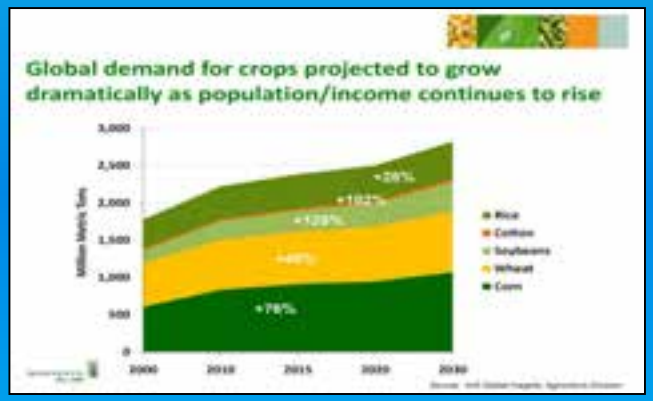
Grand Challenges For Crop Production And Irrigation



Feed the World

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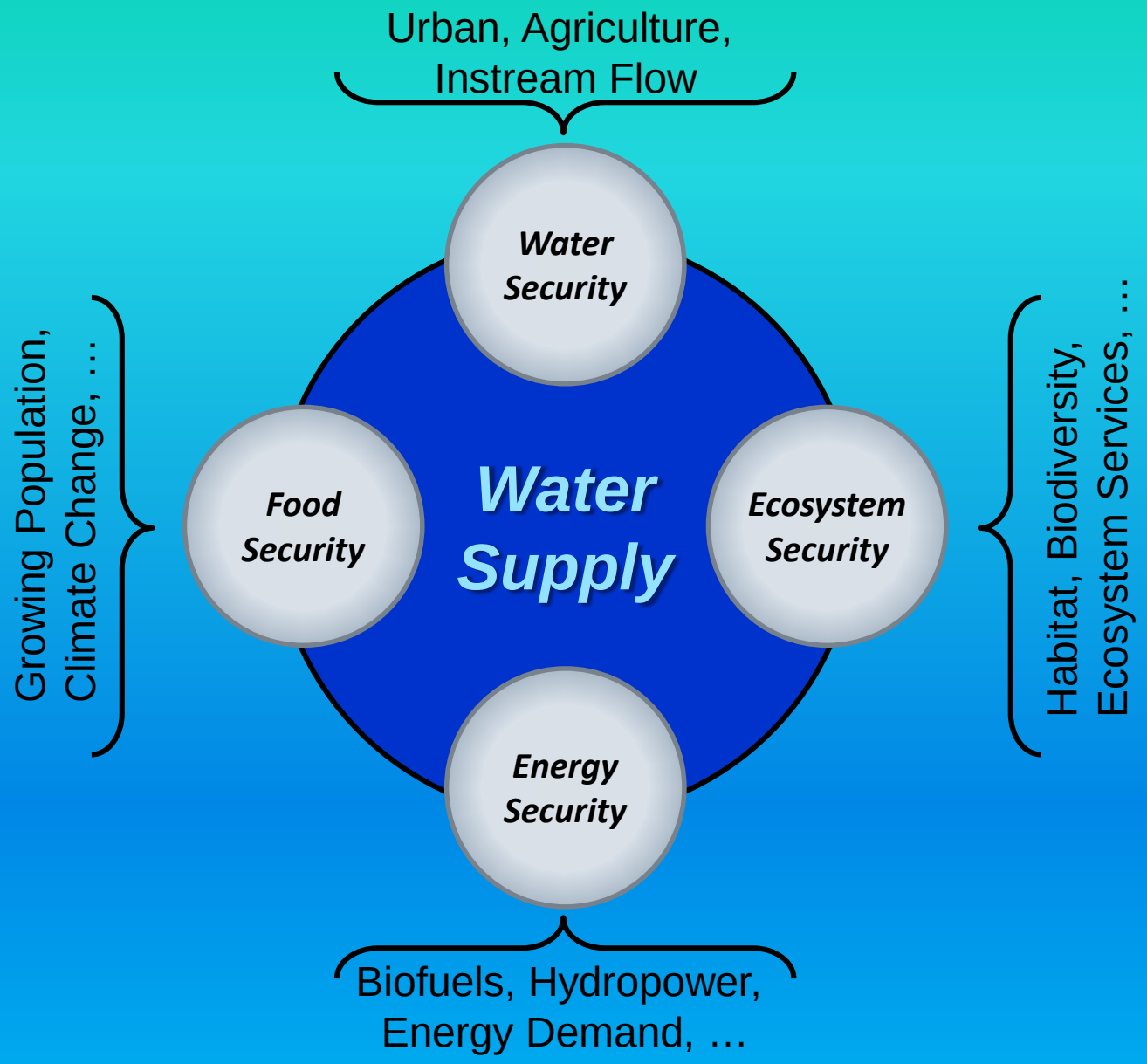
Water-Food-Energy-Environment Nexus



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What do you see in this picture?

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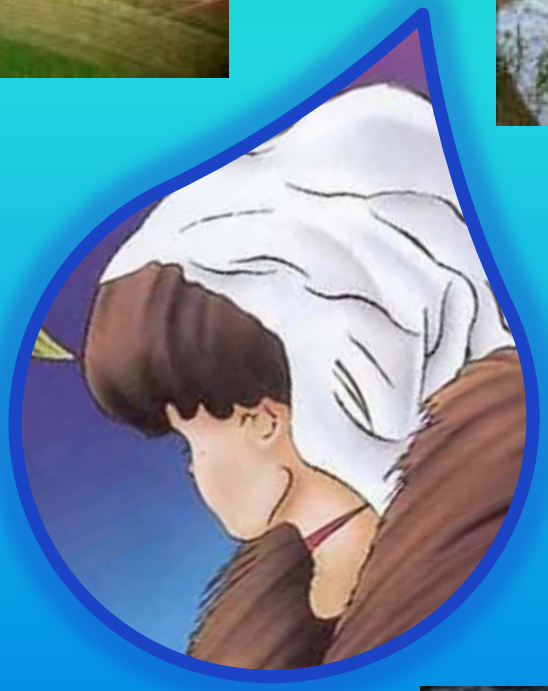

- **Many Perspectives**
- **Some of my thoughts.**

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Economic Impact of the Ability of Nebraska Agriculture to Irrigate - The Case of 2012

- **31,221** fewer jobs
- **$11.0 billion** in lower Output
- **$5.5 billion** in lower Total Value-Added
- **$3.3 billion** in lower Labor Income

Impact Type	Employment	Labor Income	Total Value-Added	Output
Direct Effect	-	($2,131,837,655)	($3,307,799,895)	($7,083,745,522)
Indirect Effect	(13,550)	($529,417,314)	($1,070,608,174)	($1,938,585,249)
Induced Effect	(17,672)	($643,189,735)	($1,150,415,492)	($1,947,118,568)
Total Effect	(31,221)	($3,304,444,704)	($5,528,823,562)	($10,969,449,338)

Prepared For: Nebraska Farm Bureau

Prepared By: Decision Innovation Solutions

November 16, 2012

Drought Year
Good Commodity Prices
Probably Higher Impact than Normal

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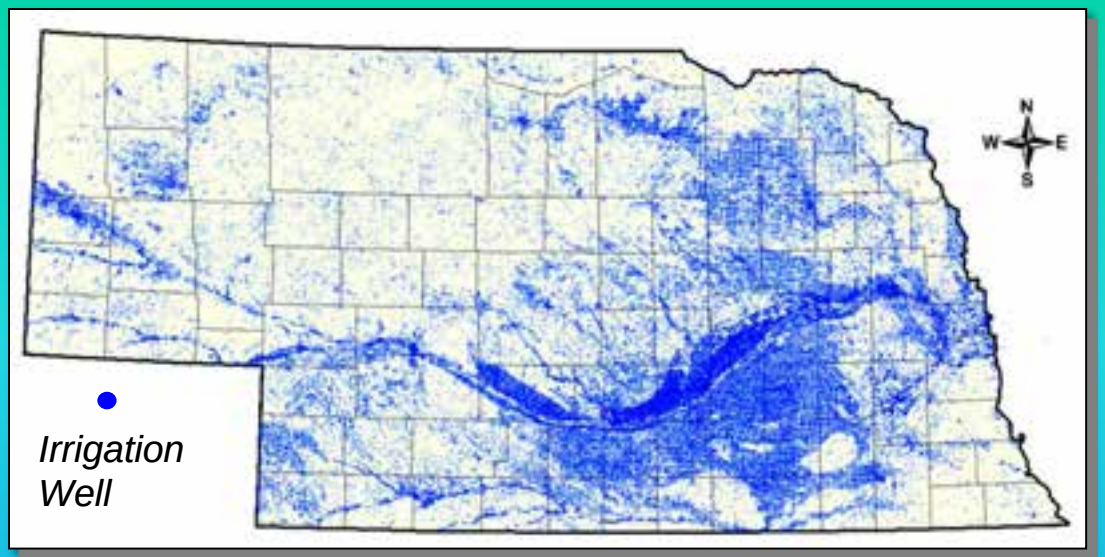
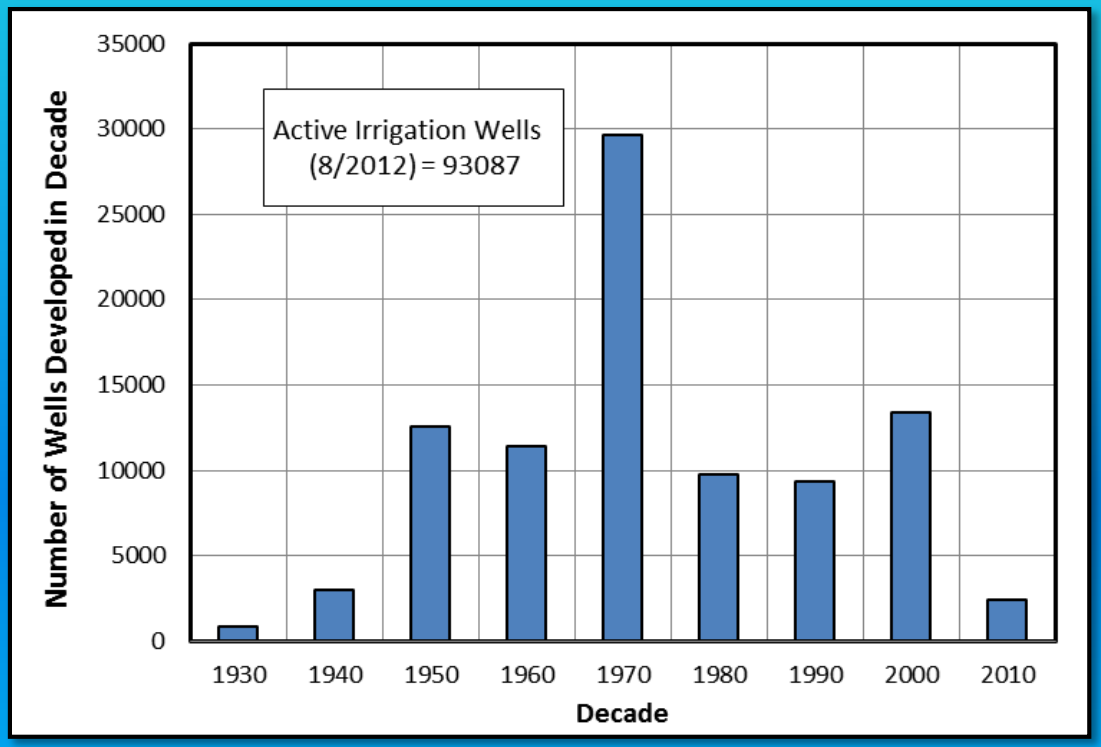
Irrigation Development

Active Irrigation Wells
~ 93,000
$6-8 Billion Investment

Major development occurred in 70's, but growth continues at about 2000 wells per year





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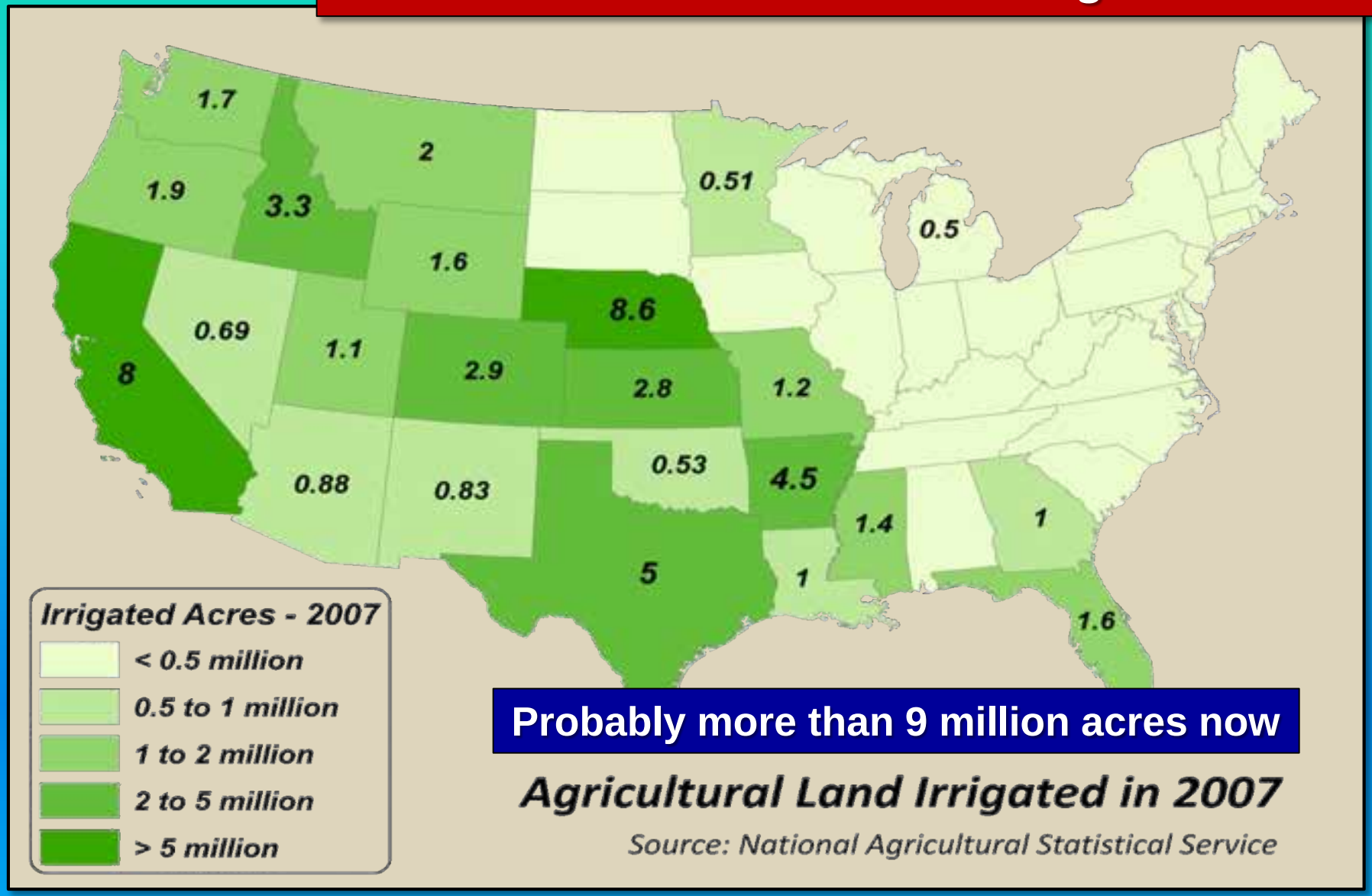
- 16% Of National Irrigated Land Is In Nebraska
- 90% Of Water Withdrawal Is For Irrigation



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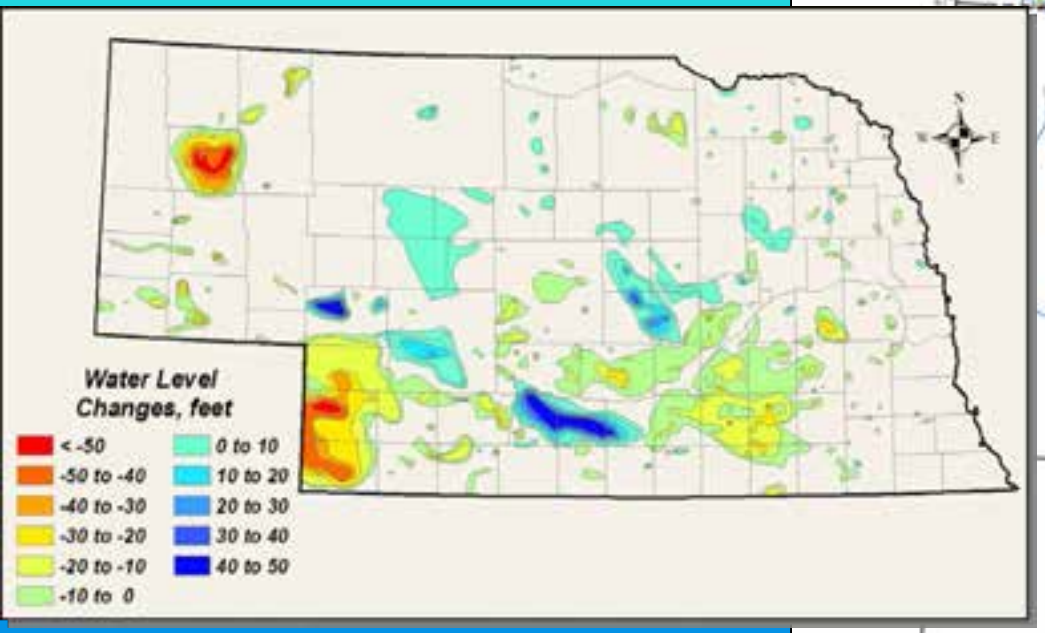
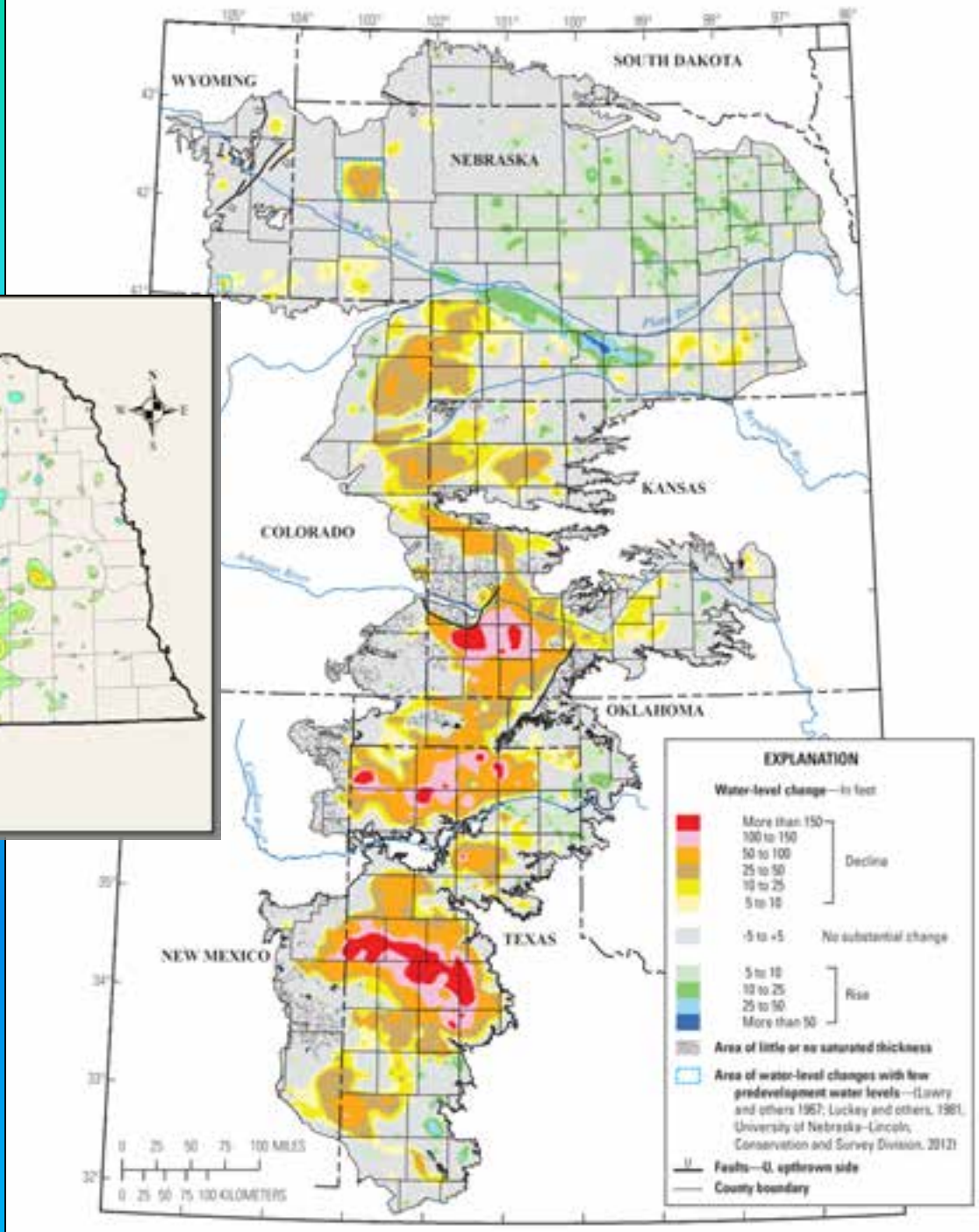
Groundwater Level Changes Since Predevelopment





Aquifer Going Dry??

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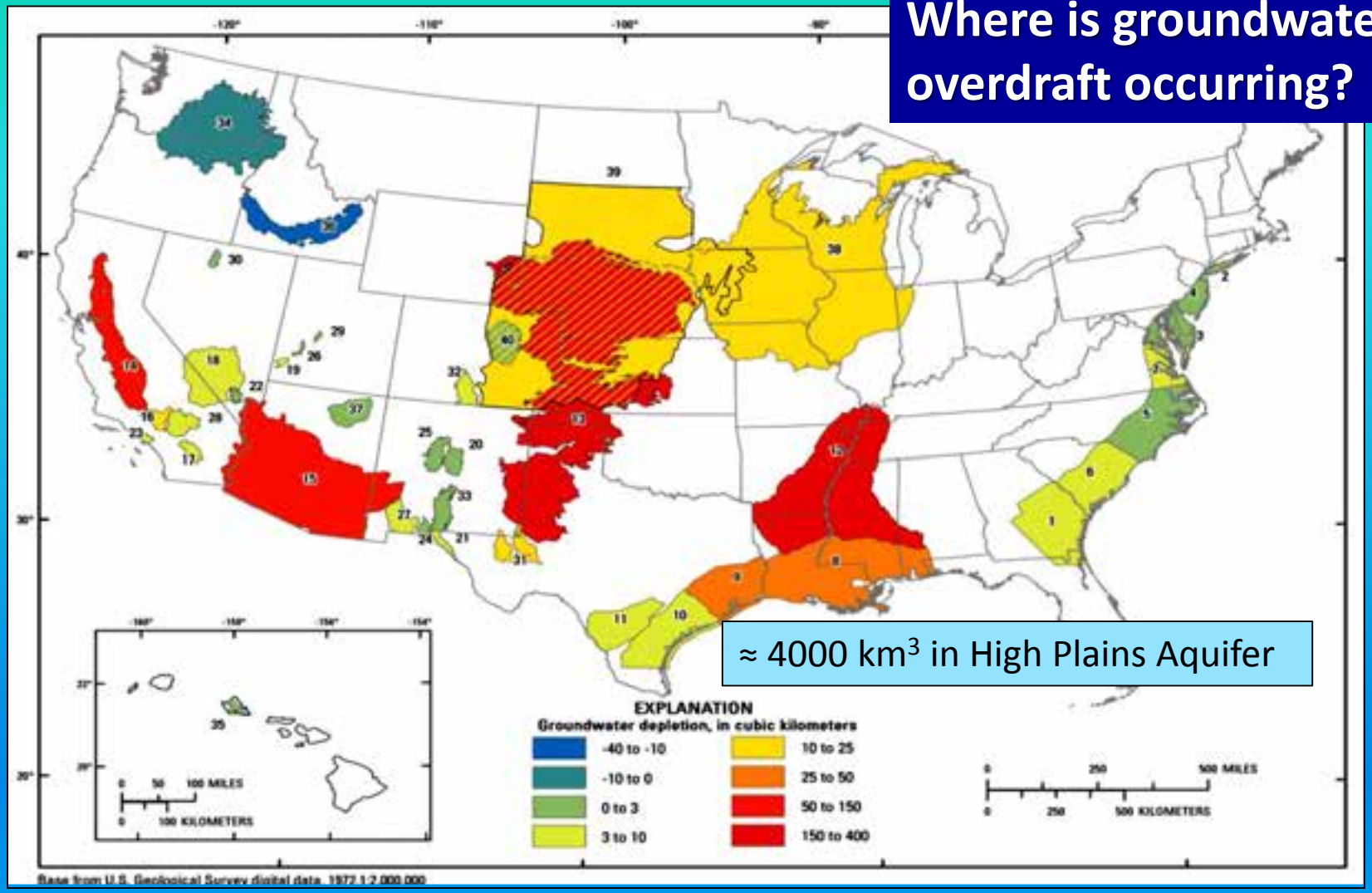
Cumulative Groundwater Depletion 1900 Through 2008

Where is groundwater overdraft occurring?



≈ 4000 km^3 in High Plains Aquifer

Konikow, L.F., 2013, Groundwater depletion in the United States (1900–2008): U.S. Geological Survey Scientific Investigations Report 2013–5079, 63 p., http://pubs.usgs.gov/sir/2013/5079.

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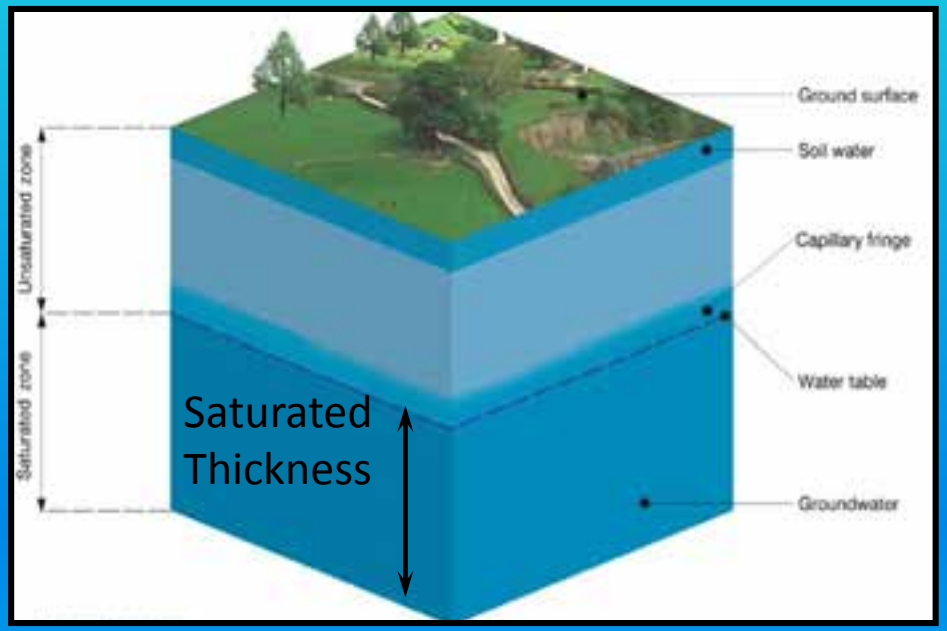
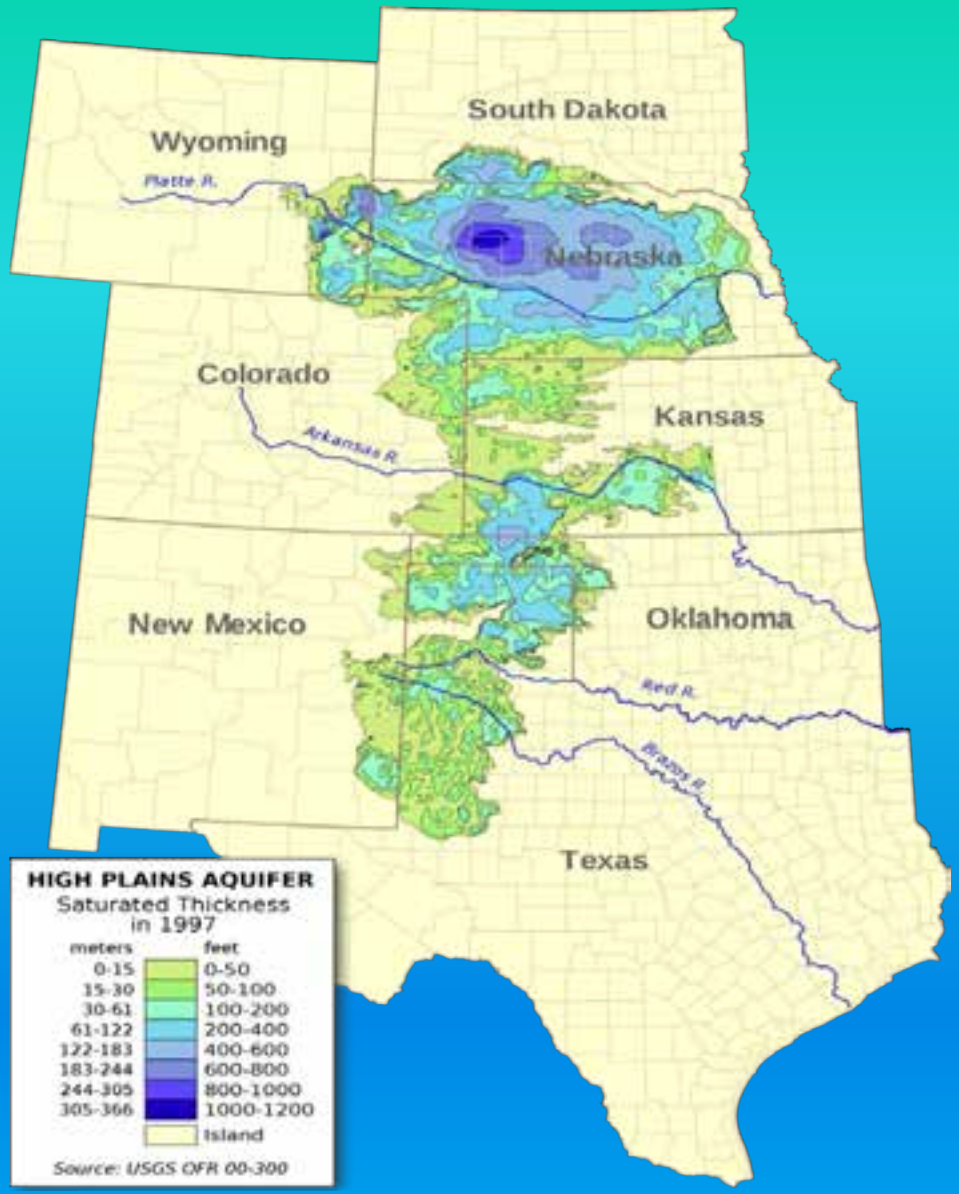
Saturated Thickness of Aquifer Defines Volume of Water Available





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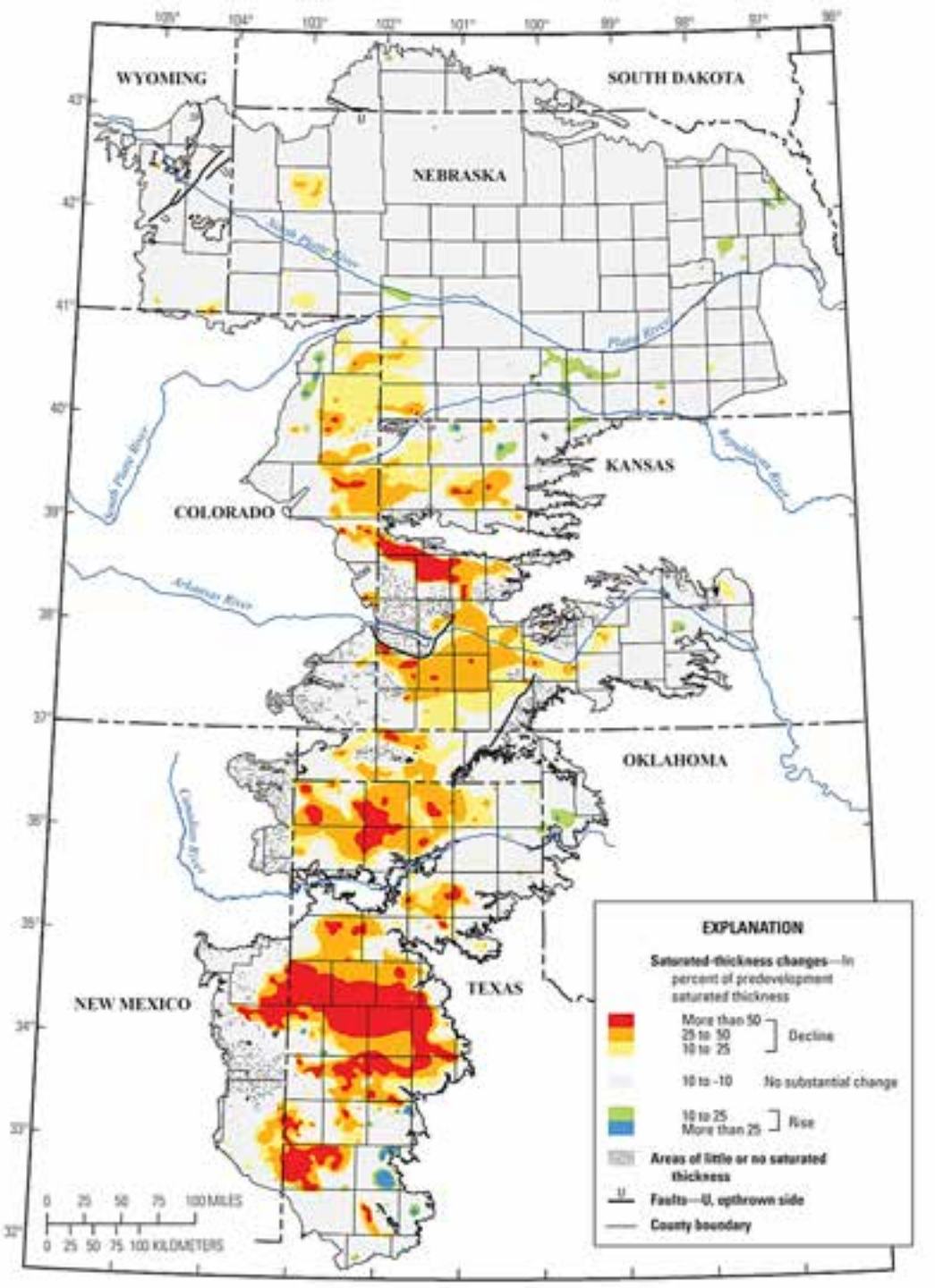
Depletion as Fraction of Saturated Thickness of the Aquifer

(McGuire , 2011)

Depletions in southern High Plains > 50% of saturated thickness

Small area in Nebraska > 25% of saturated thickness

Aquifer Going Dry??



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Characteristics of the High Plains Aquifer (McGuire, 2009)

State	Percent of total aquifer area, %	Average area-weighted saturated thickness in 1980, ft	Volume of drainable water in storage in 1980, million ac-ft	Portion of H.P. Aquifer Drainable Water in State (1980), %	Change in Storage from ~ 1950 to 2007, million ac-ft	2007 Aquifer Depletion as Percent of 1980 Storage
CO	8.6	79	120	3.7%	-17.4	14.5%
KS	17.5	101	320	9.8%	-63	19.7%
NE	36.6	342	2,130	65.5%	-21.4	1.0%
NM	5.4	51	50	1.5%	-10.3	20.6%
OK	4.2	130	110	3.4%	-12.2	11.1%
SD	2.7	207	60	1.8%	-0.6	1.0%
TX	20.4	110	390	12.0%	-140.1	35.9%
WY	4.6	182	70	2.2%	-2.3	3.3%
Total	100	190	3,250		-267.5	8.2%

Drainable Water in NE ≈ Half of Volume of Lake Michigan

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Changes in High Plains Aquifer (1950 - 2011)

State	Area-Weighted Water-Level Change, feet	Change In Water Storage, millions acre-feet
Colorado	-12.9	-14.8
Kansas	-23.5	-58.2
Nebraska	0.7	1.1
New Mexico	-15.2	-8.2
Oklahoma	-11	-7.5
South Dakota	1.9	0.2
Texas	-38.9	-136.5
Wyoming	-1.1	-0.7
High Plains Aquifer	-13.9	-224.6

60% of Total Volume Depleted in Texas & 26% in Kansas

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McGuire, V.L., 2013, Water-level and storage changes in the High Plains aquifer, predevelopment to 2011 and 2009–11: U.S.G.S. Scientific Investigations Report 2012–5291. (http://pubs.usgs.gov/sir/2012/5291/.)

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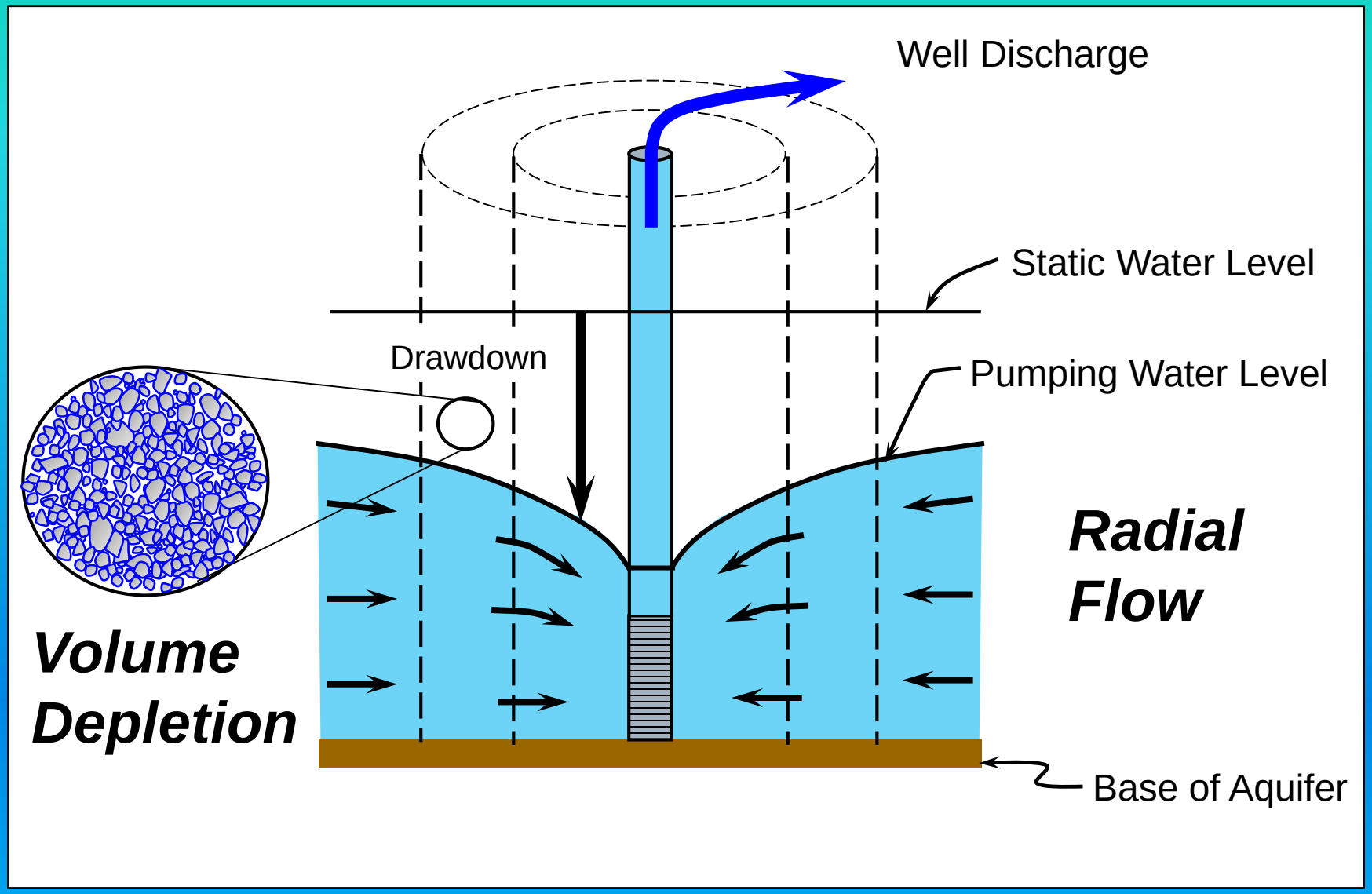
Pumping From An Unconfined Aquifer

Where does the water come from?



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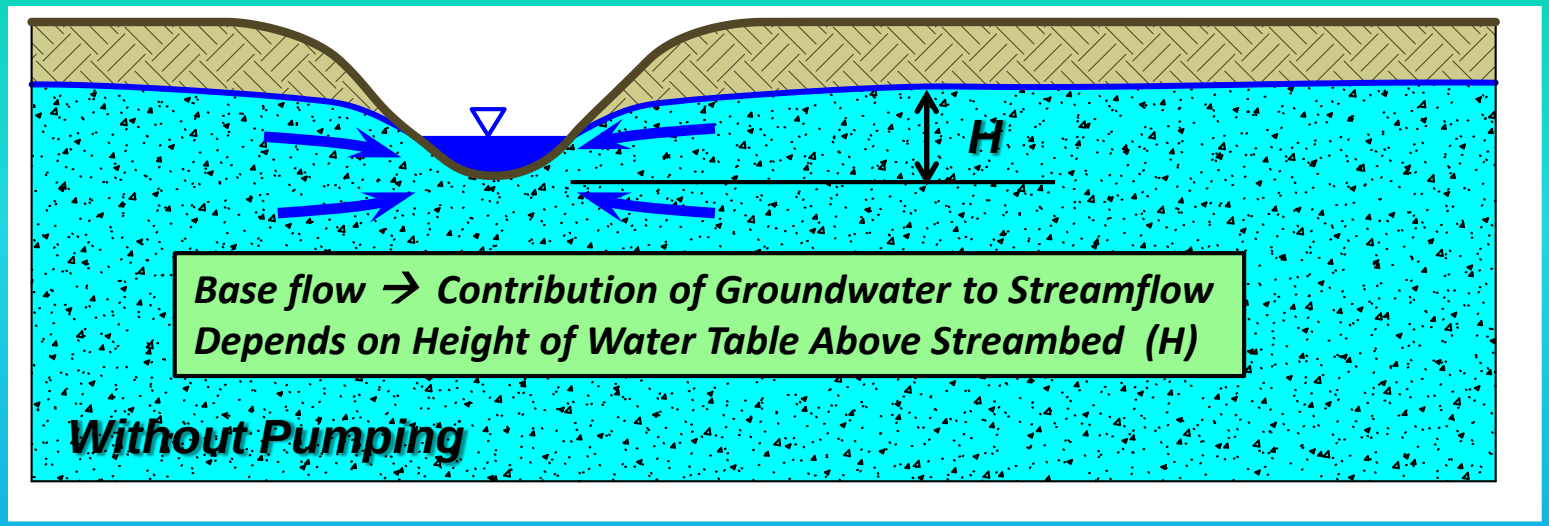
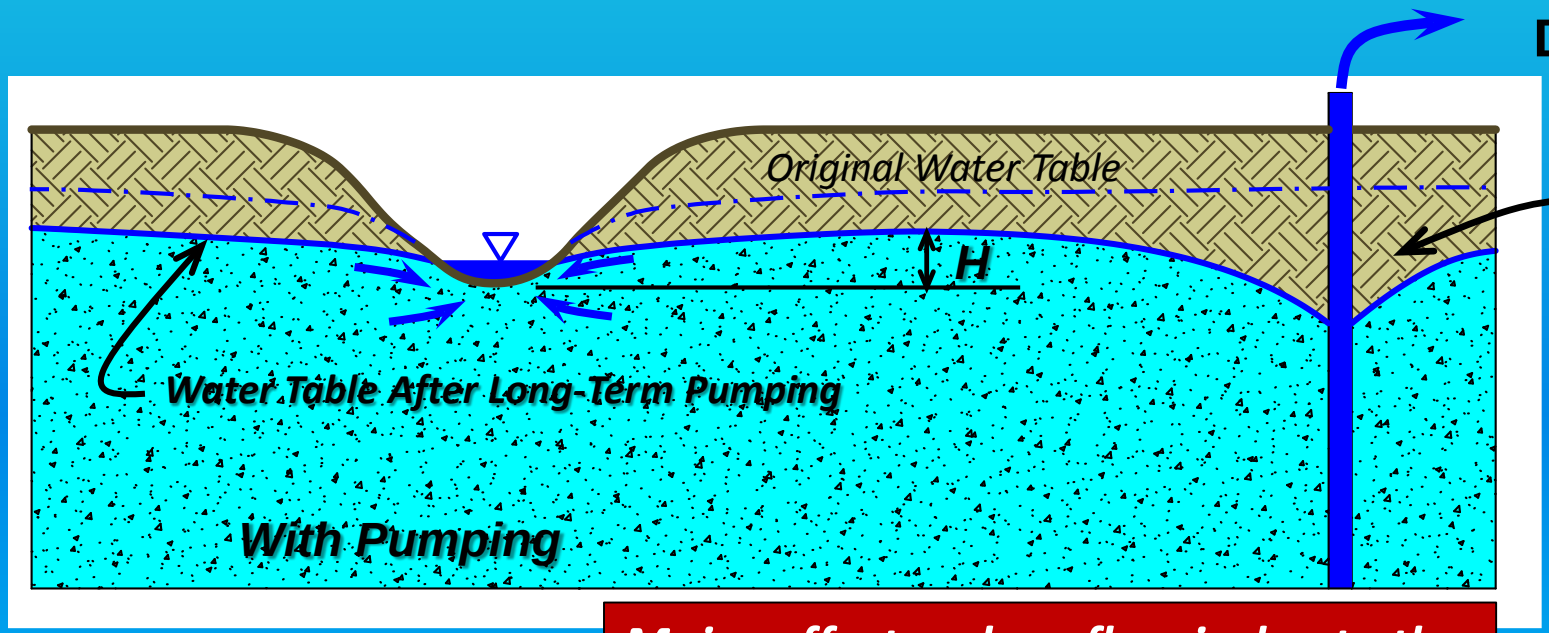
Affect of Pumping on Stream Flow





Major affect on baseflow is due to the drop of the static water level.

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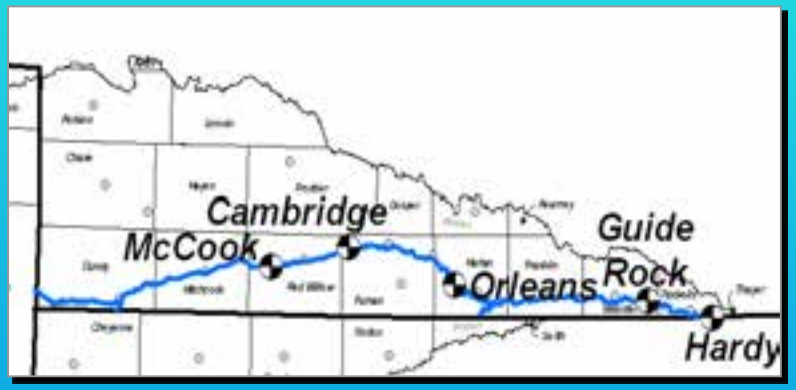
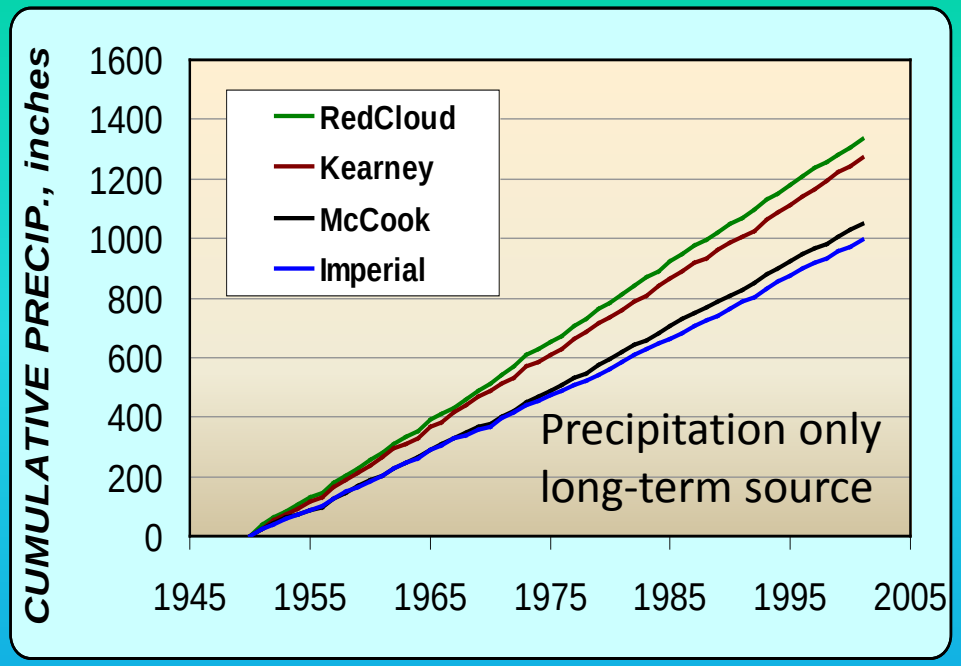
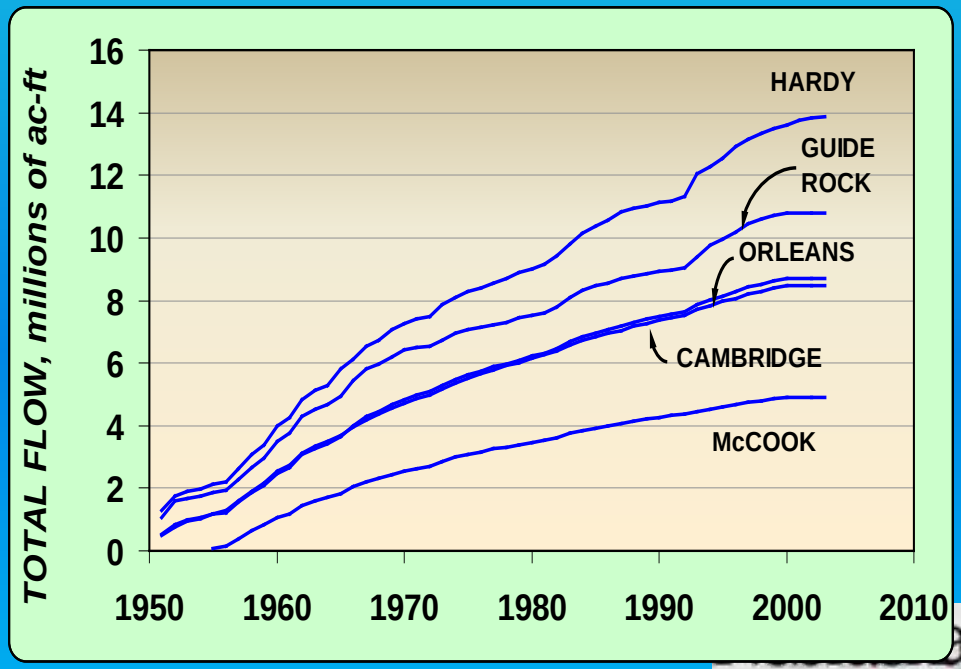
Cumulative Flow Changes in Republican River Basin





- No change in precipitation trend
- Decreasing portion of precipitation as streamflow
- Not all impact is due to irrigation, other land use practices influence outflow
- Need methods to assess all changes



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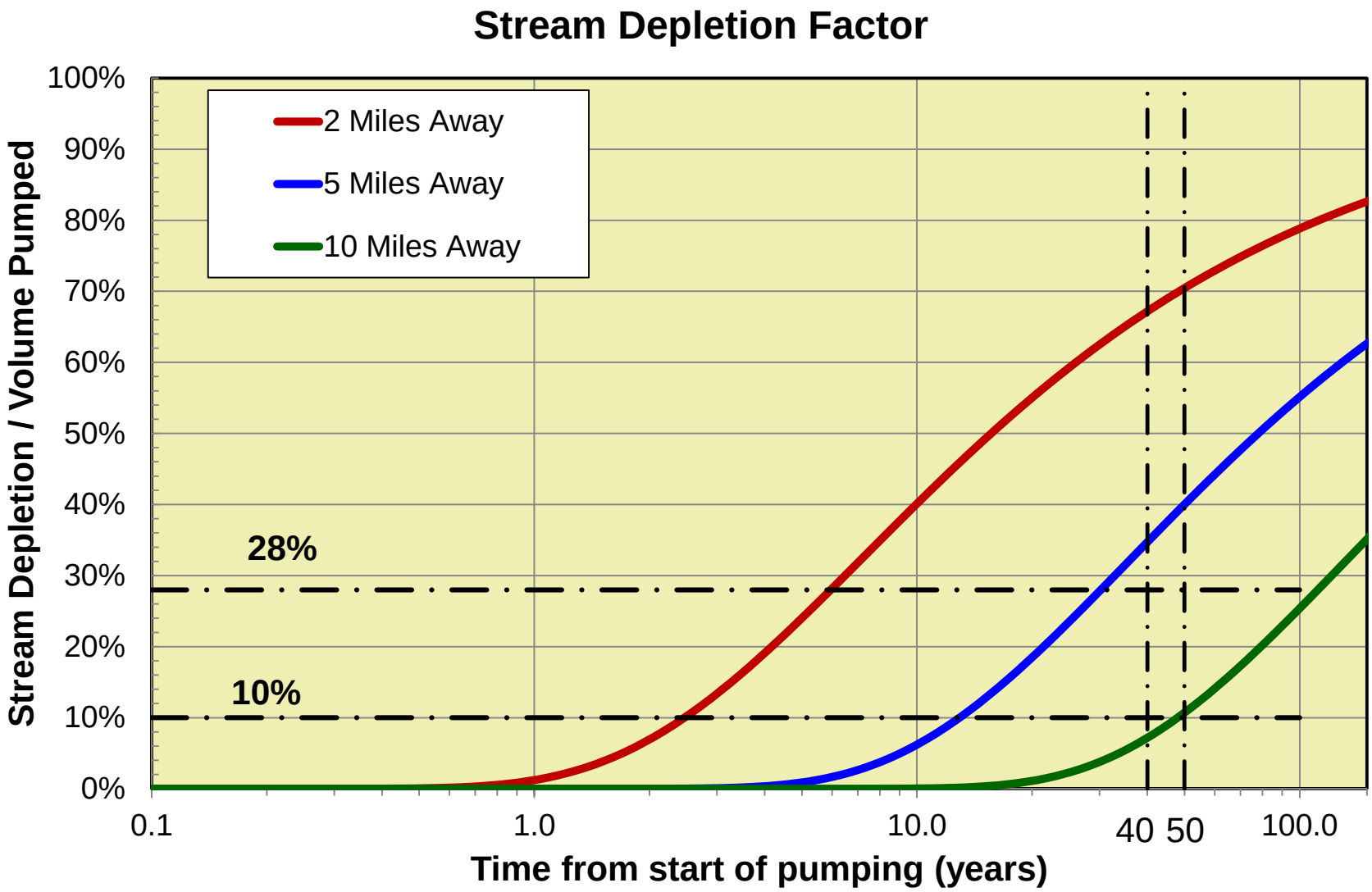

Impact today resulted from past actions, maybe decades ago

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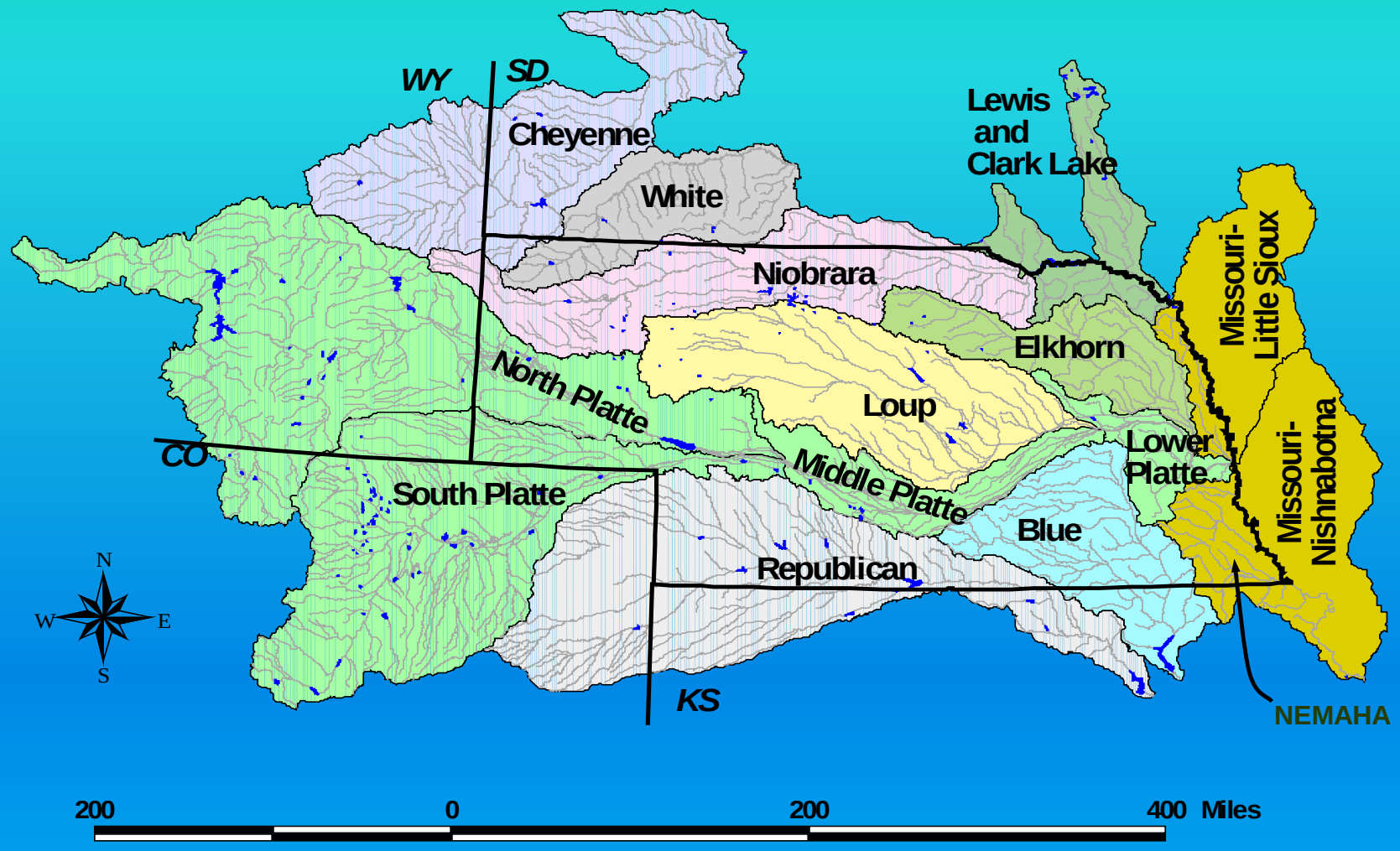
Shared Watersheds Exacerbates Conjunctive Management

Maintenance of Instream Flow is **THE** Issue for Downstream State/User



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Endangered/Threatened Species → Big Instream Demand
Flows for Non-Threatened Species May Also Increase

Colored watersheds are affected by endangered or threatened species

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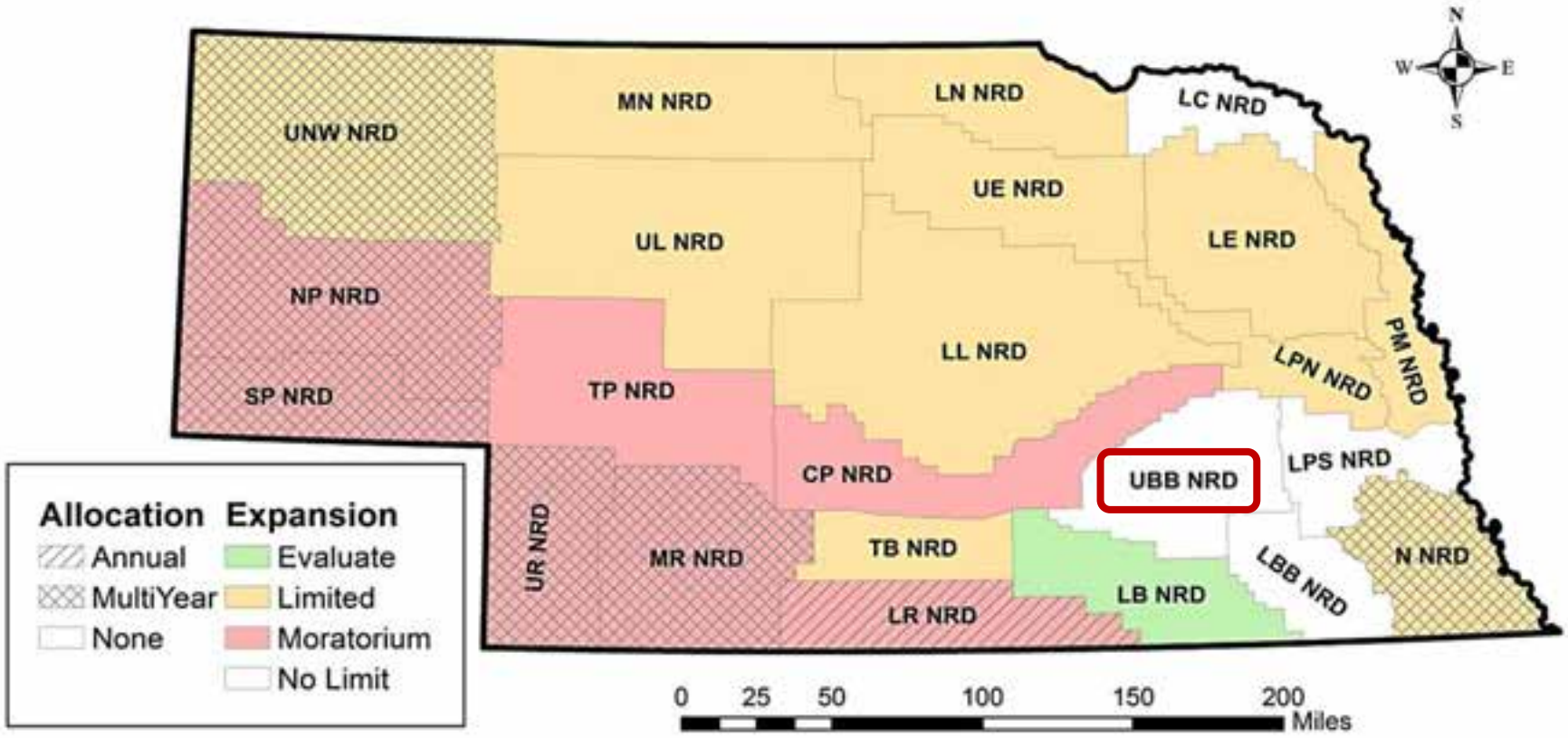
Water Control Programs in Nebraska



- Allocation Programs Limit Volume of Pumpage Over a Period of Time
- Expansion Limits Restrict Development of New Wells or New Irrigated Areas
- Upper Big Blue Considering Allocation Program
- Other Western States Have Similar Issues/Programs

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- ***Nebraska energy use for irrigation - 2007***
  - ***Approximately 8.6 million irrigated acres***
  - ***Use about 40 gallons of diesel fuel per acre per year***
- ***About 1/3 of wells use diesel engines to lift and pressurize water***
- ***If all land was irrigated with diesel powered engines:***
  - ***About 340 million gallons of diesel fuel per year***
  - ***@ $3/gallon > $ 1 billion per year for diesel fuel***
- ***One of the largest uses of energy in agriculture***

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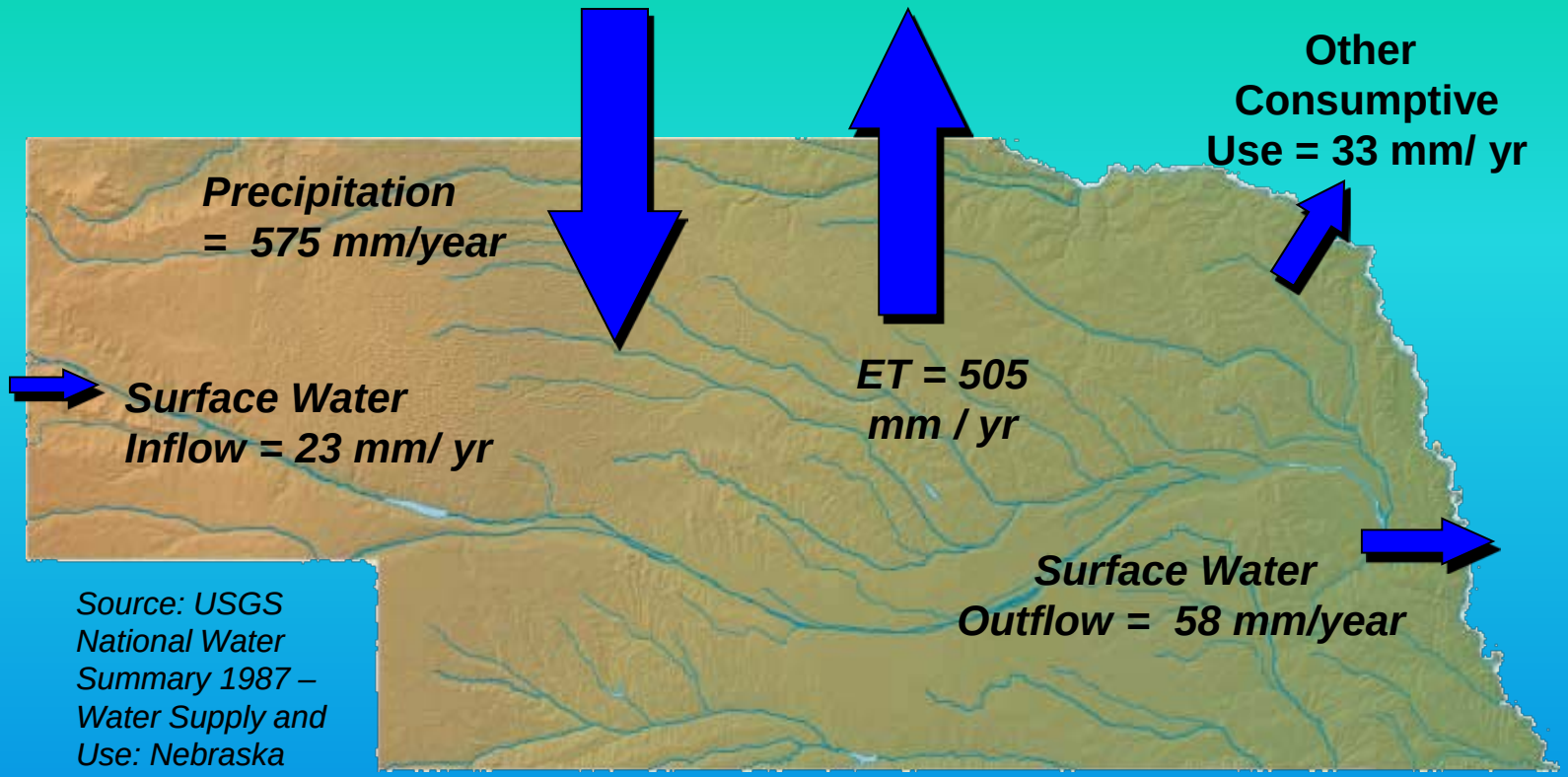
Nebraska's Water Supply (average conditions)



Source: USGS National Water Summary 1987 – Water Supply and Use: Nebraska

~ 88% of Precipitation Goes to Evapotranspiration

~ 6% of Precipitation Goes to Increased Stream Flow

~ 8% of Evapotranspiration due to Irrigation

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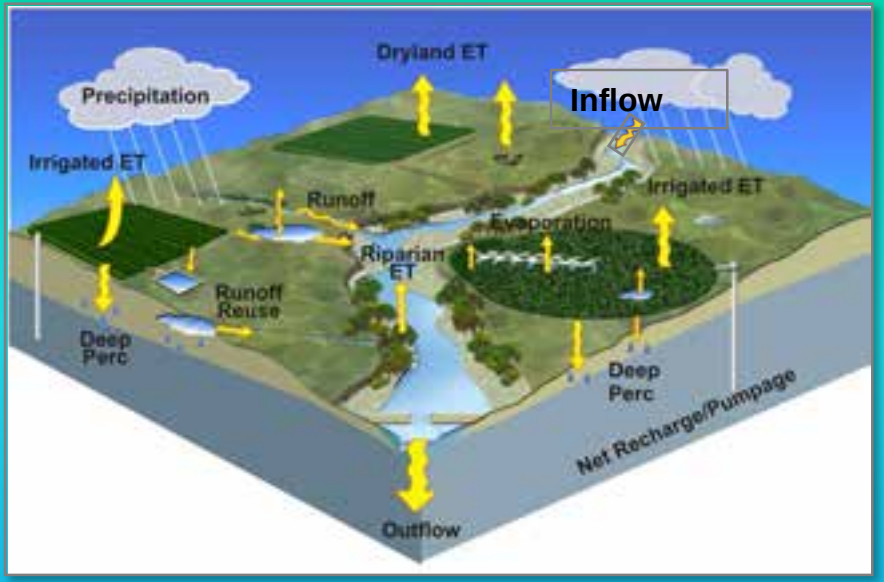
Irrigation Sustainability
vs
Sustainable Development

Seems simple but there are many questions and unintended consequences.



1. **What to sustain, economy, ecosystems, …?**
2. **Balance upstream (rural) opportunity vs downstream thirst?**
3. **What to do with ground water?**
4. **What management timeframe?**
5. **Property rights versus "Community" good?**
6. **Define "Adaptive Management" strategy and benchmarks?**
7. **Need a systematic approach that is well conceived.**

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Activities Affecting Watersheds

- Groundwater Pumpage
- Farming Practices – Reduced Tillage, Less Runoff, More ET
- Terraces
- Reservoirs
- Cropping Patterns → Land Use Change
- Irrigation Efficiency
- Deficit Irrigation
- Expansion of Riparian Species that May Use More Water
- Biofuel Expansion
- Future Augmentation Projects to Capture "Flood" Flows
- …..

Need to assess all of these to manage the watershed

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Resource Management Tradeoffs

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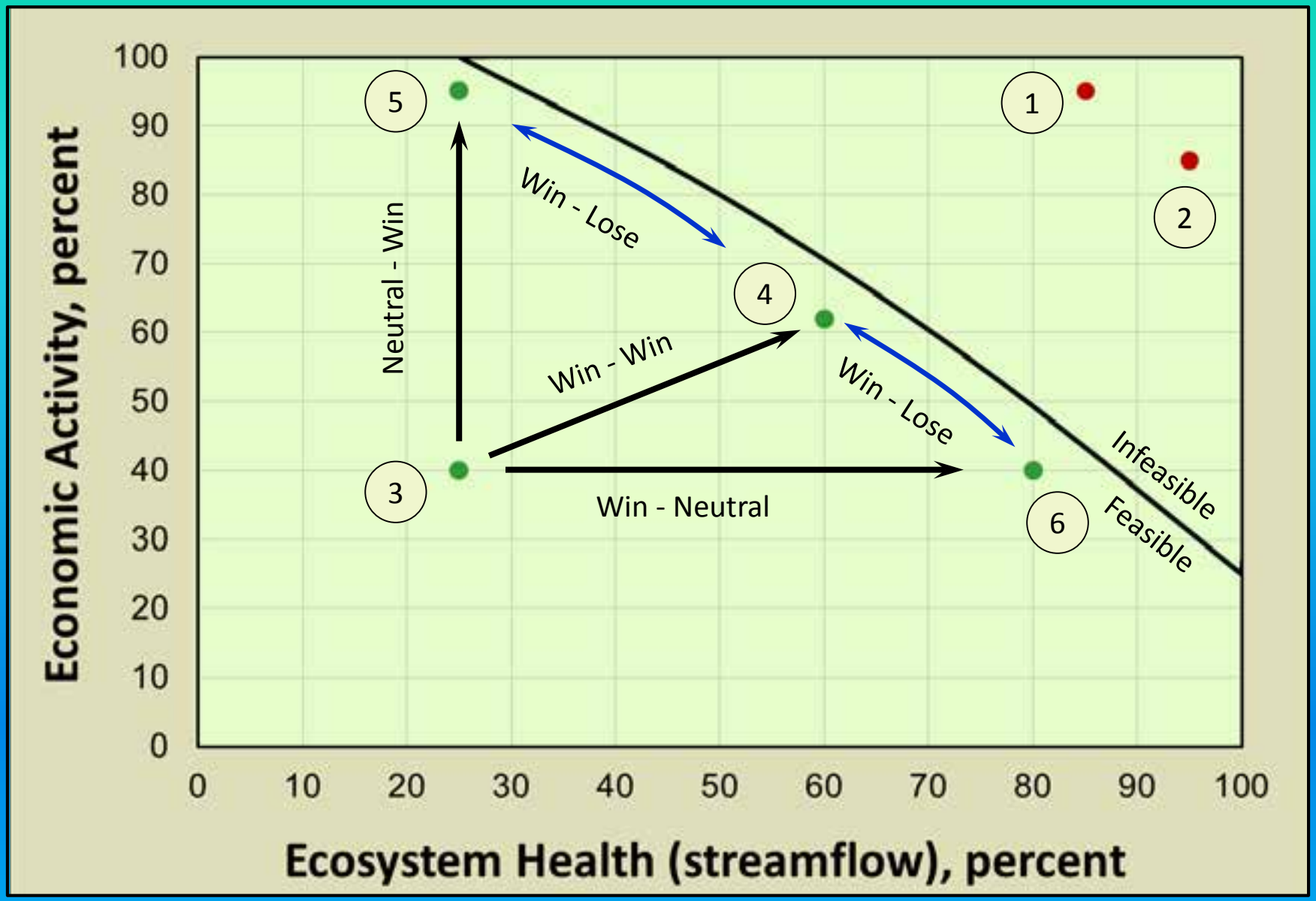
Classic Tradeoff



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Performance Indices

Water Footprint

(Volume of Water/Unit Food):

- What is alternative use of land?
- How would the alternative land use affect the watershed?
- Useful but misleading??

Water Use Efficiency or Water Productivity:

$$WUE = \frac{Yield}{Irrigation\ Water\ Withdrawn} = \frac{Crop}{Drop}$$

$$= \frac{Irrigated\ Yield\ -\ Rainfed\ Yield}{Irrigation\ Water\ Withdrawn}$$

- More useful but
- Does not show how to improve
- Where to spend efforts?
- Maximizing WUE → Don't irrigate
- How to feed 9 billion people?

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Breaking Down Water Use Efficiency - Productivity

$$\frac{Yield_{irr} - Yield_{rainfed}}{Trans_{irr} - Trans_{rainfed}}$$

genuity
ROUNDUP READY 2 YIELD®
SOYBEANS

MONSANTO

NEBRASKA INDEPENDENT CROP CONSULTANT ASSOCIATION

Genetics

Agronomics

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Breaking Down Water Use Efficiency- Productivity

$$\frac{Trans_{irr} - Trans_{rainfed}}{ET_{irr} - ET_{rainfed}}$$

Field Practices

- **Reduced Tillage**
- **Residue Management**
- **Improved Water Application**
- **Deficit Irrigation**

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Breaking Down Water Use Efficiency- Productivity

$$\frac{ET_{irr} - ET_{rainfed}}{\text{Root Zone Storage}}$$

Utilize Soil Water
for Beneficial Uses

- Measure & Manage Soil Water
- Measure & Predict Evapotranspiration
- Schedule Irrigations

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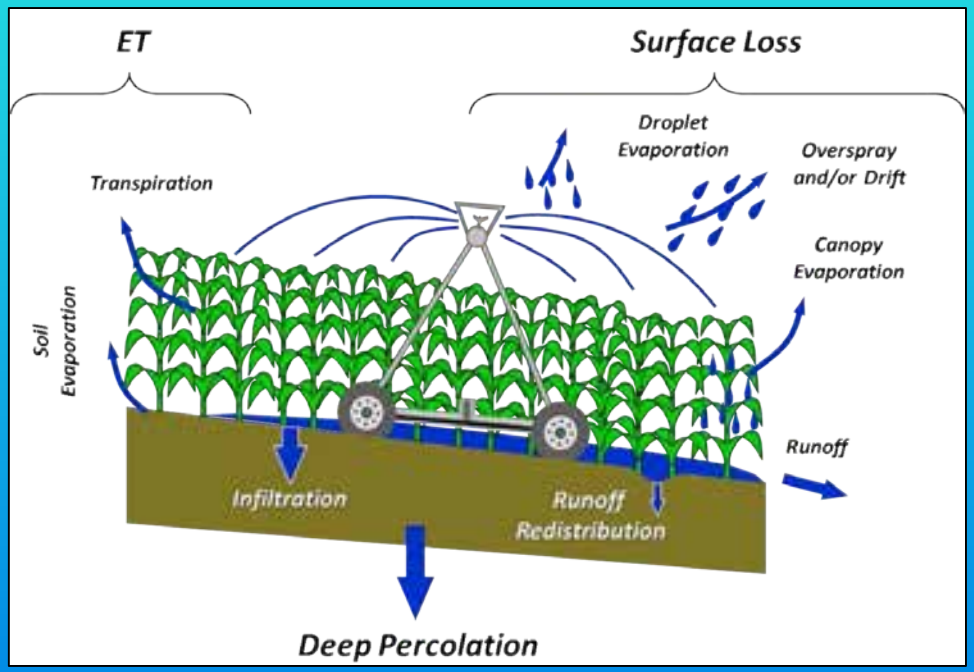
Breaking Down Water Use Efficiency- Productivity

$$\frac{\text{Root Zone Storage}}{\text{Irrigation Application}}$$

Maximize Efficiency of Application



Better Accounting of Where the Water Goes

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Breaking Down Water Use Efficiency- Productivity

$$\frac{\textit{Irrigation Application}}{\textit{Withdrawal}}$$

Control Water to Maximize Beneficial Use and Protect Water Quality

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Opportunities for Improvement



River and Watershed Systems and Management

On-Farm Systems & Management




Plant Productivity & Water Use


Where does the water go?
Must be interdisciplinary.
Need better accounting tools.

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Innovation

New Applications for Existing Systems

New Products

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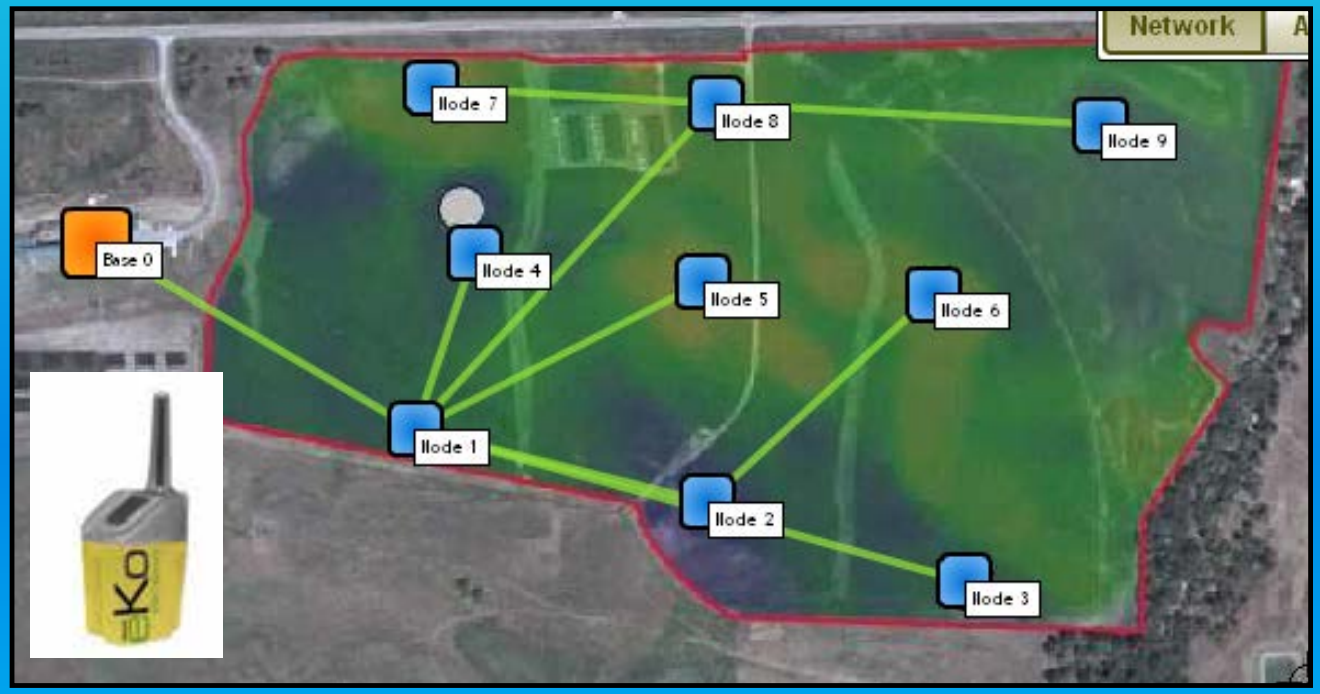
Soil Water Monitoring

Excellent Recent Developments to Improve Management to Conserve Water and Energy, and Protect Water Quality

Sensors

Data Logger

Satellite Communication



Wireless Network

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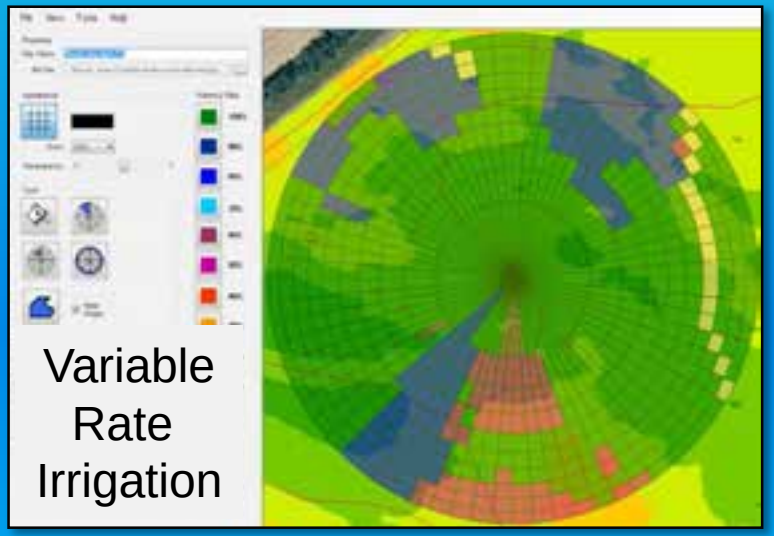
Decision Support Systems

- *Technology outpacing ability to manage*
- *Important role is to develop management aids*
- *Need on-farm and watershed tools*
- *Stronger interdisciplinary efforts*
- *More modesty in promotion*
- *Need to integrate individual developments*

websoilsurvey.nrcs.usda.gov



Variable Rate Irrigation

SoyWater

Water Optimizer

A Decision Support Tool

Hybrid-Maize

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Management for Soil Protection and Water Conservation

Continue evolution of tillage for soil, water and energy conservation

CRP reverting to cropland → what are the impacts?

How does it affect streamflow?

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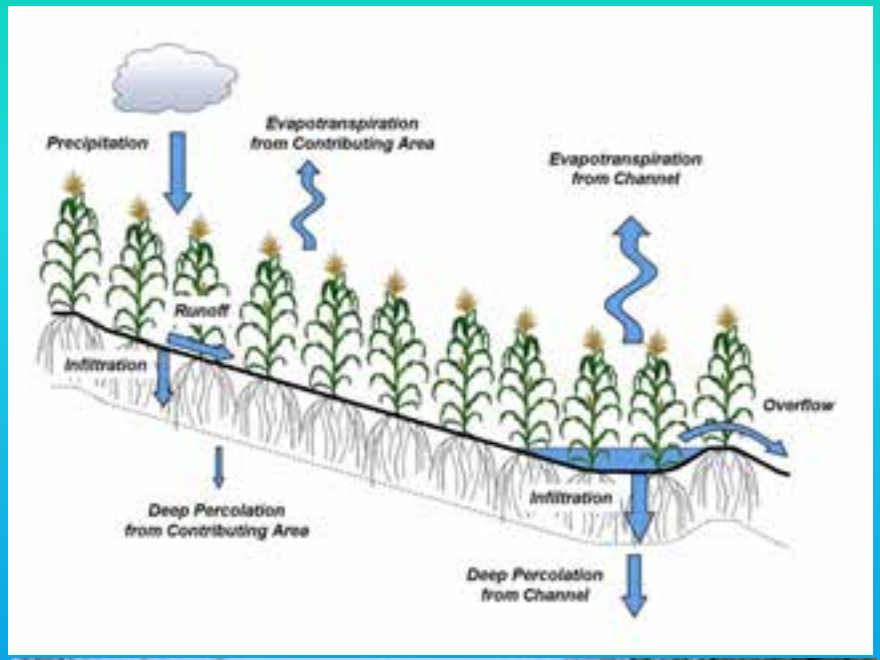
Impact of Land Use on Streamflow



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Increase Irrigation Efficiency



OLD

NEW





1. *Reduces Runoff , Deep Percolation and Labor Input*
2. *Can Apply Smaller Depths When Water Is Needed*
3. *Could Irrigate More Land or Land That Was Previously Impractical*
4. *Diminishes Energy Use And Groundwater Pollution*

But, What Is The Impact Of Increased Efficiency On The Watershed?

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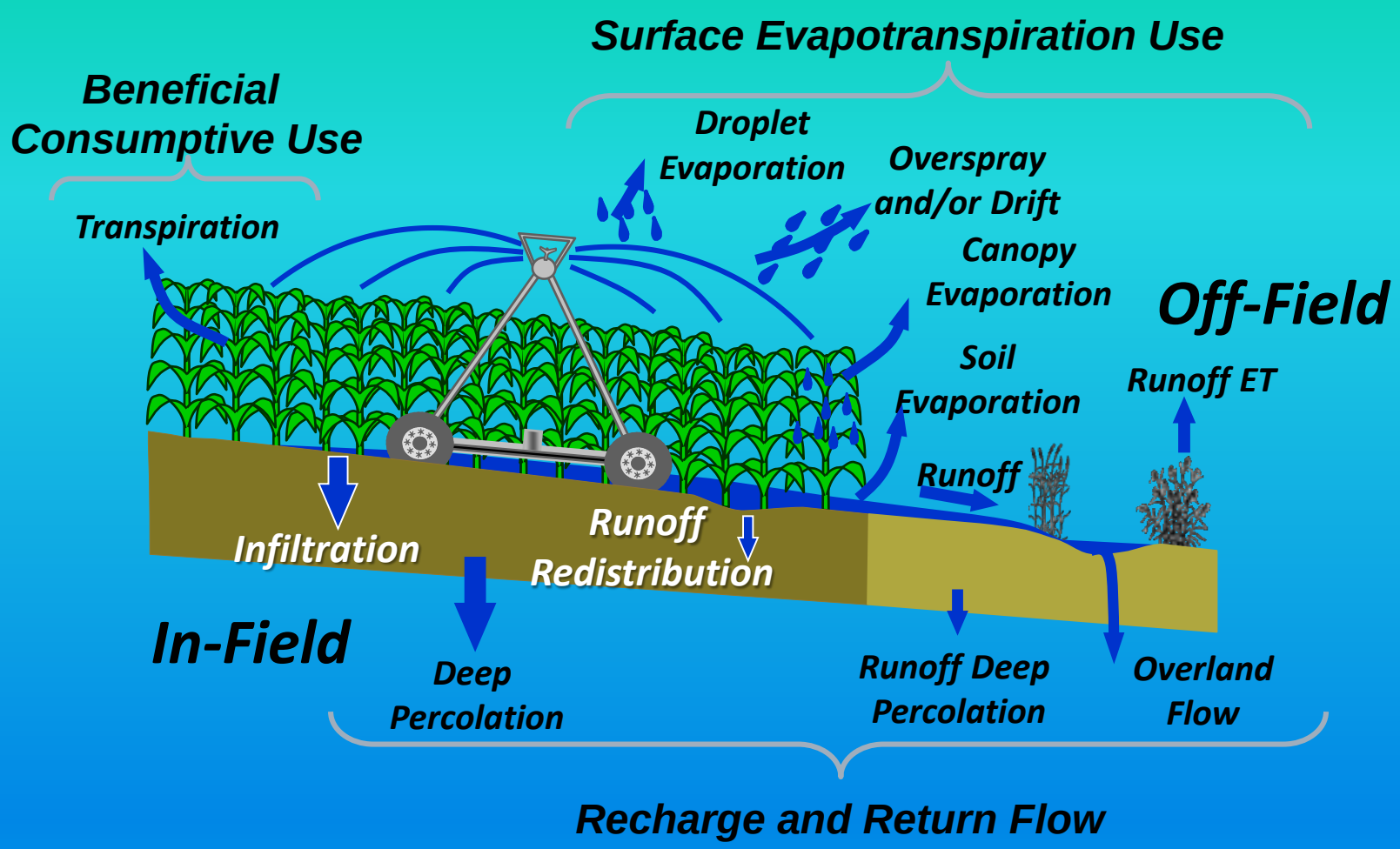
Water Balance



- *Manage watersheds by accounting for where the water goes.*
- *Developing tools for water transfers and offsets to meet instream flow needs*

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Benefits of Technology

versus

Past improvements irrigator focused, not watershed

- *Improvements not always beneficial to watershed*
- *Innovation for watershed enhancement is possible*
- *Hopefully win-win advancements*
- *Who will pay for watershed technology?*

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Examples of Impact of Land Use at Farm and Watershed Levels

Practice / Impact	Crop Production	Streamflow
Improved Irrigation Efficiency		
Runoff Reduction	☺	☹
Deep Percolation Reduction	☺	☹
Evaporation Reduction	☺	☺
Improved Irrigation Scheduling	☺	😐
Conservation Tillage:		
Enhanced Infiltration – Less Runoff	☺	☹
Increased Crop ET and Productivity	☺	☹
Reduced Evaporation from Soil	☺	☺
Canal Lining and Automation		
Seepage and Spill Reduction	☺	😐
More Water Delivered	☺	☹
More Water Retained in Storage	😐	☺

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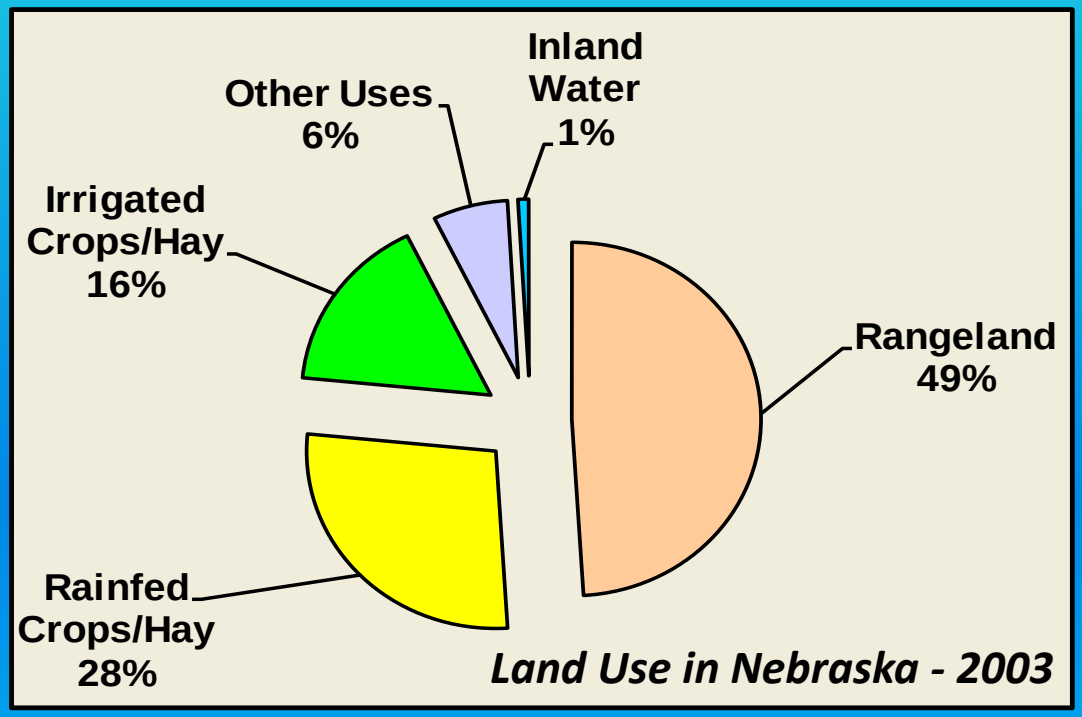
Must Focus on Needs of Clients / Stakeholders

- *Our clients are not all the same*
- *We have to design for variability and acceptance*



- **Private ownership of 93% of land in Great Plains**
- **Must consider how stakeholders are affected**

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Need Based Issues

1. *Groundwater / streamflow depletion due to pumping → Sustainability*
2. *Groundwater pumping allocation → Deficit irrigation*
3. *Limitations on irrigation development → Transfer programs*
4. *Streamflow & recharge reduction from land use changes*
5. *Competition agricultural, environmental, ecological, and domestic*
6. *Consumption of energy for pumping water*
7. *Improve productivity for burgeoning global need for food and fuel*
8. *Great Plains applies to semi-arid & subhumid areas around world*

Avoid chasing opportunities

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What an Exciting Future – Think of the Possibilities

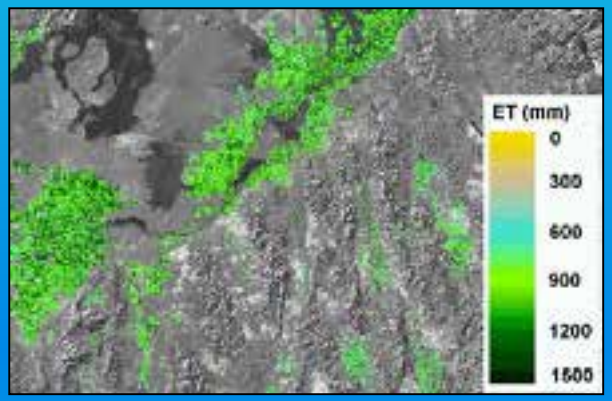
Look at Recent Developments

GMO Crops

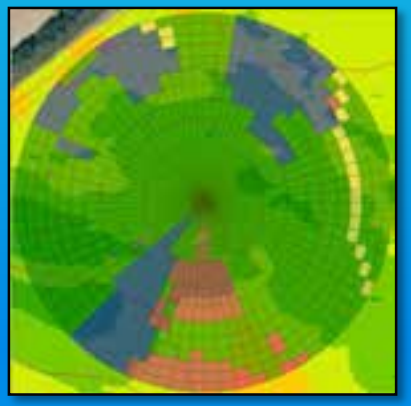
Encapsulated Fertilizer

Soil/Plant Monitoring
Satellite Communication

Auto Steer Vehicles



ET from Remote Sensing



Variable Rate
Irrigation

Monitoring with
Unmanned Vehicle

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Biological Systems Engineering

How do we put it all together

University of Nebraska Lincoln

Thank You, Questions?

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