Appendix E.3

Groundwater Technical Memorandum
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ATTACHMENTS

Attachment A. Abbreviations and Acronyms
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APPENDIX E.3
GROUNDWATER TECHNICAL MEMORANDUM

This technical memorandum describes the existing conditions for groundwater resources along the proposed Nebraska Reroute corridor; the potential impacts from construction, operation, and maintenance of the Keystone XL Pipeline; and general mitigation measures to avoid or reduce these potential impacts. The resource impacts that are evaluated include impacts on major and shallow aquifers, groundwater use and water quality, and registered groundwater well survey and wellhead protection areas.

The term *groundwater* refers to water that is below the land surface and in the saturated zone. The *saturated zone* is the zone in which all of the cracks in the rock and all of the pore spaces between the grains of rock or within the soil are filled with water. The upper limit of the saturated zone is known as the *water table*. The zone above the water table, where pore spaces contain both air and water, is known as the *unsaturated zone* (UNL, 2012).

In Nebraska, usable groundwater is present in voids or pore spaces in various layers of geologic material such as sand, gravel, silt, sandstone, and limestone. Where such geologic units yield enough water for human use, these layers are referred to as *aquifers*. In parts of Nebraska, groundwater might be encountered just a few feet below the surface, while in other areas it might be a few hundred feet underground. The amount of water that can be withdrawn from a given aquifer can range from a few gallons per minute (which is just enough to supply a typical household) to many hundreds or even thousands of gallons per minute (which is the yield of large irrigation, industrial, or public water supply wells) (Nebraska Department of Environmental Quality [NDEQ], 2011).

As groundwater is pulled by gravity and pushed by the force of the water, it flows through pore spaces and cracks in the rock. The water moves from an area where it enters the aquifer (a *recharge zone*) to an area where water exits the aquifer (a *discharge zone*). Aquifers are recharged primarily from precipitation and to a smaller extent by surface water. Water infiltrates the land surface and percolates down through the unsaturated zone until it reaches the *zone of saturation* (where groundwater flow occurs). The rate of infiltration and percolation is a function of the soil type, rock type, and time (UNL, 2012).

The maximum slope of the water table at a given location is called the *hydraulic gradient*. This slope determines the direction and relative rate of groundwater flow. Groundwater flows from areas with a higher water table elevation (upgradient) to areas with a lower water table elevation (downgradient). Groundwater generally flows much more slowly than surface water (NDEQ, 2011).

The movement of groundwater depends on the hydraulic properties of the rock and sediment and on the hydraulic gradient. Two hydraulic properties, transmissivity and specific yield, are important for estimating groundwater flow. *Transmissivity* is an aquifer’s ability to allow the movement of fluids. Transmissivity depends on the size and connectivity of pore spaces and the saturated thickness of the water-bearing zone. Aquifers that have a high transmissivity will yield and transmit more water than similar aquifers with a low transmissivity. *Specific yield* is the...
amount of water that the aquifer releases when the water table is lowered. Specific yield
accounts for the change from saturation to unsaturation due to the lowering of the water table
(Ingebritsen and Sanford, 1998).

E.3.1 EXISTING CONDITIONS

E.3.1.1 Regional Hydrogeology

In Nebraska, the principal aquifer underlying the proposed Nebraska Reroute corridor is the High
Plains Aquifer (Gutentag et al., 1984; Weeks et al., 1988). The High Plains Aquifer consists mainly
of hydraulically connected geologic units of late Tertiary or Quaternary age. The Tertiary rocks
include the Brule Formation, Arikaree Group, and Ogallala Group. The Quaternary deposits in
the aquifer consist of alluvial, dune-sand, and valley-fill deposits (Gutentag et al., 1984).

The High Plains Aquifer is a regional water-table aquifer that extends from south-central South
Dakota to the southern part of the panhandle of Texas. The High Plains Aquifer contains about
3.25 billion acre-feet of water in storage. Approximately 66 percent of the water stored in the
High Plains Aquifer is located in Nebraska (Gutentag et al., 1984). Most of this water is in the
Sand Hills.

The geologic units that make up the High Plains Aquifer could be hydraulically interconnected,
and this interconnection supports a continuous water table throughout most of the region (see
Figure E.3-1). The aquifer has an average saturated thickness of 200 feet and a maximum
saturated thickness of about 1,000 feet. The hydraulic conductivity and specific yield of the
aquifer depend on the type of sediment, which varies greatly, both horizontally and vertically.
Hydraulic conductivity typically ranges from less than 25 to 300 feet per day and averages
60 feet per day. Specific yield ranges from less than 10 to 30 percent and averages about
15 percent (Gutentag et al., 1984).

Groundwater elevations in the High Plains Aquifer along the proposed Nebraska Reroute
corridor range from about 2,400 feet above mean sea level (amsl) in Keya Paha County near the
Niobrara River to about 1,600 feet amsl in Merrick County near the Platte River. Water in the
High Plains Aquifer generally is unconfined. The configuration and slope of the water table are
similar to the configuration and slope of the land surface, but they are influenced by significant
pumping and recharge. Across Nebraska, groundwater generally flows from northwest to
southeast. Water moves in response to the slope of the water table, which typically averages
between 10 and 15 feet per mile. On the basis of this average slope and the hydraulic properties
of the aquifer, the velocity of water that moves through the aquifer is estimated to average about
1 foot per day (Gutentag et al., 1984).

The Ogallala Group is the principal geologic unit in the High Plains Aquifer. Other important
geologic deposits that form the aquifer are Quaternary-age wind-deposited loess and fine-grained
sand, alluvial silt, sand, and gravel, and Tertiary-age silts, sands, and gravels (Condra and Reed,
1943, Korus and Joeckel, 2011). The Ogallala Group consists of a heterogeneous sequence of
clays, silts, siltstone, sands, sandstone, and gravels deposited by streams that flowed eastward
from the Rocky Mountains. Within the Ogallala Group, sediment zones cemented with calcium
carbonate are resistant to weathering and form escarpments that typically mark the boundaries of
the High Plains (Gutentag et al., 1984). The saturated thickness of the Ogallala Group ranges
from 10 to 200 feet in the northern part of Nebraska to more than 800 feet in central Nebraska
beneath the Sand Hills (Bleed and Flowerday, 1990).
Figure E.3-1. Regional Groundwater along the Proposed Nebraska Reroute

Legend
- Water Table
- Groundwater Contour (feet above mean sea level)
- Nebraska Reroute
- Nebraska Sand Hills

Source: Water Table Contours, Conservation and Survey Division UNL
Hydrogeologic Units

The High Plains Aquifer consists of all or parts of several geologic units of Quaternary and Tertiary age. Table E.3-1 shows the stratigraphic column of the aquifer, including the formation name, generalized rock type, and age of the geologic units that make up the aquifer.

<table>
<thead>
<tr>
<th>Period</th>
<th>Epoch</th>
<th>Geologic Unit</th>
<th>Lithology</th>
<th>Hydrogeologic Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Holocene</td>
<td>DeForest Formation</td>
<td>Dune sands, alluvium</td>
<td>High Plains Aquifer</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Multiple loesses and alluvial units</td>
<td>Sand, gravel, silt and clay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertiary</td>
<td>Pliocene</td>
<td>Broadwater Formation</td>
<td>Sand and gravel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miocene</td>
<td>Ogallala Group</td>
<td>Sandstone and siltstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oligocene</td>
<td>Arikaree Group</td>
<td>Sandstone and siltstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eocene</td>
<td>White River Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brule Formation</td>
<td>Siltstone, sandstone and claystone</td>
<td></td>
</tr>
</tbody>
</table>

Source: Modified from Korus and Joeckel, 2011

Brule Formation

The Brule Formation of Oligocene age is the oldest geologic unit in the aquifer. The Brule Formation is the upper unit of the White River Group and is primarily massive siltstone with beds and channel deposits of sandstone. The Brule Formation underlies most of western Nebraska and generally has little permeability (which is the rate at which water moves through an aquifer). However, in some locations, the permeability of the formation has been increased by dissolution or fracturing (secondary porosity) of the formation. The Brule Formation is considered part of the aquifer only in areas where it contains saturated zones that result from interconnected secondary porosity. Where secondary porosity has not been developed, the top of the Brule Formation is considered the base of the High Plains Aquifer (Gutentag et al., 1984). Major thicknesses of this formation are found primarily in the panhandle of Nebraska.

Well yields in the Brule Formation are highly variable because the yield depends on the degree to which secondary porosity has been developed. Groundwater wells in the Brule Formation can yield up to 1,500 gallons per minute (gal/min), but wells in this formation typically yield less than 300 gal/min (Gutentag et al., 1984). Very few wells within the Nebraska Reroute are in the Brule Formation, as this units is not a major source of groundwater because of their consolidated nature (Gutentag et al., 1984).

Arikaree Group

The Arikaree Group comprises the late Tertiary deposits between the underlying Brule Formation and the overlying Ogallala Group. The Arikaree Group of Miocene and Oligocene age is above the Brule Formation and consists primarily of massive, very fine to fine-grained sandstone. Locally, the Arikaree Group includes beds of volcanic ash, siltstone, claystone, and...
The Arikaree Group is exposed at the surface in western Nebraska and pinches out to the south and east as does the Brule Formation. The maximum thickness of the Arikaree Group is about 1,000 feet in Nebraska (Gutentag et al., 1984). Major thicknesses of this formation are found primarily in the panhandle of Nebraska.

Wells completed in the Arikaree Group generally do not yield large amounts of water. Well yields of about 350 gal/min can be expected from about 200 feet of saturated thickness. Secondary porosity, similar to that in the Brule Formation, also occurs in the Arikaree Group.

**Ogallala Group**

The Ogallala Group is all Miocene rock that is younger than that in the Arikaree Group. The Ogallala Group is the principal geologic unit in the High Plains Aquifer. The Ogallala Group consists of consolidated and unconsolidated gravel, sand, silt, and clay. The Ogallala Group was deposited by an extensive eastward-flowing system of braided streams that drained the eastern slopes of the Rocky Mountains during late Tertiary time. The Ogallala Group has an average thickness of 200 to 400 feet and a maximum thickness of about 1,800 feet (Miller and Appel, 1997; Bleed and Flowerday, 1990). The aquifer thins from west to east across Nebraska.

Saturated sediments in the Ogallala Group are not distributed evenly throughout the formation. In some areas, irrigation wells that yield about 1,000 gal/min can be developed at a depth of about 100 feet in saturated sand and gravel, while in other areas, wells that yield 100 gal/min can be developed at a depth of as little as 20 feet in saturated sand and gravel (Gutentag et al., 1984).

**Broadwater Formation**

The Broadwater Formation is comprised of Pliocene rocks. The Broadwater Formation consists of mainly sand and gravel (Condon, 2005).

**Surface Deposits**

Unconsolidated deposits of Quaternary age overlie the Ogallala Group. These Quaternary-age deposits consist of gravel, sand, silt, and clay, much of which is reworked material that was derived from the Ogallala Group. These Quaternary alluvial deposits have a maximum thickness of about 400 feet. Where these unconsolidated sediments are saturated, they make up part of the High Plains Aquifer.

Deposits of loess overlie the Ogallala Group or the unconsolidated Quaternary sediments in some locations. The loess was deposited as windblown material and consists mostly of silt with small quantities of very fine-grained sand and clay. Where the loess is thick, it forms the upper unit of the High Plains Aquifer.

Sand sheets of Quaternary age make up part of the aquifer where they are saturated. The sand sheets are most extensive in north-central Nebraska where they have a thickness of about 100 feet. The sand sheets are highly porous and permeable and, therefore, quickly absorb rainfall that recharges the High Plains Aquifer (Bleed and Flowerday, 1990). Valley-fill deposits along the channels of streams, such as the Platte River, also are considered to be part of the aquifer where they are hydraulically connected. In such places, the valley-fill deposits directly link the streams to the High Plains Aquifer and allow water to move freely between the aquifer and the surface water streams.
E.3.1.2 Groundwater Basins

The proposed Nebraska Reroute corridor passes through five Natural Resources Districts (NRDs) (see Figure E.3-2). The major river basins are:

- Lower Niobrara
- Upper Elkhorn
- Lower Loup
- Lower Platte North
- Central Platte
- Upper Big Blue

The local hydrogeology is discussed in further detail for each NRD following the figure.
Figure E.3-2. Natural Resources Districts along the Proposed Nebraska Reroute

Legend
- Nebraska Reroute
- Nebraska Sand Hills

Source: Natural Resource Districts, 2010 U.S. Census Data
Lower Niobrara NRD

The proposed Nebraska Reroute corridor enters Nebraska in Keya Paha County, which is part of the Lower Niobrara NRD. This NRD includes Keya Paha and Boyd Counties.

The general hydrogeology of this NRD (see Table E.3-2) is typical for an area dominated by sediments of recent origin (Quaternary-age sands, gravel, and silt). The principal aquifer is defined as all saturated sediments of Quaternary age and the Tertiary Ogallala Formation (see Attachment B). Secondary aquifers are made up of the remaining bedrock aquifers, which range in age from Tertiary to Cretaceous. The bedrock aquifers supply a small amount of water but are an important source locally (Nebraska Department of Natural Resources [NDNR], 2005). Refer to Attachment B for the bedrock aquifer table and figures for this NRD (saturated thickness and depth to water).

The principal aquifer is generally unconfined and is hydrologically connected to the streams in the NRD (NDNR, 2005). The groundwater table reflects a pattern of groundwater movement toward the Niobrara River and its tributaries. Groundwater tends to move from the uplands to streams (NDNR, 2005).

<table>
<thead>
<tr>
<th>Table E.3-2. Lower Niobrara Hydrogeology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Saturated Thickness (feet)</strong></td>
</tr>
<tr>
<td>0–900</td>
</tr>
</tbody>
</table>

Groundwater is used for a variety of purposes including domestic, industrial, livestock, and irrigation. The main use of groundwater is for irrigation.

Upper Elkhorn NRD

The Upper Elkhorn NRD includes parts of Holt and Antelope Counties. The proposed Nebraska Reroute corridor continues through area underlain by the Ogallala Group in Holt County. The general hydrogeology of this NRD (see Table E.3-3) is complex because of the wide range of depositional environments from eolian in the west to glacial in the east. The principal aquifer units include all unconsolidated sediments of Quaternary age and the Tertiary Ogallala Group (see Attachment B). The bedrock aquifers are considered secondary aquifers that range in age from Tertiary to Cretaceous (NDNR, 2005). Refer to Attachment B for additional figures for this NRD (saturated thickness and depth to water).

<table>
<thead>
<tr>
<th>Table E.3-3. Upper Elkhorn Hydrogeology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Saturated Thickness (feet)</strong></td>
</tr>
<tr>
<td>0–800</td>
</tr>
</tbody>
</table>
The western and central parts of this NRD are hydrologically connected to the surface water streams and are unconfined (NDNR, 2005). The groundwater reflects a normal gaining stream pattern in the west and central areas and reflects the complicated nature of the glaciated area in the east. Groundwater tends to move from the uplands to the streams (NDNR, 2005).

Groundwater is used for a variety of purposes including domestic, irrigation, industrial, and livestock. The main use of groundwater is for irrigation.

**Lower Loup NRD**

The Lower Loup NRD includes most of Boone and Nance Counties. Nance County borders the Platte River Valley and the Loup River Valley aquifers. The depth to water is 50 to 100 feet bgs in the highland areas and less than 50 feet bgs in the lowland areas (Miller and Appel, 1997).

The general hydrogeology of this NRD (see Table E.3-4) reflects the nature of the eolian and fluvial origin of the recent sediments. The principal aquifer includes all saturated unconsolidated sediments of Quaternary age and the Tertiary Ogallala Formation (see Attachment B). The bedrock aquifers are considered secondary aquifers that range in age from Tertiary to Cretaceous. Refer to Attachment B for additional figures for this NRD (saturated thickness and depth to water).

The principal aquifer is generally unconfined and is hydrologically connected to the surface streams (NDNR, 2005). The groundwater table reflects the regional nature of the area, in which groundwater tends to move from the uplands to the streams (NDNR, 2005).

<table>
<thead>
<tr>
<th>Saturated Thickness (feet)</th>
<th>Depth to Groundwater (feet below ground surface)</th>
<th>Transmissivity (gallons per day per foot)</th>
<th>Specific Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1,100</td>
<td>0–200</td>
<td>20,000–250,000</td>
<td>5–20</td>
</tr>
</tbody>
</table>

Groundwater is used for a variety of purposes including domestic, irrigation, industrial, and livestock. The main use of groundwater is for irrigation (NDNR, 2005).

**Lower Platte North NRD**

The Lower Platte North NRD encompasses parts of seven counties in east central Nebraska. The Lower Platte North NRD Groundwater Management Plan subdivides the district into four regions with distinct hydrogeology. The Nebraska Reroute passes through the Shell Creek Region which extends from the Sand Hills to the Platte River. In the upper reaches of the Shell Creek Region, the principal source of groundwater is from the Ogallala Group.

The north extent of the Shell Creek Region is designated as the Upper Newman Grove. The Upper Newman Grove has a saturated thickness of 50–150 feet. Over most of the Shell Creek Region groundwater very deep and is not directly connected to surface water (Lower Platte North NRD, 2009).
Central Platte NRD

The Central Platte NRD includes most of Merrick County. This NRD is part of the Cooperative Hydrology Study (COHYST), which is a geohydrologic study of surface and groundwater resources of the Platte River Basin upstream from Columbus, Nebraska. The Cooperative Hydrology Study divides the High Plains Aquifer into eight hydrostatic units (see Attachment B). Hydrostatic units are geologic units that have been grouped based on hydraulic properties such as water storage capacity and permeability (Cannia et al., 2006). The principal aquifer consists of various Quaternary-age deposits and deposits of the Ogallala Formation of Tertiary age. Wells in these alluvial deposits yield large amounts of water (Peterson, 2007).

Upper Big Blue NRD

The Upper Big Blue NRD includes Polk and York Counties. Groundwater originates mainly as infiltration from precipitation. The basin hydrogeology is complex due to the glacially influenced origin of the sediments (see Table E.3-5). The principal aquifer includes all saturated unconsolidated sediments of Quaternary age and the Tertiary Ogallala Formation (see Attachment B). Most of the principal aquifer in the upper part of the NRD is capped by a thick mantle of loess that either does not supply a significant amount of water or is not saturated (NDNR, 2005). The bedrock aquifers are considered secondary aquifers that range in age from Tertiary to Cretaceous. Refer to Attachment B for additional figures for this NRD (saturated thickness and depth to water).

<table>
<thead>
<tr>
<th>Saturated Thickness (feet)</th>
<th>Depth to Groundwater (feet below ground surface)</th>
<th>Transmissivity (gallons per day per foot)</th>
<th>Specific Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–400</td>
<td>0–200</td>
<td>20,000–200,000</td>
<td>5–25</td>
</tr>
</tbody>
</table>

Groundwater is used for a variety of purposes including domestic, irrigation, industrial, and livestock. The main use of groundwater is for irrigation (NDNR, 2005).

E.3.1.3 Regulatory Requirements

Permits, licenses, approvals, and consultations are required prior to construction in each of the five NRDs.

Lower Niobrara NRD

Well construction in the Lower Niobrara NRD would require a Ground Water Well Permit for a well that pumps over 50 gal/min. This permit would allow groundwater to be pumped and used for an approved beneficial use.

Upper Elkhorn NRD

Well construction in the Upper Elkhorn NRD would require a Ground Water Well Permit and a Request for Variance. The Ground Water Well Permit would permit a well that pumps over 50 gal/min. The Request for Variance would allow groundwater to be used where water rights
are limited for new development. These permits would allow groundwater to be used for an approved beneficial use.

**Lower Loup NRD**

Well construction in the Lower Loup NRD would require a Well Construction Permit for a well that pumps over 50 gal/min. This permit would allow groundwater to be used for an approved beneficial use.

**Lower Platte North NRD**

The Lower Platte North NRD has established a groundwater management area (GWMA) for quality purposes. As part of the GWMA requirements, permits are required prior to the construction of wells pumping greater than 50 gallons per minute (NDNR, 2005).

**Central Platte NRD**

Well construction in the Central Platte NRD would require a Request of Variance, which would allow groundwater to be used where rights are fully appropriated. This Request for Variance would allow groundwater to be used for an approved beneficial use.

**Upper Big Blue NRD**

Well construction in the Upper Big Blue NRD would require a permit to construct a water well and an authorization to transfer groundwater. Water use in the Upper Big Blue NRD is also subject to the Kansas-Nebraska Big Blue River Compact.

### E.3.1.4 Water Quality

**Safe Drinking Water Act**

The Safe Drinking Water Act was originally passed by Congress in 1974 to protect Americans’ health by regulating the nation’s public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and groundwater wells. Under the Safe Drinking Water Act, the U.S. Environmental Protection Agency (EPA) sets legal limits on the levels of certain contaminants in drinking water. The legal limits reflect both the level that protects human health and the level that water systems can achieve using the best available technology (EPA, 2012).

**National Primary Drinking Water Regulations**

National Primary Drinking Water Regulations (primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water (EPA, 2012).

**National Secondary Drinking Water Regulations**

National Secondary Drinking Water Regulations (secondary standards) are non-enforceable guidelines regulating contaminants that can cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards for water systems, but these standards are not enforceable. However, States may choose to adopt them as enforceable standards (EPA, 2012).
Title 118 – Ground Water Quality Standards and Use Classification

Groundwater quality in Nebraska is regulated by Nebraska Department of Environmental Quality (NDEQ) through Title 118 – Ground Water Quality Standards and Use Classification (Standards). The Standards are intended to be the foundation for other groundwater regulatory programs and are implemented in conjunction with other regulatory programs. If other regulatory programs do not exist, these Standards alone may be used as the basis for remedial action of groundwater contamination. The groundwater standards and groundwater classifications apply to all groundwaters of the state with the exception of an aquifer or a part of an aquifer that has been exempted through the Rules and Regulations of the Nebraska Oil and Gas Conservation Commission, or through NDEQ Title 122 – Rules and Regulations for Underground Injection and Mineral Productions Wells (NDEQ, 2006).

Numerical standards (maximum contaminant levels) apply to groundwater in Nebraska. The numerical standards are intended to protect the beneficial uses of groundwater. The standards apply if beneficial uses of groundwater would be impaired, if public health and welfare would be threatened, or if the beneficial use of hydrologically connected groundwaters would be impaired. Any substance introduced directly or indirectly by human activity is not allowed to enter groundwater if one or more of the numerical standards would be exceeded or if it degrades the present groundwater quality. Any pollutant introduced directly or indirectly by human activity that would impair the beneficial uses of groundwater due to unacceptable color, corrosivity, odor, or any other aesthetic characteristic is also not allowed (NDEQ, 2006).

High Plains Aquifer Water Quality

The quality of the water in the High Plains Aquifer generally is suitable for irrigation use, but, in many places, the water does not meet EPA’s drinking-water regulations. Excessive concentrations of dissolved solids (see Table E.3-6), fluoride, chloride, and sulfate are present in parts of the aquifer (Gutentag et al., 1984).

The dissolved-solids concentration in groundwater is a general indicator of the chemical quality of the water. Dissolved-solids concentrations in water from the High Plains Aquifer are less than 500 milligrams per liter (mg/L) in most of Nebraska, but locally they can exceed 1,000 mg/L. Generally, dissolved-solids concentrations are lowest in areas covered by sand because of relatively high rates of recharge and because the sand contains few readily soluble minerals.

Excessive concentrations of sodium in water can adversely affect plant growth and soil properties, and they also present salinity and sodium hazards that can limit irrigation and the associated agriculture development. Sodium concentrations in water from the High Plains Aquifer in Nebraska are less than 25 mg/L (Gutentag et al., 1984).

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Secondary Standard (^a)</th>
<th>Maximum Contaminant Level (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dissolved solids (TDS)</td>
<td>500 milligrams per liter</td>
<td>500 milligrams per liter</td>
</tr>
</tbody>
</table>

\(^a\) Source: National Secondary Drinking Water Regulations

\(^b\) Source: Nebraska Department of Environmental Quality, Title 118 – Ground Water Quality Standards and Use Classification
Farming and livestock operations affect shallow groundwater. Where crops are irrigated in areas with shallow groundwater, there are elevated levels of fertilizers, pesticides, and herbicides. Concentrations of these constituents are generally higher in the near-surface groundwater (Stanton and Qi, 2006).

**E.3.1.5 Shallow Aquifers**

Shallow aquifers are areas where the groundwater is less than 50 feet bgs. Shallow aquifers were identified using digital data provided by NDNR. The database from which this data was taken includes data from 1957 to the present and is regularly updated by NDNR. The digital data used in the interpolation were downloaded in July 2012. Figure E.3-3 shows the average groundwater depth below the surface.

Review of the average groundwater depth indicated that shallow aquifers within the 110-feet permanent easement are present in Keya Paha, Holt, and Merrick Counties.
Figure E.3-3. Static Groundwater Levels along the Proposed Nebraska Reroute

Legend
- Nebraska Reroute
- Nebraska Sand Hills
- Depth to Static Groundwater
  - 0 - 5 ft
  - 5 - 10 ft
  - 10 - 15 ft
  - 15 - 20 ft
  - 20 - 50 ft

Source: Static Groundwater Levels, Nebraska DNR Wells
E.3.1.6 Groundwater Use and Registered Well Survey

A database analysis was conducted to determine the presence of water wells within the 110-foot temporary construction easement. The database used was a publicly available and searchable database maintained by NDNR. The database was queried for data about domestic, livestock, irrigation, and public water supply wells.

Table E.3-7 lists the only registered groundwater well within the temporary pipeline construction easement as of the date of the search (see Figure E.3-4) (NDNR, 2012). The Draft Evaluation Report listed five groundwater wells within or very close to the temporary easement. It was confirmed in the FER development process that these four wells are outside the 150 foot construction ROW and were removed from the Final Evaluation Report. The remaining identified well within the temporary easement is an irrigation well. The main use of groundwater along the proposed Nebraska Reroute corridor is for irrigation (NDNR, 2012). Not all wells are registered in the NDNR database. In particular, stock and domestic wells drilled before 1993 are not required to be registered. Certain dewatering and other temporary wells are also not required to be registered.

Table E.3-7. Registered Groundwater Well within the Temporary Pipeline Construction Easement for the Proposed Nebraska Reroute

<table>
<thead>
<tr>
<th>Well Registration Number</th>
<th>County</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Total Depth (feet)</th>
<th>Static Water Level (feet)</th>
<th>Use</th>
<th>Pumping Rate (gallons per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-108715</td>
<td>Antelope</td>
<td>42.34230</td>
<td>-98.1791</td>
<td>360</td>
<td>78</td>
<td>Irrigation</td>
<td>900</td>
</tr>
</tbody>
</table>
Figure E.3-4. Registered Groundwater Well within the Temporary Construction Easement for the Proposed Nebraska Reroute

Legend
- One Registered Well within 110 foot Construction ROW
- Nebraska Reroute
- Nebraska Sand Hills

Source: Wells, Nebraska DNR
E.3.1.7 Wellhead Protection Areas

In Nebraska, Wellhead protection areas (WHPAs) and protection activities (including Wellhead Protection Area Plans) are established on a voluntary basis by local communities and state governments to protect municipal groundwater resources. WHPAs are generally defined as surface and subsurface areas that surround a water well or well field supplying a public water system and through which contaminants are reasonably likely to move toward and reach the water well or well field (NDEQ, 2001). The Nebraska Wellhead Protection Program generally includes a 20-year time of travel area in WPAs for community wells. This time of travel area is determined based on computer modeling that accounts for geologic information and the amount of groundwater pumped annually from the specific well or wells in the system (TransCanada Keystone Pipeline, LP [Keystone], 2012).

WPAs within 1 mile of the proposed Nebraska Reroute corridor were evaluated. The Keystone XL Pipeline would not pass through any mapped WHPAs, but the proposed Nebraska Reroute would pass within 1 mile of the WHPAs for St. Edward (Boone County) and Bradshaw (York County). The Nebraska Reroute would be within a half mile downgradient of the St. Edward WHPA boundary and approximately a half mile upgradient of the Bradshaw WHPA boundary (see Figure E.3-5).
Figure E.3-5. Wellhead Protection Areas along the Proposed Nebraska Reroute

Legend
- Nebraska Reroute
- Nebraska Sand Hills
- Wellhead Protection Area One Mile Radius

Source: Wellhead Protection Areas, NDEQ


E.3.1.8 Irrigation Infrastructure

Nebraska is an important national agricultural area, and groundwater withdrawn from the High Plains Aquifer is the principal water resource for most of Nebraska. Irrigation in Nebraska is possible because of the availability of large quantities of groundwater that are suitable for irrigation. In the 1960s, the development of center-pivot irrigation systems that were adapted to sandy soils and rolling terrain made land available for irrigation that previously was not suitable for furrow irrigation (Gutentag et al., 1984).

As Table 4.10-5 shows, there are approximately 1,644 acres of cropland within the width of the temporary pipeline easement. A large portion of this cropland is irrigated with center-pivot systems.

E.3.2 POTENTIAL IMPACTS

Potentially affected groundwater resources within the proposed Nebraska Reroute corridor include shallow aquifers, WHPAs, and groundwater wells. Potential impacts on groundwater resources from construction, operation, and maintenance of the pipeline were evaluated.

E.3.2.1 Construction

Potential impacts on groundwater during construction activities would include:

- Aquifer impacts due to water use and dewatering during construction
- Contamination of shallow aquifers from releases of fuel or other chemical contamination from construction-related equipment

Water for Construction

Water will be used during construction of the pipeline. Water will be used to control dust, perform hydrostatic testing of the pipeline and facility piping (described further below), and perform horizontal directional drilling (HDD) activities. Other potential uses of water during construction include washing equipment, providing water when placing backfill or embankment, and hydromulching. Potable water might also need to be supplied from groundwater sources for potential construction camps. Groundwater resources along the proposed Nebraska Reroute corridor might be used for these activities. Groundwater recharge and production in domestic and irrigation wells could decrease.

Hydrostatic Testing

Groundwater might need to be withdrawn for hydrostatic testing where surface water or municipal sources are not available or cannot be used. Hydrostatic testing of the pipeline would need to comply with the requirements of a National Pollutant Discharge Elimination System (NPDES) Permit (NEG672000) that authorizes the discharge of water used for hydrostatic testing to upland areas or into surface waters. NDEQ administers this permit to control the pollutant discharges from hydrostatic testing.

Construction Camp

Rural Nebraska might not have enough temporary housing near the proposed Nebraska Reroute corridor to house all the construction personnel working in those areas. In those remote and rural
areas, a temporary work camp might be constructed to meet the housing needs of the construction workforce. The construction camp site (and associated contractor yard) could be up to 100 acres in size. Part of that area might be used as a contractor yard, while the majority would be used for housing and administration facilities. The camps would require systems and infrastructure, including parking, for up to 900 workers (Keystone, 2012).

Potable water would be provided by drilling a well where feasible. If enough water could not be obtained from a well, water would be obtained from municipal sources or trucked to the camp. A self-contained wastewater treatment facility would be included in each camp except where a licensed and permitted publically owned treatment works could practicably be used (U.S. Department of State [DOS], 2011). Permits would also need to be obtained as necessary for drilling wells and withdrawing and using groundwater.

Required permits include a permit from Nebraska Department of Health and Human Services to operate a public water system for the construction camp and an Onsite Wastewater Permit or Wastewater Construction Permit to build a wastewater treatment system at the construction camp.

Groundwater Contamination

Aquifers are susceptible to contamination from a variety of human activities. The vulnerability of an aquifer to contamination depends on a number of factors: the type and thickness of the overlying deposits (both soil and geology), the thickness of the unsaturated zone (that is, the depth to the water table), the speed with which the water flows through both the unsaturated and saturated zones, and contaminant characteristics such as solubility, mobility, toxicity, and durability.

Certain areas within the Ogallala Group of the High Plains Aquifer have soil or lithologic zones that inhibit the downward migration of contaminants (Gurdak et al., 2009). In these areas, dissolved chemicals from the land surface are transported to the water table more slowly, taking decades to centuries (Gurdak et al., 2009). However, even in these areas, local preferential flow paths could allow dissolved chemicals to move faster through the unsaturated zone to the water table. These preferential flow paths are more likely to be present beneath topographic depressions, where precipitation or surface water collects. Preferential flow paths with lower infiltration rates are more likely to be present in areas of fine-grained sediments or beneath flat terrain where free-standing water does not pool or collect (Gurdak et al., 2009).

Shallow Aquifers

Shallow groundwater is at a higher risk of being adversely affected by human activities than deep aquifers. Surface spills, agricultural chemicals, feedlot wastes, and other sources of contamination will affect shallow groundwater faster than deeper groundwater.

It might be necessary to dewater trenches while lowering in and backfilling areas with shallow groundwater. Dewatering could temporarily draw down the aquifer.

Wellhead Protection Areas

WPAs downgradient of the proposed Nebraska Reroute corridor could be at risk of contamination. A WHPA might be the only source of drinking water for local residents and livestock.
E.3.2.2 Spills and Leaks

Construction and operation activities that could reduce groundwater quality include inadvertent releases from the refueling and maintenance of construction equipment, leaks from equipment hoses and seals, and the storage, transportation, and use of petroleum and hazardous materials. Chapter 5 discusses the mitigation associated with construction impacts on groundwater resources associated with spills and leaks of hazardous liquids.

E.3.2.3 Normal Operation

Spills during operation of the pipeline could reduce the quality of groundwater. Operational spills could originate from the pipeline, pumping stations, or delivery points. The extent of the impact would be related to the quantity of product released, the topography, the weather and soil conditions (such as temperature, precipitation, soil saturation, ground frost, etc.), the soil type(s) above the groundwater table, the characteristics of the contaminant (its solubility, permeability, toxicity, durability, etc.), the depth to groundwater, and the speed and effectiveness of emergency response measures. Groundwater wells located outside the pipeline easement could be adversely affected by surface or subsurface releases of contaminants.

E.3.3 MITIGATION

Keystone has committed to implement the procedures in its Construction, Mitigation, and Reclamation Plan (CMRP) (Keystone, 2012). This plan provides several measures that would reduce or avoid the impacts described above. A brief summary of the commitments relative to groundwater is presented below.

The potential for contamination of water supplies is a major concern for Nebraskans. The impacts of a spill are discussed in detail in Chapter 6, Pipeline Safety and Potential Spills. Keystone has also committed to conducting baseline water quality testing for domestic and livestock wells within 300 feet of the final centerline of the approved route in Nebraska, upon the request of individual landowners who provide the necessary access to perform the testing. These baseline samples would be collected prior to placing the pipeline in service. Subsequently, in the event of a significant spill in the area, Keystone would conduct water well testing as required by NDEQ pursuant to Title 118 of the Nebraska Administrative Code. Keystone would also provide an alternative water supply for any well in which water quality was found to be compromised by the spill.

Keystone has also committed to ensuring the safe operation of its pipeline to prevent any incidents from occurring. Should a release occur from the Keystone XL pipeline, Keystone has committed to clean up any releases that may occur. Keystone is also legally required to clean up spills under Title 118 and the Oil Pollution Act of 1990. In addition to all of the above, and in response to public concerns, Keystone would commit to file annually with the NDEQ, by May 1 of each year:

(a) A certificate of insurance as evidence that it is carrying a minimum of $200 million in third-party liability insurance adjusted by calculating the GDP-IPD from the date of a Presidential Permit is issued for the project and adjusting the amount of third-party liability insurance policy by this percentage. The third-party liability insurance shall cover sudden and accidental pollution incidents from Keystone XL Pipeline in Nebraska, and
Keystone has also committed to keeping abreast of the latest developments in external leak-detection technologies (above and beyond those already proposed to be implemented on the project, as described in the August 2011 Final Environmental Impact Statement), that could be installed along the pipeline at sensitive locations. Keystone would report to, and discuss with, the NDEQ the status of innovation in such pipeline leak-detection equipment and methods on or before January 1, 2014, and at such times thereafter until 2024 as the NDEQ shall specifically request, but in no case more frequently than once in every 3 years.

Once a final project route would be determined in Nebraska, Keystone will conduct a detailed spill risk assessment for the section of the Keystone XL Pipeline in the state. Utilizing that assessment, Keystone will determine the optimal location of spill response equipment and resources, taking into account response times to sensitive areas and receptors. The spill response locations will be reflected in the Emergency Response Plan that Keystone will submit to the federal Pipeline and Hazard Materials Safety Administration for review and approval.

E.3.3.1 Water for Construction

The use of water for construction will comply with all water-use and water-rights regulations. Because construction activities would move and the construction in any area would be relatively brief, no long-term effects on groundwater levels are expected.

E.3.3.2 Hydrostatic Testing

Hydrostatic test water will be tested and discharged in accordance with state and federal permits. All applicable water withdrawal and discharge permits will be acquired prior to hydrostatic testing. Hydrostatic testing is not expected to cause long-term effects on groundwater levels. Hydrostatic testing would be a one-time event and would not entail a prolonged used of water resources.

E.3.3.3 Wellhead Protection Areas

Route variations were made to avoid WHPAs. Even with the route variations to avoid WHPAs, mitigation activities will include the use of best management practices (BMPs) to reduce potential impacts that would impair water quality, decrease yield, or potentially disrupt service.

E.3.3.4 Shallow Aquifers

Dewatering activities for trench construction in shallow aquifers will be completed in accordance with NPDES requirements and BMPs.

Groundwater contamination in shallow aquifers from pipeline leaks and potential spills from construction activities would be addressed by the procedures in Keystone’s Spill Prevention, Containment, and Countermeasure Plan (SPCC), which would be prepared specifically for the Nebraska Reroute. An outline of this plan is provided in Section 3.0 of the CMRP, which is shown in Appendix C of this Draft Evaluation Report.

The SPCC would provide detailed requirements for preventing spills and would include such issues as managing hazardous materials during construction in staging areas and in the
construction right-of-way. The SPCC requires developing emergency response procedures for all incidents involving hazardous materials that could pose a threat to human health or the environment. The SPCC also prescribes requirements for emergency response equipment (such as first aid supplies, radios, hand-held fire equipment, and so forth) in all areas where hazardous materials are handled or stored.

The SPCC would also establish emergency notification procedures. These procedures would identify the individuals and agencies to be contacted in the event of a spill that meets government reporting requirements.

Finally, the SPCC would prescribe the procedures to be followed in the event of a spill. For example, when notified of a spill, Keystone would immediately ensure that:

- Action is taken to control danger to the public and personnel at the site.
- Spill contingency plans are implemented and necessary equipment and personnel are mobilized.
- Measures are taken to isolate or shut down the source of the spill.
- All resources necessary to contain, recover, and clean up the spill are available.
- Any resources requested by the contractor from Keystone are provided.
- The appropriate agencies are notified. For spills on public land, into surface water, or into sensitive areas, the appropriate federal or State managing office would also be notified and involved in the incident.

E.3.3.5 Spills and Leaks

Groundwater contamination from potential operational pipeline leaks and spills will be addressed by specific preventive and mitigative measures discussed in Chapters 5 and 6.

E.3.4 WESTERN ALTERNATIVE

The Western Alternative was developed to avoid the WHPA near Western. The Final EIS alignment is now located upgradient of the WHPA near Western.

E.3.5 REFERENCES


———. 2006. Title 118 – Groundwater Quality Standards and Use Classification.


## Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation or Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bgs</td>
<td>below ground surface</td>
</tr>
<tr>
<td>BMP</td>
<td>best management practice</td>
</tr>
<tr>
<td>COHYST</td>
<td>Cooperative Hydrology Study</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>gal/min</td>
<td>gallons per minute</td>
</tr>
<tr>
<td>HDD</td>
<td>horizontal directional drilling</td>
</tr>
<tr>
<td>mg/l</td>
<td>milligrams per liter</td>
</tr>
<tr>
<td>NDEQ</td>
<td>Nebraska Department of Environmental Quality</td>
</tr>
<tr>
<td>NDNR</td>
<td>Nebraska Department of Natural Resources</td>
</tr>
<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
</tr>
<tr>
<td>NRD</td>
<td>Natural Resources District</td>
</tr>
<tr>
<td>TDS</td>
<td>total dissolved solids</td>
</tr>
<tr>
<td>UNL</td>
<td>University of Nebraska–Lincoln</td>
</tr>
<tr>
<td>WPA</td>
<td>wellhead protection area</td>
</tr>
</tbody>
</table>
# Lower Niobrara

<table>
<thead>
<tr>
<th>System</th>
<th>Hydrogeologic Unit</th>
<th>Character and Description</th>
<th>Maximum Thickness (feet)</th>
<th>Hydrogeologic Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Recent to Late Pleistocene Deposits</td>
<td>Gravel, sand, silt and clay. Includes dune sand and loess in upland areas and think alluvial deposits below the floors of principal valleys.</td>
<td>150</td>
<td>An important source of water where saturated. Beds of sand and gravel below bottom land yield small to moderate amounts of water to wells. Some deposits mantling upland areas may also serve as water sources. Variable water quality, generally suitable for livestock and domestic use.</td>
</tr>
<tr>
<td></td>
<td>Early Pleistocene Deposits</td>
<td>Gravel, sand, silt and clay in upland areas. Generally south of the Niobrara River.</td>
<td>175</td>
<td>Thick saturated deposits of sand and gravel yield moderate to large quantities of water to wells.</td>
</tr>
<tr>
<td></td>
<td>Dune Sand</td>
<td>Wind-blown very fine to fine sand</td>
<td>200</td>
<td>Yields large supplies to stock wells tapping thick sequences of saturated sand.</td>
</tr>
<tr>
<td></td>
<td>Grand Island Formation</td>
<td>Cross-bedded sand and gravel deposits derived mostly from granitic crystalline rocks.</td>
<td>100</td>
<td>Yields moderately large to large amounts of water tapping thick sequences of saturated material.</td>
</tr>
<tr>
<td></td>
<td>Holdrege Formation</td>
<td>Sand and gravel made up mostly of reworked Tertiary material and some quartz and granitic crystalline material.</td>
<td>50</td>
<td>Yields large supplies of water.</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Ogallala Group</td>
<td>Fine to medium sand and silt containing volcanic ash; calcareous in places.</td>
<td>400</td>
<td>Yields small to moderately large amounts of water to wells tapping thick beds of saturated material.</td>
</tr>
<tr>
<td></td>
<td>Miocene Silt Beds</td>
<td>Silt, Clay, siltstone and claystone beds</td>
<td>80</td>
<td>Source of water to stock and domestic wells in some places. Excellent water quality.</td>
</tr>
<tr>
<td></td>
<td>Brule Formation</td>
<td>Sandy siltstone.</td>
<td>350</td>
<td>Not a source of water</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Pierre Shale</td>
<td>Claystone, shale, chalk to chalky shale</td>
<td>800</td>
<td>Yields little to no water to wells, generally very poor quality</td>
</tr>
<tr>
<td></td>
<td>Niobrara Formation</td>
<td>Chalk, shaly chalk, shale and limestone</td>
<td>220</td>
<td>Not an important source of water</td>
</tr>
<tr>
<td></td>
<td>Carlile Shale</td>
<td>Sandstone, siltstone and clayey siltstone</td>
<td>60</td>
<td>Yields water, satisfactory for livestock and domestic purpose</td>
</tr>
</tbody>
</table>

*Source: Modified from NDNR, 2005*
## Upper Elkhorn

<table>
<thead>
<tr>
<th>System</th>
<th>Hydrogeologic Unit</th>
<th>Character and Description</th>
<th>Maximum Thickness (feet)</th>
<th>Hydrogeologic Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Alluvium, loess, dune sand and soil</td>
<td>Clay, silt, sand and gravel alluvium in reworked stream valley lands and sand and gravel in stream channels. Loess deposited on valley terraces and upland surfaces</td>
<td>30</td>
<td>Not an important source of water except in areas where the water table is close to land surface.</td>
</tr>
<tr>
<td></td>
<td>Peorian Loess</td>
<td>Wind deposits of massive clay on uplands an on terraces; some dune sands</td>
<td>45</td>
<td>Yields water slowly to wells in areas where it occurs below the water table.</td>
</tr>
<tr>
<td></td>
<td>Todd Valley Formation</td>
<td>Eolian or alluvial sand and gravel. Dune-like topography on upper surfaces.</td>
<td>50</td>
<td>May yield water to wells where it occurs below the water table.</td>
</tr>
<tr>
<td></td>
<td>Loveland Formation</td>
<td>Stratified silt and clay and fine sand laminae in valleys. Massive silt and clay (loess) in uplands.</td>
<td>50</td>
<td>Yields water slowly to wells in areas where it occurs below the water table.</td>
</tr>
<tr>
<td></td>
<td>Crete Formation</td>
<td>Sand and gravel deposited as channel fill. Modified by local materials.</td>
<td>30</td>
<td>May yield water to wells in areas where it occurs below the water table.</td>
</tr>
<tr>
<td></td>
<td>Kansan (Glacial) Drift</td>
<td>Boulder till</td>
<td>100</td>
<td>Not an important source of water.</td>
</tr>
<tr>
<td></td>
<td>Grand Island Formation</td>
<td>Sand and gravel deposited by streams</td>
<td>75</td>
<td>Yields abundant good quality water to wells in areas where it occurs below the water table.</td>
</tr>
<tr>
<td></td>
<td>Holdrege Formation</td>
<td>Fluvial sand and gravel</td>
<td>15</td>
<td>Yields abundant supplies of good quality water to wells.</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Ogallala Group</td>
<td>Fluvial gravel, sand, silt and clay</td>
<td>200</td>
<td>Yields abundant supplies of good quality water to wells.</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Pierre Shale</td>
<td>Shale that is generally weathered at the top.</td>
<td>400</td>
<td>Not an important source or water but may yield small amounts of poor quality water were fractured.</td>
</tr>
<tr>
<td></td>
<td>Niobrara Formation</td>
<td>Soft shaley limestone or impure chalk with some clay</td>
<td>250</td>
<td>Not an important source by may yield small amounts of water to wells.</td>
</tr>
</tbody>
</table>

*Source: Modified from NDNR, 2005*
## Lower Loup

<table>
<thead>
<tr>
<th>System</th>
<th>Hydrogeologic Unit</th>
<th>Character and Description</th>
<th>Maximum Thickness (feet)</th>
<th>Hydrogeologic Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent to Quaternary</td>
<td>Undifferentiated sand, gravel, silt and clay</td>
<td>Eolian (dune) sand and alluvial fill. Sandy and clayey silt and sandy clay</td>
<td>180</td>
<td>Provides moderate to high well yields</td>
</tr>
<tr>
<td></td>
<td>Todd Valley Sand</td>
<td>Fine sand and gravel deposited as valley fill.</td>
<td>50</td>
<td>Yield water to wells in areas where it is saturated</td>
</tr>
<tr>
<td></td>
<td>Crete Formation</td>
<td>Sand and gravel deposited as channel fill. Modified by local materials.</td>
<td>30</td>
<td>Yield water to wells in areas where it is saturated</td>
</tr>
<tr>
<td></td>
<td>Grand Island Formation</td>
<td>Sand and gravel deposited by streams</td>
<td>60</td>
<td>Yield water to wells in areas where it is saturated</td>
</tr>
<tr>
<td></td>
<td>Holdrege Formation</td>
<td>Sand and gravel deposited by streams</td>
<td>15</td>
<td>Yields abundant supplies of water to wells</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Plio-Pleistocene sands and gravels</td>
<td>Sand and gravel interbedded with silt.</td>
<td>&gt;100</td>
<td>High capacity wells</td>
</tr>
<tr>
<td></td>
<td>Ogallala Group</td>
<td>Sand, silty sand, sandy and clayey silt, sandstone, siltstone and some gravel</td>
<td>600</td>
<td>Hydraulically connected to unconsolidated sediments, part of the primary aquifer.</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Niobrara Formation</td>
<td>Shaley chalk and limestone</td>
<td>400</td>
<td>Secondary aquifer where fractured.</td>
</tr>
</tbody>
</table>

*Source: Modified from NDNR, 2005*
## Groundwater Technical Memorandum
### Central Platte

<table>
<thead>
<tr>
<th>System</th>
<th>Hydrogeologic Unit¹</th>
<th>Character and Description</th>
<th>Hydrogeologic Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valley-fill deposits</td>
<td>Gravel, sand silt and clay</td>
<td>Source of major supply of water in the alluvial valleys</td>
<td></td>
</tr>
<tr>
<td>Dune Sands</td>
<td>Generally fine sand but may contain some medium to coarse sand. Wind blown deposits</td>
<td>Source of water to livestock and domestic wells. Usually shallow groundwater</td>
<td></td>
</tr>
<tr>
<td>Loess Deposits</td>
<td>Generally silt, but may contain some very fine sand and clay. Deposited as wind blown dust.</td>
<td>Rarely used as water source for low yielding wells</td>
<td></td>
</tr>
<tr>
<td>Alluvial Deposits</td>
<td>Gravel, sand, silt, and clay</td>
<td>Major source of water</td>
<td></td>
</tr>
<tr>
<td>Broadwater Formation</td>
<td>Coarse fluvial gravel and sand with some silt and clay</td>
<td>Major source of water where saturated thickness is sufficient for large capacity wells</td>
<td></td>
</tr>
<tr>
<td>Ogallala Group</td>
<td>Heterogeneous mixture of gravel, sand, silt, and clay. Generally stream deposits, but also contains wind blown deposits</td>
<td>Major source of water</td>
<td></td>
</tr>
<tr>
<td>Arikaree Group</td>
<td>Very fine to fine-grained sandstone, but may also contain siltstone</td>
<td>Not a major source of water in eastern model unit</td>
<td></td>
</tr>
<tr>
<td>Brule Formation of White River Group</td>
<td>Predominately siltstone, but may contain sandstone and channel deposits</td>
<td>Generally an aquiclude except where fractured or alluvial channel deposits exist</td>
<td></td>
</tr>
<tr>
<td>Chadron Formation of White River Group</td>
<td>Silt, siltstone, clay and claystone</td>
<td>Generally an aquiclude for basal fluvial sediments</td>
<td></td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Undifferentiated</td>
<td>Shale, chalks, limestone, siltstone and sandstone</td>
<td>Generally an aquiclude except for sand deposits.</td>
</tr>
</tbody>
</table>

¹Stratigraphic description of geologic and hydrostatigraphic units used in the Cooperative Hydrology Study
Source: Modified Gutentag et al. 1984
### Upper Big Blue

<table>
<thead>
<tr>
<th>System</th>
<th>Hydrogeologic Unit</th>
<th>Character and Description</th>
<th>Maximum Thickness (feet)</th>
<th>Hydrogeologic Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Undifferentiated fluvial and terrace deposits, Todd Valley Sand</td>
<td>Clay, silt, sand and fine gravel; underlie valley-side terraces and valley floor of drainage courses. Sand and gravel valley and terrace deposits, mostly along stream valleys</td>
<td>30</td>
<td>Generally saturated, wells yield water at a moderate rate.</td>
</tr>
<tr>
<td></td>
<td>Crete Formation, Undifferentiated fluvial, lacustrine and eolian deposits.</td>
<td>Sand and gravel channel-fill deposits. Silt, sand and gravel restricted to broad valleys.</td>
<td>130</td>
<td>Generally saturated where thick and coarse textured, yields water to wells at a high rate.</td>
</tr>
<tr>
<td></td>
<td>Sappa Formation</td>
<td>Stratified deposits of silt, clay sand and gravel</td>
<td>60</td>
<td>Sand lenses yield water at a slow rate in wells.</td>
</tr>
<tr>
<td></td>
<td>Grand Island Formation</td>
<td>Stream deposited sand and gravel with a persistent aqueous-eolian deposited silt and clay later</td>
<td>200</td>
<td>Yields abundant water to wells.</td>
</tr>
<tr>
<td></td>
<td>Red Cloud sand and gravel and Holdrege Formation</td>
<td>Stream deposited sand and gravel with nonsistent silt and clay, probably of aqueous eolian origin</td>
<td>200</td>
<td>Yields abundant water to wells.</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Ogallala Group</td>
<td>Silt, sandy and clayey silt with lenses of sand and gravels, partly calcareous</td>
<td>200</td>
<td>Not an important supply of water. May yield sufficient water to domestic wells</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Niobrara Formation</td>
<td>Chalky shale, weathered in parts</td>
<td>380</td>
<td>Generally not known as a source of water but yields water to wells at a moderate rate where it is fractured.</td>
</tr>
</tbody>
</table>

*Source: Modified from NDNR, 2005*
Appendix E.3 | Groundwater Technical Memorandum

Depth to Water
BIG BLUE RIVER BASIN

Explanations:
- Big Blue Basin
- Depth to Water
  - 0 - 50 feet
  - 50 - 100 feet
  - 100 - 200 feet
  - > 200 feet

Cultural Features
- County Boundary
- State Boundary
- NRCS Boundary

Location Map

Figures BB-21, BB-32

Base map produced by Josh Lee, February 4, 2005
Base map approved February 6, 2005
Depth to water map produced by Kevin J. Schwartzman, October 6, 2005
# Lower Platte North

<table>
<thead>
<tr>
<th>System</th>
<th>Hydrogeologic Unit</th>
<th>Character and Description</th>
<th>Maximum Thickness (feet)</th>
<th>Hydrogeologic Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Platte River Aquifer</td>
<td>Alluvial sand, gravel and silt deposited within incised bedrock valley of the Platte River</td>
<td>70</td>
<td>Unconfined and hydraulically connected with Platte River. Yields 900 to 2,000 gal/min of water to wells.</td>
</tr>
<tr>
<td></td>
<td>Missouri River Aquifer</td>
<td>Alluvial sand, gravel and silt deposited within incised bedrock valley of the Missouri River</td>
<td>80</td>
<td>Wells generally yield 300 to 700 gal/min, and locally yield as much as 1,500 gal/min.</td>
</tr>
<tr>
<td></td>
<td>Paleovalley Alluvial Aquifers</td>
<td>Fluvial silt, sand, gravel and clay deposits within bedrock valleys. Commonly underlying thick fine-grained deposits of glacial till and loess</td>
<td>275</td>
<td>May yield 400 to 1,200 gal/min of water to wells</td>
</tr>
<tr>
<td></td>
<td>Loess</td>
<td>Silt with a little very fine sand and clay deposited as wind-blown dust</td>
<td>Unknown</td>
<td>May provide small amounts of water to shallow stock or domestic wells.</td>
</tr>
<tr>
<td></td>
<td>Till</td>
<td>Ice deposited silty, sandy clay with some gravel, pebble and cobbles</td>
<td>Unknown</td>
<td>Relatively impermeable, but may contain small perched groundwater or sand deposits that yield water to small capacity wells.</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Ogallala Group</td>
<td>Gravel, sand, silt, clay, with some lime-cemented beds</td>
<td>0-200</td>
<td>Not an important source of water in the Lower Platte River Basin</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Dakota Sandstone</td>
<td>Massive to crossbedded friable sandstone interbedded with clayey to slightly sandy shales</td>
<td>&lt;140</td>
<td>Wells can yield 50 to 750 gal/min of water to wells. Water is of variable quality. Used as a primary water source only when other sources are not available.</td>
</tr>
</tbody>
</table>

*Source: Modified from NDNR, 2005*
Saturated Thickness
LOWER PLATTE RIVER BASIN

Explanation
- Lower Platte basin
- Saturated Thickness
  - Absent
  - 0 - 100 ft.
  - 100 - 200 ft.
  - 200 - 300 ft.
  - 300 - 400 ft.
  - 400 - 500 ft.
  - > 500 ft.

Cultural Features
- County Boundary
- State Boundary
- NDR Boundary

This map is intended only as a general information resource and may not be used for legal boundaries or real estate transactions. Users should consult local authorities for information needed for those purposes.

Figure LP-16.

Base map produced by Josh Loef, February 4, 2005
Saturated thickness map produced by Kevin J. Schwartman, October 12, 2005

LP-27
References