Hydrogeological and Subarea Delineation Report

Prepared for:
Lower Big Blue Natural Resources District

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1.0 INTRODUCTION

The Lower Big Blue Natural Resources District (NRD) is located in the southeast corner of Nebraska and covers approximately 1,646 square miles (see Figure 1, Location Map Lower Big Blue Natural Resources District). It includes portions of Saline, Gage, Jefferson, and Pawnee counties. The District has a complex assemblage of aquifers that supply most of the water used for irrigation, drinking and by industry. With 274 dams providing flood control in 11 completed watersheds, the Lower Big Blue NRD is considered the Watershed Capital of Nebraska. The Big Blue River and its tributaries are the sources of surface water in the area, though they are not commonly used as a water supply in the Lower Big Blue NRD.

Currently there are 4,618 registered wells in the Lower Big Blue NRD, 3,426 of which are active. The wells are illustrated in Figure 2, Registered Well Location Map. Table 1 compares the number and type of registered wells in 1985, when the first groundwater management plan was written for the District, and the number of wells in 2013. In this 28 year period, the number of active wells has doubled. The spatial distribution of the wells is not equally distributed across the district and some areas show well densities of greater than ten wells per square mile (see Figure 3, High Capacity Registered Well Density Map). Recently, some areas of the District have experienced well interference problems causing reducing well production capacities. With the increase in demand on the groundwater resources of the Lower Big Blue NRD, comes the need to ensure that the aquifers are adequately managed and protected for future use.

The need to manage and protect the groundwater supplies of the Lower Big Blue NRD is the primary responsibility of the staff and the Board of Directors of the Lower Big Blue NRD. In 1985, the District developed a Groundwater Management Plan that included the technical aspects of the groundwater supplies and policy considerations related to management of the groundwater resources. The plan was developed for the staff, directors and the citizens of the NRD to use in order to understand the nature of the groundwater resources and the best way to manage them. The plan was updated in 1993 and 1995 with additional information regarding water quality investigations that were initiated in an effort to provide information on the concentration, scope, and trends of potential contaminants in the District. In the 1995 update, the Lower Big Blue NRD proposed a Special Protection Area in a six township area northwest of Beatrice.

Table 1 Registered Wells in the Lower Big Blue NRD, 1985 and 2013

Registered Well Type	Number of Wells Registered in 1985	Number of Active Wells Registered in 2013
Irrigation	1596	2283
Industry/Commercial	6	15
Monitoring	9	424
Domestic	142	550
Livestock	11	62
Observation	1	23
Ground Heat Exchanger Well	0	36
Recovery	0	22
Other	3	11
Total Wells	1768	3426

In late 2013, the Board of Directors approved a resolution placing an immediate temporary 180-day stay on construction of any new water well designed to pump greater than 50 gallons per minute (gpm). The temporary moratorium on new well construction was imposed while the Board of Directors evaluated options for new well permitting requirements. In 2013 and 2014, the Lower Big Blue NRD developed Groundwater Management Plan Rules and Regulations in order to better manage groundwater development across the District. In early 2014, the temporary stay was lifted and, as written in the new Rules and Regulations, the entire District was placed into a Phase 1 Groundwater Management Area. The Phase 1 designation requires that a well owner obtain a permit for any new wells designed and constructed to pump more than 50 gallons per minute.

In conjunction with the changes to the new Groundwater Rules and Regulations, this report was prepared. The report is intended to provide a geologic framework and an understanding of the aquifers that supply groundwater to the district. A thorough understanding of the aquifers is critical as water supply demands, and issues related to groundwater quantity, continue to increase.

2.0 GEOLOGIC SETTING

The groundwater resources of the Lower Big Blue NRD do not occur in an underground river as some like to say. Groundwater occurs in the space between the grains of sand, silt, clay and in the fractured rock deposited over millions of years by shallow seas, rivers, streams and glaciers. Table 2 provides a generalized geologic and hydrogeologic framework of the strata that underlay the Lower Big Blue NRD. As illustrated in the table, the NRD is underlain by Quaternary Alluvium composed of clay, silt, sand, and gravel deposited by glacial processes during the Pleistocene and Holocene. Beneath the alluvium, four formations deposited over 65 million years ago (Cretaceous) are common across the NRD. Table 2 also provides insight into the water bearing capabilities of the geologic formations in the NRD. The Dakota is the only Cretaceous formation in the area which is water bearing. The Dakota Formation is underlain by formations that are over 250 million years old, they are the Permian and Pennsylvanian limestone and shale of the Council Grove, Admire, and Chase Groups (University of Nebraska – Conservation Survey Division [UNL-CSD], 2013).

Table 2 Geologic Units in the Lower Big Blue Natural Resources District and their Water Bearing Properties (Adapted from Korus and Joeckel (2011)).

Primary and secondary aquifers are highlighted in blue.

Geochronology	Age in Millions of Years	Hydrogeologic Unit	Lithology	Water Supply Information
Quaternary	2.6 - Present	Undifferentiated Alluvial Valley and Paleovalley Units	Stratified clay, silt, sand, and gravel deposits.	Part of regional High Plains Aquifer. Principal source of water supply to wells, reported yields range from 550 to 1,500 gal/min; also transmits water to recharge other aquifers.
Cretaceous	145 – 65.5	Carlile Shale	Moderate gray calcareous shale, fissile, soft, weak: interbedded with clayey siltstone.	Not a source of water supply to wells.
		Greenhorn Shale	Light to medium dark gray limestone, interbedded with argillaceous limestone, marl, calcareous shale, and two very thin layers of bentonite.	Not a source of water supply to wells.
		Graneros Shale	Medium to dark gray shale, fissile, soft, weak; interbedded with thin layers of silt and sand in lower part. Few scattered thin layers of bentonite material.	Not a source of water supply to wells.
		Dakota Group	Sandstone, yellowish white in color, cementer in part by calcium carbonate, interbedded with medium to dark claystone and shale; numerous thin layers of black carbonaceous material.	Part of regional Great Plains Aquifer System. Significant source of water supply to domestic and stock wells. Irrigation wells possible. Potential yields may be as much as 600 gal/min.
Permian	299 - 251	Upper Council Grove, Admire, and Chase Groups	Limestone, shale, mudstone, and evaporites.	Not a significant source of water supply to wells.
Pennsylvanian	318 - 299	Lower Council Grove Group	Limestone, shale, mudstone, and sandstones.	Not a significant source of water supply to wells.

For a more detailed look at the subsurface geology, generalized east-west and north-south geologic cross sections are presented in Figures 4a and 4b. The cross sections illustrate the subsurface geology as identified in the test-holes drilled by the Conservation Survey Division. For reference points, the test-hole identification numbers are provided at the top of the illustration and the location of the profiles are illustrated in the bottom right hand corner of Figures 4a and 4b.

The cross sections are intended to provide a visual representation of the complexity of the geologic units that blanket the District. As illustrated in both cross sections (A-A' and B-B'), thick deposits of clay and silt overlie sand and gravel units. These impermeable clays and silts were deposited across the district by glaciers. Beneath the silts and clays are saturated sands and gravels of the Lower Big Blue NRD. These sand and gravel deposits are highly productive aquifers and for this reason their lateral distribution is presented in more detail later in this report.

For another view of the bedrock geology, instead of looking at the distribution of these bedrock units from the side, take a birds-eye view of the first bedrock unit encountered in the subsurface of the Lower Big Blue NRD. Figure 5 illustrates the distribution of the bedrock units as mapped by UNL-CSD. Figure 5 indicates the Dakota Formation is the most continuous bedrock formation across the Lower Big Blue NRD, underlying roughly two thirds of the District. Using this map and the cross sections, one can begin to gain an understanding of the three dimensional distribution of the important bedrock formations that comprise some of the groundwater aquifers in the Lower Big Blue NRD.

3.0 AQUIFER TYPES

There are two main aquifer types that produce significant quantities of water in the Lower Big Blue NRD. These two main aquifer types were described in several publications developed under the research project entitled the Eastern Nebraska Water Resources Assessment (ENWRA). The goal of the ENWRA project is to develop a three-dimensional geologic framework and water budget for eastern Nebraska. ENWRA has published several documents about the current findings of their investigations and the publications are available on the project website (www.enwra.org). In the publication entitled "Introduction to a Hydrogeological Study", the ENWRA team described the types of aquifers encountered in eastern Nebraska (Divine, et al, 2009). Although the groundwater assessment conducted by ENWRA did not include the Lower Big Blue NRD the same aquifer types are used in this report to describe the aquifers of the Lower Big Blue NRD in order to remain consistent with the nomenclature currently in use.

The two main types of aquifers in the Lower Big Blue NRD are aquifers in the unconsolidated units that overlie the bedrock (alluvial aquifers) and bedrock aquifers. The first group includes three main subtypes: 1) paleovalley aquifers that represent buried ancient stream valleys; 2) alluvial aquifers that were deposited in modern and abandoned stream valleys; and 3) isolated smaller scale aquifers of multiple origins (Divine, et al, 2009). The second group includes aquifers that consist of consolidated to semi-consolidated rock.

The two aquifer types have distinctions based on their lithology, geochemistry, and stratigraphic position that affect their viability as water supplies. For example, the coarse grained sediments of the ancient river valley deposits can transmit significantly more water than the finer-grained deposits of the Dakota Group that occur in this area. Other aspects of aquifer host rock that affect the viability of the aquifer include geochemistry. An example of this is the Dakota Formation with its relatively high levels of total dissolved solids (TDS). A report by Gosselin et al. (2001) determined that groundwater samples extracted from the Dakota formation in Saline, Gage, and Jefferson counties had TDS values ranging from 315-13,000 mg/L.


University of Nebraska Conservation Survey Division drilling a test hole. Photo courtesy of the University of Nebraska.

A third aspect of the aquifer's viability is simply the depth at which the water must be pumped. As shown in Figure 6, Estimated Depth to Bedrock Map, the depth to bedrock varies from rock exposed at the ground surface to areas where the depth to bedrock is over 400 feet below ground surface. Where the bedrock aquifers are deeper than the unconsolidated units, the well installation and pumping costs can be expensive. The following sections provide information on the overall geologic setting of the Lower Big Blue NRD and more detailed information on the two main types of aquifers and their subdivisions.

3.1 ALLUVIAL AQUIFERS

As stated above, the alluvial aquifers are comprised of unconsolidated sediments that overlie the bedrock. The majority of high capacity registered wells (wells that pump greater than 100 gallons per minute) are completed in the alluvial aquifers of the Lower Big Blue NRD. The alluvial aquifers have been subdivided into three main subtypes by the ENRWA group and are described in more detail below.

3.1.1 Paleovalley Aquifers

Paleovalley aquifers represent ancient river valleys that were formed when the rivers and streams cut channels into the bedrock surfaces. The paleovalley aquifers were filled with coarse sands and gravels as the river system developed over time. The paleovalleys were incised both before and between major glacial advances of the Late Pliocene and Pleistocene (Johnson and Keech, 1959). After deposition of the sands and gravels, the river deposits were subsequently overlain by low-permeability tills. Since the paleovalleys are often hidden under a thick blanket of clay sediments, they can be indistinguishable from the ground surface. Although paleovalley aquifers have not been mapped in detail across the Lower Big Blue NRD, the aquifers can be very productive due to their high porosity and permeability. Examples of a productive paleovalley aquifer occurs from the west central portion of the Lower Big Blue NRD, just south of the border between Saline and Jefferson County. In this area are some of the most productive wells in the District with registered well rates as high as 2,500 gpm.

3.1.2 Stream Valley Aquifers

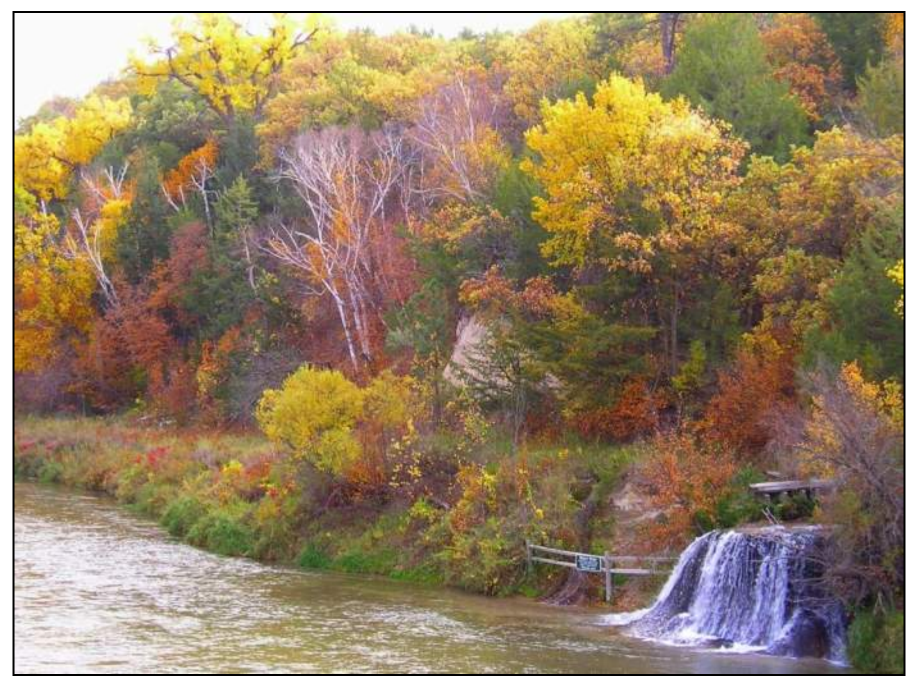
Sand and gravel deposits associated with modern stream valleys such as the Big Blue River and the Little Nemaha River alluvium are known for their excellent water production capabilities. Along the eastern margin of the Lower Big Blue NRD, the Big Blue River alluvium is an example of this type of alluvial aquifer. The Little Nemaha River provides the water supply for over 3,000 citizens from a well field adjacent to the river operated by the Auburn Board of Public Works.

3.1.3 Smaller Aquifers of Multiple Origins

Throughout Eastern Nebraska, numerous small alluvial aquifers occur that, in general, produce less significant quantities of water than the paleovalley and stream valley aquifers. These smaller aquifers were deposited by streams that flowed on top, within or under glaciers (Divine, et al, 2009). Domestic and stock wells are typically completed within these smaller aquifers.

3.2 BEDROCK AQUIFER

The Dakota aquifer system, also known as the Great Plains aquifer system, is the most extensive aquifer system in North America and underlies about 94% of Nebraska. (Ellis, 1986; Gosselin et al., 2001). The Dakota Formation is described as a yellow to whitish colored sandstone with interbedded claystone and shale. Currently, out of the 1,353 wells reviewed as part of this analysis, less than 200 of those wells were completed within the Dakota Formation in the Lower Big Blue NRD. Even though some of these wells completed in the Dakota sandstone units are very productive (600 gallons per minute), there are several reasons that there are not more wells completed in this formation. First, water quality can be an issue with the Dakota Formation since total dissolved solids are above secondary drinking water standards in certain wells. Additionally, the Dakota Formation lies stratigraphically below the alluvial aquifers so from a purely economic perspective, drilling through shallow more productive aquifers is not practical. For this reason, Dakota Formation well completions are primarily isolated to areas were alluvial aquifers are absent such as areas along the southwestern portion of the Lower Big Blue NRD.



Photograph courtesy of the Nebraska Game and Parks Commission.

4.0 SUBAREA DELINEATION

Currently, the Lower Big Blue NRD's Groundwater Management Plan is implemented across the entire district without any subdivisions based the local geology or aquifer distribution. As stated above, with increased pressures of well development, the Lower Big Blue NRD initiated this study to subdivide the district in to hydrogeologically defined subareas. The intent was to better understand the extent and distribution of the aquifers so that groundwater management decisions can be based on geologic, geospatial, as well as regulatory requirements.

The first step to subarea delineation was to gather and evaluate the existing hydrogeologic data across the District. Information was gathered from UNL-CSD, the Nebraska Department of Natural Resources, (NDNR), and the University of Nebraska-School of Natural Resources. Geographic information system (GIS) data sets were developed, integrated and interpreted to produce geographic data sets to illustrate the hydrogeologic characteristics. For example, well logs provided by the NDNR and CSD, and the bedrock surface from the CSD were reviewed and used to estimate the thickness of gravel and the presence of paleovalleys. This was integral in delineating subareas within the Lower Big Blue NRD.

For areas in which the principal source of groundwater was alluvial deposits, well logs were reviewed and the likelihood of a productive aquifer being present at each location was determined by the presence of sand and gravel overlying bedrock. Significant aquifers were identified as areas with 40 feet or more of saturated sand and gravel deposits, similar to methods to delineate aquifers in the Lower Platte South NRD (Druliner and Mason, 2001). For the Lower Platte North NRD (Olsson Associates, 2009) and the Lewis and Clark NRD (Olsson, 2010) hydrogeologic subarea delineation studies, significant aquifers were identified as areas with 30 feet or more of saturated thickness.

As with any scientific evaluation, the interpretations and conclusions are only as good as the data set used to develop them. To complete the evaluations, only well logs that had useful lithologic descriptions were included in the study. Sand and gravel thickness was not the only parameter evaluated. After the gravel thickness was spatially interpolated, it was compared to other sources of spatial data such as the bedrock surface, transmissivity and specific yield.

The following sections describe in more detail how the subareas were delineated. The subareas were delineated based on the data sets and maps available at the time of the study. Reinterpretations of the subarea delineations may be warranted should new information become available for a specific area.

The distribution of continuous saturated sand and gravel aquifers is of primary importance to the groundwater management of the Lower Big Blue NRD. For this reason, Saturated Sand and Gravel Thickness Maps, were generated for the entire district (Figure 7) and then detailed maps of each county were developed and presented in Figures 7a-d. Saturated sand and gravel thickness was determined from well logs downloaded from the NDNR website and test-hole boring logs downloaded from the UNL-CSD website. Logs were reviewed and if penetration depth was adequate and the logs were of sufficient quality, the saturated sand and gravel thickness was calculated from the well logs. Using this technique, the saturated sand and gravel thickness at each well was recorded in a geodatabase. The thickness of the saturated sand and gravel deposits were then interpolated across the Lower Big Blue NRD using GIS interpolation techniques. The distribution patterns illustrate saturated sand and gravel deposits that varied from 0 to 290 feet in thickness.

As a quality control check on the maps, sand and gravel thickness distribution patterns were compared to the surface of the bottom of the principal aquifer provided by the CSD (Figure 8, UNL-CSD Base of the Principal Aquifer Map and Figure 9, UNL-CSD Aquifer Transmissivity Map) as well as to the maps developed during this study such as Figure 6 (Estimated Depth to Bedrock Map).

Based on the hydrogeologic data evaluation, the Lower Big Blue NRD was subdivided into six subareas (Figure 10). The subareas were named after the largest community in the subarea with one exception. There were no communities in the subarea to the northeast of Clatonia so the subarea is named "Northeast of Clatonia".

There are three main paleovalley subareas with thick deposits of sand and gravel that are oriented east/west across the Lower Big Blue NRD. The primary paleovalley subareas are the Crete, Plymouth, and Blue Springs subareas. The distribution of the paleovalley subareas were delineated using the bedrock surface and by the thickness of saturated sand and gravel.

The remaining subareas were delineated primarily by the absence of productive and continuous saturated sand and gravel aquifers. For example, in the Beatrice subarea, saturated sand and gravel thickness ranged primarily from 0 to less than 40 feet in thickness.

Finally, the Cortland and Northeast of Clatonia subareas were identified on the northeast and along the eastern margin of the District and have saturated sand gravel deposits greater than 40 feet in thickness.

5.0 GROUNDWATER MANAGEMENT AREAS

On March 20, 2014, the Lower Big Blue NRD held a public hearing to receive public comment on proposed new groundwater management rules and regulations. After hearing the public comments, on March 27, 2014, the Board of Directors adopted the updated Groundwater Rules and Regulations. Under the new rules and regulations, there are three groundwater quantity management areas that identify different options that the Board of Directors can adopt to ensure groundwater is managed sustainably. The three groundwater quantity management areas are:

Phase I – The entire District is designated as a Phase I Groundwater Quantity Management Area and groundwater level monitoring is performed on a District-wide basis.

Phase II – Areas where the static water level elevation has decreased below the trigger level set in the Groundwater Management Plan for three consecutive years.

Phase III – Areas where the static water level elevation has decreased by 30% or more below the Phase II triggers for three consecutive years.

When the new rules were adopted in March, all new wells designated to pump 50 gallons per minute or more must apply for a permit through the NRD. The well permit application includes a scoring system for evaluating the potential impacts of the proposed new well on existing groundwater users in the surrounding area. The permitting requirements include drilling a test-hole to evaluate aquifer parameters along with evaluating the density and types of existing wells in the area.

Along with these new groundwater management rules and regulations, the information provided in this report can be used to help understand areas where well conflicts are arising or where wells are reaching critical trigger levels. The following sections include discussion on the critical well locations currently identified in the Lower Big Blue NRD.

5.1 Groundwater Monitoring Well Trigger Level Status Map

Figure 11 illustrates the monitoring wells' status related to trigger levels based on static water level measurements collected at each well in the spring and the fall from 1981-2014. The static water level measurements were used to create hydrographs so that the wells could be assigned to one of four categories:

1. Critical Wells
2. At Risk Wells
3. Wells Currently Not at Risk
4. Not Enough Information

Critical wells include those wells that have three consecutive water level measurements below the Phase II trigger level. These critical wells are indicated in red. At risk wells, indicated in yellow, are defined as those wells where the static water level has dropped below the 1982 baseline level for three or more years but not below the trigger level. These wells are therefore at risk of becoming a critical well and should be monitored closely. Not at risk wells are designed in green because they have not met the trigger level criteria and furthermore, the water levels are not below the 1982 baseline. Wells that do not have enough information to accurately determine the well status are illustrated in gray. For the not enough information wells, water levels have only been recorded for the last three years and according to the Lower Big Blue NRD Groundwater Management Plan there must be at least four water level measurements to determine a well status. An example of each type of hydrograph (critical, at risk, and not at risk) is illustrated in Figure 12. On Figure 12, the yellow box highlights the water level measurements for the last three years. As stated in the plan, the comparison of the water levels to the trigger value for the last three years determines the status of the well.

Olsson performed a detailed analysis at each critical well to identify the specific aquifer conditions. Based on the current water level monitoring data, most of the critical wells fall into two categories:

1. The wells are located in areas where the aquifer is thin
2. The wells are located in areas where high capacity well density is high

The first category of wells have water levels that apparently have reached the trigger levels because they are located in an area where the aquifer is thin and does not have enough saturated thickness to support the pumping rates. For example, on Figure 11, critical wells are located near west and northeast of Diller, northeast of Blue Springs, west of Swanson, west of DeWitt, and north of Wilber.

For the second category of wells, the critical wells are located in or adjacent to areas where there are more than six per square mile as illustrated on Figure 3. Other reasons for wells to fall into the critical or at risk categories may be the rate of recharge in an area. Some wells with confining conditions may have slow recharge rates that may restrict replenishment of the aquifer. For this reason, additional monitoring and potentially, further management actions may need to be taken to ensure that the aquifer managed to protect existing water users while still allowing for future development where conditions warrant.

6.0 MAP AND DESCRIPTION DETAILS

The following sections provide additional insight and information on how the maps presented in this report were generated. For reference purposes, data source information used to generate the maps is provided in the title block of each map. For all of the maps, the city, county, major highways and NRD boundaries were from the NDNR website. Streams and watershed boundaries were from the United States Geological Survey (USGS).

6.1 Location Map Lower Big Blue Natural Resources District

Figure 1, Location Map Lower Big Blue NRD was generated using the data described above. For Figure 1 and all subsequent maps in this report, the city, county, major highways, and NRD boundaries were generated from NDNR datasets. Streams and watershed boundaries were from the United States Geological Survey (USGS). No data interpretation was made to generate Figure 1.

6.2 Registered Well Location Map

Figure 2, Registered Well Location Map was generated using data from the NDNR registered well website (http://dnrdata.dnr.ne.gov/wellssql/). The well locations and well completion information was current at the time of publication of this report. Additionally on the map, the UNL-CSD test-hole locations are indicated in red. The test-hole data was generated using data from the (http://snr.unl.edu). No data interpretation was made to generate the map.

6.3 High Capacity Registered Well Density Map

Figure 3, High Capacity Registered Well Density Map was generated by calculating the density of registered wells (with capacities listed as greater than 100 gallons per minute) per square mile across the entire Lower Big Blue NRD.

6.4 Generalized Geologic Cross Sections

Figure 4a, Generalized Geologic Cross Section (East-West), and Figure 4b, Generalized Geologic Cross Section (North - South), illustrate the subsurface geology across the NRD. The cross sections were generalized using test-holes drilled by the Conservation Survey Division and have a vertical exaggeration in order to better illustrate the subsurface geology. The north-south and east-west lines of cross section were chosen based on the existing network of UNL-CSD test-holes. Because of the large distances that the cross-sections cover, the lithostratigraphic units are generalized to emphasize the hydrostratigraphy. For example, sand and gravel deposits are combined to illustrate areas where if saturated conditions exist, productive aquifers are likely. Alternatively, soil/fill, clay and silt are grouped together since their transmissive properties are significantly less than sand and gravel. Till units deposited by glaciation are illustrated separately.

6.5 UNL-CSD Bedrock Geology Map

Figure 5, UNL-CSD Bedrock Geology Map was generated using the geology map developed by UNL-CSD and posted on their GIS data website (http://snr.unl.edu/data/geographygis/NebrGISdata.asp). The maps illustrate the bedrock geology map as generated from CSD's digital coverage of the bedrock formations underlying alluvial deposits in the Lower Big Blue NRD. No data interpretation was made to generate the map.

6.6 Estimated Depth to Bedrock Map

Figure 6, the Estimated Depth to Bedrock Map was generated by subtracting the elevation of the bottom of the principal aquifer from the ground surface elevation. In most areas, the bottom of the principal aquifer represents the change from alluvial deposits to bedrock deposits. Another way to think of this map is that it represents an estimated thickness of alluvium. Some areas lacked information for calculation and are marked as such on the map.

6.7 Saturated Sand and Gravel Thickness Maps

Figure 7 illustrates the thickness of saturated sand and gravel across the district. As described in more detail above in Section 4.0, saturated sand and gravel thicknesses were calculated from NDNR well logs and UNL-CSD test-hole boring logs. Included on the map are the irrigation wells from the NDNR which were reviewed for spatial interpolation. Figures 7a-7d illustrate the saturated sand and gravel thicknesses by county.

6.8 UNL-CSD Base of the Principal Aquifer Map

Figure 8 is the UNL-CSD Base of the Principal Aquifer Map as provided by the CSD. As described above, the information from this map was used to calculate Figure 6, the Estimated Depth to Bedrock. No new data was incorporated into the CSD data set and no data interpretation was made to generate the map.

6.9 UNL-CSD Aquifer Transmissivity Map

Figure 9 is the UNL-CSD Aquifer Transmissivity Map illustrating the aquifer transmissivity as estimated by the CSD. Transmissivity can be described as the rate water is transmitted through a specific unit area of the aquifer. Specifically in Figure 9, the transmissivity of the aquifer is described in gallons per foot per day. The transmissivity value for an area therefore indicates how many gallons of water are transmitted through one foot of saturated aquifer thickness per day. The darker areas are areas where the transmissivity and therefore the aquifer production capacity are greater. For the transmissivity map, no new data was incorporated into the CSD data set and no data interpretation was made to generate the map.

6.10 Groundwater Subarea Map

Figure 10 illustrates subareas described in more detail in Section 4 of this report. The NRD is separated into six subareas and the subareas were named after the largest community in the subarea with one exception. There were no communities in the subarea to the northeast of Clatonia so the subarea is named "Northeast of Clatonia".

6.11 Groundwater Monitoring Well Trigger Level Status Map

Figure 11 is the location of critical wells as defined in the NRD Groundwater Management Plan. A critical well was identified by evaluating water level monitoring data from the first time measurements were collected to present (1981-2014). An example of the water level analysis are illustrated in Figure 12. Critical wells are defined by the Lower Big Blue Natural Resources District Rules and Regulations as a well in which, "the static water level elevation has decreased by 5 feet below 1982 baseline levels or 5% or more below the upper elevation of the saturated thickness for any well with saturated thickness less than 100 feet in the Observation Well Monitoring Network for a three consecutive year period". These critical wells are indicated in red. At risk wells, indicated in yellow, are defined as those wells which the static water level has dropped below the 1982 baseline level for three or more years, though not below the trigger level. These wells are therefore at risk of becoming a critical well and should be monitored closely. Green wells indicate those which are currently not at risk of overproduction.

6.13 HPRCC 1971-2000 Mean Precipitation Map

Figure 13 is the mean annual precipitation map illustrating the mean precipitation across the NRD as provided by High Plains Regional Climate Center (HPRCC) Weather Stations for years 1971-2000. For the precipitation map, no new data was incorporated into the HPRCC Weather Station data set. As illustrated in the precipitation map, mean precipitation increases southeastern across the NRD.

6.14 Average Annual Net Recharge Map 2000-2009

Figure 14 is the Average Annual Net Recharge Map illustrating the estimated mean recharge across the NRD as calculated by Szilagyi and Jozsa (2012) for the years 2000-2009. For the recharge map, no new data was incorporated into the Szilagyi and Jozsa (2012) data set. The map of net annual recharge illustrates an estimated range of recharge from less than 1 to 8 inches per year. Based on this analysis, the recharge rate appears to be higher in the south-central portion of the District. This estimate may be high based on long-term average recharge rates for Nebraska. In a personal communication with Dr. John Gates (Senior Quantitative Hydrologist at the Climate Corporation), the average recharge rate for the state of Nebraska is 1.5 inches per year. The highest average recharge rate is in the Sandhills (2.9 inches per year) and in glaciated eastern Nebraska, including the Lower Big Blue, the long-term average recharge rate is estimated at 2.2 inches per year (unpublished data from Gates, 2013).

Recharge and weather monitoring instrumentation in the Lewis and Clark Natural Resources District. Photo courtesy of Dr. John Gates.

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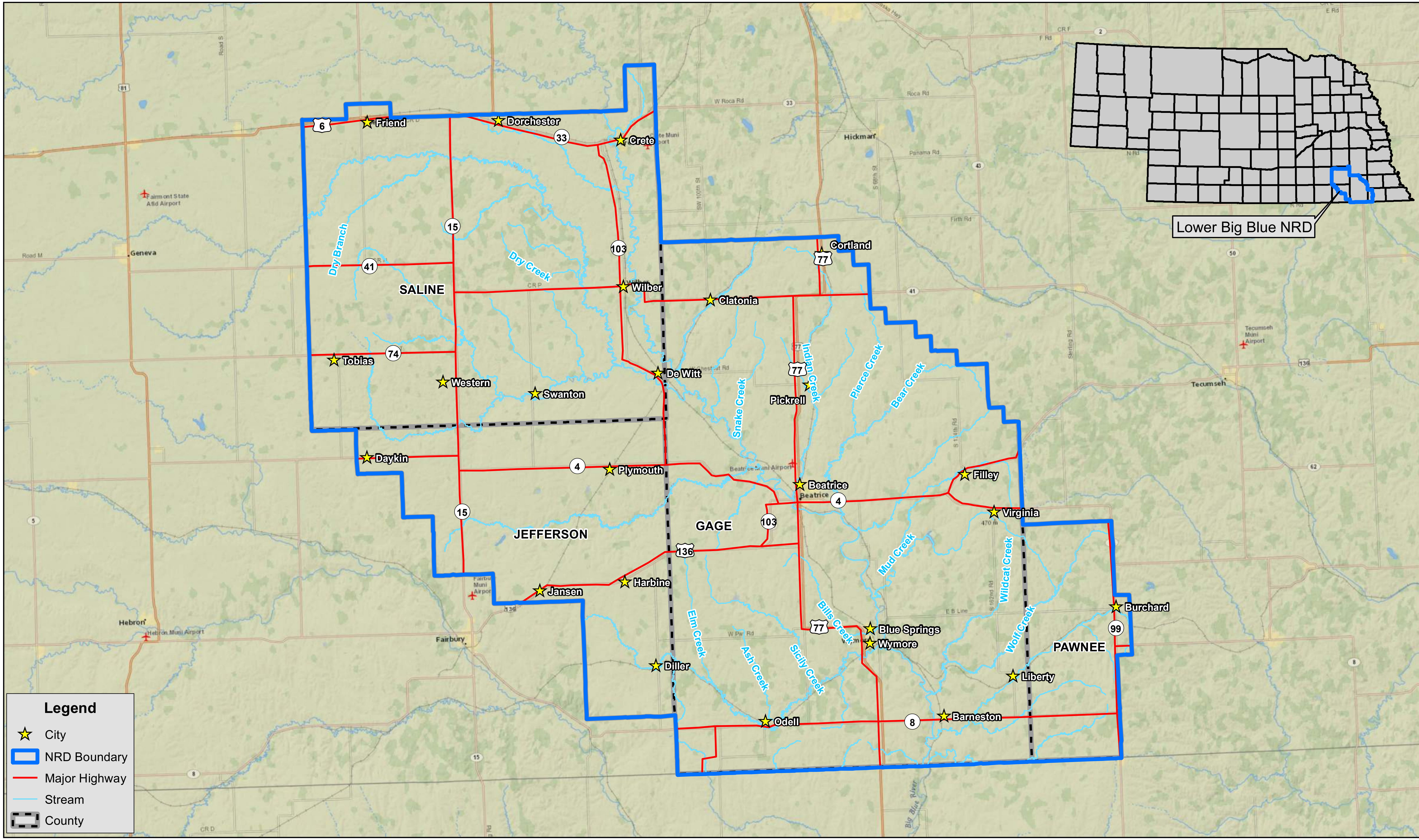


PROJECT: 013-2535

DRAWN BY: RD

DATE: September 08, 2014

Sources:
DNR: City, County, Major Highway, NRD Boundary
USGS: Stream, Watershed Boundary

3 0 3 6 9 Miles

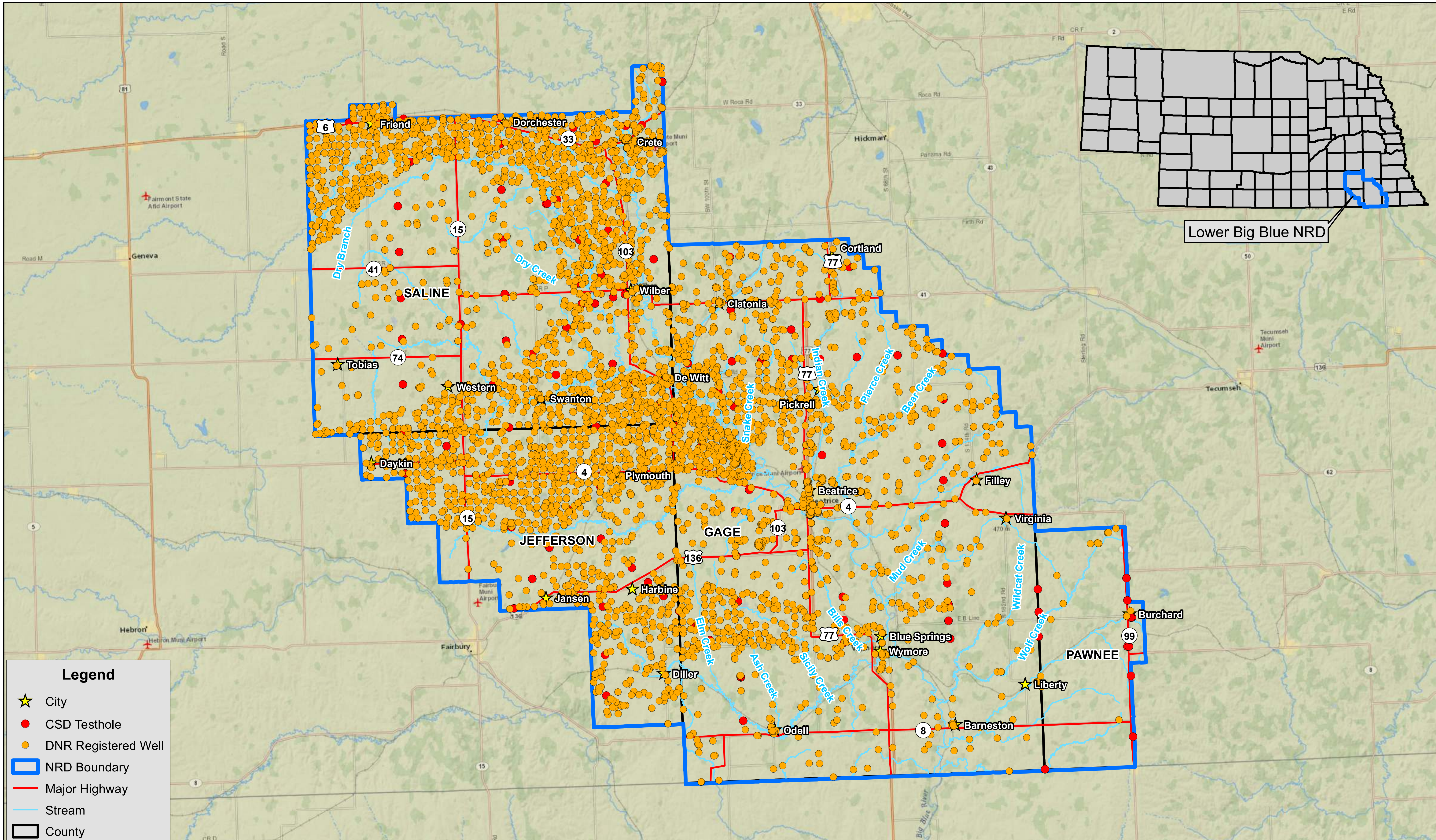
N

Location Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE 1

F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535

DRAWN BY: RD

DATE: September 08, 2014

Sources:
DNR: City, County, Major Highway, NRD Boundary, Registered Wells
CSD: CSD Testholes
USGS: Stream, Watershed Boundary

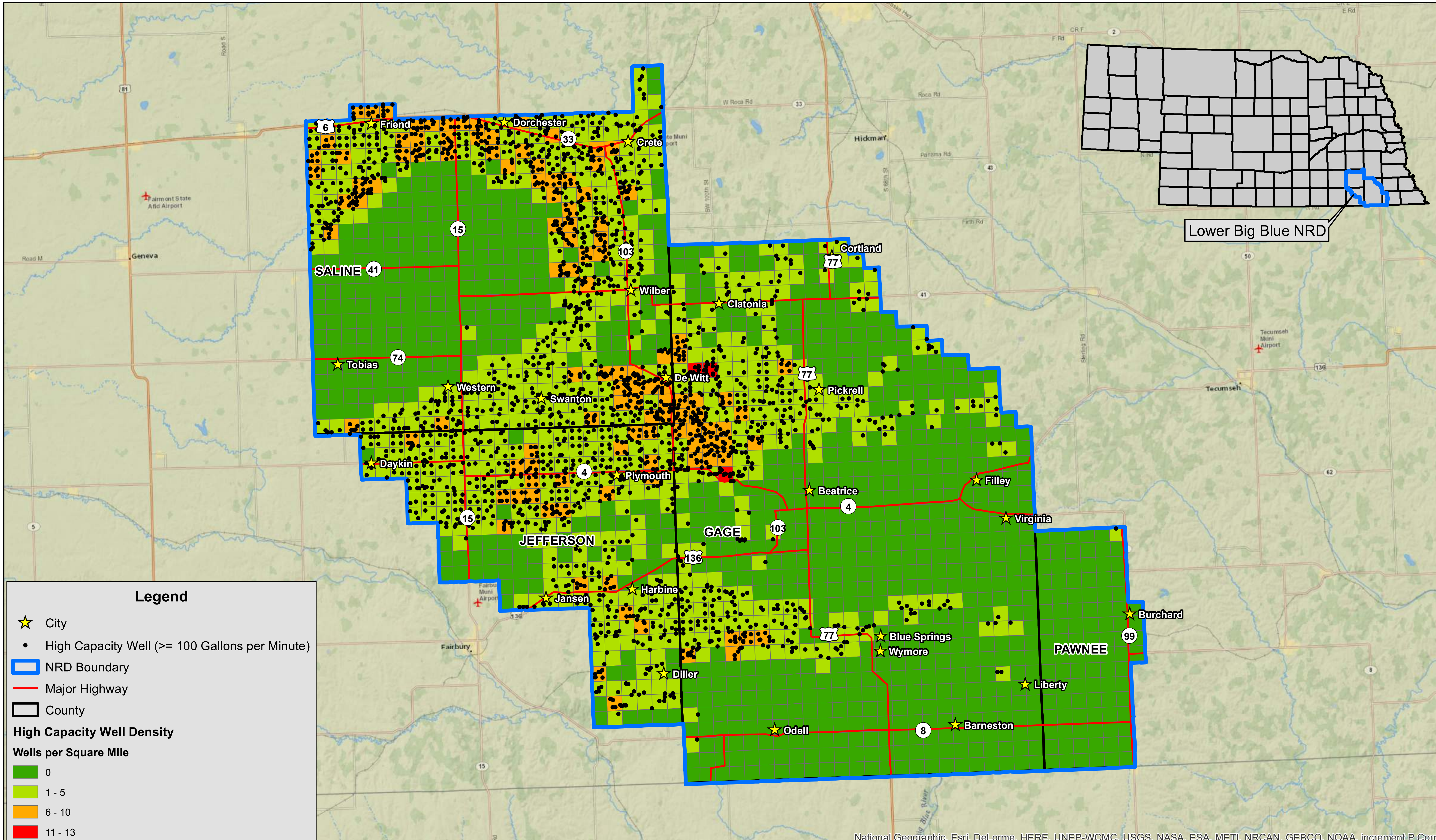
3 0 3 6 9 Miles

N

Registered Well Location Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE
2



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535	Sources: DNR: City, County, Major Highway, NRD Boundary, Registered Wells	
DRAWN BY: RD		
DATE: September 08, 2014		

3 0 3 6 9 Miles

N

High Capacity Registered Well Density Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

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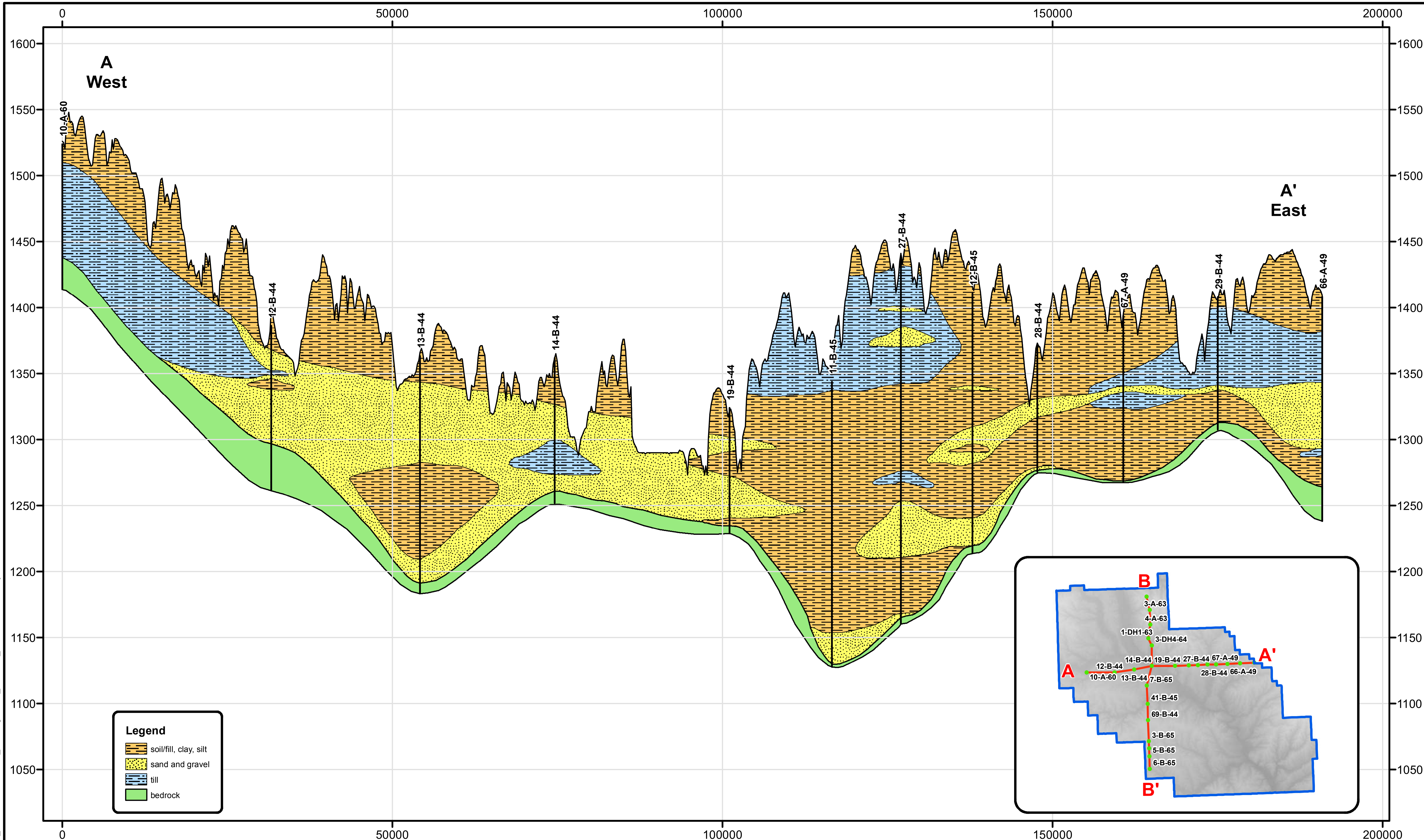
FIGURE

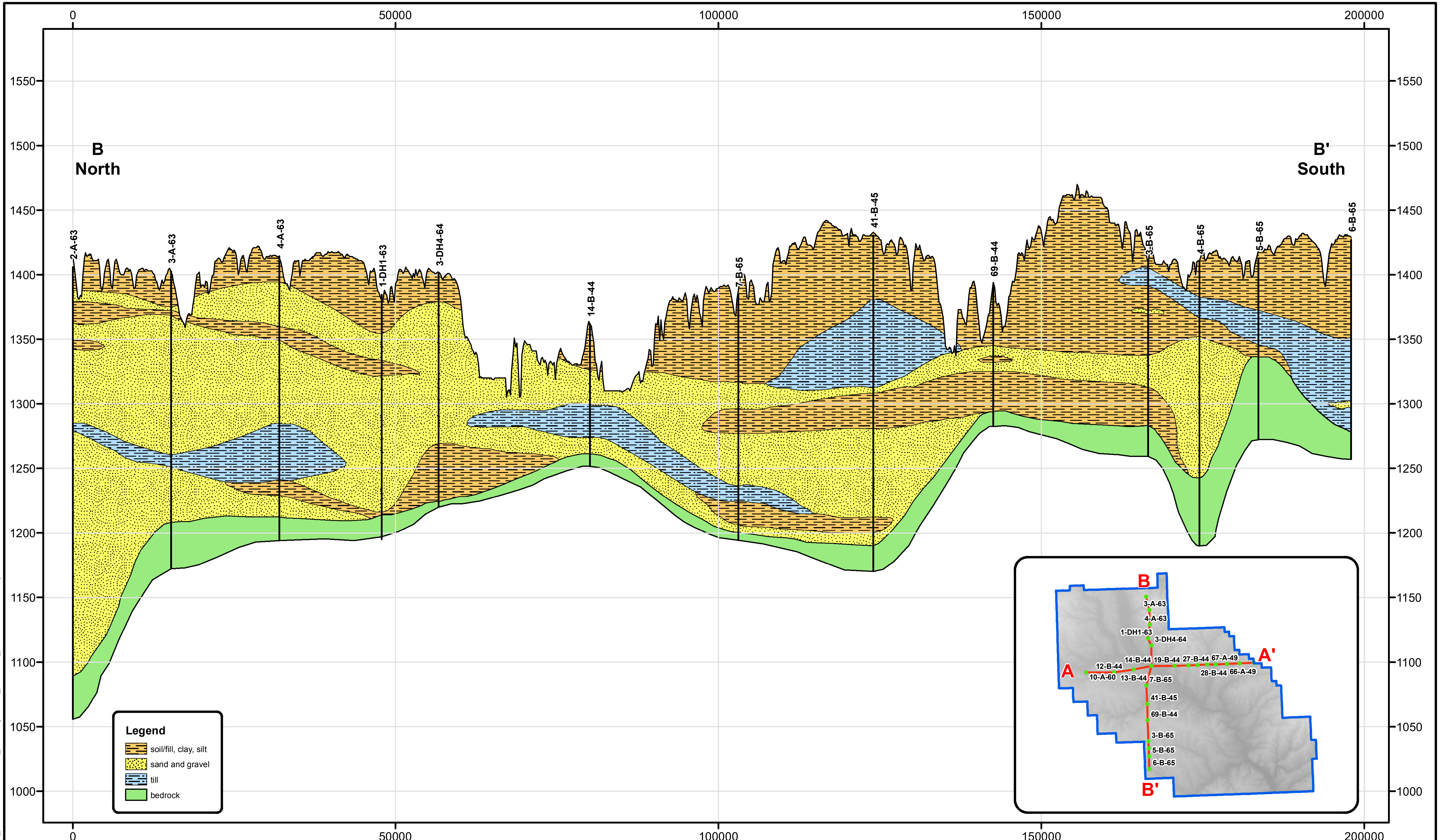
3



F:\Projects\013-2535_GEOHY\GIS\Jordan_Working\Cross_Sections_Jordan.mxd User: jdornbierer

PROJECT: 013-2535 DRAWN BY: CW DATE: August 15, 2014	Sources: DNR: NRD Boundary CSD: Testholes, Borelogs	Horizontal Distance (ft) Elevation (ft above mean sea level) Vertical Exaggeration Factor: 200	**GEOLOGIC CROSS SECTION** **Lower Big Blue Natural Resource District** **Southeast, Nebraska**	OLSSON ASSOCIATES

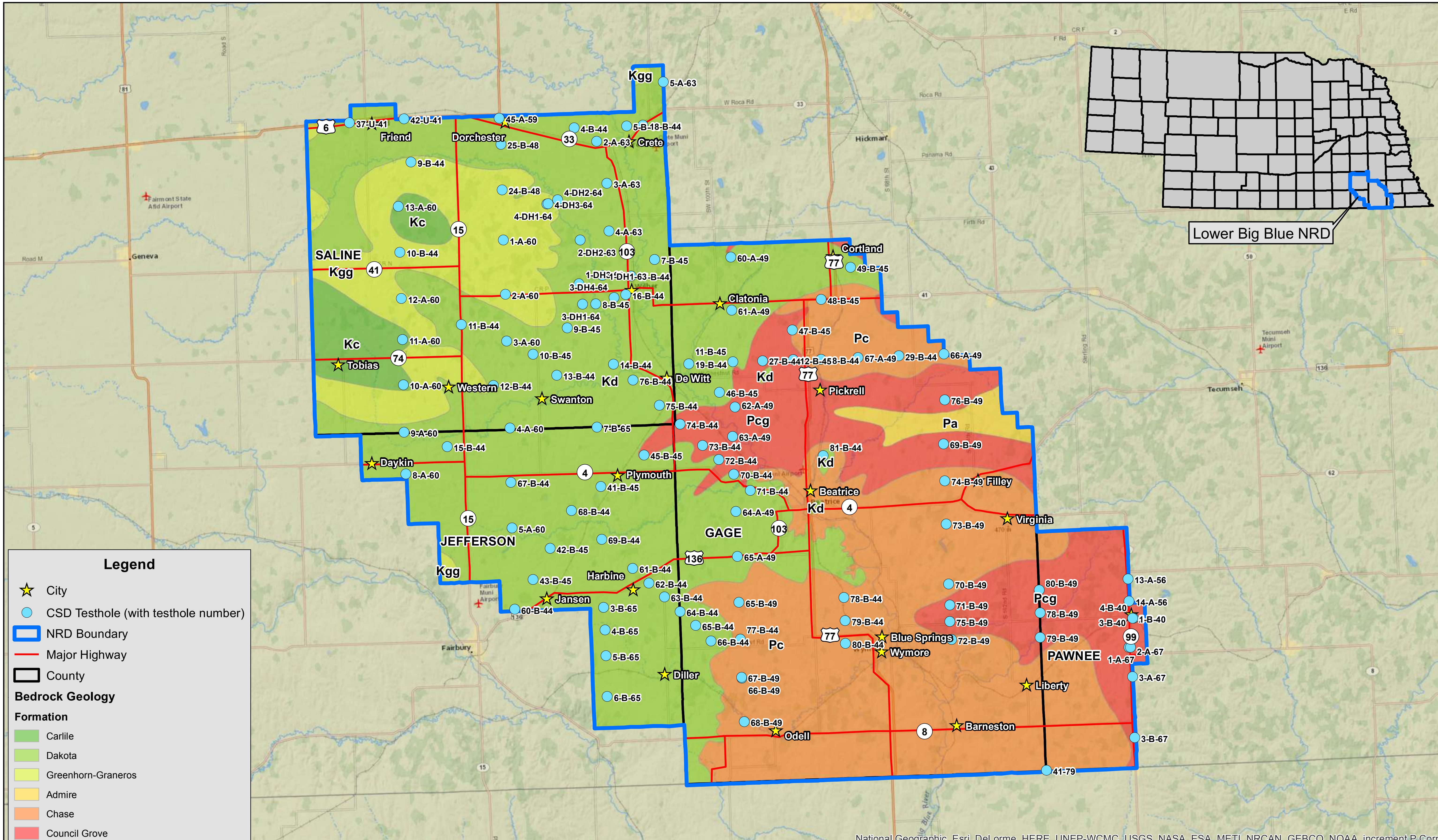
FIGURE
4A



PROJECT: 013-2535 DRAWN BY: CW DATE: August 15, 2014	Sources: DNR: NRD Boundary CSD: Testholes, Borelogs	Horizontal Distance (ft) Elevation (ft above mean sea level) Vertical Exaggeration Factor: 200	**GEOLOGIC CROSS SECTION** **Lower Big Blue Natural Resource District** **Southeast, Nebraska**	OLSSON ASSOCIATES

FIGURE
4B

F:\Projects\013-2535_GEOHY\GIS\Jordan_Working\Cross_Sections_Jordan.mxd User: jdornbierer



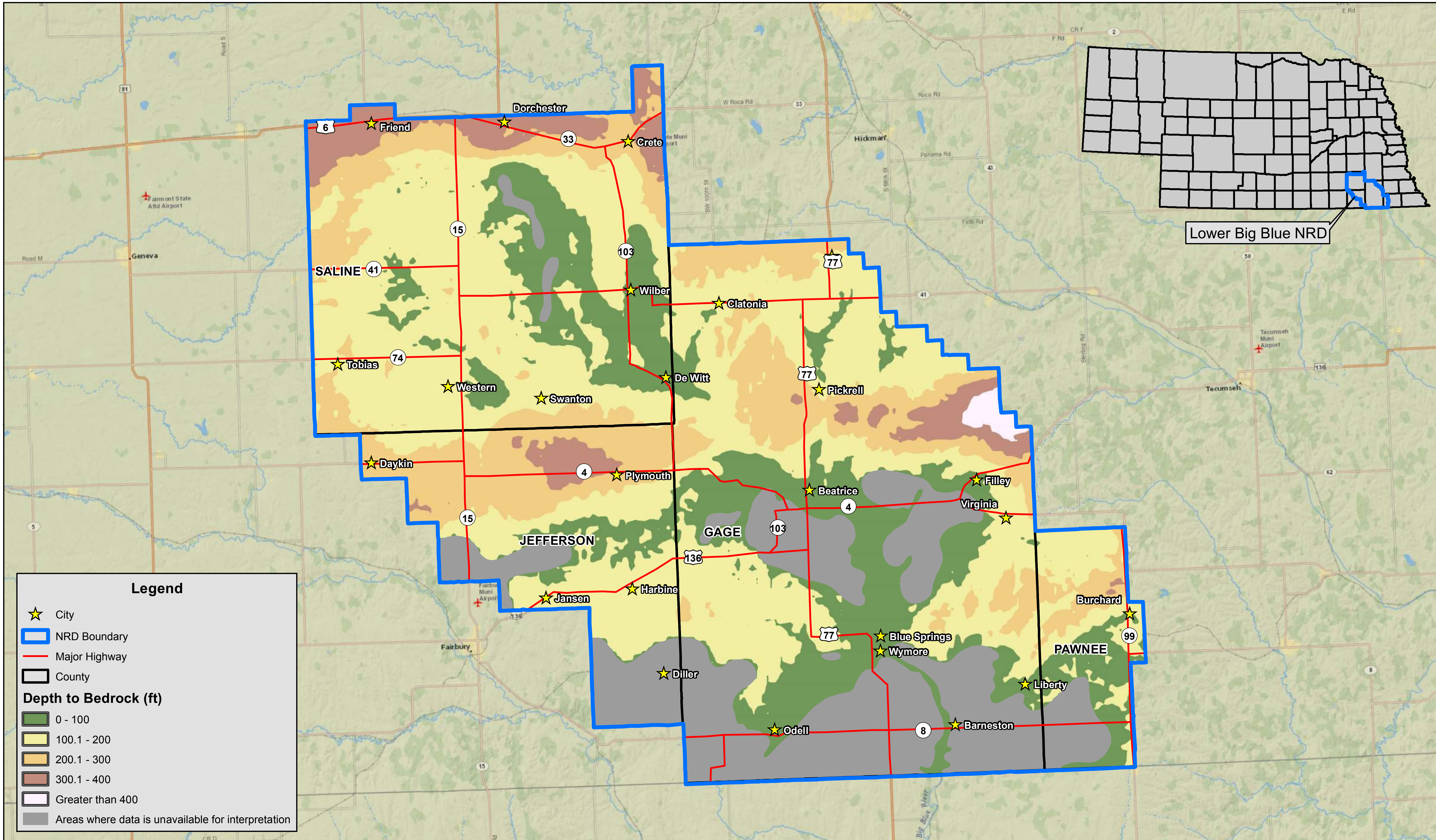
F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535	Sources: DNR: City, County, Major Highway, NRD Boundary CSD: CSD Testholes, Bedrock Geology	3 0 3 6 9 Miles N
DRAWN BY: RD		
DATE: September 08, 2014		

UNL - CSD Bedrock Geology Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE 5



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535

DRAWN BY: CW

DATE: September 08, 2014

Sources:
DNR: City, County, Major Highway, NRD Boundary
CSD: Base of Principal Aquifer

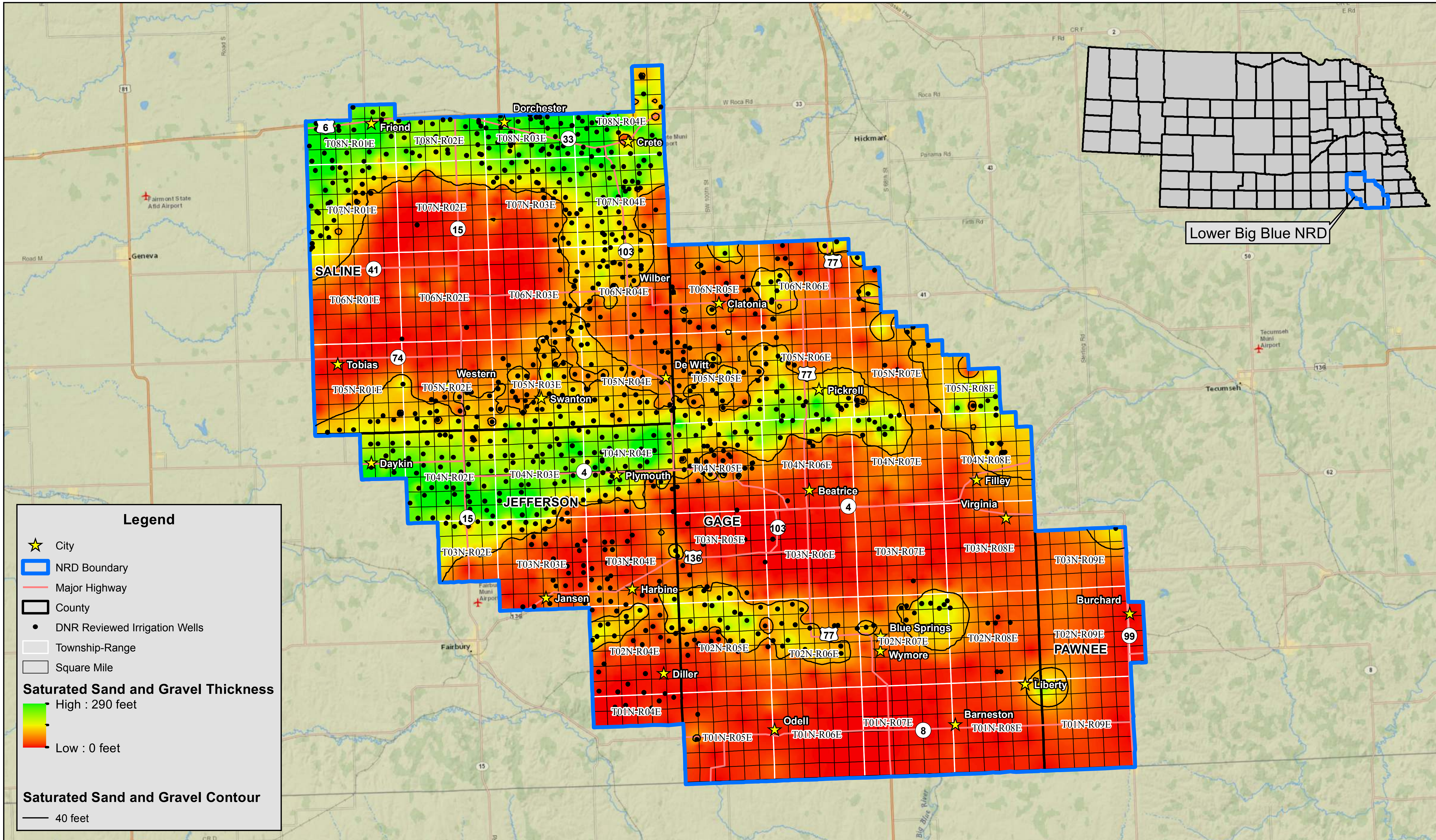
3 0 3 6 9 Miles

N

Estimated Depth to Bedrock Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE 6



F:\Projects\013-2535_GEOHYGIS\Draft Maps.mxd User: cweaver

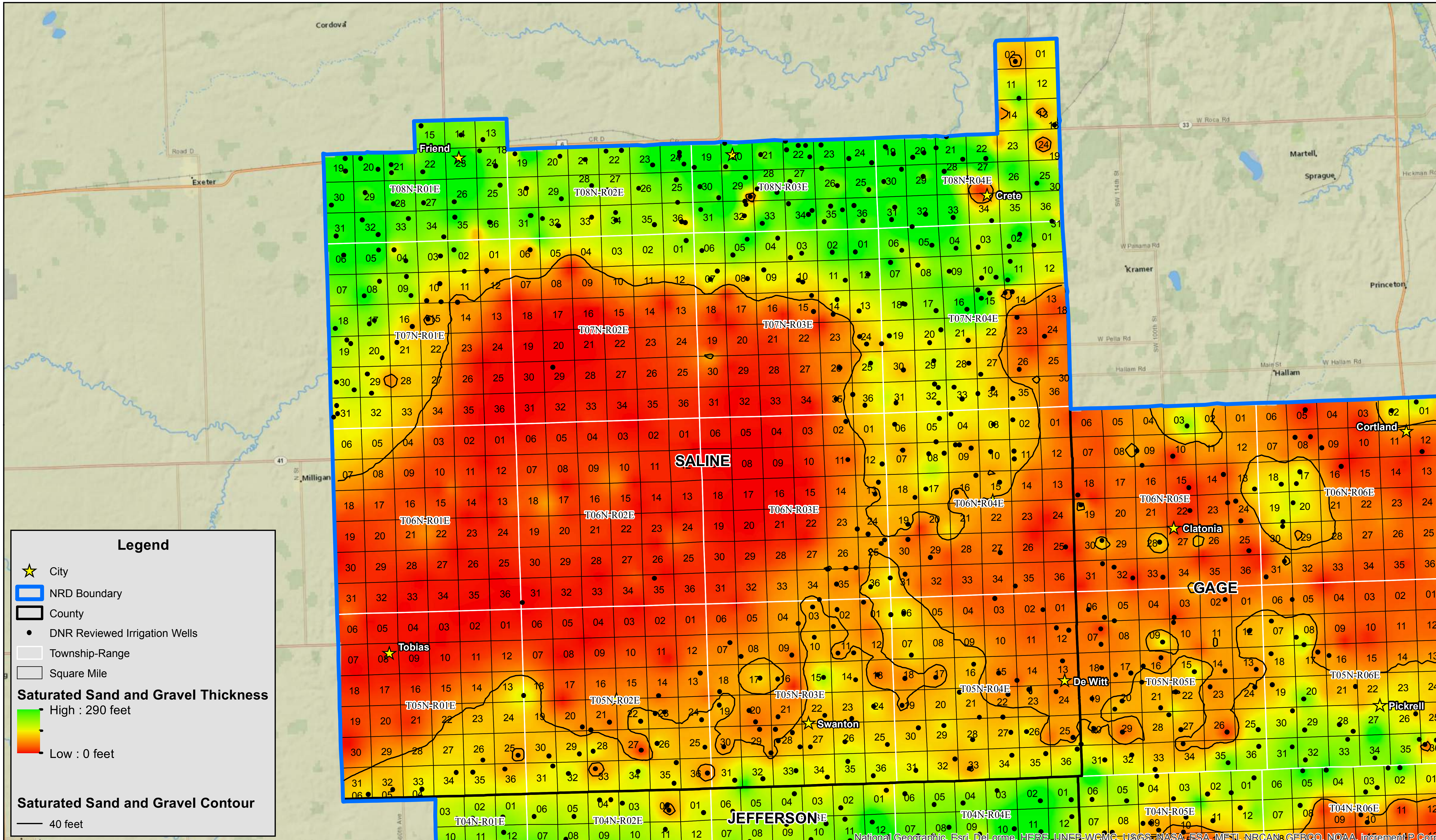
PROJECT: 013-2535	Sources: DNR: City, County, Major Highway, NRD Boundary, Registered Wells		FIGURE
DRAWN BY: CW			
DATE: September 11, 2014			7

3 0 3 6 9 Miles

N

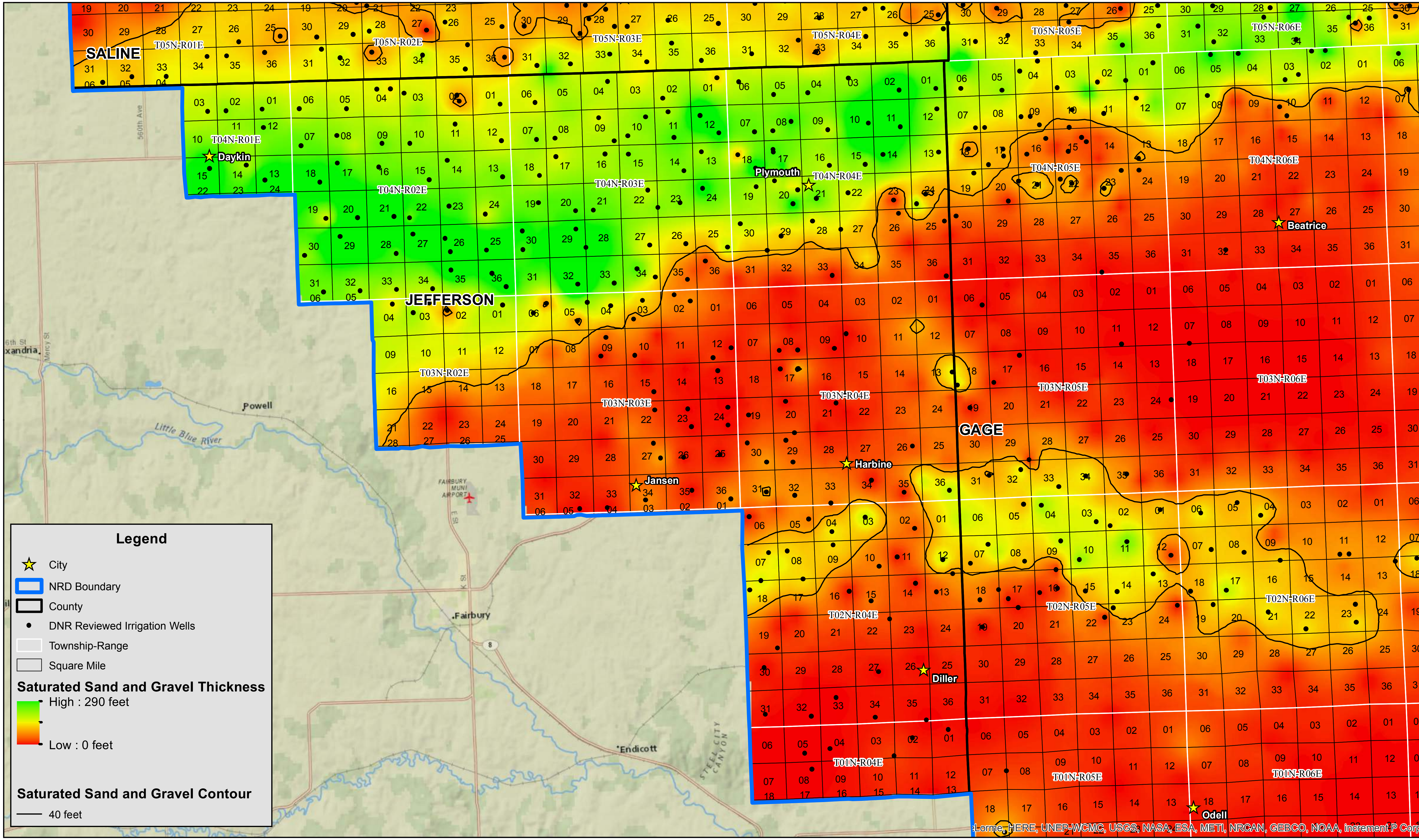
Saturated Sand and Gravel Thickness Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535 DRAWN BY: CW DATE: August 29, 2014	Sources: DNR: City, County, Major Highway, NRD Boundary, Registered Wells	**Saturated Sand and Gravel Thickness Map** **Saline County** **Lower Big Blue Natural Resource District** **Southeast, Nebraska**	OLSSON ASSOCIATES	FIGURE 7a



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535

DRAWN BY: CW

DATE: August 29, 2014

Sources:
DNR: City, County, Major Highway, NRD Boundary, Registered Wells

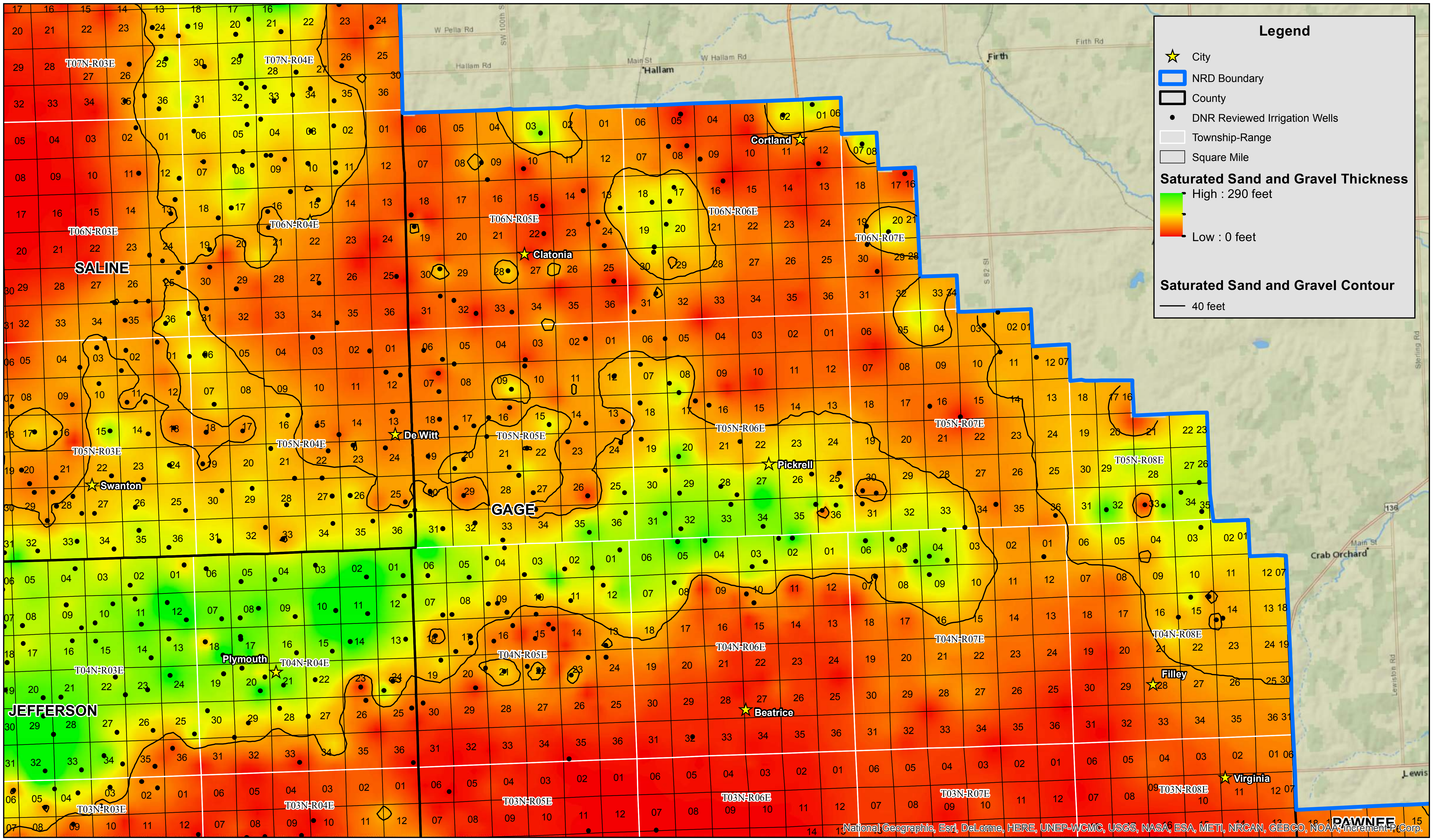
3 0 3 Miles N

Saturated Sand and Gravel Thickness Map
Jefferson County
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

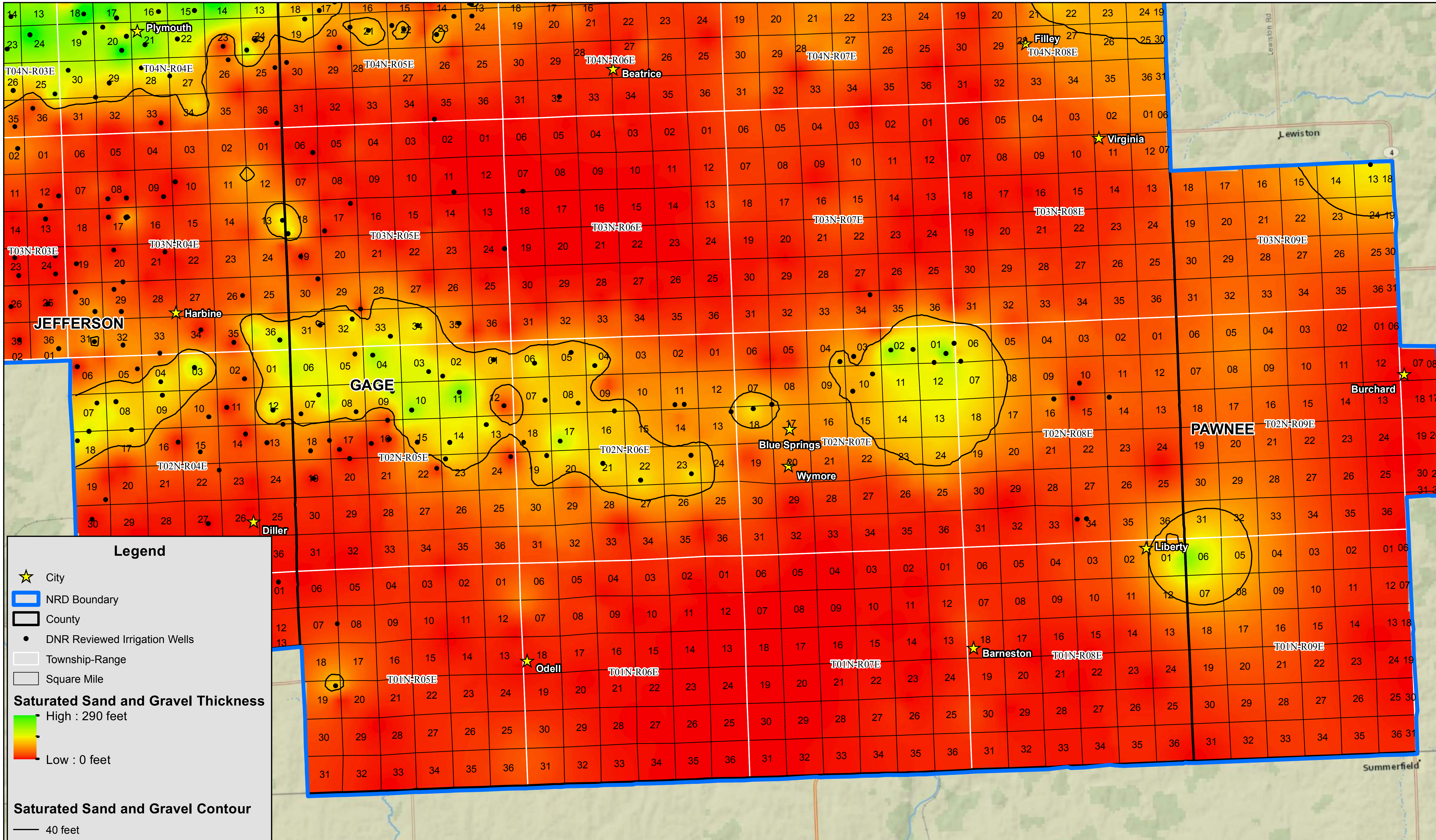
FIGURE

7b



F:\Projects\013-2535_GEOHYG\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535 DRAWN BY: CW DATE: August 29, 2014	Sources: DNR: City, County, Major Highway, NRD Boundary, Registered Wells	3 0 3 Miles N	**Saturated Sand and Gravel Thickness Map** **Upper Gage County** **Lower Big Blue Natural Resource District** **Southeast, Nebraska**	OLSSON ASSOCIATES	FIGURE 7c



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535

DRAWN BY: CW

DATE: August 29, 2014

Sources:
DNR: City, County, Major Highway, NRD Boundary, Registered Wells

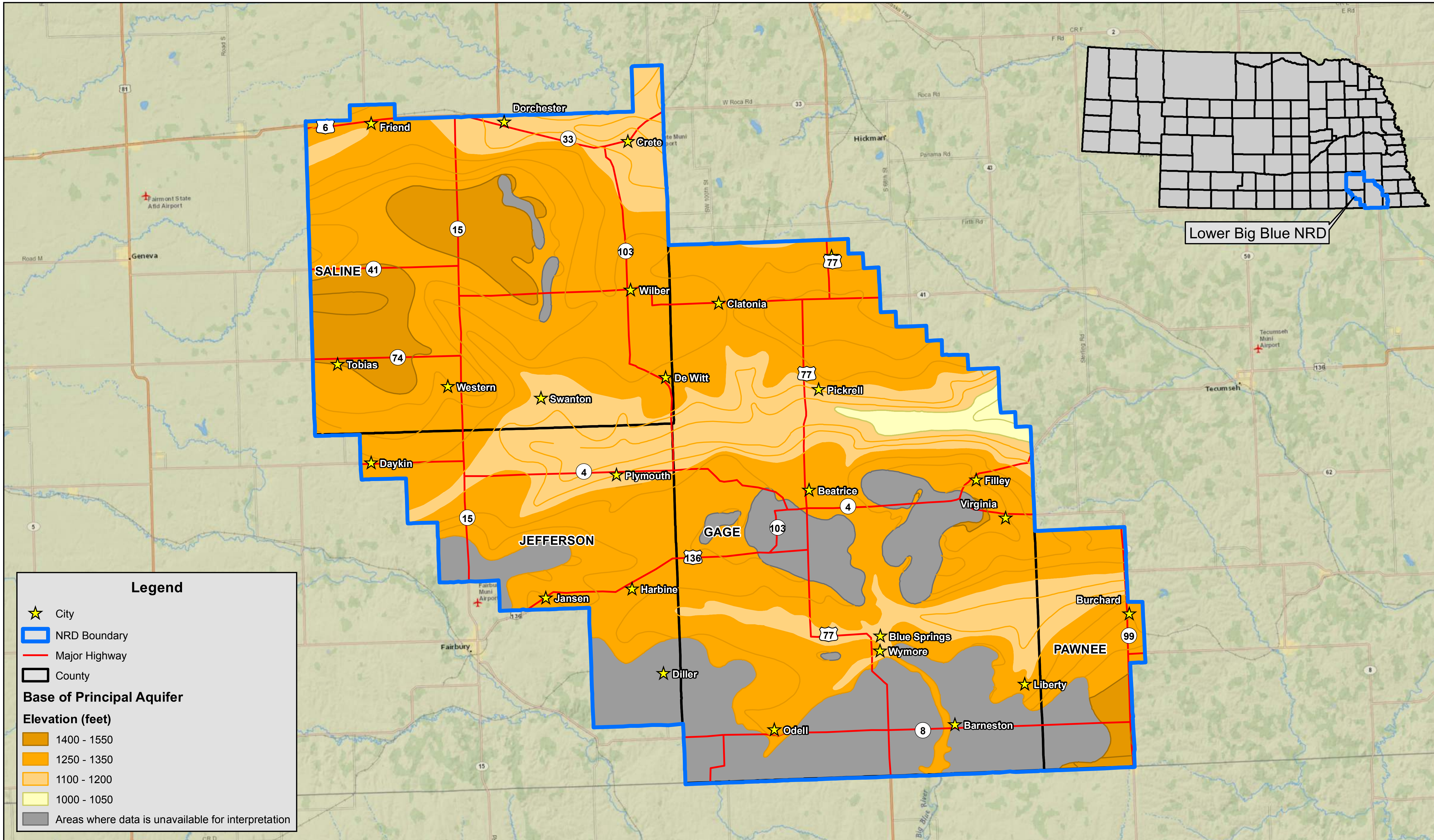
3 0 3 Miles

N

Saturated Sand and Gravel Thickness Map
Lower Gage and Pawnee County
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE
7d



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535

DRAWN BY: CW

DATE: September 08, 2014

Sources:
DNR: City, County, Major Highway, NRD Boundary
CSD: Base of Principal Aquifer

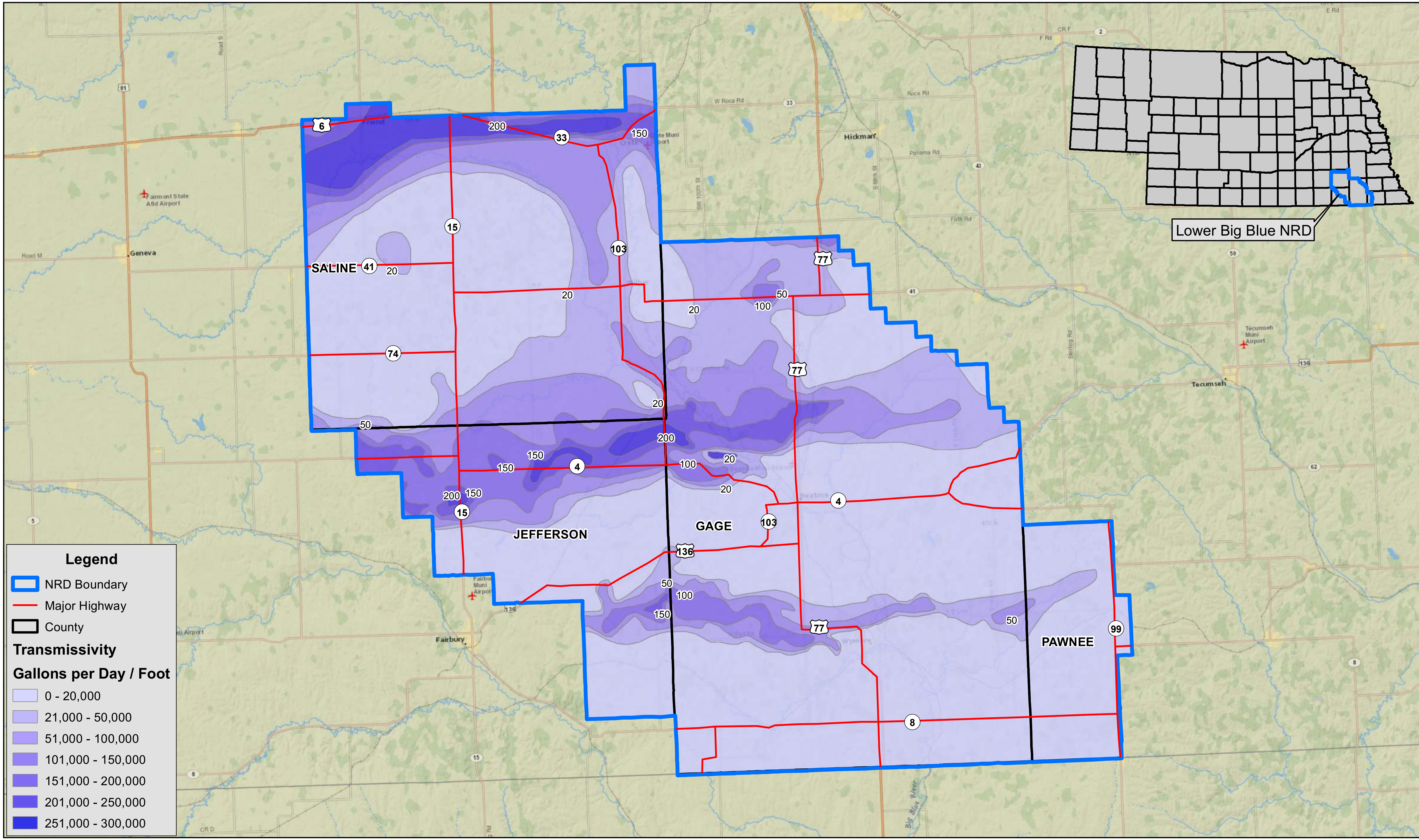
3 0 3 6 9 Miles

N

UNL-CSD Base of Principal Aquifer Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE 8



PROJECT: 013-2535

DRAWN BY: JD

DATE: September 08, 2014

Sources:
DNR: County, Major Highway, NRD Boundary
CSD: Transmissivity

3 0 3 6 9 Miles

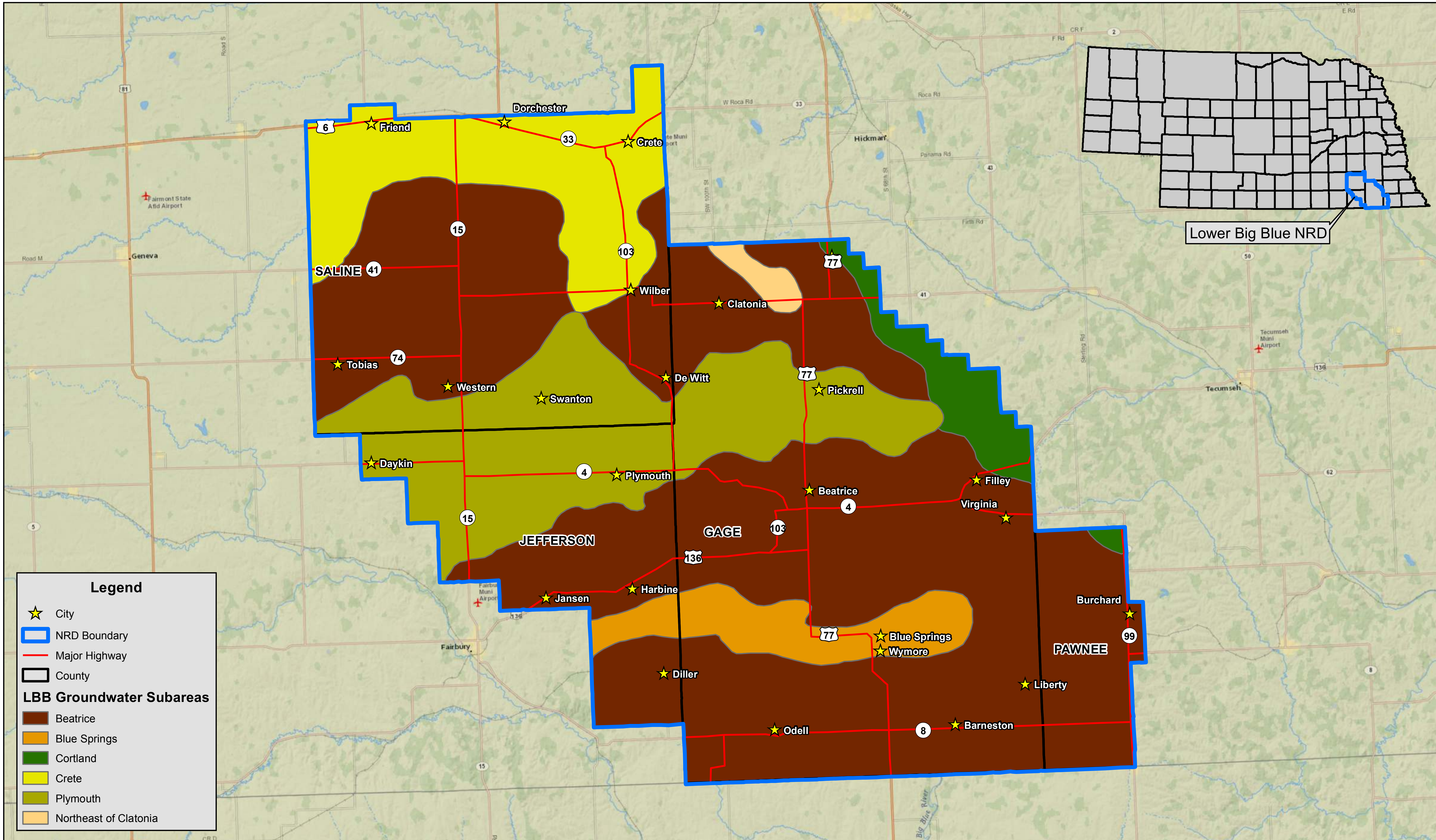
N

UNL - CSD Transmissivity Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE 9

F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver



PROJECT: 013-2535	Sources: DNR: City, County, Major Highway, NRD Boundary
DRAWN BY: CW	
DATE: September 11, 2014	

3 0 3 6 9 Miles

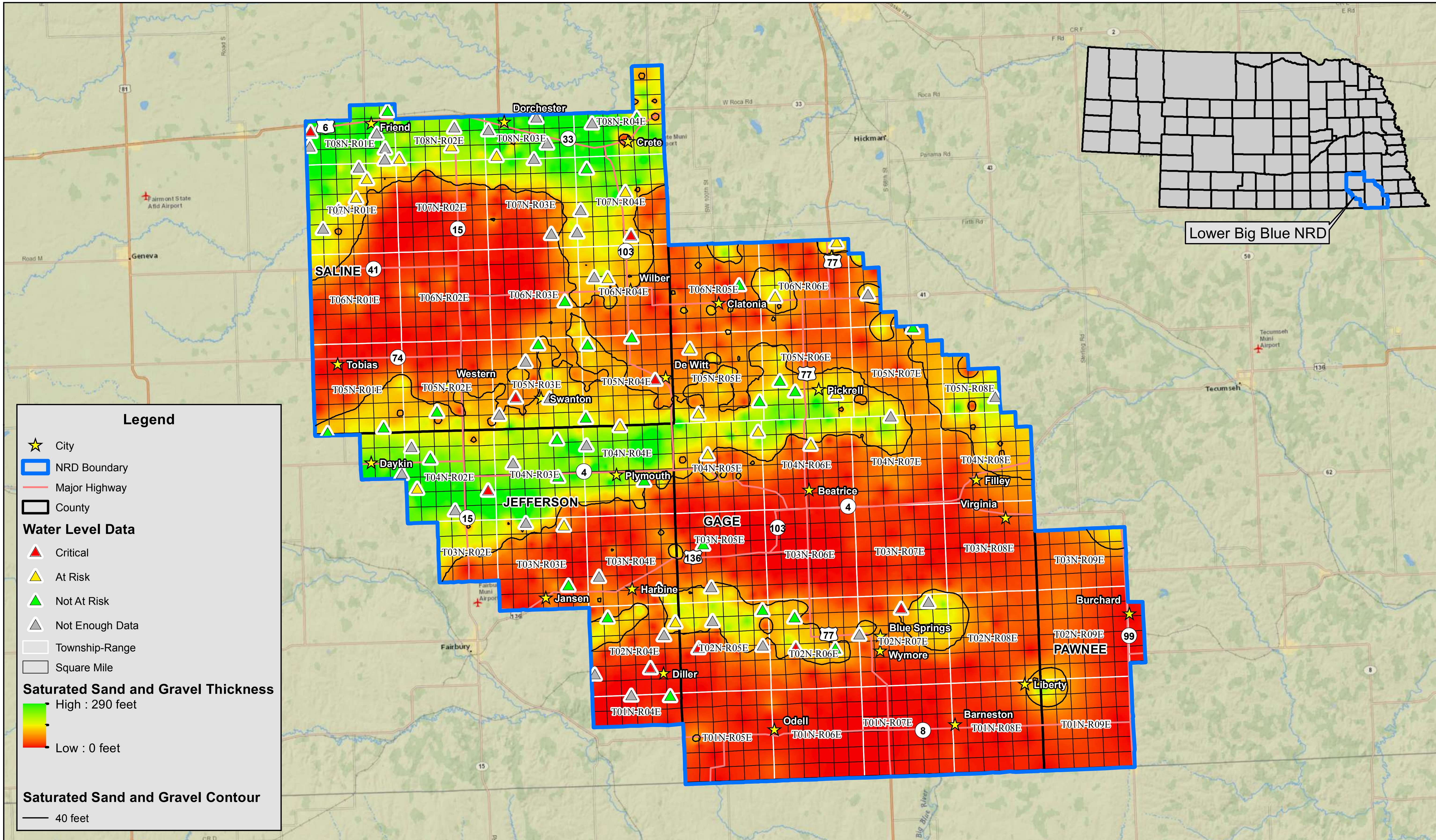
N

Groundwater Subarea Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE 10

F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535	Sources: DNR: City, County, Major Highway, NRD Boundary NRD: Water Level Data
DRAWN BY: CW	
DATE: September 11, 2014	

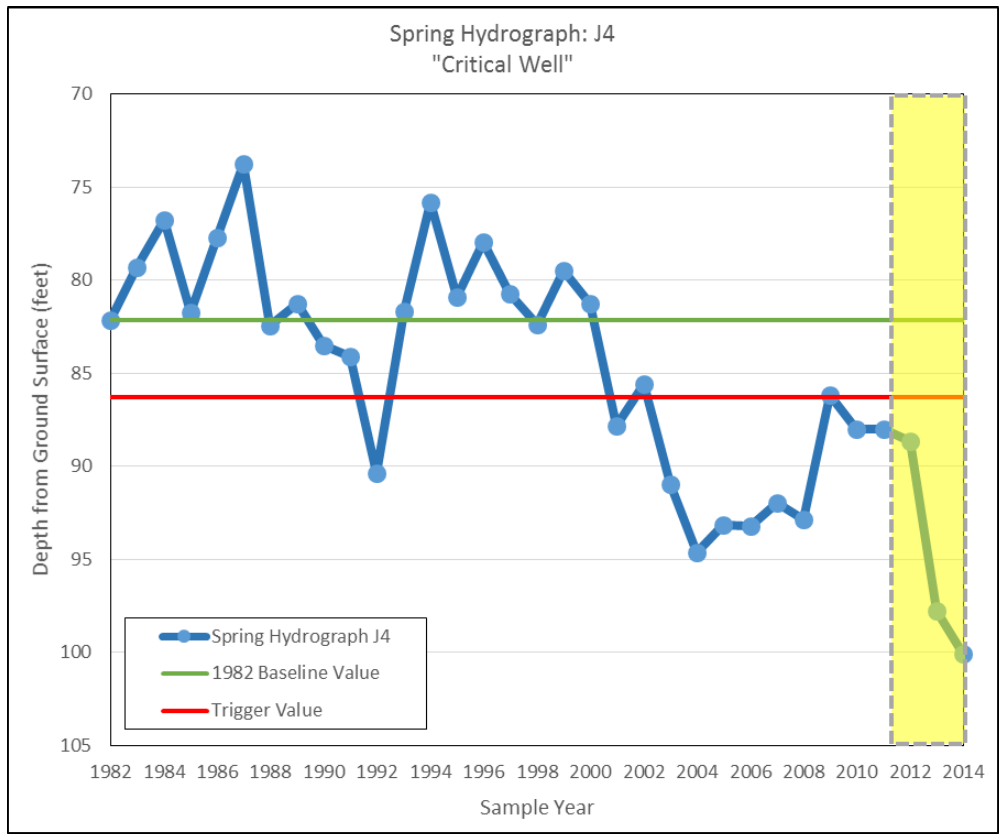
3 0 3 6 9 Miles

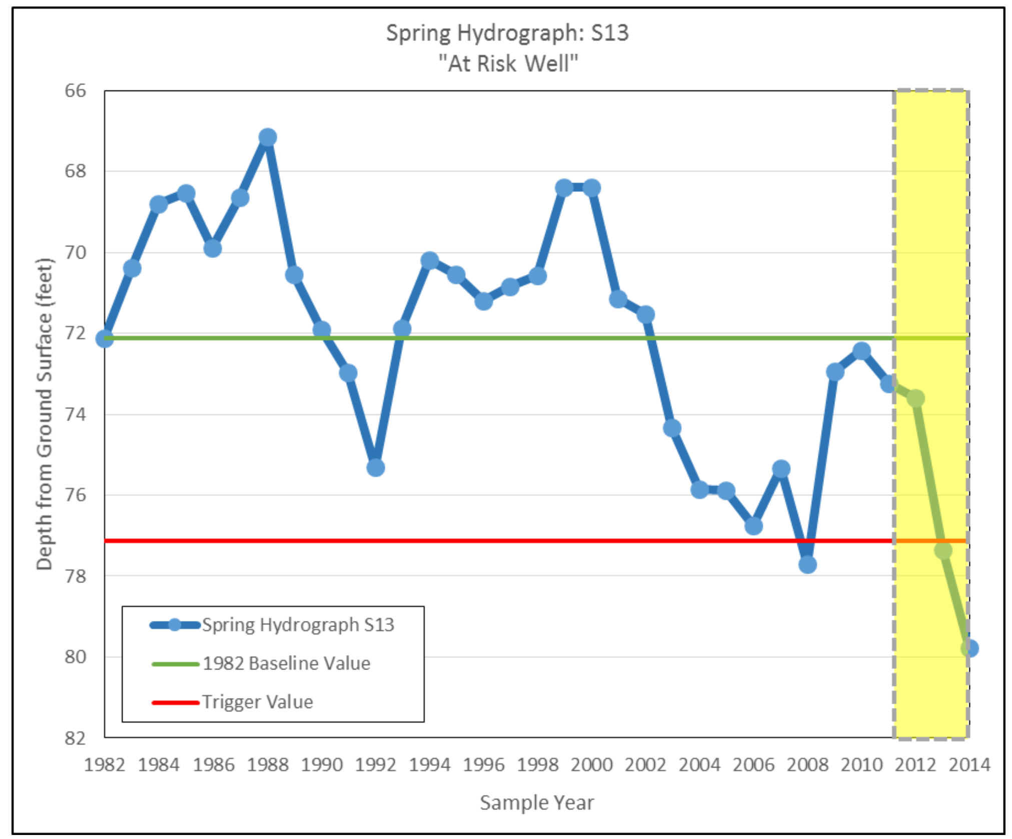
N

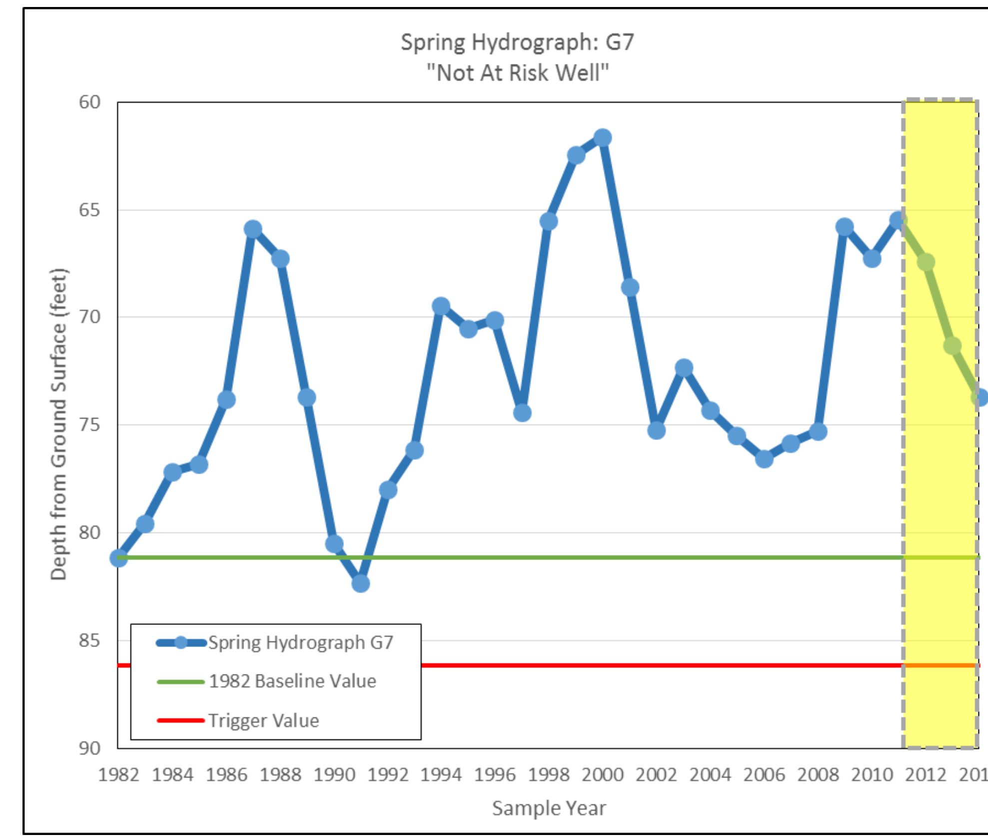
Groundwater Monitoring Well
Trigger Level Status Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE
11

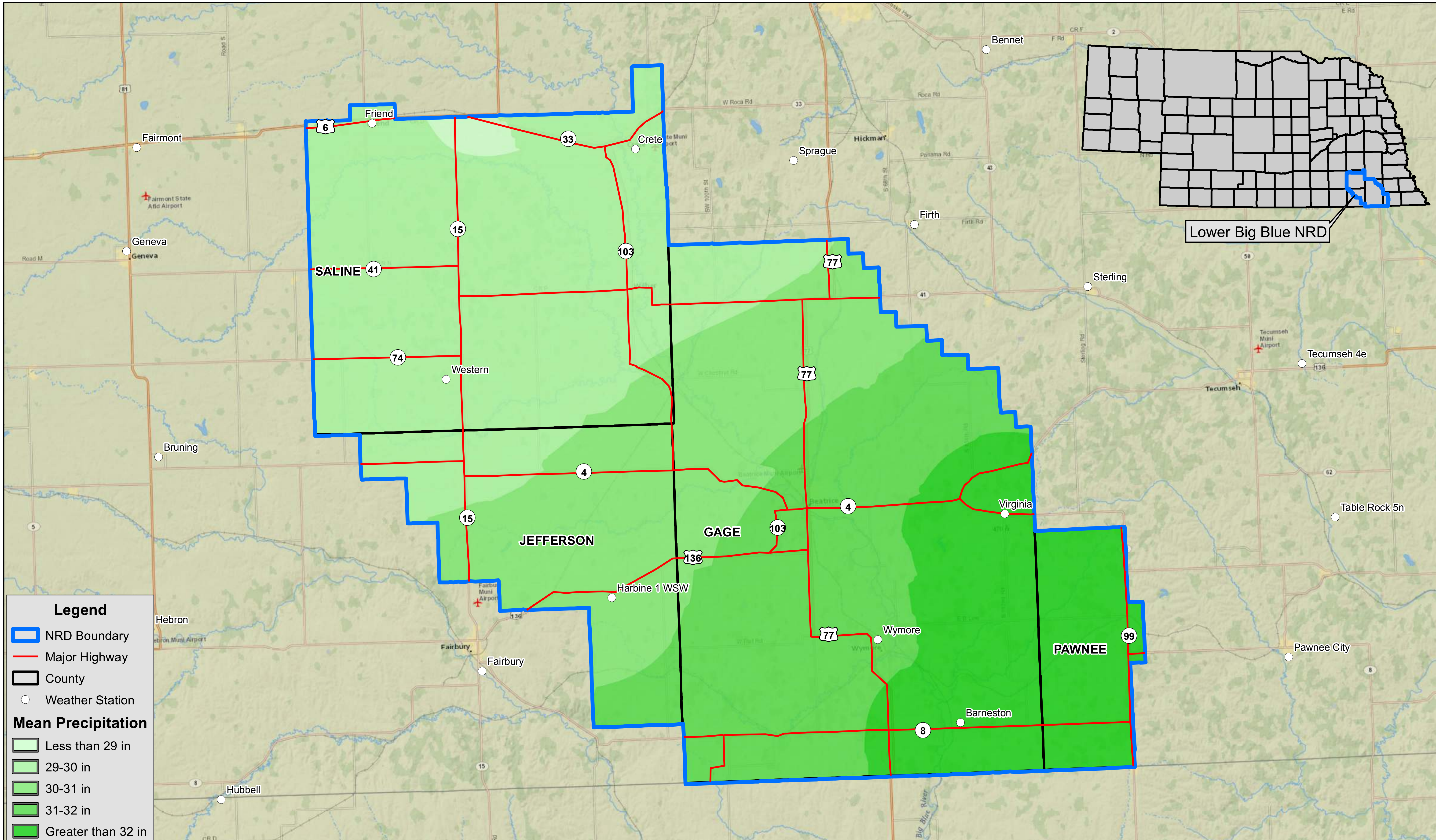






PROJECT: 013-2535 DRAWN BY: CW DATE: August 29, 2014	Sources: NRD: Water Level Data	**Groundwater Monitoring Well Trigger Level Status - Examples of Hydrographs** **Lower Big Blue Natural Resources District** **Southeast, Nebraska**	OLSSON ASSOCIATES	FIGURE 12

F:\Projects\013-2535\Data User:cweaver



F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver

PROJECT: 013-2535

DRAWN BY: LD

DATE: September 08, 2014

Sources:
DNR: County, Major Highway, NRD Boundary
HPRCC: Weather Stations, Precipitation

3 0 3 6 9 Miles

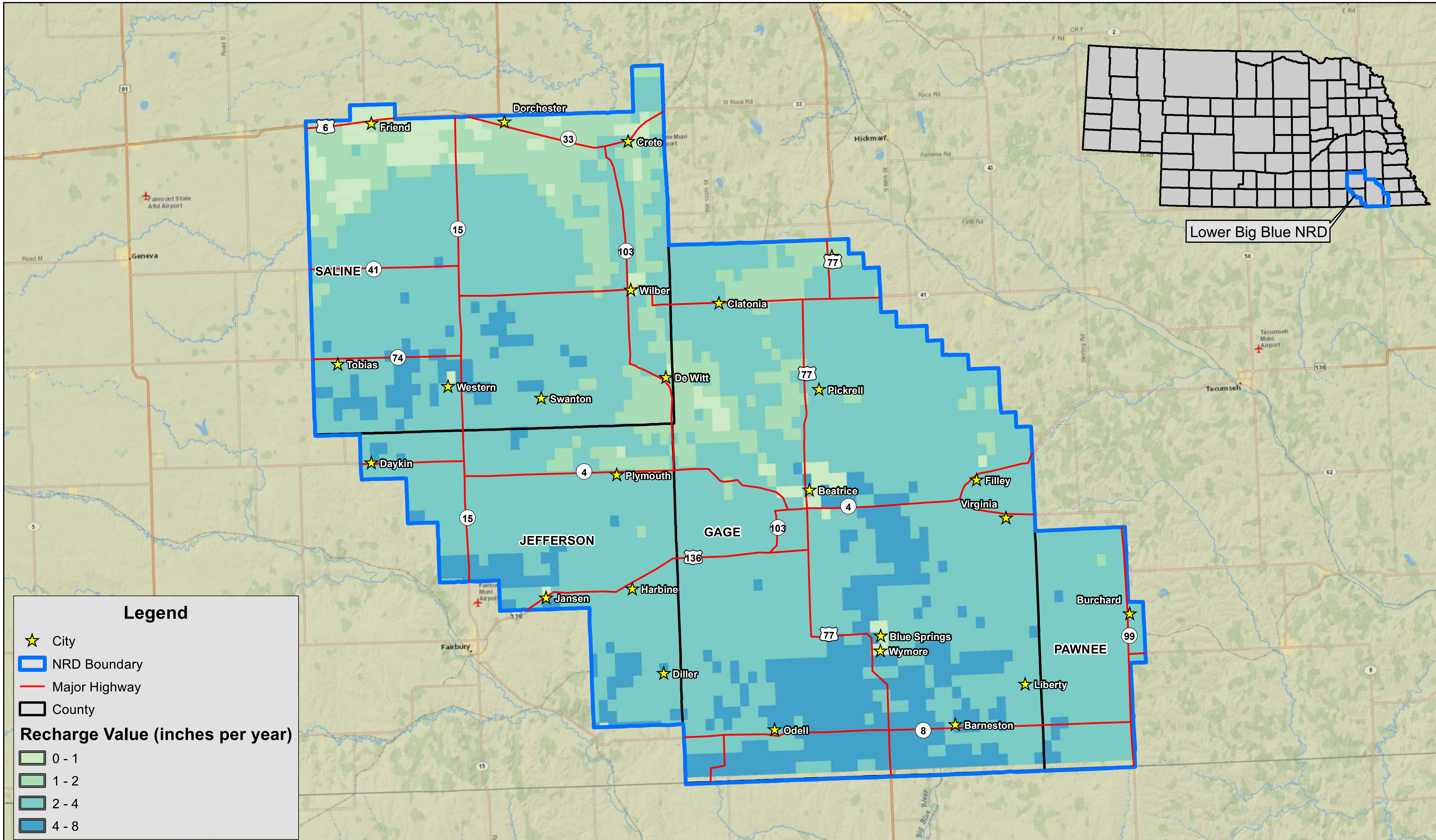
N

HPRCC 1971-2000 Mean Precipitation Map
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE

13



PROJECT: 013-2535	Sources:
DRAWN BY: JD	DNR: County, Major Highway, NRD Boundary
DATE: September 08, 2014	CSD: Szilagyi and Jozsa Recharge 2012

3 0 3 6 9 Miles

N

Average Annual Net Recharge Map
2000 - 2009
Lower Big Blue Natural Resource District
Southeast, Nebraska

OLSSON ASSOCIATES

FIGURE
14

F:\Projects\013-2535_GEOHY\GIS\Draft Maps.mxd User: cweaver