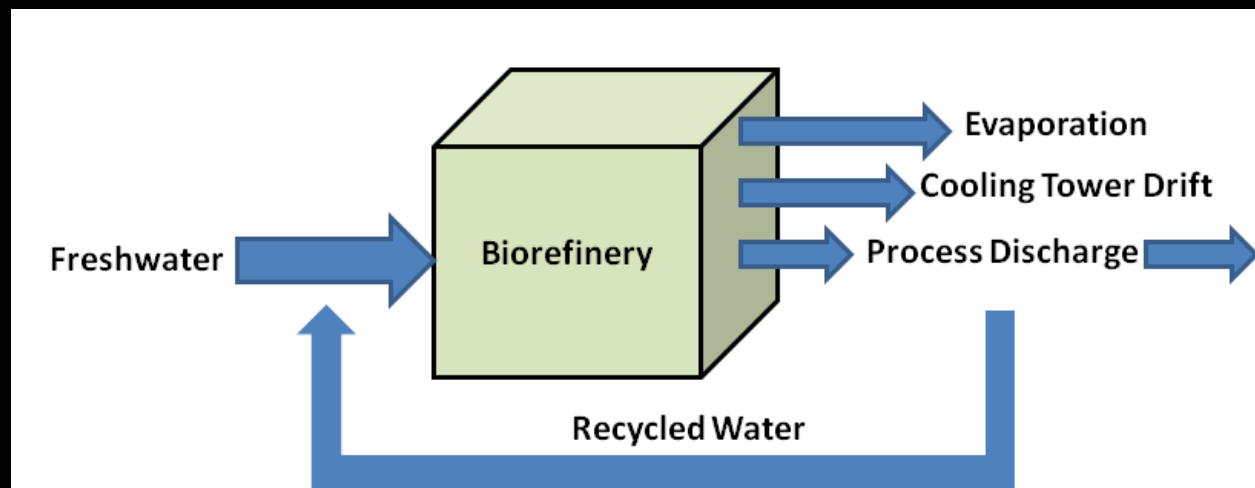


Biorefinery Water Use

- 3 – 11 gal water /gal corn ethanol
- 1.5 Kwh / gal ethanol
- 20 % decline in CWU 2000 – 2006
- 2 – 10 gal water / gal cellulosic ethanol
- Cellulosic biorefinery technology has potential for much lower CWU (or not)



Biorefinery Water Budget

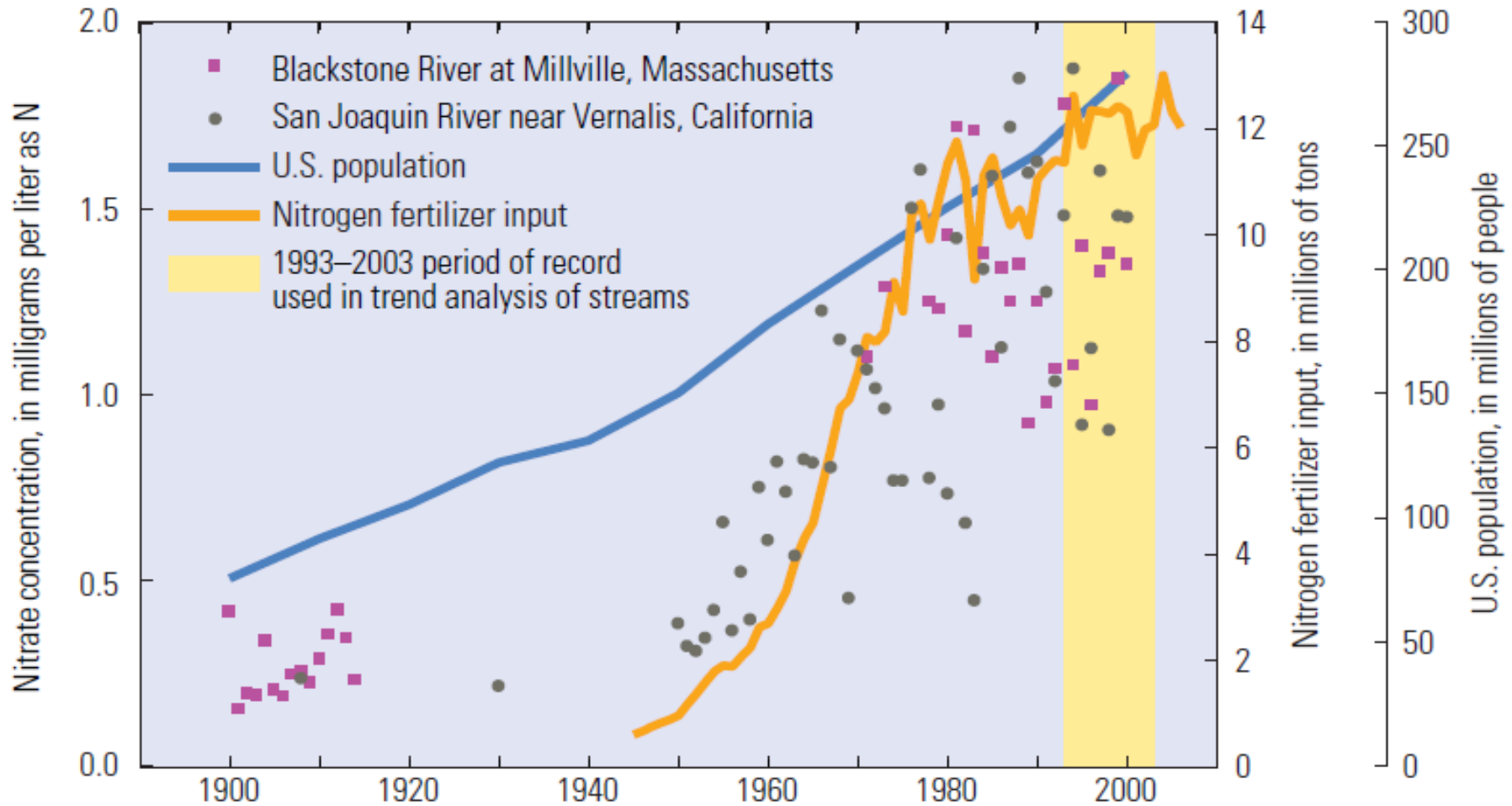


After Wu et al., 2009

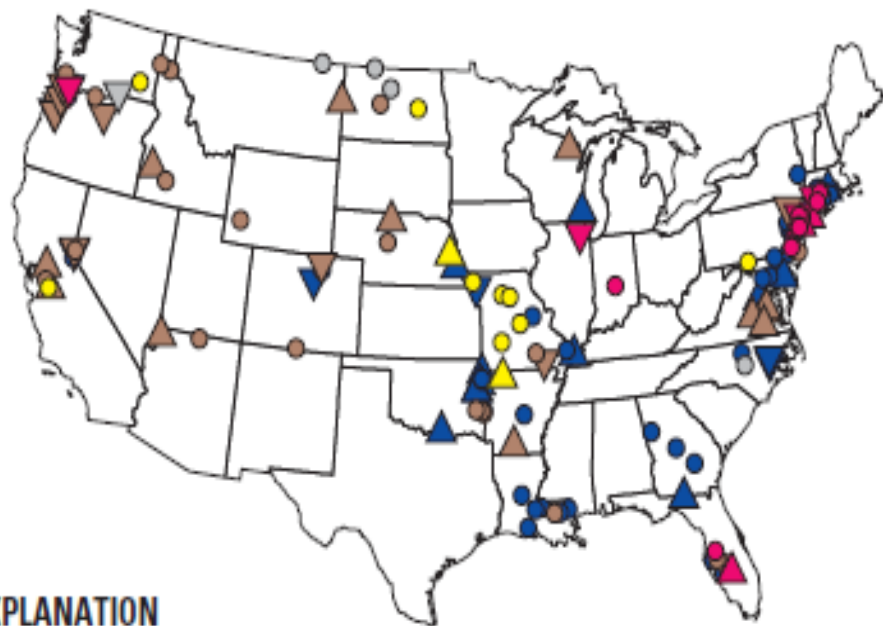
Comparison of Water Use Intensity

Fuel (values in gal water per vehicle mile)	King and Webber (2008)	Harto et al., (2010)
Biodiesel soybeans	0.05 (non-irrigated)	0.23 – 5.3
Conventional petroleum	0.15	0.04 -0.13
Non-irrigated corn ethanol (E85)	0.4	0.8
Plug-in hybrid	0.3 – 0.75 (grid)	0.016 – 0.26 (solar)
Irrigated corn ethanol (E85)	38	13

Nitrogen in Streams



Recent Trends in Stream Nitrogen



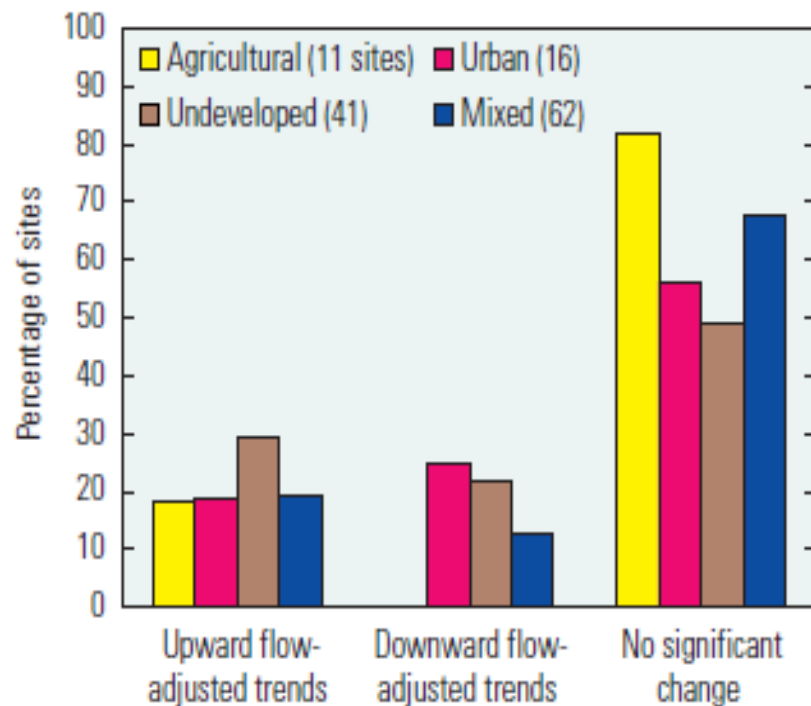
EXPLANATION

Direction of trend (1993–2003)

- △ Upward
- ▽ Downward
- No significant trend

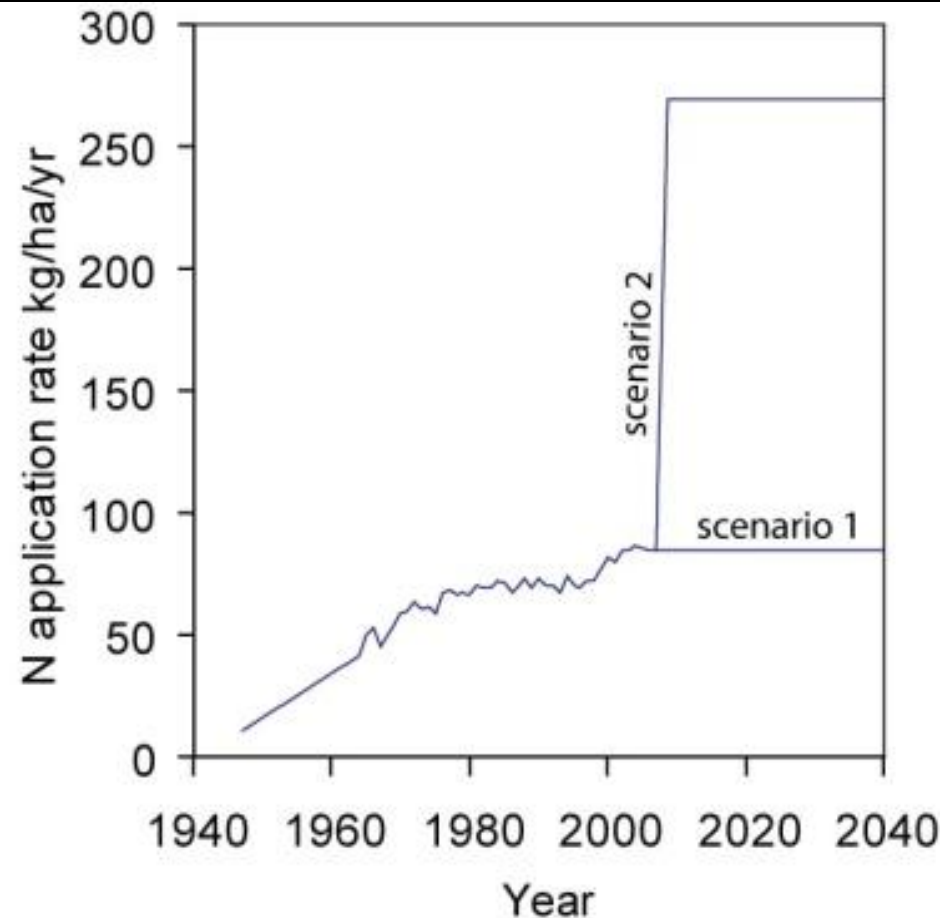
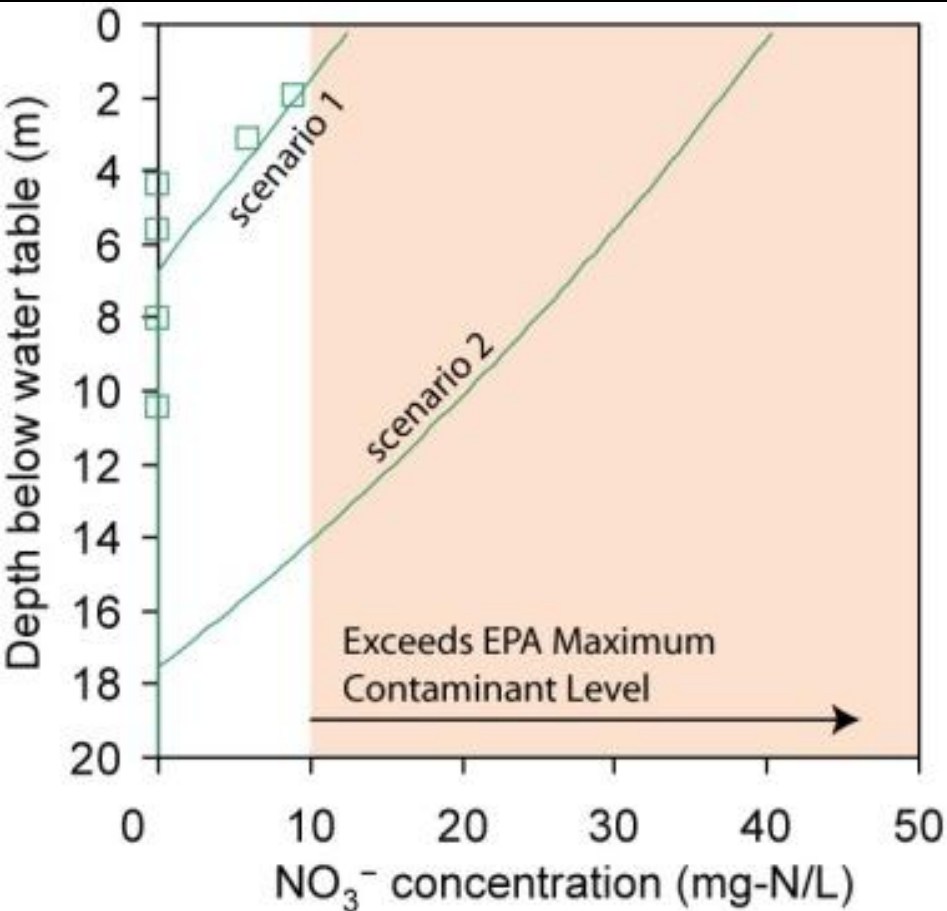
Watershed land use

- Agricultural
- Urban
- Undeveloped
- Mixed
- Undetermined



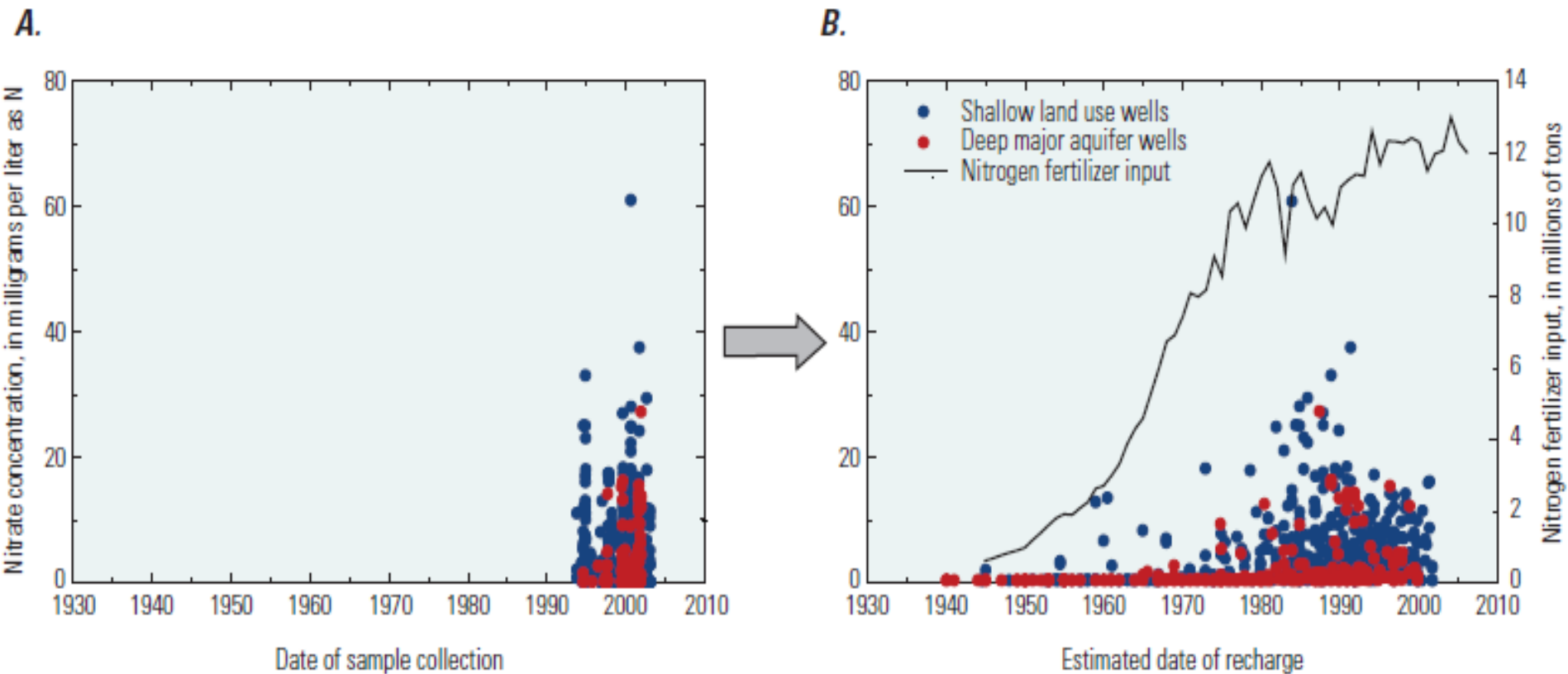
(Dubrovsky, et al., 2010)

Fertilizer Application and Groundwater



Simulated nitrate concentrations in groundwater

Persistence of NO_3 in Groundwater



Measured nitrate concentration in shallow groundwater and deep aquifers by (A) date of sample collection and (B) estimated date when the groundwater was recharged

Summary

- **Water budgets are useful tool for evaluating potential effects of biofuel production and conversion.**
- ***Effects on water budget, particularly groundwater system, may not be manifested for years to decades.***
- **Routinely collected, continuously analyzed data on withdrawals, streamflow, groundwater levels, and water quality are required to manage effects of biofuel production and conversion on water resources.**

Contact Information

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USGS Web resources:

USGS Water Programs: <http://water.usgs.gov>

Water Use Program: <http://water.usgs.gov/watuse/>

Nutrient Enrichment: <http://wa.water.usgs.gov/neet/>

NAWQA Program: <http://water.usgs.gov/nawqa/>