Nebraska Statewide Groundwater-Level Monitoring Report

2011

Jesse T. Korus
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Nebraska Water Survey Paper Number 79

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The CSD is authorized to enter into agreements with federal and state agencies to engage in cooperative surveys and investigations of the State. Publications of the CSD and the cooperating agencies are available through the Conservation and Survey Division, 101 Hardin Hall, University of Nebraska-Lincoln, Lincoln, NE 68583-0961. Contact the address above, phone : (402) 472-3471, or e-mail snrsales@unl.edu. The CSD web site is: http://snr.unl.edu/csd/.

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February 2012

ISBN 1-56161-020-8
ISBN-13 978-1-56161-020-4

ACKNOWLEDGMENTS

The cooperation and assistance of the following agencies and associations in collecting and providing water-level data during 2011 are gratefully acknowledged: U.S. Bureau of Reclamation; Central Nebraska Public Power and Irrigation District; U.S. Geological Survey; and the following Natural Resources Districts; Lower Republican, Middle Republican, Upper Republican, Upper Big Blue, Little Blue, Lower Big Blue, Lower Platte South, Lower Platte North, Central Platte, Twin Platte, North Platte, South Platte, Lower Niobrara, Middle Niobrara, Upper Niobrara-White, Lower Loup, Upper Loup, Lower Elkhorn, Upper Elkhorn, Papio-Missouri River, Lewis and Clark, Nemaha, and Tri-Basin. We also thank the many hundreds of land-owners who graciously allowed these agencies to collect water-level information from their wells and install observation wells on their land.

Thanks to Dee Ebbeka for assisting with the preparation of this report.

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FORWARD

Nebraska's proud tradition of natural-resources stewardship is particularly apparent in the case of groundwater. Groundwater is inextricably linked to the State's rich heritage; it also maintains our agricultural economy and provides steady flows to some of the Nation's most admired natural streams. The groundwater resources that lie beneath Nebraska are indeed vast, but they are also vulnerable: even small changes in groundwater levels can have profound impacts.

We are proud to present this report, which is a continuation of the series of water resources reports and maps published by the Conservation and Survey Division (CSD) of the School of Natural Resources. The information provided herein can be used to inform, educate, and guide the citizens of Nebraska as we enter new and challenging times regarding water resources.

INTRODUCTION

Groundwater-level information is valuable to citizens and stakeholders for understanding water resource availability and making informed management decisions.

This report is a statewide synthesis of groundwater-level monitoring programs in Nebraska. It is a continuation of the series of annual reports and maps produced by the CSD of the University of Nebraska in cooperation with the U.S. Geological Survey (USGS) since the 1950's. Groundwater-level monitoring began in Nebraska in 1930 in an effort to survey the State's groundwater resources and observe changes in its availability on a continuing basis. The CSD and USGS cooperatively developed, maintained, and operated an observation well network throughout the State. These two agencies were responsible for collecting, storing, and making this information available to the citizens.

Although CSD and USGS still occupy a central role in the statewide groundwater-level monitoring program, other agencies have assumed the responsibilities of building and maintaining observation networks and measuring water levels. The CSD and USGS continue to operate some of the original observation wells, but today the majority of measurements are made by agencies such as the Natural Resources Districts, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Public Power and Irrigation Districts, County Extension offices, and municipalities. Because these agencies are located throughout the State, they are able to implement groundwater-level monitoring programs using local field staff, landowner contacts, taxing and regulatory authority, and first-hand knowledge of local conditions. Collectively, these agencies have developed an extensive network of observation wells throughout the State.

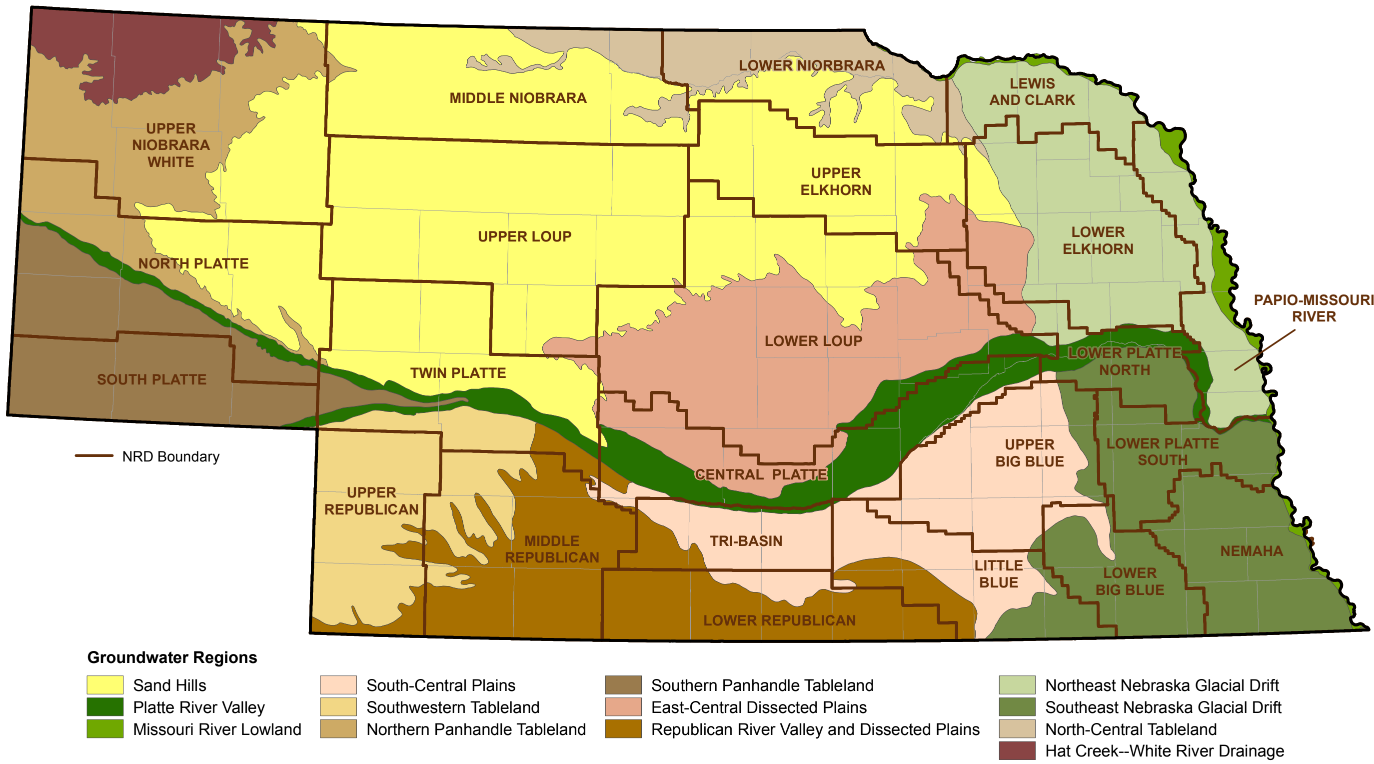
The CSD plays a vital role in providing technical expertise to these agencies as they develop and implement groundwater-level monitoring plans. The CSD evaluates the adequacy and accuracy of the water-level data and provides the statewide assessment of groundwater-level changes across all groundwater regions (Fig. 1) and in many of the State's aquifers (Figs. 2, 3).

The CSD has long provided technical services to stakeholders by integrating groundwater-level change data with multiple data sets in order to:

1) Determine the amount of groundwater in storage and its availability for use.
2) Assess the water-supply outlook by determining changes in the volume of groundwater in storage.
3) Identify areas in which changes in groundwater levels may have an economic impact.
4) Assist state and local agencies in the formulation and administration of resource-management programs.
5) Determine or estimate the rate and direction of groundwater movement, specific yield of aquifers, base flow of streams, sources and amounts of groundwater recharge, and locations and amounts of groundwater discharge.
6) Assess the validity of hydrogeologic interpretations and the assumptions used in developing models of a groundwater system.

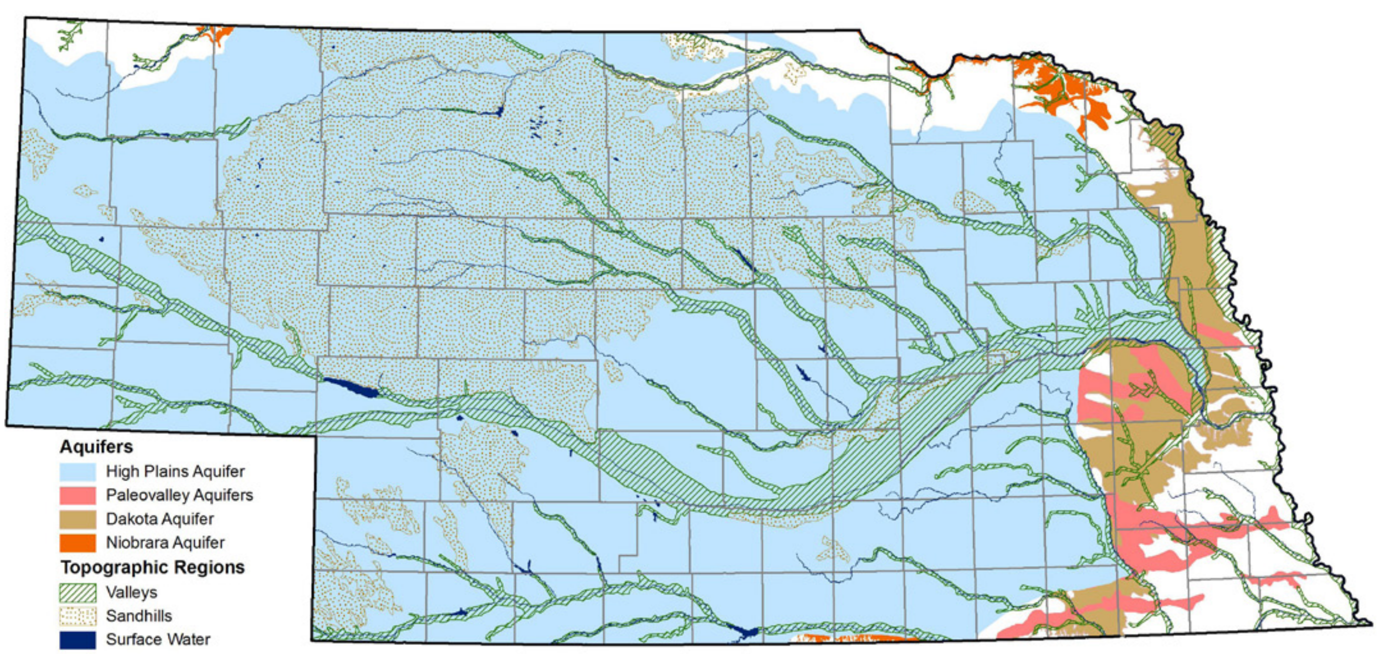
The need for this information has increased tremendously over the past few years, yet the resources available for fulfilling this need have decreased. The CSD strives to meet this challenge by focusing on fundamental data, building collaborative relationships with the agencies that depend on the information, and providing scientifically accurate information in a timely manner.

Figure 1. National Resources Districts and Groundwater Regions of Nebraska



Groundwater regions from Flowerday et al. (1998)

Figure 2. Important Aquifers and Topographic Regions of Nebraska



Note: In some areas, the aquifer units shown here may contain little or no saturated thickness.

Purpose and Methods

This report summarizes changes in Nebraska's groundwater levels over periods of 1, 5, 10, and 30 years prior to 2011, as well as from predevelopment to 1981 and predevelopment to 2011. These changes are depicted in maps that delineate regional trends on a statewide basis. Although localized conditions may vary considerably, the maps presented in this report provide an overview of the general locations, magnitudes, and extents of rises and declines. The reader should use figures 1 – 4 to locate groundwater regions, aquifers, and counties mentioned in the text.

The 1-, 5-, 10-, and 30-year changes are presented in the spring 2010 to spring 2011, spring 2006 to spring 2011, spring 2001 to spring 2011, and spring 1981 to spring 2011 maps, respectively. Groundwater levels measured from thousands of wells throughout the State in spring 2011 (Fig. 5) were compared to levels measured in the same wells in the spring of the earlier year. For the 1-, 5-, and 10-year change maps, contours were generated using computer interpolation. These contours were incorporated into the final maps in areas where the principal aquifer is continuous, is in relatively good hydraulic connection over large areas, and where data density is relatively high. In areas not meeting the above conditions, the computer-generated contours were manually edited on maps at a scale of 1:500,000 in order to conform to hydrogeologic boundaries that prevent the flow of groundwater. Such boundaries include 1) areas where relatively impermeable bedrock units outcrop or exist in the shallow subsurface, such as southeastern Nebraska and in areas of Scotts Bluff County, 2) valley boundaries in eastern Nebraska where alluvial aquifers are a major source of groundwater but upland areas between them lack a primary aquifer, and 3) areas where the High Plains Aquifer is separated by deeply entrenched parts of the Niobrara, Republican, and Platte River valleys. For the spring 1981 to spring 2011 map, computer interpolation was impractical because data was sparse in many areas. Contours were therefore drawn manually with knowledge of the major hydrogeologic boundaries listed above.

For the predevelopment to spring 2011 and predevelopment to spring 1981 maps, water levels from wells measured in 2011 and 1981 were compared to estimated predevelopment water levels in the same wells. An estimated predevelopment water level is the approximate average water level at a well site prior to any development that significantly affects water levels. Predevelopment water levels for most of the State are the estimated water levels that generally occurred before the 1930s, 1940s, or early to mid-1950s. These dates, which vary throughout Nebraska, generally depend on the beginning dates of intensive use of groundwater for irrigation. Typically all available water-level data collected prior to or during the early stages of groundwater development are used to estimate predevelopment water levels. Contours were drawn manually with the aid of previously existing maps for similar time periods and with knowledge of major hydrogeologic boundaries.

Areas of sparse data are shown with a hatched pattern on all maps. A computer point density interpolation was used to determine the number of observation points within a 6 mile (10 kilometer) search radius. Areas of sparse data were defined as areas with zero observation points within the search radius.

Precipitation maps were prepared by comparing total precipitation over the time period of interest to the 30-year normal provided by the National Climate Data Center. The 30-year normal currently in use is based on average annual precipitation from 1970 to 2000. Computer interpolation was used to generate contours for these maps.

The average daily streamflows were computed by taking the average of all daily mean values for the water year, which was from October 1, 2009 to September 30, 2010. The long-term average is calculated from all available annual data from the 30 year period previous to the current water year. The 2010 stream flows were compared to the average annual flows from 1980 to 2009. For a few sites, less than 30 years of data is available for computing the long term average.

Factors Causing Groundwater-Level Changes

Long-term groundwater-level changes are a reflection of the changing balance between recharge to, discharge from, and storage in an aquifer. If recharge and discharge are in balance, such as they were before widespread irrigation development, groundwater levels are generally steady because the amount of water stored in the aquifer does not change. Minor changes in groundwater levels may occur due to natural variations in precipitation and streamflow, but generally the system is in equilibrium. If, however, the rate of recharge exceeds the rate of discharge over a long period, the amount of water stored in the aquifer increases and groundwater levels rise. Conversely, if the rate of discharge exceeds the rate of recharge for a long period, the amount of water in storage is depleted and groundwater levels decline. The magnitudes, locations, and rates of groundwater level changes are controlled by many factors, including: the aquifer's storage properties, permeability, and saturated thickness; the locations, rates, and pumping schedules of wells; the locations and rates of artificial recharge areas; and the degree of hydraulic connection between the aquifer and surface water bodies.

Figure 3. Generalized Geologic and Hydrostratigraphic Framework of Nebraska

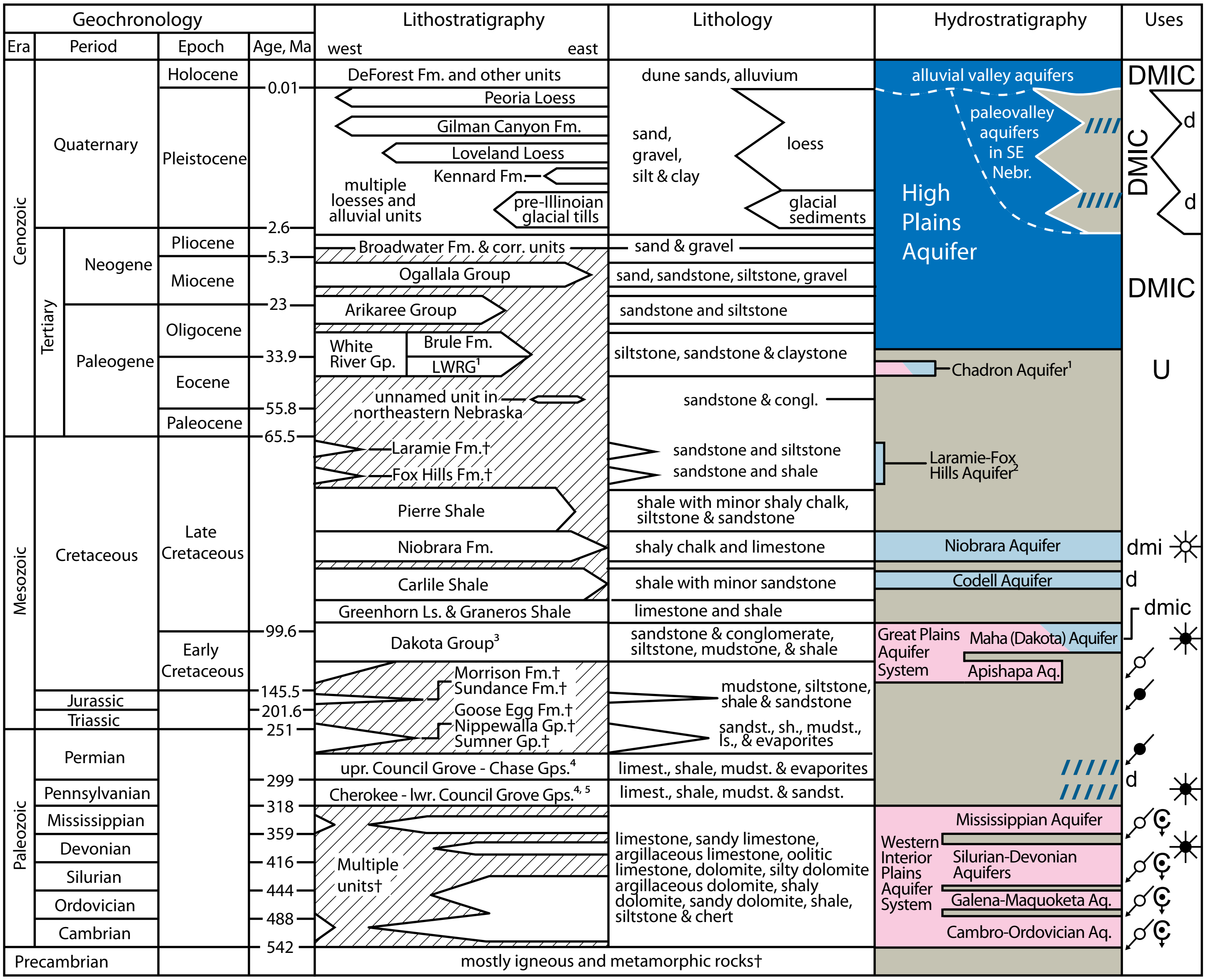


Diagram is not to scale relative to geologic time and stratigraphic thicknesses.

Hydrostratigraphic characteristics and water quality

- primary aquifers with good quality water
- secondary aquifers with good quality water
- secondary aquifers with generally poor quality water
- //// aquitards with local low-yield aquifers
- aquitards

[1] lower White River Group - includes Chamberlain Pass and Chadron Formations according to some authors; "Chadron Aquifer" historically refers to aquifer in lower White River Group

[2] important aquifer in Colorado, but present in Nebraska only in extreme southwestern Panhandle

[3] Dakota Formation in adjacent states

[4] includes correlative units with different names in northwest Nebraska

[5] Cherokee, Marmaton & Pleasanton Groups are not exposed in Nebraska

†present only in subsurface

Groundwater uses and related aspects

- D major domestic use
- d minor domestic use
- I major irrigation use
- i minor irrigation use
- M major municipal use
- m minor municipal use
- C major commercial/industrial use
- c minor commercial/industrial use
- units used for wastewater injection
- units with potential use for wastewater injection
- U unit mined for uranium by in-situ leaching (Dawes Co.)
- unit with potential use for carbon sequestration
- unit producing petroleum or natural gas
- unit with natural gas potential

From Korus and Joeckel, 2011

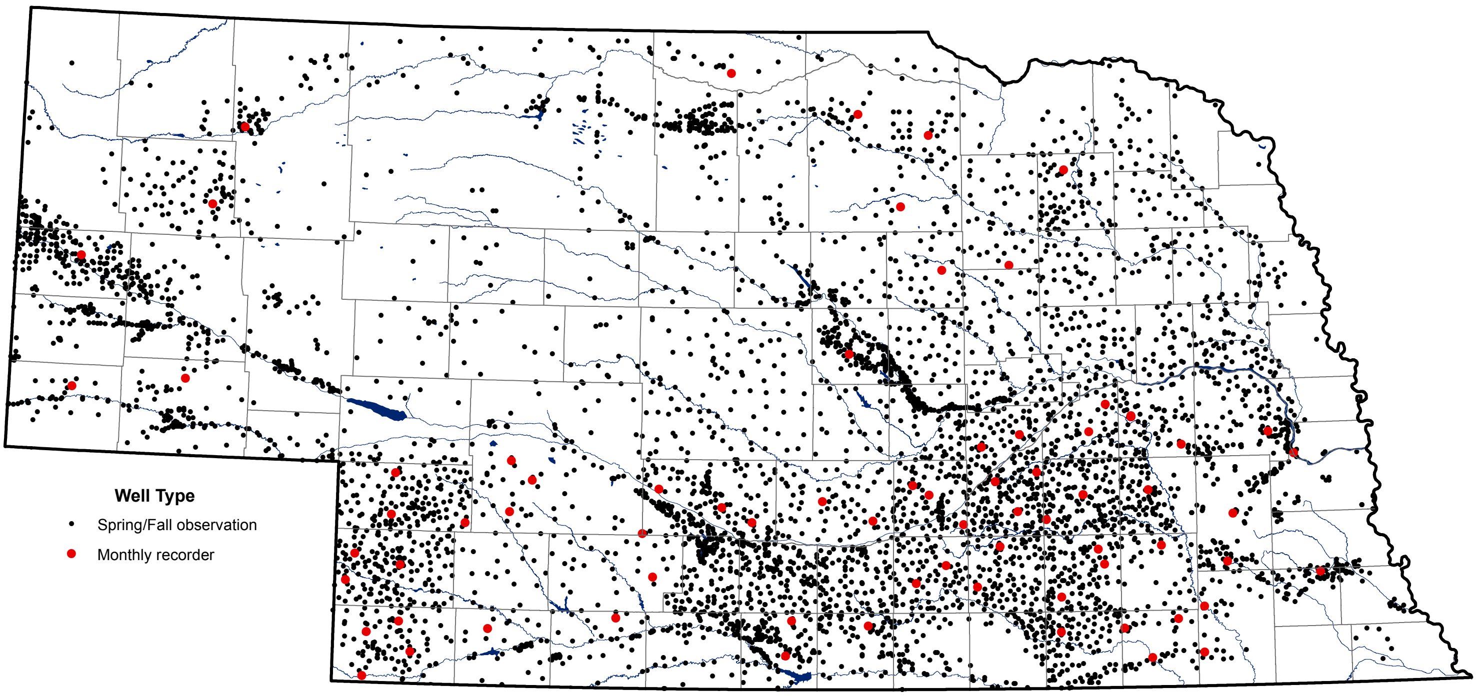
It is a common misconception that the rate of recharge from precipitation can be used as a "safe yield" or "sustainable limit" on the rate of groundwater extraction from an aquifer (Bredehoeft, 1997). This idea is too simplistic. The aquifer properties and all sources of recharge and discharge must be taken into consideration. Recharge is provided primarily by precipitation, but also by irrigation return flow and seepage from canals, reservoirs, and streams. Discharge occurs as baseflow to streams and lakes, evapotranspiration, and groundwater pumping. Groundwater levels, therefore, respond to a variety of natural and anthropogenic factors affecting recharge and discharge and are controlled largely by the physical properties of the aquifer. Limiting groundwater extraction to a rate equal to or less than the rate of recharge from precipitation will not prevent depletion of the aquifer. In fact, groundwater "mining" is prone to occur to one degree or another in any heavily pumped aquifer. A holistic, adaptive approach to groundwater management based on hydrologic mass balance is more appropriate. These strategies are discussed by several authors (e.g. Sophocleous, 1997, 2000; Alley and Leake, 2004; Maimone, 2004; Korus and Burbach, 2009a).

Groundwater-level changes can be observed at many different temporal scales (Fig. 6). Changes may occur over several minutes or hours in response to pumping, floods, or earthquakes. Long-term changes may occur due to the cumulative effects of pumping over many irrigation seasons, prolonged droughts or periods of high rainfall, or seepage from man-made water bodies. Similarly, groundwater levels can be observed at multiple spatial scales. For example, groundwater levels decline around the immediate vicinity of an individual well during pumping, but also from the cumulative effects of many irrigation wells pumped over many irrigation seasons at the scale of an entire regional aquifer. Groundwater levels rise along the banks of a stream during a flood, but may also rise significantly over an entire drainage basin during a prolonged wet period. The temporal and spatial scales of observation must be taken into account when using the maps presented in this report.

The maps presented in this report were generally created at a scale of 1:500,000. They are intended to identify regional trends at medium and long-term time scales throughout the entire state of Nebraska. As such, these changes chiefly reflect the interplay between precipitation, groundwater pumping, and artificial recharge from reservoirs and canals.

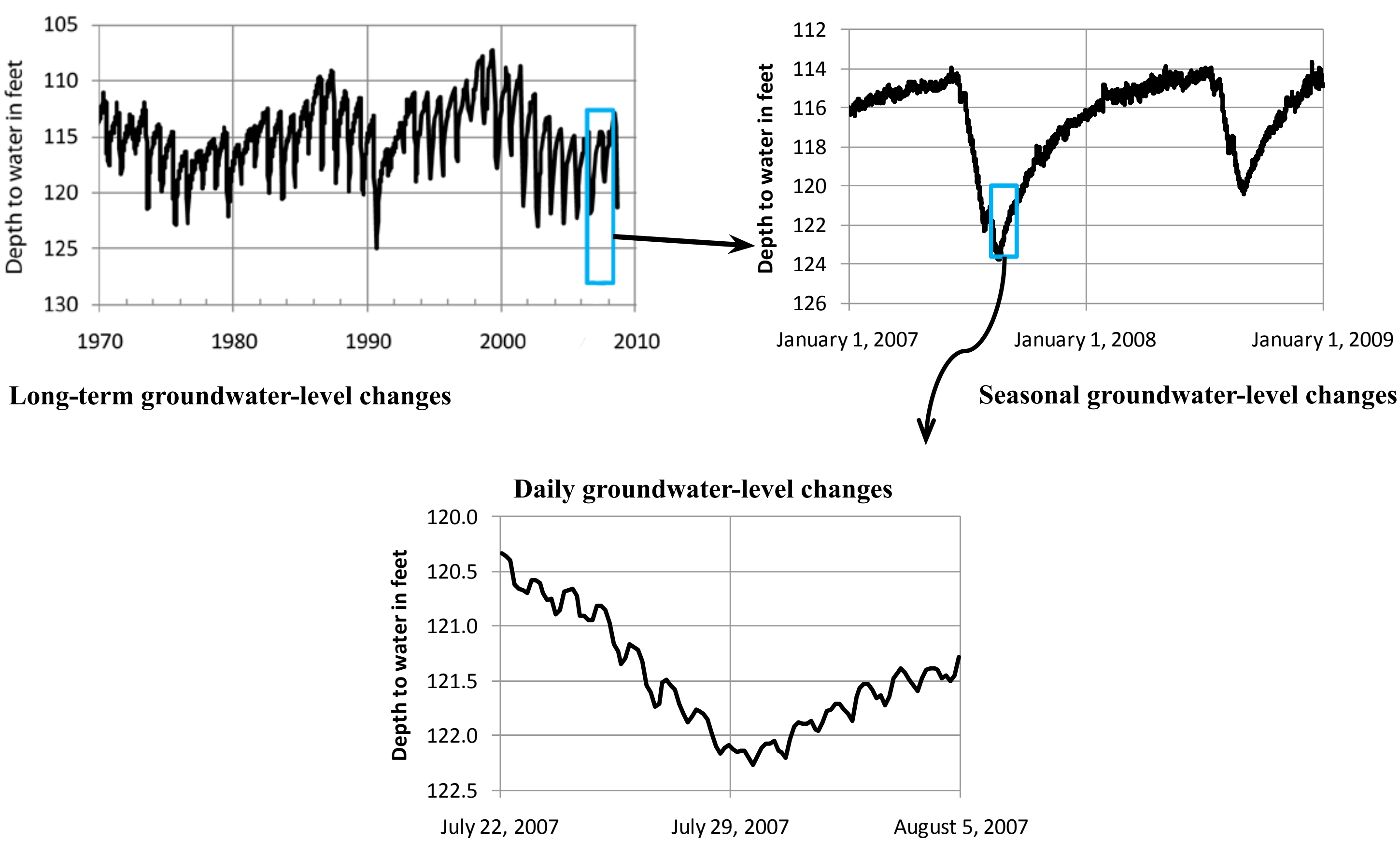
Figure 4. Counties, Major Cities, and Streams of Nebraska

Figure 5. Locations of Spring/Fall and Monthly Observation Wells



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District; Conservation and Survey Division, School of Natural Resources, University of Nebraska–Lincoln

Figure 6. Example of Groundwater-Level Changes at Different Temporal Scales



Based on data from Plymouth Recorder well, Jefferson County

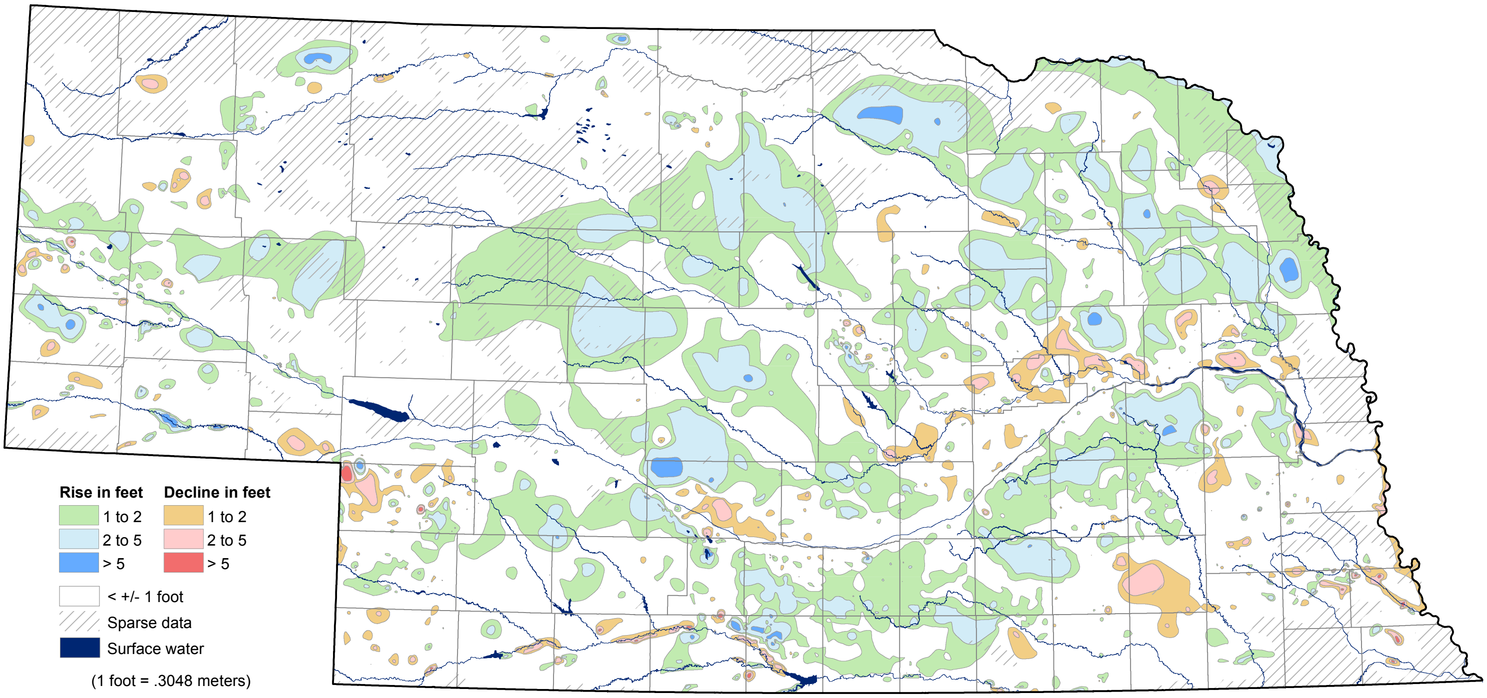
CHANGES IN GROUNDWATER LEVELS, SPRING 2010 TO SPRING 2011

Groundwater levels rose or were unchanged throughout much of Nebraska from 2010 to 2011. Declines occurred in several small areas.

Groundwater levels rose throughout most of Nebraska from spring 2010 to spring 2011 (Fig. 7). Rises were recorded in 70% of the wells that were measured, and 36% experienced rises of greater than one foot. Rises of greater than one foot occurred in many areas. The largest of these areas were in the eastern Sand Hills and East Central Dissected Plains where precipitation in 2010 was 120-170% of the 30-year average (Fig. 8). The South Central Plains and Northern Glacial Drift regions also experienced significant groundwater level rises. Precipitation was 100-130% of the 30-year average in these areas, except for an area around York and Fillmore Counties where precipitation was lower than normal. Groundwater-level rises in the South Central Plains largely reflect response of the aquifer to reduced irrigation withdrawals during the 2010 growing season because irrigation well density is high and aquifers, which exist largely under confined conditions, respond rapidly to changes in pumping. Groundwater levels also rose in large areas of the western Sand Hills and Panhandle Tablelands. Precipitation in these areas was 100-150% of the 30-year average. Many other, smaller areas also experienced groundwater-level rises from spring 2010 to spring 2011. The wide distribution of areas with rising groundwater levels reflects decreased irrigation demands, increased streamflows, and increased aquifer recharge throughout the State due to generally higher than normal precipitation during this period.

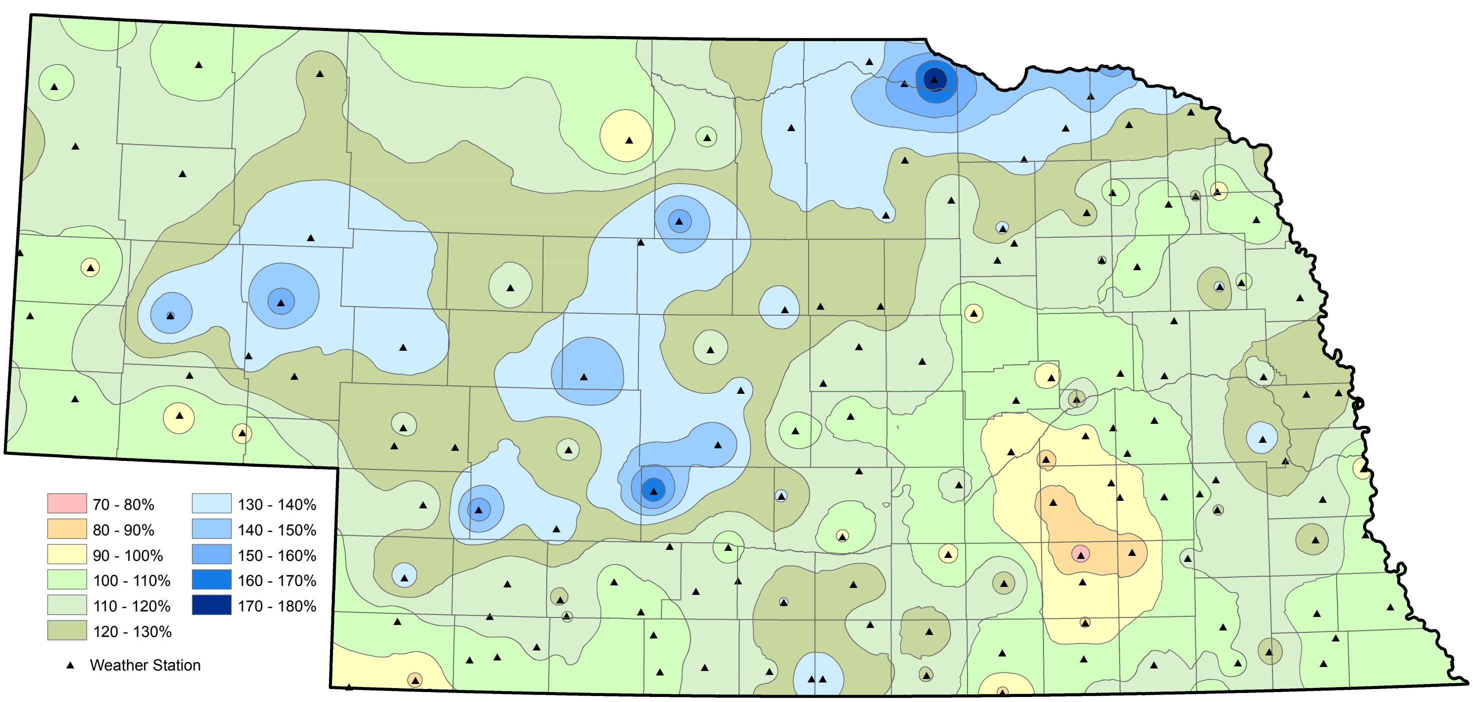
Groundwater-level declines occurred in a few, scattered, and comparatively small areas of Nebraska from spring 2010 to spring 2011 (Fig. 7). Declines were recorded in 30% of the wells that were measured, and 11% experienced declines of greater than one foot. Declines of greater than one foot occurred in eastern parts of the East Central Dissected Plains, the Platte River Valley, parts of the southern Glacial Drift region, and the Southwestern Tablelands. Only the area of decline in Saline County in the Southeast Glacial Drift region corresponds to an area of below normal precipitation (Fig. 8). Groundwater-level declines may occur in areas that experienced above-normal precipitation, especially if excess precipitation was received during the fall, winter, and spring months rather than during the summer growing season.

Figure 7. Groundwater-Level Changes in Nebraska - Spring 2010 to Spring 2011



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

Figure 8. Percent of Normal Precipitation - January 2010 to January 2011



Sources: National Climate Data Center, Asheville, North Carolina; High Plains Regional Climate Center, University of Nebraska–Lincoln

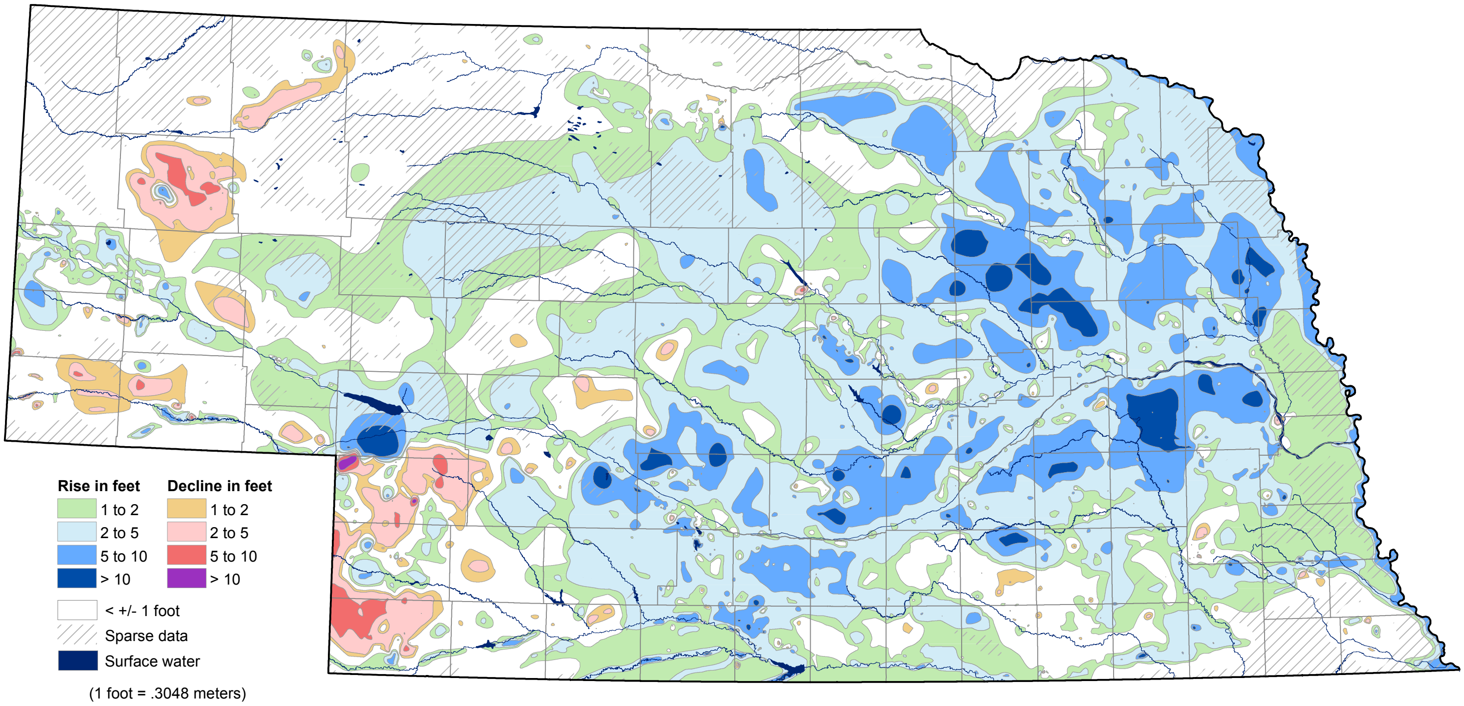
CHANGES IN GROUNDWATER LEVELS, SPRING 2006 TO SPRING 2011

The majority of Nebraska experienced groundwater level rises from 2006 to 2011, but declines occurred in the southwest and the panhandle.

The five-year period from spring 2006 to spring 2011 was characterized by groundwater level rises in almost all areas of Nebraska, except in the Southwest Tablelands and Panhandle Tablelands (Fig. 9). The largest rises were in the East Central Dissected Plains, Platte River Valley, South Central Plains, and Glacial Drift regions. Rises of greater than ten feet occurred in large areas of Antelope, Madison, Boone, Platte, and Butler Counties, and in several other, smaller areas in and adjacent to the Platte River Valley. Rises were comparatively modest in the Sand Hills, Republican River Valley and Dissected Plains, and the Southeast Glacial Drift region. Rises were recorded in 82% of the wells that were measured, and 66% experienced rises of greater than one foot. Precipitation was above the 30-year average for all areas east of the Panhandle, with the exception of Fillmore County in the South Central Plains (Fig. 10). Groundwater-level rises from 2006 to 2011 resulted from a combination of factors, including increased flows in streams and canals, decreased irrigation withdrawals, and increased recharge to aquifers, compared to the several dry years prior to 2006 (c.f. Burbach, 2006). The relative importance of each factor in contributing to the rises depends on the depth of the water table, density of irrigation wells, and degree of connection between groundwater and surface water. Rises in the Platte River Valley and the Sand Hills were largely driven by increased recharge to aquifers and higher flows in streams and canals, whereas decreased irrigation withdrawals probably account for most of the rises in other areas.

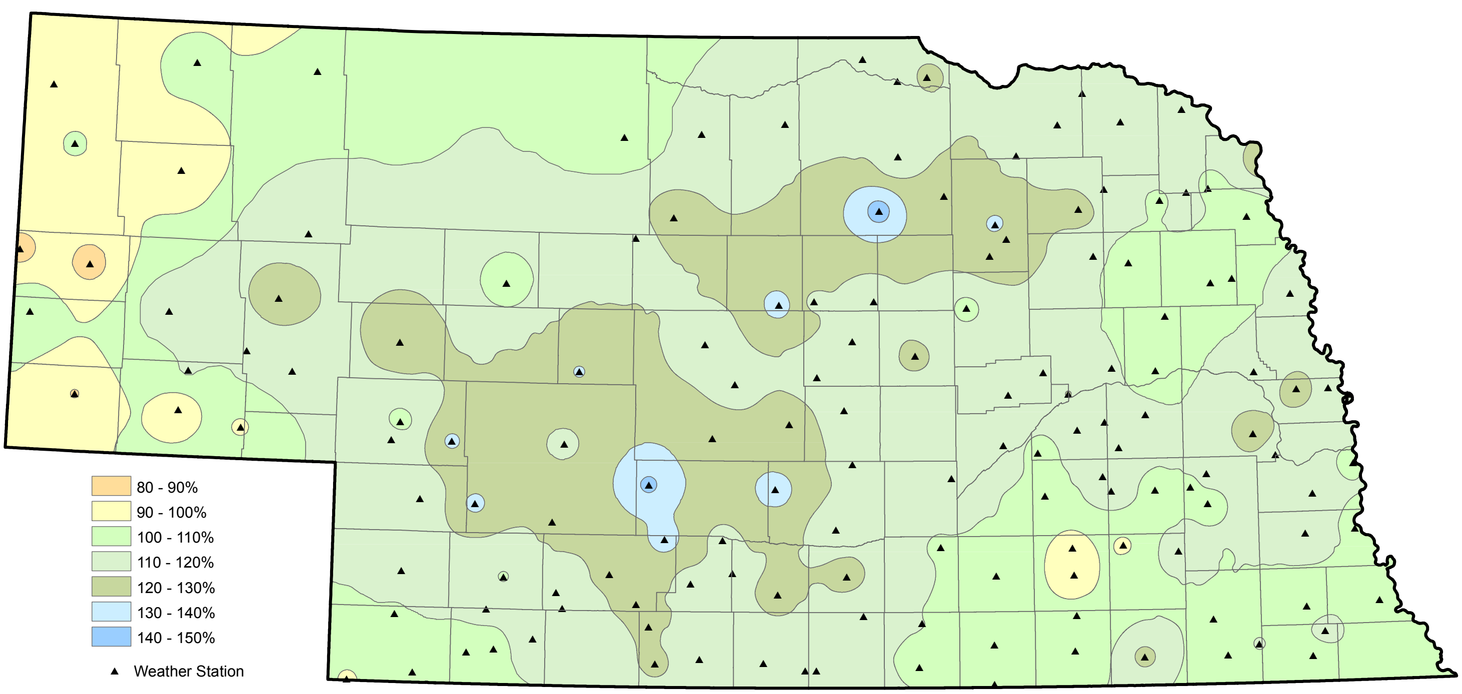
Groundwater level declines from spring 2006 to spring 2011 occurred in three main areas: the Southwest Tablelands, the Lodgepole Creek drainage basin in the Panhandle Tablelands, and in Box Butte and Sheridan Counties in the Panhandle Tablelands (Fig. 9). Dundy and Box Butte Counties experienced the most significant declines. Precipitation was near normal to slightly below normal in areas of groundwater-level declines in the Panhandle, but precipitation was 100-120% of the 30-year average in the Southwestern Tablelands (Fig. 10). Declines continue in these areas because large irrigation withdrawals are required to grow crops in the dry climate of the Southwest and Panhandle, even during years of above normal precipitation.

Figure 9. Groundwater-Level Changes in Nebraska - Spring 2006 to Spring 2011



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

Figure 10. Percent of Normal Precipitation - January 2006 to January 2011



Sources: National Climate Data Center, Asheville, North Carolina; High Plains Regional Climate Center, University of Nebraska–Lincoln

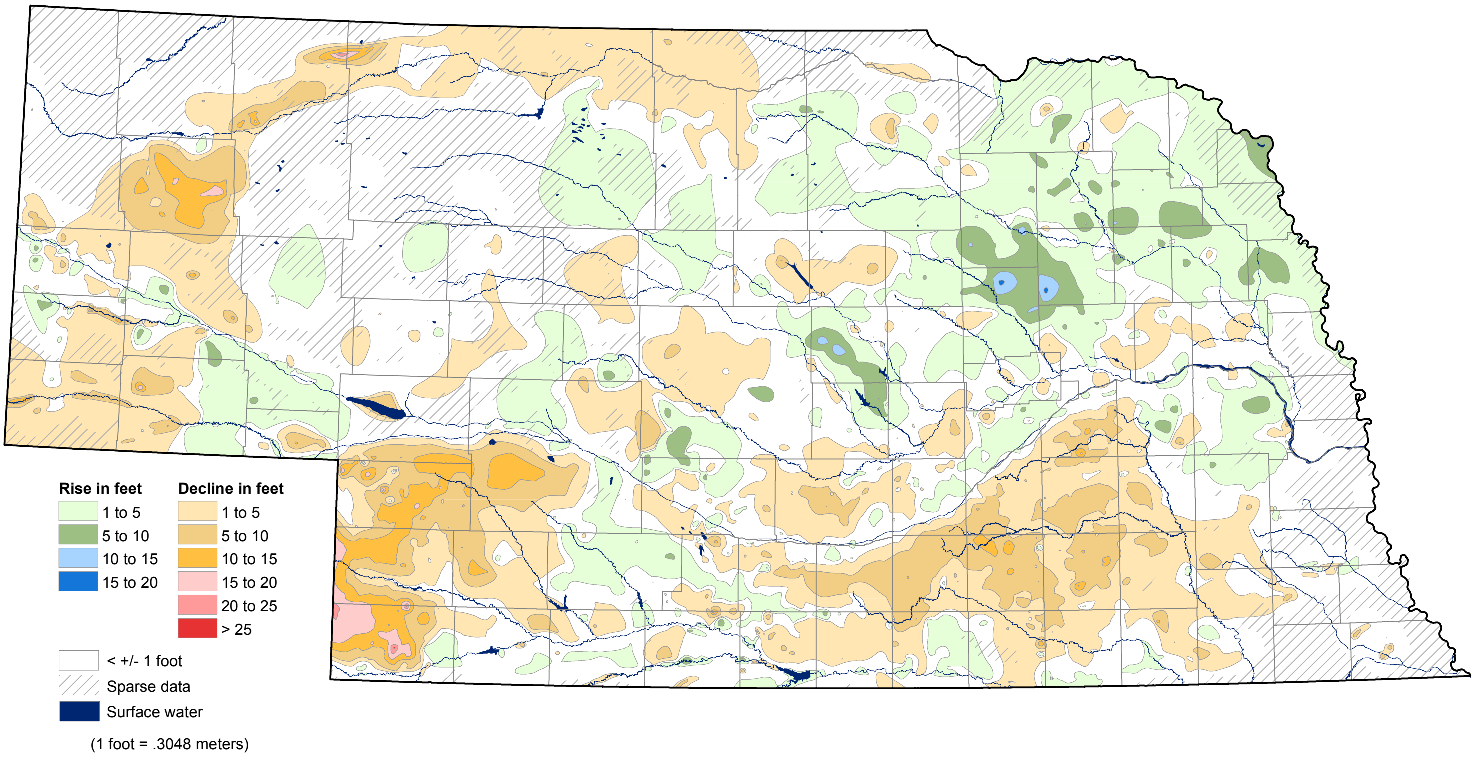
CHANGES IN GROUNDWATER LEVELS, SPRING 2001 TO SPRING 2011

Contrasting patterns of groundwater level changes over the past ten years reflect variations in the timing and locations of precipitation and irrigation withdrawals.

Two highly contrasting periods of groundwater-level changes occurred during the ten years from spring 2001 to spring 2011. Groundwater levels declined statewide due to drought from 2000 to 2007 (Burbach, 2007), then rose throughout the majority of the State during a period of above-normal precipitation from 2007 to 2011. Groundwater levels rose to above pre-drought levels in some areas, but in other areas they remained below pre-drought levels. Changes over the 10-year period were therefore highly variable (Fig. 11). Groundwater levels rose in a large, continuous area extending from the East Central Dissected Plains to the Northeast Glacial Drift region. Rises greater than 5 feet occurred in Valley, Boone, Madison, and Antelope Counties, as well as scattered locations in the northeast part of the State. Groundwater-level rises of between 1 and 5 feet occurred in parts of the Panhandle Tablelands, Sand Hills, Republican River Valley and Dissected Plains, in Hall and Merrick Counties in the Platte River Valley, as well as the Southeast Glacial Drift region in Butler, Saunders, and Lancaster Counties. Total precipitation over the 10-year period was above the 30-year average in the central and northeastern parts of the State where groundwater-level rises were greatest (Fig. 12).

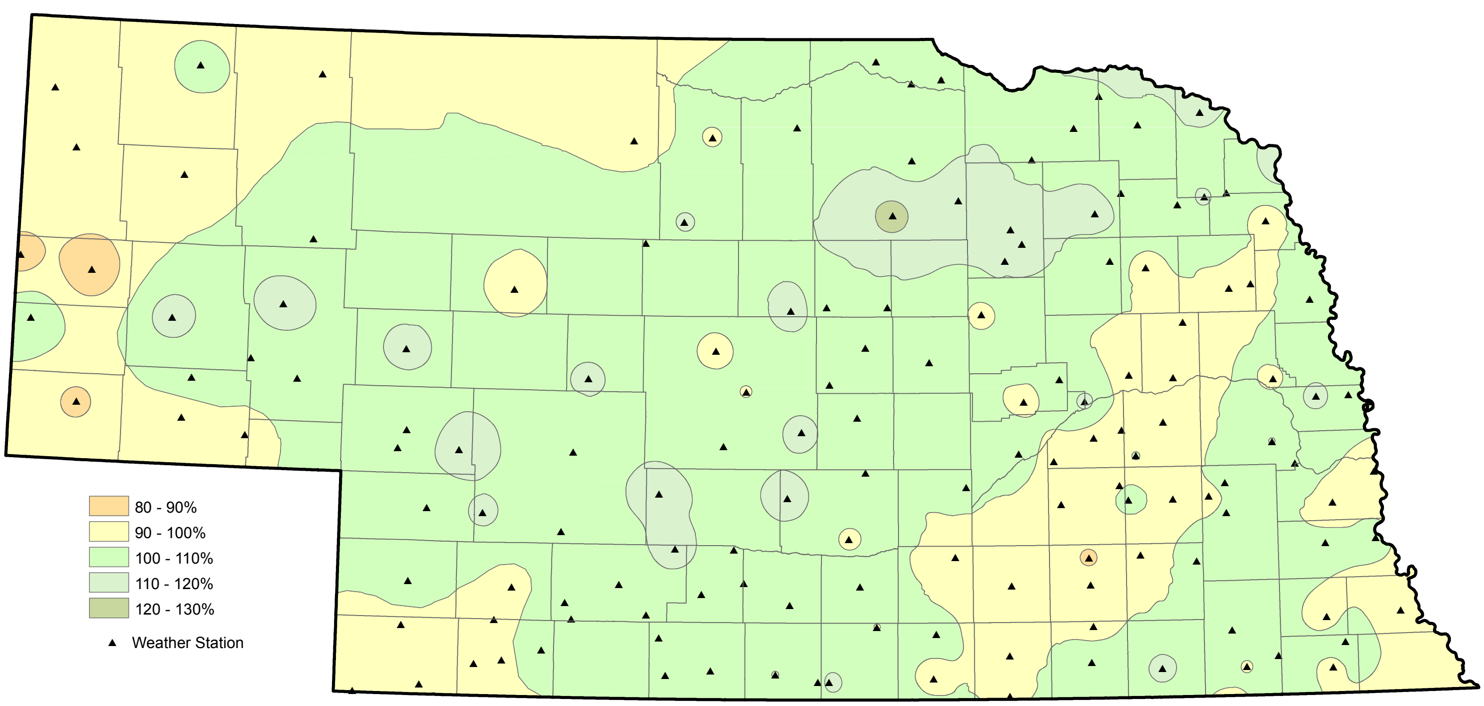
The three largest areas in which groundwater levels declined from spring 2001 to spring 2011 were in the South Central Plains, Southwestern Tablelands, and the Panhandle Tablelands (Fig. 11). Declines were greater than five feet in many of these areas. Declines of 15 to 25 feet occurred in Dundy and Chase Counties. The size and severity of declines in these areas can be attributed largely to irrigation withdrawals from relatively deep aquifers that have little or no connection to surface water. Declines of 1 to 5 feet occurred in many locations, including parts of the North Central Tablelands, Southeast Glacial Drift region, East Central Dissected Plains, and the Sand Hills. Below normal precipitation occurred in the South Central Plains and parts of the Glacial Drift region, the western Panhandle, the extreme southwest and southeast corners of the State, and along the Nebraska-South Dakota boundary west of Keya Paha County (Fig. 12).

Figure 11. Groundwater-Level Changes in Nebraska - Spring 2001 to Spring 2011



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

Figure 12. Percent of Normal Precipitation - January 2001 to January 2011



Sources: National Climate Data Center, Asheville, North Carolina; High Plains Regional Climate Center, University of Nebraska–Lincoln

CHANGES IN GROUNDWATER LEVELS, PREDEVELOPMENT TO SPRING 2011

Long-term groundwater-level changes in Nebraska primarily reflect aquifer depletion in areas of dense irrigation development and increases in storage due to seepage from canals and reservoirs.

Spring 2011 groundwater levels continue to indicate long-term declines and rises in certain areas of Nebraska (Fig. 13). With a few exceptions, areas of significant groundwater level declines generally correspond to areas where irrigation well density is high and aquifers are deep and have little or no connection to surface water (Fig. 14). The largest groundwater-level declines from predevelopment to spring 2011 occurred in the Southwestern Tablelands and the Panhandle Tablelands. Some smaller areas of declines occurred in the extreme southern East-Central Dissected Plains and the South-Central Plains. The largest rises occurred in Gosper, Phelps, and Kearney Counties in the South-Central Plains and in the East-Central Dissected Plains: both are areas where canals and surface irrigation systems exist.

The predevelopment groundwater levels used in the Southwestern Tablelands are representative of the approximate average water levels prior to 1953. Available data indicate that, as a result of intensive use of groundwater for irrigation, a general trend of declining water levels began in about 1966. Predevelopment water levels used to develop the groundwater-level change map in Box Butte County are the approximate average water levels prior to 1946. Intensive groundwater development for irrigation since 1950 has caused water-levels to decline 5 to more than 70 feet from predevelopment levels (Fig. 13). Records from recorder wells in both areas indicate that rates of decline have been more or less steady despite changes in groundwater management practices, water use allocations, and fluctuations in the amount of annual precipitation (see Korus and Burbach, 2009b, and forthcoming section).

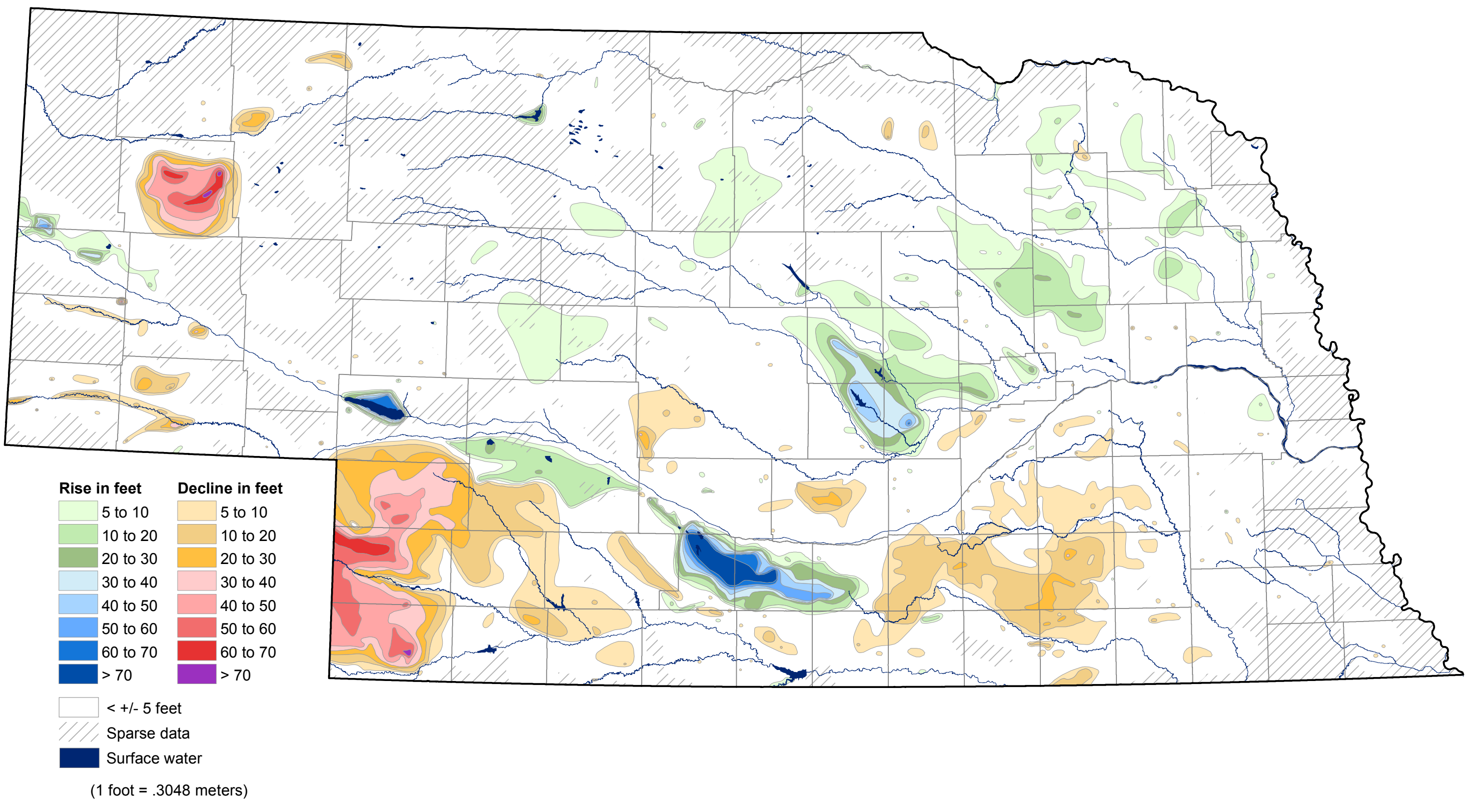
A large portion of the South-Central Plains has experienced long-term groundwater-level declines since predevelopment (Fig. 13). Predevelopment water levels in this area are generally representative of the approximate average water levels prior to 1950. Groundwater levels in large parts of this region have declined more than 10 feet, and in some areas more than 20 feet, from predevelopment. Declines in other areas of the South-Central Plains are at least 5 feet from predevelopment. The declines in this region, however, are much less severe than in recent years (cf. Burbach, 2007).

Parts of other regions that experienced relatively large areas of decline include the East-Central Dissected Plains; Republican River Valley and Dissected Plains; Southern Panhandle Tableland; Northern Panhandle Tableland; and northeastern Sand Hills (Fig. 13). Irrigation well density is high in some, but not all, of these areas. Other factors such as aquifer characteristics, rates of recharge, and irrigation scheduling could be contributing to the declines.

Groundwater-level rises from predevelopment generally occurred in areas of surface irrigation systems. Storage of water in Lake McConaughy began in 1941, and seepage losses caused water-level rises of as much as 60 feet in nearby observation wells (Ellis and Dreeszen, 1987). Water levels generally stabilized by about 1950 and since then have fluctuated in response to changes in reservoir levels and precipitation (Johnson and Pederson, 1984). Water is released from storage in Lake McConaughy, is subsequently diverted from the Platte River near North Platte, and then flows through the Tri-County Canal and a series of reservoirs toward Dawson, Gosper, Phelps, and Kearney Counties, where it has been used for irrigation since 1941. Deep percolation of water from these irrigation-distribution systems and from excess water applied to crops has raised groundwater levels as much as 70 feet (Fig. 13). Groundwater levels have also risen in association with seepage from Sutherland Reservoir, Lake Maloney, and their associated canals in eastern Keith and central Lincoln Counties. Rises of as much as 60 feet in the Northern Panhandle Tableland region are also associated with irrigation canal systems.

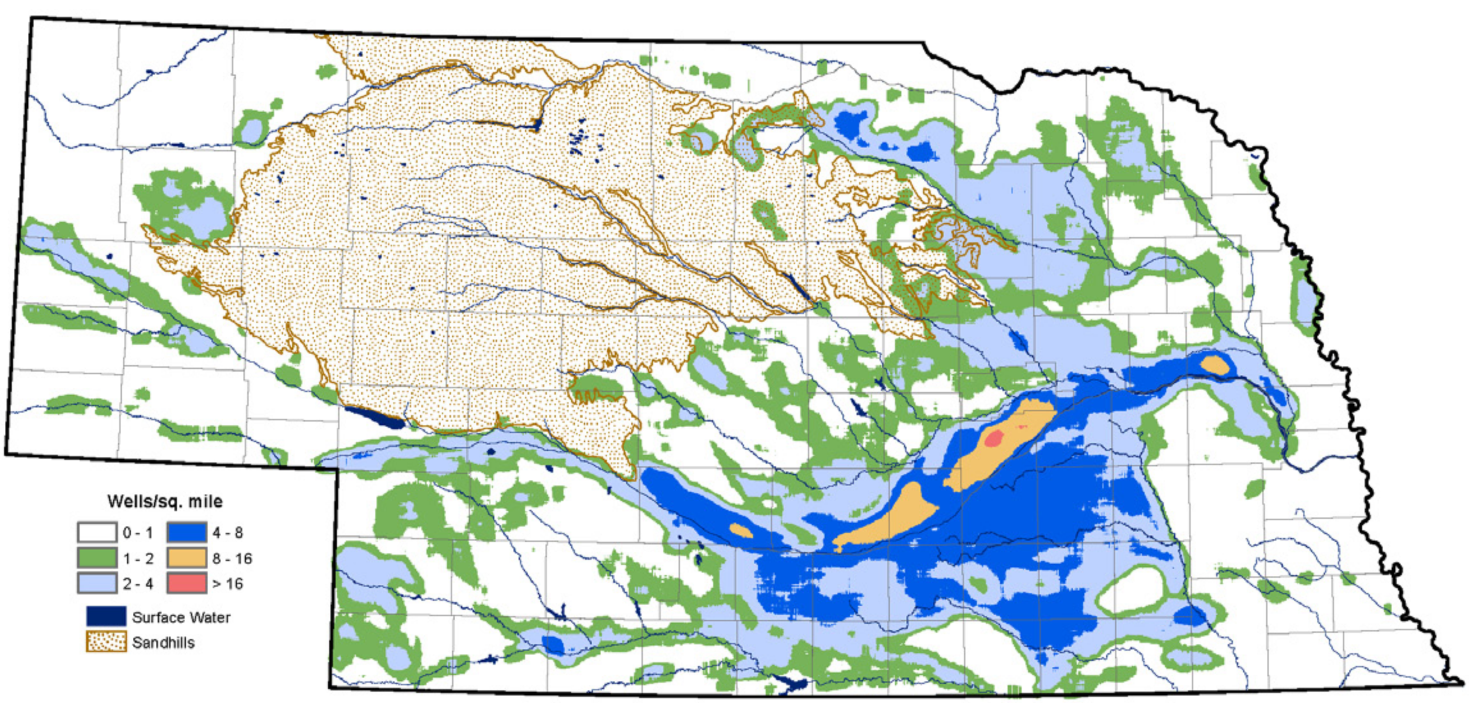
Groundwater-level rises of 10 to more than 60 feet occurred in portions of the East-Central Dissected Plains and Northeast Glacial Drift region (Fig. 13). The highest water-level rises occurred in Valley, Sherman, and Howard Counties as the result of seepage from irrigation canals, Sherman and Davis Creek Reservoirs, and deep percolation of irrigation water applied to crops. Eastward of that area, rises occurred in aquifers that are relatively deep, have little connection to surface water, and have high densities of irrigation wells. In other areas of Nebraska, this combination of factors has resulted in groundwater-level declines, so the rises in northeast Nebraska are most likely the result of higher than average precipitation spanning several decades.

Figure 13. Groundwater-Level Changes in Nebraska - Predevelopment to Spring 2011



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

Figure 14. Density of Active Registered Irrigation Wells - December 2011



Source: Nebraska Department of Natural Resources

CHANGES IN GROUNDWATER LEVELS, PREDEVELOPMENT TO SPRING 1981 AND SPRING 1981 TO SPRING 2011

Prior to 1981, groundwater levels were declining in nearly all areas of the State. After 1981, however, markedly different changes occurred in the east compared to the west.

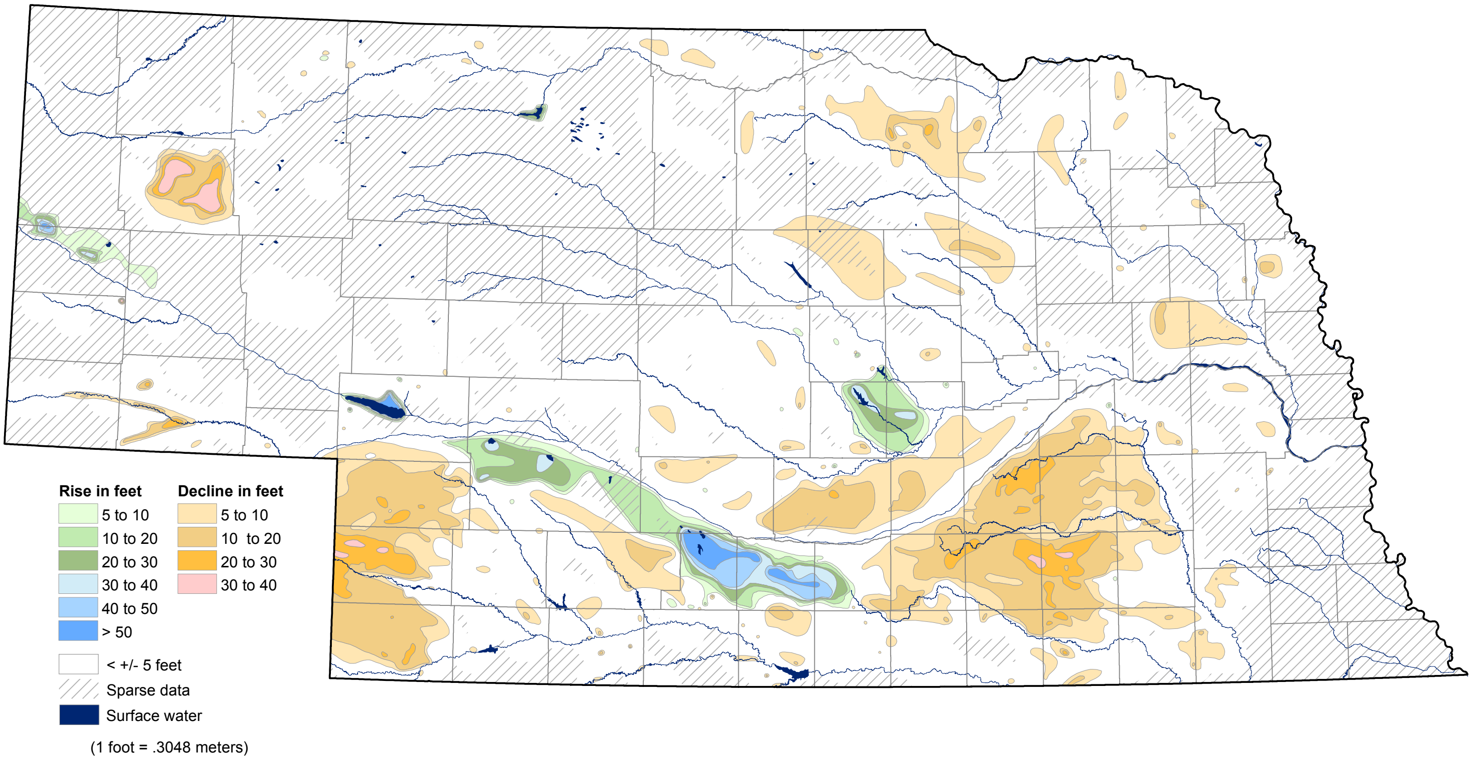
Groundwater-level changes from predevelopment to Spring 1981 reflect the responses of aquifers to the development of groundwater and surface water irrigation systems in Nebraska. Areas of significant groundwater level declines generally corresponded to areas of dense irrigation well development (cf. Johnson and Pederson, 1981). Declines were generally equal in magnitude in eastern and western areas (Fig. 15). The largest areas in which declines occurred were in the Panhandle Tablelands, Southwestern Tablelands, South-Central Plains, Platte River Valley, East-Central Dissected Plains, and northeast portion of the Sand Hills. Declines exceeded 30 feet in Box Butte County in the Panhandle, Chase County in the Southwestern Tablelands, and Clay and Fillmore Counties in the South-Central Plains. Declines occurred in smaller areas of the Republican River Valley and Dissected Plains as well as the Northeast Glacial Drift region. Almost all groundwater-irrigated areas of Nebraska experienced declines associated with groundwater withdrawals. Such declines are a necessary response of the aquifer to development according to principles of hydrologic mass balance (c.f. Korus and Burbach, 2009a).

Groundwater level rises from predevelopment to Spring 1981 were associated with irrigation canal systems and reservoirs (Fig. 15). The rise in southern Sioux and northern Scotts Bluff Counties was associated with seepage from the Interstate canal system, among numerous smaller systems, and excess water applied to crops beginning in the early 20th century. The rise in these counties exceeded 60 feet in some areas. The rise in Cherry County was associated with seepage from Merritt Reservoir beginning in the mid-1960s and exceeded 20 feet immediately adjacent to the reservoir. Seepage from Lake McConaughy beginning in 1941caused groundwater levels to rise as much as 70 feet by 1981. Reservoirs and canals south of the Platte River, which are used for hydroelectric power production and irrigation, provided seepage that caused groundwater-levels to rise from eastern Keith County to western Kearney County (see discussion in previous section). Water levels began rising in this area after 1941 and had nearly reached their maximum by 1981. In the East-Central Dissected Plains, groundwater levels began rising in 1963 due to seepage from Sherman Reservoir, its irrigation-distribution system, and deep percolation of irrigation water applied to crops. Rises of 10 to more than 30 feet occurred in in this area by 1981.

Compared to the changes discussed above, a much different pattern of groundwater-level changes has emerged in Nebraska since 1981 (Fig. 16). In central and eastern Nebraska, areas in which declines had occurred from predevelopment to 1981 experienced rises of 5 to more than 20 feet from 1981 to 2011. This pattern of pre-1981 decline and post-1981 recovery is observed in many wells, including the Hastings Recorder well, which has a continuous record dating to the mid-1930's, and the Aurora Recorder well, which dates to the mid-1950's (Fig. 17). In areas such as the East-Central Dissected Plains, Northeast Glacial Drift region, and extreme eastern Sand Hills, a net rise in groundwater levels has occurred from predevelopment to 2011 (Fig. 13). Rises in areas such as Hall County in the Platte River Valley and Colfax and Dodge Counties in the northern Glacial Drift region erased earlier declines that were similar in magnitude, resulting in little or no observable change today.

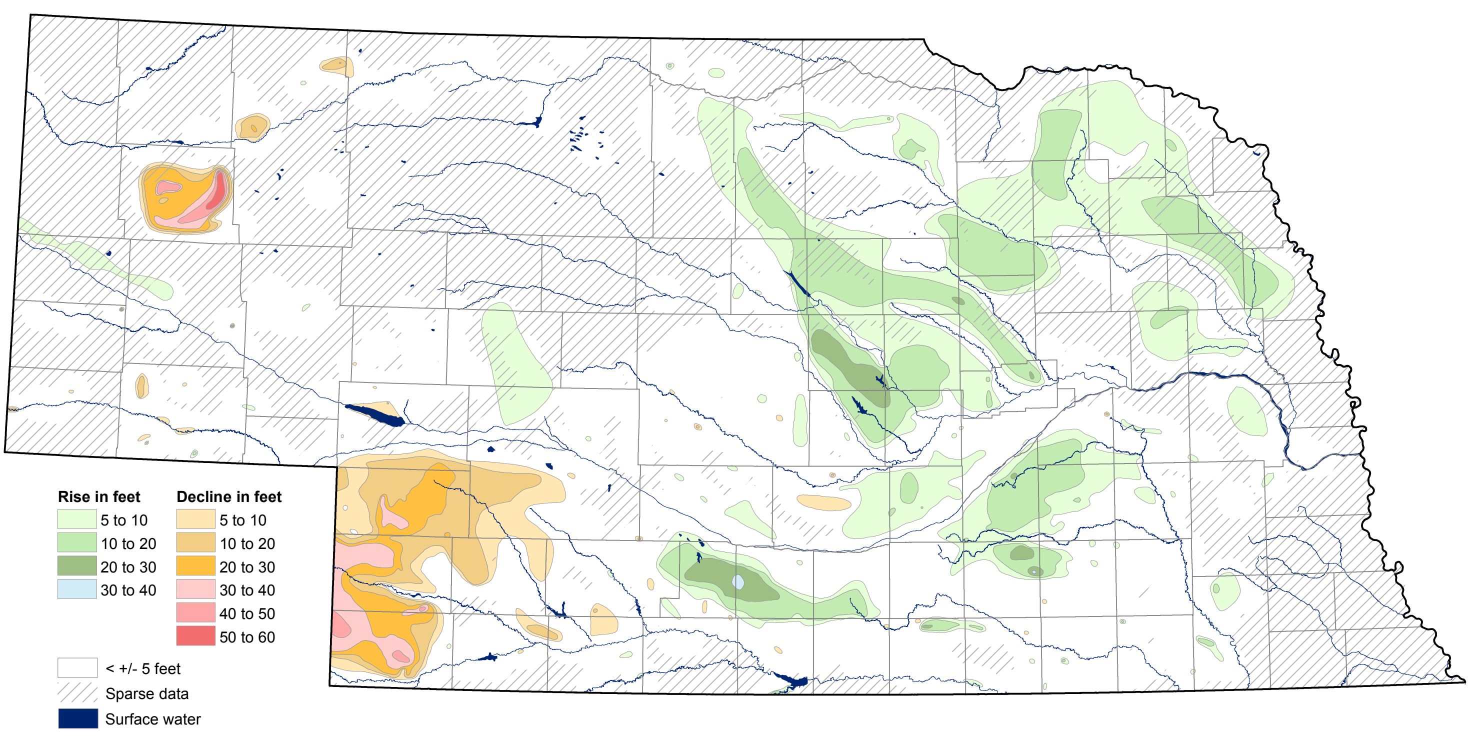
Declines in the South-Central Plains reached a maximum in 1981 and have since recovered such that changes in some areas are now less than 5 feet compared to predevelopment levels (Figs 13, 15, 16). Groundwater levels in most of this area, however, remain below predevelopment levels. It is hypothesized that the post-1981 recovery of groundwater levels in central and eastern Nebraska resulted from a combination of factors, including (1) reduced groundwater withdrawals during several long periods of above-average precipitation, (2) increased irrigation efficiencies that resulted in reduced pumping rates and volumes, and (3) stabilization of groundwater-levels as the aquifer equilibrated to the new hydrological conditions imposed on it by irrigation development decades earlier (see Korus and Burbach, 2009a). Another possible explanation for these rises may be related to increasing rates of recharge. In some areas, a shallow water table aquifer is separated from the primary aquifer by a confining layer. Irrigation during the first several decades after development was primarily by means of flooding along rows of crops. This method resulted in over-application and deep percolation, which thereby recharged the shallow aquifer. Evidence for this phenomenon is shown in the hydrograph for the Exeter Recorder Well, which is screened in the shallow aquifer (Fig. 17). The steady rise from 1956 to 1981 in this well corresponds to the steady decline observed in nearby wells that are screened in the deep aquifer. This excess water may have served as a source of new recharge to the primary aquifer in areas where the confining layer is sufficiently permeable.

Figure 15. Groundwater-Level Changes in Nebraska - Predevelopment to Spring 1981



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

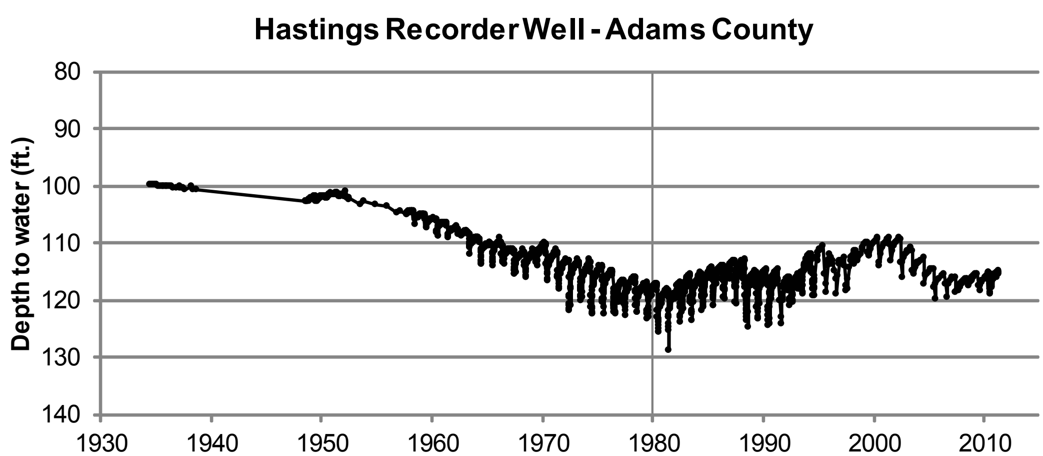
Figure 16. Groundwater-Level Changes in Nebraska - Spring 1981 to Spring 2011

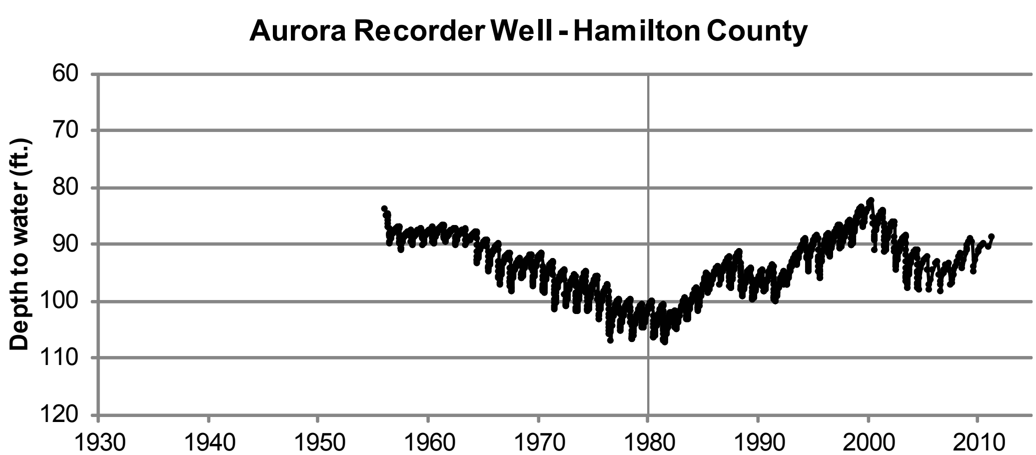


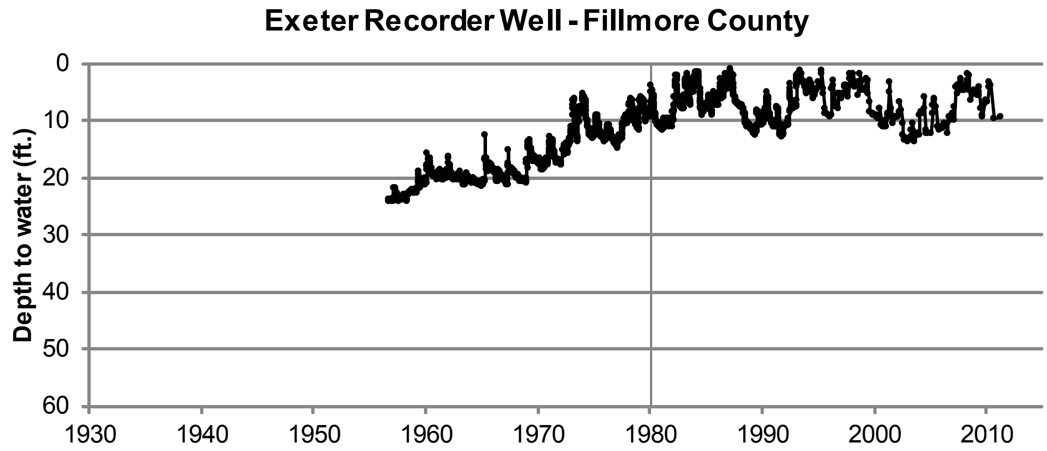
Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

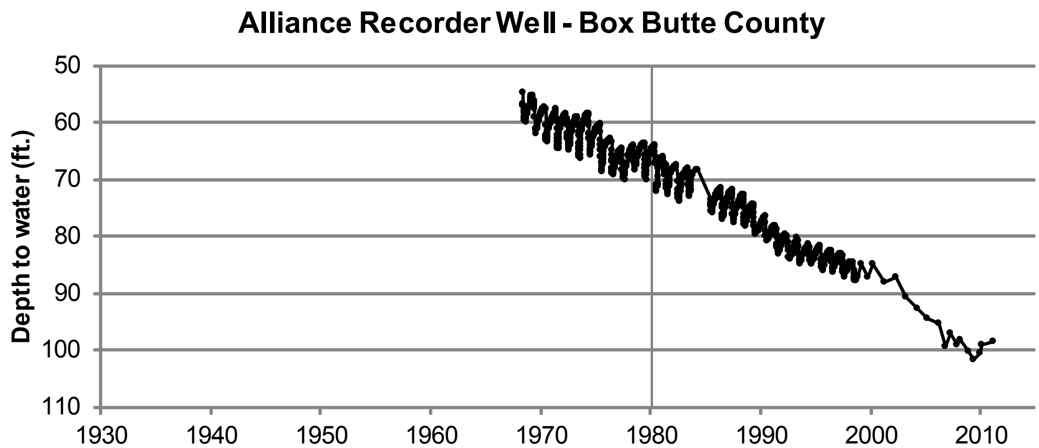
In contrast to the groundwater-level rises in the east, levels continued to decline in parts of western Nebraska from 1981 to 2011 (Fig. 16). The Alliance, Benkelman, and Imperial Recorder wells show declines of 50 to 60 feet in just 50 years, an average of about 1 foot per year (Fig. 17). Brief periods of unchanging or rising groundwater levels occurred, but the rates of decline were steady overall despite changes in groundwater management practices, water use allocations, and fluctuations in the amount of annual precipitation over the past 30 years. The pattern of long-term groundwater-level decline over a large region, such as the Southwest Tablelands and Box Butte County, is a normal response of an aquifer to irrigation development. Such declines reflect the release of water from storage in the aquifer and the adjustment of the water table to new hydrological stresses (see Korus and Burbach, 2009a). These declines will stabilize only if groundwater withdrawals do not exceed the total yield of the aquifer, which is a function of its hydrogeological characteristics as well as its sources and rates of replenishment.

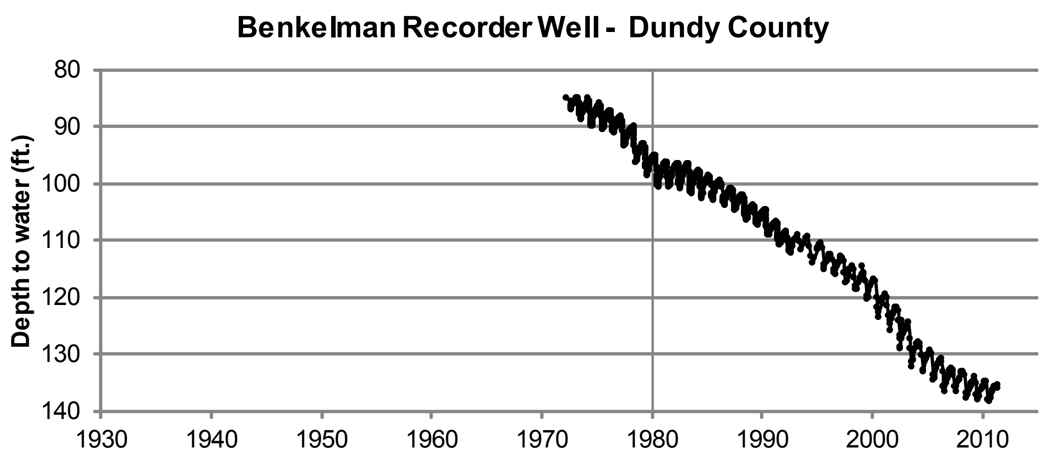
Figure 17. Groundwater-Level Hydrographs typical of southeast and southwest Nebraska

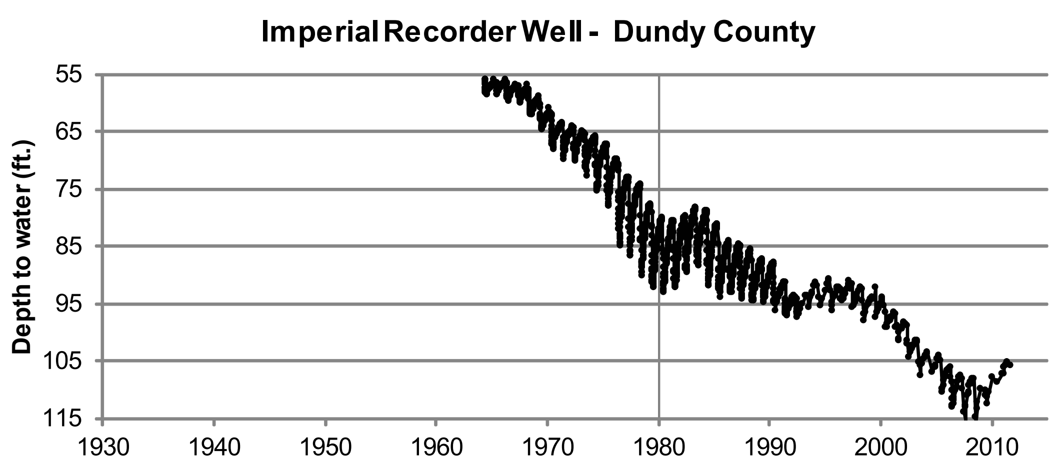





Exeter Recorder Well - Fillmore County
Depth to water (ft.)
0
10
20
30
40
50
60
1930
1940
1950
1960
1970
1980
1990
2000
2010


Alliance Recorder Well - Box Butte County
Depth to water (ft.)
50
60
70
80
90
100
110
1930
1940
1950
1960
1970
1980
1990
2000
2010


Benkelman Recorder Well - Dundy County
Depth to water (ft.)
80
90
100
110
120
130
140
1930
1940
1950
1960
1970
1980
1990
2000
2010


Imperial Recorder Well - Dundy County
Depth to water (ft.)
55
65
75
85
95
105
115
1930
1940
1950
1960
1970
1980
1990
2000
2010

AVERAGE DAILY STREAMFLOWS, 2010

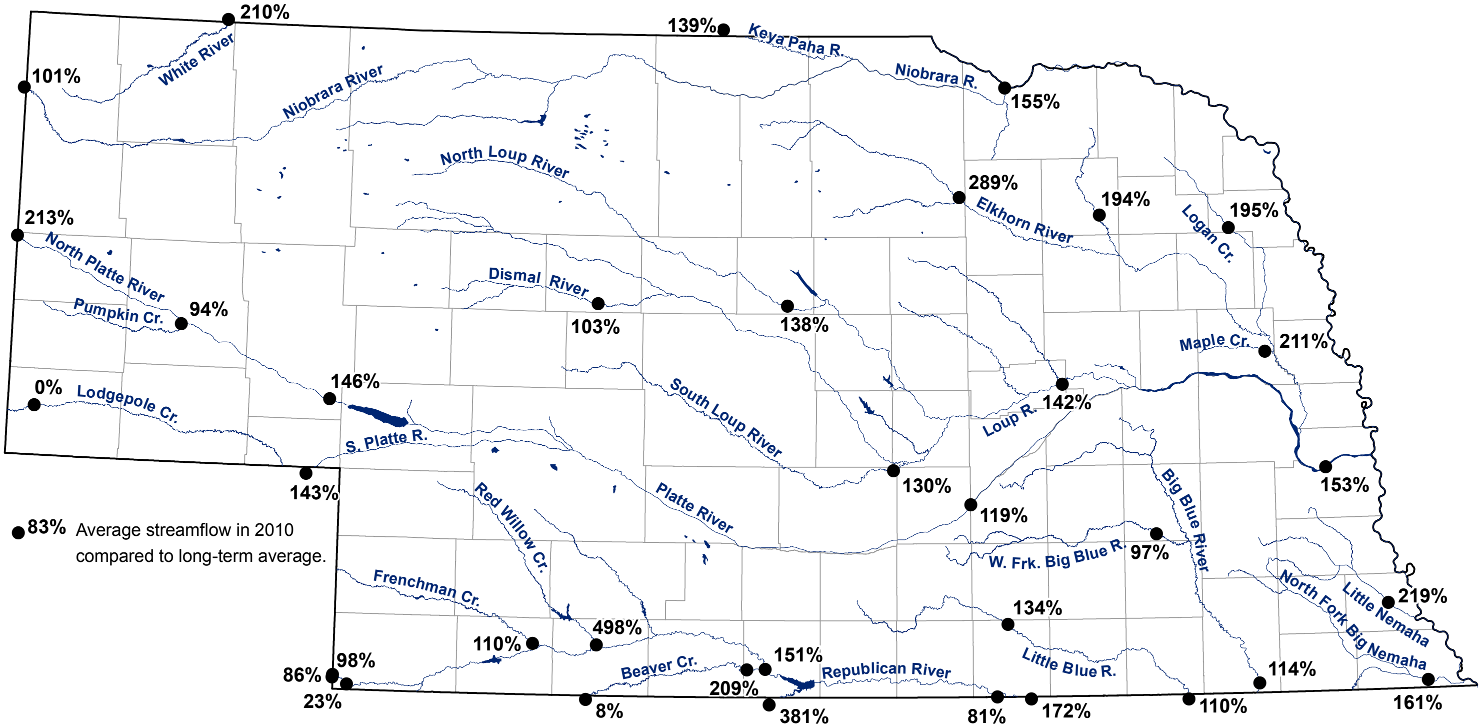
Above-average precipitation resulted in high streamflows throughout most of the State in 2010.

The flows in Nebraska streams have several different sources. Snowmelt in the Rocky Mountains provides springtime flows for the Platte River as it enters Nebraska. Variations in the amount of winter snowpack have a profound impact on discharges, but so also can the timing and amount of releases from dams in Nebraska, Wyoming, and Colorado. Runoff from precipitation is the source of many of the peak flows in Nebraska streams. Runoff is greatest on soils with low infiltration rates and/or high slopes. As such, many streams in eastern Nebraska have 'flashy' discharges characterized by high flows immediately following large precipitation events. Streams with headwaters in the Sand Hills are characterized by steady flows year-round because high infiltration rates in the sandy soils limit runoff and provide constant groundwater discharge to streams.

Average daily streamflow values were higher than the 30-year average for most of Nebraska's streams in water year 2010 (Fig. 18). The highest discharges occurred in Red Willow Creek and other tributaries to the Republican River, Elkhorn River and its tributaries, North Platte River, White River, and Little Nemaha River. Flows were above average in all other streams except the West Fork of the Big Blue River, Pumpkin Creek, and several tributaries and canals of the Republican River that enter Nebraska from Colorado and Kansas. Little or no flow was observed in Lodgepole Creek.

The factors affecting streamflows are numerous and complex. Nonetheless, groundwater-level declines in areas where streams are well-connected to aquifers have lowered or altogether halted flows to some streams that overlie the High Plains Aquifer (Sophocleous, 1998). Continued monitoring of groundwater-level changes throughout Nebraska is necessary in order to evaluate and manage these interconnected resources.

Figure 18. Average Streamflow in Water Year 2010, as a Percentage of the 30-Year Average



Sources: U.S. Geological Survey; Nebraska Water Science Center and Nebraska Department of Natural Resources

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Reports Containing Water-level Information

Year	Publication and Number	Author(s) and year published
pre 1954	U.S.G.S. Open-File Rpt. 54-138	Keech, C.F.; Case, R.L., 1954
1954	U.S.G.S. Open-File Rpt. 55-80	Keech, C.F.; Case, R.L., 1955
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ISBN 1-56161-020-8
ISBN-13 978-1-56161-020-4