2.3.2 Aquifer Characteristics

Available aquifer parameter data are based primarily on regional aquifer evaluations. Transmissivity within the Maha aquifer beneath the project area ranges from around 7,500 to 75,000 gpd/ft (1,000 to 10,000 ft^2/day). In the south-central portion of the project area, transmissivities exceed 75,000 gpd/ft (10,000 ft^2/day) beneath Colfax and northern Butler Counties (Helgesen et al., 1993).

Limited information exists on the porosity of the Maha aquifer. Helgesen et al. (1993) present a regional porosity map within this aquifer based on borehole geophysical logs and laboratory-derived values from literature originating in the oil and gas industry. The nearest contour to the project area, which sits north-south across central Nebraska indicates a porosity value of 0.3. Specific yield estimates for sandstones in the Dakota aquifer in Kansas and Colorado range from 0.1 to 0.2. No storage coefficient values for the confined portion of the system have been identified. However, a specific storage value of 9.5×10^{-7} per ft of aquifer was reported (Helgesen et al., 1993). Multiplying this by 400 ft, the average thickness of the Maha aquifer beneath of the project area, results in a storage coefficient of 3.8×10^{-4}.

2.3.3 Connectivity to Surface Water

Recharge to the Maha aquifer beneath the project area is limited to locations where the bedrock is close to the surface. This occurs most often along deeply-incised surface drainages. In other regions of the Maha aquifer, recharge occurs via infiltration of precipitation along exposed outcrops or shallow subcrops (Helgesen et al., 1993).

Connection to surface water features is limited to where outcrops of the *Kd* are in direct contact with streams at the surface or where permeable bedrock and or fractures are separated from the surface streams by highly permeable streambed sediments.

2.3.4 Connectivity to other Aquifers

Communication with overlying buried glacial outwash aquifers likely occurs, but specific quantification of these fluxes is not known. Gosselin et. al (2001) identified specific geochemical groundwater signatures that indicated a source from overlying glacial outwash. The degree of communication between the Quaternary and Cretaceous groundwater flow systems is not well understood and likely varies considerably due to local, ambient vertical gradients or through influence of pumping that occurs from both aquifers. Upward vertical communication of groundwater from underlying bedrock units is also possible. The highly saline sources in the Maha Aquifer southeast of the project area in Lancaster County have been attributed to sources from the underlying Paleozoic units (Helgesen et al., 1993).

2.4 Water Quality

A total of 740 historic water quality samples were analyzed from the USGS National Water Information System (NWIS) to determine water chemistry characteristics of the project area, — 423 water samples from 184 stream-valley or alluvial wells, 192 water samples from 62 glacial-fill wells, 32 water samples

from 31 High Plains wells, and 93 water samples from 29 wells tapping Cretaceous strata (most likely *Kd*). The water-quality samples from the High Plains wells likely were collected from wells screened in or open to the *To*. The High Plains aquifer also includes Quaternary deposits.

Median specific electrical conductance for all groundwater samples was 718 µS/cm (Table 2-2). Median calcium, sodium, chloride, and total dissolved solids (TDS) were 99.5, 25.9, 3.6, 39.0, and 448 mg/L, respectively (Figure 2-7 [sulfate not shown], Table 2-2). The maximum specific conductance value was 4,710 µS/cm and the maximum calcium, sodium, chloride, sulfate, and TDS concentrations were 527, 281, 110, 1,390, and 2,470 mg/L, respectively. The maximum value for both specific conductance and TDS was from a sample in a shallow glacial well open to loess or till deposits. Specific conductance values averaged 2,550 µS/cm from 5 water samples. So the 4,710 µS/cm reading would appear as or approach an outlier value.

Most groundwater in the area appears fresh. In some locations, larger specific conductivity, sulfate, and total dissolved solids concentrations were observed. The quality of the groundwater in the project area should pose no interference for interpretation of AEM data.

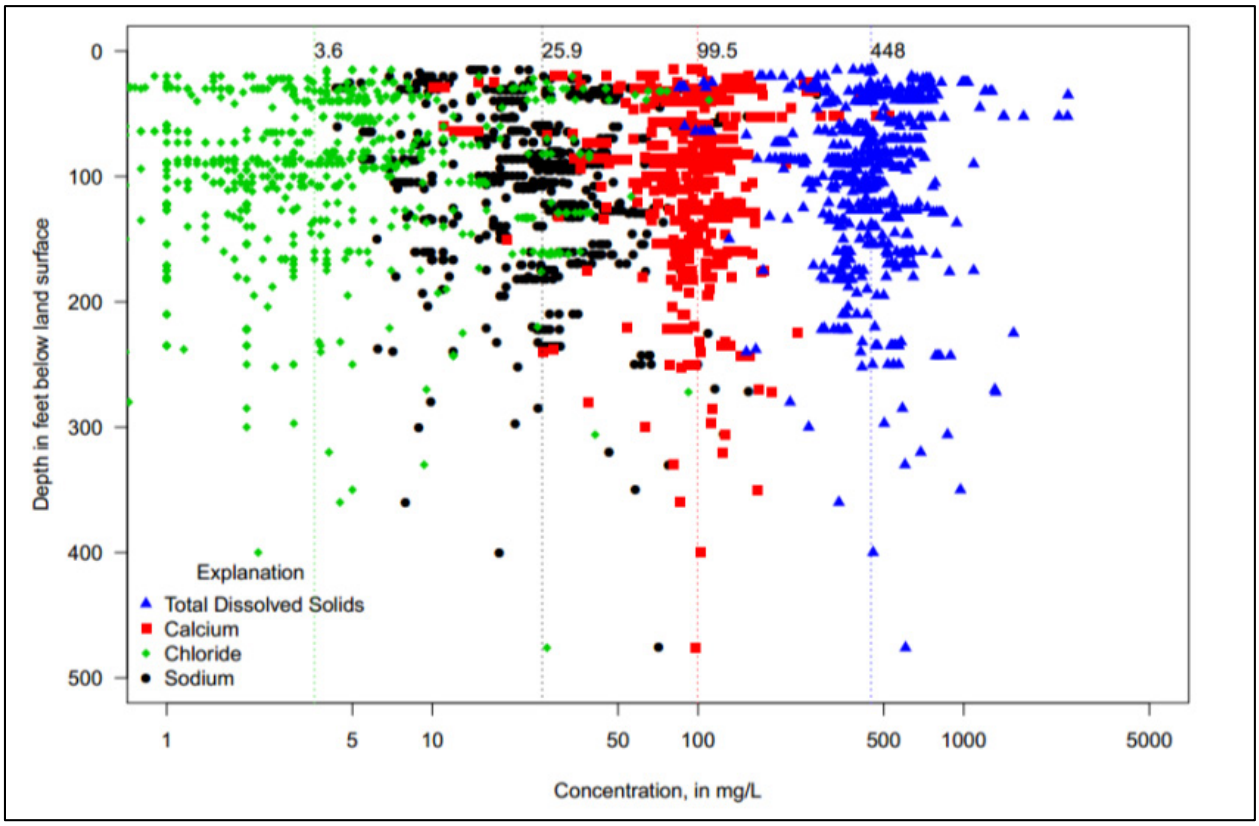


Figure 2-7: Concentrations (x-axis) of TDS, calcium, chloride, and sodium in water samples verses depth (y-axis) Data are from the US Geological Survey NWIS database.

Table 2-2: Statistical results of water-quality analyses from groundwater samples collected in or near the project area, from all wells. Units in milligrams per liter unless stated otherwise. Data are from the US Geological Survey NWIS database.

	Water temperature, in °C	Specific conductance, in uS/cm at 25°C	pH, in standard units	Dissolved oxygen	Total dissolved solids	
Minimum	8.30	96.0	5.90	0.10	85.0	
25th	11.5	597	7.00	0.20	355	
Median	12.5	718	7.20	0.70	448	
Mean	12.7	764	7.31	2.44	483	
75th	13.9	890	7.60	4.10	571	
Maximum	22.2	4,710	8.50	17.2	2,470	
NA's	18	2	83	384	23	
	Calcium	**Magnesium**	**Sodium**	**Sodium adsorption ratio**	**Potassium**	
Minimum	10.1	1.90	4.34	0.13	1.41	
25th	82.0	16.0	17.0.	0.40	4.1	
Median	99.5	21.9	25.9	0.60	6.34	
Mean	104	23.6	30.7	0.70	7.14	
75th	120	29.0	36.0	0.80	9.00	
Maximum	527	90.5	281	3.52	29	
NA's	0	0	0	0	18	
	Chloride	**Sulfate**	**Fluoride**	**Silica**	**Alkalinity, as $CaCO_3$**	**Bicarbonate, as $CaCO_3$**
Minimum	0.54	<0.18	0.09	8.20	30.3	37.0
25th	1.80	16.0	19.0	27.8	332	390
Median	3.60	39.0	23.0	33.0	360	440
Mean	8.08	77.9	28.7	32.5	371	465
75th	7.20	89.0	35.0	39.0	400	494
Maximum	110	1,390	93.0	66.8	1,020	1,240
NA's	2	1	213	200	454	628

2.4.1 Quaternary Aquifer Water Quality

Groundwater quality in both stream-valley and glacial-fill (Quaternary surficial aquifers) depends largely on overlying deposits. In areas where low yield deposits (i.e., till and loess) overlie aquifers, groundwater quality largely is less impacted than those where sand and gravel deposits are near land surface. In stream-valley systems, groundwater is in close proximity to the land surface and therefore subject to water quality changes due to land use/land cover.

Median specific conductance values from water-quality samples collected from stream-valley and glacial wells were 663 µS/cm (Table 2-3) and 779 µS/cm (Table 2-4), respectively. These values are lower than water samples from the *Kd* wells where median specific conductance was 845 µS/cm (Table 2-5). For

stream-valley wells the median calcium, sodium, chloride, sulfate, and total dissolved solids concentrations were 91.0, 20.2, 3.20, 40.0, and 413 mg/L, respectively (Table 2-3). The maximum specific conductance value was 1,930 µS/cm and the maximum calcium, sodium, chloride, sulfate, and TDS concentrations were 237, 116, 56.0, 875, and 1,540 mg/L, respectively (Table 2-3). For glacial-fill wells the median calcium, sodium, chloride, sulfate, and TDS concentrations were 104, 33.4, 3.37, 29.0, and 468 mg/L, respectively (Table 2-4). The maximum specific conductance value was 4,710 µS/cm and the maximum calcium, sodium, chloride, sulfate, and TDS concentrations were 527, 281, 110, 1,390, and 2,470 mg/L, respectively (Table 2-4).

Generally, median concentrations of ions and TDS in groundwater were slightly higher in water samples from glacial-fill wells than from stream-valley wells. Sulfate was the only exception where the stream-valley systems contained higher sulfate concentrations than glacially derived systems. This is thought to be due to the larger dissolved oxygen concentrations observed in the glacial systems than the stream-valley aquifers (2.50 to 0.65 mg/L). Small dissolved oxygen concentrations would help promote oxidation-reduction reactions (redox), which can increase SO_4 concentrations. Dissolved oxygen, however, was not collected in most stream-valley groundwater samples.

Table 2-3: Statistical results of water quality analyses from groundwater samples collected in or near the project area, from stream-valley/alluvial wells. Units are in milligrams per liter unless stated otherwise. Data are from the US Geological Survey NWIS database.

	Water temperature, in °C	Specific conductance, in µS/cm at 25°C	pH, in standard units	Dissolved oxygen	Total dissolved solids	
Minimum	8.30	96.0	5.90	0.10	85.0	
25th	11.7	513	7.10	0.20	320	
Median	12.9	663	7.30	0.65	413	
Mean	12.9	682	7.44	1.77	434	
75th	14.0	857	7.80	1.82	537	
Maximum	22.2	1,930	8.50	9.00	1,540	
NA's	10	2	17	343	13	
	Calcium	**Magnesium**	**Sodium**	**Sodium adsorption ratio**	**Potassium**	
Minimum	10.1	1.90	4.34	0.20	1.53	
25th	68.0	14.0	11.0	0.32	4.10	
Median	91.0	20.0	20.2	0.50	6.10	
Mean	93.7	21.8	23.4	0.55	6.42	
75th	120.	28.0	29.0	0.68	8.10	
Maximum	237.	89.0	116.	1.80	17.0	
NA's	0	0	0	0	9	
	Chloride	**Sulfate**	**Fluoride**	**Silica**	**Alkalinity, as $CaCO_3$**	**Bicarbonate, as $CaCO_3$**
Minimum	0.54	0.80	0.10	12.0	30.3	37.0
25th	1.70	15.0	0.30	29.8	330	44
Median	3.20	40.0	0.30	33.0	352	413
Mean	6.43	67.4	0.35	33.8	326	330
75th	5.94	84.8	0.40	39.0	392	437
Maximum	56.0	875	0.9	53.0	574	699
NA's	2	1	50	46	369	402

Table 2-4: Statistical results of water quality analyses from groundwater samples collected in or near the project area from glacial wells. Units are in milligrams per liter unless stated otherwise. Data are from the US Geological Survey NWIS database.

	Water temperature, in °C	Specific conductance, in µS/cm at 25°C	pH, in standard units	Dissolved oxygen	Total dissolved solids	
Minimum	9.10	418	6.50	0.10	261	
25th	11.6	687	6.90	0.40	408	
Median	12.3	779	7.00	2.50	468	
Mean	12.5	910	7.08	3.51	576	
75th	13.2	915	7.20	6.40	618	
Maximum	20.8	4,710	8.20	17.2	2,470	
NA's	7	0	48	24	1	
	Calcium	**Magnesium**	**Sodium**	**Sodium adsorption ratio**	**Potassium**	
Minimum	63.0	11.0	8.73	0.13	1.41	
25th	94.0	19.2	25.0	0.59	3.81	
Median	104	24.4	33.4	0.73	5.44	
Mean	122	27.7	42.8	0.94	7.67	
75th	117	29.9	47.0	1.04	8.98	
Maximum	527	90.5	281	3.52	29.0	
NA's	0	0	0	0	0	
	Chloride	**Sulfate**	**Fluoride**	**Silica**	**Alkalinity, as $CaCO_3$**	**Bicarbonate, as $CaCO_3$**
Minimum	<1.00	<0.18	0.17	14.9	158	192
25th	1.58	15.8	0.30	30.8	349	429
Median	3.37	29.0	0.40	33.6	368	477
Mean	7.76	78.5	0.49	32.5	402	545
75th	5.99	58.2	0.60	37.6	400	514
Maximum	110	1,390	1.22	50.4	1,020	1,240
NA's	0	0	104	104	30	123

Table 2-5: Statistical results of water quality analyses from groundwater samples collected in or near the project area from *Kd* wells. Units are in milligrams per liter unless stated otherwise. Data are from the US Geological Survey NWIS database.

	Water temperature, in °C	Specific conductance, in µS/cm at 25°C	pH, in standard units	Dissolved oxygen	Total dissolved solids	
Minimum	10.8	582	6.70	0.10	292	
25th	11.0	755	7.00	0.10	460	
Median	11.5	845	7.10	0.30	534	
Mean	13.4	880	7.10	0.48	559	
75th	13.0	938	7.20	0.60	602	
Maximum	143.	2,050	7.70	2.40	1,490	
NA's	1	0	18	11	9	
	Calcium	**Magnesium**	**Sodium**	**Sodium adsorption ratio**	**Potassium**	
Minimum	70.1	14.2	16.0	0.40	<3.21	
25th	104.	21.5	27.4	0.63	6.73	
Median	119.	23.7	32.7	0.73	9.90	
Mean	118.	25.3	43.3	0.94	9.74	
75th	129.	29.7	43.7	0.99	11.4	
Maximum	215.	47.0	186.	3.00	28.0	
NA's	0	0	0	0	9	
	Chloride	**Sulfate**	**Fluoride**	**Silica**	**Alkalinity, as $CaCO_3$**	**Bicarbonate, as $CaCO_3$**
Minimum	<1.00	<2.00	0.71	8.20	295	367
25th	2.00	68.9	0.87	12.7	317	372
Median	14.0	90.0	0.92	14.0	368	384
Mean	17.3	127.3	1.10	13.9	367	385
75th	25.6	157	1.10	14.8	417	392
Maximum	106	755	2.80	21.9	507	410
NA's	0	0	59	50	45	87

2.4.2 Bedrock Aquifer Water Quality

Water quality within the bedrock aquifers varies considerably by location and depth. Quality in the *Kd* in eastern Nebraska varies from (1) a Ca(±Mg)HCO_3-type water associated with local precipitation and where the Maha aquifer is unconfined, (2) a $CaSO_4$ and Ca-Na SO_4-type water associated with meltwater from Pleistocene glaciers and where the confining unit is thick, or (3) mixed waters of either $CaSO_4$ and Ca-Na SO_4-type water or NaCl-type water, which represent a possible interaction of the first

two types of water or recharge waters have been displaced by NaCl at depth (Gosselin et al., 2001). In the project area, water quality in the *Kd* likely is a $CaSO_4$ and Ca-Na SO_4-type water.

Groundwater can be potable in areas where the *Kd* is unconfined or subject to recharge from local precipitation. Dissolved-solids concentrations at these locations can be 500 mg/L or less (Ellis, 1984). Elsewhere, groundwater in the *Kd* can be highly mineralized (Stanton et al., 2007).

The median specific conductance value from water quality samples collected from *Kd* wells was 845 µS/cm (Table 2-5). As mentioned, this median value is higher than median specific conductance water samples from the stream-valley and glacial wells (Table 2-3 and Table 2-4). For *Kd* wells, the median calcium, sodium, chloride, sulfate, and TDS concentrations were 119, 32.7, 14.0, 19.0, and 534 mg/L, respectively (Table 2-5). These values are also larger than water samples collected from stream-valley and glacial wells. The single glacial well has large specific conductance and total dissolved solids values. Maximum calcium, sodium, chloride, sulfate, and TDS concentrations from *Kd* wells were 215, 186, 106, 755, and 1,490 mg/L, respectively (Table 2-5). Maximum calcium, chloride, and TDS concentrations were smaller than samples from glacial wells, a condition which is likely due to samples collected from the glacial well discussed above.

2.5 Water Use

The public supply wells within the LENRD area are displayed in Figure 2-8. The greatest concentrations of public wells are near the more populated area of northeast Madison County. Registered wells other than public supply wells are found throughout the LENRD, with irrigation wells being the most numerous. The densest concentrations of irrigation wells are in the western third of the LENRD as well as in smaller areas near the center of the district and along the district's southern boundary northwest of Fremont, NE. Domestic wells are scattered throughout the LENRD, with the greatest concentration surrounding the Norfolk, NE area.

Figure 2-9 displays the depth to groundwater in the registered wells. Relatively shallow groundwater (less than 50 ft below the subsurface) is present along the surface drainages that slope east/southeastward across the district, most notably along the Elkhorn and North Fork of the Elkhorn River valleys. Trending north/south through the middle of the project area is a zone of wells where groundwater is typically 150 ft deep or greater. In the western third of the area, depth to groundwater is slightly more variable, with the static levels typically between 50 and 150 ft. This variation could be due to wells tapping different aquifers, as the *To* is present in this area. Similar patterns in depth to groundwater are also apparent in the north-central portion of the project area.