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Nebraska Department of Natural Resources

Task Order #11

Development of Niobrara Basin Hydrogeologic and Hydrostratigraphic Framework

Completion Report

By

Conservation and Survey Division

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Introduction

The Nebraska Department of Natural Resources (DNR) and the Natural Resource Districts (NRDs) impacted by the fully appropriated determination in January 2008 worked in conjunction with the University of Nebraska, Lincoln (UNL) to develop a refined hydrogeologic framework for the Niobrara River basin. The results of this project provide data to update current maps (10/50 area) delineating areas which are subject to the rules of integrated management plans that will be developed by DNR and the NRDs. In addition, the results may be utilized in the future to develop a groundwater-flow model for all or part of the basin.

Project Products

The following is a list of geographical information system (GIS) coverages produced by the methods applied during the project (three sets of CDs containing all GIS files have been delivered to DNR under separate cover):

Reference Map –

Shows river basin boundary, groundwater-flow regime boundary, counties, drainage system, CSD test-hole locations.

Hydrostratigraphic Units –

Top of Ogallala Group

Top of Arikaree Group

Top of White River Group

Top of Pierre Shale (Montana Group)

Top of Base of Aquifer (represented by the top of the White River Group and the Pierre Shale)

Thickness of Quaternary age sand-and-gravel units

Thickness of Ogallala Group

Thickness of Arikaree Group

Hydraulic Properties –

Hydraulic conductivity of Quaternary-age sediments

Hydraulic conductivity of Ogallala Group

Hydraulic conductivity of Arikaree Group

Specific yield of Quaternary-age sediments

Specific yield of Ogallala Group

Specific yield of Arikaree Group

Transmissivity of Quaternary-age sediments

Transmissivity of Ogallala Group

Transmissivity of Arikaree Group

Groundwater-related Maps –

Potentiometric surface 1995 and 1979

Groundwater-level change series (2005 to 2009)

Saturated thickness of aquifer

Description of Study Area

The Niobrara River basin covers parts of several northern Nebraska counties. Specifically, these counties are, from east to west, western part of Knox, northwestern part of Antelope, all of Boyd, northern half of Holt, all of Keya Paha, northern parts of Rock and Brown, northern half of Cherry, large part of Sheridan, southern part of Dawes, all of Box Butte, and the central part of Sioux. Parts of two counties, Niobrara County and Goshen County in southeastern Wyoming, are also within the Niobrara River basin boundary. In addition, the basin extends into southern South Dakota; however, this extended region was not addressed by this study.

Topography across the basin varies from rolling hills in the eastern part to loess and sand hills in the central part to uplands in the western part. Land use likewise varies according to the physiographic province, soil types and irrigation practices. A variety of crop types are farmed across the basin with corn, wheat, soybeans and sugar beets being the most common.

Major hydrogeologic units within the Niobrara River basin include Quaternary-age deposits underlain primarily by sediments of the Ogallala Group and the Arikaree Group. Nearly all of the groundwater extracted comes from wells penetrating these units. The Pierre Shale (Montana Group) present in the eastern one-third of the basin and formations of the White River Group beneath the remaining basin are considered to be non-groundwater producers by this study.

Methods of Study

Primary sources of subsurface information were: 1) the state-wide test-hole database developed and maintained by the Conservation and Survey Division (CSD), UNL; 2) the registered well database available through the DNR; and, 3) the deep well database established by the Nebraska Oil and Gas Commission. In addition, a number of reports and geologic maps produced by the CSD and the U.S. Geological Survey on counties and regions within the Niobrara River basin were used to supplement drill-log information. For that portion of the river basin situated in Wyoming, relevant data and information presented in the *LUSK Area Groundwater Level 1 Study* conducted by the Wyoming Water Development Commission were incorporated into the current project.

With regard to drill-log information, only those test-hole logs where stratigraphic interpretations have been completed or, in the case of registered wells with driller's logs, where a reasonable call could be made with regard to the top of particular units, were used to establish contacts between relevant hydrogeologic units. The distribution of all points used in the interpretation of subsurface strata is shown on the appropriate coverages listed above.

The initial phase of the project was to identify and establish the boundary condition that controls groundwater movement within the vicinity of the Niobrara River drainage system. To accomplish this task, a map of the Niobrara River and its tributaries was superimposed upon the 1995 potentiometric surface map of the region, then; a stream line was established along the appropriate gradient to delineate groundwater-flow divides. These divides represent no-flow boundaries where groundwater within the flow regime moves toward the Niobrara River or toward its tributaries. Groundwater outside of the no-flow boundary bypasses the basin. This encompassing hydraulic boundary coincides with the surface water divide for the basin with the exception of the southern part of Sheridan County and the northern part of Rock County (refer to the Reference Map provided to DNR).

The next phase of the study was to delineate hydrostratigraphic boundaries between the major hydrogeologic units and establish the base of the aquifer. Utilizing all of the available data and information, maps were constructed for each hydrogeologic unit indicating the topography of the top surface and the stratigraphic thickness. Total thickness of Quaternary-age sand and gravel for individual test holes was determined by totaling only sand, sand and gravel, and gravel subunit thicknesses; other subunits such as till, clay, or silt were ignored. A simple computer program was written to accomplish this task.

For purposes of this study, the base of the aquifer (no-flow boundary) is defined as the top of the Pierre Shale in the eastern-most part of the basin and the top of the White River Group in the remaining portion of the basin. A physical no-flow barrier boundary exists in the western extreme part of the basin (in Wyoming) where Precambrian rocks are present at ground surface as a result of major movement of crustal blocks along high-angle faults.

Determination of hydraulic conductivity and specific yield for each major hydrogeologic unit was accomplished using detailed lithologic descriptions from selected CSD test holes. This determination was based primarily on grain-size information derived from the data contained in the lithology table of the state-wide test-hole database (an updated version has been delivered to DNR under separate cover). A Visual Basic program (installation instructions and source code previously delivered to DNR) was written to extract lithologic information from the database through the use of key words or phrases to identify the overall grain size of subunits. The program then assigned a value of hydraulic conductivity and specific yield to that grain-size class. For example, if the lithology was determined to be fine-grained sand, values of 40 ft/day and 0.21 would be assigned for hydraulic conductivity and specific yield, respectfully. If, however, the subunit lithology was described as a siltstone, then the values assigned would be 3 ft/day and 0.1 for the hydraulic properties. Hydraulic property values for the various grain-size classes and rock types were obtained from standard groundwater hydrology text books such as *Applied Hydrogeology* by C.W. Fetter, Jr. and *Groundwater* by R.A. Freeze and J.A. Cherry. To obtain the hydraulic conductivity and specific yield for the entire hydrogeologic unit, a weighted mean was computed for each hydraulic property using the following equation:

$$\chi_{w} = \sum w\chi / \sum w$$

where w is the weight (subunit thickness) and χ is the hydraulic property. Transmissivity for the hydrogeologic unit was determined in a similar manner. That is, the representative transmissivity of the hydrogeologic unit is the weighted mean of the product of the subunit hydraulic conductivity and the subunit thickness.

Data Uncertainty

Map construction of the various hydrogeologic characteristics within the Niobrara River groundwater-flow regime was mainly based on data obtained from test holes drilled between about 1938 to the present. Supplemental information was extracted from selected driller's logs for a number of registered wells, specifically, those located in the eastern part of the study area. Because of the nature of the overall data set, the determination of uncertainty associated with the interpretation of subsurface information was made subjectively based on the following criteria:

1. Pattern and distribution of interpreted test holes across individual counties (also the distribution of registered wells with driller's logs in the eastern part of the study area).
2. Depth of penetration of test holes with regard to specific hydrostratigraphic units.
3. Quality of stratigraphic interpretations.

Percentage of Data Uncertainty by County

County	Confidence Percent	County	Confidence Percent
Knox	90	Brown	45
Antelope	90	Cherry	80
Boyd	95	Sheridan	60
Holt	75	Dawes	85
Keya Paha	40	Box Butte	95
Rock	30	Sioux	5

Values in the table range from 95 for Box Butte County to 5 percent for Sioux County and reflect the amount of subsurface information available. Easternmost counties have higher confidence percentages, in general, than the remaining counties. The reason is that a large number of registered well logs were used in the stratigraphic interpretation. Most of these counties are underlain by the Pierre Shale and easily identified by the drillers. In the western portion of the basin, Box Butte and Dawes counties (and Mirage Flats) are exceptions. This region has high confidence percentages because subsurface information was incorporated into this study from county reports on the hydrogeology and from a previous groundwater-flow modeling project by CSD. Sioux County has the lowest confidence level of all of the counties within the basin. Only one transect of CSD test holes is present. Of the 14 test holes drilled, field logs of four have not been interpreted with regard to stratigraphy. Registered well logs are virtually useless for this area because of poor identification of subsurface units by the drillers.

Confidence percentages listed in the above table only represent a very general overview of the uncertainty associated with the dataset. A more enlightened approximation of data uncertainty can be made by comparing coverages with regard to the same attribute. That is, if one compares the coverage for the top of the Ogallala with the coverage for the top of the Arikaree for example, the conclusion might be that there are more data points available to define the Ogallala top then are available to define the Arikaree top. The reason is that a test hole may have bottomed in the Ogallala and, therefore, did not penetrate the Arikaree (second criterion). This being the case, for a given county, the confidence percent for data defining the Ogallala characteristics would be higher as compared to the confidence percent for data defining the Arikaree. The point is individual coverages must be reviewed in order to determine what is needed to improve the reliability of the overall dataset associated with that coverage.

Reduction of Data Uncertainty

To decrease the amount of uncertainty associated with the development of the GIS coverages, a couple of tasks need to be undertaken. A number of test-hole samples have not been described and/or have not been interpreted with regard to stratigraphy. The highest priority should be given to completing these stratigraphic interpretations. This is particularly true for Sheridan, Brown, and Keya Paha counties. These interpretations should be performed by a qualified individual with expertise related to the geology of the region.

The next task is to determine the extent to which new data are to be collected. There are some areas within the basin that lack any subsurface information; notably, Sioux County in general (only on traverse of test holes have been drilled), south-west part of Sheridan County, eastern half of Keya Paha County, northern half of Rock County, and northern part of Holt County. In addition, the data-point distribution in Cherry County is rather thin; drilling of additional test holes should be considered. DNR should prioritize data collection with regard to importance of particular regions, what data are needed and what data collection methods are to be employed.