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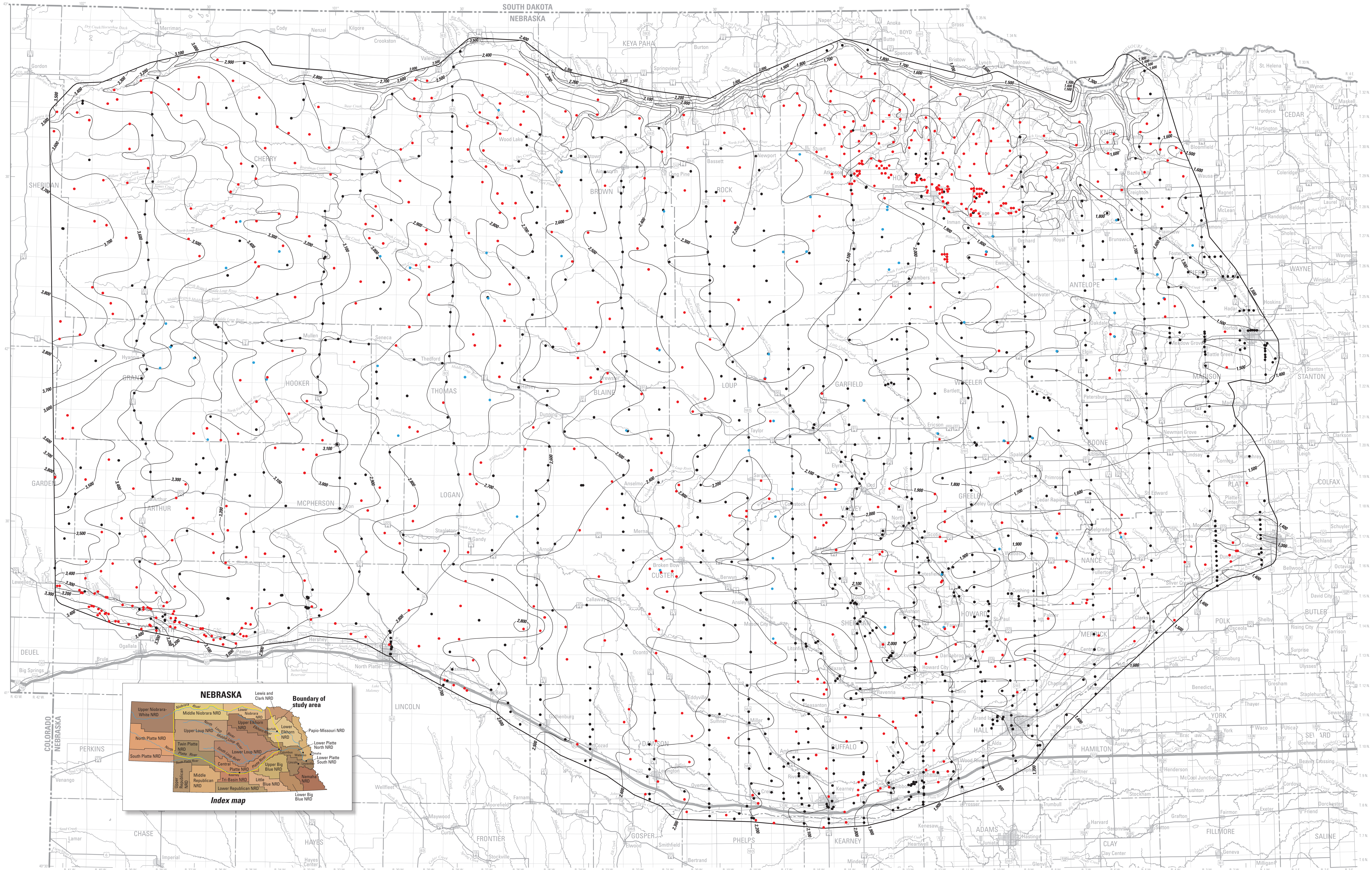
Prepared in cooperation with the
LOWER ELKHORN, LOWER LOUP, LOWER PLATTE NORTH, MIDDLE NIOBRARA, AND UPPER ELKHORN NATURAL RESOURCES DISTRICTS

SCIENTIFIC INVESTIGATIONS MAP 3259

Base of the Upper Layer of the Phase-Three Elkhorn-Loup Groundwater-Flow Model, North-Central Nebraska



Index map

Base from U.S. Geological Survey digital data, 1987, 1:100,000
Lambert Conformal Conic projection
Standard parallels 40° and 43°, central meridian 100°

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

Introduction

The Elkhorn and Loup Rivers in Nebraska provide water for irrigation, recreation, hydropower production, aquatic life, and municipal water systems for the Omaha and Lincoln metropolitan areas. Groundwater is another important resource in the region and is extracted primarily for agricultural irrigation. Water managers of the area are interested in balancing and sustaining the long-term uses of these essential surface-water and groundwater resources. Thus, a cooperative study was established in 2006 to compile reliable data describing hydrogeologic properties and water-budget components and to improve the understanding of stream-aquifer interactions in the Elkhorn and Loup River Basins. A groundwater-flow model [hereinafter referred to as the Elkhorn-Loup Model (ELM)] was constructed as part of the first two phases of that study as a tool for understanding the effect of groundwater pumpage on stream base flow and the effects of management strategies on hydrologically connected groundwater and surface-water supplies.

The third phase of the study was implemented to gain additional geologic knowledge and update the ELM with enhanced water-budget information and refined discretization of the model grid and stress periods. As part of that effort, the ELM is being reconstructed to include two vertical model layers, whereas phase-one and phase-two simulations (Peterson and others, 2008; Stanton and others, 2010) represented the aquifer system using one vertical model layer. For those previous versions of the ELM, a single vertical model layer was considered appropriate because hydrologic stresses were applied as average annual values. Vertical gradients happen primarily in the summer months as a response to irrigation-well pumpage and do not generally persist during annual or longer time periods. The refined temporal discretization of the phase-three ELM, along with the inclusion of two model layers, will allow simulation of vertical hydraulic gradients during the irrigation season.

The ELM study area covers approximately 30,000 square miles of the High Plains aquifer system, and extends from the Niobrara River in the north to the Platte River in the south (see map at left). The western boundary roughly coincides with the western boundary of the Middle Niobrara, Twin Platte, and Upper Loup Natural Resources Districts (NRDs), and the eastern boundary approximates the location of the westernmost extent of glacial till in eastern Nebraska (University of Nebraska, 2005). The important geologic units in the study area include Quaternary-age deposits, the Broadwater Formation of late Tertiary (Pliocene) age, the Ogallala Group of Tertiary age, and the Arikaree Group of Tertiary age (Gutentag and others, 1984; Swinehart and others, 1985). The Tertiary-age Brule Formation of the White River Group also is considered to be part of the High Plains aquifer system where the Brule Formation is fractured; however, the extent of fracturing has not been mapped and, therefore, those deposits are not included in the ELM. Sediments from the younger deposits, that is, those of Quaternary and late Tertiary age, generally are coarser than sediments from the older units.

This report presents a map of and methods for developing the elevation of the base of the upper model layer for the phase-three ELM. Digital geospatial data of elevation contours and geologic log sites used to estimate elevation contours are available as part of this report.

Methods

The goal of this approach was to divide the model vertically so the upper layer had different water transmitting and storage characteristics than the lower layer. The approach for defining the base of the upper model layer included the following four steps: (1) evaluate site-specific sediment texture information at test holes, registered water wells, and surface-geophysical logs to define the depth of the base of the upper model layer, (2) convert the site-specific depths of the base of the upper model layer to elevations above the National Geodetic Vertical Datum of 1929 (NGVD 29), (3) digitally interpolate between sites to construct a digital map surface and create 100-foot (ft) elevation contours of the base of the upper model layer, and (4) manually revise the base of the upper model layer 100-ft elevation contours.

The depth to the base of the upper model layer was defined at 1,876 sites within the ELM area using sediment texture information from 1,116 geologic test-hole logs (Tylr Naprstek, Lower Loup Natural Resources District, written commun., 2012; Chris Hobza, U.S. Geological Survey, written commun., 2012; University of Nebraska, 2012), 693 registered water-well logs (Nebraska Department of Natural Resources, 2012), and 67 surface-geophysical logs (Hobza and others, 2012). Additional registered water-well logs were reviewed but not used to determine depth to the base of the upper model layer because the log either was not deep enough or did not provide enough detail. Additional surface-geophysical logs were reviewed but not used to determine depth to the base of the upper model layer because results were not consistent with nearby test-hole or water-well logs. Texture descriptions were used in most cases to identify the depth in a test-hole, water-well, or surface-geophysical log at which dividing the aquifer produced contrasting texture characteristics for the upper and lower model layers. For most of the study area, the upper layer of geologic sediments was classified as coarse sands and gravels, and the lower part of the sediments was classified as fine sands, silts, and clays; however, the complex depositional history of the High Plains aquifer system's sediments makes it difficult to identify a clear boundary between an upper and lower model layer for some areas. For example, in parts of the eastern study area, the aquifer is composed mostly of coarse sands and gravels but also includes multiple clay layers of variable thicknesses. If no clear distinction between an upper and lower layer could be determined based on sediment texture, the base of the upper layer was either (1) estimated from the age of geologic deposits and set at the base of late Tertiary- or Quaternary-age sediments, or (2) estimated by correlating sediment textures with neighboring geologic logs that had clearer differences in texture with depth. In a few cases, professional judgment was used to define the depth to the bottom of the upper layer.

The site-specific depths representing the base of the upper model layer were converted to elevations by subtracting the depth from the land-surface elevation at the site location, which had been derived from a 10-meter (m) (32.8-ft) digital elevation model (DEM) (Nebraska Department of Natural Resources and U.S. Geological Survey, 1998). Preliminary interpolation of the elevation of the base of the upper model layer between the data points (geologic-log sites) was accomplished using a Geographic Information System (GIS) interpolation function (Topo to Raster; Environmental Systems Resources Institute, 2011) based on the ANUDEM program developed by Hutchinson (1988, 1989). The computer-generated elevation contours were then manually adjusted within the GIS to reflect plausible contour patterns consistent with an interpreted paleodrainage system (Swinehart and others, 1985). In areas where the aquifer was thin or absent (mostly in the northern and eastern parts of the study area and along modern river valleys), the manually adjusted elevation contours were then digitally compared with the DEM and modified again, where needed, so the base of the upper model layer was either (1) at least 10 ft below the land surface where the aquifer was expected to be thin but present, or (2) at land surface where the aquifer was expected to be absent.

Base of the Upper Layer of the Phase-Three Elkhorn-Loup Groundwater-Flow Model

For much of the study area, the upper layer consisted of mostly coarse sediments, such as coarse-grained sand and gravel. The lower layer typically consisted of silt and fine-grained sand. Where the Ogallala and Arikaree Groups are present, the upper layer generally coincided with late Tertiary- and Quaternary-age deposits, and the lower layer generally coincided with the older, Tertiary-age Ogallala and Arikaree Groups; however, in parts of the eastern study area, the older, Tertiary-age deposits were thin or absent, and late Tertiary- and Quaternary-age sediments generally composed both layers. The elevation contours of the base of the upper layer of the phase-three ELM are shown on the map at left. Elevations generally decrease from west to east; the base of the upper model layer ranged in elevation from less than 1,300 ft above NGVD 29 in the southeastern part of the ELM study area to more than 3,800 ft above NGVD 29 in the west.

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Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

EXPLANATION

2,300 — **Line of equal elevation of base of upper layer of two-layer model**—Dashed where approximately located. Contour interval 100 feet. Vertical datum is the National Geodetic Vertical Datum of 1929 (NGVD 29). Elevation refers to distance above the vertical datum

Location of wells, geophysical data, and test holes with base-of-upper-model-layer elevation— Symbol color indicates source of elevation data

- Test hole
- Registered water well
- Surface-geophysical data

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5231 South 19th Street, Lincoln, Nebraska 68512
(402) 328–4100
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By Jennifer S. Stanton, 2013

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