Nebraska LB-517 Task Force

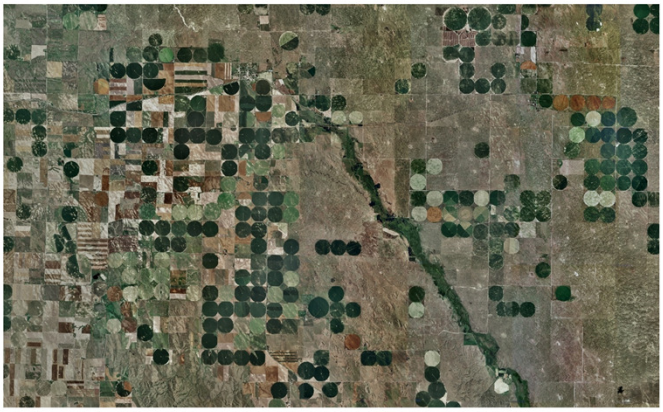
H_2Options Engr. LLC

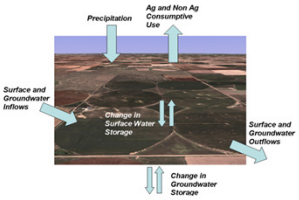
with
Brown and Caldwell

August 9, 2013

Republican River Basin Water Balance Study

Frank Kwapnioski, P.E.





To EFFECTIVELY MANAGE, it helps to FIRST UNDERSTAND

This is the premise on which we provide this study
At this level, the study is more inventory tool than solution tool

Disclaimer

This presentation is intended for discussion purposes only.

The information contained herein does not represent the views, conclusions or opinions of the Upper Republican NRD, Middle Republican NRD, Lower Republican NRD, nor the State of Nebraska nor its agencies.

We were requested to add this disclaimer to our presentations of the Republican River study. Similar disclaimers are required on some UNL research work as well

Presentation Context

- In water there is no single Silver Bullet
- I am painting with a broad brush
- Even with the facts it is not easy
- We can not solve a problem with the same thinking that created it
- What you see here might challenge you

Here are my stipulations as well. **A Water Budget inventory is an indispensible tool but it is not the solution**.

•To be successful with water management, I believe we must be comprehensive and look at the entire resource and all possible opportunities. I would be happy to help develop more detail

•It is a big job so a big brush or even a sprayer is necessary. An artist or trim brush is not likely to be effective

•Because of social, political and statutory restrains, even understanding what is happening isn't always enough. We must be able to keep water management process simple so we can encourage enough people to go along. Use of Mark Twain "Whisky is for drinking …" quote is not helpful

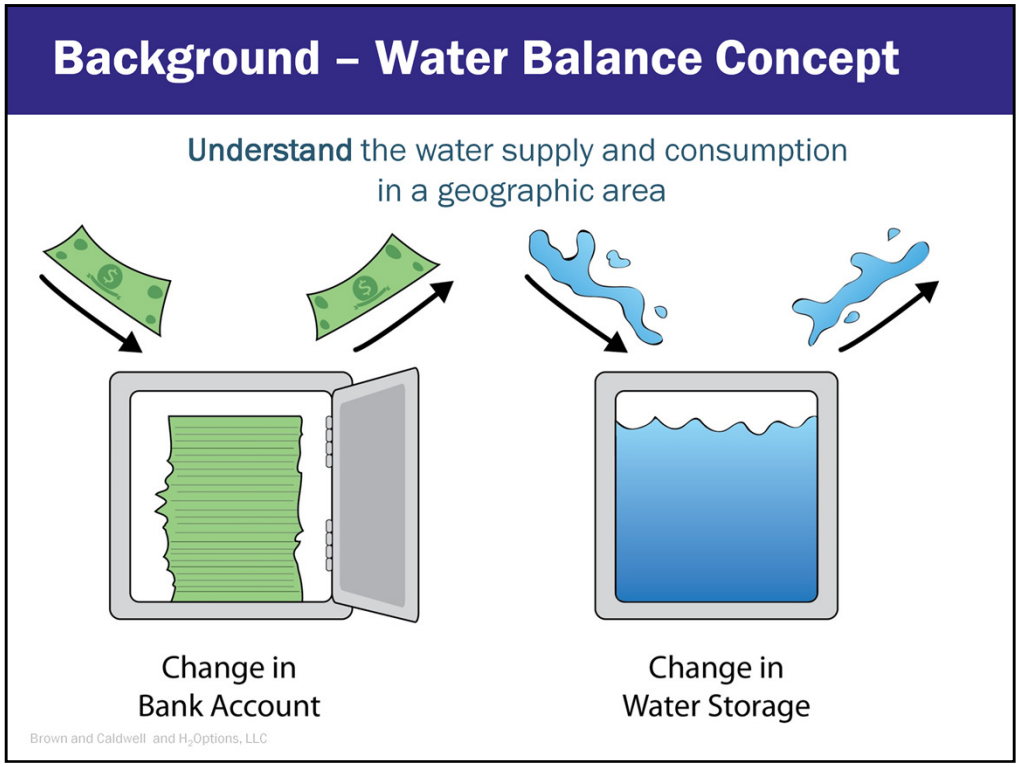
•Loose paraphrase of Albert Einstein quote. If we don't explore and look outside the box, real water management success is unlikely

•Hope this presentation raise some questions on what we are currently thinking and doing.

Presentation Overview

- Background
- Study Objectives
- Description of Analysis
- Results
- Conclusions
  - Uses of Water Balance Inventory as a Tool
  - Funding Needs

These are my major presentation objective



To be successful, water management must be easy to understand, relevant and effective
Water management can be as easy to understand as balancing your checkbook
For it to work, users must be able to see how implementation impacts and creates outcomes

Background - Water Budget Confirmations

- Water Budget inventory -- not revolutionary or untested. Long history and a high degree of utility for water management.
- Inventory technique used in 1960s-70s for 13 Nebraska river basins. (*Availability and Use of Water in Nebraska* - Ray Bentall, F. Butler Schaffer)
- USGS is currently using water budget as the basis for pursuing a National Water Census.
  - http://water.usgs.gov/watercensus/

    "A USGS research program on national water availability and use that develops new water accounting tools and assesses water availability at the regional and national scales." "The goals of a national assessment of water availability and use are to clarify our understanding of water-availability status and trends and improve our ability to forecast the balance between water supply and demand for future economic and environmental uses."
  - http://water.usgs.gov/watercensus/water-budgets.html

    "To illustrate the science behind the USGS Water Census, it is helpful to understand the concept of a *water budget*."

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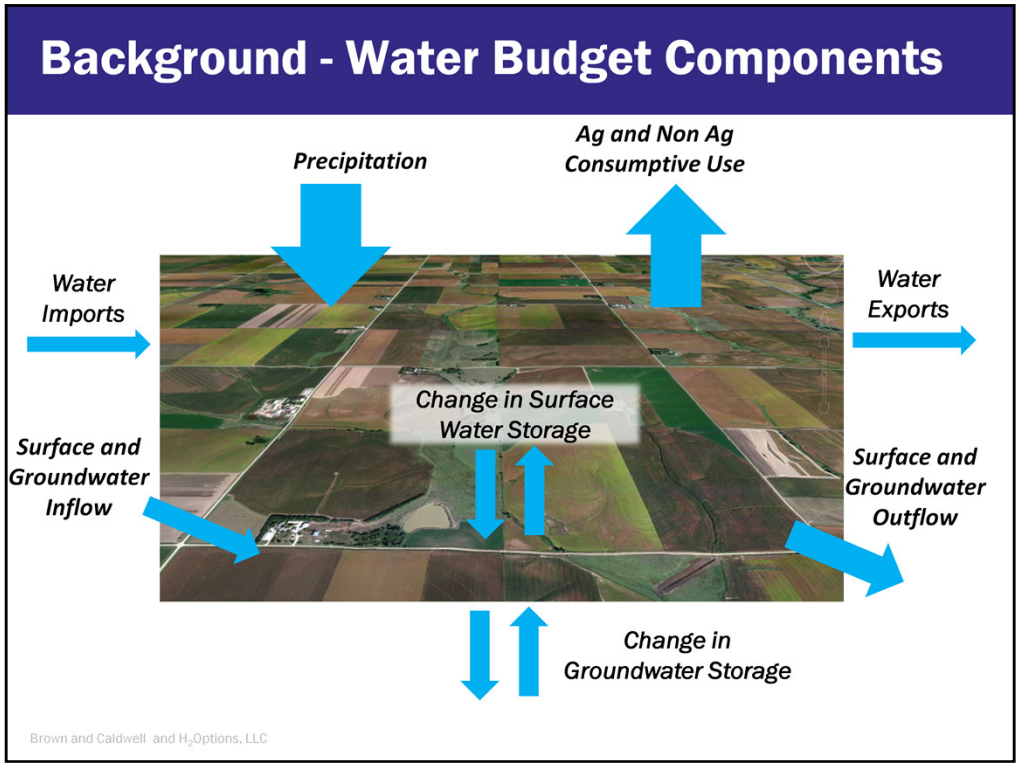
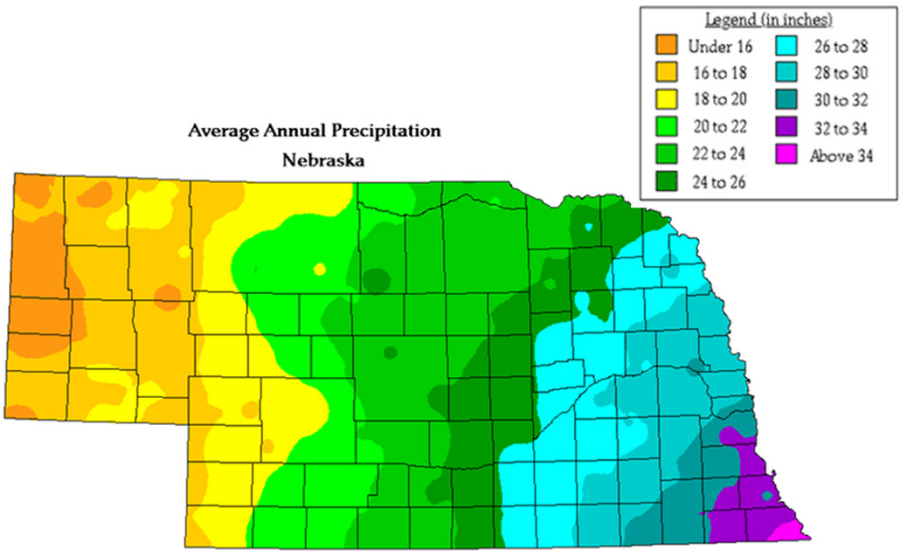
Can measure how things have actually changed since the 1960's-70's
The USGS intends to apply this same concept on a national level to a HUC-12 (township size) scale



In a water challenged area like Nebraska you must be willing and able to look at and assess the total resource

The arrows give some idea of the relative importance of these components of the water budget

Background - Statewide Precipitation



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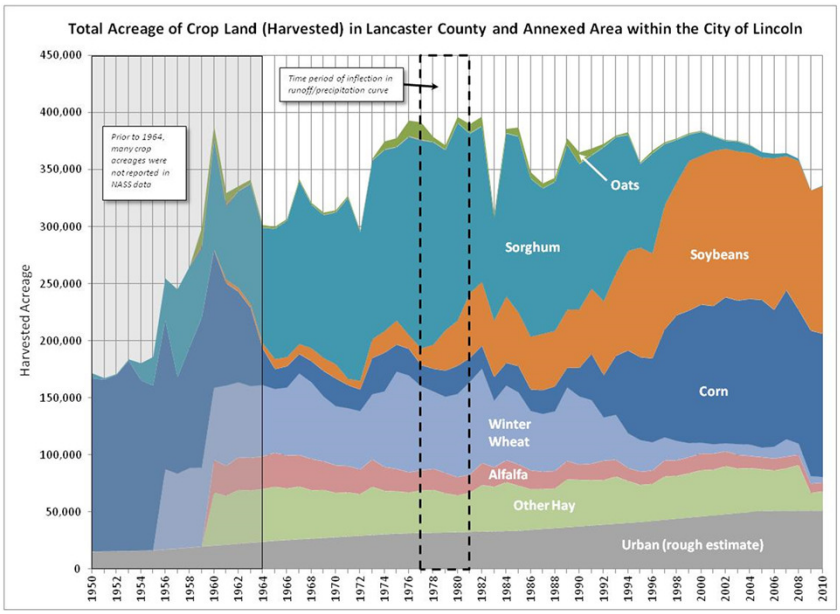
There is a lot of water in Nebraska but it is not always where or when you need it

This map represents over 90 million acre-feet of average annual renewable water supply

Unfortunately, historically between 25–30 million acre-feet of the water supply evaporate before we even consider management

Background - Sample Land Use



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Land use is not constant or linear over time and this is important if you want to manage water.

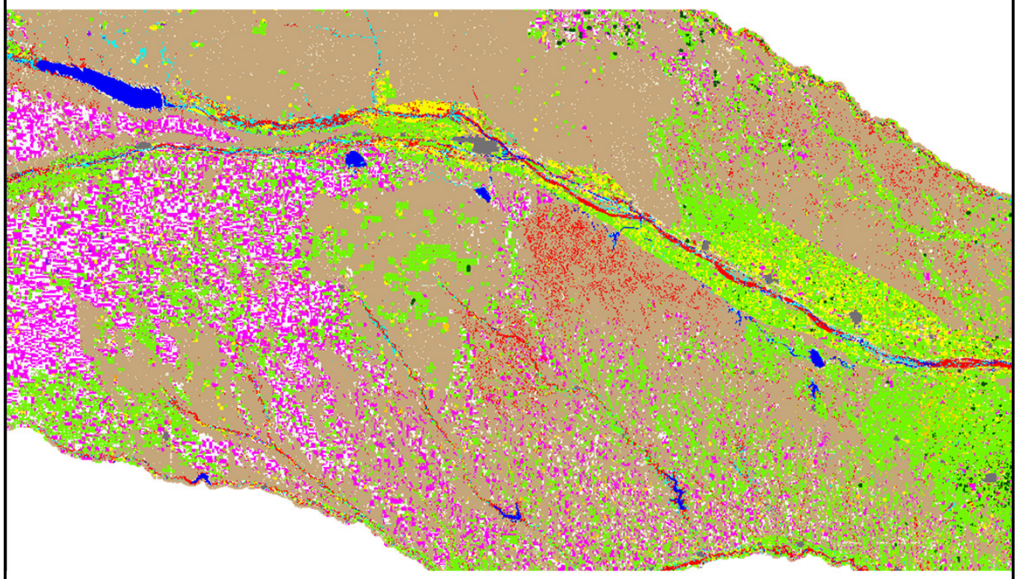
Different land uses have different water foot prints

There are many things you can see and learn from this type of graph

The 50's drought and it long term impact can be seen

If we are to manage effectively we must understand how we got here

1982 Land Use Determined by CALMIT



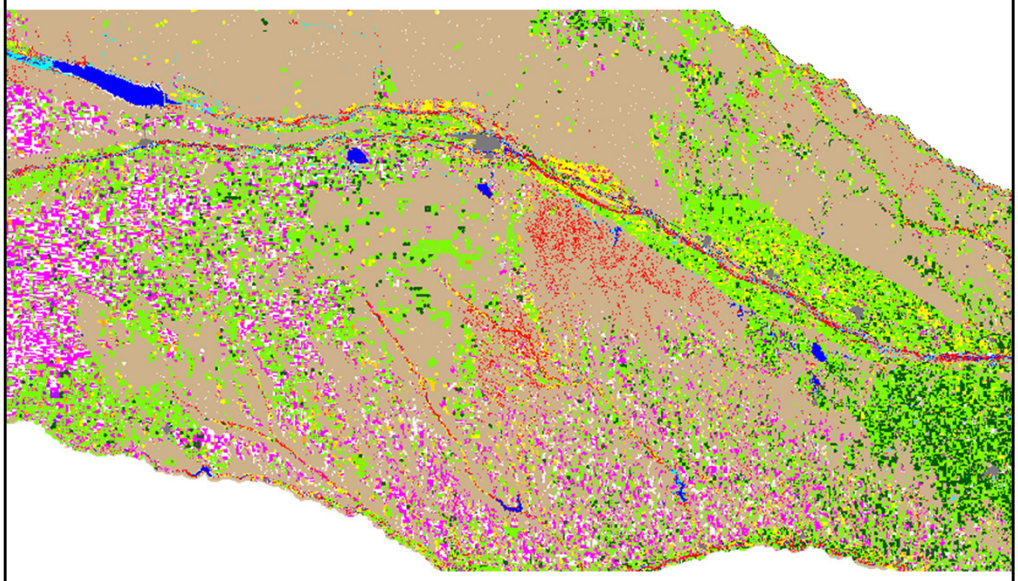
Indicates a way to show land use and land use changes. The various colors represent different land uses

The pink and white are summer fallow and the light green is corn

This map suggests how much of NE is not irrigated

But it also shows where and how the water consumption is occurring

2001 Land Use Determined by CALMIT



The conversion in the western area from summer fallow, pink and white, to continuous cropping, mostly light green, shows how major consumption changes can occur regardless of irrigation
The conversion in the eastern area from corn, light green to soybeans, dark green, indicates how irrigation consumption can be changed also

Available and updated land use and use change information is critical if we want to be able effectively manage the resource

Republican River Study Objectives

- Better understand the water balance
  - Full spectrum and extent of water supply and uses
- Tool to identify water management opportunities
- Identify data and research needs
- Foster understanding across state lines
- Publish study findings

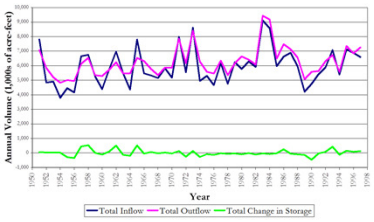
The study is within Nebraska, but it could be discuss with others across state lines

Description of Analysis

- We processed a lot of data
  - Precipitation
  - Consumption
  - Streamflow
  - Groundwater
  - Surface water
- Data was available from public sources
  - NDNR
  - University of Nebraska
  - COHYST
  - USGS
  - NRD

Raw Data

Processing



Results

We processed a lot of data but it was all currently available or easily developed

Description of Analysis

- Water balances were developed for
  - Each Republican River NRD
  - The Republican River NRDs combined
- Water balances were assessed over
  - A long term average
  - Annual time steps
- Today's presentation focuses on the basin-wide Republican River NRDs combined

We also did individual NRD by NRD inventories

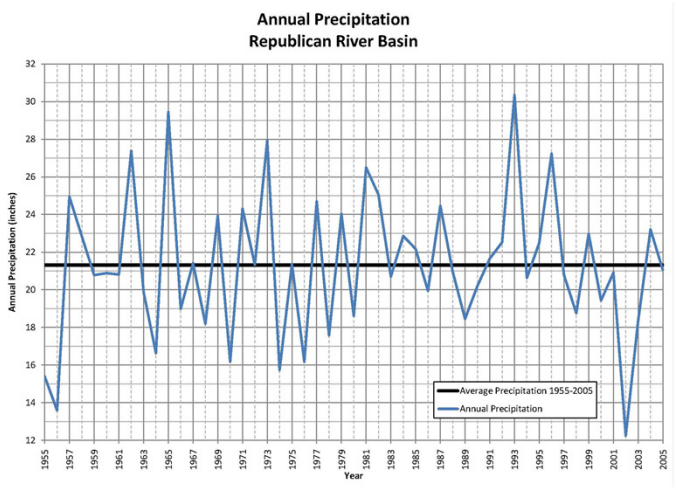
Description of Analysis - Data

- Mapping program used to quantify data
  - Program allows the user to overlay layers of mapping data (i.e. land use, study area boundary, etc.) and perform calculations
- Used study period of 1955 – 2005
  - Availability of historic data varied
  - Some aspects of basin hydrology changed around the time Harlan County Reservoir was constructed

We used GIS to quantify precipitation and ET amounts and based on our data availability assessments used 1955-2005 for the data period
One reason this concept has not been extensively been used was the lack of data and an effective way to assess it. GIS and other new technologies have removed this road block

Analysis: Precipitation

- The Republican River Basin receives 21.3 inches of annual precipitation on average



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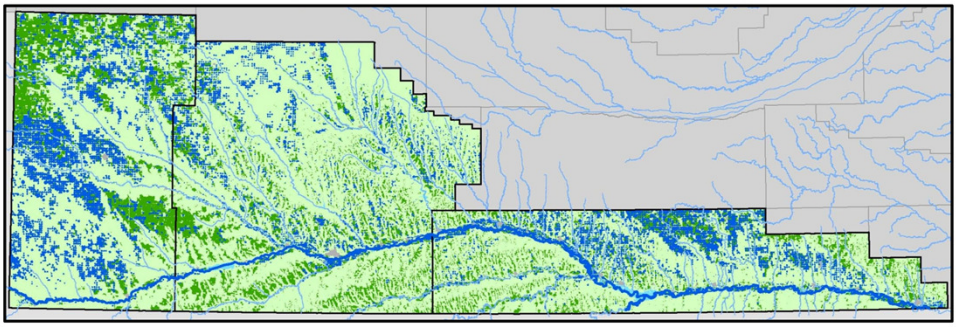
This graph shows average annual precipitation and variability over time in the study area. No real trend in precipitation evident

2002 was the lowest precipitation during this specific period of record

Interesting to note, the statewide average annual precipitation is 22.8” (for longer average timeframe, 1895 to present)

Analysis: Consumption - Land Use

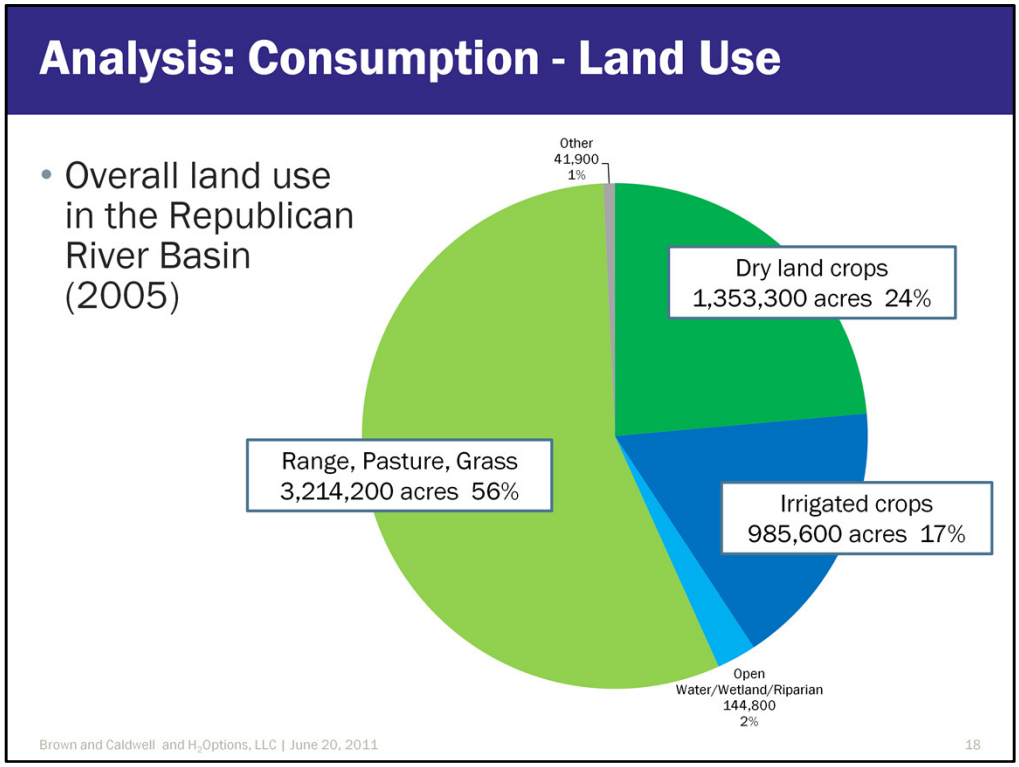
- 5.74 million acres
- 2005 CALMIT land use in the Republican River Basin



At the time of the study, the best land use available was 2005 data from UNL CALMIT and as far ass I know this is still the best data available. There was talk that NDNR was working on 2010 data but I am not aware that this is available.

I think an import water funding requirement is getting this information current and keeping it current.

Why is this important? Next slide

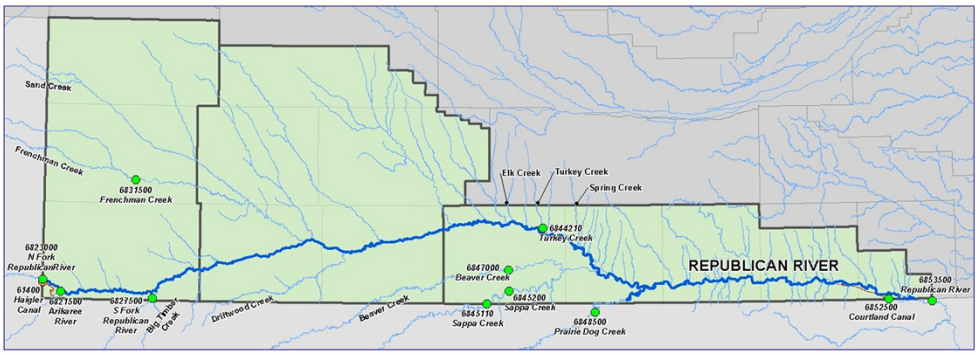


We can't manage what we can't quantify

In the Republican Basin, 64% of the irrigated cropland in 2005 was corn

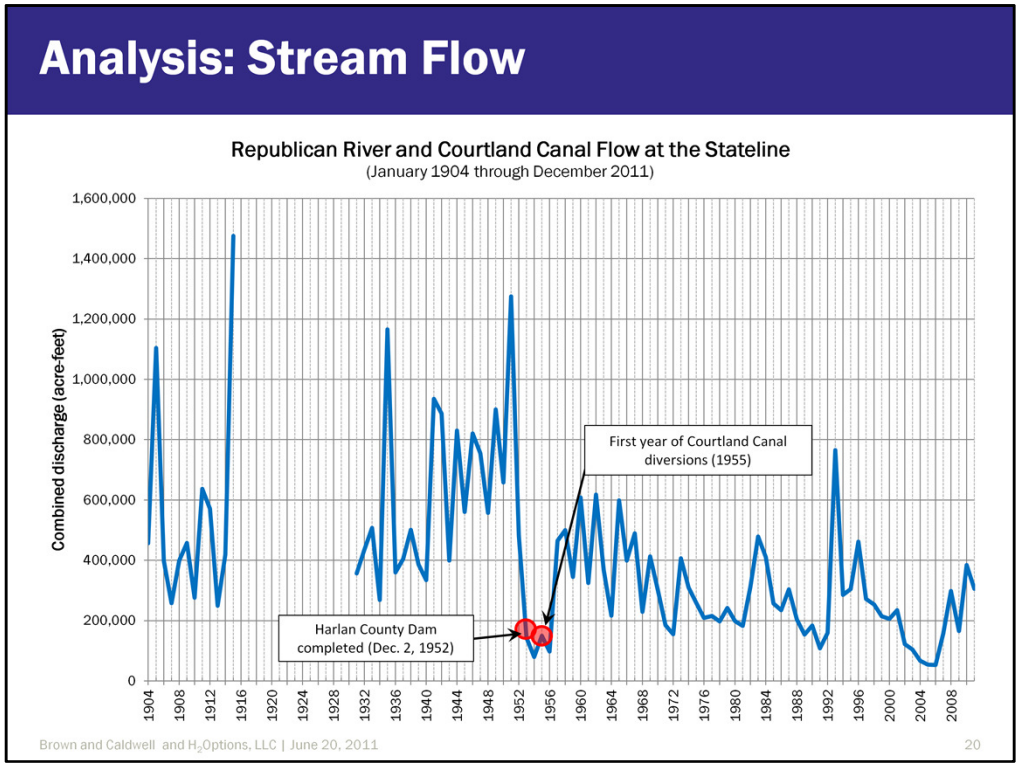
Analysis: Surface Flow

- Quantification of surface water inflow and outflow incorporated several stream gages and statistical relationships



This slide represents the study assessment of surface water flow

The labels identify all surface flows quantified and the green dots identify actual flow gages used



There is a significant apparent change in Republican Basin hydrology between 1904-1950 and 1955-2011. For this purpose, we chose to look at a study period that extended from 1955 to 2005 as most representative of current conditions.

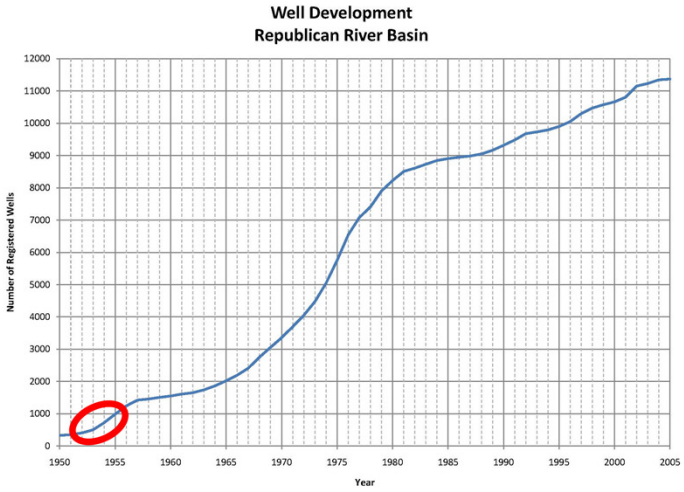
From this slide you might think you see why Republican River flow into Kansas may have declined, but wait a minute

The red circles are just for reference and this slide does not suggest that the major runoff change is in any way related to these surface water developments. If fact if you look at it, the drop predates them. It could have a significant tie to the 1950's drought.

It is commonly perceived that stream flow depletion lags well development. As you will see on the next slide, in the Republican, irrigation well development seems to lag the major depletion.

Analysis: Ground Water Irrigation

- Irrigation wells help agricultural producers weather the variability in precipitation supplies



This is a graph of irrigation well development in the study area.

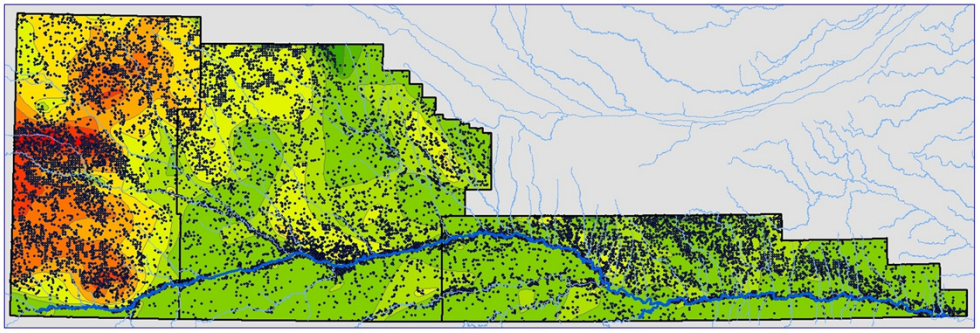
The red oval marks the point in ground water irrigation well development where the major break in Republican River flow into Kansas shifted down on the previous slide

The red oval is just for time frame reference and is not intended to suggest any form of relationship between the two

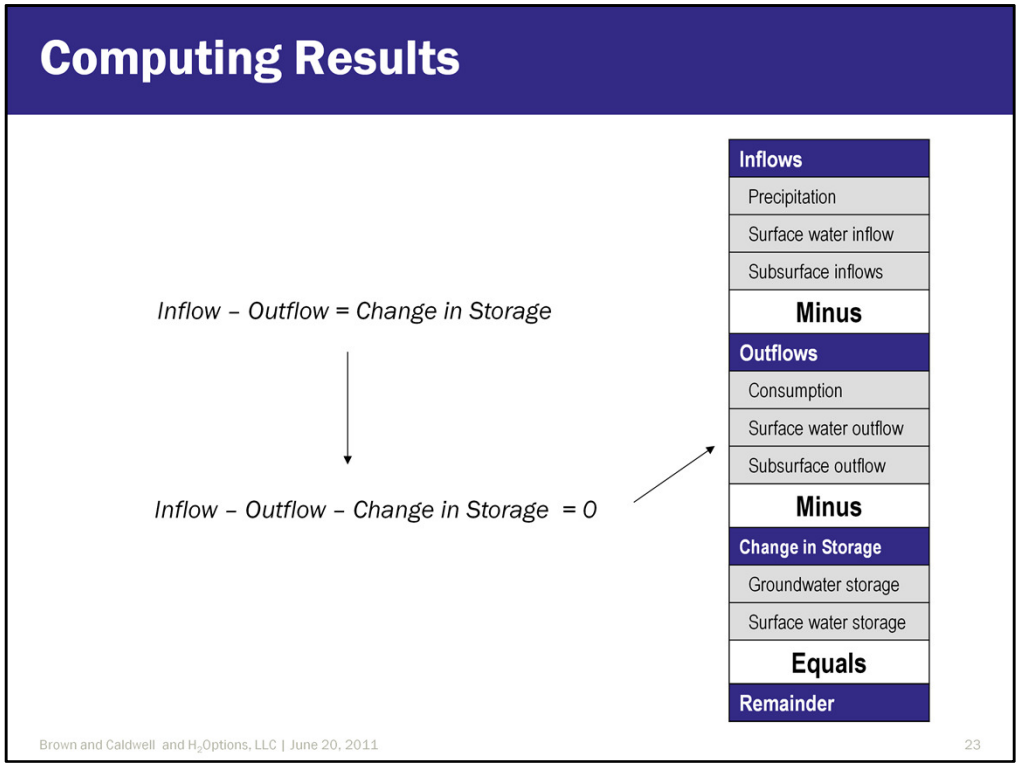
Most groundwater development lags the break in flow

Analysis: Ground Water Storage

- Some portions of the Republican River Basin have experienced long term groundwater aquifer declines



This slide indicates ground water level changes or the period of the study
Red/yellow indicating declines while green is more stable
As you can see from the amount of green, not the entire area has seem decline



The first equation is the classic water budget equation
The second is our modified equation and is more reflective of a water balance assessment

This modification can help us understand error and what components of the water budget have the greatest uncertainty
It can help better understand where we need to get more data. **Helps verify that the analysis is on target**

Neither of these equations are intended to define or measure if the system is in balance or sustainable
They are simply mathematical forms to determine and understand the relative position of the various components of the water supply in either a current annual or average condition

Water Balance Result

- Water balance for Republican River Basin based on recent land use and stream flows
- Consider this to be a snapshot of present conditions

	Amount (1000s of acre-feet)	Period of Study
Inflows		
Precipitation	10,130	1950-2009
Surface water inflow	100	1990-2005
Subsurface inflows	20	(from groundwater mound)
Total	**10,250**	
Outflows		
Consumption	10,500	1950-2005 (based on 2005 land use)
Surface water outflow	240	1990-2005
Subsurface outflow	n/a	
Total	**10,740**	
Change in Storage		
Total	**-490**	1990-2005

This is the outcome of the classic water budget equation for the Republican River basin in NE as of 2005 development levels and conditions

As you can see it indicates 490KAF of excess outflow as depicted by the calculated change in storage amount. Compare this to the results on the next slide

Water Balance Result

- Error check for Republican River Basin Water balance based on recent land use and stream flows

	Amount (1000s of acre-feet)	Period of Study
Inflows		
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Total	**10,250**	
Outflows		
Consumption	10,500	1950-2005 (based on 2005 land use)
Surface water outflow	240	1990-2005
Subsurface outflow	n/a	
Total	**10,740**	
Change in Storage		
Groundwater storage	-540	2000-2009 (reflects 2005 land use)
Surface water storage	-1	1952-2009
Total	**-541**	
Remainder	**51**	

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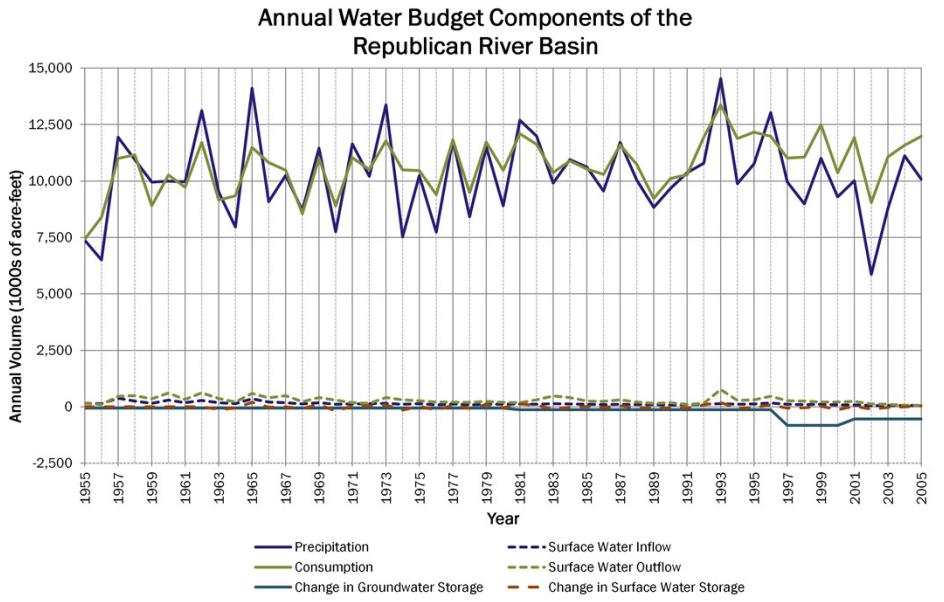
Using the modified or balanced form, second equation, you get more insight into what is actually happening with storage and how accurate this result might be. In this form, rather than simply making storage the remainder we actually quantify storage change and include it as a know component. The change in groundwater was derived from the Republican River model results.

It is possible that the remainder is due in part to additional consumption resulting from soil and water conservation measures like terraces and small flood control ponds

Water Balance Results



Many of the results of this study are represented in annual average values. This graph represent the fact that we actually did annual assessments of all the components as well It also shows the relative amounts of the various components in the study area and any trends

Water Balance Use

Republican River NRD
Summary of
Consumption

CALMIT Land Use Category	2005 CALMIT Land Use (acres)	Net Irrigation Requirement (acre-feet)	Consumption Volume (acre-feet)	Percent of Total
Barren	10,247	0.0	16,547	0.2%
Dry land Alfalfa	178,227	0.0	312,704	3.0%
Dry land Corn	224,641	0.0	376,653	3.6%
Dry land Dry Edible Beans	37,150	0.0	52,493	0.5%
Dry land Small Grains	472,651	0.0	782,367	7.4%
Dry land Sorghum	44,081	0.0	75,659	0.7%
Dry land Soybeans	42,134	0.0	66,348	0.6%
Dry land Sunflower	8,179	0.0	11,782	0.1%
Irrigated Alfalfa	72,187	131,125.5	254,733	2.4%
Irrigated Corn	627,068	562,054.3	1,483,638	14.1%
Irrigated Dry Edible Beans	43,220	29,091.0	79,916	0.8%
Irrigated Potatoes	7,307	8,245.6	16,414	0.2%
Irrigated Small Grains	58,260	52,891.8	134,751	1.3%
Irrigated Sorghum (Milo, Sudan)	15,976	14,301.8	38,641	0.4%
Irrigated Soybeans	150,070	107,786.5	320,189	3.0%
Irrigated Sugar Beets	4,821	6,423.3	13,274	0.1%
Irrigated Sunflower	6,771	4,762.6	13,317	0.1%
Open Water	17,049	0.0	73,586	0.7%
Other Agricultural Land	3,411	0.0	5,485	0.1%
Range, Pasture, Grass	3,214,160	0.0	5,459,336	52.0%
Riparian Forest and Woodlands	96,556	0.0	395,220	3.8%
Roads	10,296			
Summer Fallow	346,245	0.0	324,254	3.1%
Urban Land	17,895			
Wetlands	31,154	0.0	149,258	1.4%
Total	5,739,755	916,683	10,504,571	

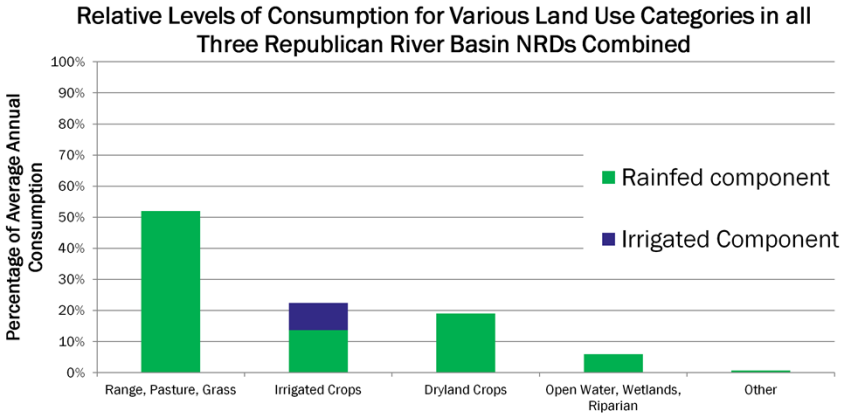
This is an important table that actually identifies and defines land use water consumption in the basin
It quantifies the consumption by land use type. Area in acres X CROPSim land use coeficient

It can also be used as a management tool to identify where reductions in no or lower value consumption could be made

This information can be valuable in looking for opportunities where you can meaningfully affect the water budget or the relative amount of consumption based on relative value

Water Balance Results

- Graph represents all basin consumptions

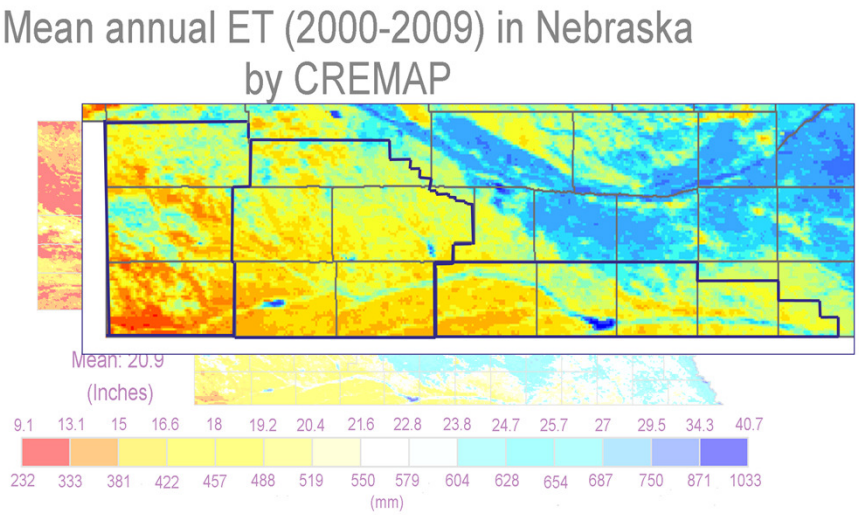


These bar charts show the relative consumption of major land uses
The green bars represent the actual total consumption per land uses
The blue area represents the relative amount of supplemental irrigation consumption.

You can actually use this information to look for opportunities where you can meaningfully affect the water budget

Water Balance Validation

- Updates to the water balance and new information



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This process developed by Joe Szilagyi @ UNL was an important confirmation tool for this study. It can also be an important water management and ET compliance tool into the future

This is why it is so important that the process be update and continued into the future.

Water Balance Validation

Comparisons of Consumption and Precipitation Derived by Different Methods

	Avg. Annual CREMAP consumption (2000-2005) (KAF)	Avg. Annual Consumption based on methods in the report (2000-2005) (KAF)	Ratio (CREMAP/this study)	Avg. Annual Precipitation from PRISM database (2000-2005) (KAF)	Avg. Annual Precipitation based on methods in the report (2000-2005) (KAF)	Ratio (PRISM/this study)
URNRD	3,029	3,006	1.01	2,414	2,367	1.02
MRNRD	4,327	4,245	1.02	3,802	3,843	0.99
LRNRD	2,953	3,132	0.94	2,965	2,983	0.99
Combined	**10,309**	**10,383**	**0.99**	**9,181**	**9,193**	**1.00**

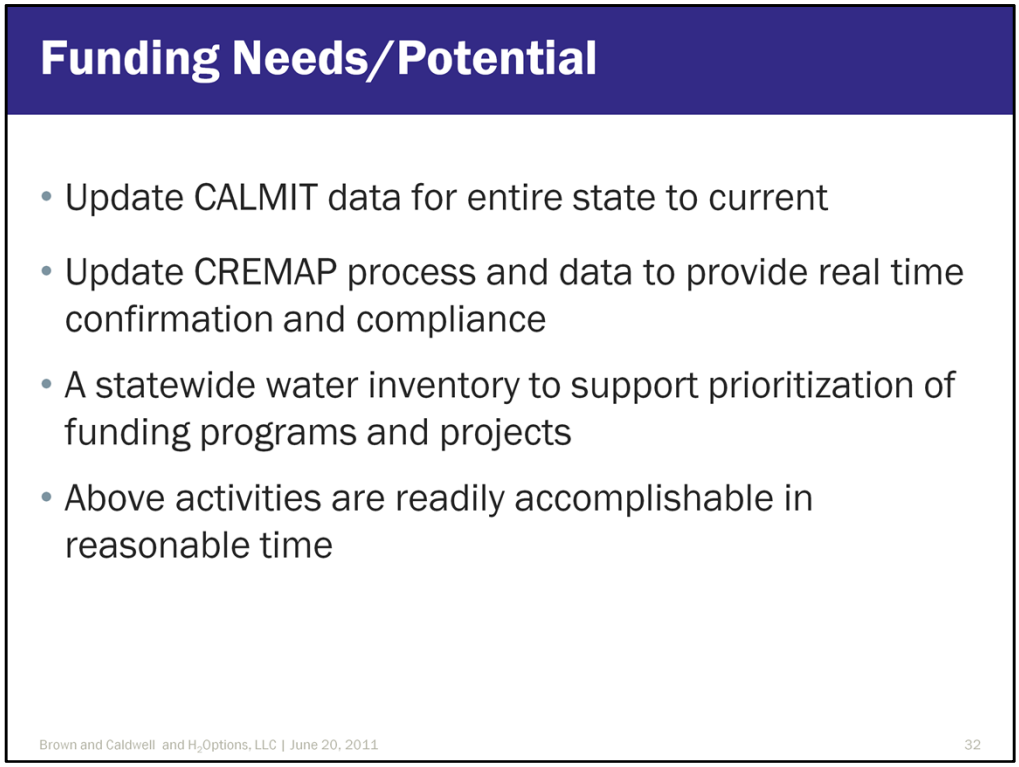
This table shows the value of using Joe's approach, a completely separate and different concept, to validate the relative accuracy of the results of this study

The close correlation between two independent studies that come from completely opposite directions serves to validate both

Study Conclusions

- The water balance for the Republican River Basin was quantified with a relatively high degree of accuracy.
  - This understanding of the balance can be improved over time.
  - As necessary, more complex estimations of water balance components can be conducted.
- Majority of supply used by native vegetation and dry land crops.
- Water level declines have occurred due to land use changes, one of which is conversion to irrigated crops
- Surface water outflows are related to surface water inflows
- A water balance assessment can help identify ways to accomplish water management goals.

Here is what we found



Because you are working on funding, thought I would take this opportunity to promte several effrts that I see could be very helpful for better water management planning in Nebraska

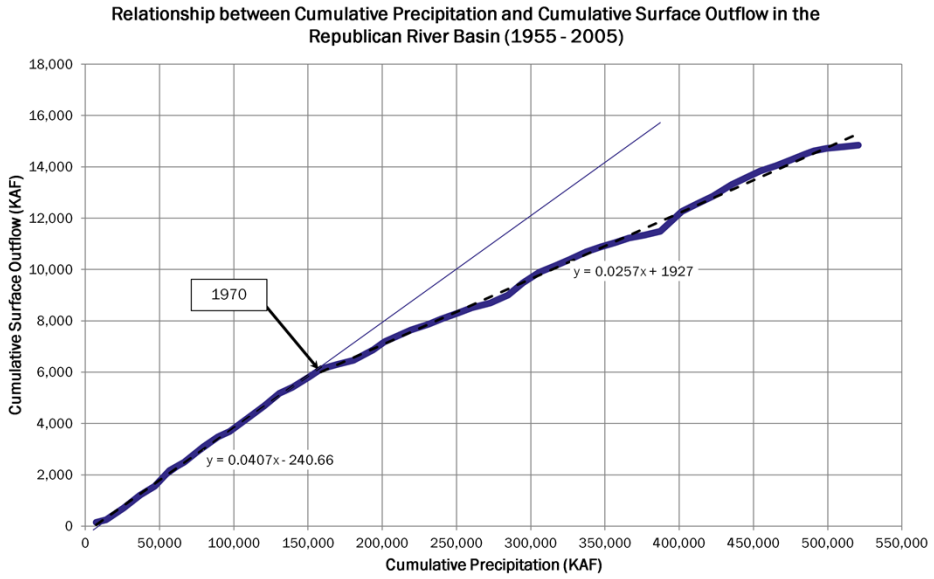
Hope you also see the inherent value, cost/benefit and importance of funding these components for doing a statewide inventory to not only appropriately manage but also regulate water consumption in NE with a better informed point of reference

Time frame and cost for the above critical management components could be around a year and $1 million depending on which efforts are funded and the specific requirements and expectations for each

Present day water budget/balance inventories can be used to compared with historic efforts such as Bentall's to get a real measured understanding of water consumption change in Nebraska over this significant amount of time. Bentall's reports cover the water use in all thirteen of Nebraska's river basins.

In fact, current level of water use data and understanding could be used to compare current land use development to conditions where all agricultural land is reverted back to grassland. This could be a likely representation of water conditions in Nebraska before the impacts of European settlement.

Republican River Results



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Here is something we found that could use more work and analysis

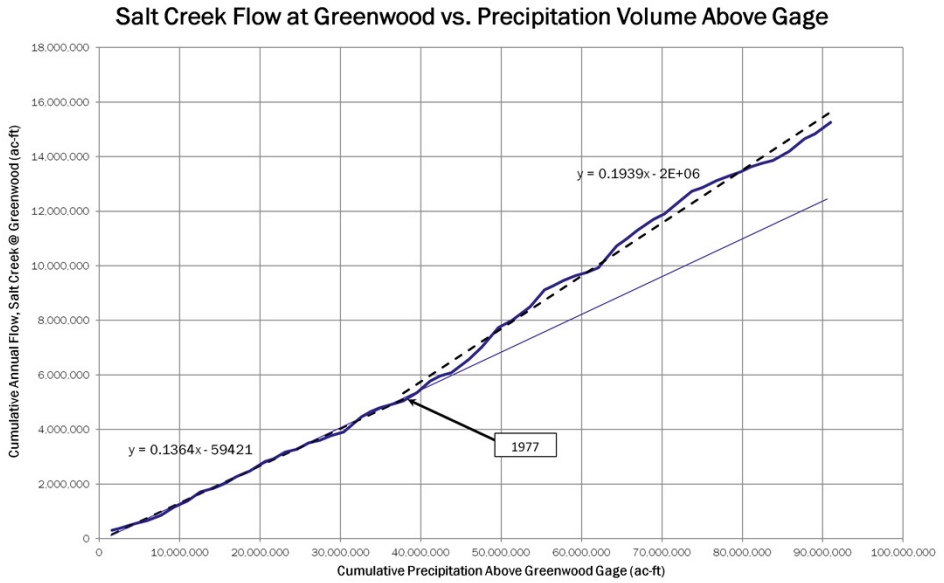
This is a graph of the relationship between outflow and basin precipitation as gaged at the NE-KS state line

As you can see on this graph, there is a significant, consistent and persistent departure in this relationship from 1970 on

Interestingly, this apparent break does not line up well with any single development or climatologically event in the basin

We have seem a pronounced break like this in other areas

LPSNRD Results



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This is a graph from some work we did in the LPSNRD at the Greenwood gage
It shows a similar but opposite shift in this relationship

There are likely may reasons for these breaks but they appears to be quite extensive in extent which could also suggest more than a local cause

USGS Stream Flow Analysis

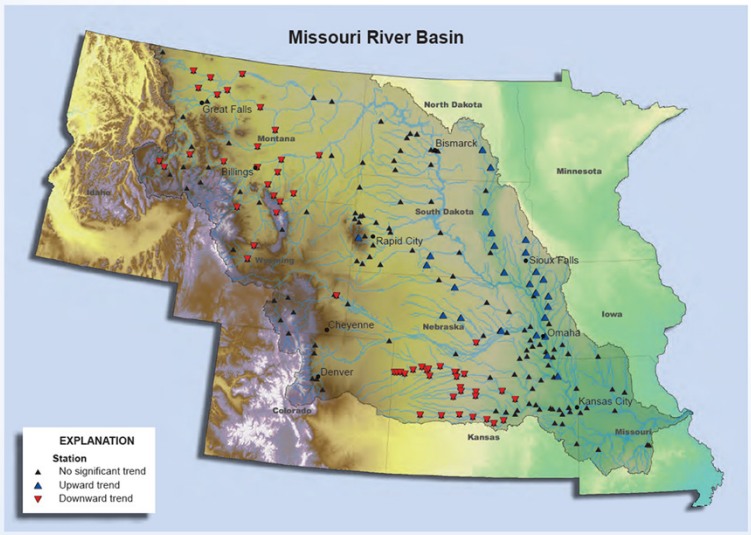


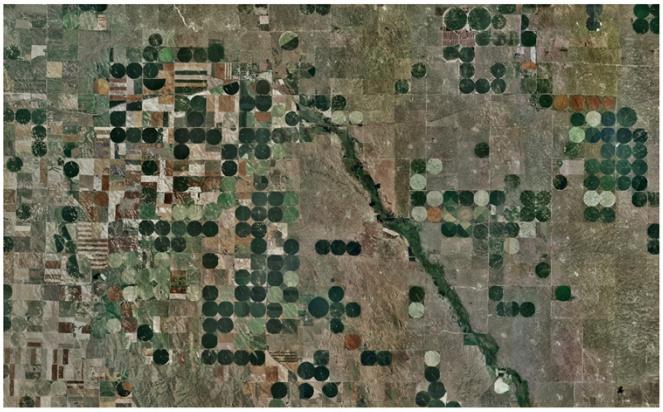
Figure 2. Annual streamflow trends for 205 stations with 50 years of record, 1957–2006.

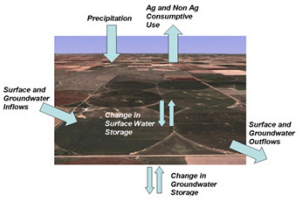
In fact, USGS stream flow analysis shows similar results as we identified in our various NRD water balance studies

The picture above show where they found decrease departures, red triangles, no apparent change, black triangles and increases, blue triangles, across the entire Missouri basin

Questions

- Thank you!





I would be happy to answer any questions you may have