Nebraska Statewide Groundwater-Level Monitoring Report

2010

Jesse T. Korus
Mark E. Burbach
Leslie M. Howard
R. Matthew Joeckel

Conservation and Survey Division
School of Natural Resources

Nebraska Water Survey Paper Number 77

Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln

Nebraska Statewide Groundwater-Level Monitoring Report 2010

Jesse T. Korus, Mark E. Burbach, Leslie M. Howard and R. Matthew Joeckel

Conservation and Survey Division
School of Natural Resources

Nebraska Water Survey Paper Number 77

Conservation and Survey Division
School of Natural Resources
Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln

University of Nebraska-Lincoln

Harvey S. Perlman, J.D., Chancellor, University of Nebraska-Lincoln
Ronald D. Green, Ph.D., NU Vice President and IANR Harlan Vice Chancellor
Donald A. Wilhite, Ph.D., Director, School of Natural Resources
Mark S. Kuzila, Ph.D., Director, Conservation and Survey Division

The Conservation and Survey Division (CSD) of the University of Nebraska-Lincoln is the agency designated by statute to investigate and interpret the geologically related natural resources of the state, to make available to the public the results of these investigations, and to assist in the development and conservation of these resources. It consists of program areas in geology, water, soils, and remote sensing-geographic information systems.

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/.

It is the policy of the University of Nebraska-Lincoln not to discriminate based upon age, race, ethnicity, color, national origin, gender, sex, pregnancy, disability, sexual orientation, genetic information, veteran's status, marital status, religion or political affiliation.

December 2010

ISBN 1-56161-014-3
ISBN-13 978-1-56161-014-3

ACKNOWLEDGMENTS

The cooperation and assistance of the following agencies and associations in collecting and providing water-level data during 2010 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.

CONTENTS

FIGURES

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. For many years, these two agencies were primarily responsible for collecting, storing, and making this information available to the citizens.

Over the years, other agencies began to assume 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 U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service, Public Power and Irrigation Districts, County Extension offices, municipalities, and particularly Natural Resources Districts (Fig. 1). 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 their particular conditions. Collectively, these agencies have developed an extensive network of observation wells throughout the State (Fig. 2).

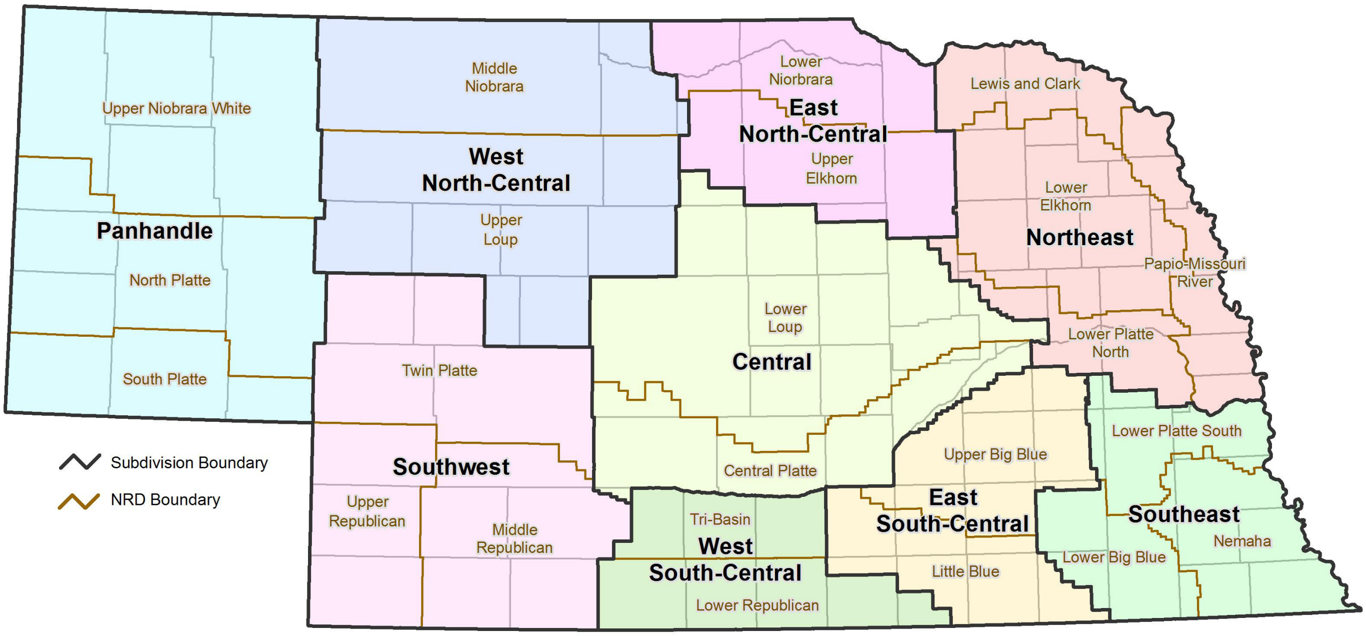
The CSD plays a vital role in providing technical expertise to these agencies as they develop and implement groundwater-level monitoring plans. The CSD evaluates the adequacy and accuracy of the water-level data and provides the statewide assessment of groundwater-level changes across all geographic regions and aquifers.

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.

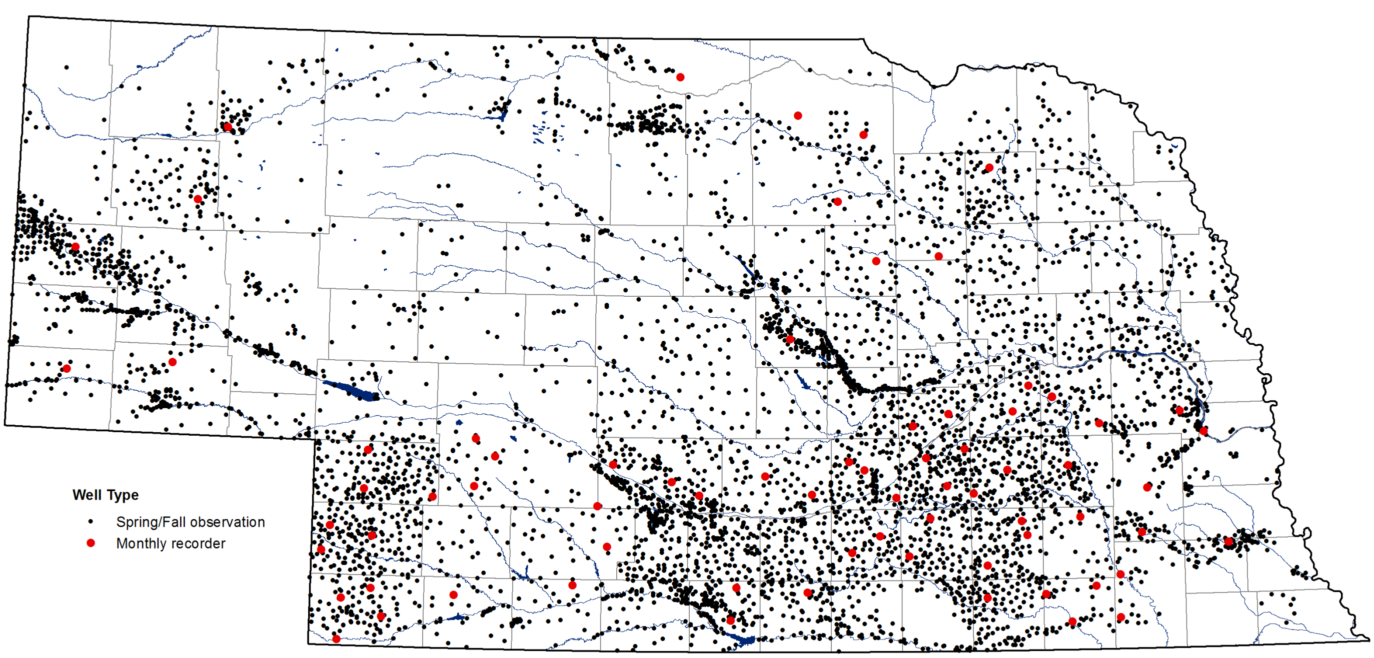
The need for this information has increased tremendously over the past few years, yet the resources available for fulfilling this need have decreased. The CSD strives to meet this challenge by focusing on fundamental data, building collaborative relationships with the agencies that depend on the information,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

Figure 1. National Resources Districts and Regional Subdivisions of Nebraska



Divisions are based on Natural Resources District boundaries and are consistent with divisions used in previous reports to categorize and describe regional trends.

Figure 2. 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.

Purpose and Methods

This report summarizes annual and long-term changes in Nebraska's groundwater levels. 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 spring 2009 to spring 2010 and the spring 2007 to spring 2010 groundwater-level change maps in this report were prepared by comparing groundwater levels measured in spring 2010 to levels measured in the same well in the spring of the earlier year. Data were collected from thousands of sites throughout the State (Fig. 2). Initial 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, 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 included 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 drought-period map, water levels were compared in wells for which both spring 2000 and spring 2010 levels were measured. In order to be consistent with previous versions of this map, contours were drawn manually with the aid of the previous year's map and with knowledge of major hydrogeologic boundaries.

For the predevelopment to spring 2010 map, comparisons were made between spring 2010 water levels and estimated predevelopment water levels. 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 are dependent 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 on the predevelopment to spring 2010 water-level map were drawn manually with the aid of the previous year's map 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. The water year is defined as the one year period from October 1 for any given year through September 30 of the following year. The 2009 water year was from October 1, 2008 to September 30, 2009. The long-term average is calculated from all available annual data from the 30 year period previous to the current water year. The 2009 stream flows were compared to the average annual flows from 1979 to 2008. 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 in 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.

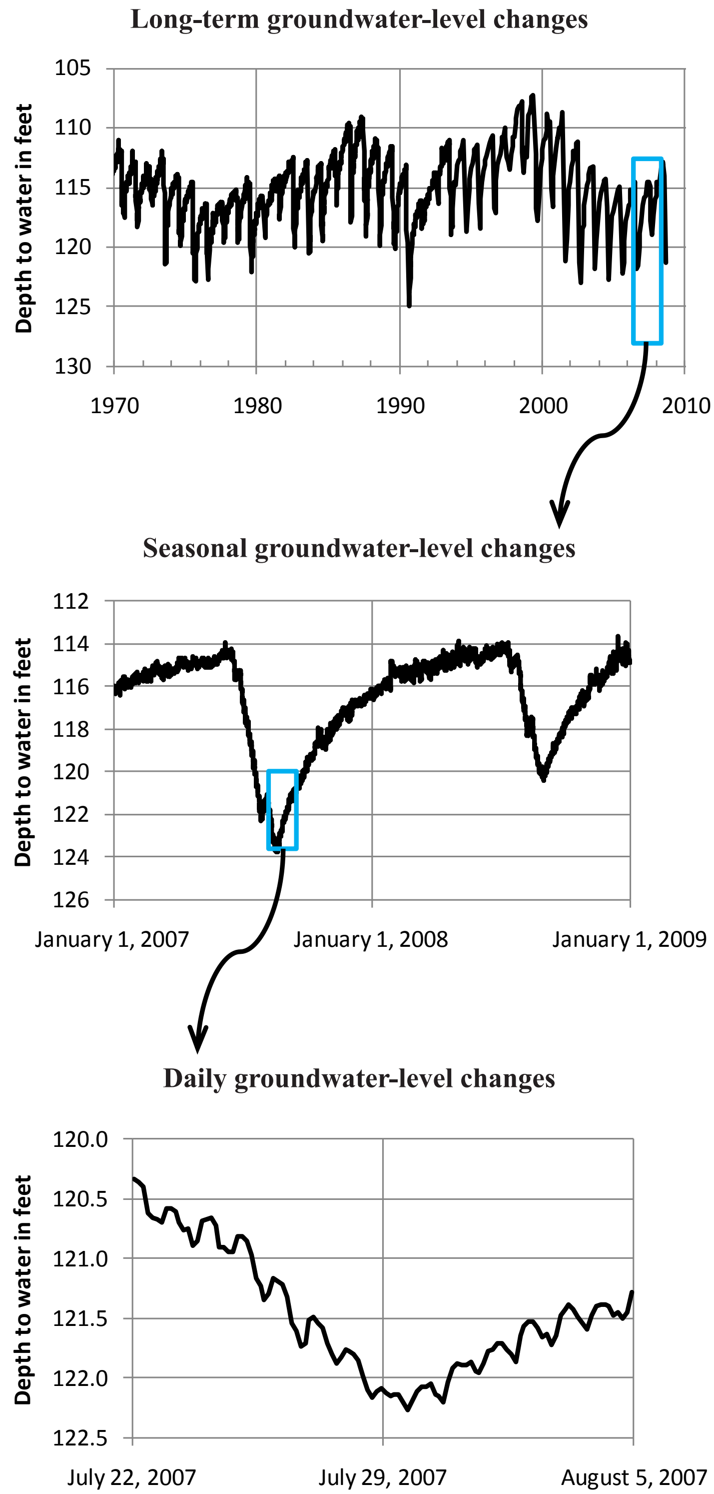
It is a common misconception that the rate of recharge from precipitation can be used as a "safe yield" or "sustainable limit" on the rate of pumping (Bredehoeft, 1997). This idea is too simplistic. The aquifer properties and all sources of recharge and discharge must be taken into consideration. Recharge 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. Groundwater "mining" is prone to occur to one degree or another in any heavily pumped aquifer and any attempt to manage groundwater withdrawal based solely on comparison with the rate of recharge from precipitation is fundamentally flawed. 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, 2009).

Groundwater-level changes can be observed at many different temporal scales (Fig. 3). 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.

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. Similarly, 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 maps presented in this report were generally mapped 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 3. Example of Groundwater-Level Changes at Different Temporal Scales



Based on data from Plymouth Recorder well, Jefferson County

GENERALIZED GEOLOGIC AND HYDROSTRATIGRAPHIC FRAMEWORK OF NEBRASKA

The abundance of groundwater in Nebraska is directly related to its geologic framework. In order to understand groundwater we must first understand geology.

Figure 4 defines the relationship between geologic time, stratigraphic units, lithologic descriptions, and important groundwater units in Nebraska. This diagram incorporates information from Condra and Reed (1959), but we have revised certain units in the regional stratigraphic scheme relative to the occurrence of groundwater. Nebraska is covered by thick sediments and sedimentary rocks spanning over 500 million years of Earth's history. Many of the layers of sediments and sedimentary rocks in the State have sufficient porosity and permeability to serve as aquifers, but other layers do not transmit water easily or in significant quantities, and these layers serve as confining units or aquitards. Sands, gravels, sandstones, and conglomerates usually make good aquifers because they contain abundant well-connected pore spaces that allow groundwater to flow relatively freely. Other rocks, such as dolomites and limestones in the Paleozoic section and siltstones such as the Oligocene Brule Formation, contain joints, fractures, secondary porosity resulting from dissolution, and weathering features (e.g., pipes) that also transmit groundwater. Aquifers in Nebraska are hosted by Cambrian, Ordovician, Silurian, Devonian, Mississippian, Cretaceous, Tertiary, and Quaternary sediments and sedimentary rocks. Older aquifers usually contain poorer quality water than younger aquifers (Carlson and Sibray, 1992; Miller and Appel, 1997). Precambrian igneous and metamorphic rocks in Nebraska are aquitards and they are present only at depths of hundreds of feet or more below the surface.

Alluvial valley aquifers

The valleys of many modern streams in Nebraska contain sand and gravel deposits that provide usable quantities of groundwater. These alluvial valley aquifers exist throughout Nebraska, but in eastern Nebraska and other, smaller areas of the State (e.g., the valleys of the Niobrara and Republican Rivers), they are considered separate and distinct from the High Plains Aquifer because the two are not in direct hydrologic connection.

Paleovalley aquifers

Paleovalley aquifers in southeastern Nebraska consist of sands and gravels that fill ancient (Pliocene-Pleistocene) stream valleys. These paleovalleys can be mapped as distinct entities because they lie within materials that have contrasting lithologies and because many of them were eroded into bedrock units and can be delineated on the basis of the topography of the bedrock surface. Similar paleovalley aquifers probably exist in northeasternmost Nebraska, but they have not yet been mapped in detail.

High Plains Aquifer

The most widely used and best-known aquifer in Nebraska is the High Plains Aquifer (HPA). It consists of multiple layers of sand, gravel, and sandstone and lesser amounts of silt, siltstone, and clay. The HPA underlies most of Nebraska, except for the extreme northwestern Panhandle and the easternmost part of the State. The units of the HPA are, from oldest to youngest, the Brule Formation, Arikaree Group, Ogallala Group, Broadwater Formation (and correlative units), and multiple sand and gravel units of Late Neogene and Quaternary ages. The Brule Formation is included in the HPA only where its siltstones are fractured and weathered, or where isolated sandstone bodies exist within it. Fractures and weathering exist where the Brule crops out or where is present in the shallow subsurface. Unfractured and unweathered Brule Formation siltstones lack secondary porosity and therefore they are aquitards. The Arikaree Group comprises sandstone and siltstone and it is an important part of the HPA in western Nebraska. The Ogallala Group is the principal unit of the HPA under most of Nebraska. It consists of sand, sandstone, siltstone and gravel. Pliocene and Pleistocene sands and gravels comprise the uppermost portion of the HPA in central and eastern Nebraska.

The HPA includes stream sediments that fill ancient valleys as well as sediments deposited over broad alluvial plains. Paleovalley fills in the HPA are generally less distinct than those in southeastern Nebraska because they are usually surrounded by deposits with similar lithologies, making them difficult to distinguish on the basis of lithology alone. Nonetheless, Diffendal (1982) mapped paleovalleys in the Ogallala Group in the Nebraska Panhandle on the basis of observations made in outcrop. Paleovalley fills in the Broadwater Formation in the Nebraska Panhandle are comparatively distinct because they contain lithic gravels (Stanley and Wayne, 1972).

Chadron Aquifer

The Chadron Aquifer historically refers to a sandstone aquifer in the lower White River Group. Evans and Terry (1994) renamed certain sandstones in the lower White River Group as the Chamberlain Pass Formation, rather than the Chadron Formation. We retain the name Chadron Aquifer, however, for the aquifer in the lower White River Group in the Panhandle. It serves as a secondary aquifer where the HPA is thin or absent.

Cretaceous aquifers

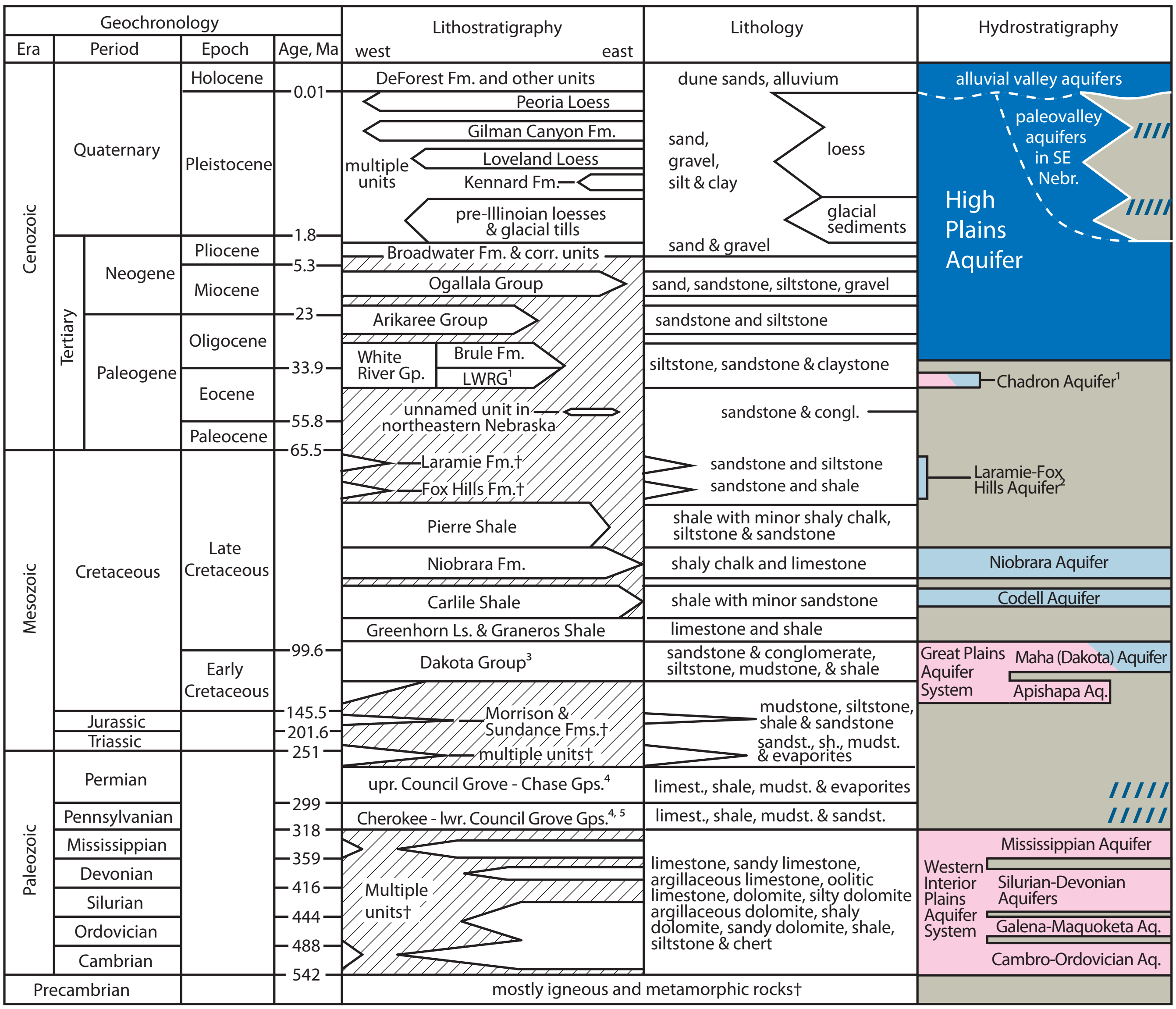
Cretaceous rocks in Nebraska include several important secondary aquifers. The Laramie-Fox Hills Aquifer is an important aquifer in Colorado, but it underlies only the extreme southwestern Panhandle and it is not known to be a source for any wells in Nebraska. The Niobrara and Codell

Aquifers are important secondary aquifers in northeast Nebraska where the HPA is absent (Souders, 1976). The Great Plains Aquifer System exists under most of Nebraska except for the southeast and along the Missouri River. It consists of two main aquifers separated by an aquitard. The Apishapa Aquifer is the lowermost aquifer unit. It exists only in west-central and western Nebraska and contains mostly poor quality water or oil and gas (Miller and Appel, 1997). The Maha Aquifer, commonly known as the Dakota Aquifer in Nebraska, is the upper aquifer unit and is used in eastern Nebraska for many municipal, domestic, and irrigation water supplies. Water quality in the Maha (Dakota) Aquifer is highly variable, but fresh water exists locally in subcrop in eastern Nebraska (Lawton et al., 1984). The Maha (Dakota) Aquifer is not widely used as a source of water in central and western Nebraska because it is deeply buried by overlying strata, including units of the HPA, and because the waters are generally too salty for most uses (Miller and Appel, 1997).

Paleozoic aquifers

The Western Interior Plains Aquifer System (*sensu* Miller and Appel, 1997) underlies most of Nebraska. This aquifer system is subdivided into separate aquifers in southwestern Iowa (Prior et al., 2003), and we have adopted this subdivision in Figure 4.

Figure 4. Generalized Geologic and Hydrostratigraphic Framework of Nebraska



[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

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

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

J.T. Korus and R.M. Joeckel
Conservation and Survey Division, SNR, UN-L, 2011

CHANGES IN GROUNDWATER LEVELS, SPRING 2009 TO SPRING 2010

Groundwater levels rose or were unchanged throughout much of Nebraska in 2009. Declines occurred in several small areas.

Groundwater levels under most of Nebraska generally changed by less than one foot from spring 2009 to spring 2010. Groundwater levels rose under many scattered locations around the State, but there were also a few, scattered, and comparatively small areas under which groundwater levels declined. Some, but not all of these trends are reflective of statewide precipitation patterns in 2009 in relation to long-term norms (Fig. 5).

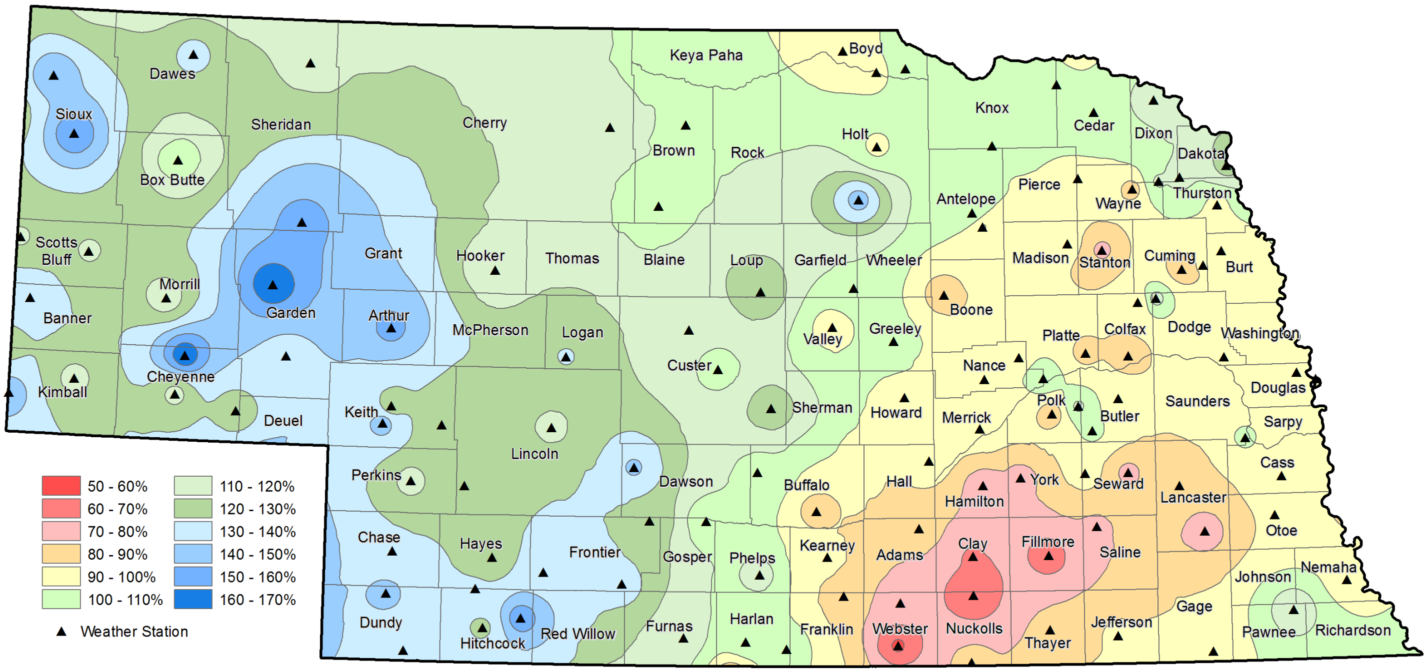
Groundwater-level rises of greater than one foot occurred throughout the State (Fig. 6). The largest areas under which groundwater rises occurred were in the panhandle, west north-central, southwest, central, west south-central, and northeast. Groundwater-level rises of greater than two feet occurred around Lake McConaughy, throughout Keith and Perkins Counties, and under most of the southern Panhandle. A large part of the western and northern Sand Hills experienced 1-2 feet of groundwater-level rise. Areas immediately south of the Platte River in west-central Nebraska and areas north of the Platte River in central Nebraska experienced rises of greater than one foot, but mostly less than five feet. Groundwater levels rose between one and five feet along the lower Platte River and along Logan Creek in the northeastern part of the State. Groundwater levels rose by more than five feet near the Missouri River and some of its major tributaries in northeastern and southeastern Nebraska. Other areas under which groundwater levels rose were scattered throughout the State. Areas under which groundwater levels rose generally correspond to areas of above normal precipitation for 2009. Areas of groundwater level rise in northeast and southeast Nebraska, however, correspond to areas with lower than normal precipitation for 2009 (Fig. 5).

Groundwater-level declines of greater than one foot occurred under a few, widely scattered areas (Fig. 6). The largest of these areas was in Clay and Fillmore Counties where declines exceeded two feet, but were generally less than five feet. Groundwater-level declines of 1-2 feet occurred under several other small areas of the east south-central, especially along the Little Blue River. These areas correspond to an area of generally less than 80 percent of normal precipitation.

Declines generally greater than two feet, but in some areas greater than five feet, occurred in northern Harlan County. The southwest experienced declines under small, scattered parts of Hayes, Frontier, Lincoln, Keith, Perkins, and Dundy Counties. These areas received above-normal precipitation for 2009.

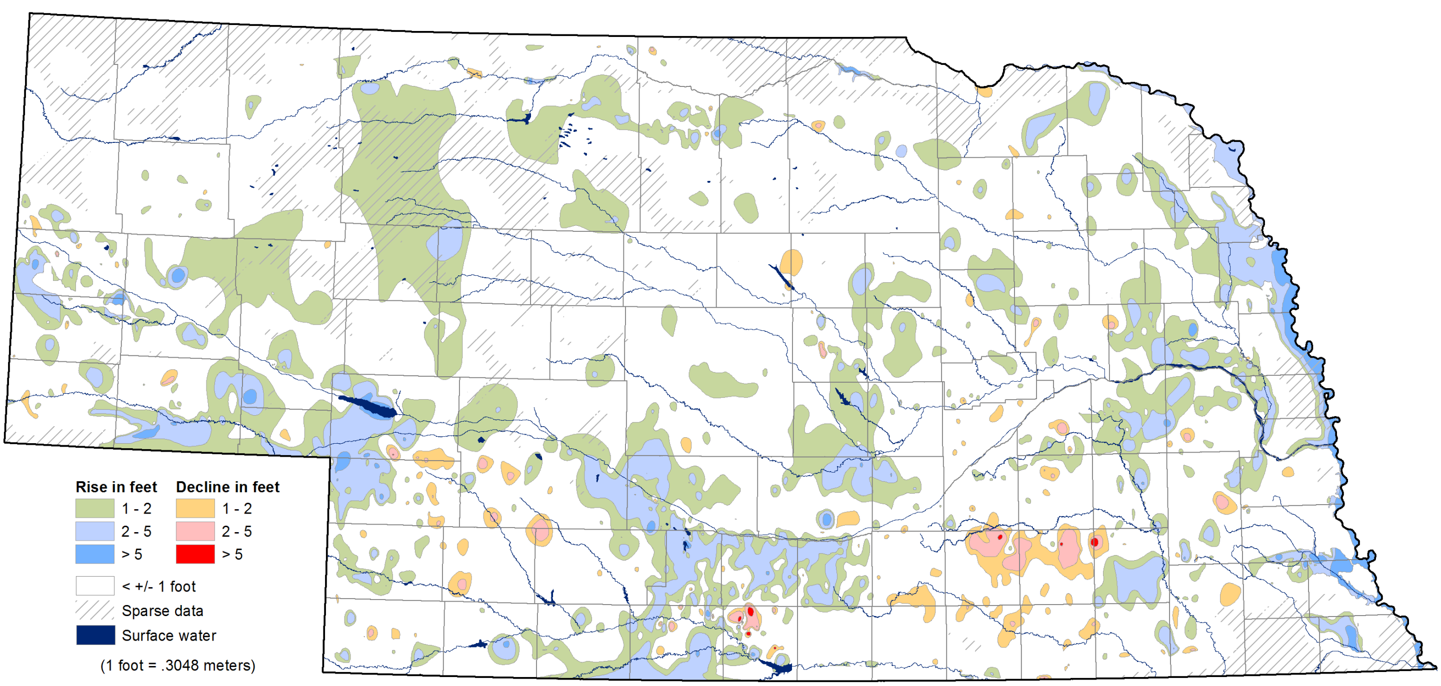
Areas of groundwater-level decline were generally isolated and small throughout the rest of the State.

Figure 5. Percent of Normal Precipitation - January 2009 to January 2010



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

Figure 6. Groundwater-Level Changes in Nebraska - Spring 2009 to Spring 2010



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.

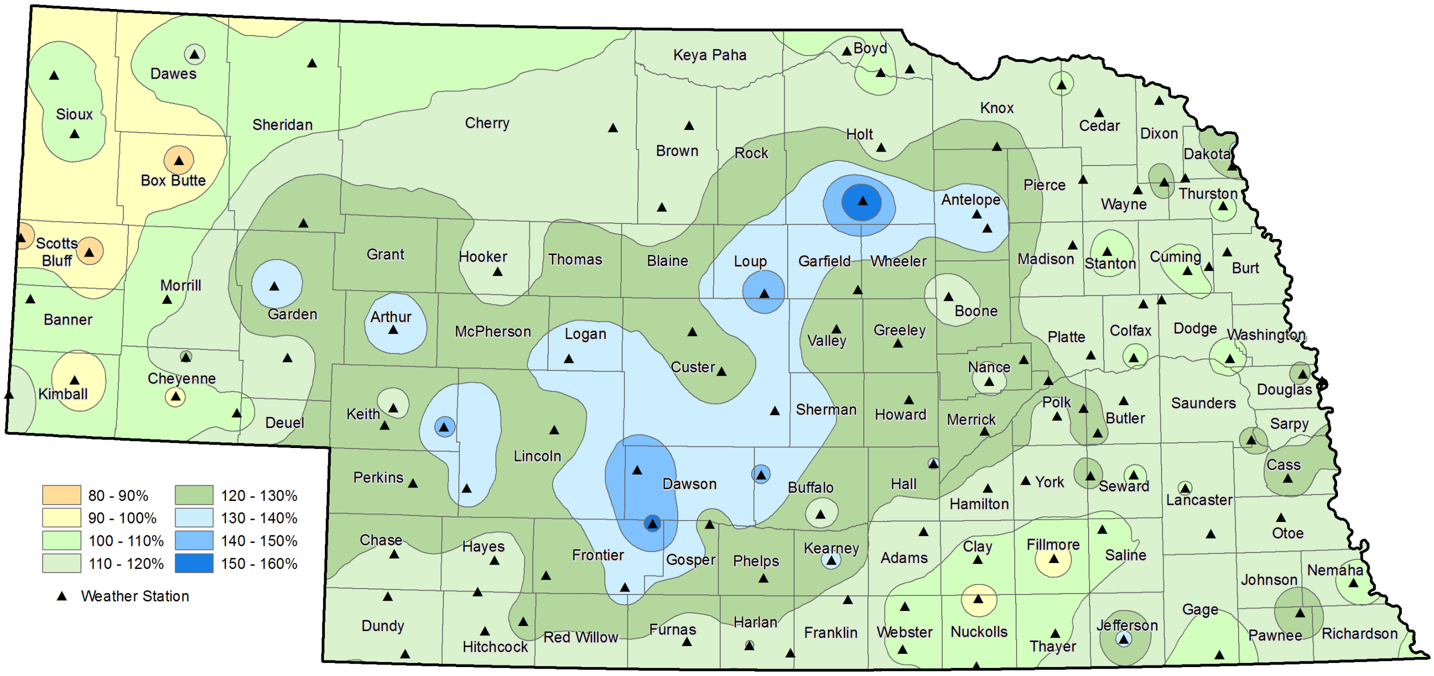
CHANGES IN GROUNDWATER LEVELS, SPRING 2007 TO SPRING 2010

The majority of Nebraska experienced groundwater level rises from 2007 to 2010, but declines occurred in the southwest and in parts of the panhandle.

Widespread rises in groundwater levels under most of Nebraska correspond to above-normal precipitation from January 2007 to January 2010 in these areas. Precipitation across central and eastern Nebraska, as well as the eastern Panhandle, was above normal for the three year period (Fig. 7). Groundwater levels rose under most, but not all of these areas. The area under which groundwater levels rose by at least one foot lies eastward of a line extending from Valentine to McCook (Fig. 8). Groundwater level rises of 2-5 feet occurred under most of this area: rises of greater than five feet also occurred in several subareas. The largest of these subareas extends across parts of Antelope, Boone, Madison and Platte Counties in the east north-central and northeast. Other large subareas extend across parts of: Buffalo, Hall, Howard, and Merrick Counties; Seward, Butler, and Saunders Counties; and Hamilton, Polk, and York Counties. The western Sand Hills and the southern Panhandle also experienced groundwater level rises under large areas, but these rises were generally less than five feet. Groundwater levels rose in parts of Scotts Bluff County where surface water irrigation canals are located, but precipitation was less than normal in this area.

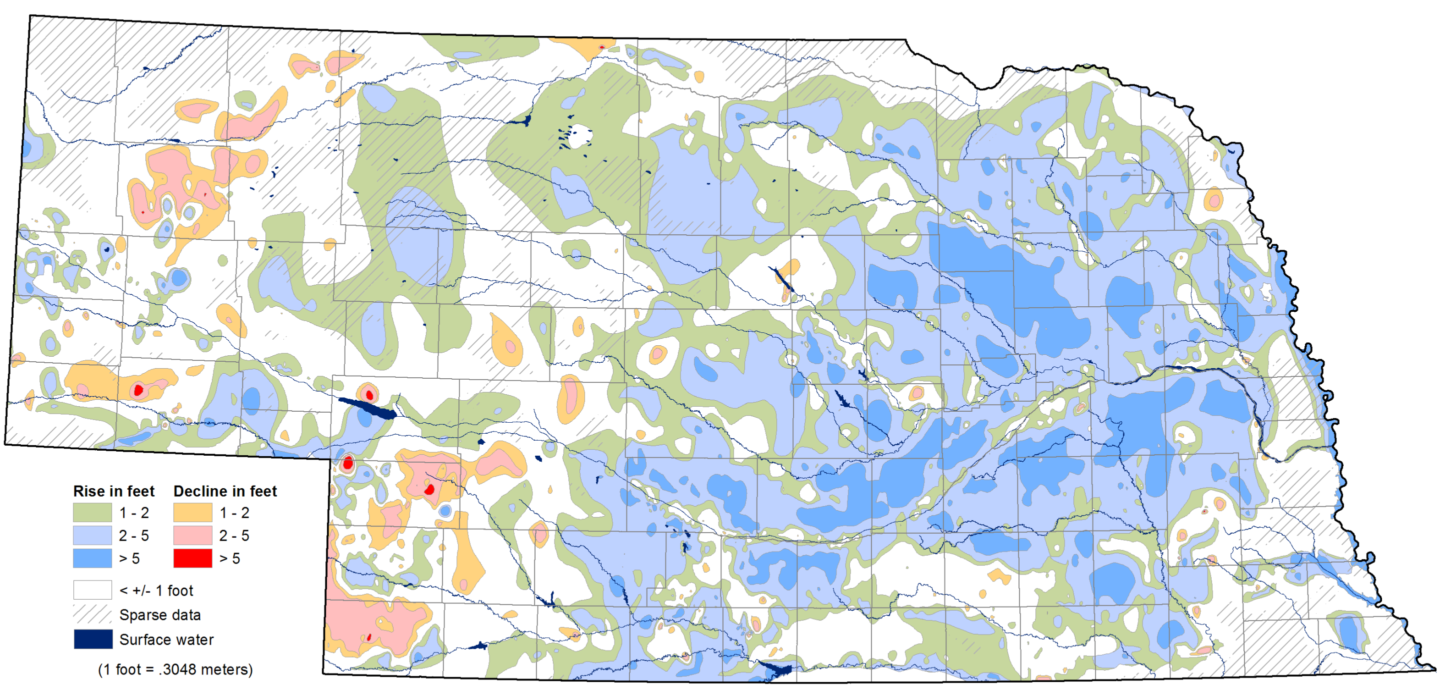
Groundwater level declines from 2007 to 2010 occurred in the Panhandle and the southwest (Fig. 8). Areas under which declines from 2-5 feet occurred were in western Chase County and most of Dundy County, parts of Perkins, Lincoln, and Keith Counties, parts of Cheyenne and Kimball Counties, as well as parts of Box Butte, Dawes, and Sheridan Counties. Precipitation was less than normal in the western Panhandle. Groundwater levels continued to decline in the southwest despite this area receiving 110-140 percent of the normal precipitation for the period (Fig. 7).

Figure 7. Percent of Normal Precipitation - January 2007 to January 2010



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

Figure 8. Groundwater-Level Changes in Nebraska - Spring 2007 to Spring 2010



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.

CHANGES IN GROUNDWATER LEVELS, SPRING 2000 TO SPRING 2010

Groundwater levels remain below pre-drought levels throughout most of the State, but some groundwater-level rises are occurring in the central and northeast.

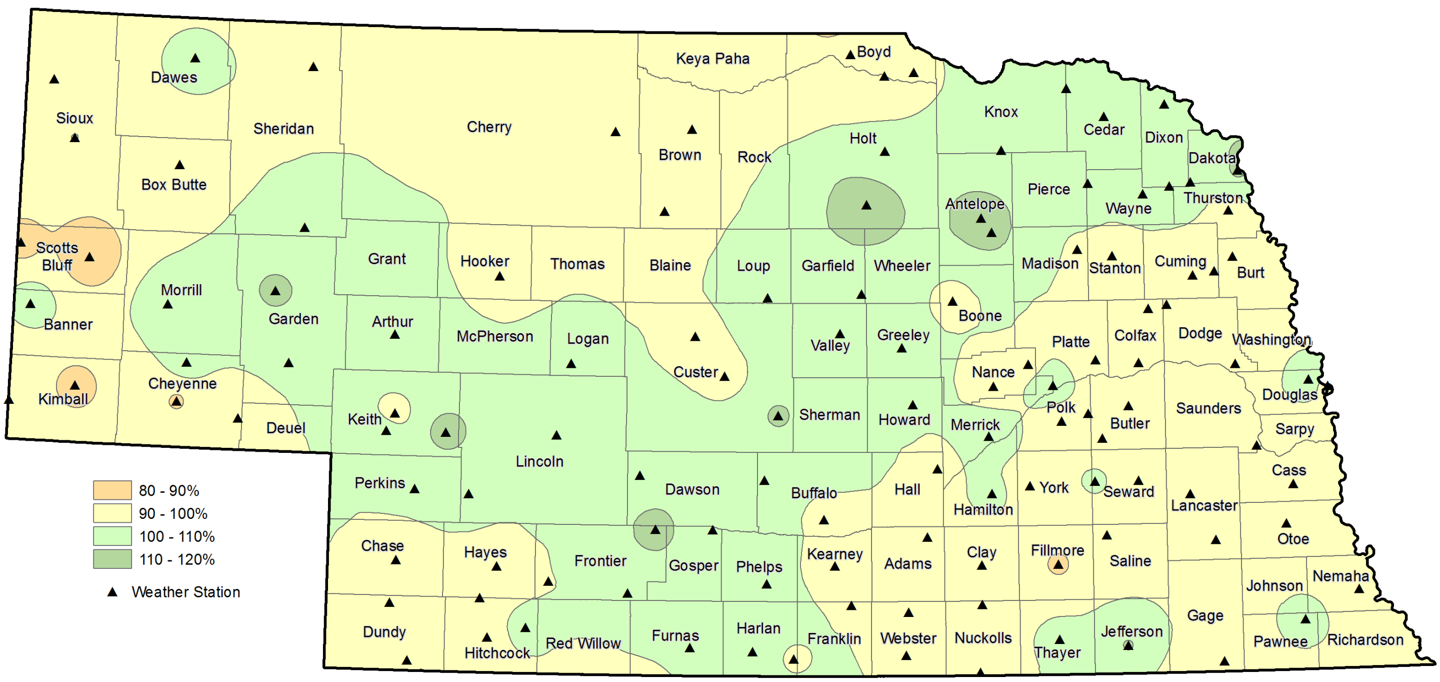
Nebraska experienced a widespread multi-year drought during the first part of the 2000 to 2010 decade. Precipitation across much of the eastern part of the State attained near-normal or above-normal levels beginning in 2007 (Fig. 9). Near-normal or above-normal conditions were attained in the western part of the State beginning in 2009. During 2000-2010 overall, precipitation was near the 30-year average for much of the State, with precipitation slightly above the 30-year average from the central to northeast part of the State to slightly below the 30-year average in parts of the Panhandle.

There was little change in groundwater levels across Nebraska during 2000-2010 in those areas that have little or no irrigated agriculture, with the exception of areas in the northeast (Fig. 10). Spring 2010 groundwater levels rose above spring 2000 levels in the areas of Holt, Antelope, Boone, Cedar, Knox, Madison, Pierce, Wayne and Wheeler Counties in the northeast, Howard, Sherman, and Valley Counties in the central, and Saunders County in the east. Groundwater-level rises were between 1 and 5 feet, although a few areas in Antelope, Boone, Madison and Valley Counties exhibited rises in excess of 5 feet. Spring 2010 groundwater levels were also higher than spring 2000 levels under large parts of the Central Platte River Valley, northeast Frontier County, Central Gosper County, and under the Republican River Valley east of Harlan County.

Groundwater level declines for the decade were most pronounced in areas of irrigated agriculture. Widespread areas showing 10 or more feet of decline appeared in the southwest, south-central, the Panhandle, and the north-central (Fig. 10).

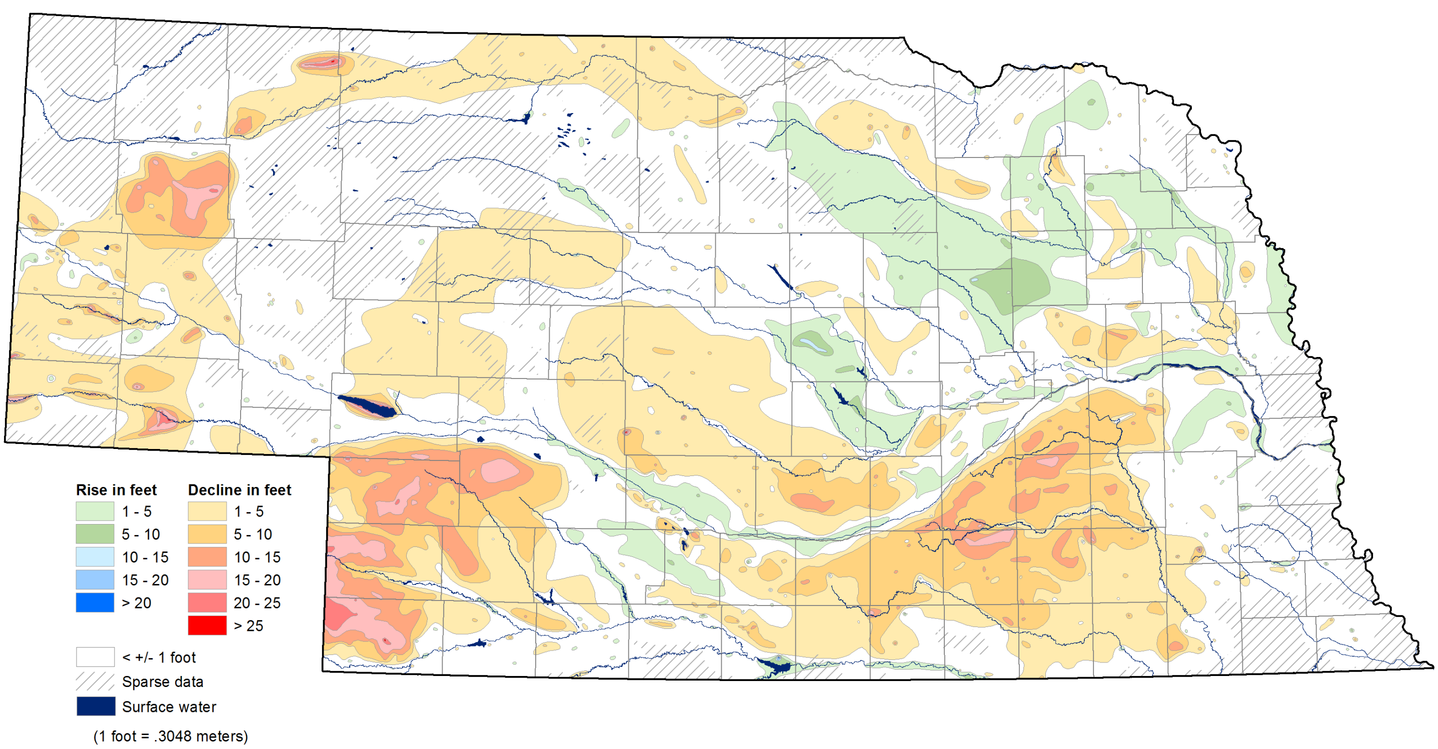
Declines in the southwest were most severe in Chase, Dundy, Lincoln, and Perkins Counties. Declines in the Panhandle were most severe in Cheyenne County near Sidney, in Box Butte County, and in Sheridan County near Gordon (Fig. 10). The largest declines in the east north-central were northwest of O'Neill in Holt County. In the east south-central the largest declines occurred in Hamilton, Polk, York, northern Clay, and northeastern Fillmore Counties. Southwestern Gage County experienced the largest declines in the southeast, and declines in the central were greatest in Buffalo County and small portions of Custer, Dawson, and Hall Counties.

Figure 9. Percent of Normal Precipitation - January 2000 to January 2010



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

Figure 10. Groundwater-Level Changes in Nebraska - Spring 2000 to Spring 2010



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.

CHANGES IN GROUNDWATER LEVELS, PREDEVELOPMENT TO SPRING 2010

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 2010 groundwater levels continue to indicate long-term declines and rises in certain areas of Nebraska. Areas of significant groundwater level declines generally correspond to areas of dense irrigation well development (Fig. 11). The largest groundwater-level declines from predevelopment to spring 2010 occurred in the southwest and in the Panhandle (Fig. 12). The largest rises occurred in the central and west south-central.

The predevelopment groundwater levels used in the southwest 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 in Chase, Dundy, and Perkins Counties. The area of decline extends into portions of Keith, Lincoln, and Hayes Counties (Fig. 12). Declines of as much as 70 feet have occurred since predevelopment times in Chase County.

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.

A large portion of east south-central Nebraska has experienced long-term groundwater-level declines since predevelopment times (Fig. 12). Predevelopment water levels in this area are generally representative of the approximate average water levels prior to 1950. Groundwater levels in large parts of Adams, Clay, Fillmore, Nuckolls, Thayer, and Webster Counties have declined more than 10 feet, and in some areas nearly 30 feet, from predevelopment. Areas of Butler, Hamilton, Polk, Seward, and York have declined at least 5 feet from predevelopment. The areal extent and magnitude of the groundwater-level declines have been reduced slightly due to recent above-average precipitation. The most notable improvement was in northeastern Clay County where much of the area that was previously 5 to 10 feet below predevelopment is now less than 5 feet below. The declines in Butler, Colfax, Hamilton, Polk, Seward, and York are much less severe than in recent years.

Parts of other counties that experienced relatively large areas of decline include Buffalo, Custer, and Dawson in the central; Harlan and Franklin in the south-central; Hitchcock, Frontier, and Red Willow in the southwest; Banner, Kimball, Morrill, Cheyenne, and Sheridan in the panhandle; and Holt in the north-central (Fig. 12). Many of these areas occur in areas of intense groundwater irrigation, but in a few areas, wells are not particularly dense. Other factors such as aquifer characteristics, rates of recharge, and irrigation scheduling could be contributing to the declines.

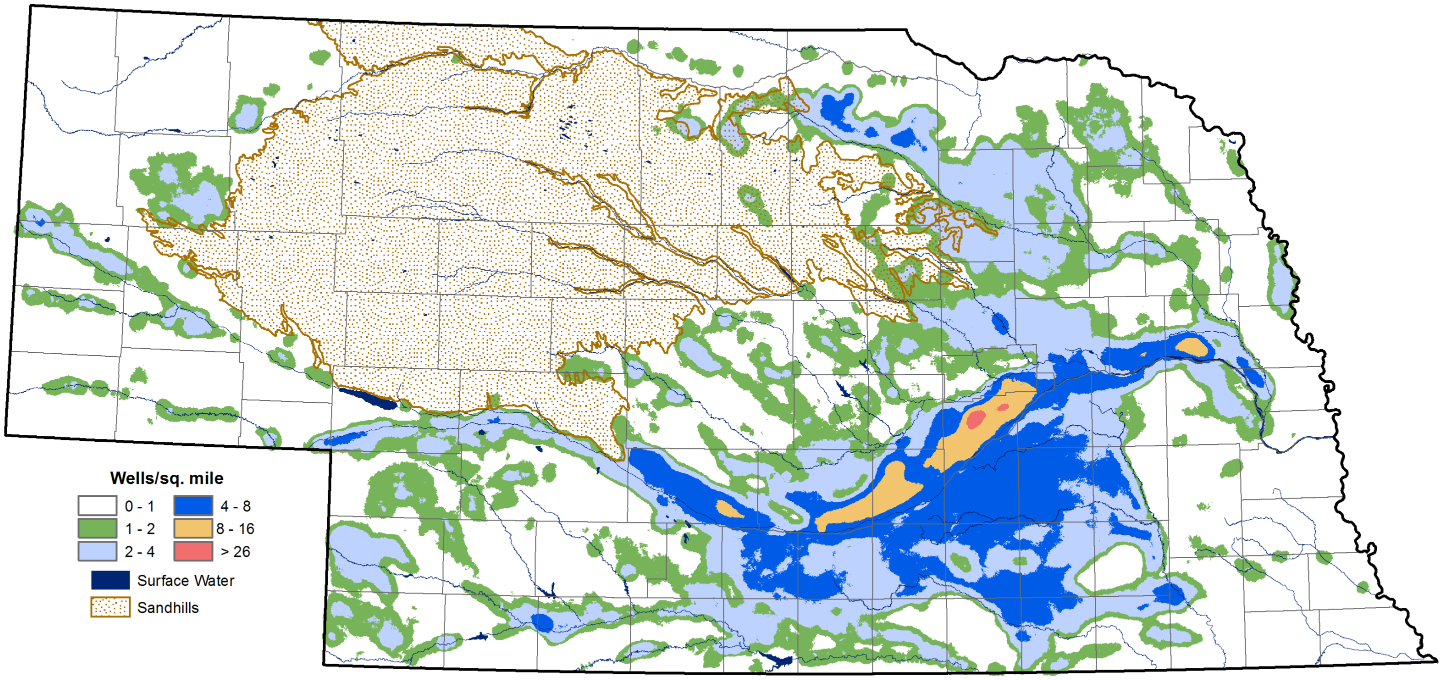
Groundwater-level rises from predevelopment generally occurred in areas of surface irrigation systems. Storage of water in Lake McConaughy began in 1941, and seepage losses caused water-level rises of as much as 60 feet in nearby observation wells (Ellis and Dreeszen, 1989). Water levels generally stabilized by about 1950 and since then have fluctuated in response to changes in reservoir levels and precipitation (Johnson and Pederson, 1984).

Water released from storage in Lake McConaughy and subsequently diverted from the Platte River near North Platte has been used for irrigation, primarily in Gosper, Kearney, and Phelps counties, since 1941. Deep percolation of water from these irrigation-distribution systems and from excess water applied to crops has raised water levels 10 to 50 feet or greater from predevelopment levels in an area extending from south-central Keith County in the west to central Kearney County in the east (Fig. 12). Rises in Gosper, Phelps, and Kearney Counties exceed 50 feet, and in some areas are as much as 136 feet. Rises of as much as 60 feet in southern Sioux and northern Scottsbluff Counties are also associated with irrigation canal systems.

Water-level rises of 5 to 30 feet have occurred south of the South Platte and Platte rivers in Keith, Lincoln, and Dawson counties (Fig. 12). Seepage from Sutherland Reservoir, Lake Maloney, and their associated canals caused water levels to start rising south and west of North Platte in about 1935. East of North Platte, water levels began rising after 1940 as a result of seepage from the Tri-County Supply Canal and Jeffrey Reservoir.

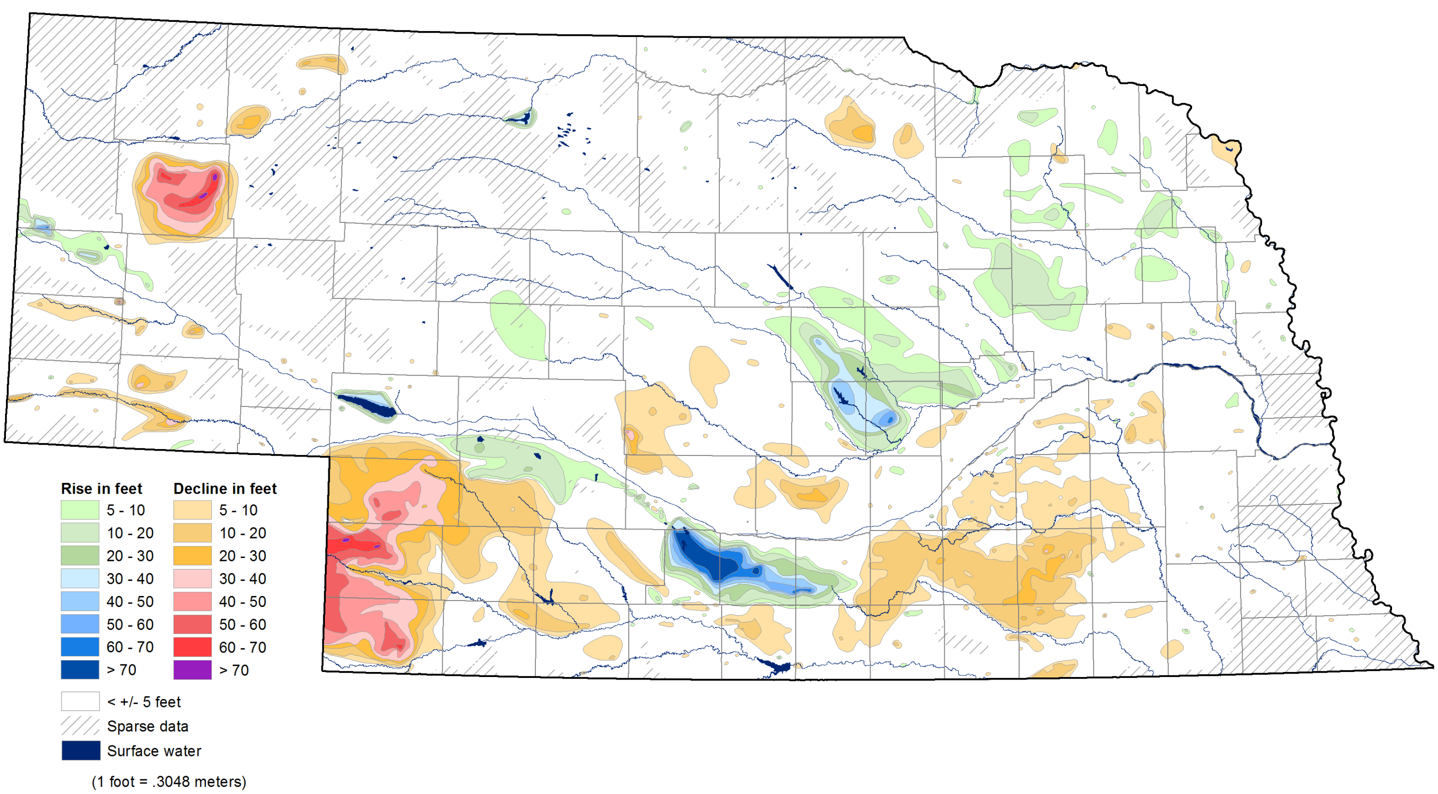
Rises of 10 to more than 60 feet occurred in portions of Greeley, Howard, Sherman, Valley, and Nance Counties (Fig. 12). The water-level rises in this area are the result of seepage from irrigation canals, seepage from Sherman and Davis Creek Reservoirs, and deep percolation of irrigation water applied to crops.

Figure 11. Density of Active Registered Irrigation Wells - January 2011



Source: Nebraska Department of Natural Resources.

Figure 12. Groundwater-Level Changes in Nebraska - Predevelopment to Spring 2010



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.

AVERAGE DAILY STREAMFLOWS, 2009

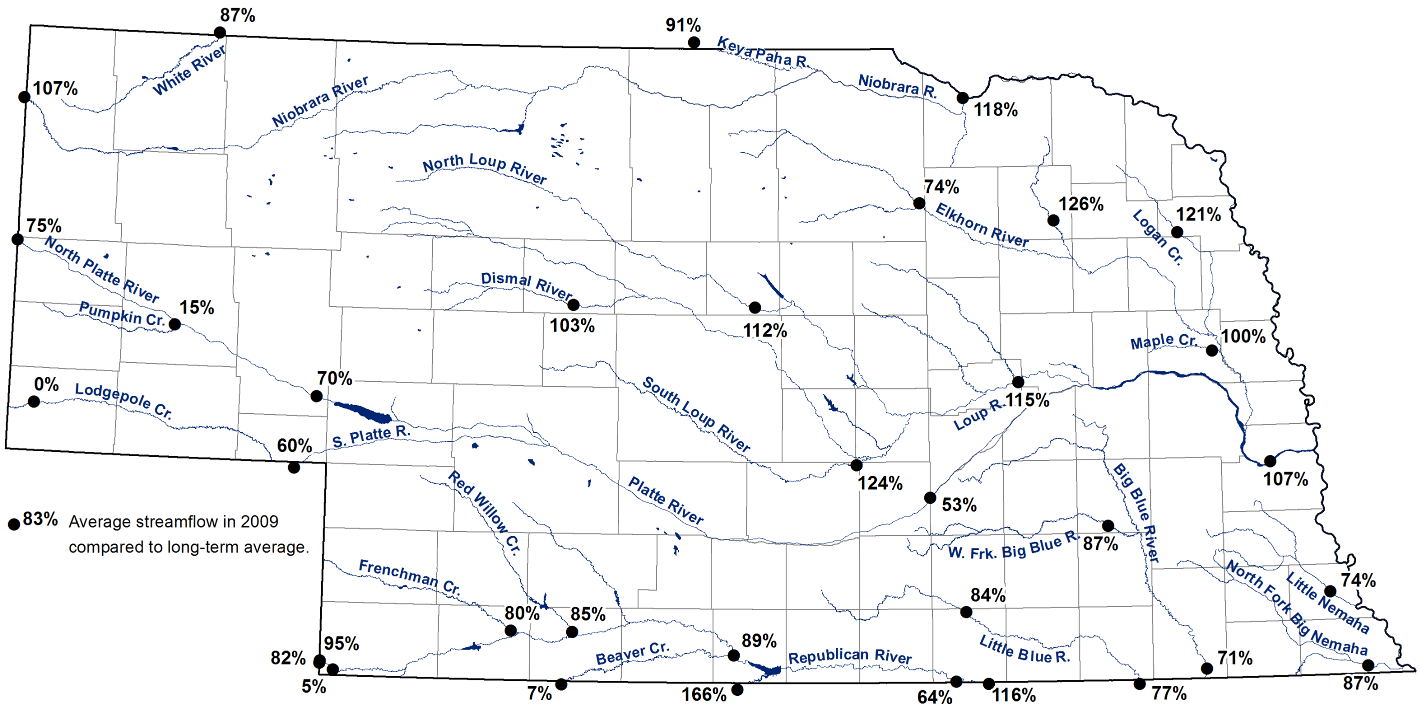
Streamflows in 2009 varied from 0% to more than 160% of the long-term average, reflecting regional trends in precipitation and long-term effects on baseflow.

The flows in Nebraska streams have several different sources. Snowmelt in the Rocky Mountains west of Nebraska 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 sandhills 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 highly variable across the state in water year 2009 (Fig. 13). Flows were above average in central and parts of northeastern Nebraska due to above-average precipitation. In parts of western, southern, and southeastern Nebraska, where precipitation was near or below average, flows were below the long-term average. The low flows in some streams in the Panhandle and the southwest are part of a regional trend in the High Plains Aquifer of long term reductions in baseflow to streams due to lowering of the regional water table (Sophocleous, 1998).

The factors affecting streamflows are numerous and complex. Nonetheless, it is commonly known that in areas where streams are well-connected to aquifers, groundwater-level changes can have an effect on baseflows. Continued monitoring of groundwater-level changes throughout Nebraska is necessary in order to evaluate and manage these interconnected resources.

Figure 13. Average Streamflow in Water Year 2009, as a Percentage of the 30-Year Average



Sources: U.S. Geological Survey; Nebraska Department of Natural Resources.

REFERENCES

Alley, W.M., and S.A. Leake, 2004. The journey from safe yield to sustainability. Ground Water, v. 42, p. 12-16.

Bredehoft, J.D., 1997. Safe yield and the water budget myth. Ground Water, v. 35, p. 929.

Carlson, M.P., and Sibray, S.S., 1992. Older groundwater reservoirs in Nebraska. University of Nebraska-Lincoln Conservation and Survey Division, Open-file report 75, 22 p.

Condra, G.E., and Reed, E.C., 1959. The geological section of Nebraska. University of Nebraska-Lincoln Conservation and Survey Division, Geological Survey Bulletin 14A, 82 p.

Diffendal, R. F., Jr., 1982. Regional implications of the geology of the Ogallala Group (upper Tertiary) of southwestern Morrill County, Nebraska, and adjacent areas. Geological Society of America Bulletin, v. 93, p. 964-976.

Ellis, M.J., and Dreeszen, V.H., 1987. Groundwater levels in Nebraska, 1986. University of Nebraska-Lincoln, Conservation and Survey Division, Nebraska Water Survey Paper Number 62, 68 p.

Evans, J.E., Terry Jr, D.O., 1994. The significance of incision and fluvial sedimentation in the basal White River Group (Eocene-Oligocene), Badlands of South Dakota, USA. Sedimentary Geology v. 90, p. 137-152.

Johnson, M.S., and Pederson, D.T., 1984. Groundwater levels in Nebraska, 1983. University of Nebraska-Lincoln, Conservation and Survey Division, Nebraska Water Survey Paper Number 57, 67 p.

Korus, J.T., and Burbach, M.E., 2009, Analysis of aquifer depletion criteria with implications for groundwater management: Great Plains Research, v. 19, p. 187-200.

Lawton, D.R., Goodenkauf, O.L., Hanson, B.V., and Smith, F.A., 1984. Dakota aquifers in eastern Nebraska: Aspects of water quality and use, In: Jorgensen, D.G. and Signor, D.C., Geohydrology of the Dakota Aquifer, Proceedings of the C.V. Theis Conference on Geohydrology. National Water Well Association, Worthington, Ohio, p. 221-228.

Maimone, M. 2004. Defining and managing sustainable yield. Ground Water, v. 42, p. 809-814.

Miller, J.A., and Appel, C.L., 1997. Ground water atlas of the United States. Kansas, Missouri, and Nebraska. U.S. Geological Survey Hydrologic Atlas HA 730-D [URL http://pubs.usgs. gov/ha/ha730/ch_d/D-text7.html].

Prior, J.C., Boekhoff, J.L., Howes, M.R., Libra, R.D., and VanDorpe, P.E., 2003. Iowa's groundwater basics. Iowa Geological Survey Educational Series 6, 83 p.

Sophocleous, M.A., 1997. Managing water resources systems: Why "safe yield" is not sustainable. Ground Water, v. 35, p. 561.

Sophocleous, M.A., 1998. On the elusive concept of safe yield and the response of interconnected stream-aquifer systems to development, In: Sophocleous, M.A., ed., Perspectives on Sustainable Development of Water Resources in Kansas, p. 6-85. Kansas Geological Survey Bulletin 239. KGS, Lawrence, KS.

Sophocleous, M.A., 2000. From safe yield to sustainable development of water resources–the Kansas experience. Journal of Hydrology, v. 235, p. 27-43.

Souders, V.L., 1976. Physiography, geology, and water resources of Boyd County, Nebraska. University of Nebraska-Lincoln Conservation and Survey Division, Nebraska Water Survey Paper Number 42, 113 p.

Stanley, K.O., and Wayne, W.J., 1972. Epiorogenic and climatic controls of early Pleistocene fluvial sediment dispersal in Nebraska. Geological Society of America Bulletin, v. 83, p. 3675-3690.

Groundwater-Level Changes in Nebraska Map Series
Available on-line at http://snr.unl.edu/data/water/groundwatermaps.asp

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
1955	U.S.G.S. Open-File Rpt. 56-70	Keech, C.F., 1956
1956	U.S.G.S. Open-File Rpt. 57-61	Keech, C.F., 1957
1957	Nebraska Water Survey Paper 4*	Keech, C.F., 1958
1958	Nebraska Water Survey Paper 5*	Keech, C.F., 1959
1959	Nebraska Water Survey Paper 6	Keech, C.F., 1960
1960	Nebraska Water Survey Paper 9	Keech, C.F., 1961
1961	Nebraska Water Survey Paper 12	Keech, C.F.; Hyland, J.B., 1962
1962	Nebraska Water Survey Paper 13	Emery, P.A.; Malhoit, M.M., 1963
1963	Nebraska Water Survey Paper 14	Emery, P.A.; Malhoit, M.M., 1964
1964	Nebraska Water Survey Paper 17	Emery, P.A.; Malhoit, M.M., 1965
1965	Nebraska Water Survey Paper 18	Emery, P.A.; Malhoit, M.M., 1966
1966	Nebraska Water Survey Paper 20*	Keech, C.F., 1967
1967	Nebraska Water Survey Paper 23	Keech, C.F., 1968
1968	Nebraska Water Survey Paper 24*	Keech, C.F.; Svoboda, G.R., 1969
1969	Nebraska Water Survey Paper 26*	Keech, C.F., 1970
1970	Nebraska Water Survey Paper 28*	Keech, C.F., 1971
1971	Nebraska Water Survey Paper 33	Keech, C.F., 1972
1972	Nebraska Water Survey Paper 34	Ellis, M.J., 1973
1973	Nebraska Water Survey Paper 36	Ellis, M.J., 1974
1974	Nebraska Water Survey Paper 40*	Ellis, M.J., 1975
1975	Nebraska Water Survey Paper 43*	Ellis, M.J.; Pederson, D.T., 1976
1976	Nebraska Water Survey Paper 44	Ellis, M.J.; Pederson, D.T. 1977
1977	Nebraska Water Survey Paper 45	Ellis, M.J.; Pederson, D.T., 1978
1978	Nebraska Water Survey Paper 49	Pederson, D.T.; Johnson, M.S., 1979
1979	Nebraska Water Survey Paper 50*	Johnson, M.S.; Pederson, D.T., 1980
1980	Nebraska Water Survey Paper 51	Johnson, M.S.; Pederson, D.T., 1981
1981	Nebraska Water Survey Paper 52	Johnson, M.S.; Pederson, D.T., 1982
1982	Nebraska Water Survey Paper 56	Johnson, M.S.; Pederson, D.T., 1983
1983	Nebraska Water Survey Paper 57	Johnson, M.S.; Pederson, D.T., 1984
1984	Nebraska Water Survey Paper 59	Ellis, M.J.; Pederson, D.T., 1985
1985	Nebraska Water Survey Paper 61	Ellis, M.J.; Pederson, D.T., 1986
1986	Nebraska Water Survey Paper 62	Ellis, M.J.; Dreeszen, V.H., 1987
1987	Nebraska Water Survey Paper 65	Ellis, M.J.; Wigley, P.B, 1988
1988	Nebraska Water Survey Paper 66	Ellis, M.J.; Steele, G.V.; Wigley, P.B., 1989
1989	Nebraska Water Survey Paper 67	Ellis, M.J.; Steele, G.V.; Wigley, P.B., 1990
1990	Nebraska Water Survey Paper 69	Steele, G.V.; Wigley, P.B., 1991
1991	Nebraska Water Survey Paper 71	Steele, G.V.; Wigley, P.B., 1992
1992	Nebraska Water Survey Paper 72	Steele. G.V.; Wigley, P.B., 1994
1994	Nebraska Water Survey Paper 74	Chen, A.H.; Wigley, P.B., 1996
1996	Nebraska Water Survey Paper 75	Chen, A.H.; Khisty, M.J., 1999
2009	Nebraska Water Survey Paper 76	Korus, J.T.; Burbach, M.E. 2009

*** Out of print, but available for study at the address below**

Nebraska Maps and More
101 Hardin Hall
3310 Holdrege Street
University of Nebraska–Lincoln
Lincoln, Nebraska 68583-0961

Voice 402-472-3471
Fax 402-472-2946
Email: snrsales@unl.edu
Website: snr.unl.edu

Conservation and Survey Division
School of Natural Resources
Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln

ISBN 1-56161-014-3
ISBN-13 978-1-56161-014-3