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NEBRASKA'S WATER MANAGEMENT RESOURCE

Providing the sound science and support for managing Nebraska's most precious resource.

INTERBASIN TRANSFERS, BASIN WATER SUPPLY, AND HYDROLOGIC CONCEPTS

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Republican River Basin-Wide Plan Stakeholder Advisory Meeting
August 18, 2015

Overview

- Update on Three-States discussions
- Interbasin transfers (Platte River)
- Impacts to streamflow: correlations
- Causes of reduced streamflow supply
- Management Plans
- Effects of groundwater pumping on streamflow
  - Hydrologic concepts
  - Stream depletions from groundwater pumping
- Conclusions

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UPDATE ON THREE-STATES DISCUSSIONS

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INTERBASIN TRANSFERS

Exploring the possibility of using high Platte River flows as a potential source of water for the Republican River Basin

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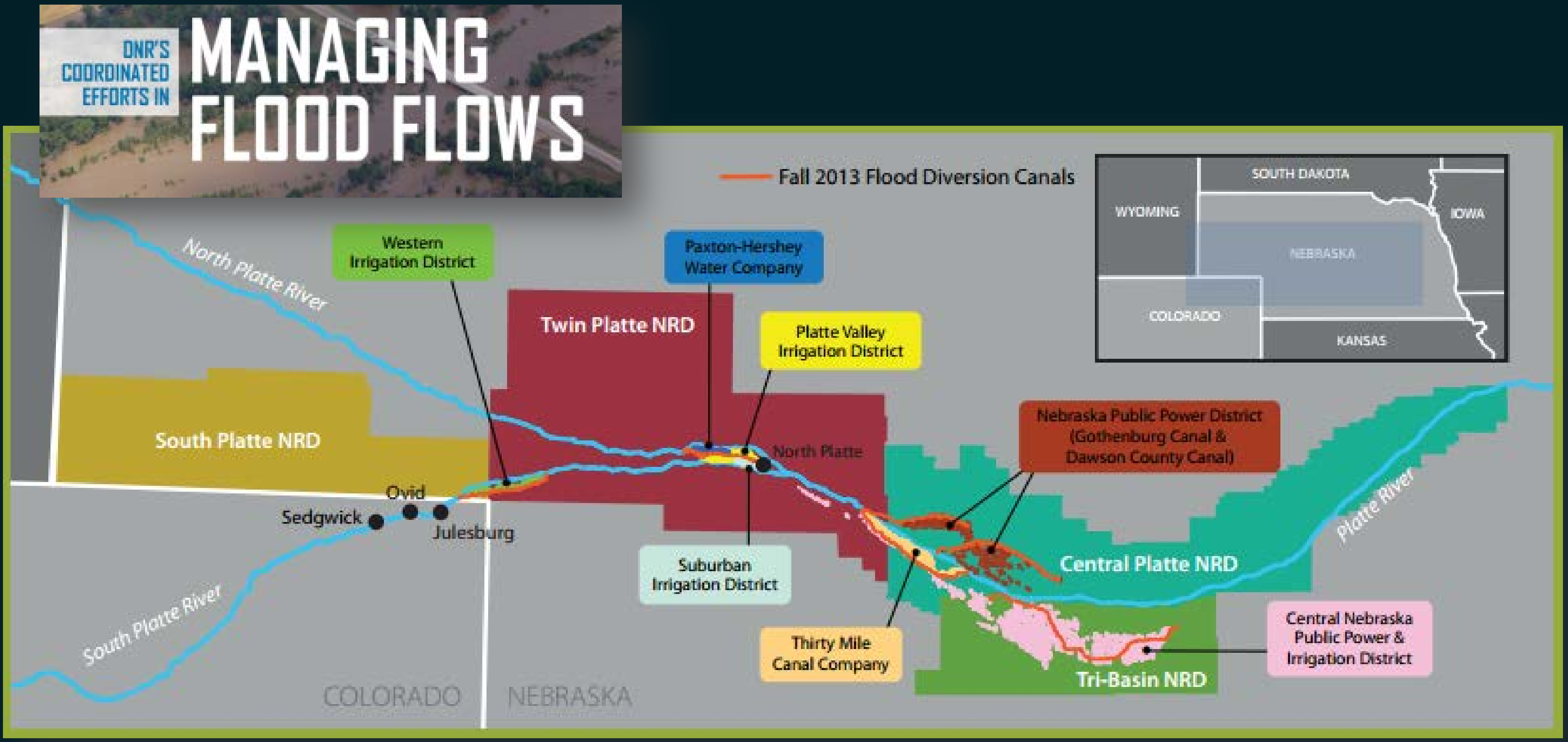
Fall 2013 Platte River Flood Diversions



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Interbasin Transfers

What's allowed under Nebraska Law?

- Relevant statutes
  - *Nebraska Revised Statute* §46-288
    - Definition of terms
  - *Nebraska Revised Statute* §46-289
    - Factors for consideration when evaluating an application involving an interbasin transfer
    - Criteria for deeming an application in the public interest

Interbasin Transfers

Terms defined in *Neb. Rev. Stat.* §46-288

- Interbasin transfer
- Basin of origin
- River basin
- Beneficial use

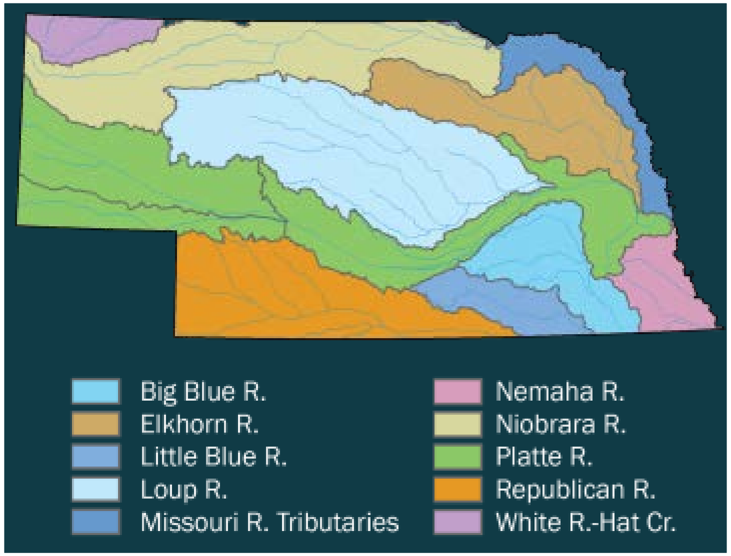
Interbasin Transfers

Terms defined in *Neb. Rev. Stat.* §46-288

- **Interbasin transfer**
  - Diverting water from one river basin (basin of origin)

    and
  - Transporting it to another basin for beneficial use or storage

- **River basin**
  - Basin designations for the purposes of interbasin transfers:



Interbasin Transfers

Terms defined in *Neb. Rev. Stat.* §46-288

- Beneficial use
  - Includes (but not limited to) reasonable and efficient use of water for the following purposes:
    - Domestic
    - Municipal
    - Agricultural
    - Industrial
    - Commercial
    - Power production
    - Subirrigation
    - Fish and wildlife
    - Groundwater recharge
    - Interstate compact
    - Water quality maintenance
    - Recreational

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Interbasin Transfers

Evaluation/Approval Process, *Neb. Rev. Stat.* §46-289

1. Application to appropriate water is filed
2. DNR considers application based on specified criteria
3. DNR evaluates whether the application is in the public interest
4. DNR issues order granting or denying application

Interbasin Transfers

Factors for Consideration, *Neb. Rev. Stat.* §46-289

Proposed interbasin transfer	Basin of origin
➢ **Economic, environmental, and other benefits** of proposed transfer and use	➢ **Economic, environmental, and other benefits** of leaving water in basin for current or future uses
➢ **Alternative sources of water** available to applicant	➢ **Alternative sources of water** available for future uses
➢ **Adverse impacts** of proposed transfer and use	➢ **Current beneficial uses** of unappropriated water
	➢ Reasonably foreseeable **future beneficial uses**

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Interbasin Transfers

Determination of Public Interest, *Neb. Rev. Stat.* §46-289

The application shall be deemed in the public interest if:

The overall benefits to
the state
and
the applicant's basin

are greater than
or equal to

the overall benefits to
the state
and
the basin of origin

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Questions?

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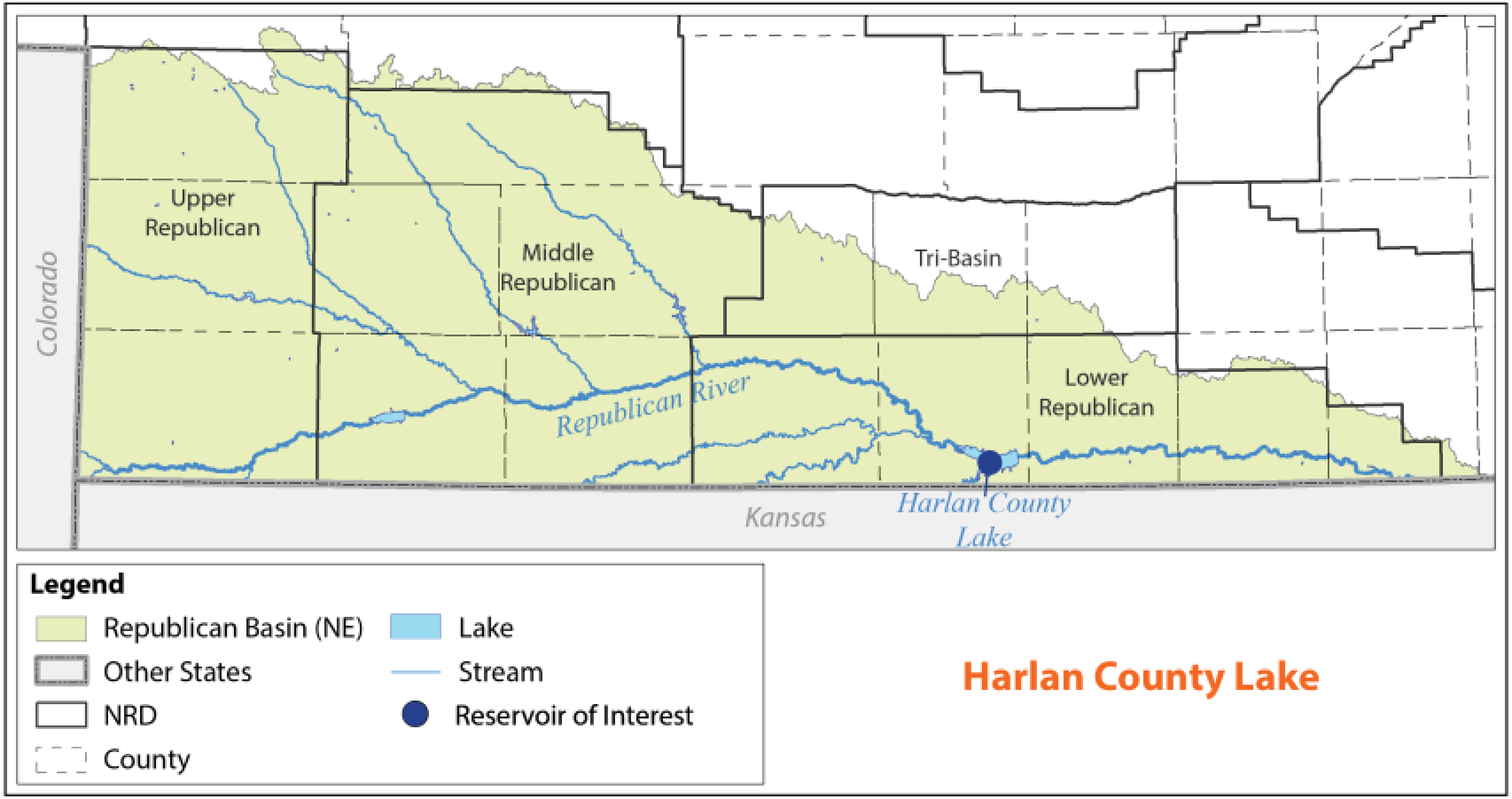
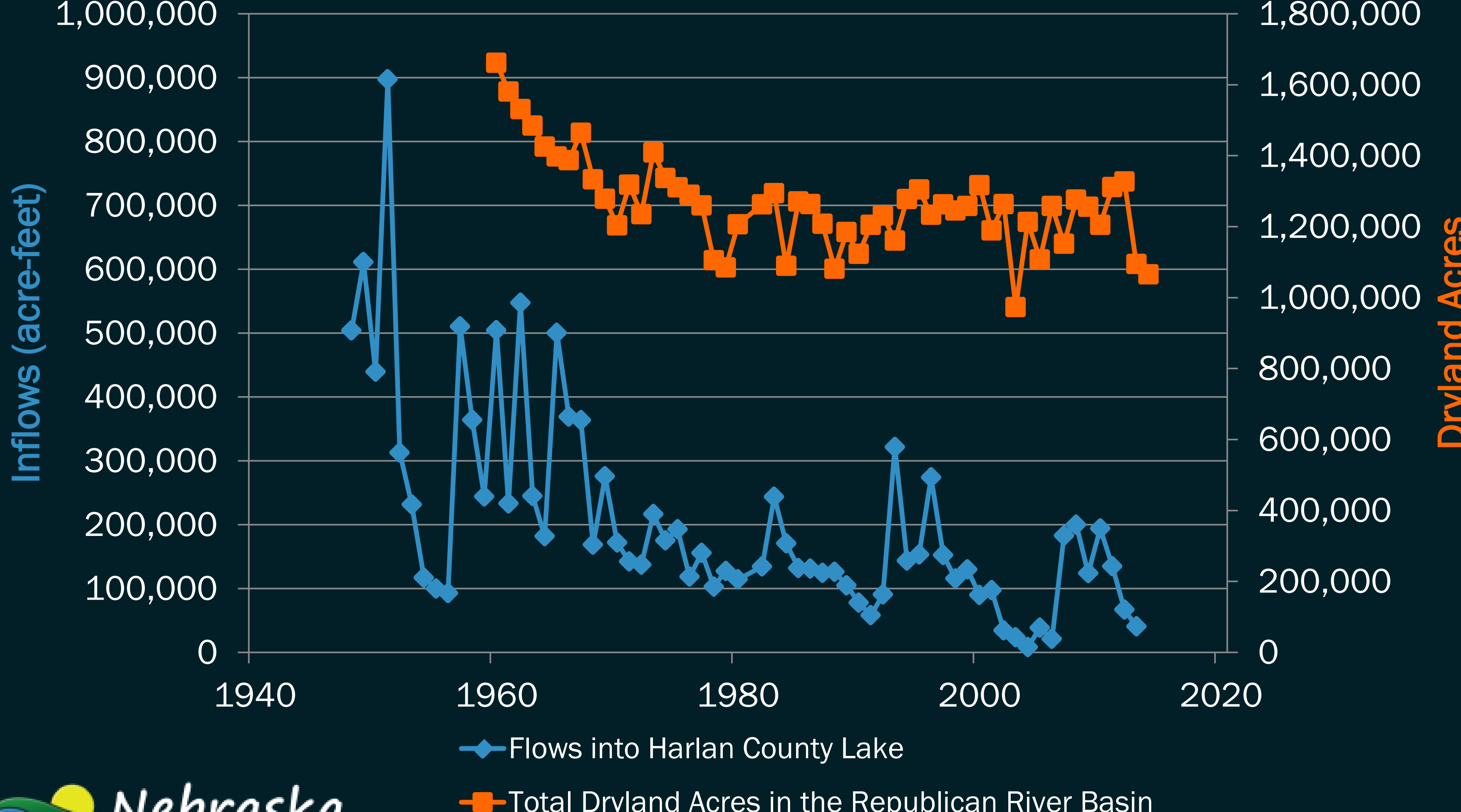
CORRELATIONS

Updated comparison between inflows to Harlan County Lake and other changes in the Republican River Basin



Harlan County Lake

Inflows vs. Dryland Acres



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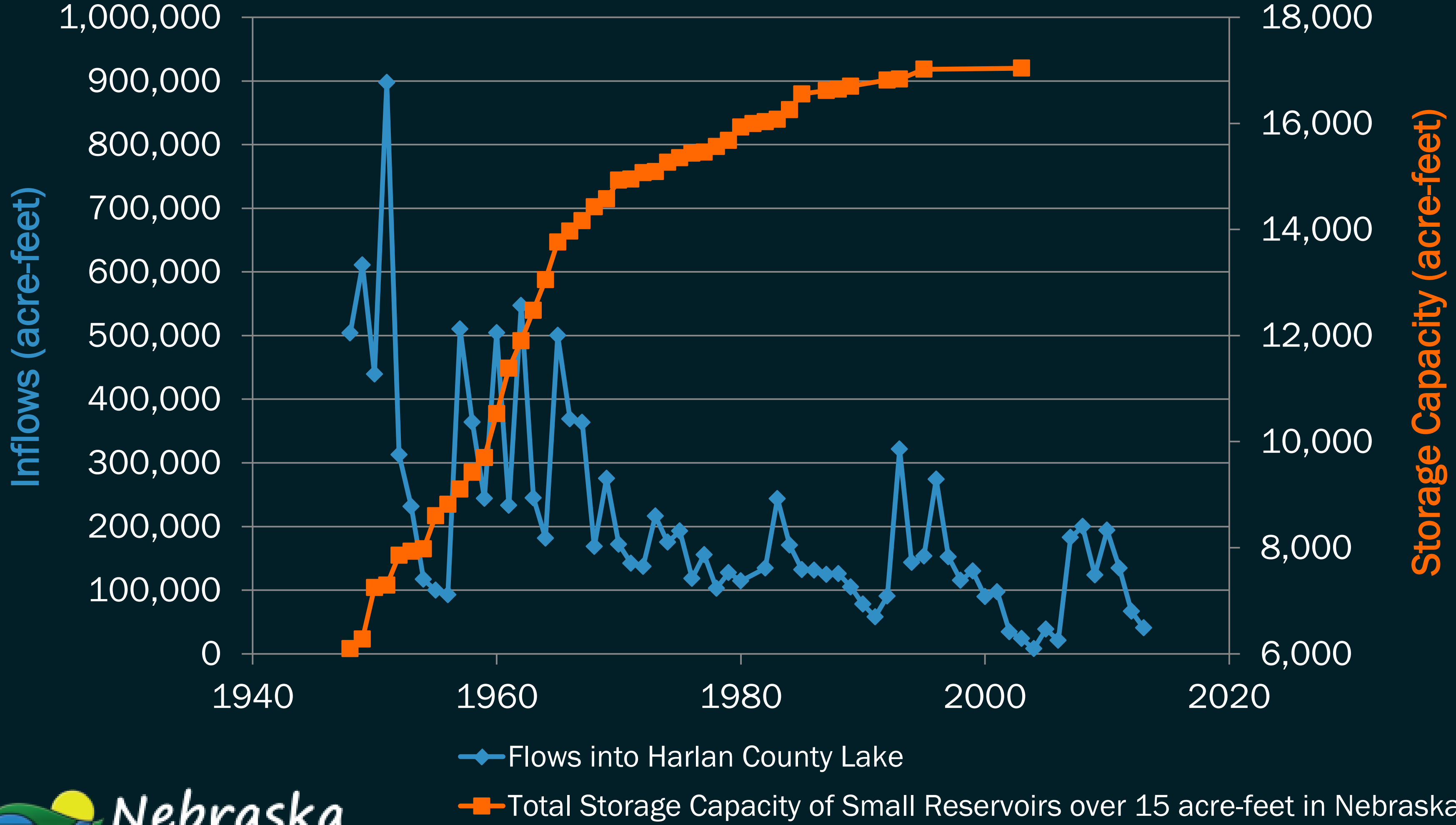
Inflows vs. Small Reservoirs



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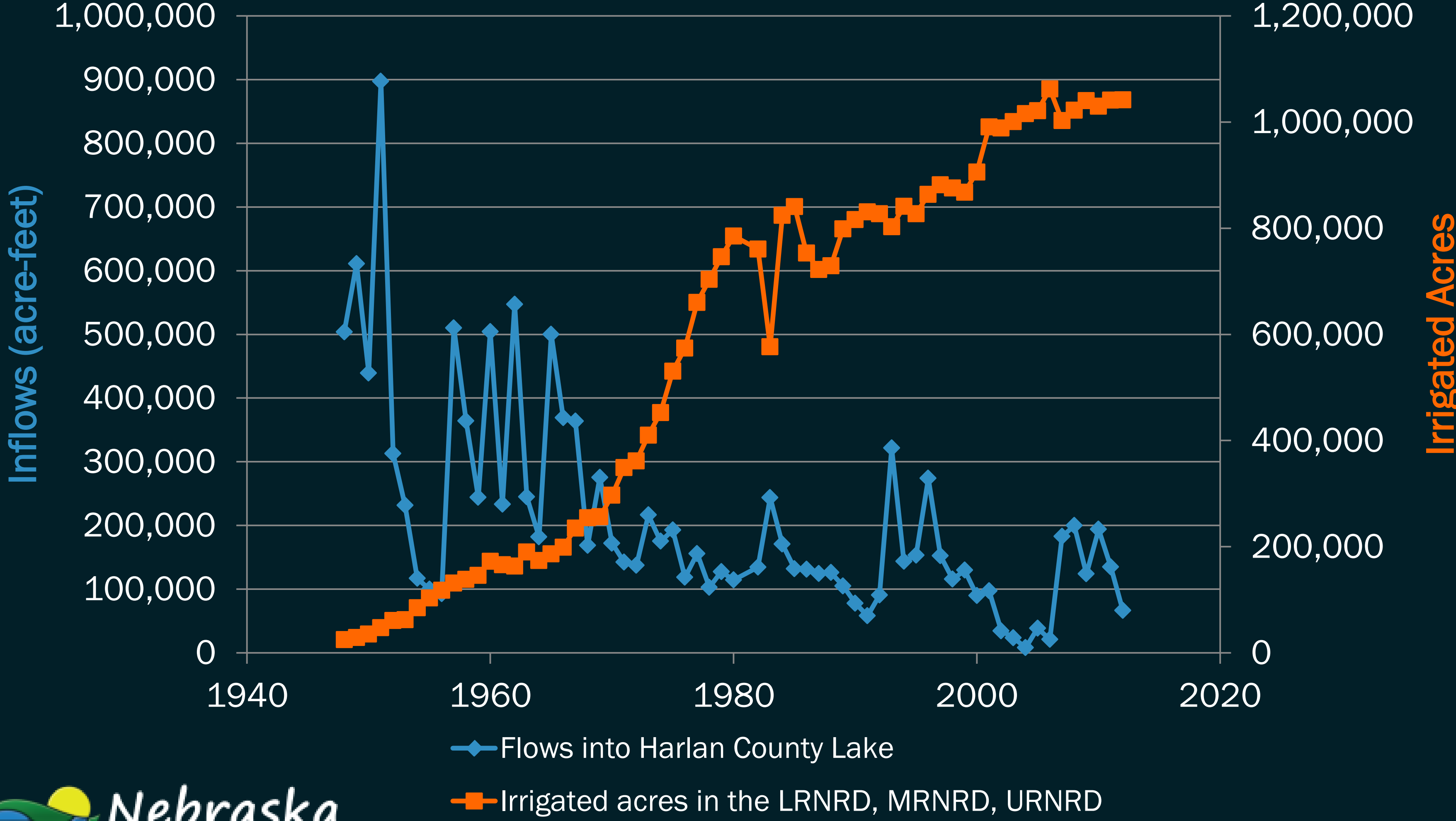
Inflows vs. Groundwater Irrigated Acres



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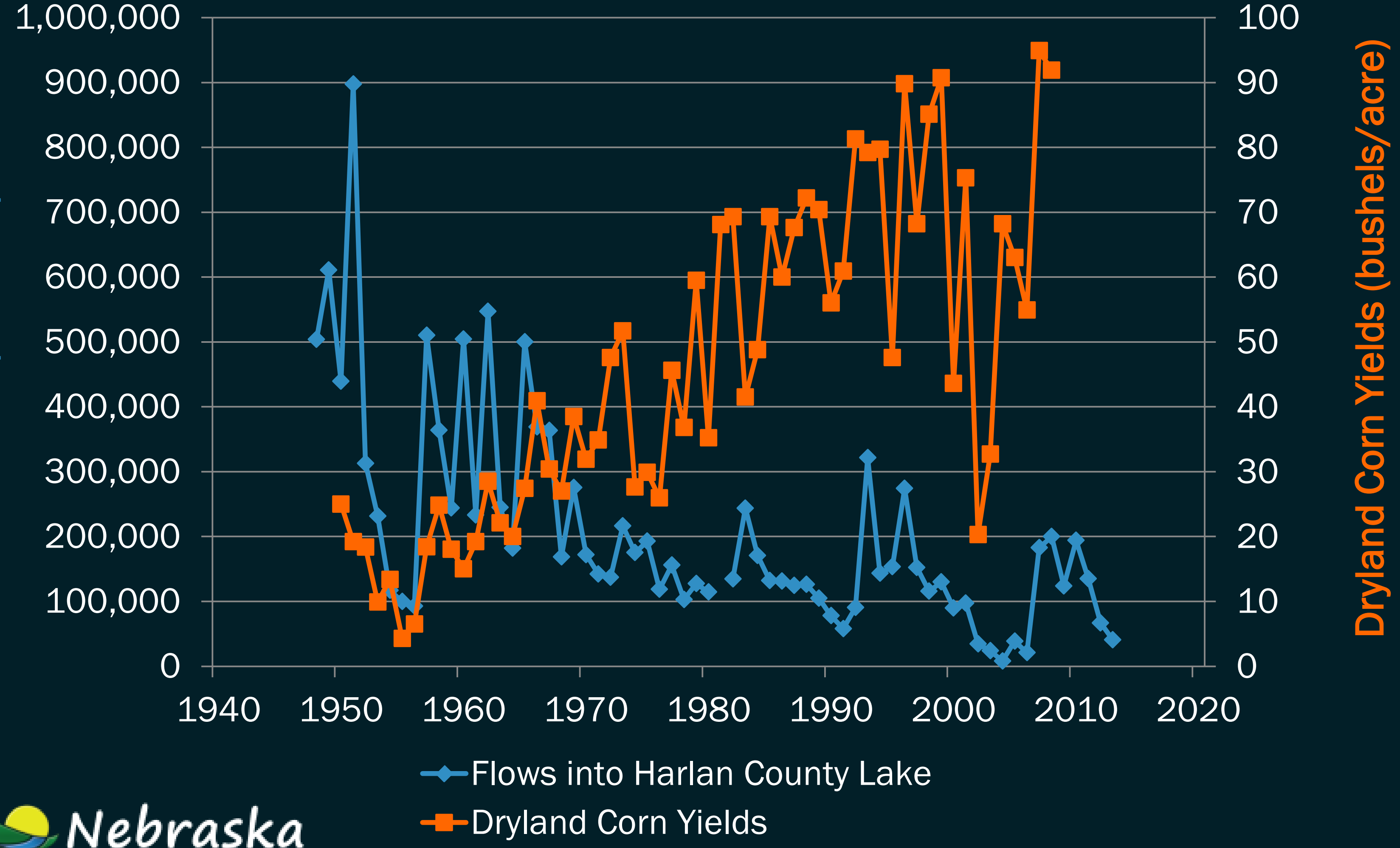
Inflows vs. Dryland Corn Yields



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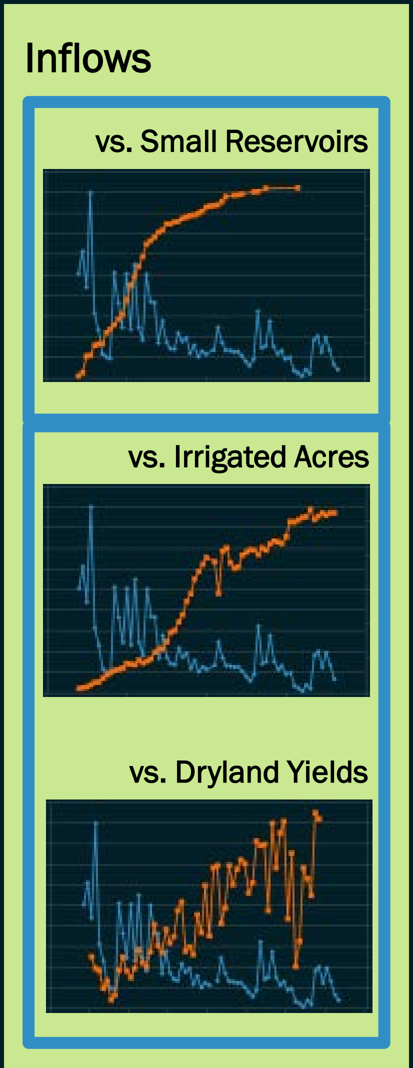
Observations Based on Correlations

- Inflows into Harlan County Lake are inversely correlated with:
  - Development of groundwater irrigation
  - Development of conservation practices such as farm ponds
  - Increase in dryland crop yields

- The most significant declines in runoff appear to have occurred:
  - Prior to 1970
  - i.e., during the time that the development of conservation practices increased the most

- Baseflow has declined more steadily, in a manner more similar to:
  - The increase in groundwater irrigation
  - The increase in dryland yields



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Questions?

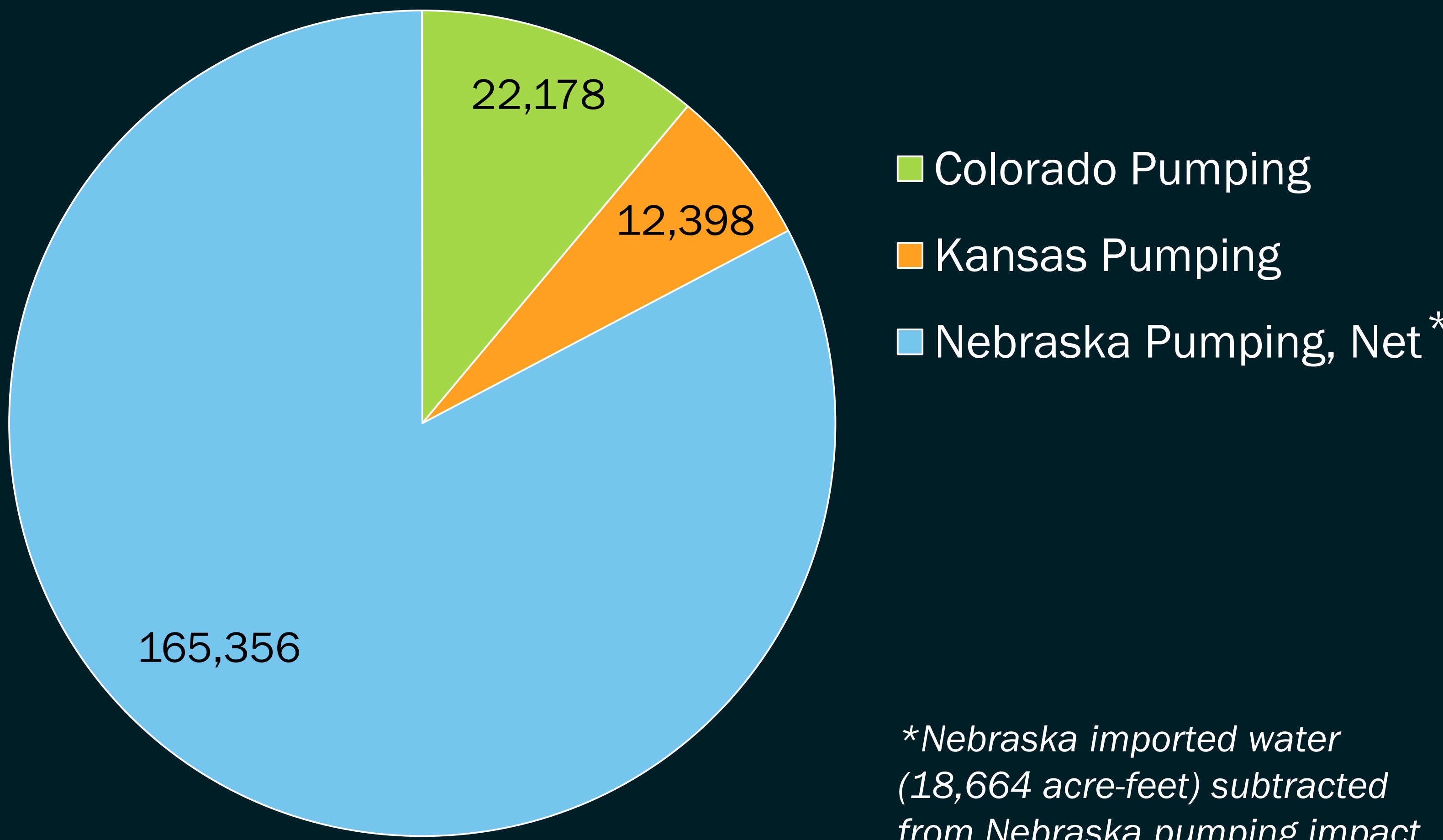
CAUSES OF REDUCED STREAMFLOW SUPPLY

Causes of Reduced Streamflow Supply

Causes	Quantifying these impacts
Groundwater pumping by the three states	→ Estimates of streamflow depletions due to groundwater pumping from the RRCA groundwater model
Reductions in runoff	→ RRCA Conservation Study, analysis of historic streamflow and baseflow information to estimate reductions in runoff
Drought	→ Comparison of 2013-2014 with longer-term averages to assess the impact of drought

Total Depletions Due to Groundwater Pumping

Basin-Wide Impacts, 2000 (acre-feet)



**Nebraska imported water (18,664 acre-feet) subtracted from Nebraska pumping impact (184,020 acre-feet)*

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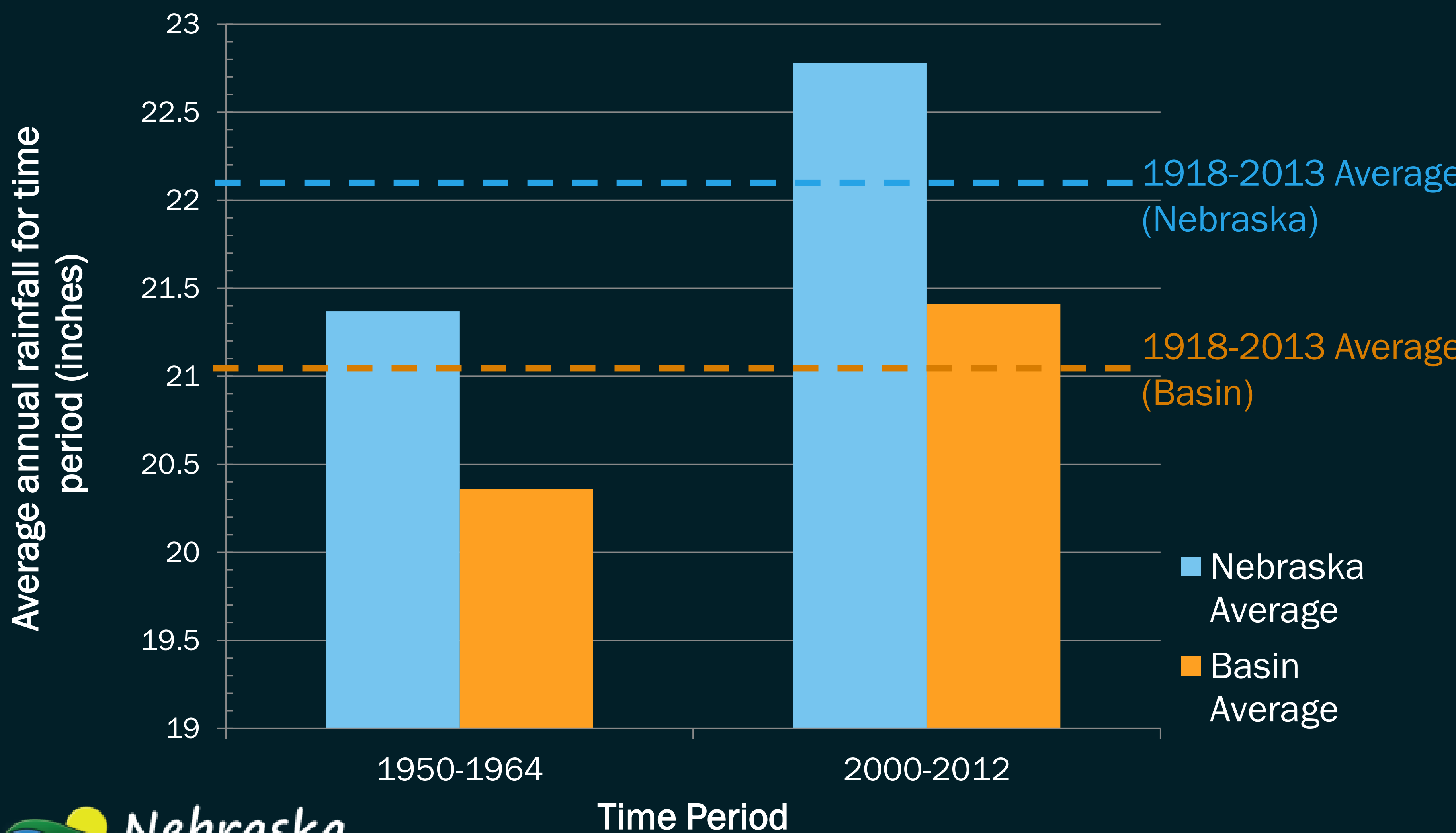
IMPACTS OVER TIME, USING STREAMFLOW AND BASEFLOW DATA

1950-1964 and 2000-2012 time periods

Rainfall Comparison



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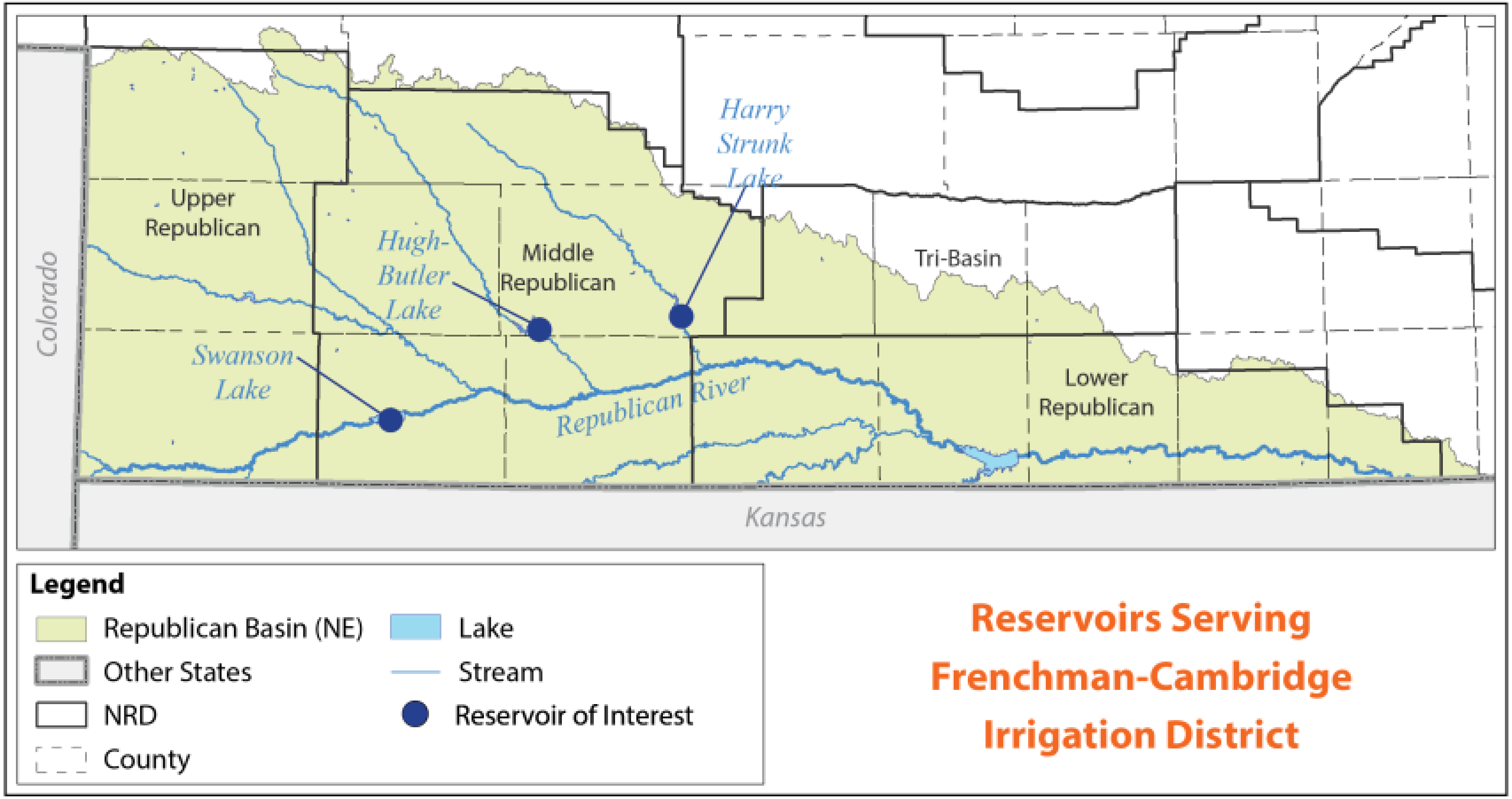

Reservoirs Serving Frenchman-Cambridge Irrigation District

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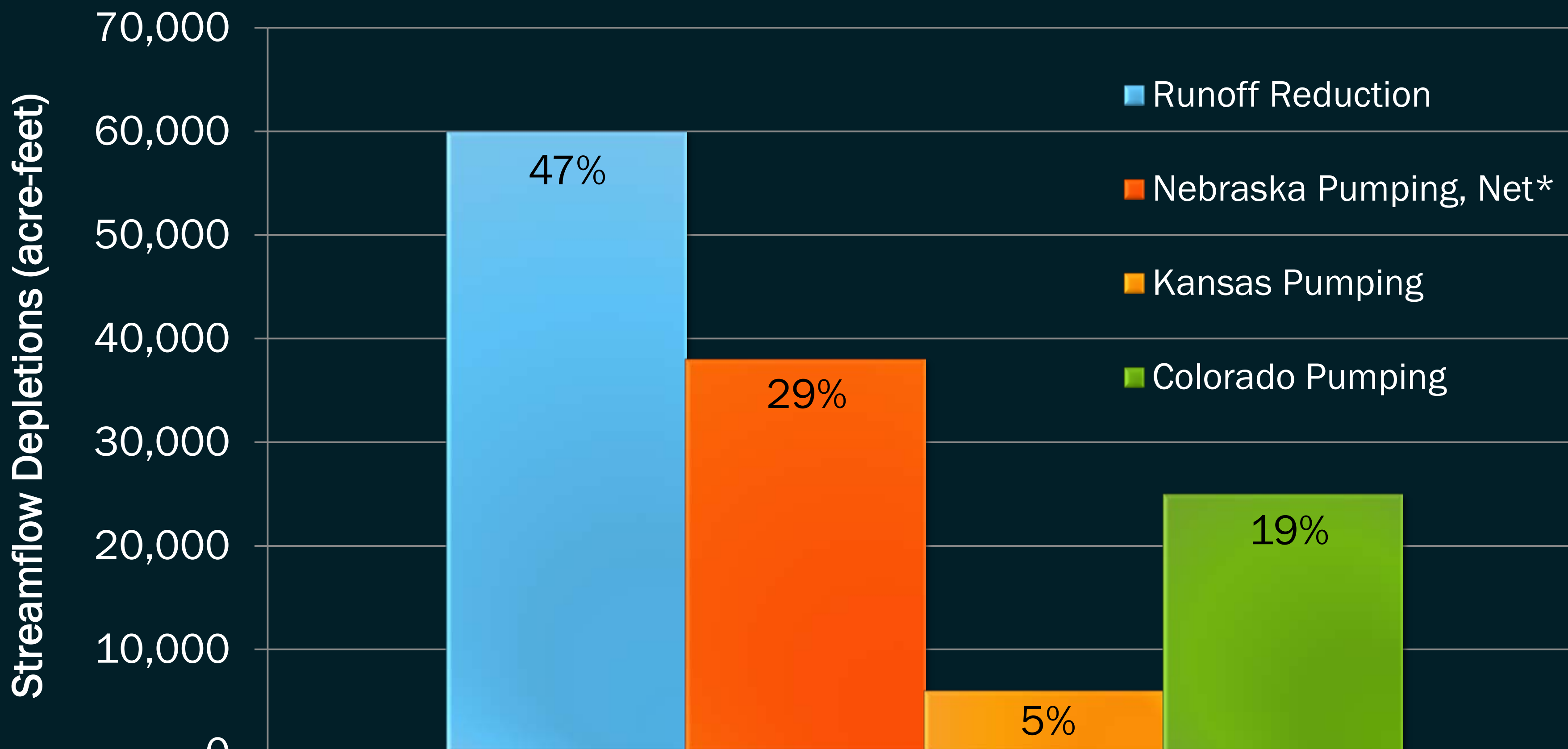
Impacts to Reservoirs Serving

Frenchman Cambridge Irrigation District



Impacts, 1950-1964
Compared to 2000-2012

**Nebraska imported water subtracted from Nebraska pumping impact*

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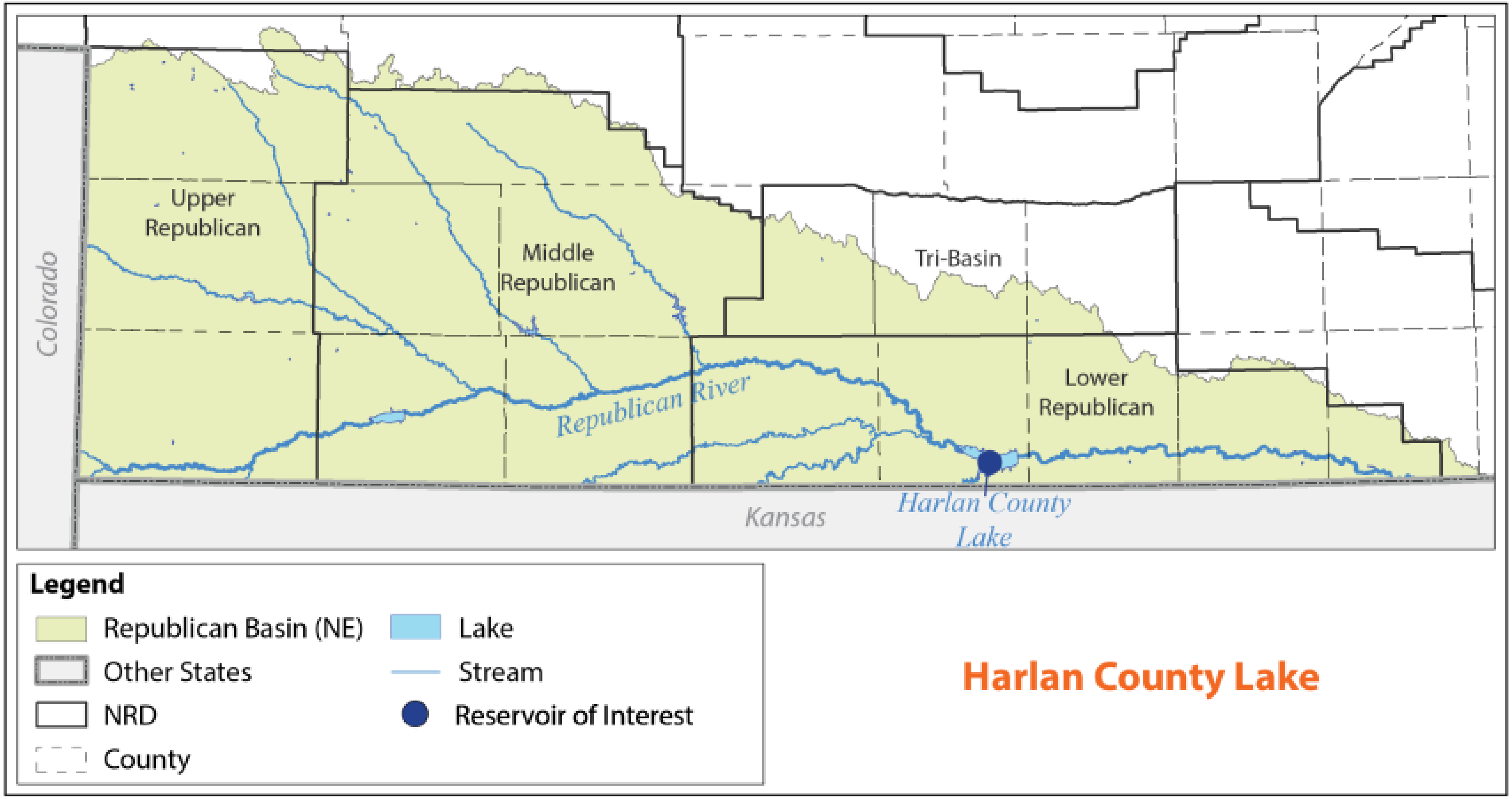

Harlan County Lake

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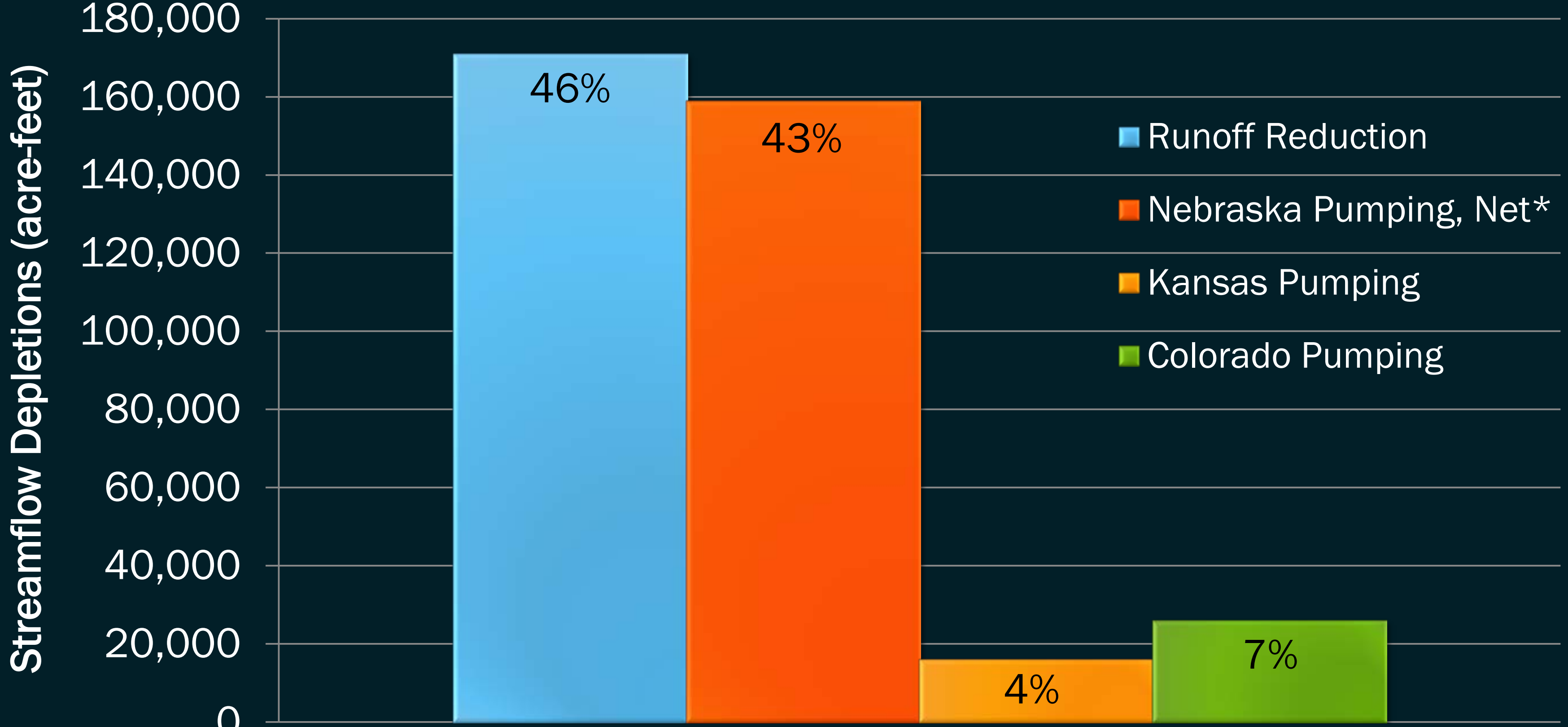
Impacts

Above Harlan County Lake



Impacts, 1950-1964
Compared to 2000-2012

**Nebraska imported water subtracted from Nebraska pumping impact*

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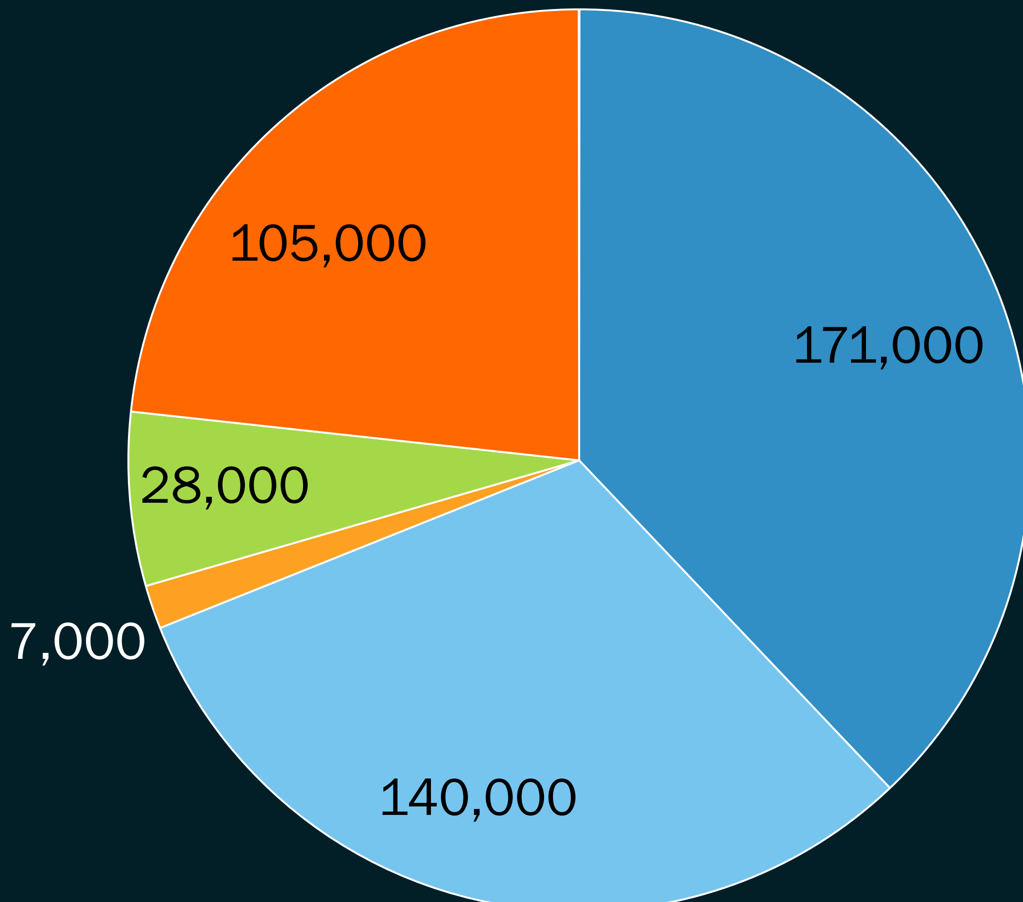
2013 Impacts, Including Drought

Above Harlan County Lake (acre-feet)



*2013 rainfall in the Nebraska portion of the Basin was **24% less** than the 1918-2013 average.*

**Nebraska imported water (12,000 acre-feet) subtracted from Nebraska pumping impact (152,000 acre-feet)*

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EFFECTS OF NEBRASKA GROUNDWATER PUMPING ON STREAMFLOW

Stream depletions from groundwater pumping 1975-2015

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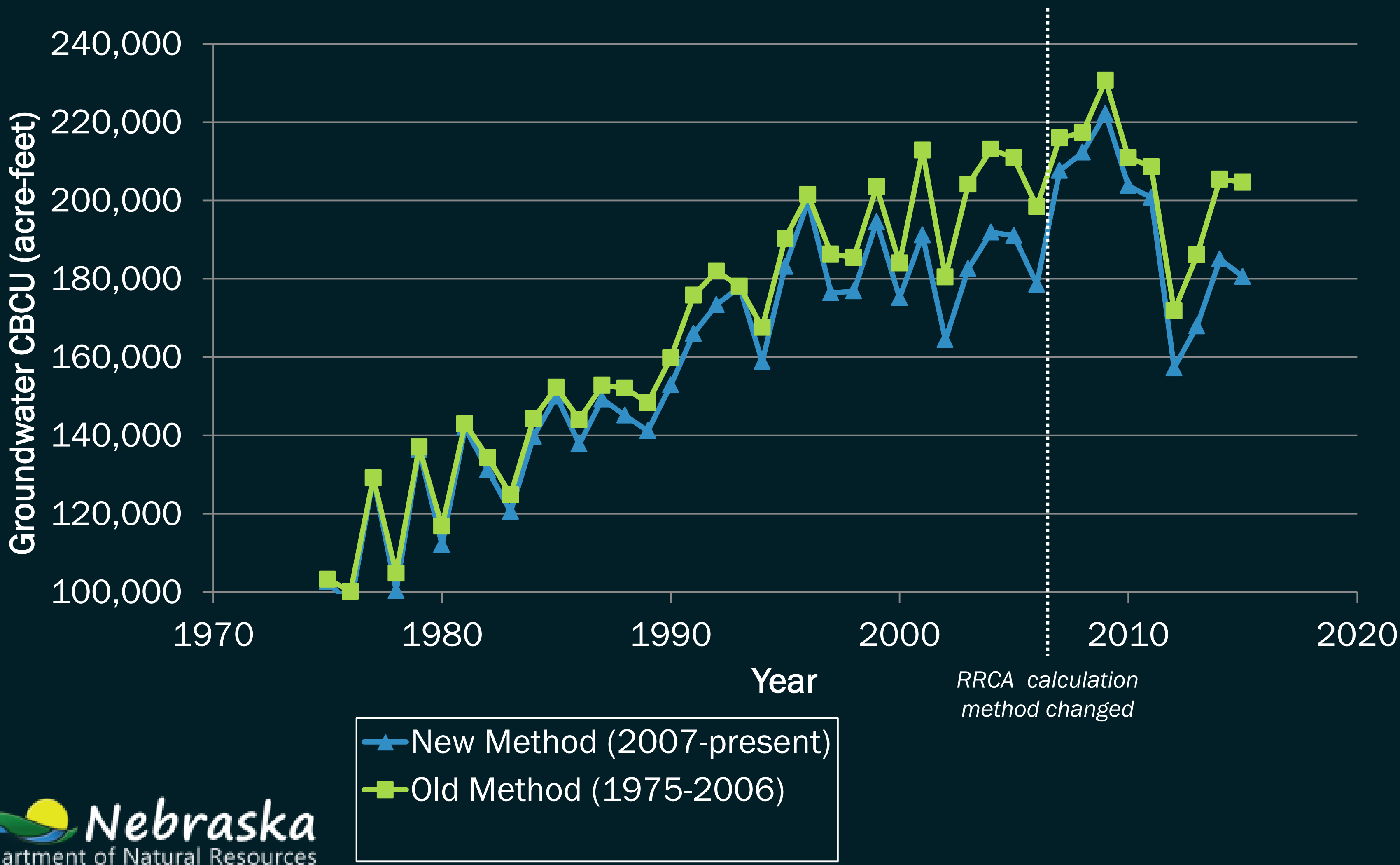
Nebraska Groundwater
Computed Beneficial Consumptive Use (CBCU)



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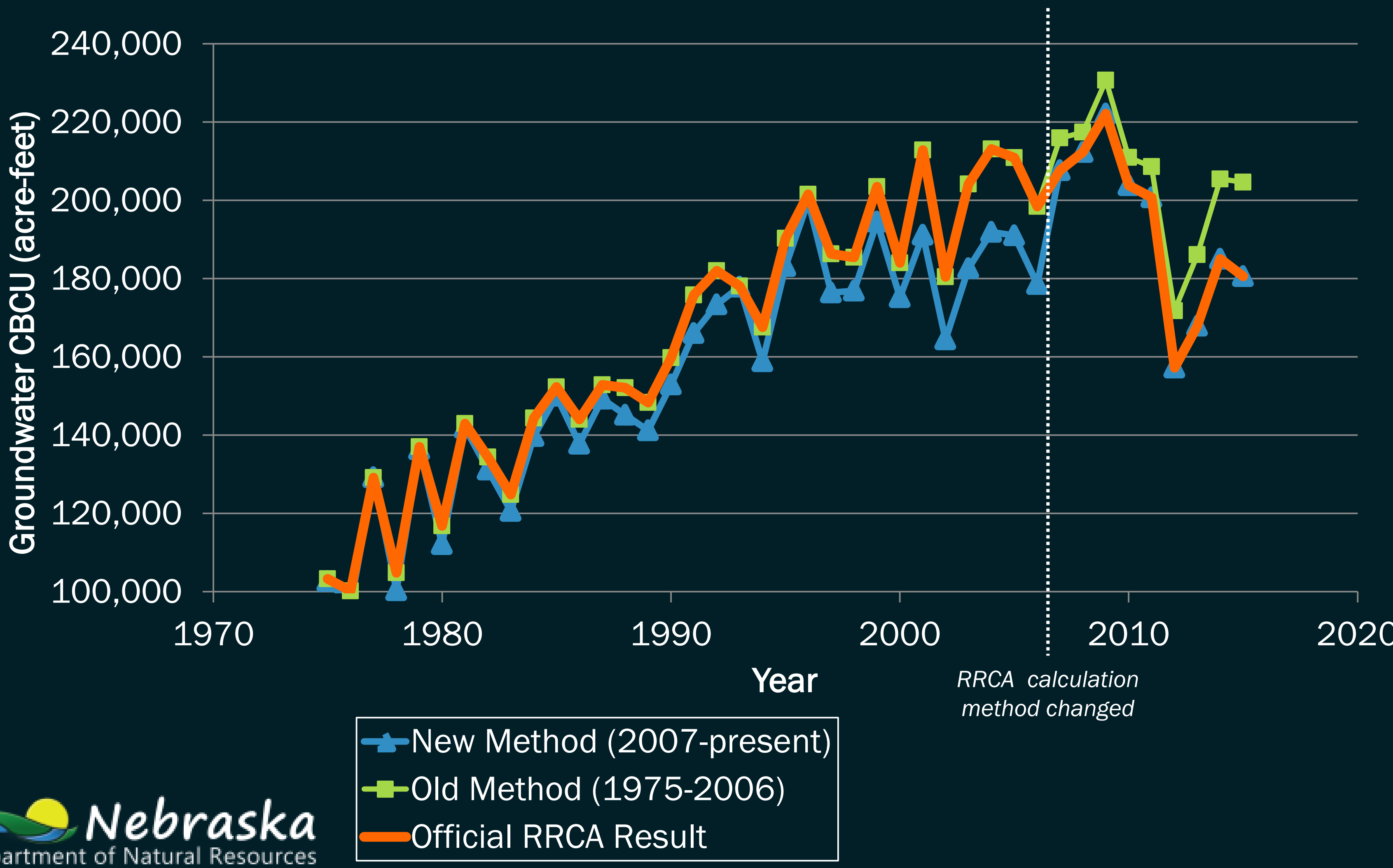
Nebraska Groundwater
Computed Beneficial Consumptive Use (CBCU)



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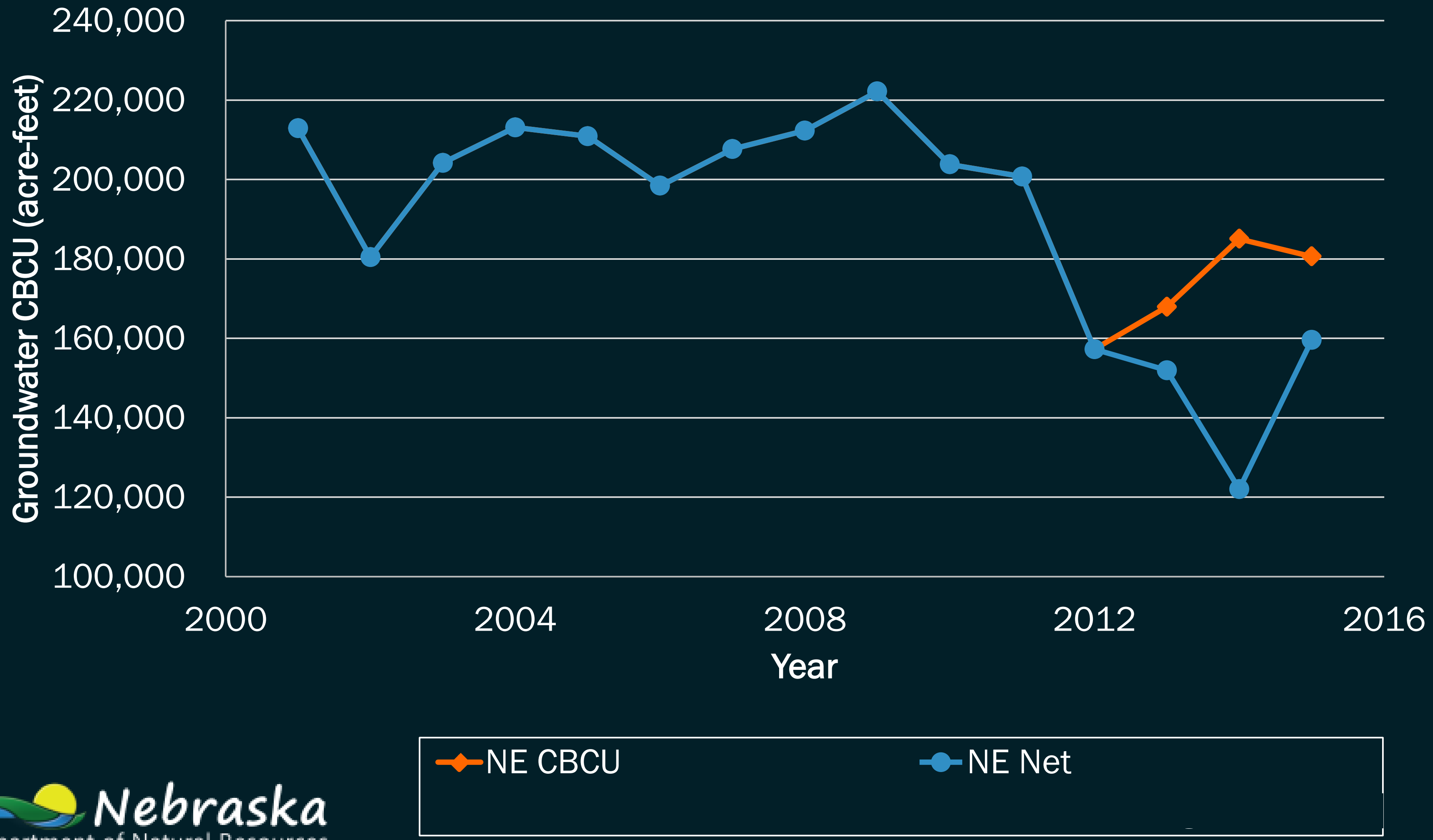
Nebraska Groundwater
Computed Beneficial Consumptive Use (CBCU)



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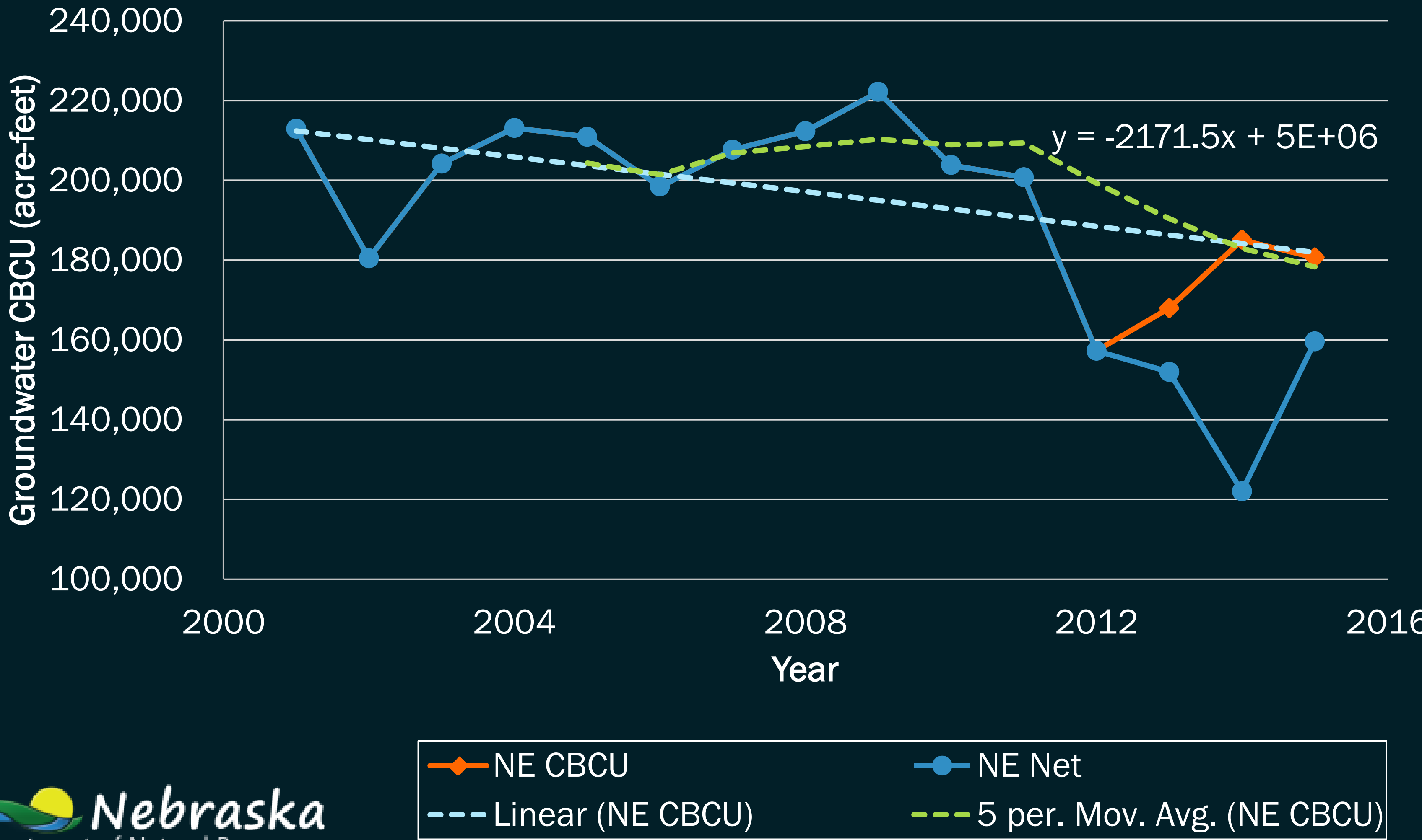
Nebraska Groundwater
Computed Beneficial Consumptive Use (CBCU)



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Key Points

- Interbasin transfers must consider the benefits of the water in the basin of origin and the basin of use
- Streamflows in the Basin have declined over time and these declines can be correlated to at least several factors
- Reductions in overland runoff is the greatest cause of these declines, accounting for nearly 50%
- The next factor is groundwater pumping in Nebraska, which accounts for 30-40% of the declines
- Impacts due to groundwater pumping have declined in recent years, especially when considering the NRD management actions in recent years

Questions?

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MANAGEMENT PLANS

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Nebraska Water Planning

- Groundwater Management Plans
  - Adopted by all 23 NRDs
- Integrated Management Plans
  - Mandatory
  - Voluntary
- Basin-wide Plans
  - Mandatory
  - Voluntary

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Groundwater Management Plans Include

- Aquifer Information
- Recharge, Precipitation, Crop information
- Data-collection Programs
- Past, Present, and Potential Groundwater Use
- Groundwater Quality Issues
- Proposed Water Conservation Programs
- Available Supplemental Supplies
- Groundwater Management Objectives, Including a Proposed Groundwater Reservoir Life Goal
- Economic Value of Existing and Proposed Groundwater Uses
- Geographic and Stratigraphic Boundaries for Plan

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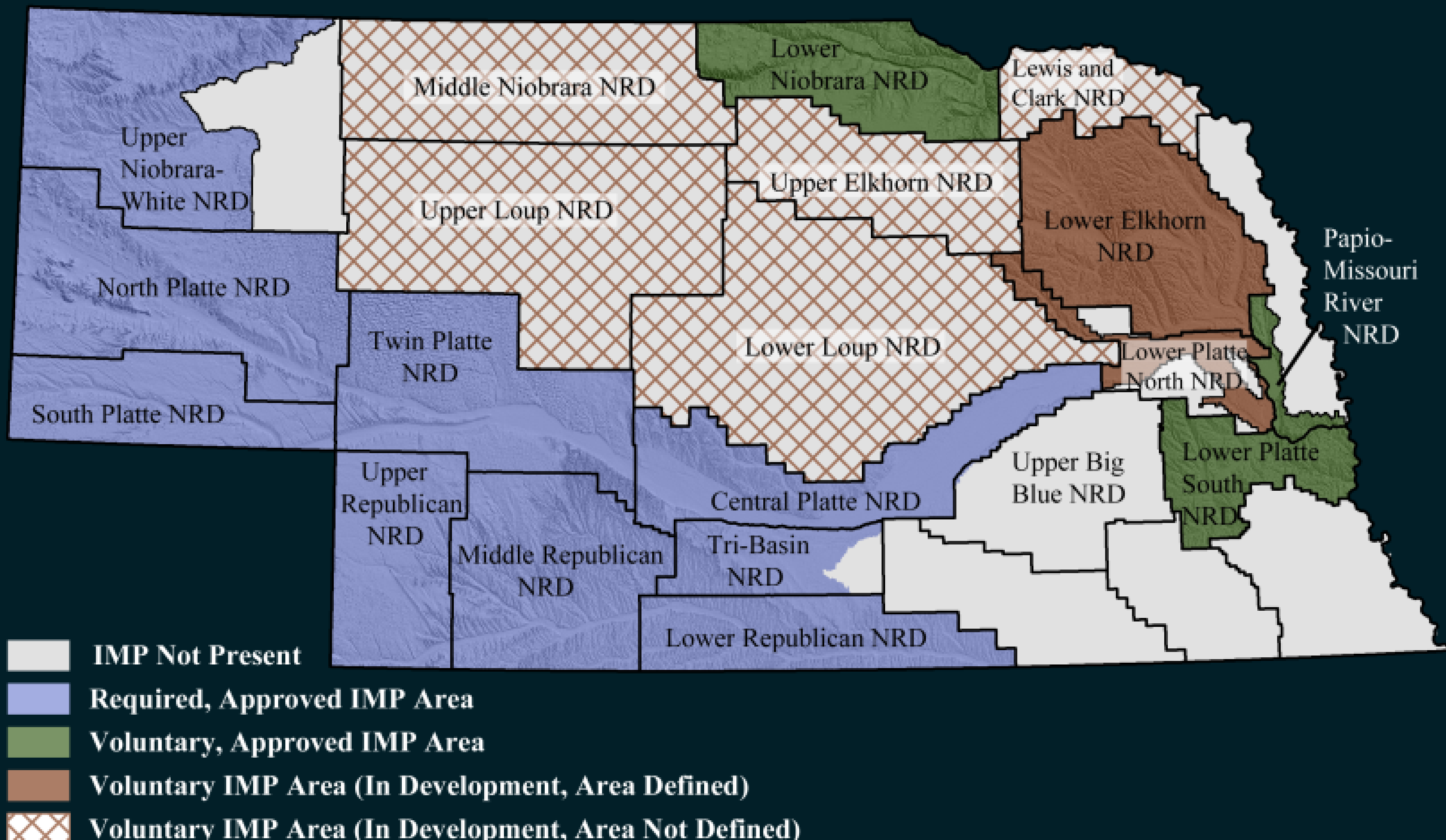
Integrated Management Planning in Nebraska

(As of May 2015)



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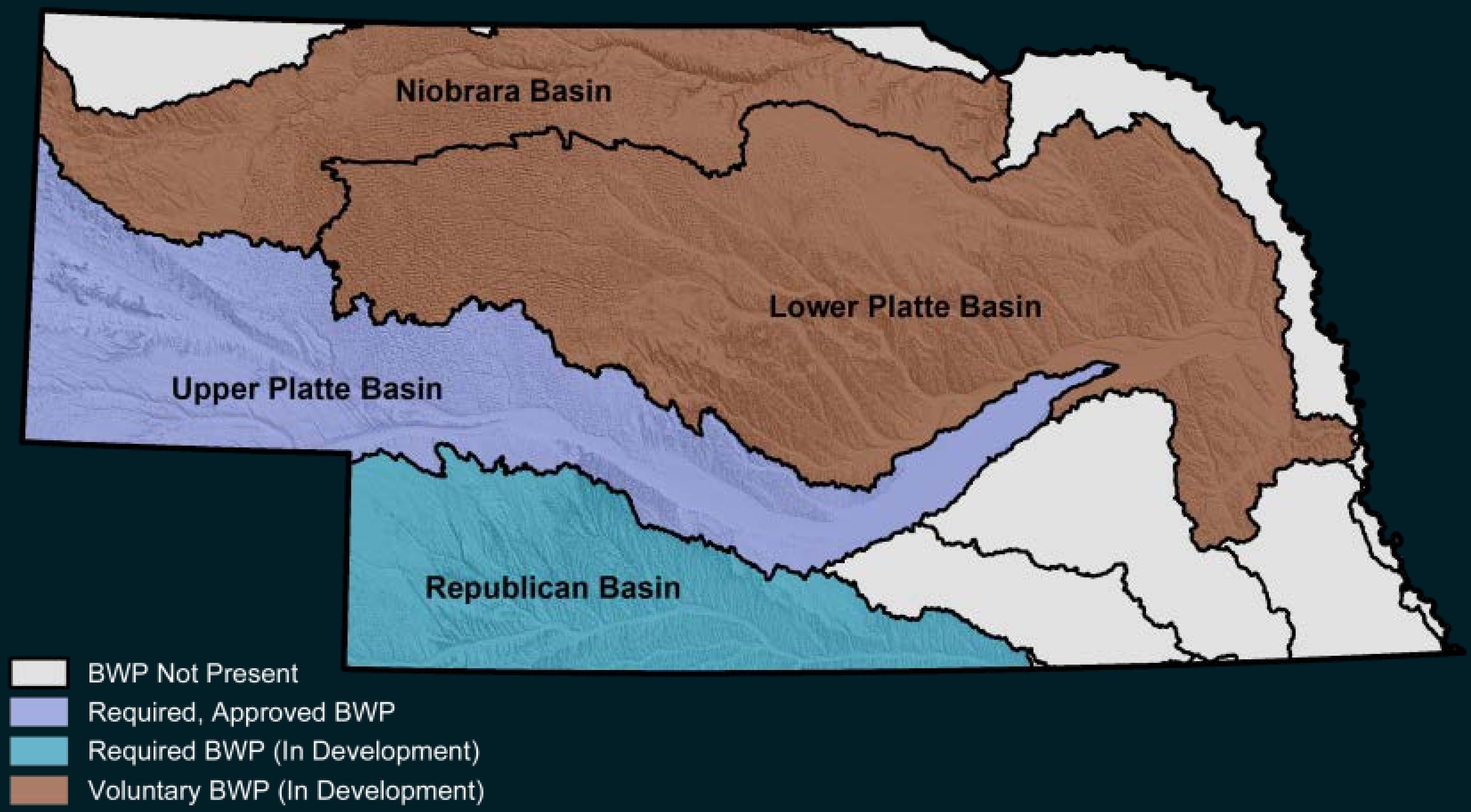
Integrated Management Plans

- For Addressing Effects of Existing and Potential New Uses on Existing Surface Water and Groundwater Users
- Contains Goals and Objectives Aimed at Balancing Water Uses and Water Supplies to Provide for Socioeconomic Viability
- Contain Groundwater and Surface Water Controls That Must
  - Be Consistent with the Goals and Objectives
  - Ensure Compliance with Interstate Compacts and Decrees
  - Protect Existing Users from Depletions Caused by New Uses
- IMPs cannot Require the Regulation of Existing Groundwater Uses, Except as Required Above

Basin-Wide Planning in Nebraska
(As of May 2015)



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Basin-Wide Plans

- Have Varying Purposes
- Voluntary Basin-wide Plans
  - Encourage collaboration Between NRDs in a Given Basin as they Develop Voluntary IMPs
- Platte Overappropriated Basin-wide Plan
  - Incrementally Return Basin to Fully Appropriated Condition
- Republican River Basin-wide Plan
  - Contains Goals and Objectives Aimed at Balancing Water Uses and Water Supplies to Provide for Socioeconomic Viability
  - Ensure Compliance with Interstate Compact
  - Set a Timeline for Achieving the Goals and Objectives of the Plan

EFFECTS OF GROUNDWATER PUMPING ON AQUIFERS AND STREAMFLOW

Hydrogeologic concepts

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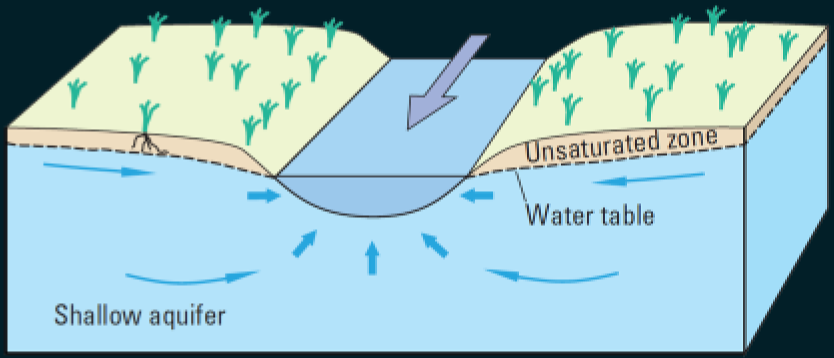
Interaction of Groundwater and Streams

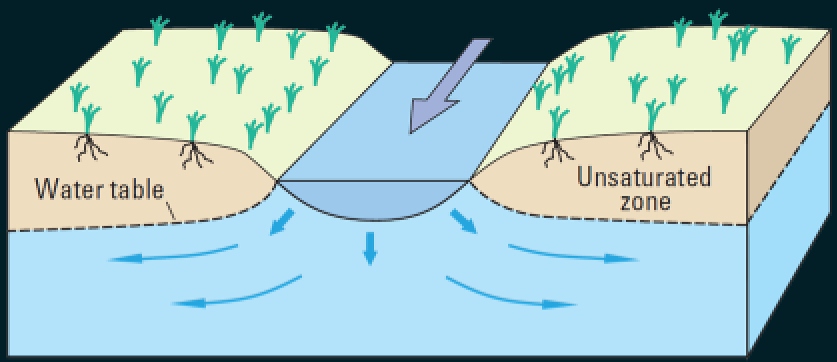
- Groundwater is discharged into streams where:
  - the altitude of the water table is greater than the altitude of the stream surface

- Conversely, streamflow seeps into the underlying groundwater system where:
  - the altitude of the stream surface is greater than the altitude of the water table

Gaining Stream



Losing Stream



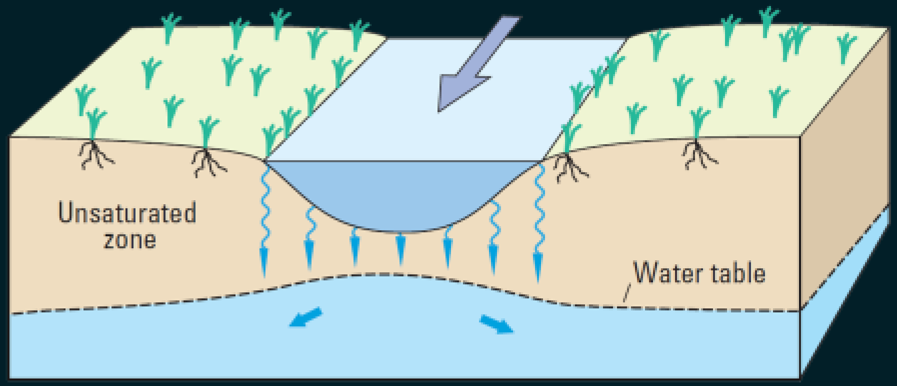
Interaction of Groundwater and Streams

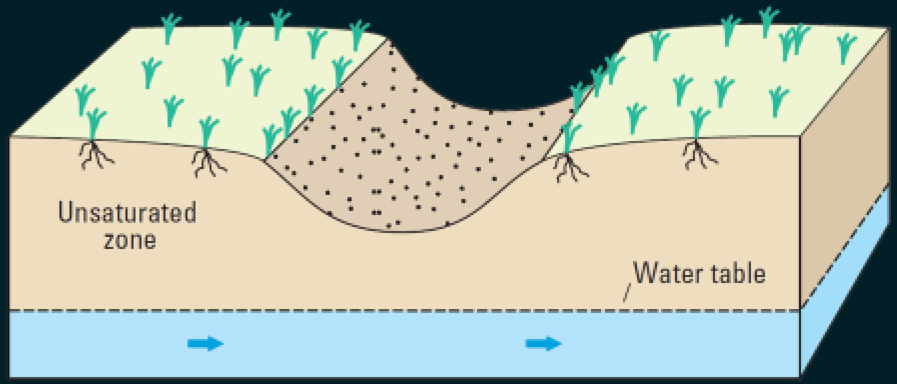
- Depletion of the water table can eventually cause the altitude of the water table to become too low to support the stream.

- The rate at which water flows between a stream and adjoining aquifer depends on:

    - the hydraulic gradient between the two water bodies

    - the hydraulic conductivity of materials located at the intersection of ground and surface water





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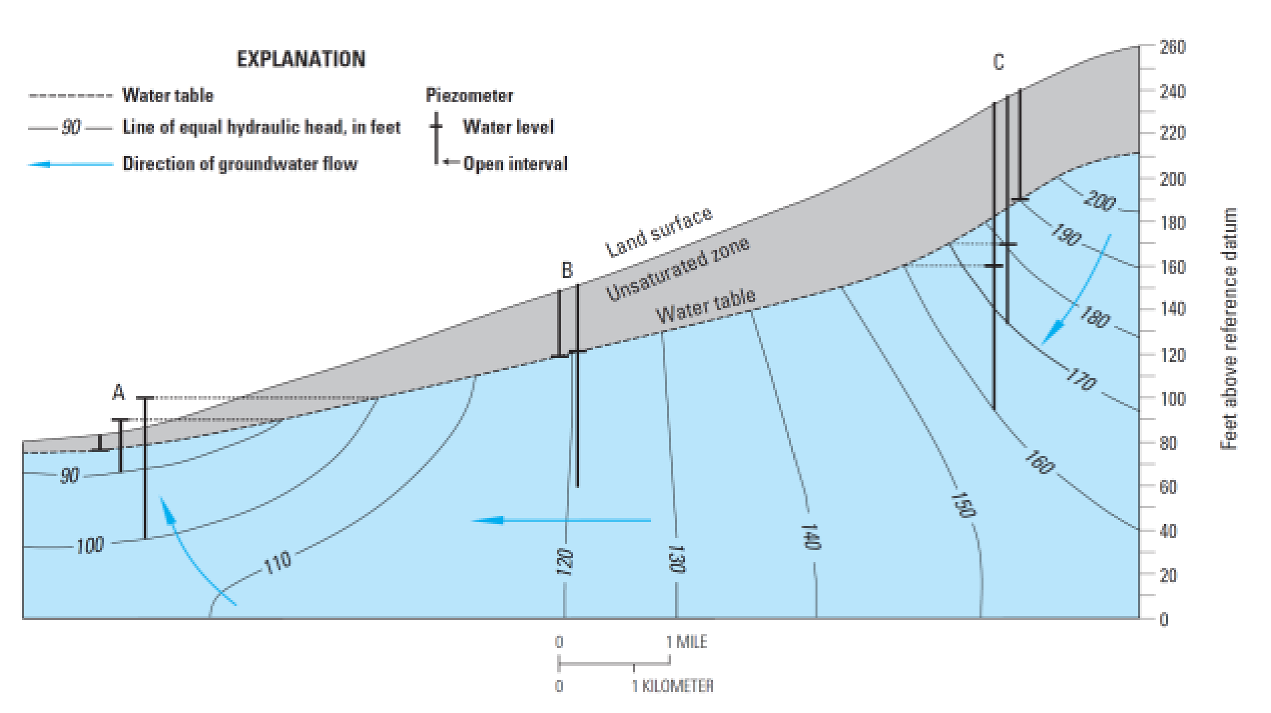
Hydraulic Gradient

- The rate of groundwater flow in a particular direction is dependent on:
  - the hydraulic conductivity of the aquifer
  - the gradient of the hydraulic head in the direction of interest

- The hydraulic gradient is equal to the change in head over a unit distance

- **Determined by**
  - water-level measurements
  - water-level contours drawn for a horizontal or vertical section of an aquifer



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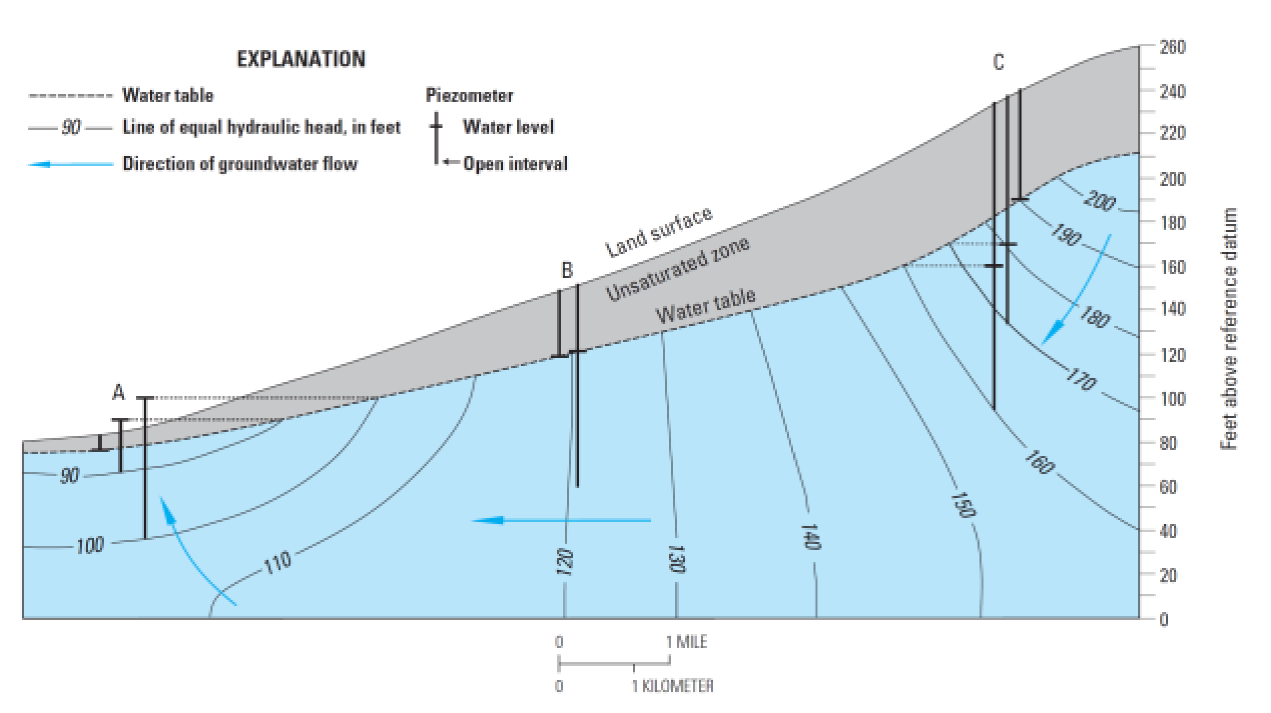
Hydraulic Gradient

- Groundwater levels are equivalent to hydraulic heads
  - They also reflect the total potential energy of the groundwater system at the point of measurement.

- Groundwater flows from locations of higher potential energy to locations of lower potential energy
  - (Decreasing hydraulic head)



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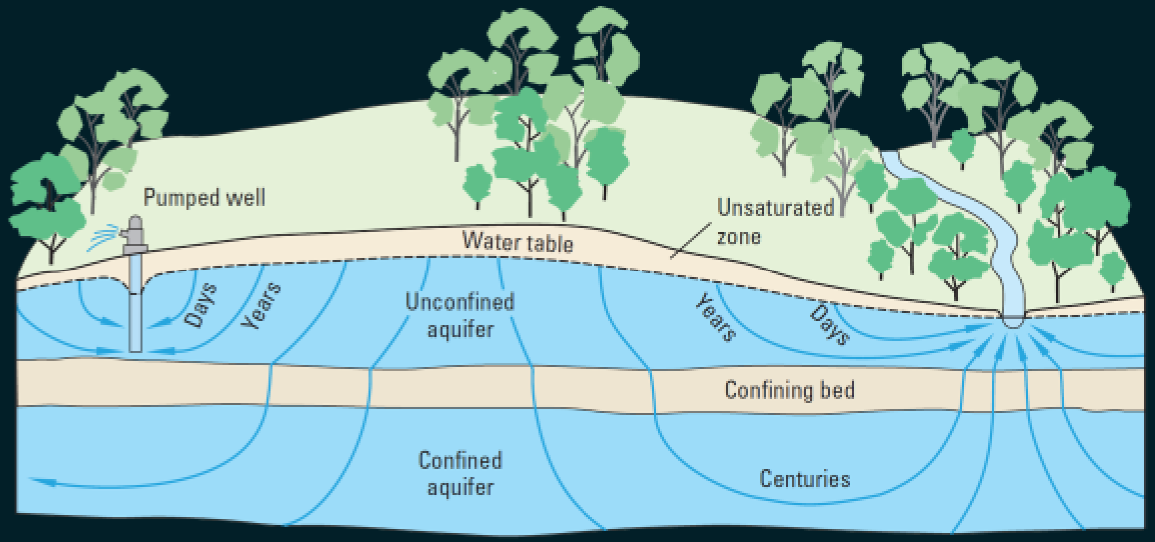
Hydraulic Conductivity

- Flow and storage of water in a groundwater system affect the timing, locations, and rates of streamflow depletion.

- Hydraulic conductivity (K)
  - describes the rate of flow of a volume of water through a unit area of aquifer under a unit gradient of hydraulic head



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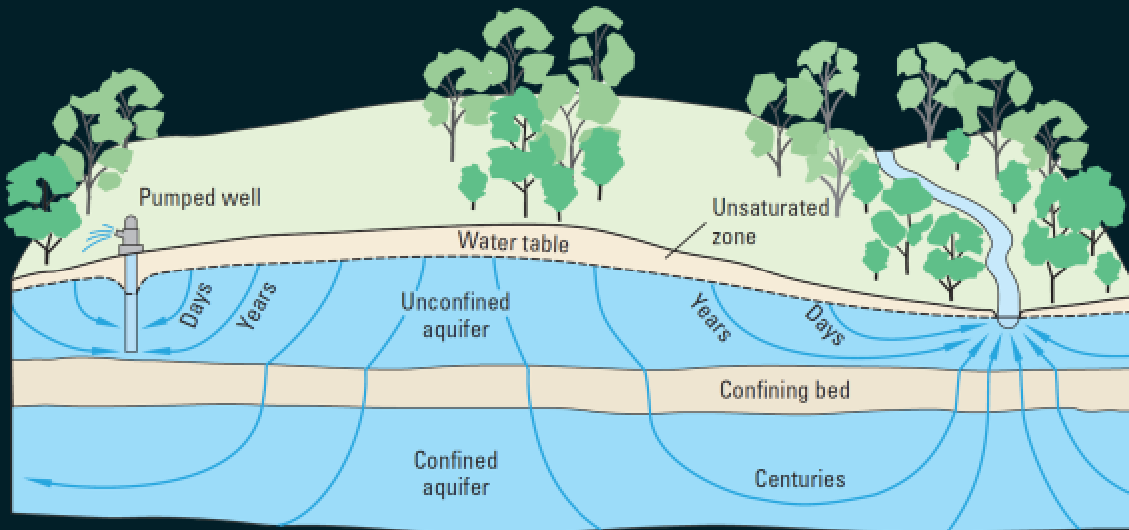
Hydraulic Conductivity

- The measurement units of K are length per time, such as feet per day (ft/d).

- Hydraulic conductivity depends on
  - the characteristics of the porous material
  - the density and viscosity of the water within the porous material



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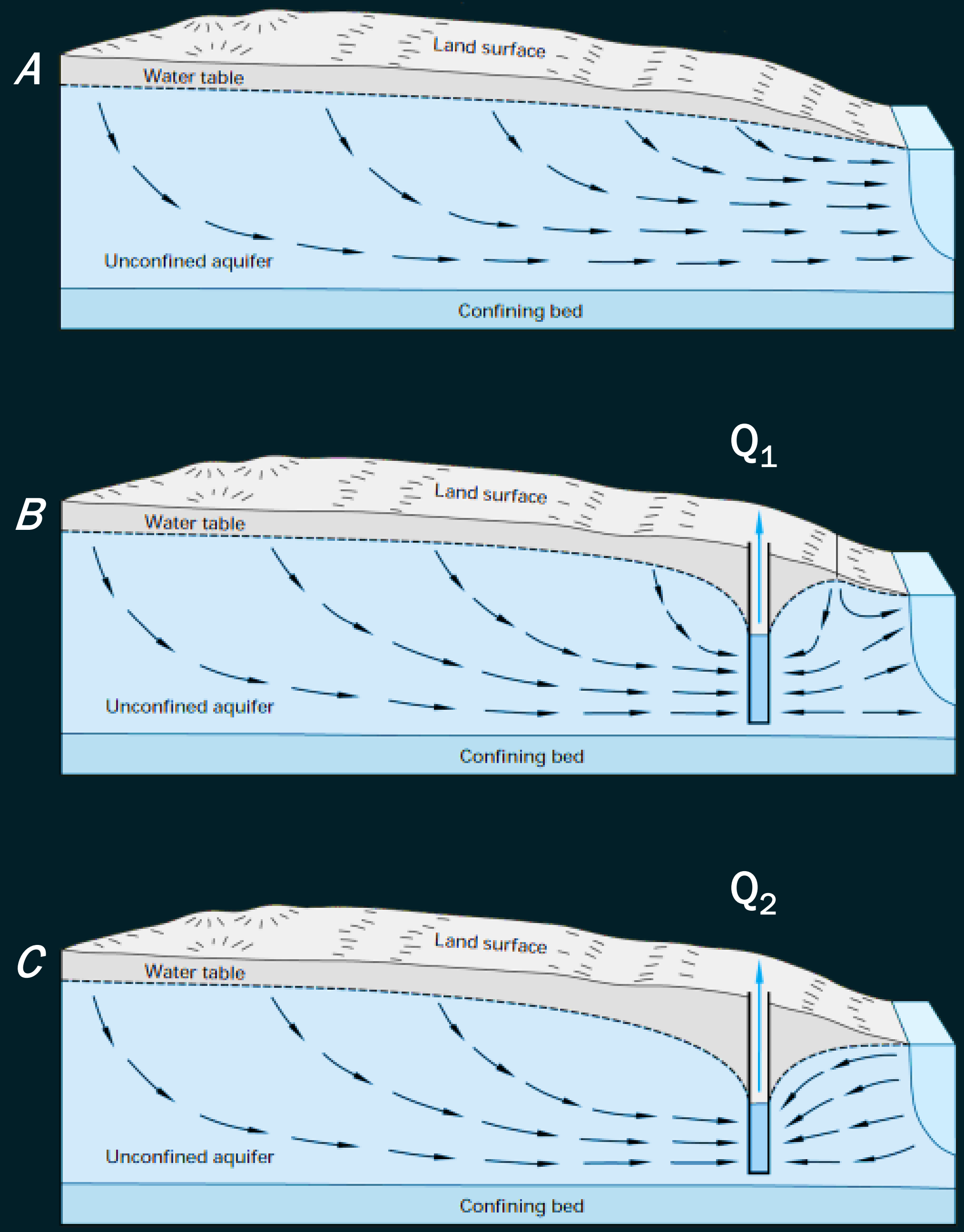
Pumping Rate

- Placement of a well pumping at a rate (Q1) near the stream will intercept part of the groundwater that would have discharged to the stream (B).

- If the well is pumped at an even greater rate (Q2), it can intercept additional water that would have discharged to the stream in the vicinity of the well and can draw water from the stream to the well (C).



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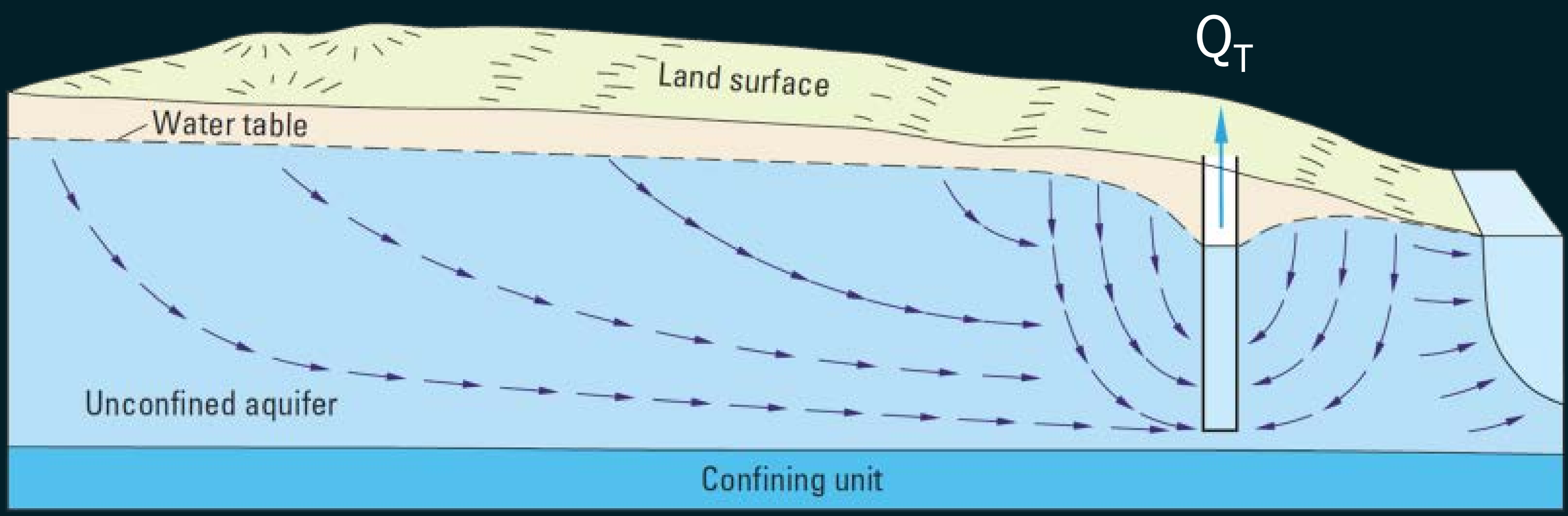
Pumping Duration

- As a well begins to pump water from an aquifer, groundwater levels around the well decline.
  - Thus creating a "cone of depression" in the water levels around the well.
  - A hydraulic gradient is now present between the normal water table and the aquifer around the well.

- The hydraulic gradient established within the cone of depression forces water to move from the aquifer into the well.



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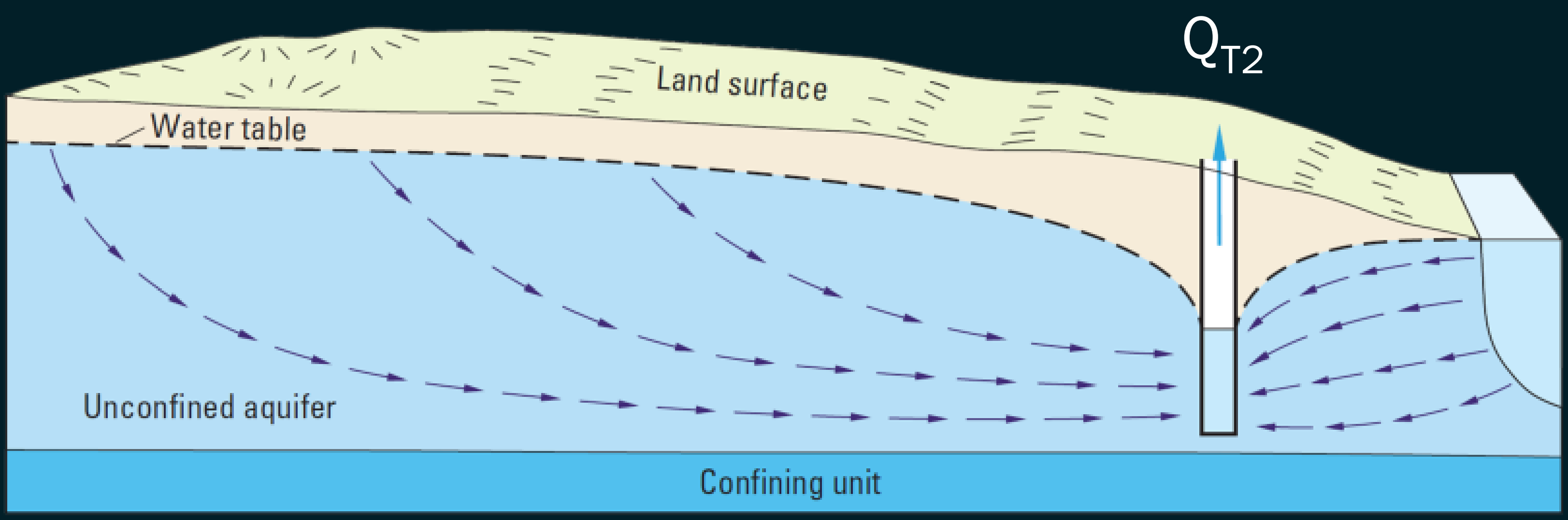
Pumping Duration

- Initially, all water pumped by the well comes from water stored in the aquifer
- With increased pumping time (Q_{T2}) the cone of depression deepens and expands laterally
- In some circumstances, the pumping rate of the well may be large enough to cause water to flow from the stream to the aquifer,



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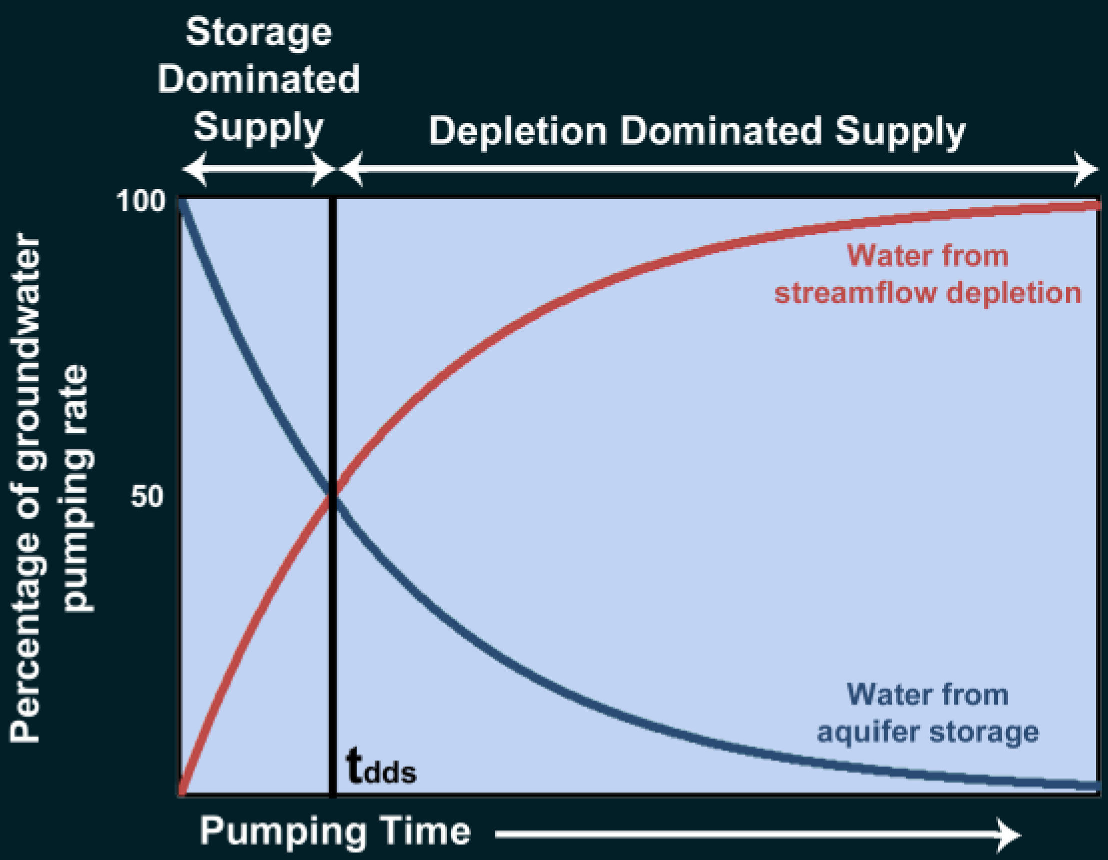
Storage vs. Depletion Dominated Supply

- Initially, the source of water to the well is dominated by reductions from aquifer storage.

- After t_{dds}, streamflow depletion is the dominant source of supply.

- Variable t_{dds} is the time to reach the condition of depletion-dominated supply.



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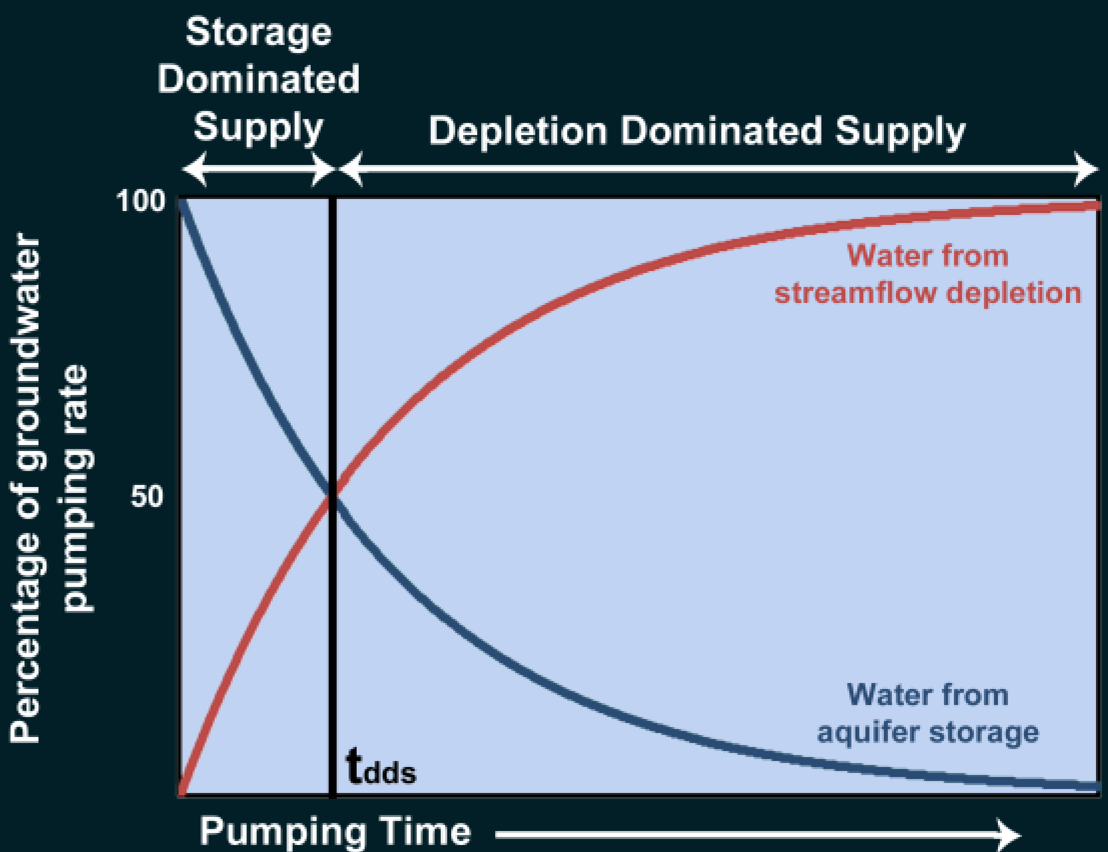
Storage vs. Depletion Dominated Supply

- If the well pumps for an extended period of time, the source of water will be entirely from stream depletion.
- When this occurs,
  - the pumping rate of the well is equal to the amount of streamflow depletion.
- The time required for a new state of equilibrium "time to full capture" can range from days to decades and even centuries.



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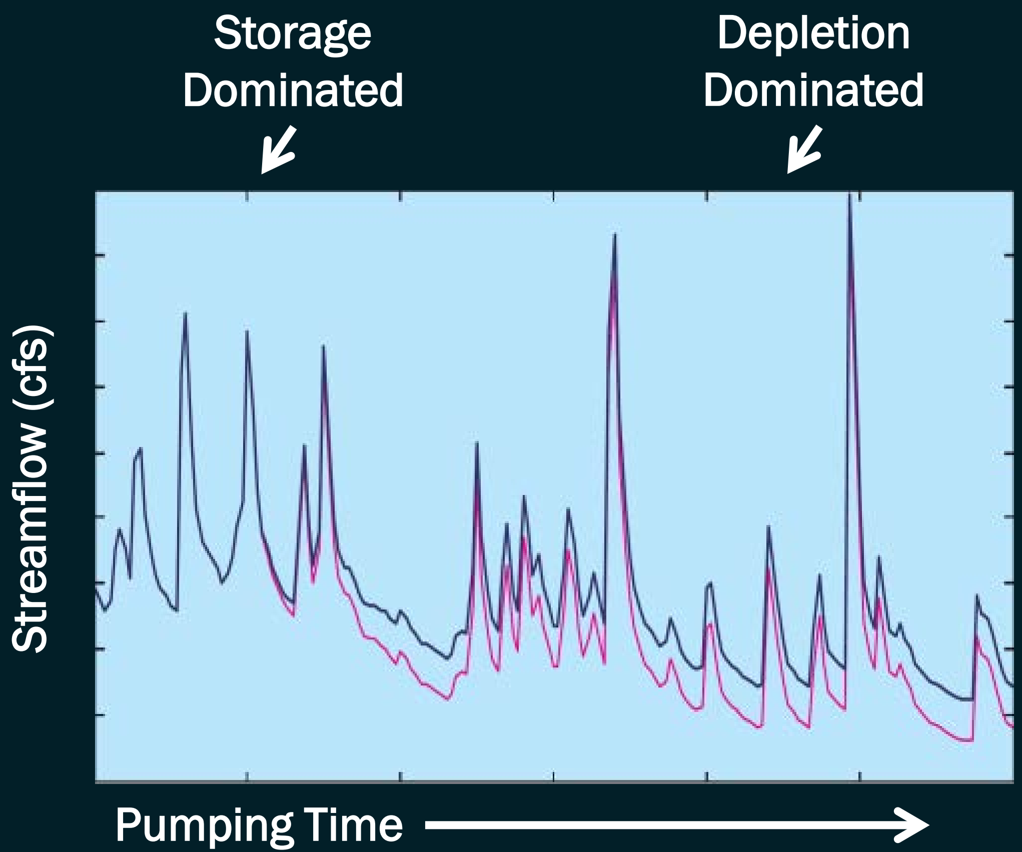

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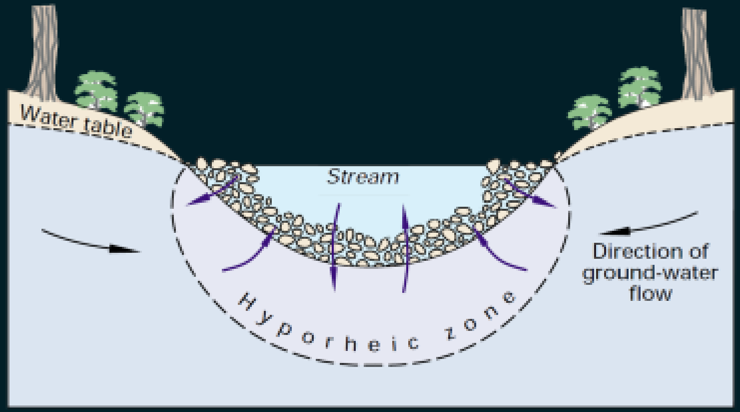
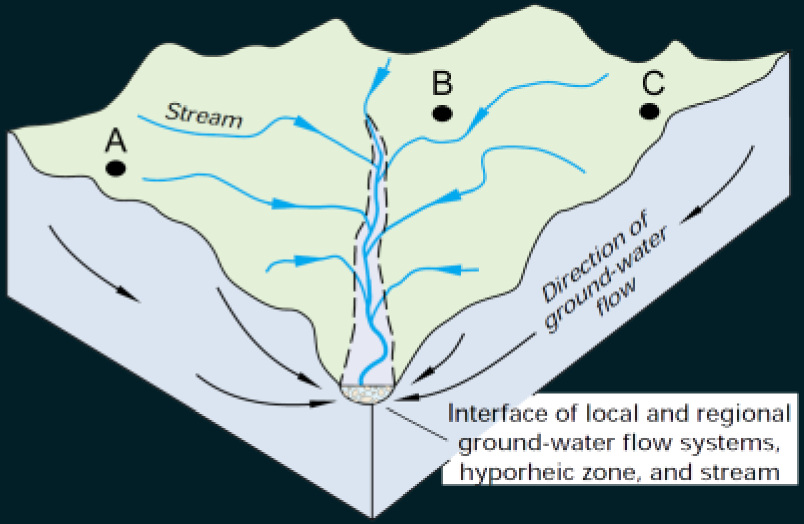
Time response of streamflow depletion due to pumping

Dependent upon

- Geologic structure, dimensions, and hydraulic properties of the groundwater system
- Geologic and hydrologic conditions along the boundaries of the groundwater system, including the stream banks
- Horizontal and vertical distances of wells from the streams.





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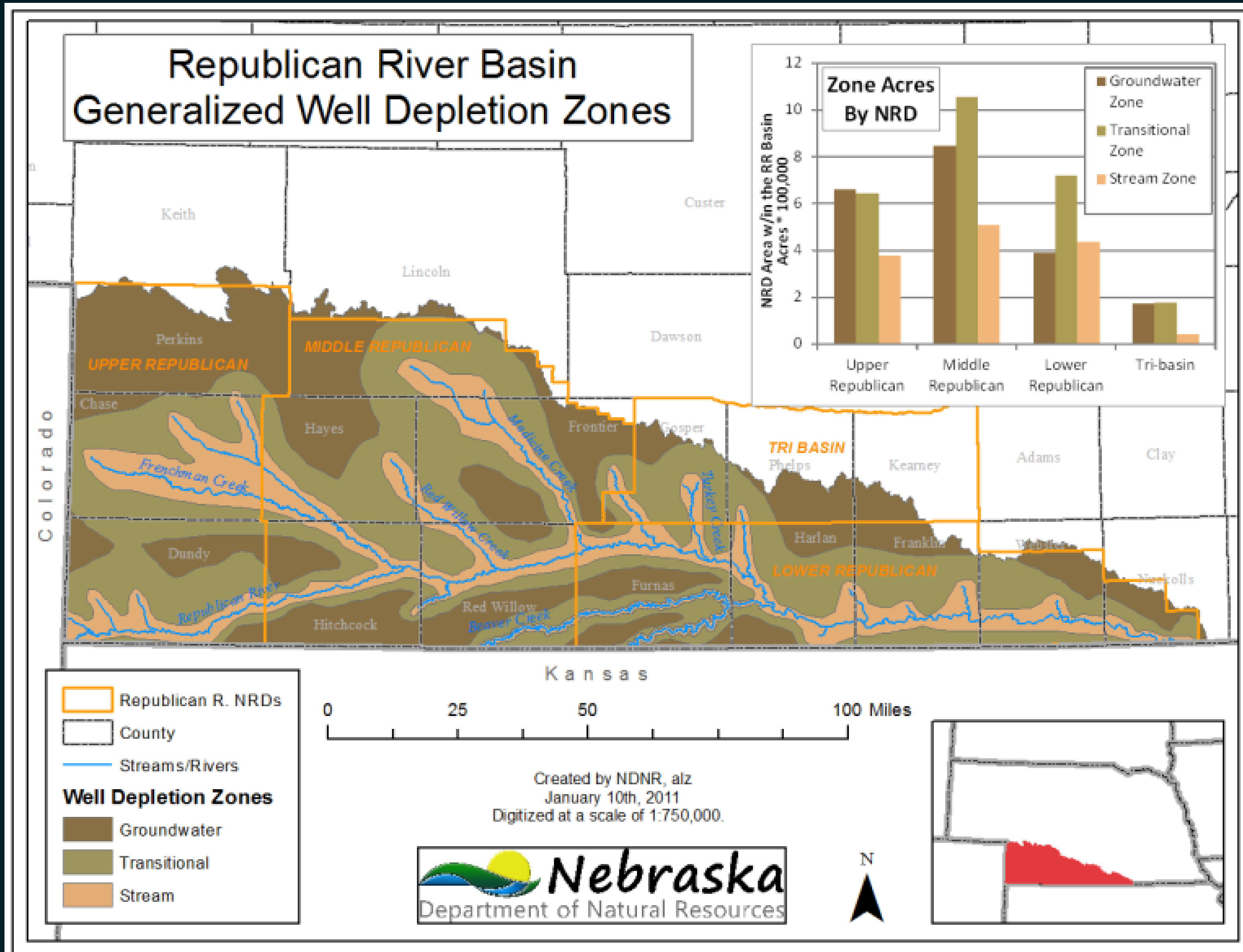

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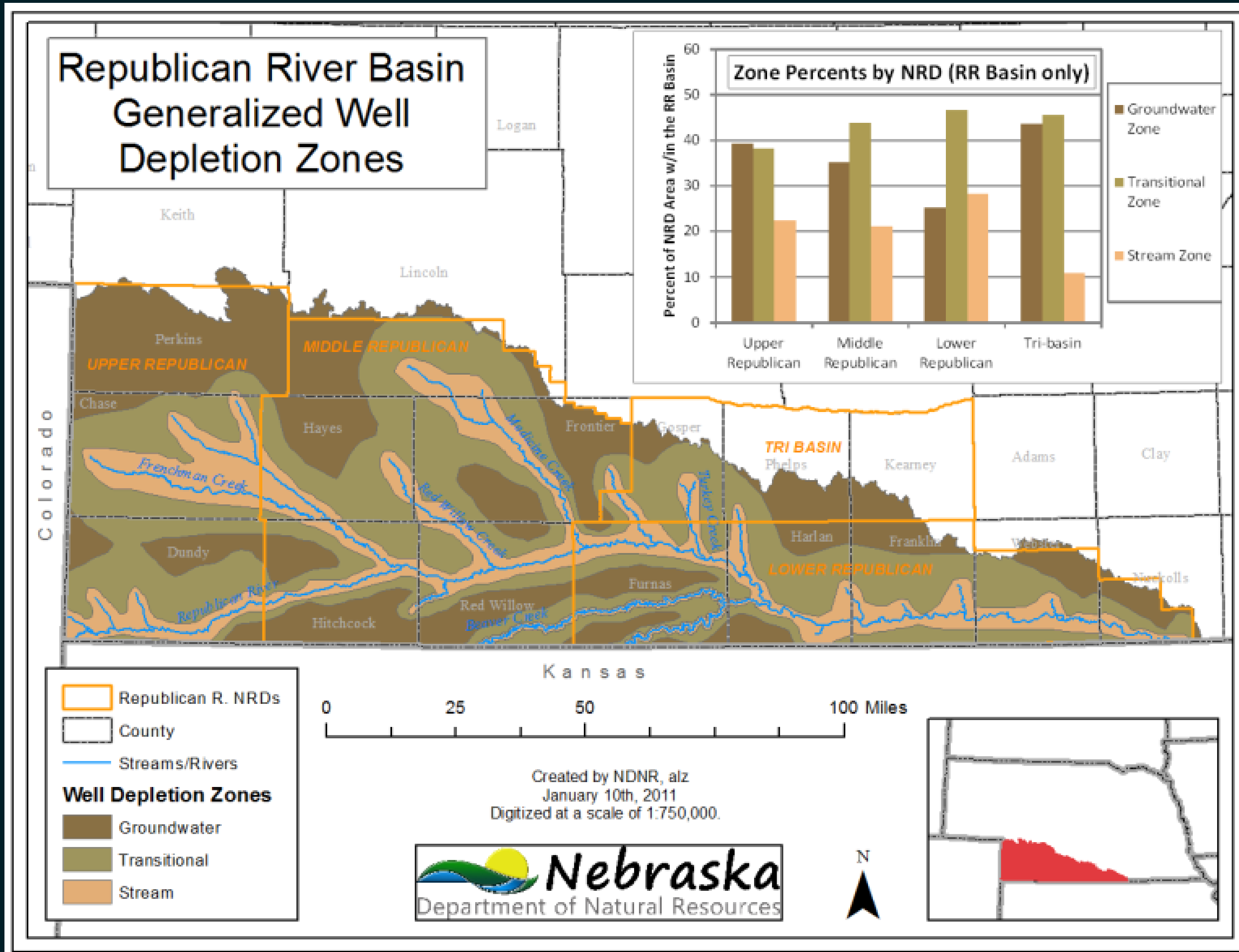

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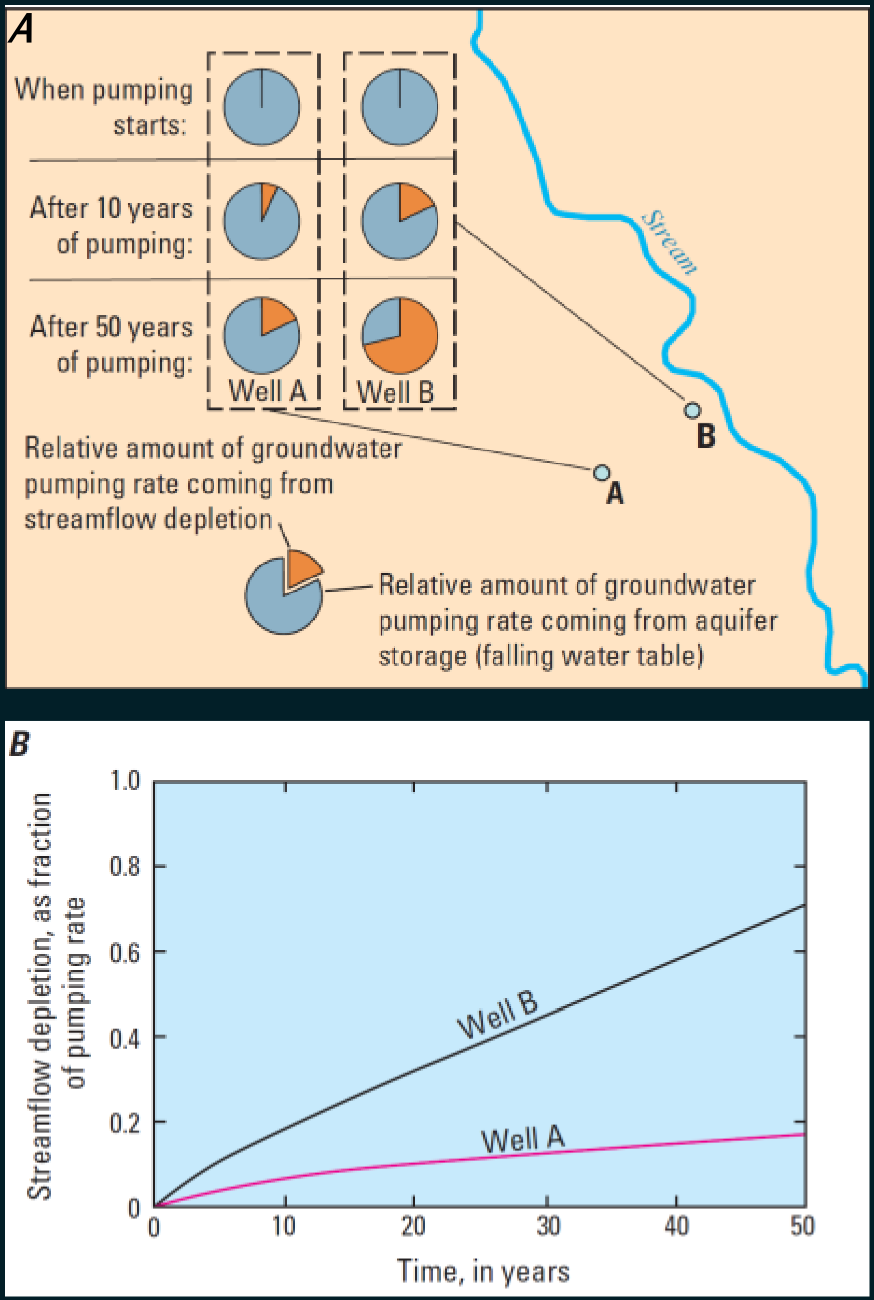
Well Location

- Well A is located much farther from the stream than well B.
- Time necessary for the cone of depression formed by pumping at well A to reach the stream is much longer than for well B.
- Groundwater-storage depletion is a source of water to the well for a longer period of time.



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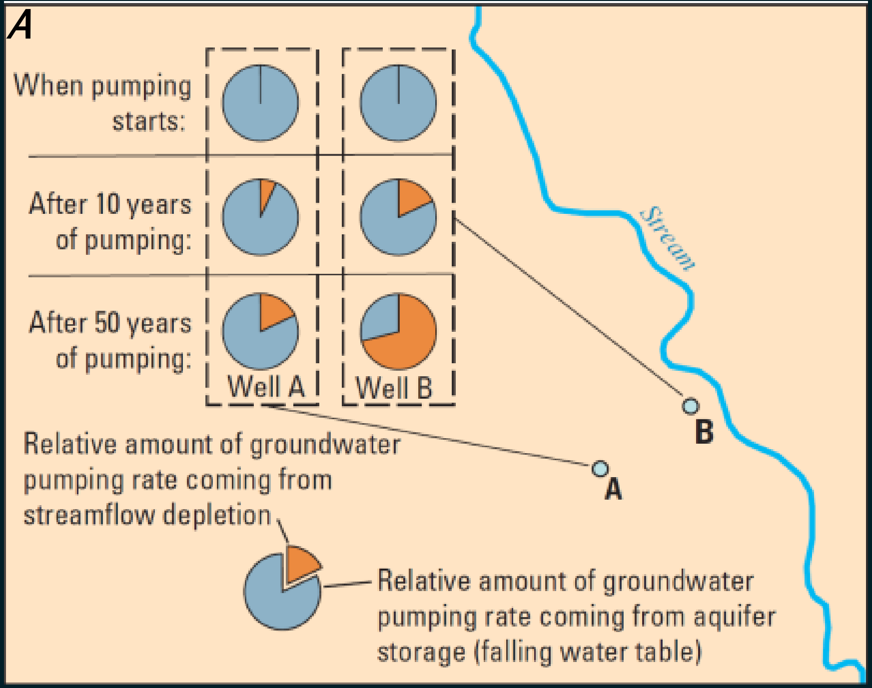
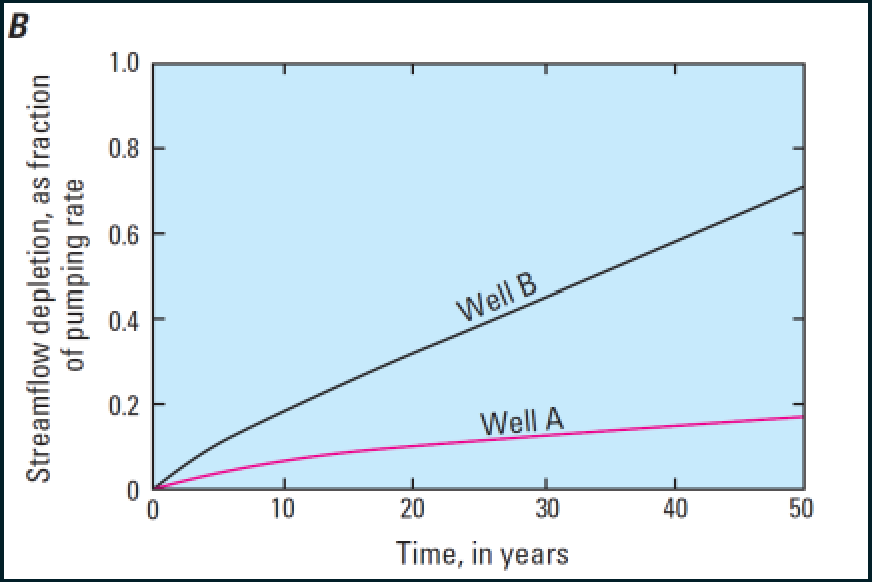
Well Location

- In contrast, the cone of depression formed by pumping at well B reaches the stream much <u>sooner</u> than for well A.

- Likewise, Streamflow depletion becomes the primary source of water to the well much <u>sooner</u> than for well A.





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Common Misconceptions

- Misconception 1: Total development of groundwater resources from an aquifer system is "safe" or "sustainable" at rates up to the average rate of recharge.

- Misconception 2: Depletion is dependent on the rate and direction of water movement in the aquifer.

- Misconception 3: Depletion stops when pumping ceases.

- Misconception 4: Pumping groundwater exclusively below a confining layer will eliminate the possibility of depletion of surface water connected to the overlying groundwater system.

Misconception : Depletion is dependent on the rate and direction of water movement in the aquifer.

- Depletion is the sum of pumping-induced increased inflow to the aquifer and decreased outflow from the aquifer.
- Depletion is independent of the natural, pre-pumping rates of recharge and discharge.
- Timing and locations of depletion are affected, however, by aquifer properties and system geometry.
- Distributions of vertical and horizontal hydraulic conductivity, specific storage, specific yield, and aquifer thickness, in addition to well distance from the stream, are the key properties that control the timing of depletion.

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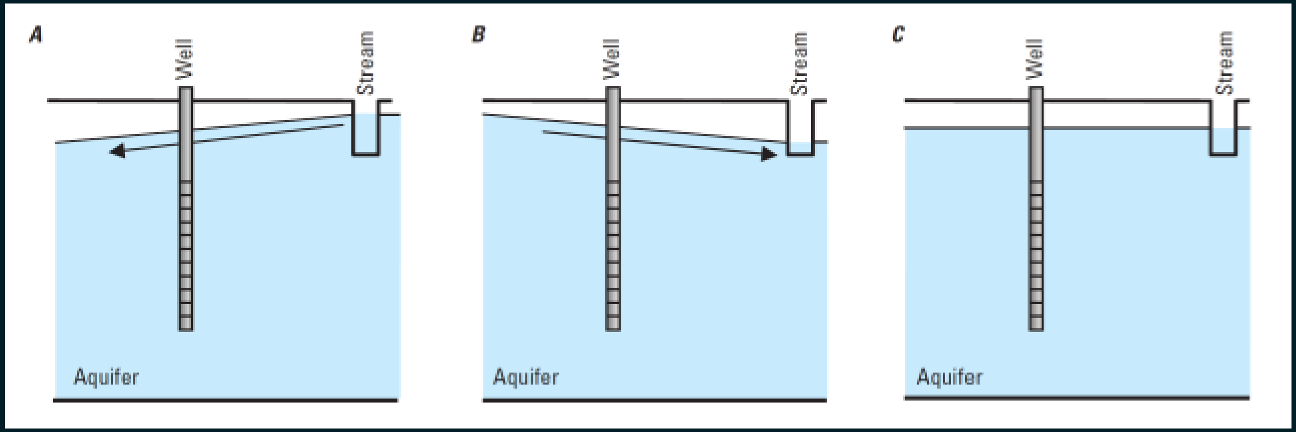
Misconception : Depletion is dependent on the rate and direction of water movement in the aquifer.

- Given that aquifer properties are the same in each case, total depletion at any given time would be the same for cases with;
  - natural pre-pumping flow from the stream to the aquifer (fig. A)
  - natural pre-pumping flow from the aquifer to the stream (fig. B)
  - no flow between the aquifer and the stream (fig. C)



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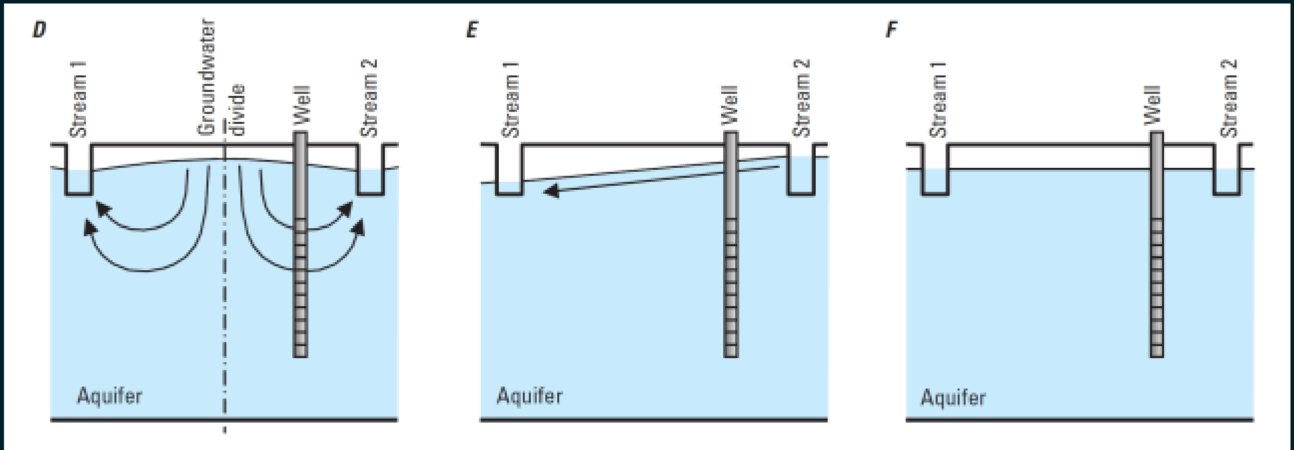
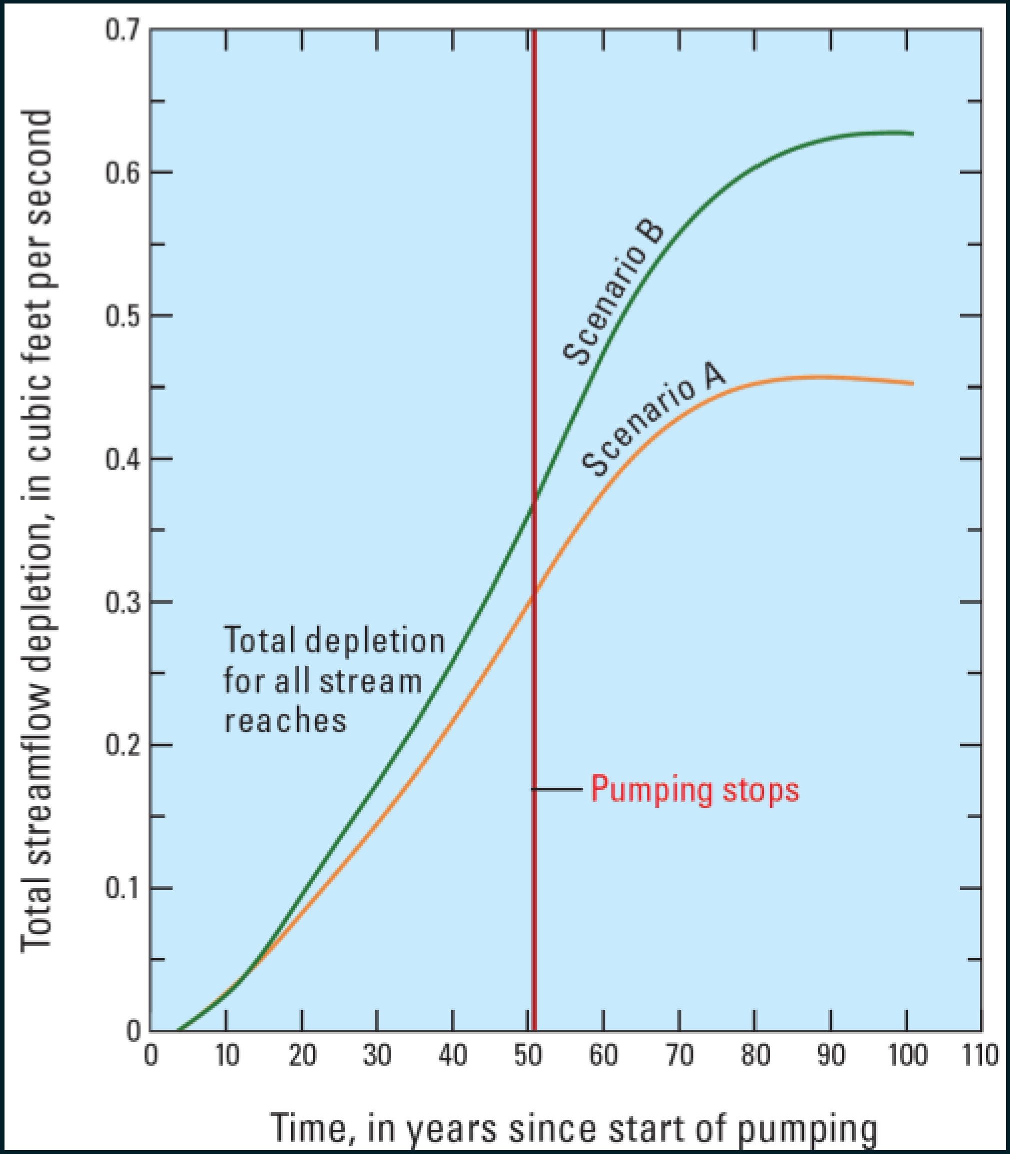
Misconception : Depletion is dependent on the rate and direction of water movement in the aquifer.

- Furthermore, relative amounts of depletion in multiple streams are the same regardless of;
  - o the existence of a divide between the streams (fig. D)
  - o natural flow from one stream to another (fig. E)
  - o no flow between the streams (fig. F)



Stream Depletion Continues as Pumping Stops

- Maximum depletion can occur after pumping stops.
  - particularly for thin aquifers with low hydraulic conductivity or
  - for large distances between pumping locations and the stream
- The time from cessation of pumping until full recovery can be longer than the time that the well was pumped.



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