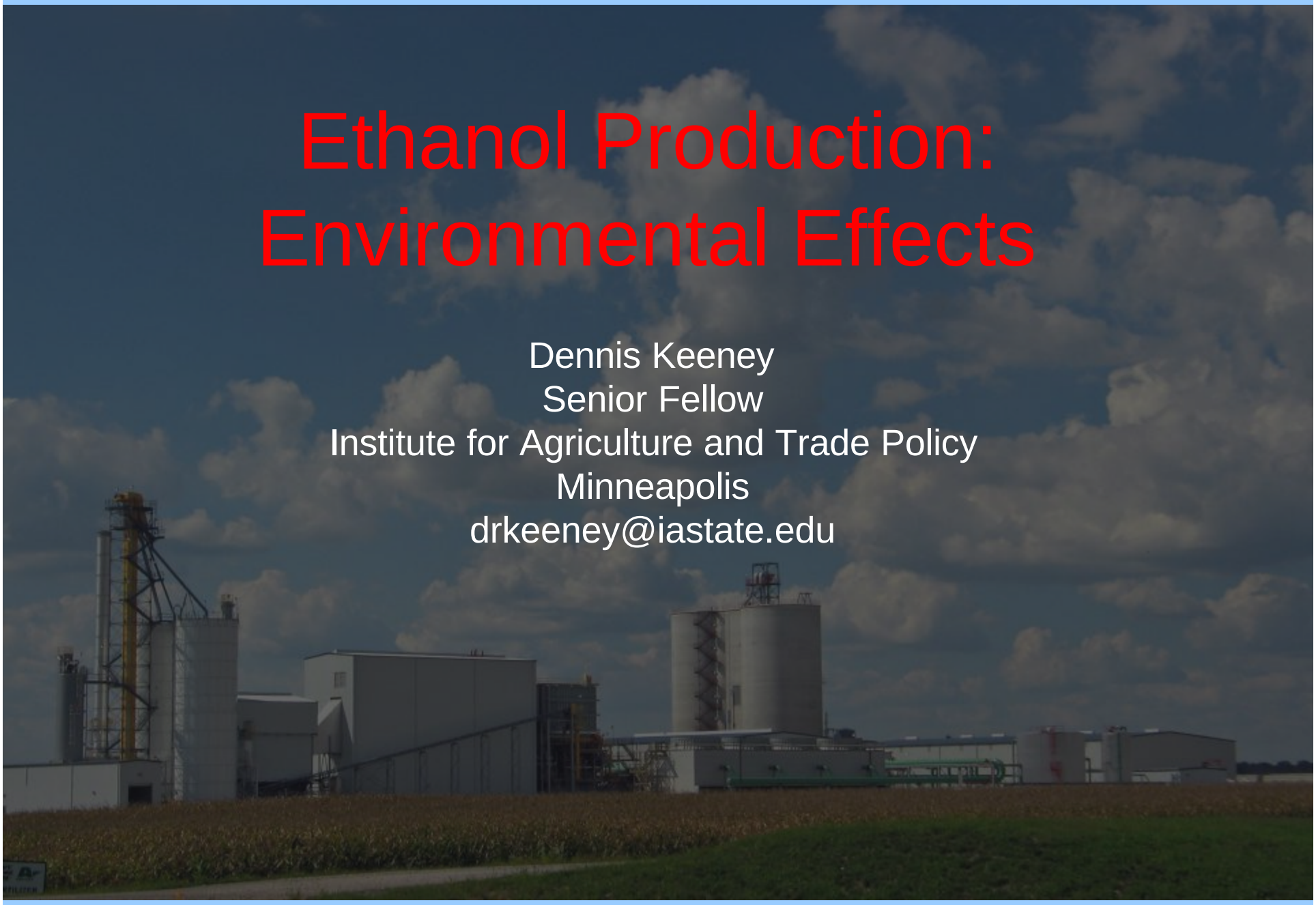

Ethanol Production: Environmental Effects

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Water Use by Ethanol Plants

Potential Challenges

Dennis Keeney and Mark Muller

www.iatp.org./iatp.publications

Institute for Agriculture and Trade Policy

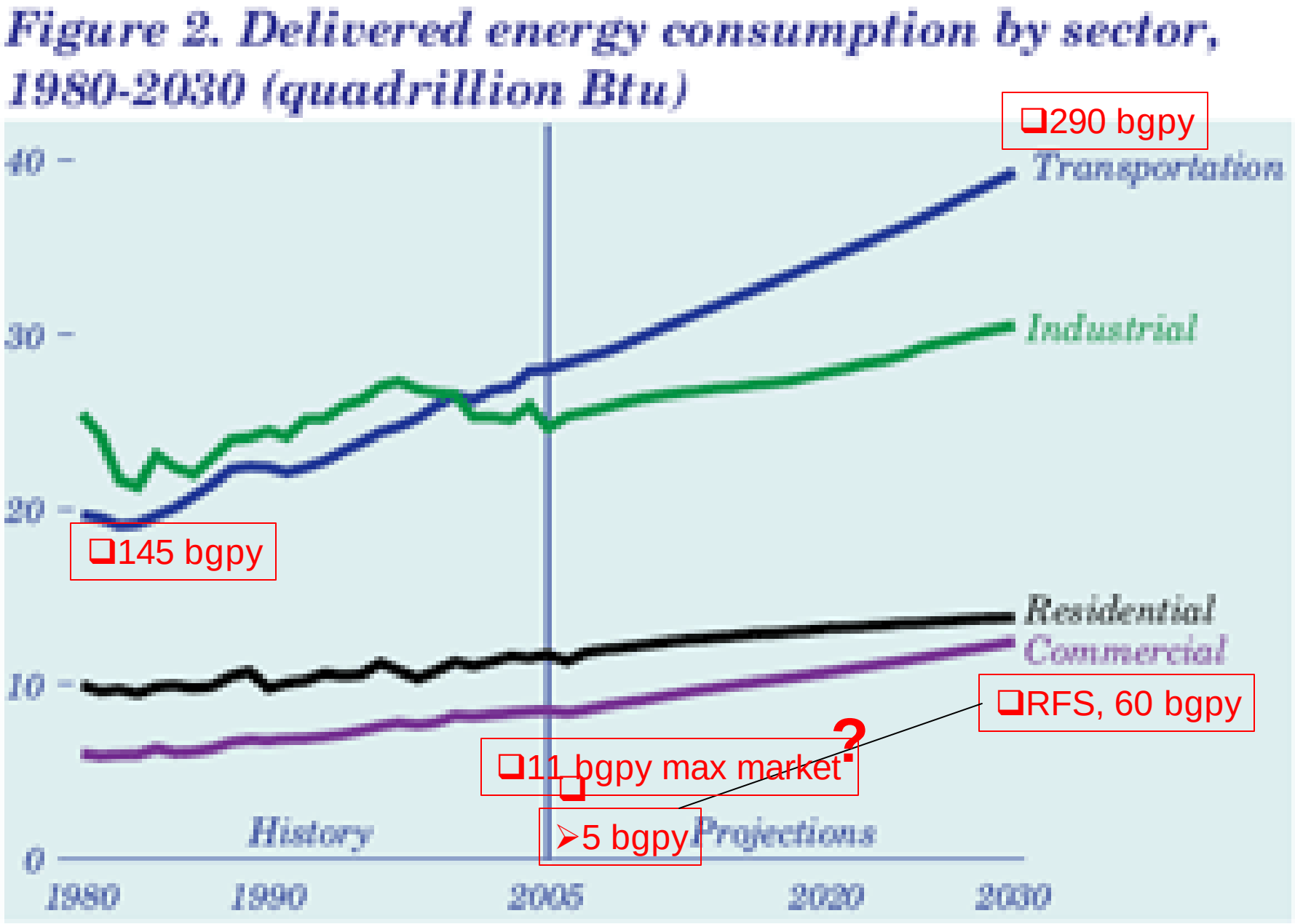
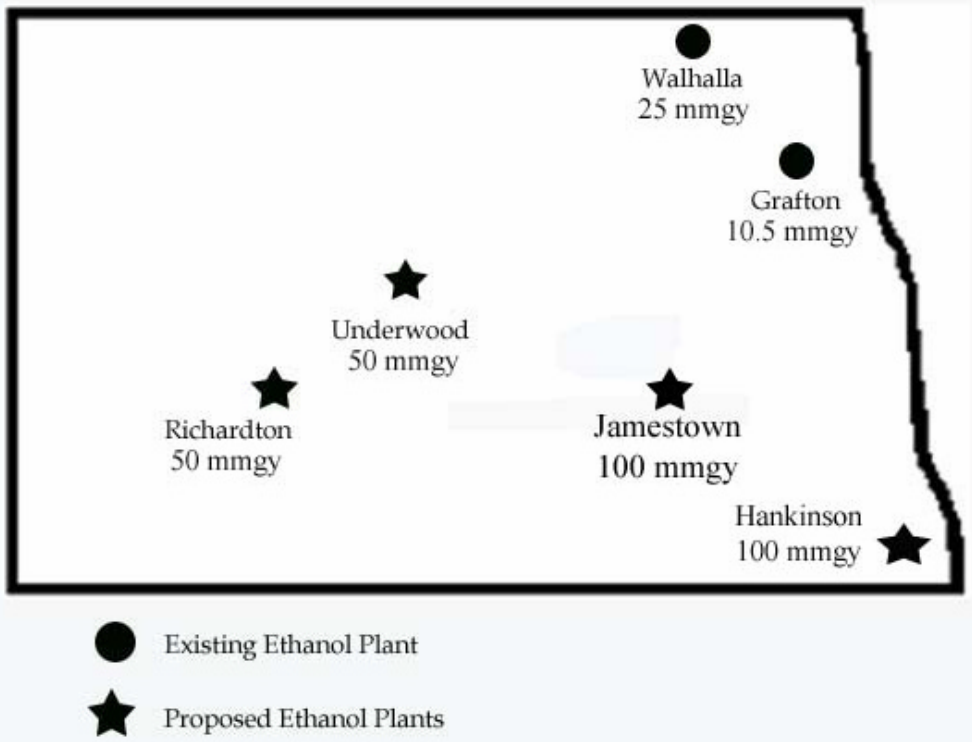


Figure 2. Delivered energy consumption by sector, 1980-2030 (quadrillion Btu)
40
30
20
10
0
Transportation
Industrial
Residential
Commercial
History
Projections
1980
1990
2005
2020
2030
❑290 bgpy
❑145 bgpy
❑RFS, 60 bgpy
❑11 bgpy max market?
❑
➢5 bgpy

Ethanol Development in North Dakota



North Dakota Department of Agriculture

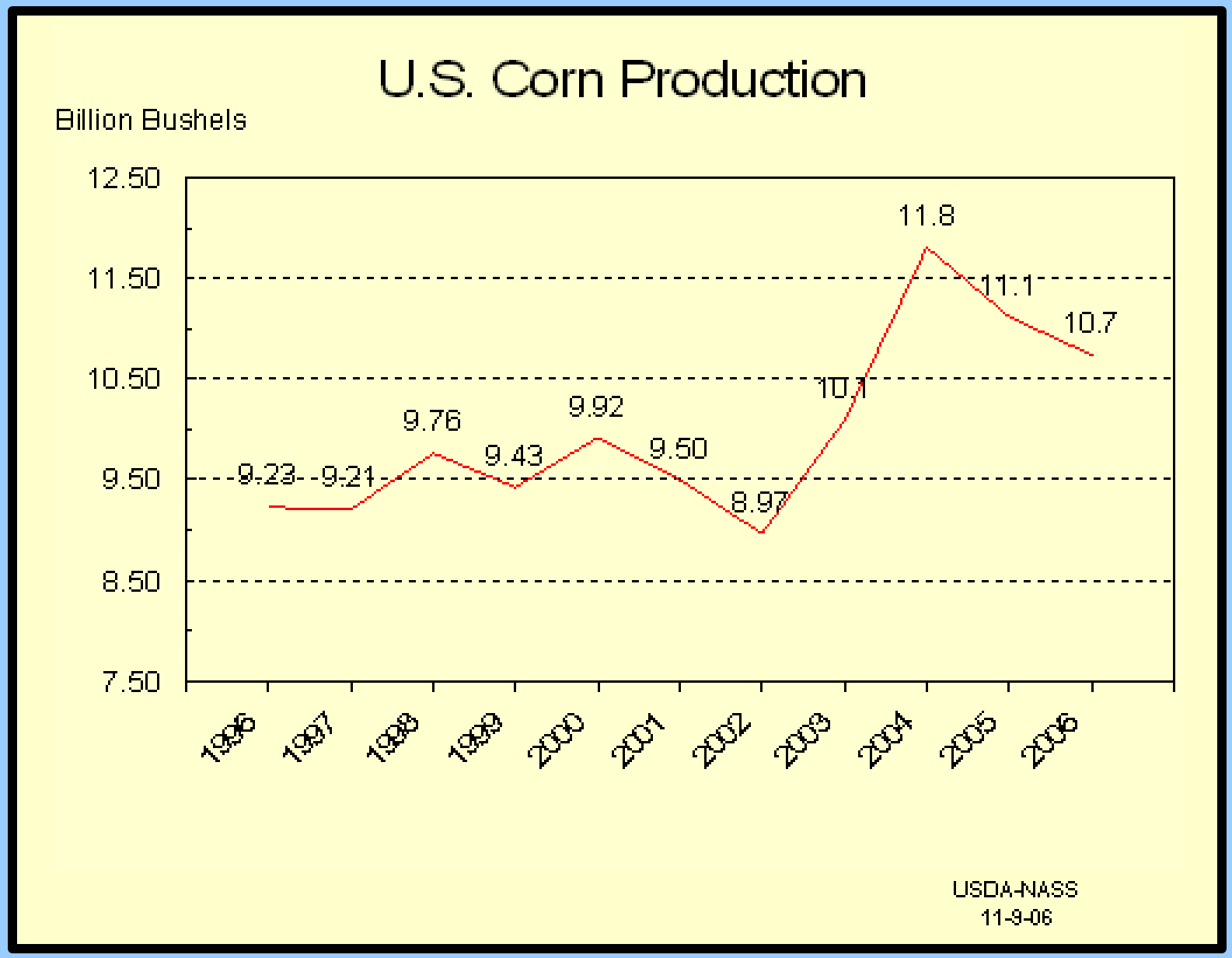
The Bioeconomy Revolution

- Bioproducts,
  - plastics, lubricants
- Biofuels
  - Ethanol from corn grain, cellulosic feedstock
  - Biodiesel from soy, other oil crops
  - Syngas, co-combustion

This revolution is rapidly changing Midwest agriculture

Ethanol

- Driven by geopolitical concerns of fuel prices, availability, and as an substitute for MTBE
- Long term political lobbying and subsidies
- Realization that fossil fuel supply is finite
- Benefits for rural economies
- Availability of a “cheap” feedstock, corn grain
- **Very high returns on investment,**
- Well developed technology, esp .for dry milling

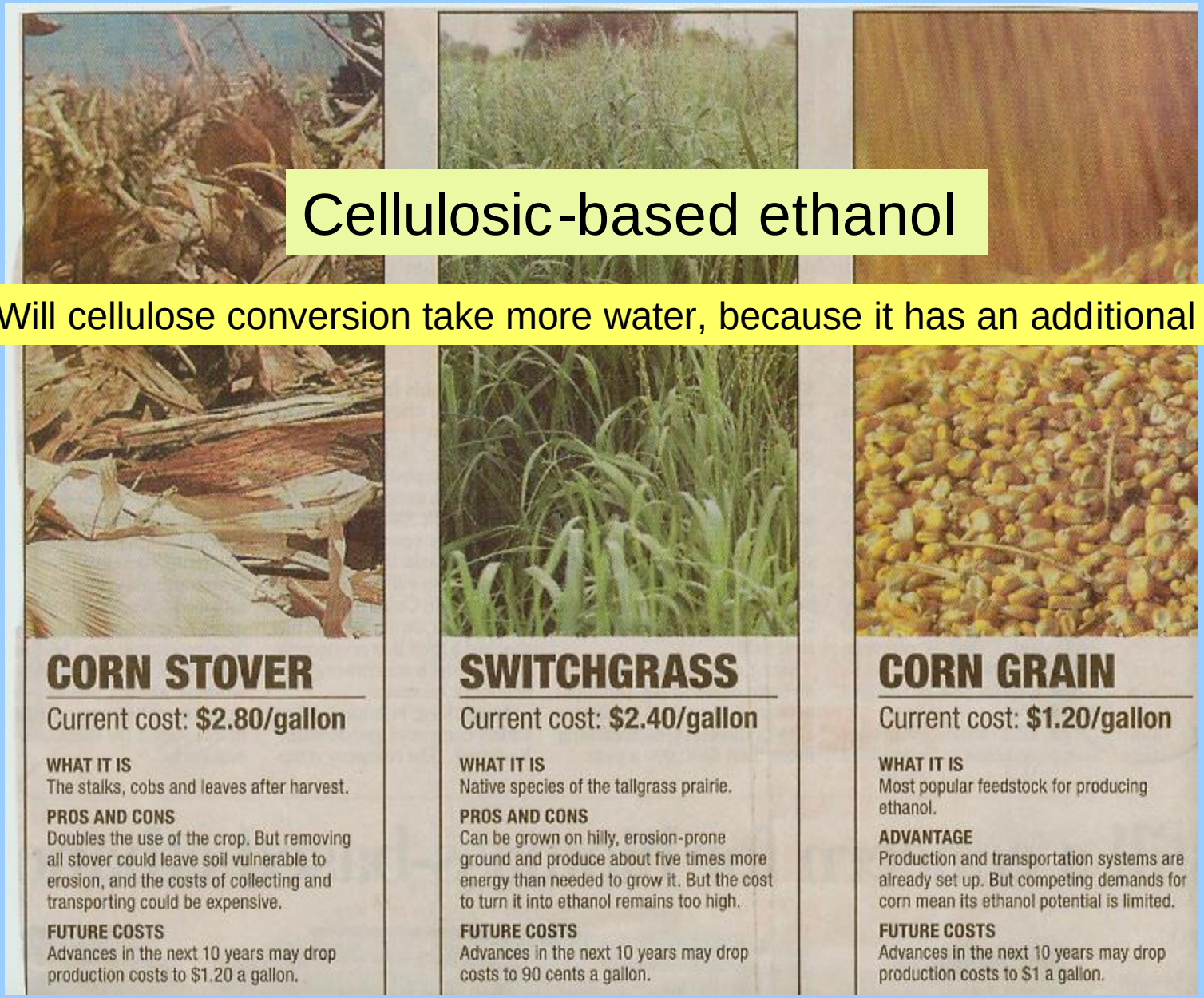

U.S. Corn Production
Billion Bushels
12.50
11.50
10.50
9.50
8.50
7.50
9.23
9.21
9.76
9.43
9.92
9.50
8.97
10.1
11.8
11.1
10.7
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
USDA-NASS
11-9-06

Consequences of expanding ethanol production from corn

- Greatly increased land in corn
- Greater dependency on one crop
  susceptible to drought, disease
- Possible loss of export markets
- Increased price, lowered availability of food,
  especially overseas
- Higher prices for processed corn and for grain for livestock
- Much higher land and input prices
- Expanded water consumption, shortages likely in some regions

Cellulosic-based ethanol

Will cellulose conversion take more water, because it has an additional step?



CORN STOVER

Current cost: **$2.80/gallon**

WHAT IT IS
The stalks, cobs and leaves after harvest.

PROS AND CONS
Doubles the use of the crop. But removing all stover could leave soil vulnerable to erosion, and the costs of collecting and transporting could be expensive.

FUTURE COSTS
Advances in the next 10 years may drop production costs to $1.20 a gallon.

SWITCHGRASS

Current cost: **$2.40/gallon**

WHAT IT IS
Native species of the tallgrass prairie.

PROS AND CONS
Can be grown on hilly, erosion-prone ground and produce about five times more energy than needed to grow it. But the cost to turn it into ethanol remains too high.

FUTURE COSTS
Advances in the next 10 years may drop costs to 90 cents a gallon.

CORN GRAIN

Current cost: **$1.20/gallon**

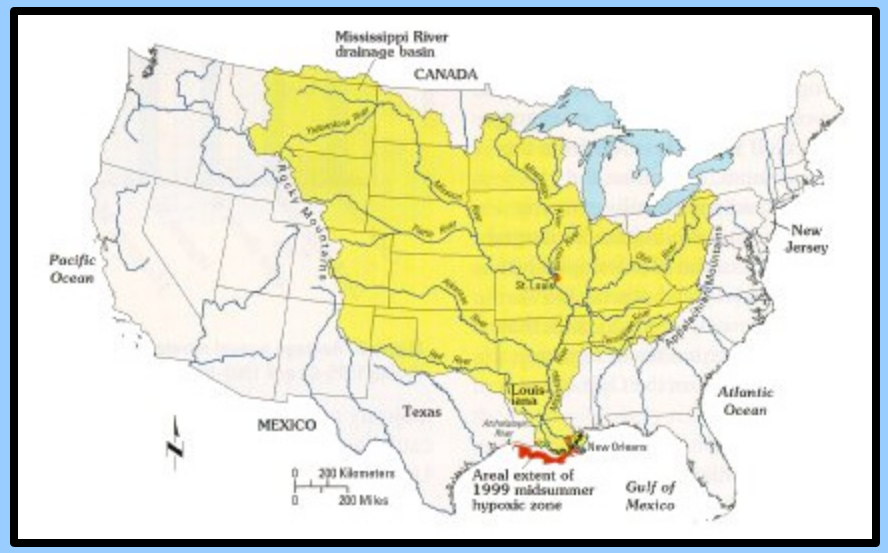
WHAT IT IS
Most popular feedstock for producing ethanol.

ADVANTAGE
Production and transportation systems are already set up. But competing demands for corn mean its ethanol potential is limited.

FUTURE COSTS
Advances in the next 10 years may drop production costs to $1 a gallon.

Water Quality

- Nitrate leaching to Gulf of Mexico
  - Conversion of CRP to corn and more continuous corn, will markedly increase N fertilizer use.

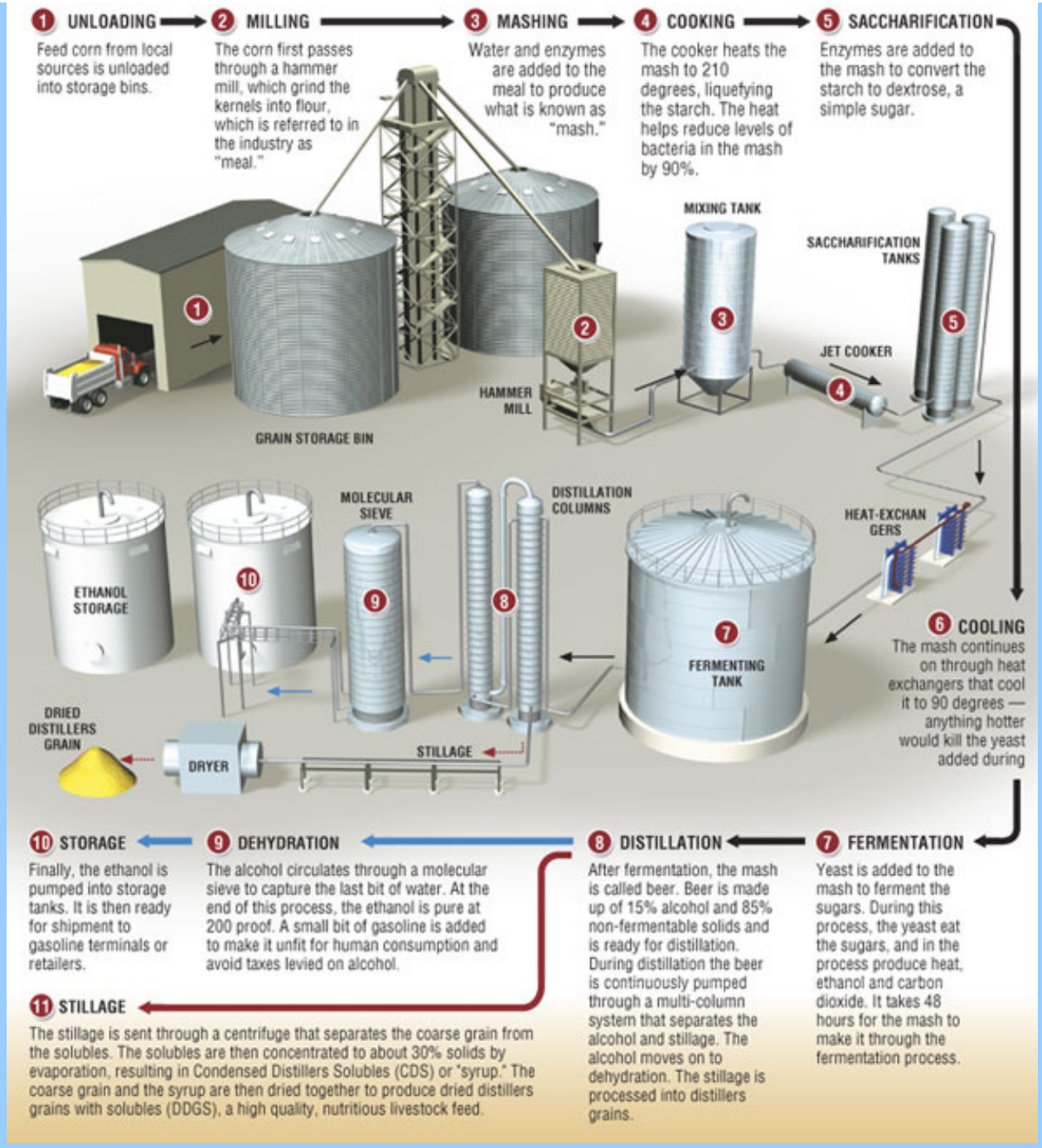


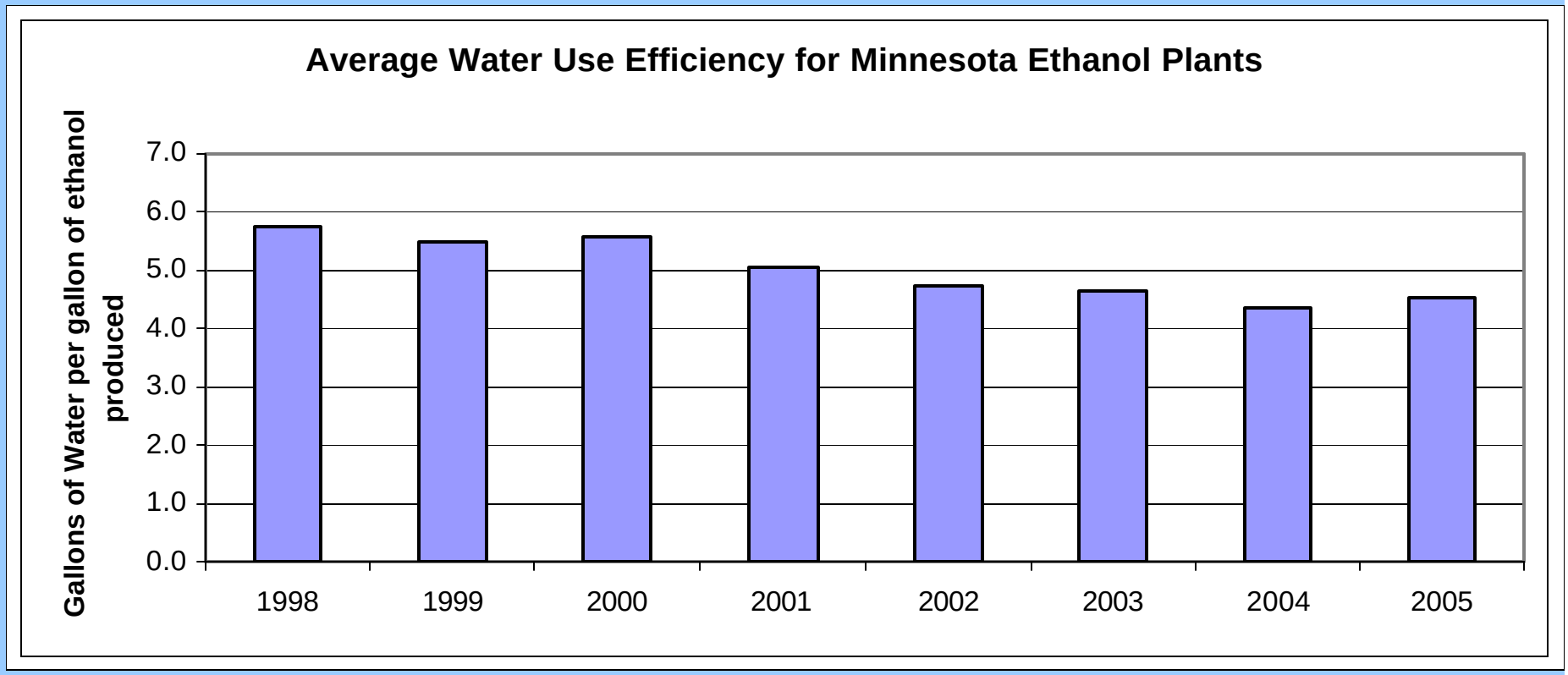
Soil erosion under row crops

- Sediment is the pollutant most affecting Iowa stream quality
- Soil loss from Iowa cultivated land averages 4.9 tons/acre/yr (USDA)
- This is equivalent to 20 pounds of soil eroded per gallon of ethanol
- Soybeans even higher, 140 lbs soil/gal
- Major concern is moving CRP land to corn in response to high corn prices

Water needs for ethanol production

- Ethanol plants consume water during various processes in the plant
  - ~4 gallons water withdraw/gallon ethanol produced
  - Cattle (beef and dairy) often close by to use DDG
  - Other development attracted to ethanol plants?
- Require high quality water, usually ground water
- Plants are located close to corn supplies, railroads, other infrastructure, not close to water
- Siting issues have developed in MN, MO, IL and KS
- Climate change indicates a trend to dryer weather, affecting both water and grain availability


1 UNLOADING
Feed corn from local sources is unloaded into storage bins.
2 MILLING
The corn first passes through a hammer mill, which grind the kernels into flour, which is referred to in the industry as "meal."
3 MASHING
Water and enzymes are added to the meal to produce what is known as "mash."
4 COOKING
The cooker heats the mash to 210 degrees, liquefying the starch. The heat helps reduce levels of bacteria in the mash by 90%.
5 SACCHARIFICATION
Enzymes are added to the mash to convert the starch to dextrose, a simple sugar.
GRAIN STORAGE BIN
HAMMER MILL
MIXING TANK
JET COOKER
SACCHARIFICATION TANKS
HEAT-EXCHANGERS
6 COOLING
The mash continues on through heat exchangers that cool it to 90 degrees — anything hotter would kill the yeast added during
7 FERMENTING TANK
8 DISTILLATION COLUMNS
9 MOLECULAR SIEVE
10 ETHANOL STORAGE
DRIED DISTILLERS GRAIN
DRYER
STILLAGE
7 FERMENTATION
Yeast is added to the mash to ferment the sugars. During this process, the yeast eat the sugars, and in the process produce heat, ethanol and carbon dioxide. It takes 48 hours for the mash to make it through the fermentation process.
8 DISTILLATION
After fermentation, the mash is called beer. Beer is made up of 15% alcohol and 85% non-fermentable solids and is ready for distillation. During distillation the beer is continuously pumped through a multi-column system that separates the alcohol and stillage. The alcohol moves on to dehydration. The stillage is processed into distillers grains.
9 DEHYDRATION
The alcohol circulates through a molecular sieve to capture the last bit of water. At the end of this process, the ethanol is pure at 200 proof. A small bit of gasoline is added to make it unfit for human consumption and avoid taxes levied on alcohol.
10 STORAGE
Finally, the ethanol is pumped into storage tanks. It is then ready for shipment to gasoline terminals or retailers.
11 STILLAGE
The stillage is sent through a centrifuge that separates the coarse grain from the solubles. The solubles are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are then dried together to produce dried distillers grains with solubles (DDGS), a high quality, nutritious livestock feed.



Reported water use by ethanol plants varies from 6:1 (Iowa, Libra) to 3:1 (industry). Most are using 4:1 Cellulosic plants could use more water

How Much Water Do We Use?

Consumed vs. Withdrawn

- **Consumptive Use is the water that is evaporated, transpired, or incorporated into a product.**
- **Water that is not returned to a source that can readily be used again. Typically discharged to a stream.**

- **Withdrawn means how much is actually removed from a stream or aquifer.**
- **Total maximum permitted withdrawals are known, but in Iowa estimates by source are over 10 years out of date.**
- **Actual withdrawals by source not adequately tracked.**

BL 2006

Groundwater is below us everywhere, but…

- **Quantity**--Is there "enough" for our purpose?
  Will it impact other users?

- **Quality**--Is it "good enough"?

- **Sustainability**--Is it dependable for the long haul?

- **Will there be "enough" in the future given periodical drought, global warming and development?**

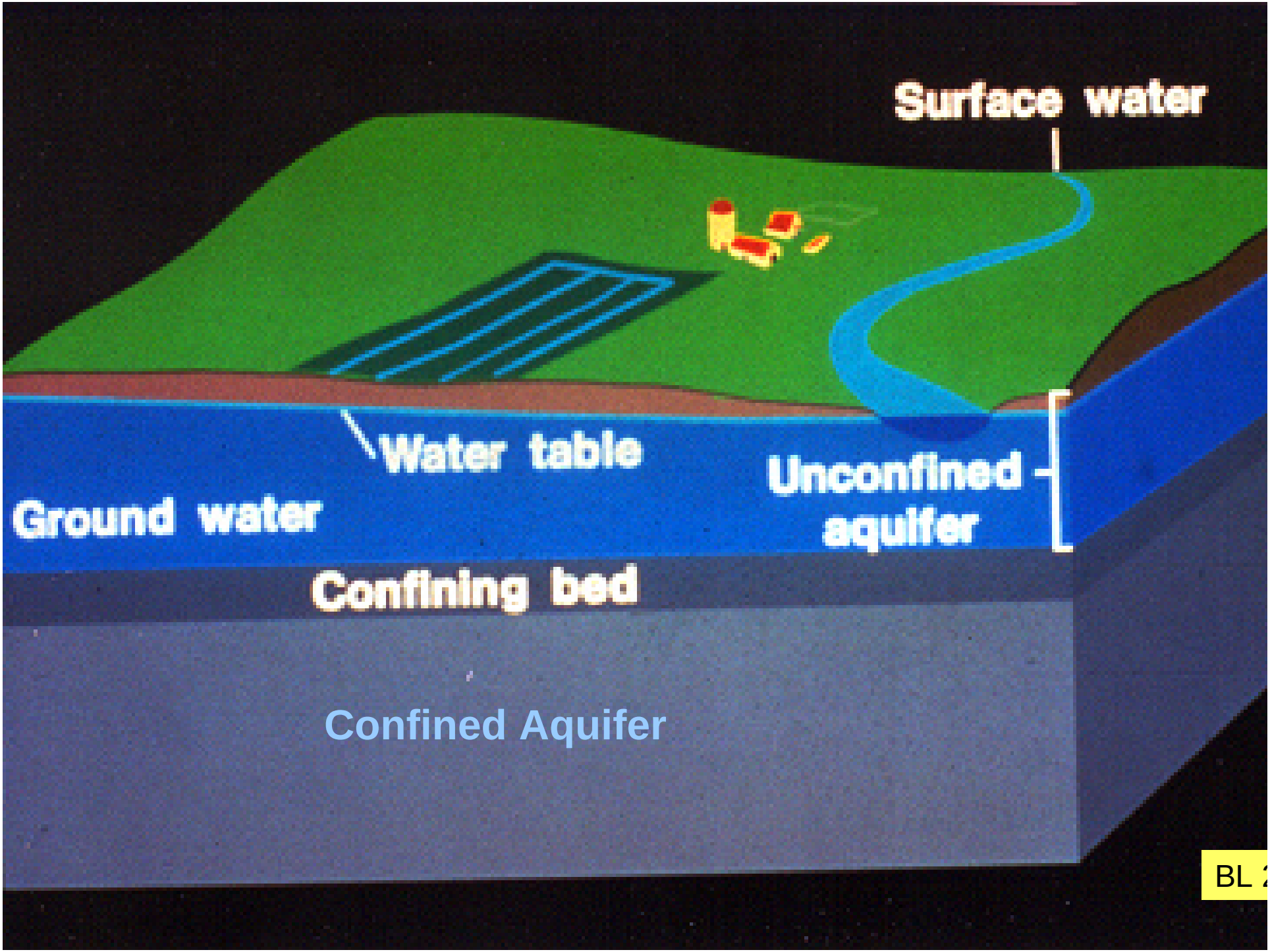
Aquifer

Zone or strata of porous earth material that yields enough water to supply wells and springs.

Confining layer

Dense, compact earth material that blocks the easy passage of water.

BI 2006


Surface water
Water table
Ground water
Unconfined aquifer
Confining bed
Confined Aquifer

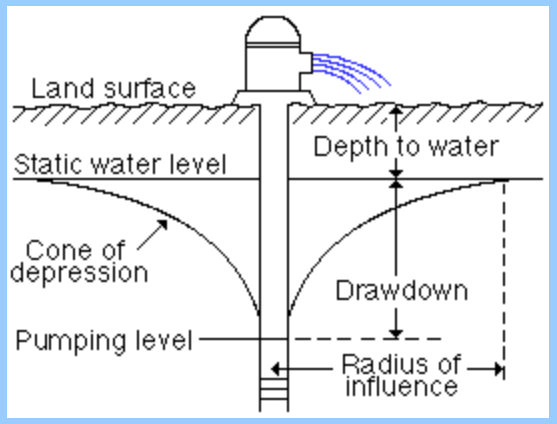
surface expression of water table

Des Moines River Van Buren Co.

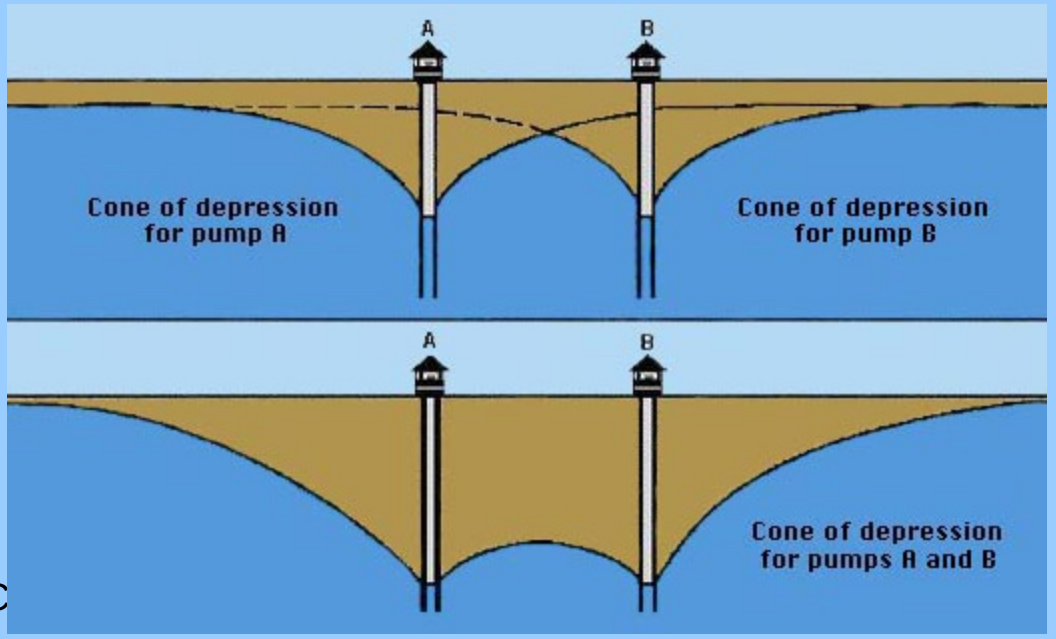
Groundwater Quantity—Well Yields

How much can the aquifer supply?

Will that withdrawal of water impact other wells?



BL 2006



RRBC

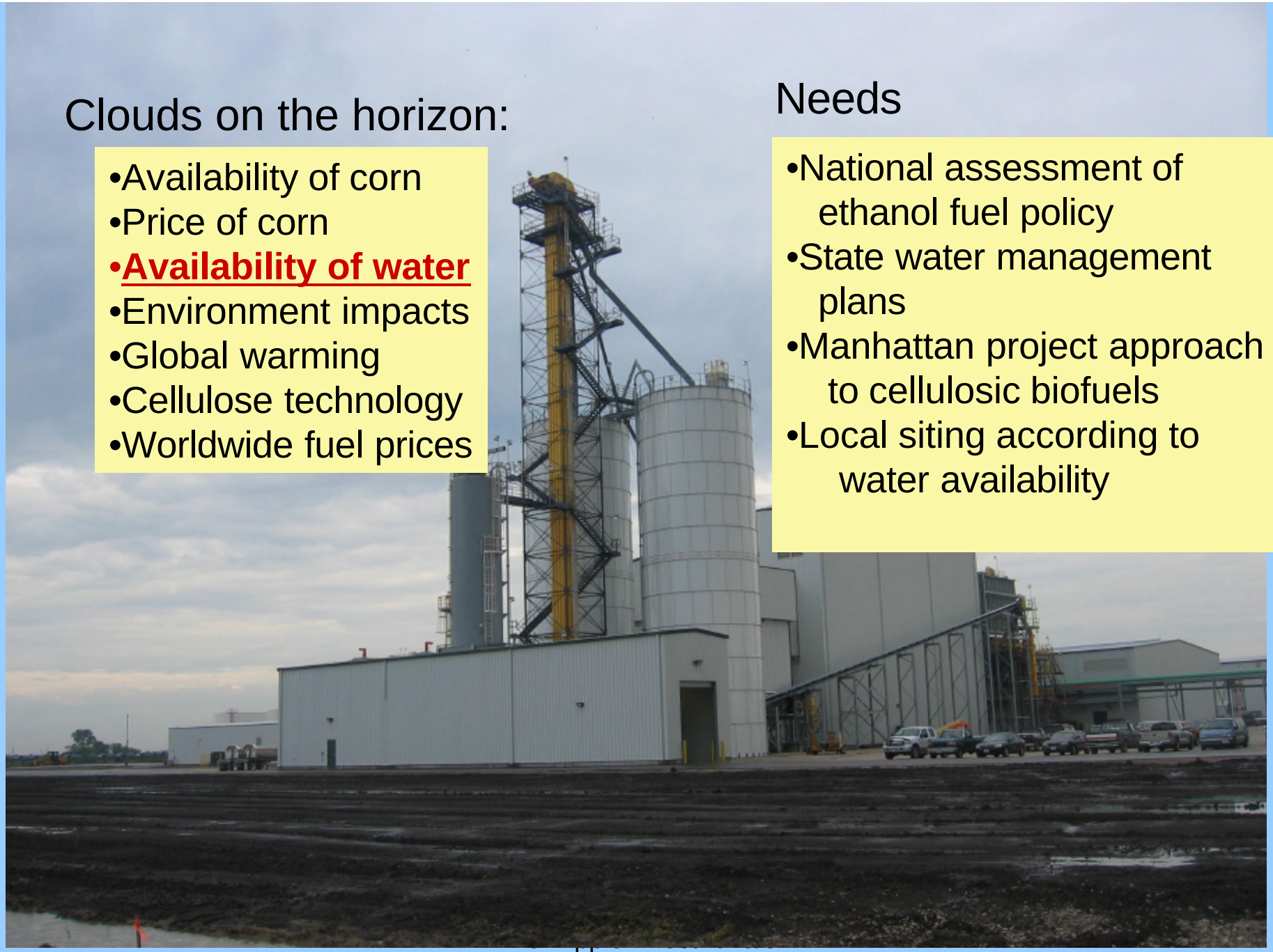
Is Ground Water Sustainable for the Long Term?

<u>Water Table (Unconfined) Aquifers (Checking Account)</u>

- **Common along streams and rivers, heavily used**
- **Readily replenished and drained**
- **Susceptible to Drought – periodically not sustainable**

<u>Confined Aquifers</u> (Investment Account)

- **Not readily replenished or drained**
- **Water can be thought of as "in storage"**
- **Drought Resistant**
- **Over-use = "Groundwater Mining" = not sustainable**
- **Deep Jordan aquifer is declining up to 3 ft/yr**



Clouds on the horizon:

- Availability of corn
- Price of corn
- **Availability of water**
- Environment impacts
- Global warming
- Cellulose technology
- Worldwide fuel prices

Needs

- National assessment of ethanol fuel policy
- State water management plans
- Manhattan project approach to cellulosic biofuels
- Local siting according to water availability