# Nebraska Statewide Groundwater-Level Monitoring Report

# 2019

**Aaron R. Young, Mark E. Burbach, Leslie M. Howard,**
**Susan Olafsen Lackey and R.M. Joeckel**

Conservation and Survey Division
School of Natural Resources

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**Nebraska Water Survey Paper Number 87**

Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln

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The Conservation and Survey Division 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 Division is authorized to enter into agreements with federal and state agencies to engage in cooperative surveys and investigations of the State. Publications of the Division 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 Conservation and Survey Division web site is: http://snr.unl.edu/csd/.




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# FOREWORD

## Nebraska Water Issues of Interest

*R.M. Joeckel, Nebraska State Geologist and Director of the Conservation and Survey Division; Senior Associate Director, School of Natural Resources*

**Nebraska's Groundwater: A Resource Worthy of Respect**

The term "groundwater" has come to be all but synonymous with Nebraska. Nearly three-quarters of the total volume of the High Plains Aquifer lies beneath the State. Groundwater maintains our streams, our ecosystems, our people, and our vitally important agricultural economy. Nebraska's total groundwater resource is vast, yet it is also vulnerable to natural and anthropogenic changes, necessitating a long-term commitment to wise management through informed decision making. Monitoring, studying, and reporting form the essential basis for such management and, ultimately, for meeting the myriad challenges presented by change.

The personnel of the Conservation and Survey Division (CSD) are proud to support wise groundwater management through the issuance of this report, a yearly continuation of a long-running series of water-resources reports and maps published by CSD. The information provided herein should be used to inform, educate, and guide the citizens of Nebraska regarding water resources. All Nebraskans need clean, abundant and accessible water to sustain our economy and way of life. Therefore, we must all partner in management as informed citizens.

**Developments in Water in Nebraska in 2019**

***Surface water***

Exceptional flooding dominated water news in Nebraska in 2019. Four-fifths of Nebraska's counties and scores of cities and towns declared emergencies in response. March 2019 flooding on the Elkhorn, Missouri, Niobrara, and Platte rivers damaged highways, roads, bridges, dikes, and levees. In addition, thousands of homes and hundreds of businesses were damaged, and hundreds of millions of dollars in cattle and crop losses were incurred by Nebraskans. March flooding was projected to cost more than $1.3 billion. Later, in early July 2019, sudden and exceptional rainfall led to historic flooding in central Nebraska on the Platte River and also along the Blue and Wood rivers. By mid-January 2020, Nebraska Governor Pete Ricketts had proposed that almost $60 million in state aid for flood recovery (Schulte, 2020), and Federal Emergency Management Agency funding was continuing to come to Nebraska at the time of the writing of this report in February 2020. The collapse of a tunnel and subsequent washout along the Goshen (Wyoming)/Gering−Fort Laramie Canal, possibly related to soil saturation above the tunnel, disrupted irrigation-water supply to 55,000 acres in Nebraska from July 17 to August 28, 2019.

***Groundwater, water-supply, and environmental issues***

Flooding also caused significant problems with respect to domestic and municipal wells, sewage disposal, and water supply infrastructure (e.g., Associated Press, 2019a; Bergman, 2019; KMTV Staff, 2019). Part of the Lincoln's well field along the Platte River had to be fortified as flood waters rose on March 17 (Anderson, 2019). On the following day, Lincoln residents were told to cut usage in half when the water-supply system temporarily lost pressure (Associated Press, 2019b). Many domestic wells in the Fremont area tested positive for contaminants such as *Escherichia coli (E. coli)* after the March floods (Waldman, 2019). Flood-related well-contamination risk across the Midwestern USA was projected to affect as many as one million private wells (Associated Press, 2019c). The Nebraska Department of Health and Human Services (DHHS) and Department of Environmental Quality (DEQ), working in part with the U. S. Environmental Protection Agency (EPA), made free testing of private water supplies available in Ashland, Columbus, Fremont, O'Neill, West Point, and Wisner into early April (Bucco-White, 2019; Meadows, 2019). Local rises of the water table were considered a physical hazard on alluvial land even after July floodwaters around Kearney had receded (Gaarder, 2019). The Central Platte Natural Resources District announced that, according to their analysis, average spring groundwater rose slightly more than two feet relative to 1982 levels, largely because of rains during the 2018 irrigation season and high spring rainfall in 2019 (Anonymous, 2019a). The city of Plattsmouth may be without a waste treatment plant until June, 2020 (WOWT, 2019).

The U. S. Department of Agriculture (USDA) awarded Beaver City more than $2.4 million in grants and loans to upgrade its water infrastructure and install a new well after long-term concerns about health and sanitary issues, including arsenic (KGHI, 2019). USDA also provided more than $1.3 million for improvements in Rural Water District No. 2 in Richardson County (Schurman, 2019). Higher-than-acceptable natural arsenic, manganese, and iron concentrations in well-derived municipal water at Mead will lead to the construction of the village's first water treatment plant in 2020 (Nelson, 2019). In August 2019, after ongoing investigations, the municipal water supply of West Point was reported to have manganese levels more than three times the maximum safe concentration and residents were told to consume bottled water only (Anonymous, 2019b). UN-L scientists continued a program measuring nitrate, nitrite, and phosphate concentrations in well water using citizen scientists (Gayman, 2019). The U. S. Army Corps of Engineers appointed a new manager for the Nebraska Ordnance Plant cleanup site south of Mead, where groundwater continues to be treated for the contaminants TCE and RDX (Brichacek, 2019). An article published in 2019 (Pedati, et al. 2019) summarized an investigation that found a significant association between the human consumption of municipal-well-derived tap water and 39 cases of *Campylobacter jejuni* infections in southwestern Nebraska, ostensibly related to livestock wastewater.

### *Legislation*

EPA's Scientific Advisory Board posted reports near the end of 2019 indicating concerns over the Trump Administration's actual and proposed rollbacks of certain water-related federal regulations (Eilperin, 2019). Nevertheless, as anticipated, some federal protections of streams and wetlands under the Clean Water Act were removed very early in 2020 (Wallace et al., 2020). Also at the end of the year, the Secretary of the Interior signed an amendment to the Platte River Recovery Implementation Program Cooperative Agreement, thereby extending it through 2032 (Anonymous, 2019c). By the end of September 2019, TC Energy filed dozens of lawsuits in Nebraska to obtain right-of-way via eminent domain for the Keystone XL Pipeline extension, which has raised concerns about groundwater safety for many Nebraskans (Hammel, 2019). The Nebraska Department of Environmental Quality and the Nebraska Energy Office merged as the Nebraska Department of Environment and Energy, in accordance with LB302, on July 1, 2019.

## SELECT RECENT GROUNDWATER PUBLICATIONS AND RESOURCES

### Online Resources

**go.unl.edu/groundwater**

***The Nebraska Real-Time Groundwater-Level Network***

The network consists of 58 observation wells. The wells take automated hourly readings, which are updated on the website in real-time.

***Historic Nebraska Statewide Groundwater-Level Monitoring Reports***

Recent reports are available for download. Water-level change maps are available for download beginning with 1954 through the maps included in this report.

***Nebraska GeoCloud***

The Nebraska GeoCloud (NGC) is an internet platform for storing, integrating, and sharing Nebraska's hydrogeological data. The NGC stores multiple databases that house airborne electromagnetic (AEM) surveys, images, GIS, test-hole, and other hydrogeological data. These data can all be combined through GeoScene3D to produce virtual models, mapping, and data exploration. More information can be found at: http://snr.unl.edu/csd/geology/nebraskageocloud.aspx

**The Groundwater Atlas of Red Willow County, Nebraska**

Divine, D.P. and Eversoll, D.A., 2018. Conservation and Survey Division, University of Nebraska, Resource Atlas 11, 35 p.

**Streambed flux measurement informed by distributed temperature sensing leads to a significantly different characterization of groundwater discharge.**

Gilmore, T.E., Johnson, M., Korus, J.T., Mittelstet, A., Briggs, M.A., and Zlotnik, V., 2019. Water 11, 2312, https://doi.org/10.3390/w11112312

### Other Online Resources

***Nebraska Natural Resources Districts:***

http://nrdnet.org/find-your-nrd.php

***United States Geologic Survey, Nebraska Water Science Center:***

http://ne.water.usgs.gov

# INTRODUCTION

*Groundwater-level information is valuable to citizens and stakeholders.*
*It quantifies the availability of groundwater and informs management decisions.*

This report is a 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 1950s. 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 the central role in the statewide groundwater-level monitoring program, other agencies have assumed the responsibilities of building and maintaining observation networks and measuring groundwater-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 Natural Resources Districts (NRDs) (Fig.1), U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and Public Power and Irrigation Districts. 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 provides vital technical expertise to these agencies as they develop and implement groundwater-level monitoring plans. The CSD evaluates the adequacy and accuracy of the groundwater-level data and provides the statewide assessment of groundwater-level changes across 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 identifying 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 groundwater systems.

The need for this essential information only escalates as water-use pressure steadily increases. 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.

### *Purpose and Methods*

The vast majority of groundwater used in Nebraska is pumped from the High Plains Aquifer (HPA), although there are multiple aquifers in the state (Fig. 2, 3). The HPA underlies parts of eight states, including South Dakota, Wyoming, Nebraska, Colorado, Kansas, Oklahoma, Texas, and New Mexico. In total, Nebraska overlies approximately 64,600 $m^2$ of the HPA, or 36% of the total aquifer by area. According to 2009 estimates, Nebraska has approximately 2.040 billion acre-feet of saturated sediments, or 69% of the total volume of the HPA (McGuire et. al., 2012). The saturated thickness in the entire HPA, nearly 1,000 feet, is under the western portion of the Nebraska Sand Hills (c.f. Korus et. al. 2013, pp. 44).

Although Nebraska is fortunate to have such vast supplies of groundwater, any groundwater supply is vulnerable to depletion through overpumping. According to the 2012 US Census of Agriculture, Nebraska leads the nation in irrigated acres with more than 8.3 million acres. Without proper oversight, irrigation pumping on this scale can rapidly deplete aquifers and lead to large-scale economic hardship. Recent news stories from Colorado (e.g., Finley, 2017) and parts of Kansas, Oklahoma, Texas and New Mexico (e.g., James and Reilly, 2015) highlight the need for groundwater conservation efforts. The present report illustrates the changes in groundwater levels in Nebraska at different time scales, resulting from both natural and human influenced changes. This information is important to both state and local lawmakers in assessing the

**Figure 1. Nebraska Natural Resources Districts**

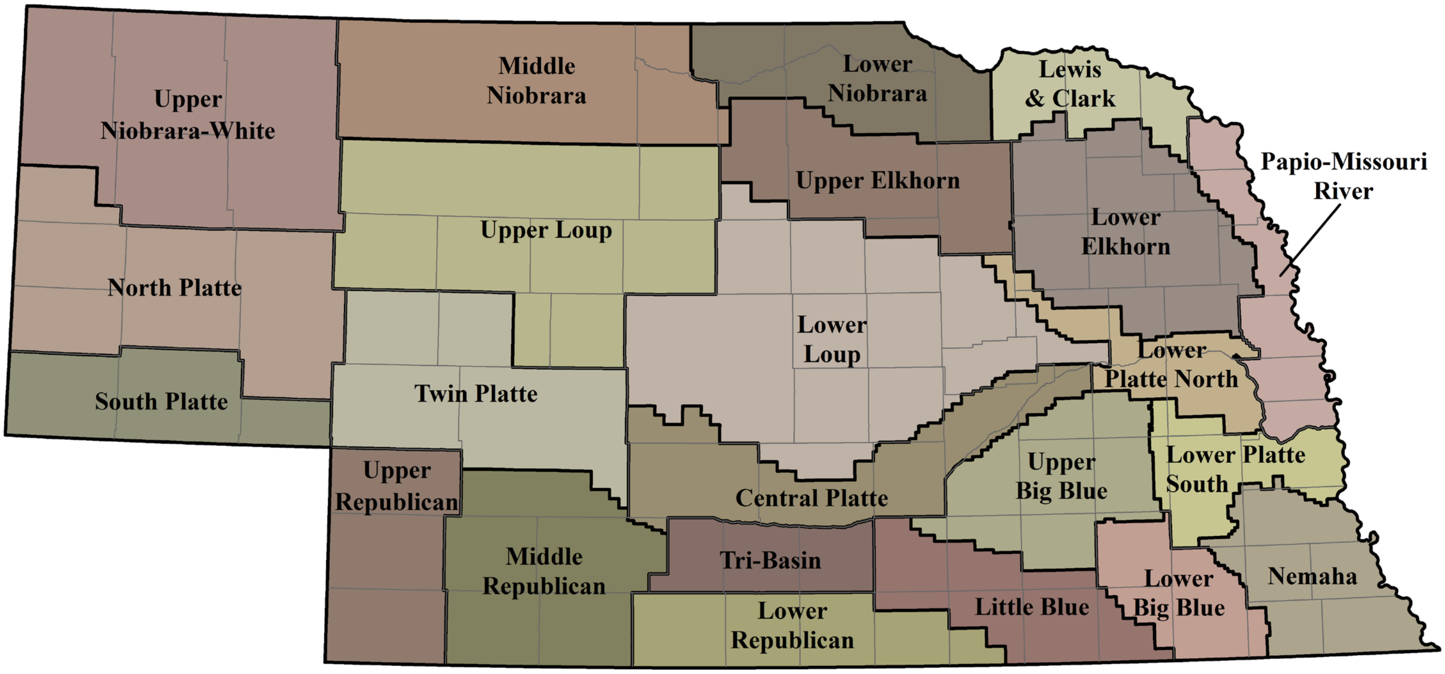
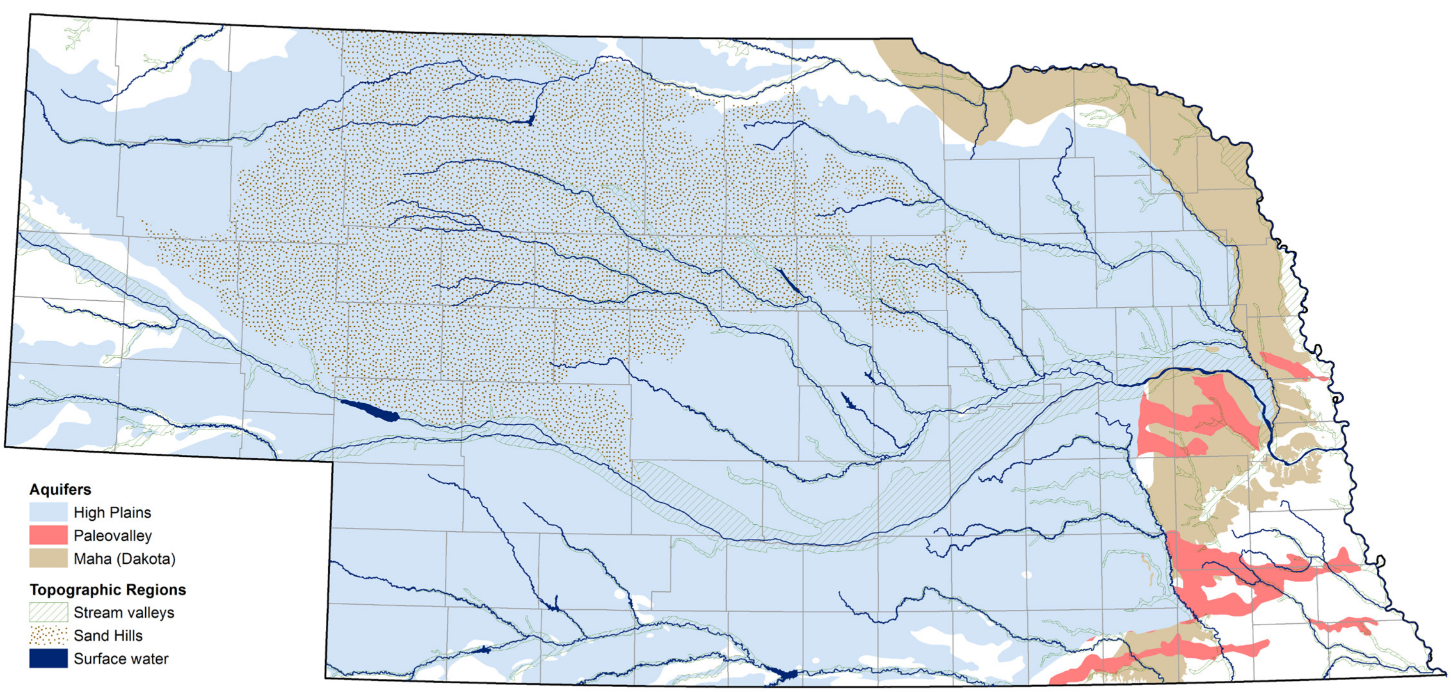



**Figure 2. Important Aquifers and Topographic Regions of Nebraska**




*Note: The aquifer units shown here may contain little or no saturated thickness in some areas.*

## Figure 3. Generalized Geologic and Hydrostratigraphic Framework of Nebraska

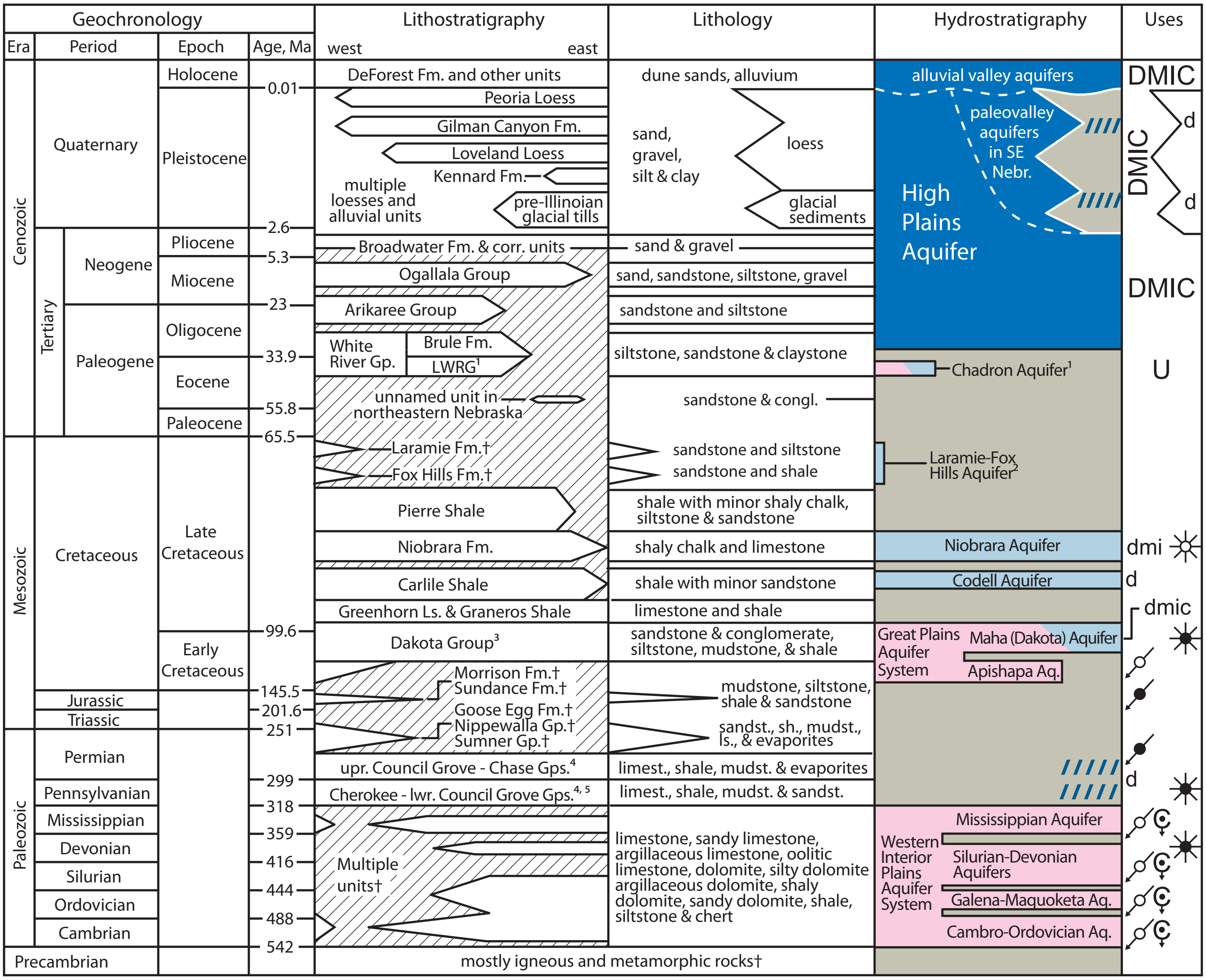



Diagram is not to scale relative to geologic time and stratigraphic thicknesses.

### 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 | I | major irrigation use |
| d | minor domestic use | i | minor irrigation use |
| M | major municipal use | C | major commercial/industrial use |
| m | minor municipal 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*

current state of Nebraska's groundwater resources, and to local producers in making land management decisions.

This report summarizes changes in Nebraska's groundwater levels over periods of one, five, and ten years prior to 2019, as well as from 1981 to 2019, predevelopment to 1981 and predevelopment to 2019. Nineteen eighty-one was selected as a fixed year, as groundwater-level declines in many parts of the state reached a maximum in 1981. These changes are depicted in maps that delineate regional trends on a statewide basis. We stress that the maps presented in this report provide overviews of the general locations, magnitudes, and extents of rises and declines. Local conditions, which may vary considerably, are not depicted in these maps and, indeed, cannot be represented with accuracy. The reader is referred to Figures 1 thru 4 for the locations of NRDs, rivers, aquifers, and counties mentioned in the text.

The one-, five-, and ten-year changes are presented in the spring 2018 to spring 2019, spring 2014 to spring 2019, and spring 2009 to spring 2019 maps, respectively. Groundwater levels measured from thousands of wells throughout the state during the spring of 2019 (Fig. 5) were compared to levels measured in the same wells in the spring of the preceding target year. A spreadsheet of wells used for mapping are available for download at http://snr.unl.edu/data/water/groundwater/gwlevelchangemaps.aspx. For the one-, five-, and ten-year change maps, contours were generated using computer interpolation. These contours were incorporated into the final maps in areas where the principal aquifer is geographically continuous and in relatively good hydraulic connection, and where data density is comparatively high. In areas not meeting these criteria, the computer-generated contours were manually edited on maps at a scale of 1:557,000 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 HPA is separated by deeply entrenched parts of the Niobrara, Republican, and Platte River valleys. For the spring 1981 to spring 2019 map, computer interpolation was impractical because data were sparse in many areas. Accordingly, contours were drawn manually at a scale of 1:500,000 to incorporate the major hydrogeologic boundaries listed above.

For the predevelopment to spring 2019 and predevelopment to spring 1981 maps, groundwater levels from wells measured in 2019 and 1981 were compared to estimated predevelopment groundwater levels in the same wells. An estimated predevelopment groundwater level is the approximate average groundwater level at a well site prior to any development that significantly affects groundwater levels. Predevelopment groundwater levels are generally presumed to be those that predated intensive groundwater irrigation. Such intensive use of groundwater began during the approximate period 1930 to 1960, although not synchronously across the state. Predevelopment map 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 (e.g. Fig. 7). A computer point density interpolation was used to determine the number of observation points within a 6-mile (approximately 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 (www.ncdc.noaa.gov). The 30-year normal currently in use is calculated on the basis of average annual precipitation during 1981-2010. A precipitation surface is generated using the inverse distance weighted interpolation method in ArcGIS with a 1,640 foot (500-meter) cell size. The resulting surface is classified with a defined interval of ten percent and contoured. The resulting contours are smoothed and then converted to polygons.

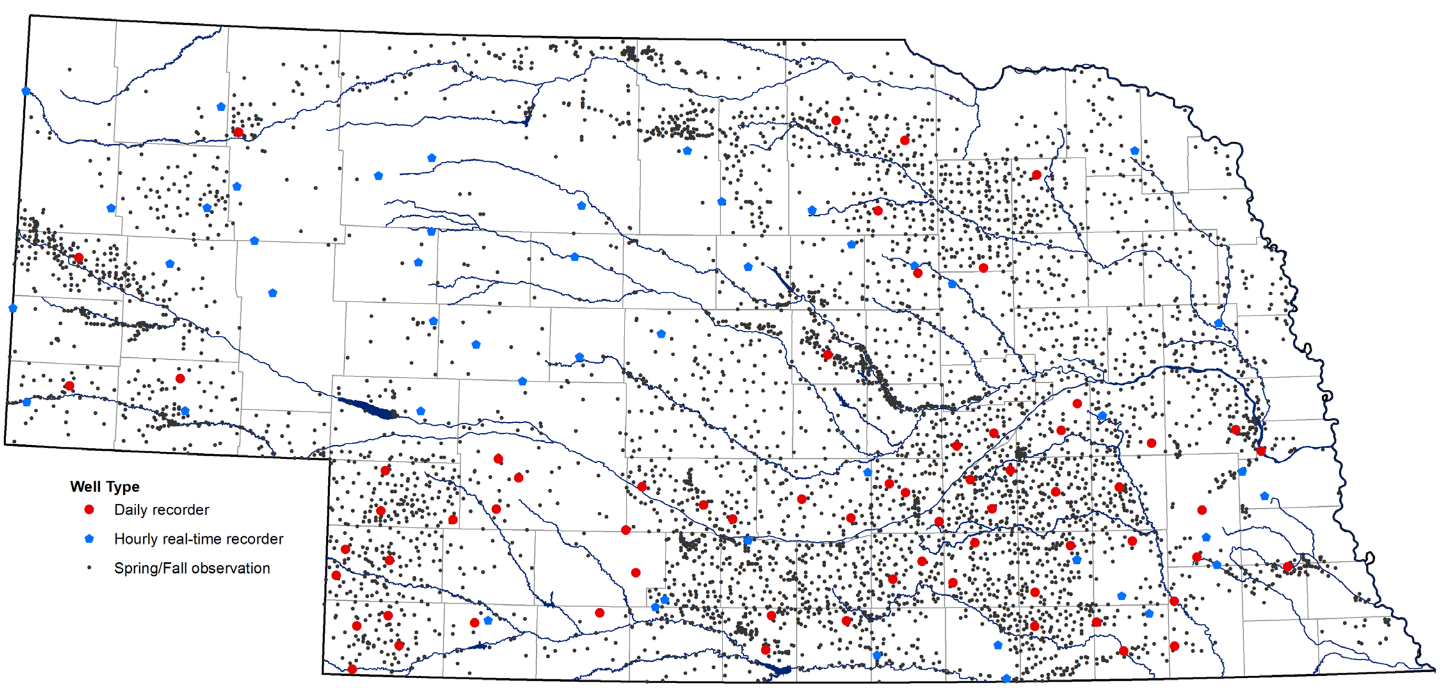
### *Factors Causing Groundwater-Level Changes*

Long-term groundwater-level changes result from 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.

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 concept is a gross

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


## Figure 5. Location of Observation Wells by Type

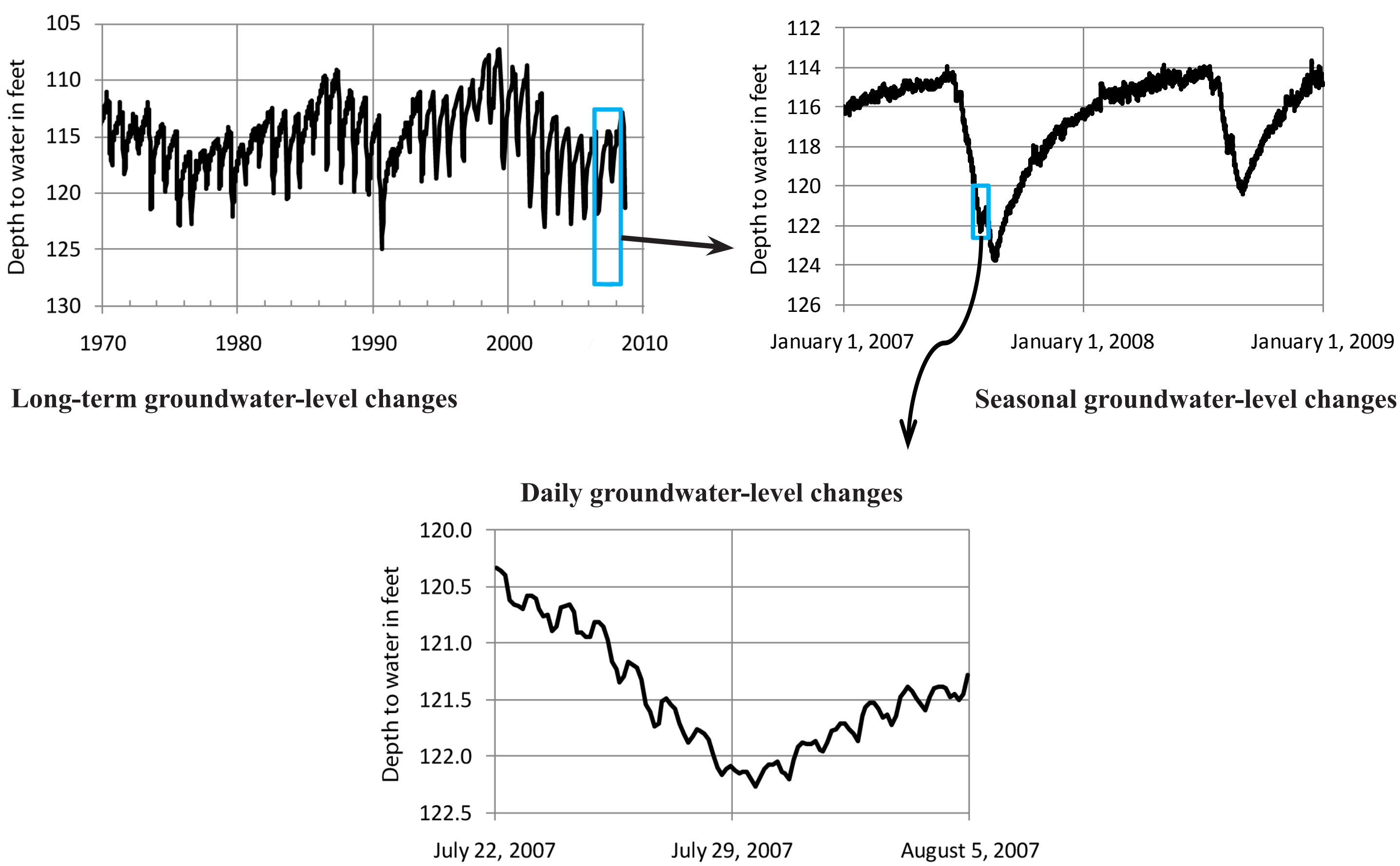



*Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District; Conservation and Survey Division, School of Natural Resources, University of Nebraska–Lincoln* oversimplification of hydrogeologic processes. 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, 1998, 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 1:557,000 or 1:500,000. **They are intended solely to identify regional conditions and trends at varying time scales throughout the entire state of Nebraska, and not at the local scale.** As such, these changes chiefly reflect the interplay between precipitation, groundwater pumping, and artificial recharge from reservoirs and canals.

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




*Data from Plymouth Recorder well, Jefferson County*

## CHANGES IN GROUNDWATER LEVELS, SPRING 2018 TO SPRING 2019

*From the spring of 2018 to the spring of 2019, groundwater levels in Nebraska recorded an averaged rise of 1.30 feet.*

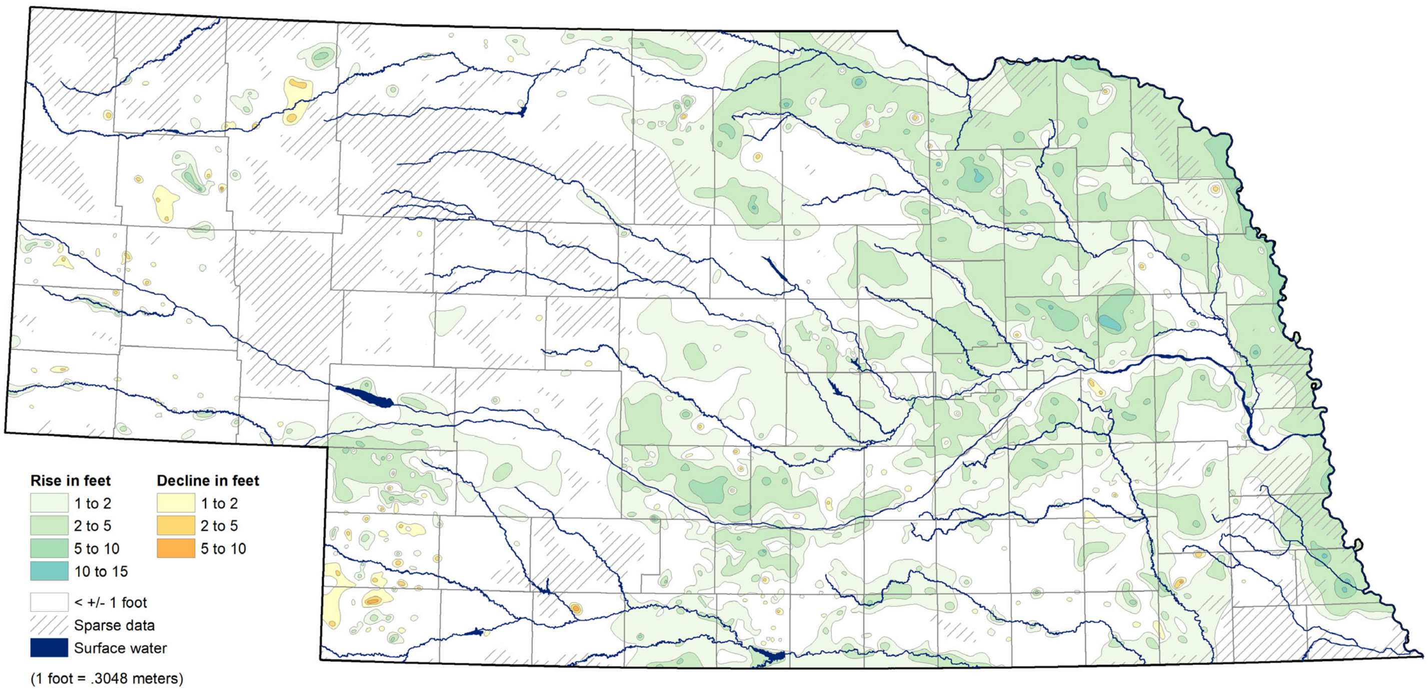
Groundwater levels in Nebraska generally rose from the spring of 2018 to the spring of 2019. In total, 5,190 wells were measured consecutively in 2018 and 2019. Groundwater-level rises were recorded in 82% of measured wells, and 49% of all measured wells recording a rise greater than one foot (Fig. 7). Groundwater-level declines were recorded in 17% of measured wells, and 4% of all measured wells experienced a decline of greater than one foot. Approximately 1% of measured wells had neither rises nor declines from the spring of 2018 to the spring of 2019. The average groundwater-level change for all measured wells in Nebraska in 2019 was a rise of 1.30 feet. From January 2018 to January 2019, precipitation values for Nebraska were above the 30-year normal for 151 of 163 reporting stations in Nebraska. Precipitation values ranged from 76 to 175% of the 30-year average at locations around the state (Fig. 8).

The production of the 2018-2019 statewide groundwater-level change map was especially challenging, and the particular limitations of this map must be borne in mind. Many wells in flooded or inaccessible areas could not be measured in 2019, creating a gap in the serial continuity of measurements from 2018 to 2019. This gap was particularly acute in the Platte River Valley, in the vicinity of Fremont Nebraska, and in Garden, Kearney, and Frontier Counties, where hundreds of wells could not be measured in 2019. Therefore, projected groundwater-level rises in these areas may underestimate actual rises in groundwater levels. Moreover, the period of record for precipitation is January 2018 to January 2019; therefore, the precipitation map in this report does not include the significant rainfall events that took place between January 2019 and March to late April 2019 when groundwater-level measurements were taken.

From the spring of 2018 to the spring of 2019, significant groundwater-level rises occurred throughout the eastern half of the state, as well as in Perkins County in the west. Groundwater-level rises of 1 to more than 12 feet were recorded. The largest rises occurred in northwest Colfax county, an area that experienced declines of more than 20 feet in the aftermath of the record-setting drought of 2012 (Young et. al., 2013). Similarly, significant areas of groundwater-level rises were recorded in northern Antelope County. Much of the Missouri River Valley recorded rises of 5 to 10 feet.

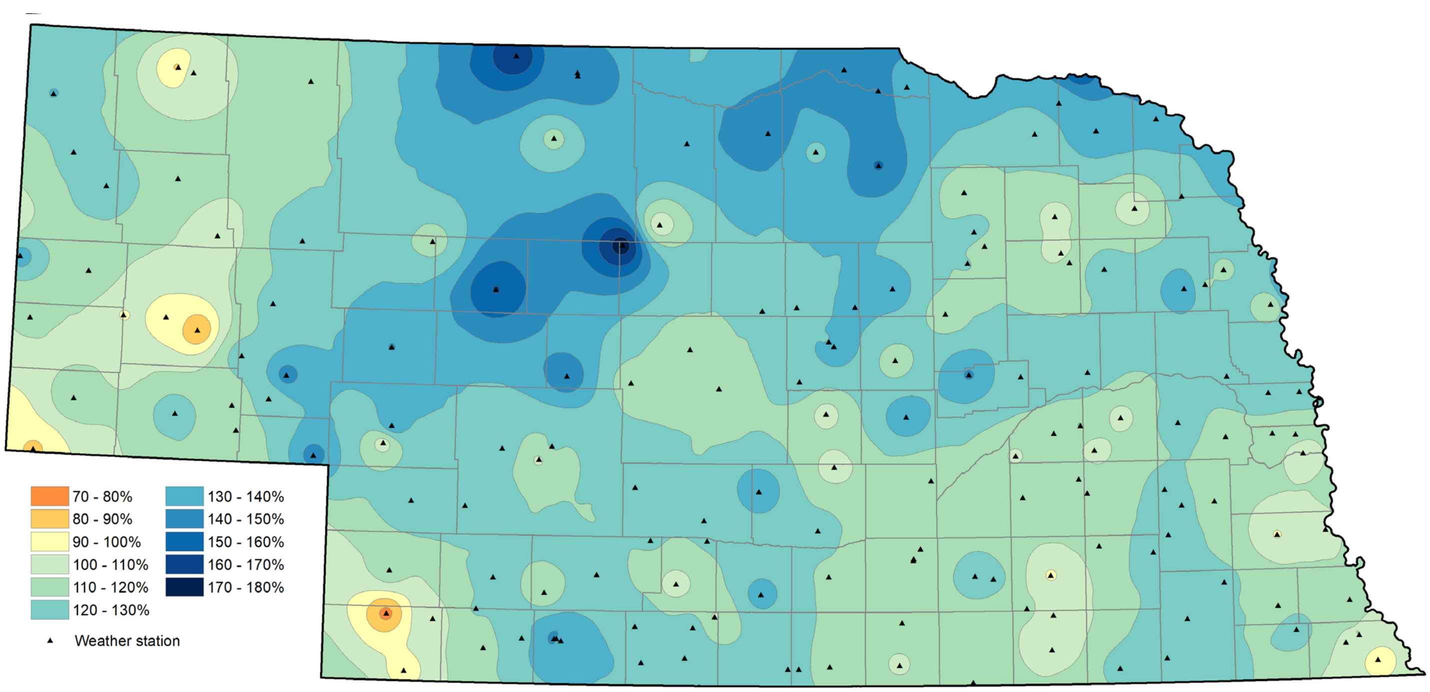
From spring 2018 to spring 2019, few localized groundwater-level declines were recorded, chiefly in the Panhandle and southwestern Nebraska. Most of these declines appear to be restricted to small areas, or to the vicinity of a single well. Possible causes for these minor fluctuations include: (1) varying pumping schedules due to local precipitation patterns, (2) changes in land use and crop rotation from well to well, (3) pumping of nearby wells around the time of measurement, or (4) local variation in precipitation, especially in areas of high well density.

## Figure 7. Groundwater-Level Changes in Nebraska - Spring 2018 to Spring 2019




*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 8. Percent of Normal Precipitation - January 2018 to January 2019




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

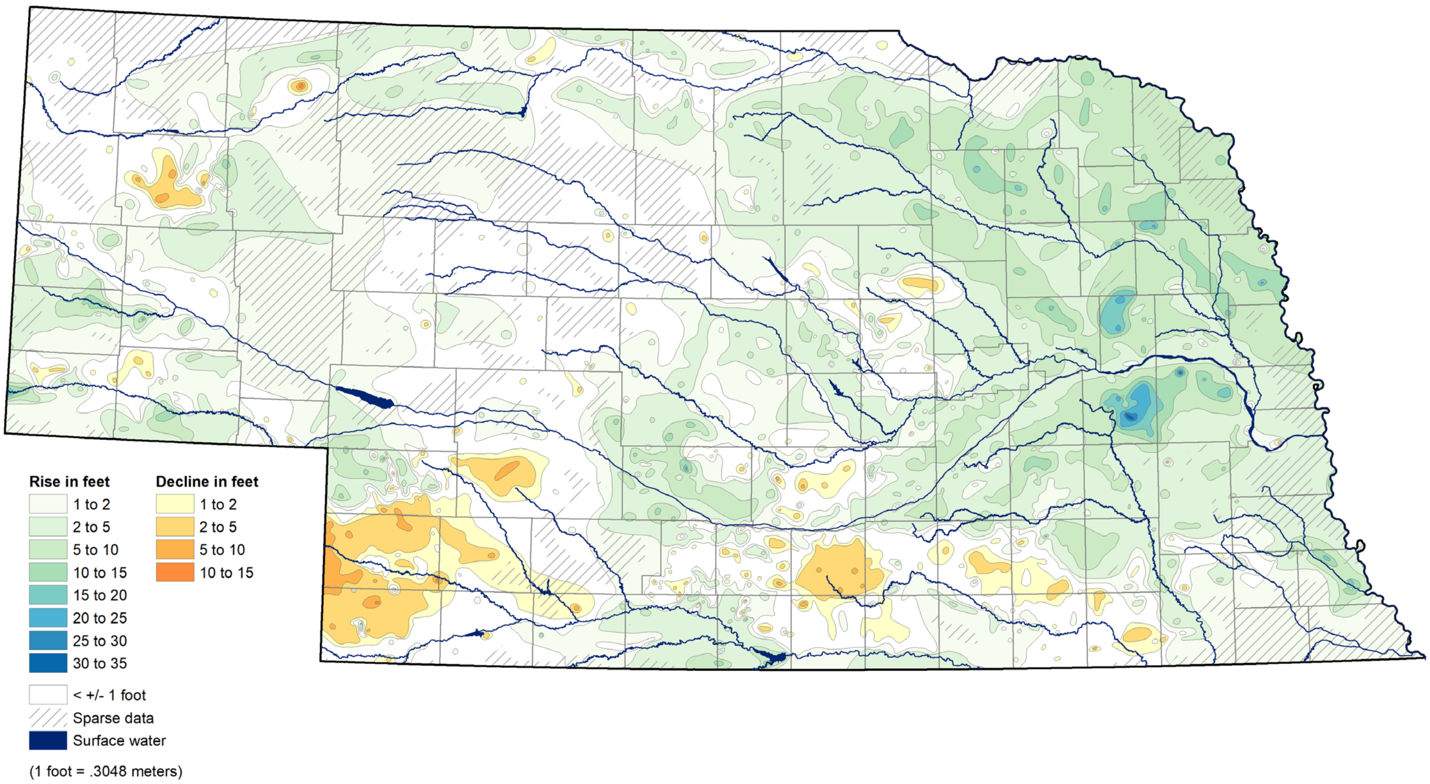
## CHANGES IN GROUNDWATER LEVELS, SPRING 2014 TO SPRING 2019

*On average, groundwater levels in Nebraska increased by 2.63 feet statewide between the spring of 2014 and the spring of 2019.*

The five-year groundwater-level change map was developed on the basis of 4,418 wells which were measured consecutively in spring 2014 and spring 2019. Of these wells, 77% recorded groundwater-level rises, and 63% of wells recording rises greater than one foot. Over the past five years, average groundwater levels have risen by an average of 2.63 feet statewide. The rises depicted in Figure 9 are largely recovery following the record-setting drought of 2012, due to above-average precipitation over the last 5 years. Of the 163 reporting stations in Nebraska, 146 reported above-average precipitation values (Fig. 10) and 91 stations reported slightly below-average values. Precipitation values in this region have varied over the same time period from 91 to 146% of the 30-year average.

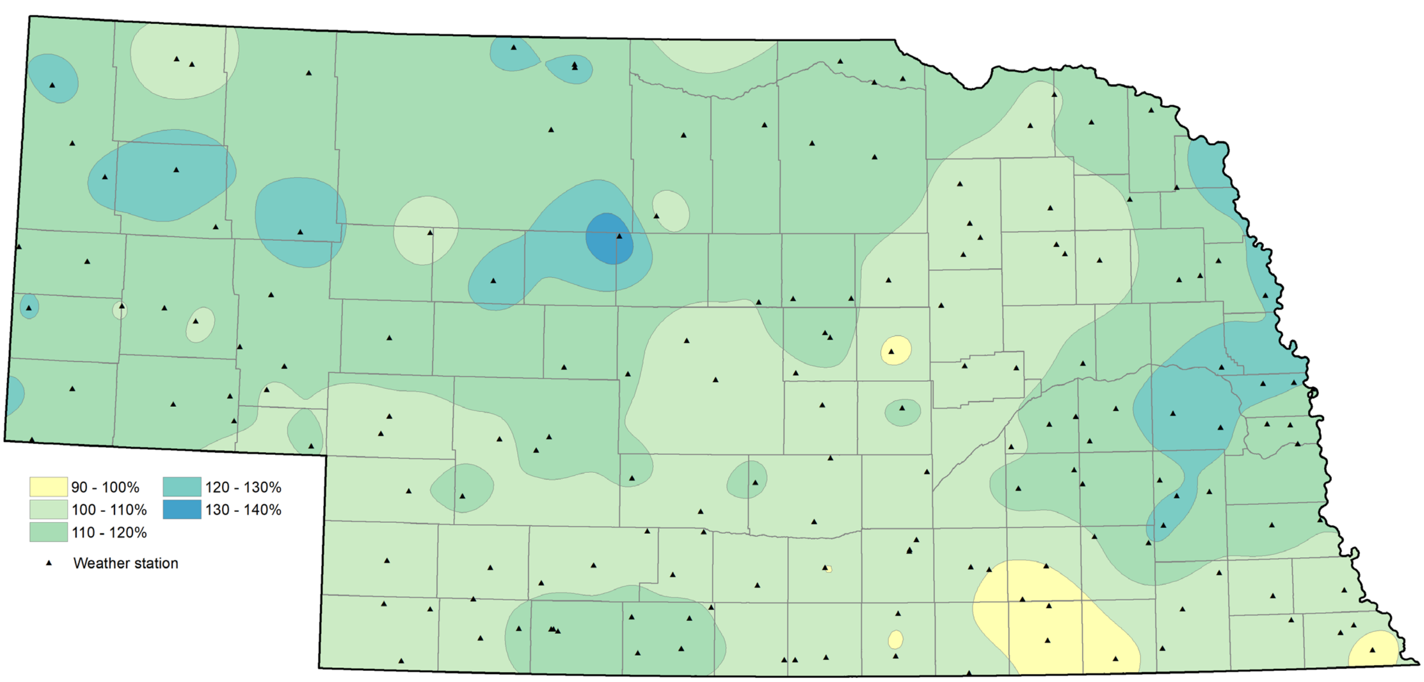
Of the 4,418 wells measured in both 2014 and 2019, 23% exhibited declines, and 14% of all measured wells recorded declines of greater than one foot. Spatially significant declines occurred in Box Butte, Chase, Dundy, Kearney and Lincoln counties. Declines in these counties may be the results of: (1) localized precipitation patterns, (2) patterns of known long-term continued drawdowns, or (3) changes to water storage or transport in canal systems. Other localized areas of groundwater-level decline appear across the state. Most of these areas are associated with a single well; thus, these declines likely resulted from changes in pumping schedules or recent pumping prior to the measurements of water levels.

## Figure 9. Groundwater-Level Changes in Nebraska - Spring 2014 to Spring 2019




*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 2014 to January 2019




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

## CHANGES IN GROUNDWATER LEVELS, SPRING 2009 TO SPRING 2019

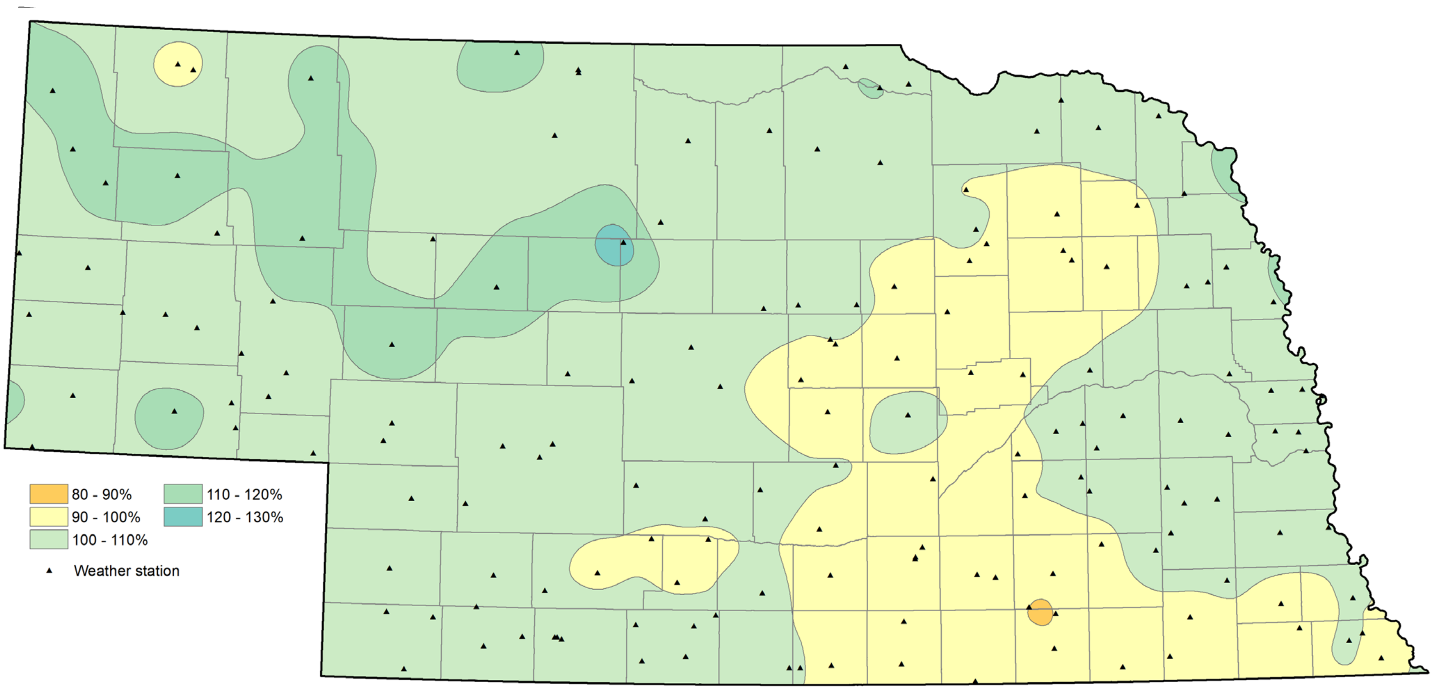
*Despite major shifts in weather conditions and record setting drought, modest groundwater-level rises were recorded throughout much of Nebraska over the last 10 years*

Weather conditions from the spring of 2009 to the spring of 2019 ranged from record-setting drought to periods of much-above-average precipitation. Much of the Midwest, and all of Nebraska were in a period of drought from 2000 to about 2007. Groundwater-level declines were recorded throughout the state during this period (Burbach, 2007). Precipitation attained above-normal levels between 2007 and early 2012, restoring groundwater levels to pre-drought conditions in much of eastern and central Nebraska. From the spring of 2012 through the spring of 2013, however, Nebraska experienced the driest single year on record, resulting in groundwater-level declines which eliminated many of the groundwater-level rises associated with the high-rainfall years between 2007 and early 2012. Precipitation values over most of Nebraska returned to near long-term averages in late 2013 and 2014. Despite the major year-to-year fluctuations in precipitation extremes, precipitation values have remained near the 30-year average for Nebraska over the last 10 years (Fig. 11).

Of 4,378 wells measured in both spring of 2009 and spring of 2019, 64% recorded groundwater-level rises, with 49% rising more than one foot(Fig. 12). Groundwater-level declines were recorded in 36% of wells measured in Nebraska from the spring of 2009 to spring 2019, and 26% of measured wells experienced declines of greater than one foot. Groundwater levels in wells have risen by an average of 0.97 foot statewide over the last 10 years.

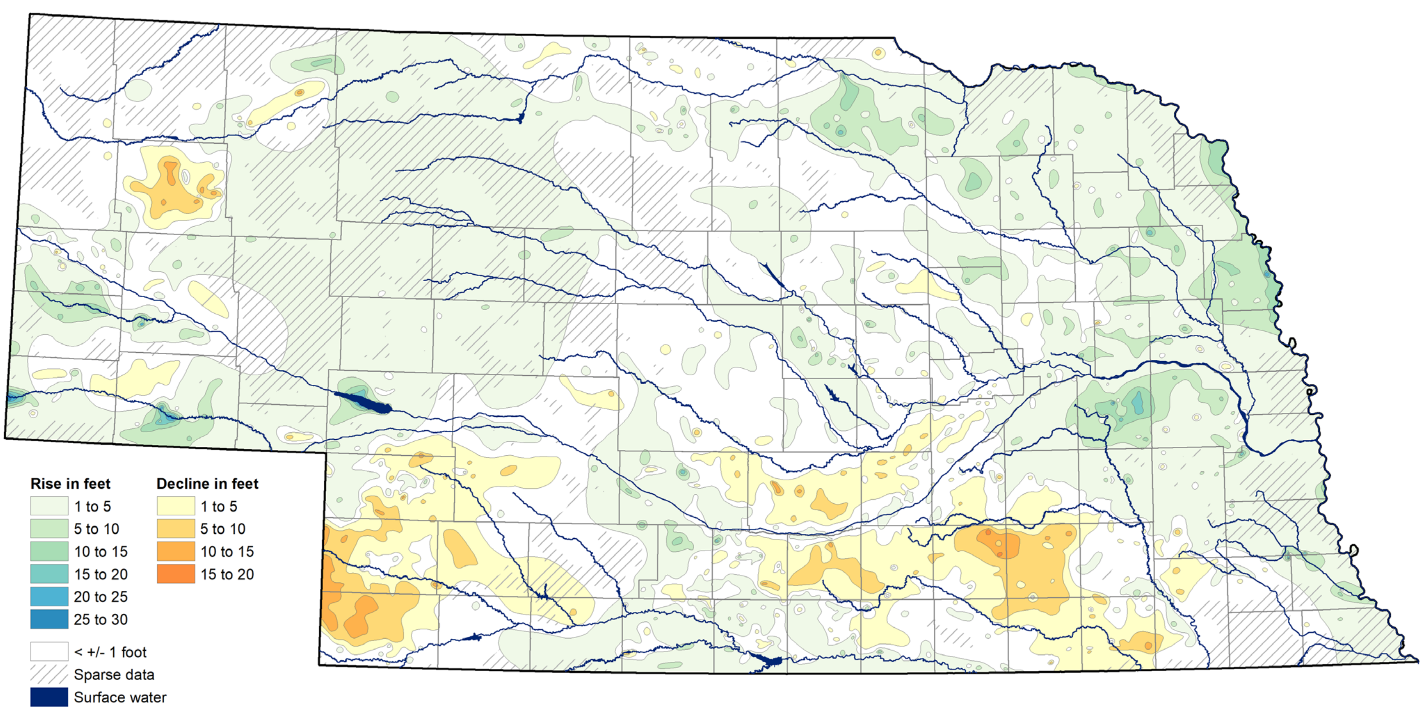
From the spring of 2009 to the spring of 2019, groundwater levels have fluctuated regionally, despite near average precipitation statewide. The regional patterns of groundwater-level changes may have resulted from: (1) extreme regional variability in year to year precipitation and associated irrigation pumping rates, (2) delayed reaction time of aquifers to climate trends, (3) and increased runoff during brief, high-intensity rainfall events. Although some long-term trends can be observed at this scale, such as steadily increasing levels in the central Sand Hills and steadily decreasing levels in known problem areas, groundwater levels have fluctuated from year to year due to extreme variations in yearly rainfall, recharge, and evapotranspiration over the past 10 years. Groundwater-level changes mapped in Figure 12, therefore, may be the effects of short-term extremes rather than long-term trends.

## Figure 11. Percent of Normal Precipitation - January 2009 to January 2019




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

## Figure 12. Groundwater-Level Changes in Nebraska - Spring 2009 to Spring 2019




*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 2019

*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.*

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 2019 groundwater levels indicate both long-term declines and long-term rises in certain areas of Nebraska (Fig. 13). Almost all of the areas of significant groundwater-level declines correspond to high irrigation-well densities in aquifers that are deep and have little direct connection to surface water (Fig. 14). The greatest decline from predevelopment to 2019 is approximately 125 feet, in Box Butte County just north of the city of Alliance. Notable groundwater-level declines from predevelopment to spring 2019 have occurred in Box Butte County, the southwestern part of the state near Chase, Perkins, and Dundy counties, and in the Panhandle. A large area of smaller declines in southeast to south-central Nebraska reflects slight depletion of the High Plains aquifer. The largest groundwater-level rises occurred in Gosper, Phelps, and Kearney counties, where there are extensive canals and surface-water irrigation systems.

The predevelopment groundwater levels used in Chase, Perkins, and Dundy counties are representative of the approximate average groundwater levels prior to 1953. A general trend of declining groundwater levels that began around 1966 correlates temporally with the intensive use of groundwater for irrigation. The approximate average groundwater levels prior to 1938 were utilized as predevelopment values for the groundwater-level change map in Box Butte County. Intensive groundwater development for irrigation since 1950 has caused groundwater levels to decline by 5 feet to more than 120 feet from predevelopment levels (Fig. 13). Records from wells in both the southwestern counties and in Box Butte County indicate that rates of decline have been essentially steady, despite subsequent changes in groundwater management practices, water use allocations, and fluctuations in the amount of annual precipitation (Korus and Burbach, 2009b).

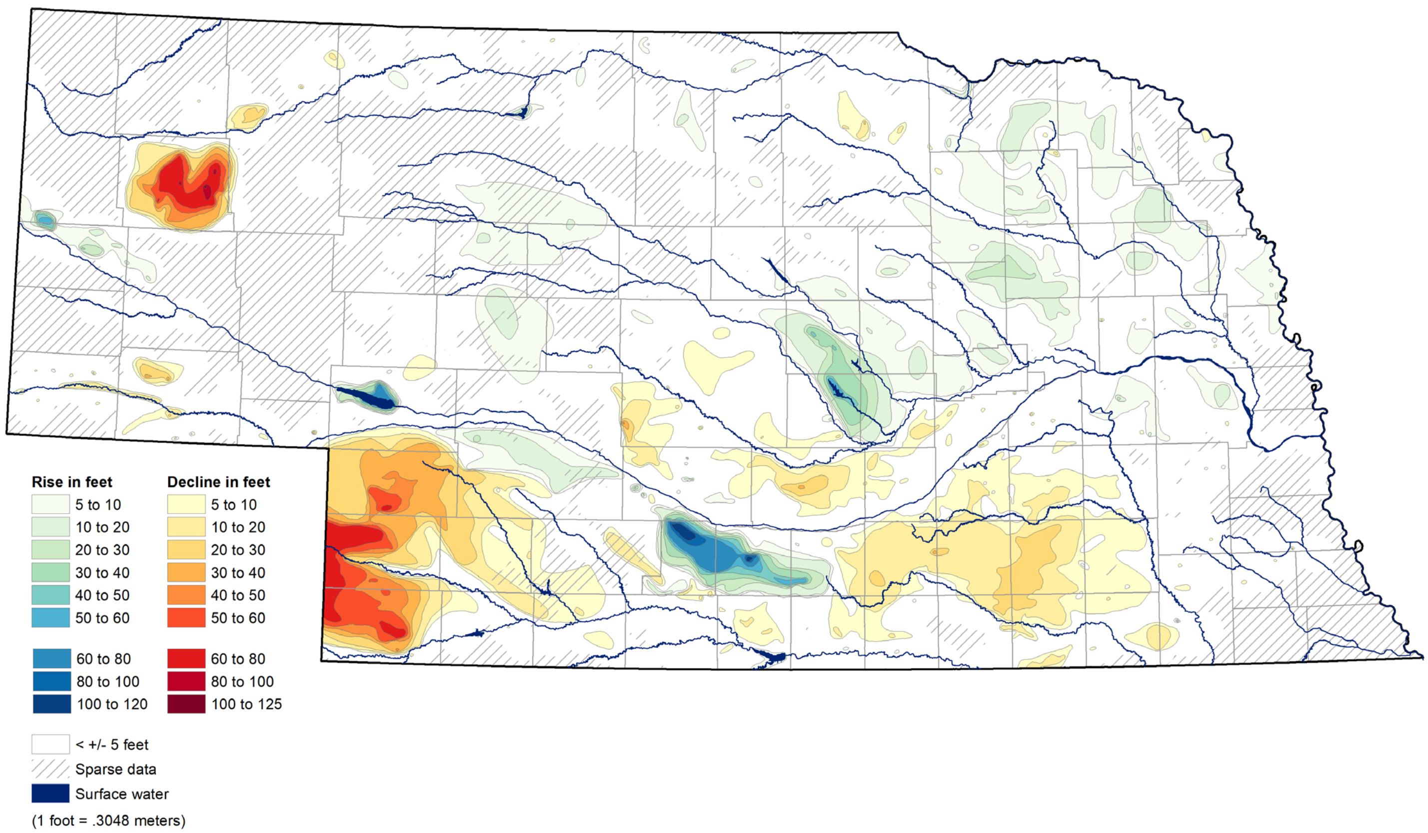
Much of southeastern to south-central Nebraska has experienced long-term groundwater-level declines since predevelopment times (Fig. 13). Predevelopment water levels in this area are generally representative of the approximate average water levels prior to 1950. Groundwater levels in large parts of this region have declined more than 10 feet, and in some areas by more than 30 feet, since predevelopment times.

Groundwater-level declines also occurred in large areas between the Platte and Loup or South Loup rivers and in the Republican River Valley and the Panhandle. Irrigation-well densities are high in some, but not all, of the aforementioned areas. Aquifer characteristics, rates of recharge, and irrigation scheduling may have contributed to these declines as well.

Groundwater-level rises from predevelopment generally occurred in areas of surface-water-irrigation systems. Storage of water in Lake C. W. McConaughy began in 1941, and seepage losses caused groundwater-level rises of as much as 60 feet in nearby observation wells (Ellis and Dreeszen, 1987). Groundwater levels around the lake 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 C. W. McConaughy is subsequently diverted from the Platte River near Sutherland west of 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. The deep percolation of water from these irrigation-distribution systems and from excess water applied to crops has gradually increased groundwater levels by more than 100 feet (Fig. 13). Groundwater levels have also risen in response to seepage from Sutherland Reservoir, Lake Maloney, and their associated canals in eastern Keith and central Lincoln counties. Similarly, there are groundwater-level rises of as much as 60 feet associated with irrigation canals in southern Sioux, Scotts Bluff, and western Morrill counties.

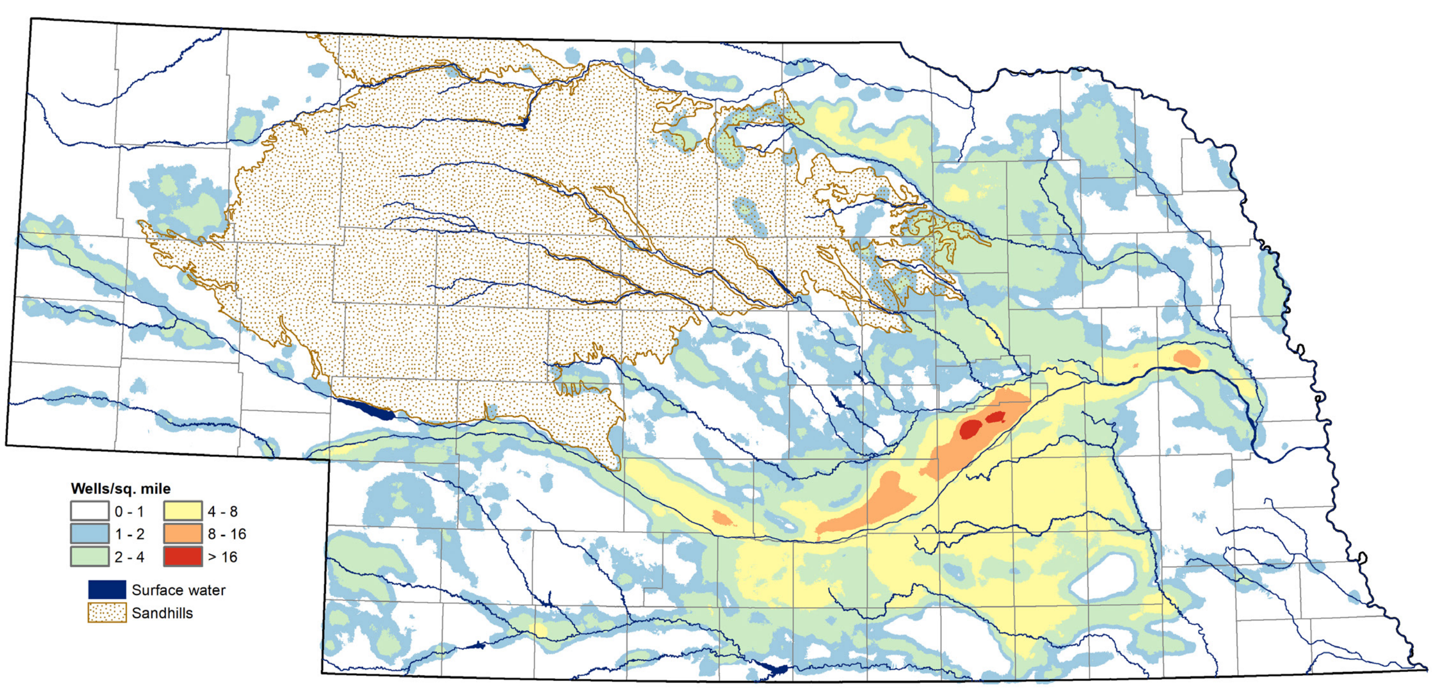
Groundwater-level rises of 10 to more than 50 feet occurred in portions of central Nebraska (Fig. 13). The highest groundwater-level rises occurred in Valley, Sherman, and Howard counties in response to sustained seepage from irrigation canals, Sherman and Davis Creek reservoirs, and the deep percolation of irrigation water applied to crops.

## Figure 13. Groundwater-Level Changes in Nebraska - Predevelopment to Spring 2019




*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 2019




*Source: Nebraska Department of Natural Resources*

## CHANGES IN GROUNDWATER LEVELS, PREDEVELOPMENT TO SPRING 1981 AND SPRING 1981 TO SPRING 2019

*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.*

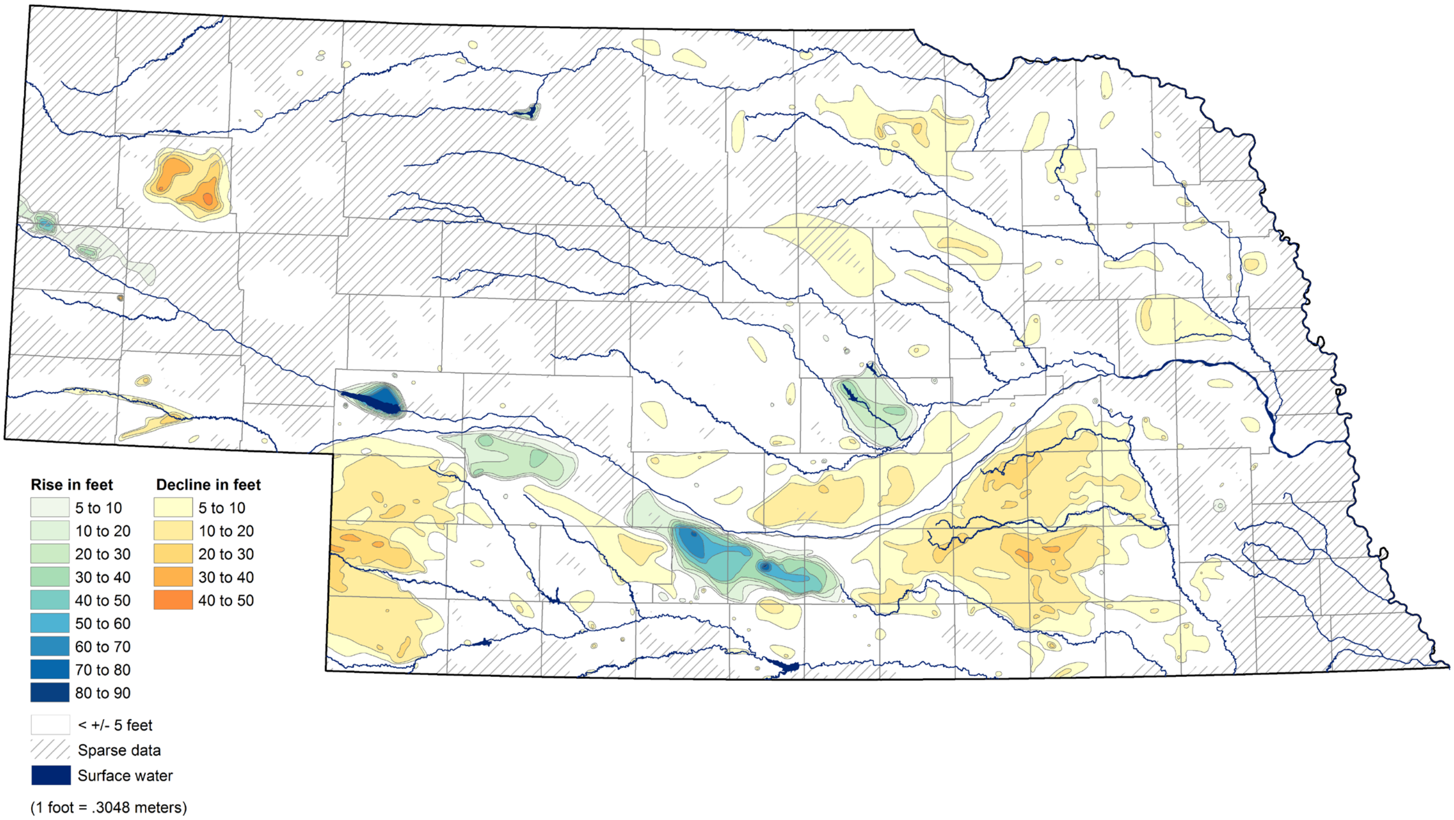
Groundwater-level changes from predevelopment to spring 1981 reflect the responses of aquifers to the spread of groundwater and surface-water-irrigation systems in Nebraska. Areas of significant groundwater-level declines exhibit a general correspondence with dense irrigation wells (cf. Johnson and Pederson, 1981). Declines were generally equal in magnitude in both the eastern and western areas (Fig. 15). The largest areas in which declines occurred were in Box Butte County in the Panhandle, Chase, Perkins, and Dundy counties in southwestern, south-central and southeastern Nebraska, Platte River Valley, central Nebraska, and northeast portion of the Sand Hills. Declines exceeded 40 feet in Box Butte County in the Panhandle, 30 feet in Chase County in the southwest, and as much as 10 feet in Clay and Fillmore counties in the south central. Declines occurred in smaller areas of the Republican River drainage as well as the northeast. Almost all groundwater-irrigated areas in Nebraska experienced declines of some magnitude. Such declines are the unavoidable responses of aquifers to development, according to laws of hydrologic mass balance (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 can be related to 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 this area locally exceeds 50 feet. The groundwater-level rise in Cherry County is associated with seepage from Merritt Reservoir since the mid-1960s. It exceeds 20 feet immediately adjacent to the reservoir. Seepage from Lake C. W. McConaughy since 1941 caused groundwater levels to rise more than 100 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). Groundwater levels began rising in this area after 1941 and had nearly reached their maximum by 1981. In Howard and Sherman counties, 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 this two-county area by 1981.

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 times until 1981 subsequently experienced rises of 5 feet to more than 20 feet from 1981 to 2019. This pattern of pre-1981 decline and post-1981 recovery is evident in many wells, including the Hastings recorder well, which has a continuous record dating to the mid-1930s. Although water levels in Polk, Hamilton and York Counties continue to rise from 1981 levels, rising levels have slowed or begun to decline in other counties in south-central and southeastern Nebraska since the drought of 2012. Thereafter, water levels in this region have fluctuated yearly. This fluctuation hampers the projection of future groundwater-level changes in this region. Declines in south-central and southeastern Nebraska may be a short-term response of the aquifer to increased pumping and decreased recharge due to extreme drought, or they may be the beginning of a declining trend in response to long-term climate trends.

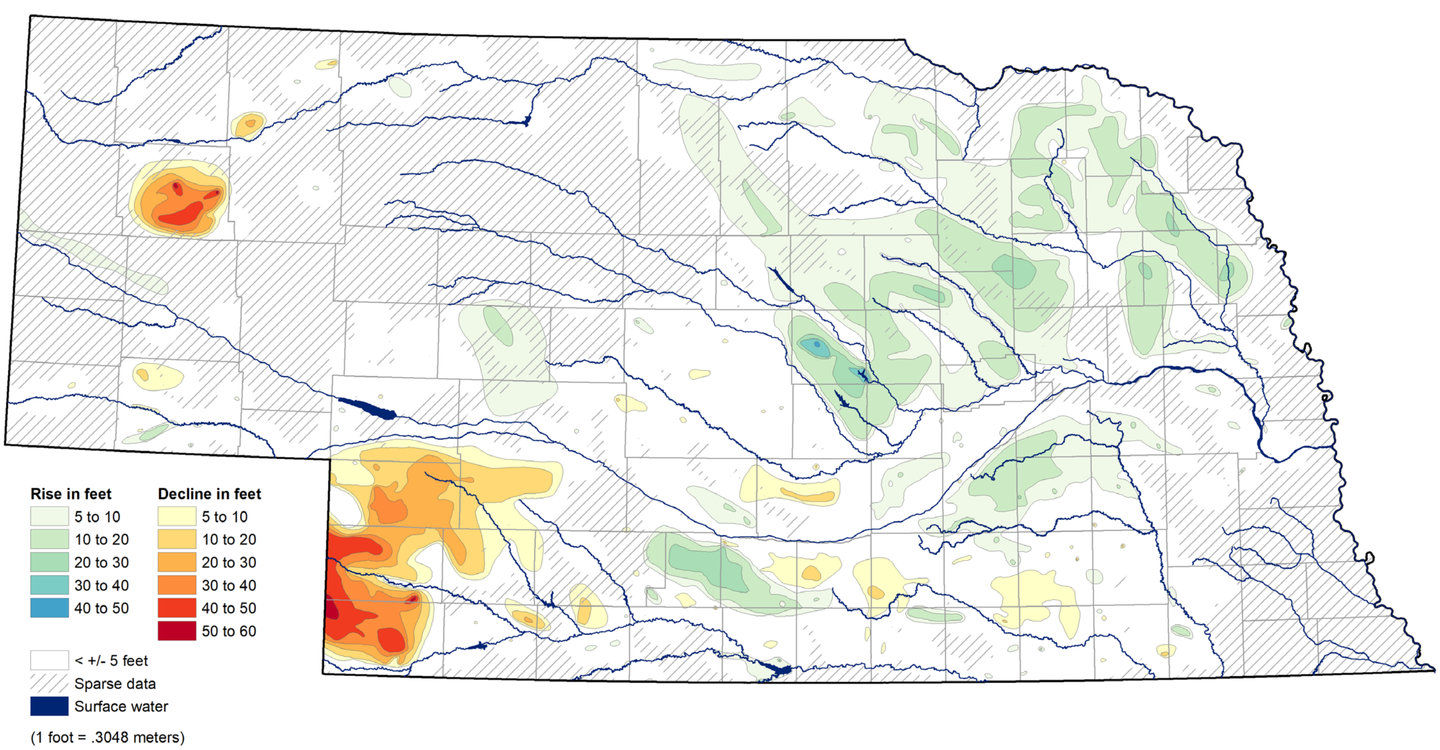
Declines in south-central and southeastern Nebraska reached a maximum in 1981 and then recovered. Declines in some parts of these two regions of the state are now less than 5 to 10 feet relative to predevelopment levels (Figs 13, 15, 16). Groundwater levels in most of south-central and southeastern Nebraska combined, however, remain below predevelopment levels. The post-1981 recovery of groundwater levels in south-central and southeastern Nebraska probably resulted from a combination: (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 (Korus and Burbach, 2009a). These rises may also 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 the overapplication of water and deep percolation, which artificially recharged the shallow aquifer. The hydrograph for the Exeter recorder well, which is screened in the shallow aquifer, exemplifies this phenomenon

## 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 2019

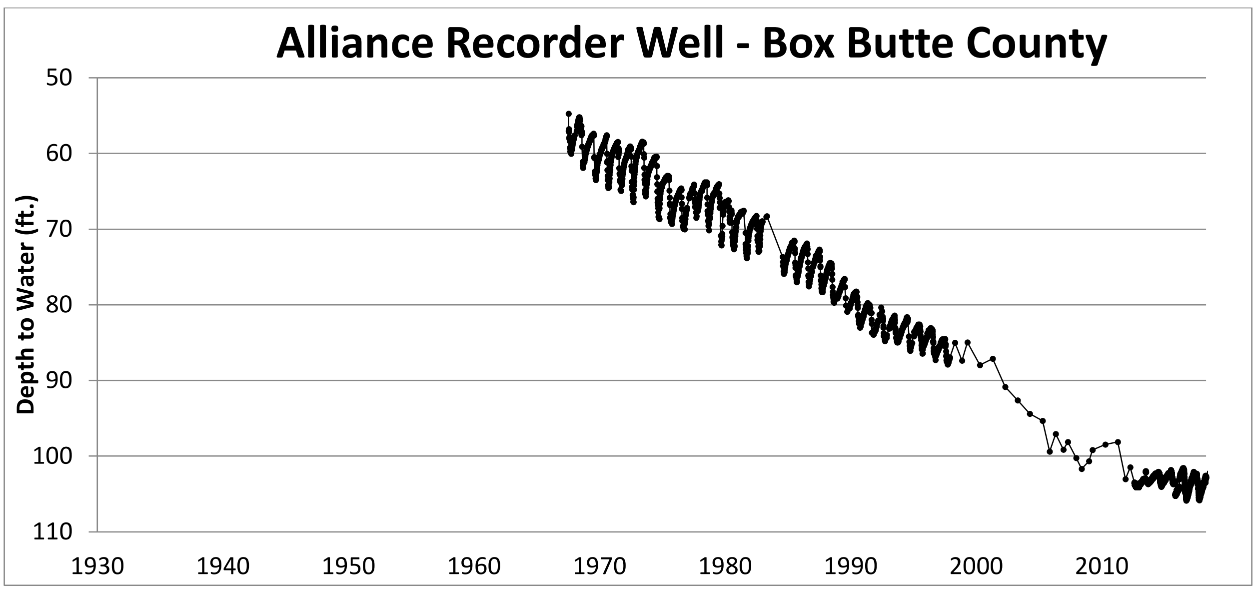


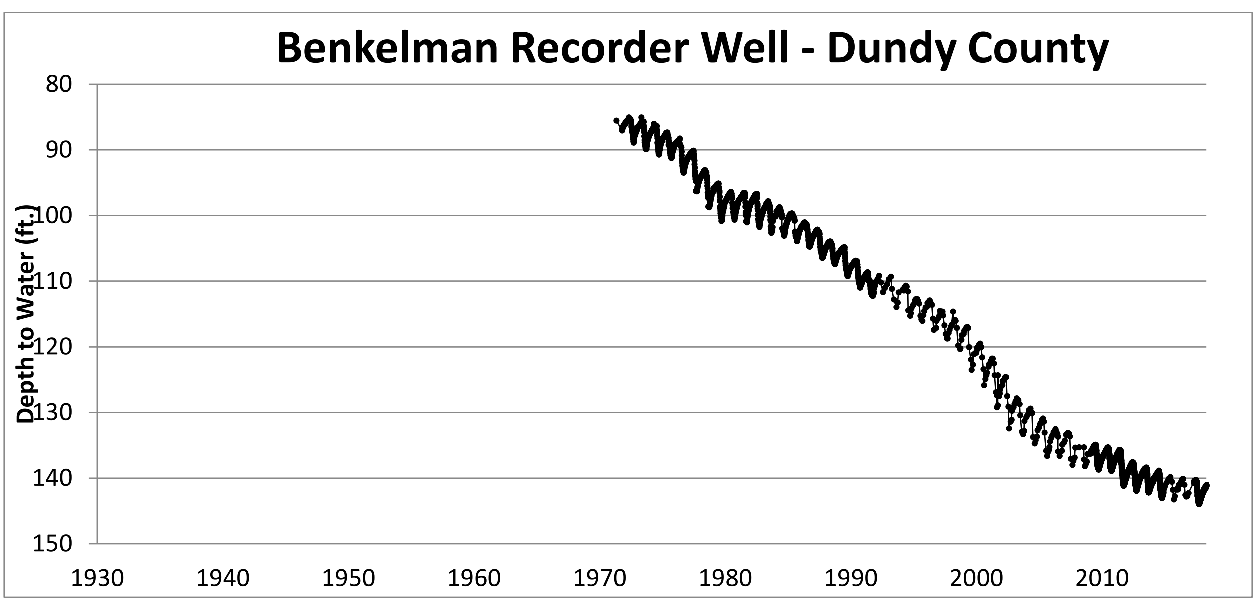

*Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District*

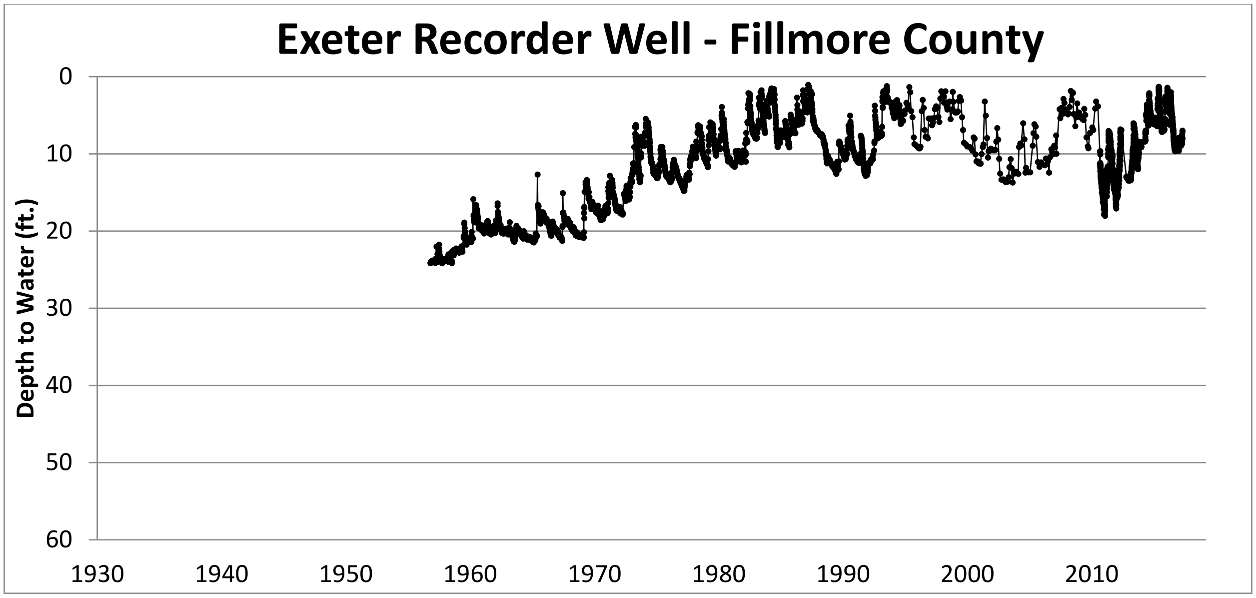
(Fig. 17). The steady groundwater-level rise in this well between 1956 and 1981 temporally corresponds to the steady decline observed in nearby wells that are screened in the deep aquifer. Excess irrigation water pumped from the deep aquifer probably recharged the primary aquifer wherever the confining layer is discontinuous or semipermeable. Under these circumstances, surface water would percolate slowly down to the primary aquifer over a long period of time.

In contrast to the groundwater-level rises in the eastern part of the state, levels continued to decline in parts of western Nebraska from 1981 to 2019 (Fig. 16). The Alliance, Benkelman, and Imperial recorder wells show declines of 50 to 60 feet in just 50 years, an average decline of about one 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 southwestern Nebraska or 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 (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 recharge.

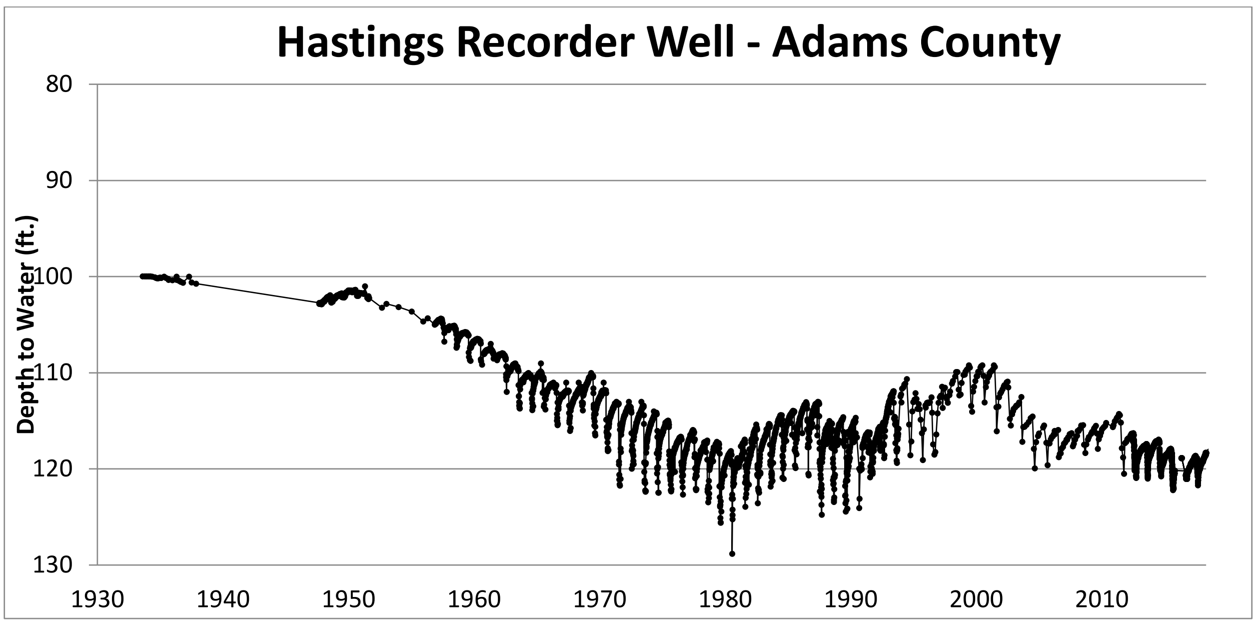
**Figure 17. Groundwater-Level Hydrographs Typical of Southwestern and Southeastern Nebraska**

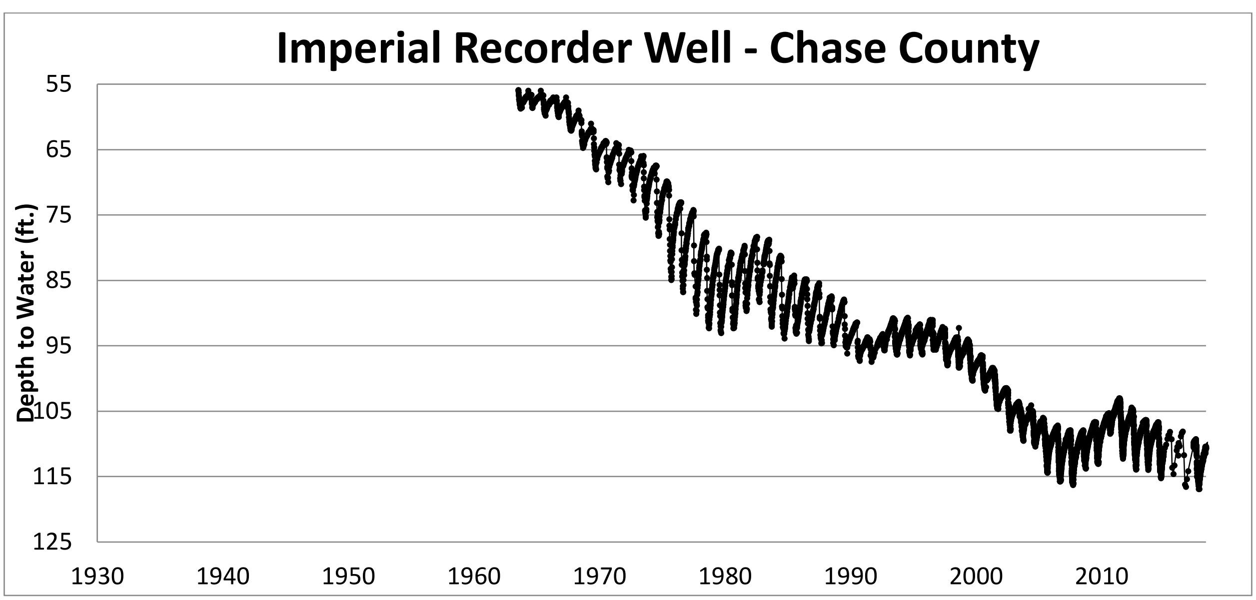





*Groundwater level measurements for the Exeter recorder well were discontinued in July 2018*



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|---|---|---|
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