

Chemical Quality of Irrigation Waters in Northwestern Kansas

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Chemical Quality of Irrigation Waters in Northwestern Kansas

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EXECUTIVE SUMMARY

In western Kansas the demand from the domestic, agricultural, and industrial sectors for groundwater continues to grow steadily. Yet, many areas are faced with declining water tables, and some regions are confronted with water-quality problems arising from natural sources or human activity. All areas are subject to increasing cost for the production of groundwater. Thus, it becomes essential to understand both the quality and quantity relationships of the aquifer systems in this part of the State. Consideration should also be given to cycling or re-use of water, where feasible, in order to extend the lifetime of the resource and minimize pumping cost.

Groundwater from shallow alluvial valley systems tends to be of lower quality than water from the Ogallala Formation in northwestern Kansas. Frequently the existence of the poorer quality groundwater in these drainageways is accompanied by the presence of saline soils. Irrigation waters from tail-water pits and the associated groundwaters in upland areas were found to be of comparable quality for their inorganic constituent levels, suggesting the possible re-use of tail waters in these regions. Future evaluation of tail-water quality in shallow alluvial valley systems and the accumulation of agrochemical organic residues in tail waters is needed.

Other areas covered by this series of studies are Greeley, Wichita, Scott, Lane, and southern Wallace counties (Kansas Geological Survey Chemical Quality Series 2); Hamilton, Kearny, Finney, and northern Gray counties (Chemical Quality Series 4); Stanton, Grant, Haskell, Morton, Stevens, Seward, Meade, and southern Gray counties (Chemical Quality Series 6); and Ford County and the Great Bend Prairie--Kiowa, Edwards, Pratt, Kingman, Stafford, Barton, Rice, and Reno counties (Chemical Quality Series 7). The final sampling in this program will be the Equus Beds area (1979).

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CHEMICAL QUALITY OF IRRIGATION WATERS IN

NORTHWESTERN KANSAS

Abstract

Field work in northwestern Kansas during July 1978 yielded groundwater samples from 315 pumping irrigation wells and samples from tail-water pits associated with eight of those wells. The area covered by this sampling includes Cheyenne, Decatur, Gove, Logan, Rawlins, Sheridan, Sherman, Thomas, Wallace, and the western half of Graham counties.

A general increase in the amount of dissolved solids is found for waters associated with portions of the alluvial systems of the South Fork of the Republican River, Beaver Creek, and Sappa Creek in the northern half of the study area; and the Smoky Hill River and Hackberry Creek in the southern portion of the study area. Calcium-bicarbonate- to calcium-magnesium-bicarbonate-type waters are generally associated with upland areas where production is from the Ogallala Formation, but a transition toward sulfate-type waters is observed for many of the shallow alluvial systems in the study area. Waters from tail-water pits are of comparable quality to those of the producing wells.

Introduction

The present study is the fifth part of a program established in 1974 to obtain a chemical-quality data base for irrigation waters of western Kansas. Previous study areas are shown in Figure 1 (Hathaway and others, 1975, 1977, 1978a, 1978b), together with the location of the current one. Figure 2 is a general map of the study area. The present area (∿9-1/3 counties) contains the region covered by Groundwater Management District

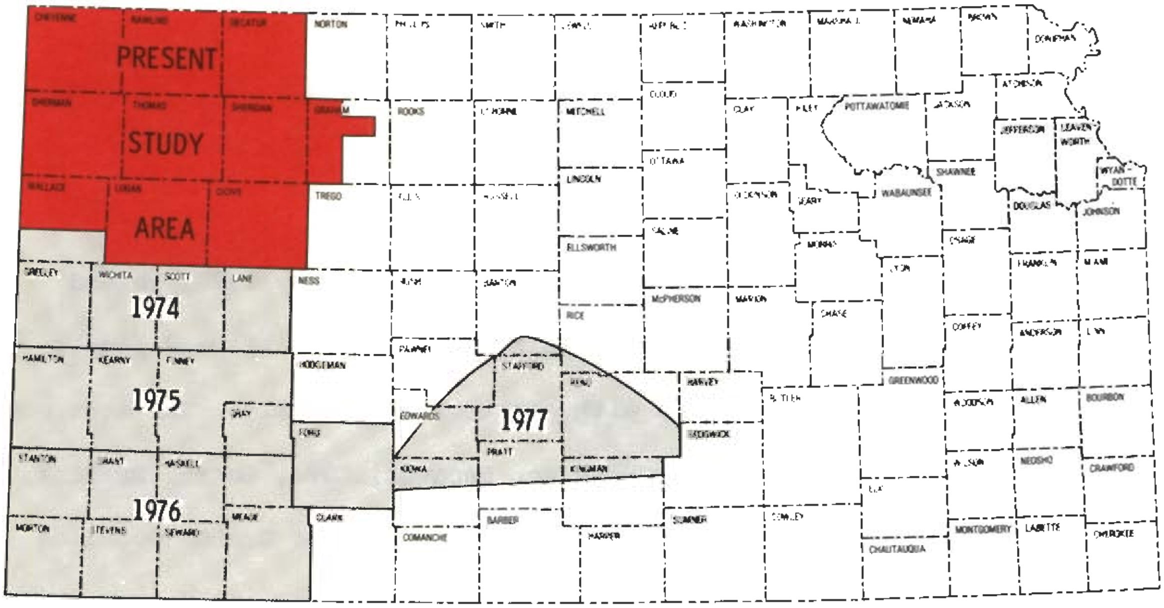

Figure 1. Map showing coverage of this report and related past reports in this Series.

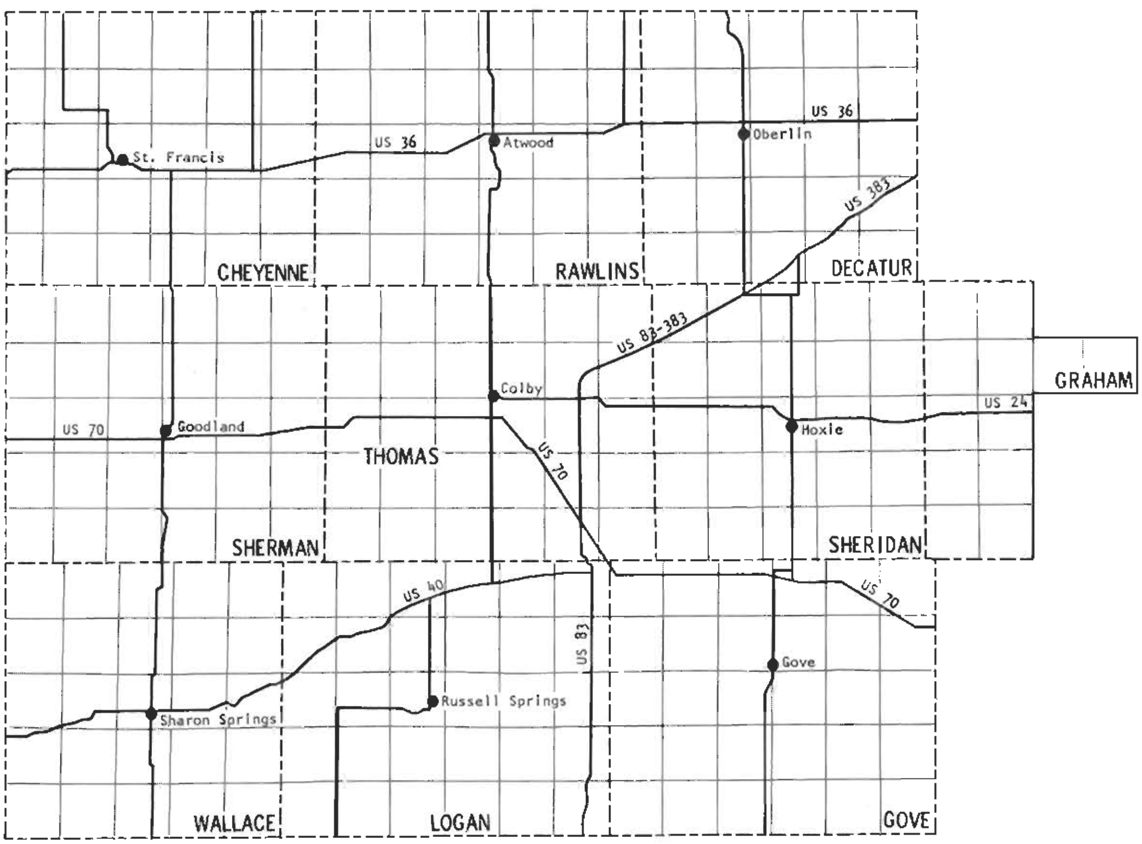

Figure 2. Location of the study area.

No. 4 as well as two of the wells in southern Wallace County that were sampled in the 1974 study.

The Ogallala Formation of Pliocene age is the major source of irrigation water in the study area. The alluvial valley systems of the Smoky Hill, Saline, Solomon, and Republican rivers, and Beaver, Sappa, Prairie Dog, and Hackberry creeks also serve as sources of groundwater. Wells in the alluvial deposits are generally shallow. From historical data it has been noted that the general quality of the groundwater in these areas is poorer than that of water derived from the Ogallala Formation. Historical chemical-quality data exist for about 15 percent of the wells sampled in this study.

Well locations used in this report are based upon the Bureau of Land Management numbering system. The location is composed of the township, the range, and the section number followed by letters designating the subdivision of the section in which the well is located (Figure 3).

Topography

Detailed discussions of the general geologic features of the counties making up the present study area are found in a number of Kansas Geological Survey Bulletins (Prescott, 1953a, 1953b, 1955; Hodson, 1963, 1969; Hodson and Wahl, 1960; Johnson, 1958; Bayne, 1956; Walters, 1956; Frye, 1945; Elias, 1931; and Pearl and others, 1972).

The present study area falls within the High Plains section of the Great Plains physiographic province. The general slope of the land surface is from west to east, with the upland plain area being a relatively flat to gently rolling surface that may exhibit numerous small depressions locally. Within the study area a general eastward flow of the

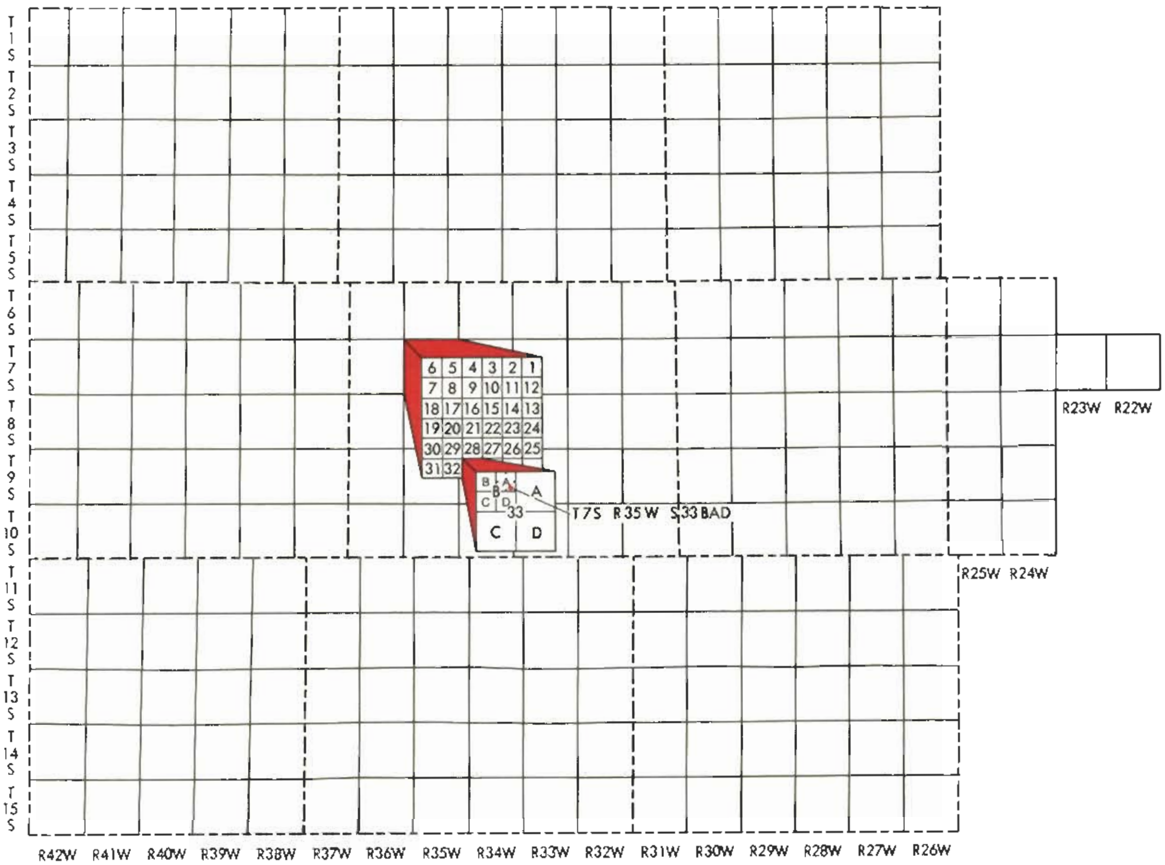

Figure 3. Illustration of the Bureau of Land Management numbering system used for well locations in this report.

groundwater is observed. The upland plain is highly dissected in the study area by the valley systems of the Republican, Saline, Solomon, and Smoky Hill rivers and Beaver, Sappa, Prairie Dog, and Hackberry creeks, which all trend in an easterly direction. Along the tributary and river valleys of the Smoky Hill River in Wallace, Gove, and Logan counties, the North Fork of the Republican River in Cheyenne County, and the South Fork of the Solomon River in western Graham County, the Ogallala Formation has been eroded away, exposing the consolidated Upper Cretaceous bedrock units. Locally the Ogallala Formation may be cemented by calcium carbonate or silica into mortar beds that are generally exposed along the drainageways in the study area. Figure 4 shows the principal drainage systems of the study area.

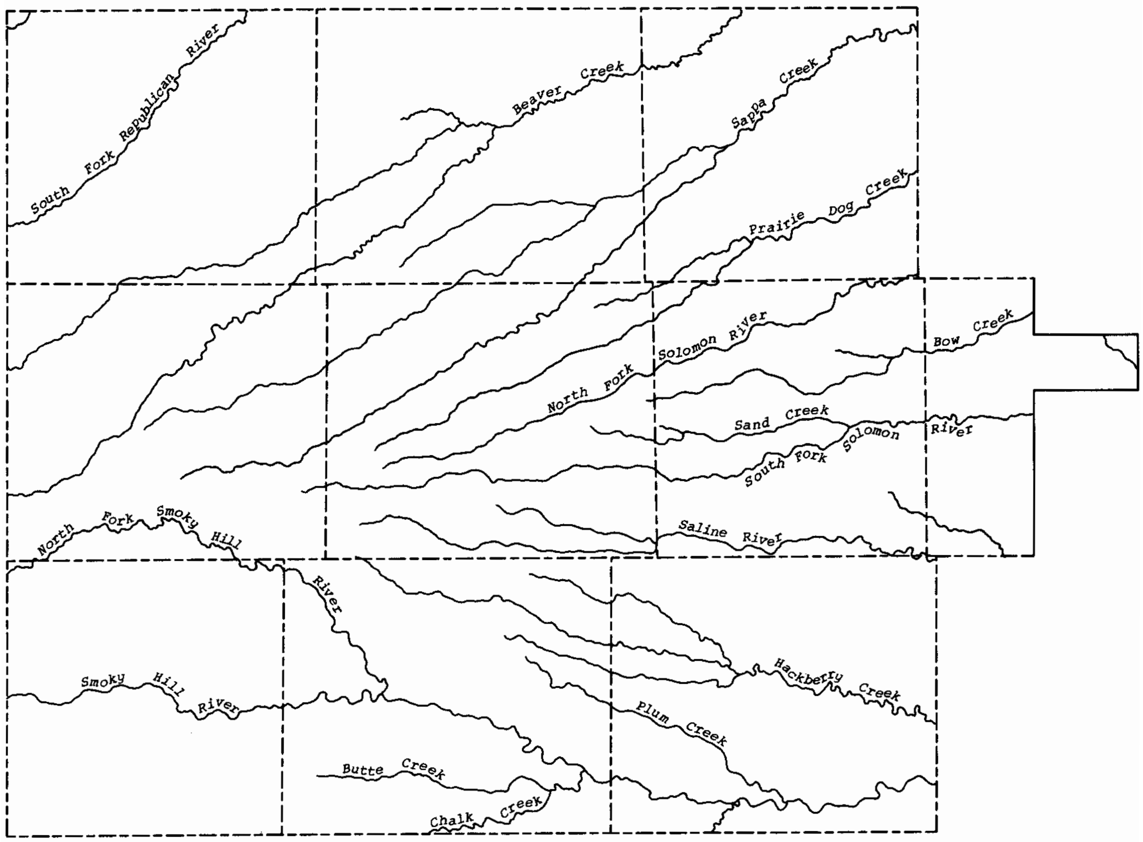

Figure 4. Drainage systems of the study area.

Bedrock

Bedrock in the study area is comprised of consolidated rocks of Upper Cretaceous age. In about the eastern third of the study area the Niobrara Chalk is the bedrock unit, but this gives way to Pierre Shale as one moves westward (Figure 5). Elias (1931) and Johnson (1958) have described faulting and folding in exposed units of the Upper Cretaceous rocks in Wallace and Logan counties. Dissolution of carbonate members

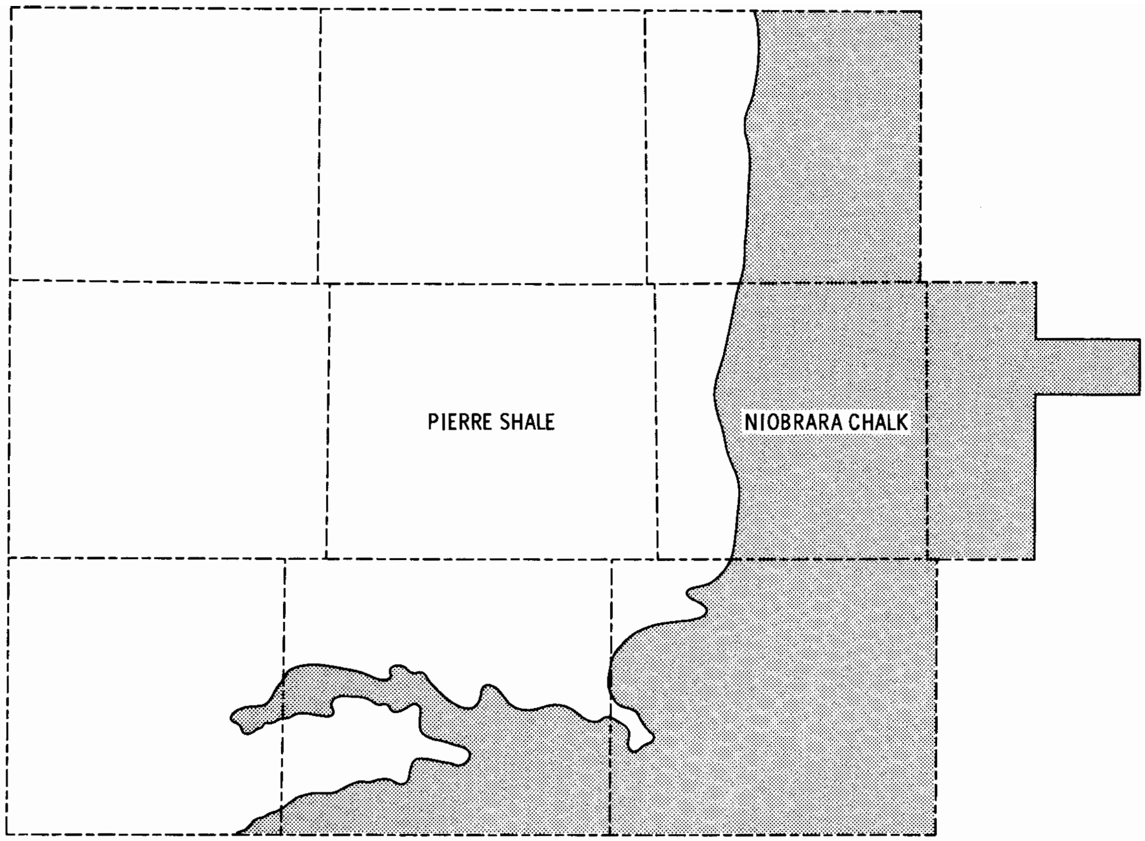

Figure 5. Generalized bedrock geology of the study area.

followed by subsidence or slumping have been suggested as important factors in accounting for the disturbances in the Upper Cretaceous. The observed folding together of the Ogallala Formation and the underlying Pierre Shale in Wallace County may indicate the presence of other mechanisms as well. Exposures of the Pierre Shale and Niobrara Chalk are prominent along the Smoky Hill River valley in eastern Wallace, Logan, and southern Gove counties.

Soils

Soils on the upland areas are derived from the loess mantle that overlies the Ogallala Formation, whereas the soils of the sloping landscapes of the drainageways are related to the erosion of material of Pliocene and Pleistocene age. Exposures of the more resistant mortar beds in the Ogallala Formation occur along some of these drainageways. Soils in the southeastern portion of the study area are derived from the Niobrara Chalk and typically exhibit a sparse vegetive covering and are subject to erosion on sloping landscapes. Saline soils are associated most notably with the alluvium of the Smoky Hill River valley.

Figure 6 presents a generalized soils association map of the study area, which has been produced through a combination of data for individual counties (Angell and others, 1978; Angell, in press; Angell and others, 1973; Barker, in press; Bell and others, 1964; Angell, 1978, written communication; Barker, 1978, written communication). This combination of data has involved some grouping of various soil associations presented in the general county soil maps and some regrouping of soil associations used in those reports in order to better reflect the pattern of soils in the natural landscapes for the multi-county area. Table 1 provides brief descriptions of the soil association groups used in Figure 6.

Sampling and Analysis

Groundwater samples were collected from 315 pumping irrigation wells and tail-water pits associated with eight of these wells over a four-day period, July 24-27, 1978. Historical chemical-quality data were found to exist for about 15 percent of the wells sampled, with two of the wells in Wallace County being ones included in the 1974 sampling program. Duplicate sets of samples were collected at 33 sites. Eighteen of the duplicate sets were the result of individual field personnel collecting duplicate sets of samples from wells within their sampling area (Individual Sets). Fifteen duplicate sets of samples were collected from wells

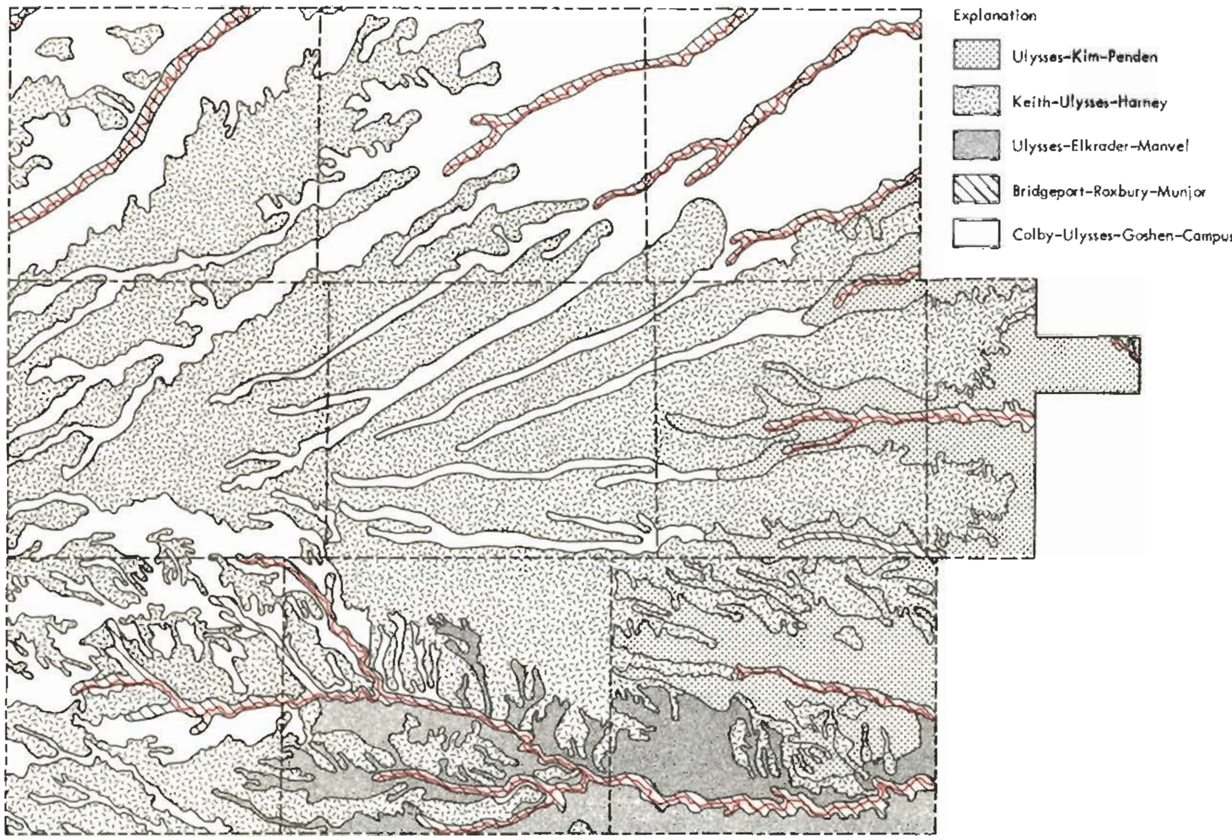

Figure 6. Soil association map.

TABLE 1. Soil Association Groups

1. Keith - Ulysses - Harney: These deep, silty soils are on nearly level and gently sloping landscapes. The amount of stream dissection increases from west to east. Low amount of runoff from these areas to stream systems.

2. Colby - Ulysses - Goshen - Campus: This association consists mostly of deep, silty and loamy soils on nearly level to steep landscapes. These soils occur in conjunction with drainageways.

3. Bridgeport - Roxbury - Munjor: These silty, loamy, and sandy soils are on nearly level and gently undulating landscapes. They occupy the valleys of the streams in the study area. There are a few small areas of saline and sodic soils in the valleys of the major streams.

4. Ulysses - Kim - Penden: Deep, loamy and silty soils occurring on nearly level to strongly sloping landscapes. Soils in this association are along drainageways in the eastern one-fourth of the study area.

5. Ulysses - Elkrader - Manvel: Deep, silty soils occurring on nearly level to steep landscapes. These soils are along the Smoky Hill River in the southeastern part of the study area. Outcrops of the Niobrara Chalk occur in this association.

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located along the boundaries of different sampling areas by two individuals sampling the same well (Overlap Sets). Time intervals between collection of the sets at overlap sites varied from part of one day to three days. In one situation an individual duplicate site also corresponded to an overlap site.

The location of the wells sampled in the study, as well as areas with generally less than 40 feet saturated thickness of unconsolidated sediments (Bayne and Ward, 1969), are shown in Figure 7. From this figure, it is readily apparent that the majority of the wells sampled are in the regions of 40 feet or more of saturated thickness. The others are generally associated with shallow groundwater systems of the valleys of the different drainageways that dissect the study area.

Sample handling and analytical procedures for most constituents were similar to those described earlier (Hathaway, 1978b). Variations from the analytical routines used previously included the use of an auto-titrimeter for the determination of carbonate (CO_3) and bicarbonate (HCO_3) levels of the water samples at a field laboratory established in Colby, Kansas. Specific conductance and pH measurements were also made at the field laboratory in order to evaluate the consistency of

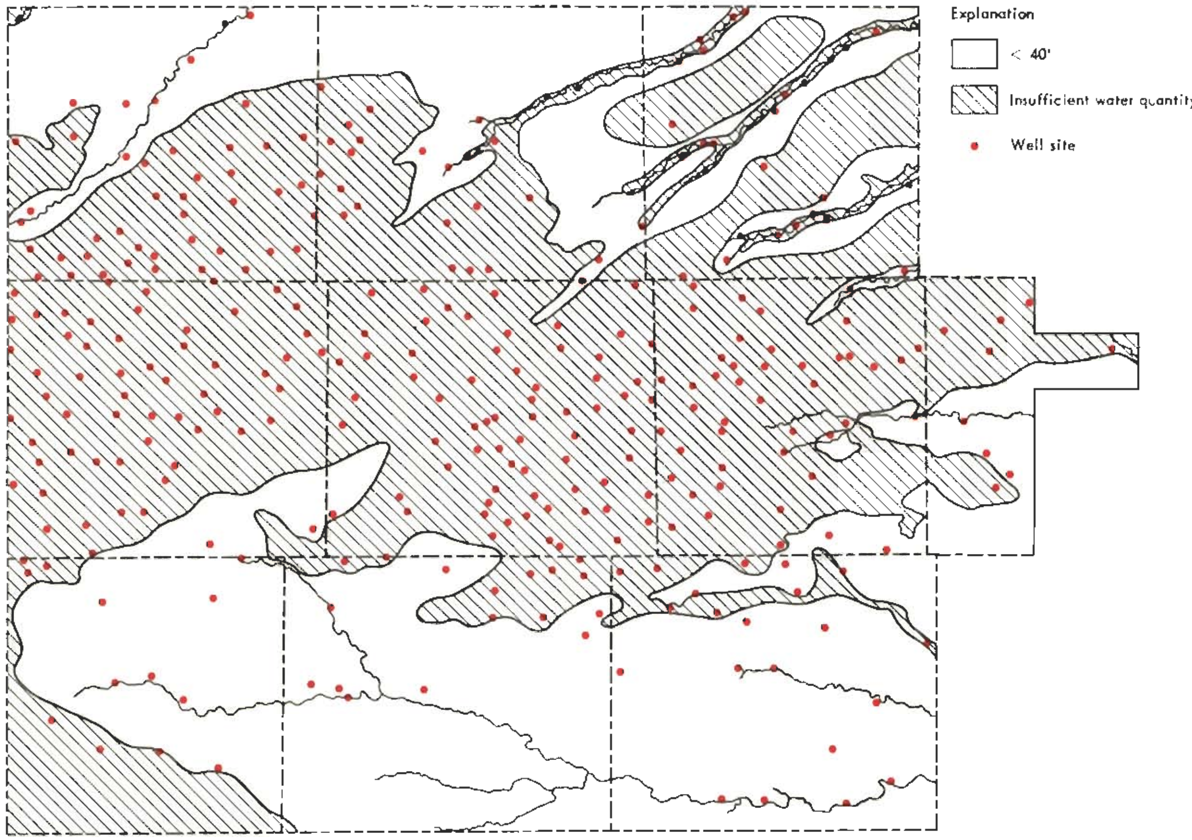

Figure 7. Location of wells in the study area and a generalized display of areas with 40 feet or more of saturated thickness.

the field measurements made at the time of sampling. Technicon Auto-Analyzer II systems were employed for the analysis of phosphate (PO_4) and sulfate (SO_4) at the Kansas Geological Survey laboratories in Lawrence. The automated systems for the determination of HCO_3, SO_4, and PO_4 thus replaced the manual systems used in prior studies.

As in the past, fluoride (F) analyses were made at the field laboratory and the determinations of silica (SiO_2), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), strontium (Sr), chloride (Cl), nitrate (NO_3), and the trace elements iron (Fe), manganese (Mn), copper

(Cu), and nickel (Ni) were all made in the Kansas Geological Survey laboratories.

Samples collected from the eight tail-water pits consisted of a one-liter unacidified sample (for major constituents) and one 250 ml acidified sample (for NO_3 and PO_4). The sample for NO_3 and PO_4 was collected into a pre-acidified bottle and filtered upon returning to the Kansas Geological Survey laboratories. This procedure may result in release of PO_4 from suspended sediment in the sample, but probably better reflects the potential available PO_4 levels of these waters if they are to be recycled onto the fields.

Standard deviations for determinations of the major constituents, based upon the 18 individual and 15 overlap duplicate sets of samples, are presented in Table 2. The magnitudes of the standard deviations noted here for both types of duplicates are comparable to those reported for earlier studies. It is interesting to note that the spread in values of the specific conductance as determined in the laboratory is similar for both types of duplicates and much tighter than those determined by individuals collecting the overlap sets of duplicates. It also appears that use of the Technicon Auto-Analyzer II system for SO_4 analyses has reduced the standard deviation for analyses of both types of duplicates by about a factor of two compared to values listed for previous studies.

A general compilation of the chemical-quality data for irrigation wells within the study area is given in Appendix A by county and location. A comparison of waters from wells and associated tail-water pits is found in the RESULTS AND DISCUSSION section of this report.

TABLE 2. Standard Deviations of Data for Duplicate Sets

Determination	Individual Duplicate Sets ±σ	Overlap Duplicate Sets ±σ
SiO_2	1.6 ppm*	2.0 ppm*
Ca	0.3 ppm	1.0 ppm
Mg	0.2 ppm	0.6 ppm
Na	1.0 ppm	0.8 ppm
K	0.08 ppm	0.2 ppm
Sr	0.04 ppm	0.1 ppm
HCO_3	1.0 ppm	0.9 ppm
SO_4	0.8 ppm	1.3 ppm
Cl	0.04 ppm	1.0 ppm
F	0.03 ppm	0.05 ppm
NO_3	0.0 ppm	1.4 ppm
Total Dissolved Solids	6.7 ppm	12 ppm
Specific Conductance (Field)		40 μ mho
Specific Conductance (Lab)	2.6 μ mho**	4.9 μ mho**

*parts per million or milligrams per liter

**micro-mhos at 25°C

$$\pm\sigma = \sqrt{\frac{1/2 \sum_{i=1}^{N} r_i^2}{N}}$$

r_i = range of analysis of sample pairs

N = number of sample pairs

Mapping of Chemical-Quality Data

The areal chemical-quality data presented in this report were plotted manually using the 40-foot saturated thickness contour of Map M-5 (Bayne and Ward, 1969) as a general boundary for mapping purposes. Areas with generally less than 40 feet of saturated thickness are represented by open spaces in Figure 7. Chemical-quality data from the 1974 sampling program for southern Wallace County have been used in the production of the current areal maps in order to provide a more complete coverage of the County. This approach seems reasonable in view of the consistency of the chemical-quality data for the two wells in Wallace County that were sampled in both 1974 and 1978.

Results and Discussion

A general impression of the variation in chemical quality of irrigation waters within the study area can be obtained from the specific-conductance data displayed in Figure 8. Table 3 lists minimum, maximum, and mean values of the major constituents, total dissolved solids, and specific conductance of the irrigation waters.

From Figures 6-8 it is apparent that higher specific-conductance values and higher dissolved-solids levels are generally associated with shallower wells in the alluvial valleys of the drainageways in the study area. Wells in the valleys of the South Fork of the Republican River, Smoky Hill River, and Hackberry Creek generally are associated with less than 40 feet of saturated thickness of the aquifer unit. Historical data also show that waters from these valley systems have tended to contain higher dissolved-solids levels than water from wells in upland regions or wells associated with a greater saturated thickness.

TABLE 3. Summary of Ranges and Means for Chemical-Quality Data

Variable	Min/Max / Mean (ppm)
SiO_2	17/68 / 46
Ca	25/343 / 59
Mg	7.6/145 / 19
Na	5.9/234 / 34
K	3.0/24 / 7.3
Sr	0.4/6.0 / 0.9
HCO_3	161/518 / 246
SO_4	7.6/1524 / 71
Cl	1.8/123 / 17
F	0.4/2.6 / 1.3
NO_3	0.0/92 / 18
Total Dissolved Solids	166/2441 / 387
Specific Conductance*	310/2900 / 581

*micro-mhos at 25°C

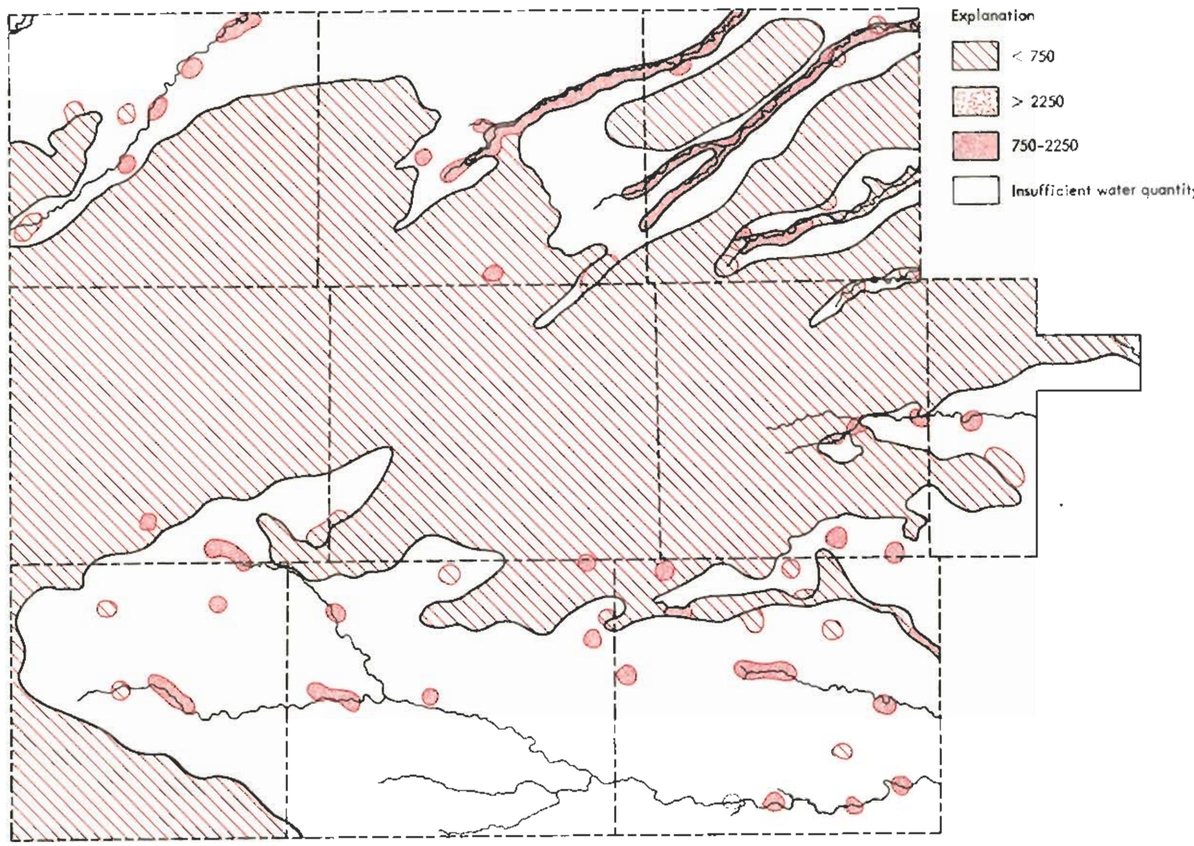

Figure 8. Specific conductance map. Units = μ Mho

Figure 9 presents Stiff diagrams (Stiff, 1951) for selected wells from the study area. With the aid of these diagrams, it is possible to obtain a general impression of the magnitude and composition of the dissolved salt loads of waters associated with the alluvium systems of the drainageways as compared to waters derived from the Ogallala Formation. Waters from alluvium of the valley systems all show increased dissolved-solids loads relative to nearby Ogallala waters, with changes in the levels of Ca, Na, Mg, SO_4, and Cl being most noticeable. This increase is most pronounced along the lower reaches of the South Fork of the Republican River, Hackberry Creek, and the Smoky Hill River in

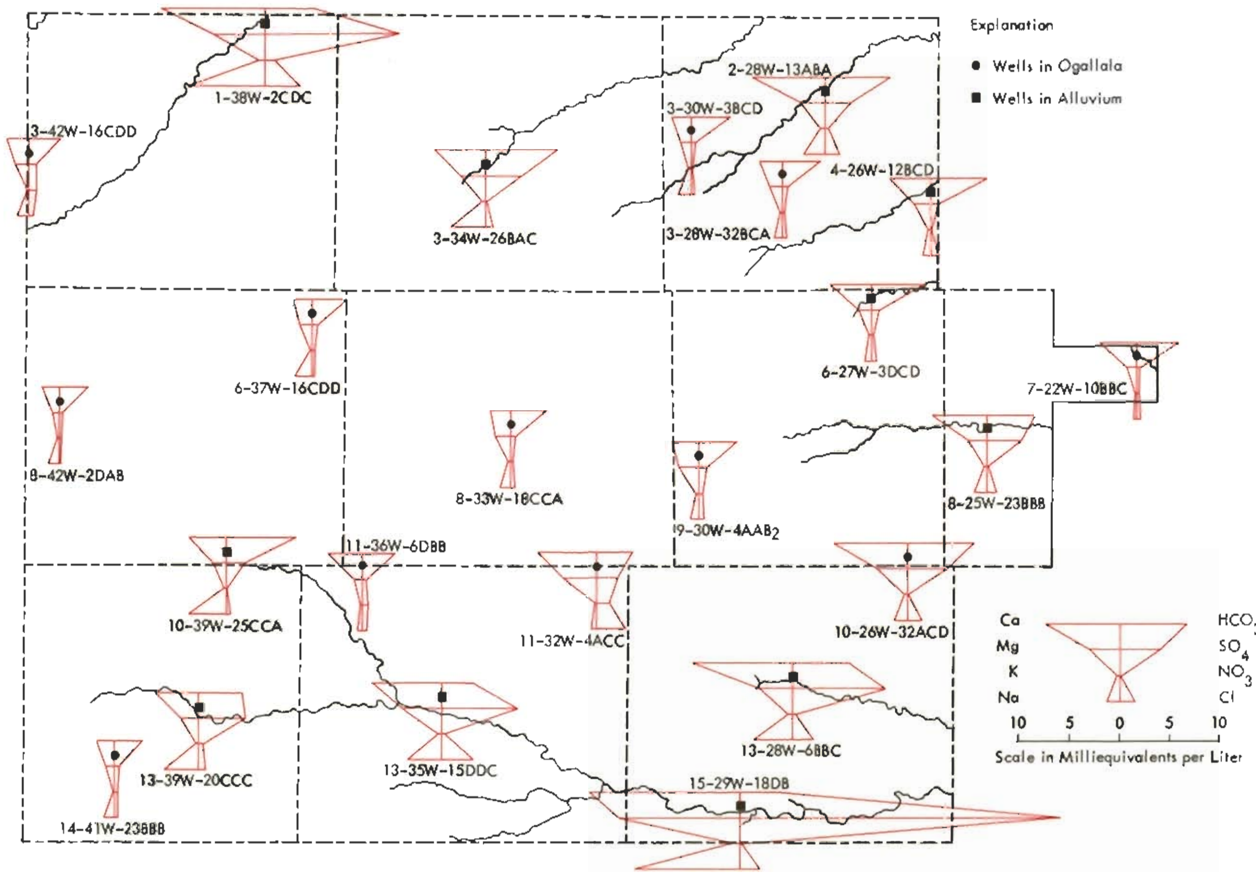

Figure 9. Areal display of Stiff diagrams for selected wells.

the study area. Waters from the lower portions of these three drainage systems all exhibit higher sulfate levels than neighboring Ogallala waters, and in fact sulfate tends to become the dominant anion in these waters. Increased SO_4 levels in these shallow alluvial systems may be the result of prolonged contact of the water with the gypsum-bearing Pierre Shale, as suggested by Walters (1956) to explain the poorer quality of waters from alluvial and terrace deposits in Rawlins County. Or these levels may result from accumulation in the sediments of the drainageways of salts generated through natural weathering processes at the surface. Both processes may be important locally. The occurrence of saline soils in parts of the valley systems suggests that salt accumulation, with resultant decrease in water quality, may be of importance locally in these shallow aquifer systems.

Figure 9 also provides a generalized representation of the transition in chemical quality of waters associated with the Smoky Hill River valley system, in which dissolved solids and sulfate levels both tend to increase as one progresses down the valley system.

The specific-conductance data of Figure 8 suggest the same trend also holds with respect to the dissolved-solids levels in waters associated with the drainage systems of the South Fork of the Republican River, Solomon River, Saline River, Hackberry Creek, Beaver Creek, Sappa Creek, and portions of Prairie Dog Creek in the present study area. Elevated dissolved-solids levels in waters from the alluvium of the drainage systems are frequently associated with the occurrence of saline soils, especially in areas where sulfate becomes the dominant anion in the groundwaters.

The Stiff diagram for well location 11-32W-4ACC, west of Oakley, indicates a higher dissolved-solids level than that of typical Ogallala water from that area. In addition, the Na/Cl ppm ratio for this water is 0.11, a value well below that for rock salt (0.65) or those that appear typical of oil-field brines in Kansas (0.40-0.60). A Na/Cl ppm ratio of 0.30 is observed at 11-30W-31DAB, about 10 miles southeast of Oakley along the North Fork of Hackberry Creek. The Cl levels for 11-32W-4ACC (100 ppm) and 11-30W-31DAB (78 ppm) are higher than those of neighboring wells that are located in the Ogallala Formation (13-44 ppm). The concentrations of Ca, Mg, and SO_4 also appear to be anomalously high at 11-32W-4ACC. Thus, the trends in the Cl levels and Na/Cl ratios for these two wells and the Stiff diagram for 11-32W-4ACC all suggest the possibility of a source relatively rich in Ca-Mg-SO_4-Cl located west of Oakley that may become mobilized and transported down the North Fork of Hackberry Creek during periods of heavy rainfall and localized flooding.

The areal distribution patterns for many of the major and minor chemical components of the dissolved-solids load of the groundwaters from the study area are similar to the trends noted for the specific-conductance data (Figure 8). An increase in the levels of Ca, Mg, Na, K, Sr, SO_4, Cl, and PO_4 is generally noted for waters from the alluvial valleys of the drainageways. Higher PO_4 values (>0.25 ppm) are generally found in systems of the northeastern quadrant of the study area, but higher values of Sr (>2 ppm) and SO_4 appear to be most common along the Smoky Hill River valley. Potassium levels in excess of 10 ppm are observed for wells in alluvium throughout the study area. In general, the build-up of these chemical species in the alluvial systems appears to be the result of natural processes of weathering, transport to, and accumulation in the soils and waters of the lower valley areas.

In the case of F, levels equal to or greater than 1.7 ppm seem to be more abundant in the northwestern quadrant of the study area; whereas SiO_2 values greater than 50 ppm are most common in the northern half of the study area. Nitrate values above 30 ppm appear to be randomly scattered throughout the study area.

Elevated levels of Fe, Mn, Cu, and Ni may result from contamination at the point of sample collection and/or from increased levels of these trace elements in the local groundwater systems. Higher values of Fe and Mn are generally associated with waters from alluvial valley systems.

The rusty color of unacidified samples from the Smoky Hill River valley in Gove County suggests that more than simple contamination is responsible for the levels of Fe and Mn observed in these samples. The Fe levels in waters collected in this study from upland areas generally are observed to be less than 50 ppb (parts per billion or micrograms per liter), which is in sharp contrast to values as high as 10 ppm that were reported by Frye (1945) for Thomas County. The higher levels of Fe found in the historical data relative to the present study probably reflect insufficient pumping of the wells prior to sample collection rather than actual chemical-quality changes in the waters of the area.

Figures 10 and 11 represent areal groundwater classification by cation and anion types, respectively. Water-type classifications used

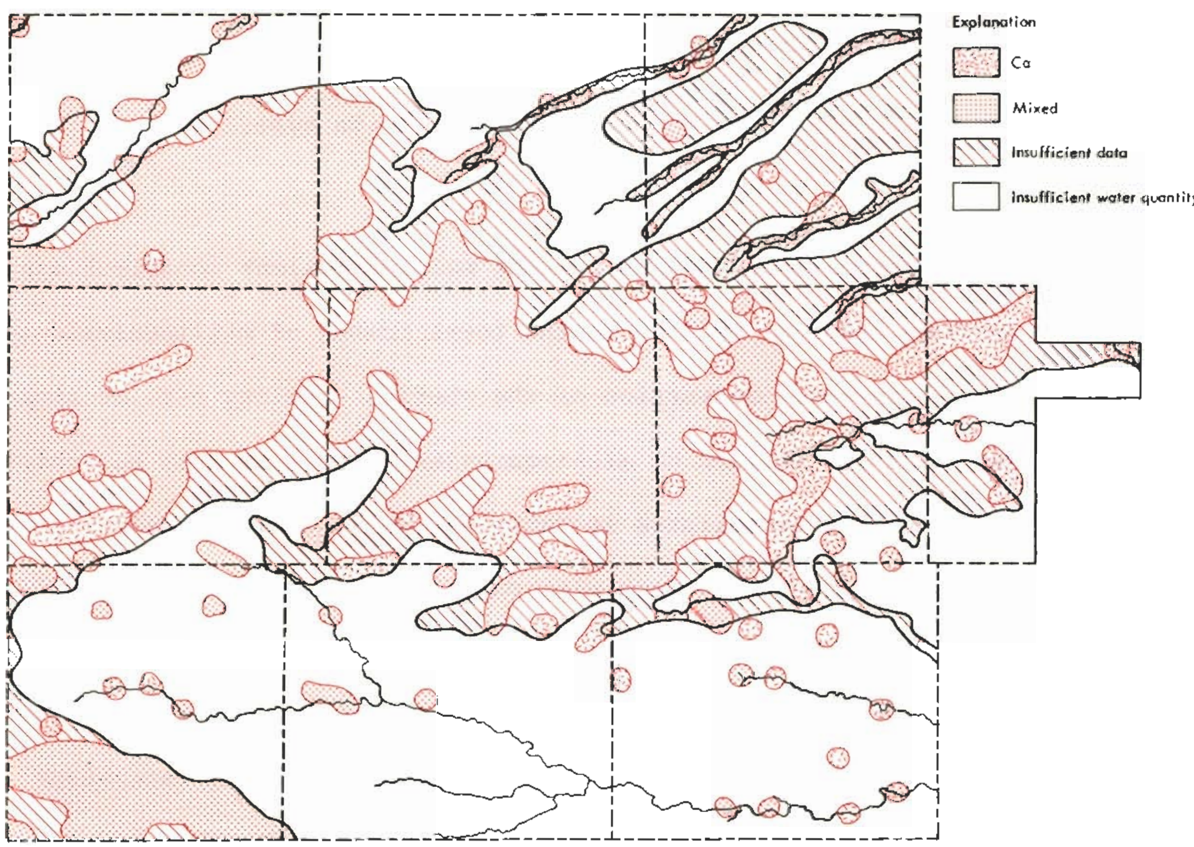

Figure 10. Groundwater classification by cation type.

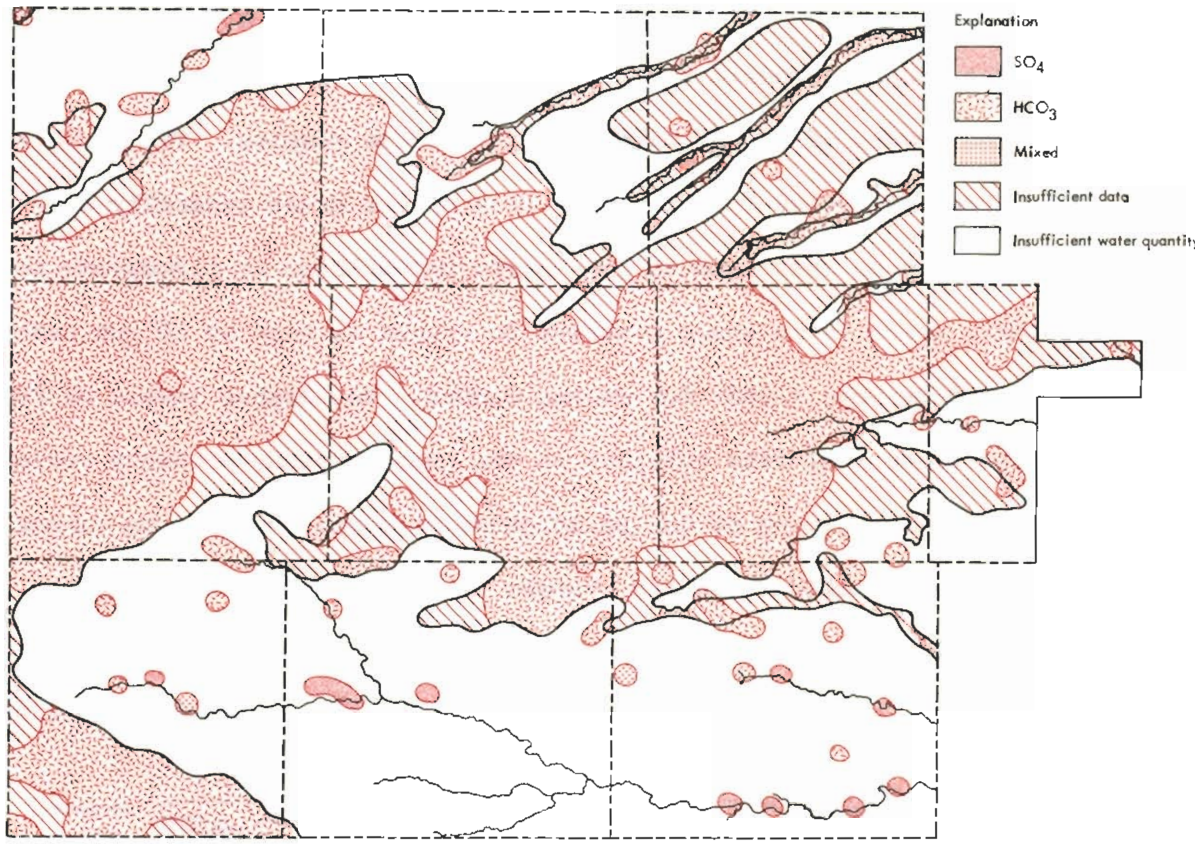

Figure 11. Groundwater classification by anion type.

in this report are based upon percent milliequivalent contributions of the various chemical species to the total number of milliequivalents of cations or anions. Conversion of the chemical-quality data of Appendix A from parts per million to milliequivalents per liter can be achieved by use of the factors listed in Table 4. These milliequivalent-per-liter values reflect the combining capacities of the various chemical species in the waters.

Areas of no control shown in Figures 10 and 11 reflect regions where the sample density is too low to allow extension of the water-type boundaries. Based upon these two figures, it appears that mixed cation -

TABLE 4. Factors for Conversion From Parts Per Million to Milliequivalents Per Liter

Species	Multiply By
Calcium (Ca)	0.04990
Magnesium (Mg)	0.08226
Sodium (Na)	0.04350
Potassium (K)	0.02557
Strontium (Sr)	0.02283
Bicarbonate (HCO_3)	0.01639
Sulfate (SO_4)	0.02082
Chloride (Cl)	0.02821
Fluoride (F)	0.05264
Nitrate (NO_3)	0.01613

HCO_3 waters (generally Ca-Mg-HCO_3) are most common in the western two-thirds of the study area, with Ca-HCO_3-type waters becoming the dominant form in the eastern third of the study area. This change in classification is probably the combined result of a general decrease in the saturated thickness and the transition of the bedrock in this area from the Pierre Shale (western two-thirds) to the Niobrara Chalk (eastern one-third). The increased importance of SO_4 in waters of the South Fork of the Republican River, the Smoky Hill River, and Hackberry Creek valleys is also apparent from Figure 11.

Sodium adsorption ratio (SAR) values are computed from the chemical-quality data using the equation

$$SAR = \frac{(Na)}{\sqrt{\frac{(Ca) + (Mg)}{2}}}$$

where values in parentheses are the milliequivalents per liter of the specific ions. Figure 12 is a map of SAR values for groundwaters from the study area. SAR values for the study area are observed to be generally less than 1.5, with values in excess of 1.5 most frequently being associated with waters near drainage systems.

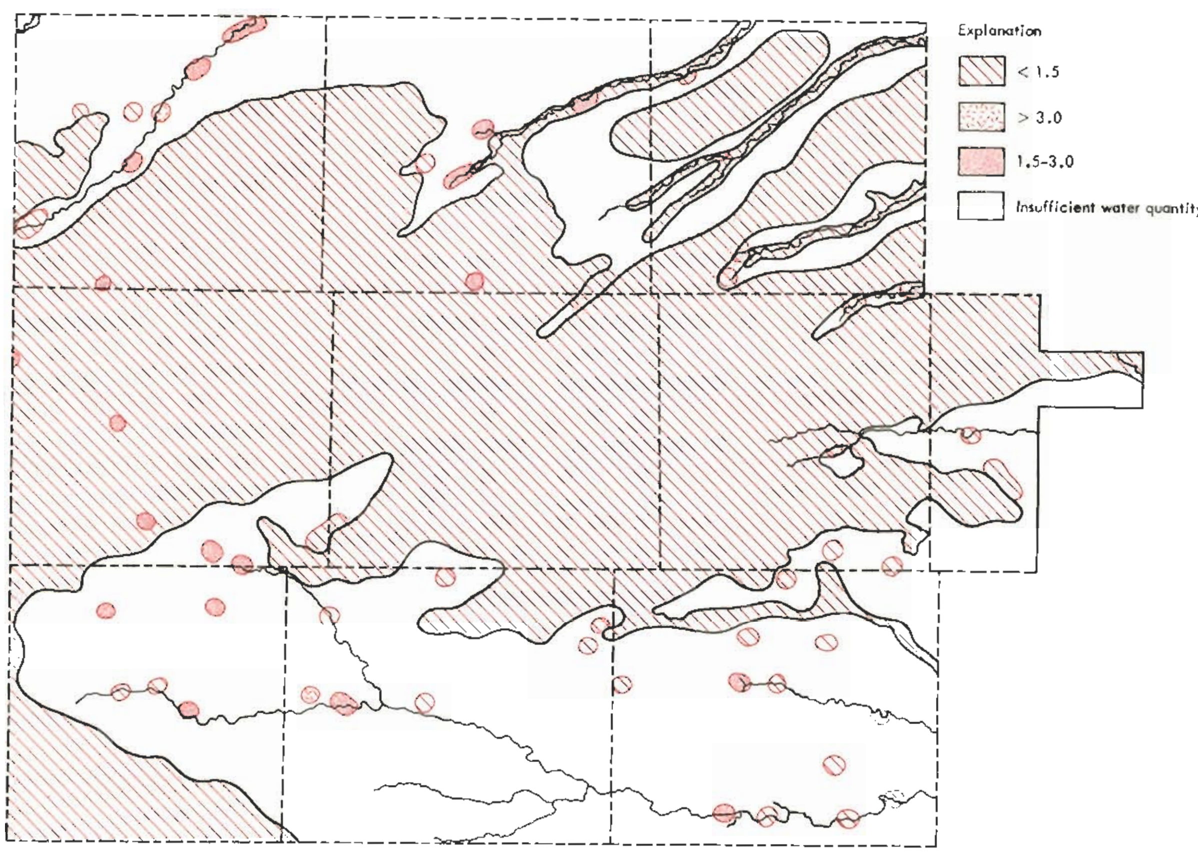

Figure 12. Areal display of SAR values for the study area.

The specific-conductance data (Figure 8) and the SAR data (Figure 12) can be used in conjunction with Figure 13 to evaluate the general suitability of groundwaters for irrigation purposes (U. S. Salinity Laboratory Staff, 1954). Generally speaking, most portions of the study area with 40 feet or more of saturated thickness fall into the medium salinity-low alkali hazard classification and, as such, would not be expected to produce detrimental effects in the soil as a result of prolonged irrigation practices. In the alluvial valley systems, especially areas of shallow water tables and limited saturated thickness such as the Smoky Hill River and South Fork of the Republican River, compatibility between the soils and groundwater may become a problem when considering long-term irrigation usage.

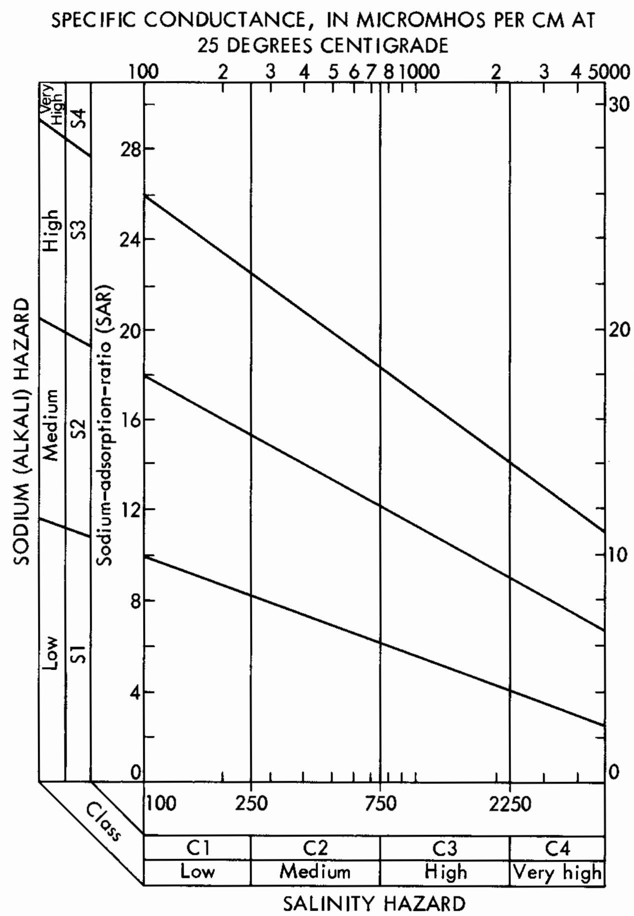

Figure 13. Diagram showing relationship between specific conductance and SAR in the evaluation of salinity and alkali hazards for irrigation.

The utilization of tail-water pits to collect residual water in areas where flood irrigation is used has been mandated. The question of re-use of this water then arises since the cost of pumpage of water from the tail-water pits is considerably less than from deep wells. Water samples were collected from eight tail-water pits and their associated irrigation wells in order to evaluate changes in water quality that might occur as a result of irrigation water leaching salts from surface soils. The locations of the tail-water pits are shown in Figure 14, and the chemical-quality data for the tail-water pits and associated irrigation wells are presented in Table 5.

Two general trends are apparent in the data from Table 5. First, increased temperatures of the tail-pit waters relative to the ground-waters are accompanied by increased pH values and the occurrence of carbonate (CO_3) in the tail-pit samples. This probably results from loss of dissolved carbon dioxide gas upon warming of the water at the

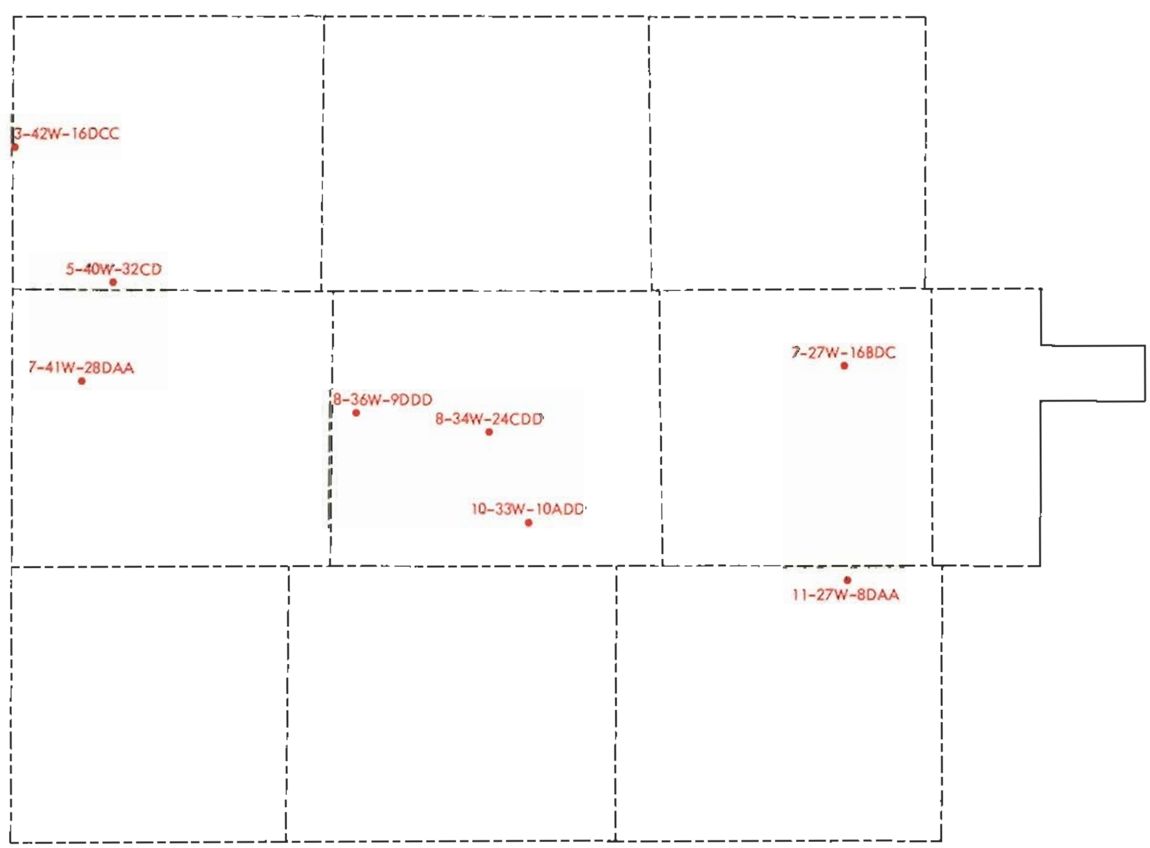

Figure 14. Location of tail-water pits sampled in study.

TABLE 5. Chemical-Quality Data For Tail-Water Pits and Associated Irrigation Wells

Location		Sp Cond µmho	Temp °C	pH	SAR	SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	HCO_3 ppm	CO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	PO_4* ppm	Total Dissolved Solids ppm
3-42W-16CDD	Well	465	18.5	8.1	0.82	66	43	16	25	7.4	0.8	184	0	33	11	1.4	42	0.2	329
3-42W-16DCC	Pit	485	27.0	8.6	0.92	62	43	16	28	8.6	0.8	174	6.5	32	12	1.3	42	0.4	322
5-40W-31DB	Well	435	15.0	8.0	1.50	63	31	12	39	5.8	0.7	203	0	21	8.9	1.3	23		290
5-40W-32CD	Pit	425	27.0	8.8	1.57	56	33	9.7	40	7.7	0.4	170	16	22	8.6	1.4	21	0.6	266
7-27W-16BAA	Well	415	15.0	7.7	0.51	48	43	19	16	6.7	0.8	226	0	15	5.5	1.3	12		280
7-27W-16BDC	Pit	405	23.0	8.5	0.56	48	42	16	17	9.3	0.7	215	5.3	16	5.0	1.3	11	0.4	262
7-41W-28DBB	Well	340	15.5	8.0	1.01	59	31	9.2	25	4.2	0.4	178	0	16	3.4	1.2	10	0.1	242
7-41W-28DAA	Pit	335	27.0	8.6	1.07	49	32	7.6	26	7.2	0.3	158	8.2	18	3.7	1.1	9.6	0.7	215
8-34W-24BAD	Well	480	16.0	7.7	0.59	54	46	20	19	6.2	0.6	227	0	33	9.3	1.4	13	0.2	293
8-34W-24CDD	Pit	460	22.0	8.6	0.60	51	47	18	19	11	0.7	195	15	36	9.2	1.3	9.5	0.6	300
8-36W-4DDC	Well	420	16.5	7.8	0.90	54	44	14	26	5.0	0.7	204	0	28	7.9	1.6	18	0.1	304
8-36W-9DDD	Pit	410	22.0	8.6	0.99	49	38	11	27	7.7	0.4	178	5.3	25	6.1	1.6	18	0.5	243
10-33W-10DAA	Well	470	15.0	7.7	1.12	18	44	13	33	5.7	0.9	228	0	26	12	1.0	16		283
10-33W-10ADD	Pit	485	21.0	8.6	1.06	20	46	14	32	7.9	0.8	224	1.9	29	14	1.0	18	0.5	278
11-27W-8DAA	Well	430	15.0	7.8	0.37	35	56	14	12	4.9	1.1	237	0	16	7.3	0.9	9.3	0.1	264
11-27W-8DAA	Pitt	340	35.0	9.2	0.48	26	32	14	13	14	0.7	124	23	21	14	0.8	0.3	0.1	223

*PO_4 values below 0.1 ppm not reported.

ground surface, allowing conversion of some HCO_3 to CO_3. Secondly, a consistent increase is observed in K and PO_4 levels in tail-pit waters. This may reflect some mobilization of soil amendments during the irrigation process. It has been noted earlier (SAMPLING AND ANALYSIS Section) that the samples for PO_4-NO_3 analyses were acidified in the field and filtered later in the laboratory. Thus, the increase in PO_4 levels in the tail-pit waters may also reflect release of PO_4 from suspended matter in the water samples, but should also reflect in a general fashion available PO_4 levels in these waters.

Appreciable increases in NO_3 values are not observed in the tail-pit waters, nor is a marked build-up of Ca, Mg, Na, SO_4, or Cl levels noted. The similarities in the specific conductances and SAR values between well and tail-water pit pairs of data suggest that re-use of the water from any of these pits is a practical option insofar as the inorganic constituents of the water are concerned. All eight wells in this group appear to be associated with 40 feet or more of saturated thickness and none of them is situated in an alluvial valley system. The re-use of water from tail-water pits in areas associated with soils of alluvial valleys where saline soils, shallow groundwater tables, and poorer groundwater quality may exist requires further evaluation. Additional studies related to the build-up of organics, i.e., pesticides and herbicides, in these tail-pit waters would be desirable for total evaluation of their re-use potential. However, data from the present study area do suggest that re-use of tail water in areas other than alluvial valley systems may be feasible in many instances and should be considered as a means of extending the utility of the groundwater resource.

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APPENDIX

Chemical Quality Data

●Cheyenne County

Well Location	[1] Geological Unit	[2] Historical Data	[3] SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	[4] Ortho PO_4 ppm
1-38W-2CDC	QA	a	49	207	61	173	19	2.4		309	639	123	1.4	62	0.3
1-38W-8DCC	QA		34	108	29	116	12	1.0		320	322	36	1.4	2.4	0.2
1-39W-34DDA	QA		51	112	30	73	13	1.2		289	231	45	1.2	20	0.2
1-42W-9ADA	QA		43	82	31	71	16	0.9		310	209	17	1.6	0.0	0.1
2-38W-27DAD	TO		44	34	16	27	8.8	0.7		212	22	5.9	1.7	16	
2-40W-25ADA	QA		50	78	28	143	14	0.9		469	175	25	2.6	39	0.2
2-40W-28DBA	TO	a	65	32	15	31	8.4	0.6		193	18	8.6	1.6	36	
2-41W-28DAD	TO		64	31	14	30	7.8	0.6		200	18	7.2	1.6	15	0.1
3-37W-14BBC	TO		66	34	13	38	8.2	0.6		220	30	5.2	1.7	16	
3-37W-19BBC	TO		67	34	12	37	8.0	0.5		213	28	5.7	1.6	18	
3-38W-21BCB	TO		65	34	14	37	7.9	0.7		207	27	7.4	1.7	27	
3-39W-20DAC	TO		63	34	15	20	7.2	0.6		199	15	4.7	1.4	12	
3-40W-28ACA	QA		64	83	25	92	10	0.9		402	105	28	2.0	41	0.2
3-40W-35AAC	TO		66	33	15	28	7.3	0.7		198	22	10	1.7	13	
3-41W-16AAC	TO		63	46	19	19	8.1	0.8		194	35	11	0.9	35	
3-42W-16CDD	TO	a	66	43	16	25	7.4	0.8		184	33	11	1.4	42	0.2
4-37W-11BCC	TO		52	39	17	29	8.0	0.8		204	27	9.7	1.7	34	
4-37W-17AAC	TO	a	57	40	16	27	7.8	0.8		207	31	8.2	1.6	23	
4-37W-25DCA	TO		51	36	13	30	6.6	0.5		198	27	8.8	1.3	18	
4-38W-4BAC	TO		52	35	13	35	7.1	0.4		210	27	6.1	1.5	16	
4-38W-21ADC	TO		52	34	13	35	6.4	0.5		206	25	6.3	1.2	17	0.1
4-39W-2DBC	TO		52	30	15	37	7.5	0.6		208	24	6.7	1.8	21	0.1
4-39W-15CCA	TO		55	31	16	36	6.9	0.7		207	29	11	1.8	14	
4-39W-18CAB	TO	a	54	30	14	33	7.3	0.6		205	25	5.2	1.8	13	
4-39W-27CCA	TO		68	32	13	31	6.2	0.6		196	22	9.1	1.5	13	
4-42W-26BCC	QA, TO		55	58	15	26	6.7	0.8		229	44	8.6	0.9	33	0.1
4-42W-34CAA	QA, TO		52	43	14	20	5.2	0.6		210	21	4.0	0.9	16	
5-37W-15DBB	TO		66	35	11	36	6.0	0.6		207	31	6.4	1.7	15	
5-37W-18DDD	TO		63	36	11	32	5.7	0.6		205	26	6.6	1.7	14	
5-38W-17CBA	TO		60	36	13	25	6.1	0.6		194	23	8.9	1.4	16	
5-38W-26CCA	TO		63	34	15	31	6.1	0.6		197	30	14	1.6	16	
5-39W-11CBC	TO	a	50	34	14	34	6.4	0.6		194	34	16	1.1	15	
5-39W-19BBC	TO	a	59	41	9.9	19	4.8	0.6		176	15	7.3	0.9	24	
5-39W-25CDA	TO		51	36	16	33	6.4	0.7		192	38	18	1.6	16	
5-39W-30CBC	TO		61	35	17	42	6.1	0.6		208	44	14	1.4	25	
5-40W-4CBD	TO		65	28	13	36	6.0	0.6		197	21	5.5	1.8	17	
5-40W-14BCD	TO		61	29	12	37	6.4	0.6		207	20	4.3	1.5	14	0.1
5-40W-27BBA	TO		58	29	11	37	5.1	0.6		203	17	3.1	1.2	12	0.1
5-40W-31DB	TO		63	31	12	39	5.8	0.7		203	21	8.9	1.3	23	
5-41W-12ADC	TO		57	41	16	34	6.1	0.8		185	26	16	1.7	58	
5-41W-20DAA	TO	a	57	37	14	26	5.8	0.6		185	25	7.5	1.4	30	
5-41W-23ACC	TO		57	32	13	28	5.5	0.6		190	19	6.4	1.8	18	
5-41W-33DAA	TO		50	36	17	27	6.0	0.7		181	24	12	1.7	42	
5-42W-14CBC	TO		47	37	12	21	5.1	0.6		176	18	6.9	1.2	20	
5-42W-36BCD	TO		60	34	14	18	5.2	0.6		192	13	2.7	1.3	10	

1. Geological Unit: QA, Alluvium; QT, Terrace deposits of Quaternary age; TO, Ogallala Formation.
2. "a" denotes historical data available in KGS-USGS data files.
3. "ppm" - parts per million.
4. Ortho-PO_4 values below 0.1 ppm not listed.
5. "ppb" - parts per billion.

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
15	2.3	0.3	37	16.0	1511	770	517	2010	2.71	8.0
13	721	0.9	22	17.0	818	390	128	1180	2.56	7.9
15	1.3	0.8	11	17.0	719	404	167	1040	1.58	7.6
198	654	0.8	17	17.0	640	333	79	930	1.69	7.5
12	0.5	1.1	4.4	19.5	299	151	0	425	0.95	7.8
0.9	2.6	1.1	18	16.5	776	311	0	1175	3.53	7.7
2.7	0.9	0.4	8.2	17.0	321	142	0	430	1.13	8.0
6.9	0.5	0.4	6.8	18.5	280	136	0	395	1.12	8.0
44	0.3	0.0	3.5	19.0	316	139	0	440	1.40	7.9
41	0.6	0.0	4.1	19.5	314	135	0	435	1.39	8.0
18	0.2	0.0	3.0	19.0	314	143	0	445	1.34	7.9
6.0	1.6	0.7	9.4	19.0	270	148	0	375	0.74	7.8
14	3.1	1.0	14	15.0	644	311	0	965	2.27	7.5
64	1.2	0.2	2.7	15.0	294	145	0	410	1.01	7.8
17	0.6	0.3	3.2	17.5	328	194	35	475	0.59	7.9
258	18	0.3	3.2	18.5	329	174	23	465	0.82	8.1
31	12	2.0	17	18.5	309	168	1.0	480	0.97	7.8
30	8.0	1.4	13	18.0	295	167	0	460	0.91	7.7
40	9.0	2.8	34	16.5	278	144	0	430	1.09	8.1
22	8.5	2.6	23	17.5	276	141	0	435	1.28	7.9
32	6.8	2.5	19	16.5	295	139	0	440	1.29	8.0
28	12	2.4	17	17.0	280	137	0	425	1.37	7.8
16	0.9	0.3	4.2	17.0	309	144	0	440	1.31	7.9
6.5	0.5	1.2	7.6	17.0	284	133	0	405	1.24	7.9
6.6	0.6	0.4	5.0	16.5	278	132	0	405	1.17	8.0
18	2.7	0.2	5.8	23.5	347	207	20	520	0.79	7.6
8.6	0.5	0.2	5.1	24.5	265	166	0	400	0.68	7.8
5.2	0.4	0.8	8.7	16.5	304	133	0	430	1.36	7.8
4.5	0.4	0.7	10	17.0	285	136	0	420	1.19	7.8
9.4	0.4	0.6	9.2	15.0	271	144	0	405	0.91	7.9
12	0.5	0.4	9.1	16.5	291	147	0	440	1.11	8.1
15	1.6	0.6	7.4	17.0	303	146	0	445	1.22	7.9
17	1.2	0.2	4.9	17.0	253	144	0	370	0.69	8.0
8.6	0.5	0.5	9.1	16.0	297	156	0	460	1.15	7.8
16	0.6	0.3	6.0	15.0	332	158	0	505	1.47	7.8
34	1.6	0.2	5.4	15.0	281	124	0	400	1.41	7.9
32	4.6	0.1	5.1	18.0	272	122	0	400	1.45	8.0
3.4	0.2	0.3	0.9	17.0	264	118	0	380	1.48	7.8
-	-	-	-	15.0	290	128	0	435	1.50	8.0
9.4	1.2	0.1	3.6	17.0	335	169	17	500	1.14	7.8
11	0.3	0.2	4.0	16.5	287	151	0	415	0.92	7.8
7.3	0.4	0.1	3.9	17.0	277	134	0	385	1.05	7.8
9.8	0.2	0.1	3.7	16.5	316	161	12	450	0.93	7.8
5.5	0.0	0.1	3.5	16.0	266	142	0	365	0.77	7.9
4.0	0.4	0.3	5.0	22.0	259	143	0	350	0.65	7.5

●Decatur County

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
1-27W-26BAD	TO		60	104	24	15	11	1.0		402	45	17	0.4	16	0.4
1-29W-1BBD	QA		46	154	36	71	16	1.5		434	224	65	0.7	32	0.5
1-29W-3DDB	QA		52	94	24	50	13	1.2		329	103	37	0.6	40	0.2
1-29W-19BDD	QA		45	108	28	65	16	1.5		379	127	29	0.7	61	0.2
1-29W-30BDD	QA	a	44	118	28	51	16	1.0		429	125	32	0.7	20	0.4
1-30W-34DDD	QA		33	146	37	78	20	1.0		483	220	54	0.8	2.0	0.3
2-28W-13ABA	QA		44	114	29	48	19	1.0		392	126	43	0.5	24	0.7
2-28W-33ABB	QA		56	136	30	27	11	1.2		413	86	46	0.5	52	0.3
3-28W-32BCA	TO	a	62	46	15	19	8.1	0.7		225	21	9.9	0.9	6.5	0.1
3-29W-17DCB	QA, TO		46	104	28	86	21	1.2		456	168	28	0.8	1.7	0.5
3-29W-18DCC	QA		48	101	27	50	20	0.9		366	145	28	0.8	0.3	0.7
3-29W-31DCC	QA		43	155	36	55	18	1.2		480	179	62	0.8	16	0.4
3-30W-3BCD	TO		67	39	13	31	8.8	0.6		232	20	8.8	0.9	7.7	
3-30W-26BBB	QA		36	188	53	67	24	2.0		409	423	59	0.8	0.7	0.5
4-26W-12BCD	QA		48	82	19	22	9.4	0.6		338	32	22	0.6	3.0	0.8
4-27W-17DAC	TO	a	61	52	13	13	6.7	0.6		235	7.6	6.3	0.6	7.8	0.4
4-27W-30DAC	QA		59	66	17	25	7.6	0.7		279	31	13	0.6	14	0.1
4-27W-33BBB	QA		48	81	20	24	10	0.8		329	48	16	0.8	4.4	0.3
4-28W-35DCA	QA, TO		50	95	22	28	9.6	0.9		343	70	20	0.6	23	0.2
5-26W-26DDA	QA		49	48	16	9.8	6.5	0.7		234	11	3.6	0.7	6.3	0.1
5-30W-35BCB	TO		51	51	18	12	6.7	0.7		242	12	7.4	0.7	16	

●Gove County

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
11-27W-8DAA	TO		35	56	14	12	4.9	1.1		237	16	7.3	0.9	9.3	0.1
11-28W-5CDD	TO		35	57	21	20	5.6	1.0		222	39	24	1.1	26	
11-28W-21DDD	TO		36	68	16	8.7	4.6	0.9		255	16	12	0.6	16	
11-29W-4DAD	TO	a	43	57	23	19	5.9	1.4		220	44	27	1.2	18	0.1
11-30W-27ABB	TO		37	47	20	22	5.3	1.0		223	34	16	1.4	13	0.1
11-30W-31DAB	TO		34	112	35	23	7.2	1.8		239	137	78	0.8	30	
11-31W-8CBA	TO	a	33	58	25	25	6.0	1.2		213	62	36	1.2	26	
11-31W-12BBB	TO		34	79	34	27	7.4	1.8		229	113	44	0.9	40	
12-26W-24CBA	QA		38	134	23	36	6.9	1.0		314	130	69	0.5	20	0.2
12-28W-12DDD	TO		37	60	16	9.9	5.1	0.9		206	23	26	0.7	14	
12-29W-10BBD	TO		40	57	21	19	6.3	1.2		253	31	17	1.1	18	
12-30W-1AAD	TO		36	51	21	20	5.4	1.0		242	27	14	1.1	16	
13-27W-25ABB	TO		39	171	34	69	10	2.7		317	383	56	0.5	7.8	0.1
13-28W-6BBC	QA		40	198	40	88	16	2.1		341	442	75	0.6	18	0.3
13-29W-4BBB	QA		41	144	40	89	19	1.5		389	332	52	0.7	6.9	
13-31W-5CBA	QA		39	112	28	34	6.7	1.4		274	153	45	1.0	27	0.1
14-27W-19AAB	QT		49	78	15	19	7.1	1.5		216	99	14	0.8	7.1	0.1
15-26W-5CCC	QA		34	223	49	69	14	3.5		225	678	20	1.0	0.5	
15-27W-21BAD	QA		33	343	85	65	17	6.0		279	1064	48	0.9	1.2	0.2
15-29W-13CCB	QA		44	160	61	72	20	3.8		221	592	25	1.4	0.6	0.2
15-29W-18DB	QA, QT	a	37	298	145	234	24	5.3		250	1524	65	1.3	1.3	0.3

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
9.7	1.7	1.4	8.7	14.5	480	359	30	750	0.34	7.4
28	2.2	0.6	8.1	13.5	858	534	178	1390	1.34	7.6
83	5.8	2.1	16	15.5	589	335	65	880	1.19	7.7
24	12	0.9	14	15.5	661	386	76	980	1.44	7.4
16	6.7	1.2	14	13.0	647	411	59	985	1.09	7.4
405	431	3.0	19	13.5	826	518	122	1260	1.49	7.5
41	220	0.5	12	14.5	656	405	84	980	1.04	7.5
88	1.8	1.9	19	14.5	635	464	126	1000	0.55	7.5
63	0.8	0.4	6.6	16.0	287	177	0	430	0.62	7.9
990	483	3.0	30	13.5	701	376	2.3	1055	1.93	7.5
1650	502	1.2	18	14.5	595	364	64	900	1.14	7.6
378	20	1.0	2.3	14.0	756	536	143	1220	1.03	7.5
7.4	0.8	0.7	8.2	16.5	299	151	0	435	1.10	7.7
3050	916	1.4	23	14.5	1060	689	354	1490	1.11	7.6
5.6	19	3.0	12	14.0	422	283	6.0	640	0.57	7.7
25	0.5	4.1	7.0	15.5	281	184	0	420	0.42	7.6
15	0.4	3.3	9.6	14.0	373	235	6.8	560	0.71	7.5
14	12	4.1	11	15.0	427	285	16	650	0.62	7.6
11	0.3	4.2	13	13.0	497	329	47	750	0.67	7.3
51	1.2	0.6	5.9	15.0	259	186	0	405	0.32	7.6
13	0.3	1.0	3.7	15.5	307	202	3.8	450	0.37	7.6

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
-	-	-	-	15.0	264	199	4.3	430	0.37	7.8
56	2.7	3.2	6.6	17.5	341	230	48	550	0.57	7.8
37	6.8	0.5	6.2	19.0	305	236	28	490	0.25	7.6
16	0.7	0.5	3.6	18.5	348	238	58	550	0.54	7.8
2.6	0.3	0.6	3.0	18.0	320	201	18	485	0.68	7.7
4.5	0.6	1.0	9.0	17.5	593	425	230	920	0.49	7.6
15	1.2	1.3	6.4	17.5	376	249	74	620	0.69	7.6
16	2.3	2.3	8.3	17.5	501	339	151	800	0.64	7.6
16	1.6	0.8	18	18.0	630	430	173	960	0.74	7.2
36	5.0	1.7	7.0	19.0	300	217	48	475	0.30	7.8
24	8.6	3.4	20	16.0	324	230	23	530	0.55	7.9
4.3	0.6	0.5	8.1	17.5	303	215	16	500	0.59	7.7
134	135	6.7	43	17.0	945	570	310	1320	1.26	7.4
69	12	6.4	47	16.0	1102	661	382	1550	1.49	7.4
1230	293	0.9	17	18.0	907	526	207	1325	1.69	7.4
25	0.9	0.6	11	17.0	566	396	172	880	0.74	7.5
23	8.3	3.3	20	17.0	401	258	81	590	0.51	7.8
6260	688	5.2	30	16.0	1210	762	578	1570	1.09	7.4
6390	630	4.9	39	17.0	1805	1212	984	2160	0.81	7.4
5040	306	3.5	32	17.5	1078	654	473	1450	1.22	7.4
7280	537	12	71	17.5	2441	1346	1141	2900	2.77	7.6

●Graham County

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
6-24W-28BAB	TO		56	52	18	9.7	5.6	0.7		239	15	6.0	0.8	7.5	
6-25W-33BCB	TO		58	49	18	9.9	5.6	0.7		237	13	3.5	0.7	5.6	
7-22W-10BBC	TO		48	73	11	9.3	4.1	0.4		256	17	8.1	0.4	16	0.2
7-24W-8CBA	TO		49	50	14	5.9	5.1	0.6		224	8.6	1.8	0.4	6.9	0.1
8-25W-23BBB	TO		44	110	22	29	12	0.8		293	157	29	0.8	0.4	0.7
9-24W-6DDD	TO		48	59	10	6.4	3.9	0.6		212	11	8.5	0.4	18	0.2
9-24W-22BAB	TO		56	64	13	7.5	3.8	0.6		257	9.5	3.5	0.6	10	

●Logan County

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
11-32W-4ACC	TO		31	118	42	11	6.8	2.0		220	103	100	0.4	73	
11-32W-15BBB	TO		31	46	20	23	5.3	1.0		228	31	13	1.2	14	0.1
11-33W-10CAB	TO		34	47	18	29	5.6	1.0		237	30	13	1.2	16	
11-33W-12ADA	TO		34	52	20	23	5.8	1.1		222	45	23	1.1	16	
11-34W-24CDC	TO		32	54	18	31	5.4	1.0		243	44	19	1.0	4.7	0.5
11-35W-12ADC	TO		24	46	14	30	4.8	0.8		210	38	10	1.4	8.3	0.3
11-36W-1BBB	TO		30	51	9.4	13	4.8	0.7		190	20	8.8	0.6	13	
11-36W-6DBB	TO		29	65	9.2	12	5.7	0.4		204	20	13	0.6	34	
12-32W-2ADB	TO		31	79	22	25	6.3	1.2		236	74	33	0.8	26	0.1
12-32W-15CAA	QT, TO		39	144	32	43	8.9	1.5		366	179	59	0.5	25	0.2
12-33W-2DBB	TO		35	78	24	35	6.5	1.2		266	79	35	0.9	29	0.2
12-34W-1CBD	TO		37	48	22	28	5.8	1.2		227	40	20	1.0	24	0.1
13-35W-15DDC	QT	a	34	137	46	76	8.6	2.4		181	363	109	0.6	17	0.1
13-36W-18CCA	QA		28	163	41	148	13	2.1		260	609	45	0.9	2.5	0.1
13-36W-20CCB	QA, QT		24	204	49	163	13	2.8		264	762	51	1.0	1.4	0.1
13-37W-15BBB	QA, QT		30	179	47	191	18	2.1		287	762	38	0.6	0.8	0.1

●Rawlins County

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
2-32W-14DCA	QA		33	104	33	75	20	1.0		452	162	25	1.2	0.5	0.4
2-32W-20CBD	QA		33	103	29	66	19	1.0		426	144	24	1.2	0.4	0.5
2-36W-18CCB	TO		57	34	17	36	9.5	0.7		221	29	7.0	1.8	23	
2-36W-36BAA	TO		56	36	18	37	9.2	0.8		220	33	7.9	1.9	31	
3-34W-1BAA	QA		40	113	41	93	22	1.3		518	183	31	1.8	3.3	0.2
3-34W-26BAC	QA		47	100	31	77	14	1.2		430	168	23	1.9	0.5	0.4
3-34W-33BCC	QA		41	83	25	65	14	1.0		403	92	23	1.8	13	0.3
3-35W-24CBB	QA	a	50	87	28	53	13	1.2		392	86	26	2.0	21	0.3
3-36W-3CCD	TO		62	37	15	33	8.9	0.7		211	29	5.6	2.0	19	
3-36W-14CBB	TO		60	34	16	31	8.6	0.7		208	28	6.6	1.9	20	
3-36W-17CCC	TO	a	56	34	15	32	8.9	0.8		207	29	7.3	2.0	23	
3-36W-22CCD	TO		56	53	25	31	10	1.0		199	58	23	1.6	70	
4-31W-36DDC	QA	a	45	147	33	63	14	1.5		389	222	47	1.0	54	0.3
4-33W-13CBB	QA, TO		58	60	16	25	8.3	0.8		258	45	9.5	0.5	15	0.1
4-34W-24CAA	TO		58	49	13	24	6.9	0.5		222	28	7.2	1.4	16	
4-34W-33CBC	TO		63	40	15	30	7.4	0.7		227	29	7.7	1.7	18	
4-36W-6BBB	TO		57	38	17	29	8.7	0.7		210	33	7.7	1.6	22	
4-36W-9CDD	QA, TO	a	50	62	23	34	9.8	1.0		300	39	8.9	1.0	38	0.1
4-36W-23CBB	TO		51	38	13	29	7.1	0.6		207	24	5.7	1.6	14	0.1
4-36W-28DDD	TO		56	43	11	27	6.7	0.7		202	28	7.3	1.4	16	
5-31W-19AAD	TO		49	46	16	24	7.6	0.7		239	28	9.6	1.3	9.5	0.1
5-32W-36CDB	TO		59	81	26	25	10	1.2		290	87	28	1.2	24	0.1
5-33W-30DBD	QA		58	76	28	43	9.7	1.2		305	101	22	1.3	34	0.1
5-34W-26ACA	TO		60	37	15	46	7.2	0.8		239	32	9.3	1.9	17	
5-34W-28ADC	TO		64	35	16	36	7.0	0.7		226	28	7.5	2.0	17	

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
5.2	1.4	0.8	4.5	15.0	292	205	8.7	420	0.30	7.5
6.2	0.4	1.2	5.5	16.0	268	197	2.9	405	0.31	7.7
3.1	0.3	1.1	8.0	14.5	321	228	18	470	0.26	7.5
3.3	0.3	0.8	10	16.5	255	183	0	370	0.19	7.6
824	206	0.8	8.7	16.0	555	366	126	830	0.66	7.9
5.0	0.2	0.8	3.3	16.0	268	189	16	400	0.20	7.9
4.8	0.3	0.8	3.6	15.5	266	214	3.2	430	0.22	7.7

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
16	0.7	5.8	11	17.5	590	469	289	990	0.22	7.5
6.2	0.8	0.9	5.5	18.0	305	198	11	480	0.71	7.7
4.7	0.3	0.8	3.2	17.0	310	192	0	495	0.91	7.8
12	0.4	1.2	4.4	17.5	342	213	31	530	0.68	7.8
362	46	13	13	18.5	346	210	11	555	0.93	7.7
118	14	14	12	17.5	301	172	0.6	475	1.00	7.8
16	3.7	4.6	16	16.0	222	167	11	390	0.44	7.8
25	5.6	3.8	12	17.0	263	200	33	470	0.37	7.8
1620	0.6	0.5	8.9	18.0	421	289	96	665	0.64	7.7
7.4	2.2	2.7	14	17.0	724	493	193	1090	0.84	7.3
10	1.1	0.6	10	17.5	453	295	77	720	0.89	7.6
48	1.2	0.2	7.9	17.0	315	212	26	540	0.84	7.7
25	8.6	3.3	17	17.0	900	534	385	1350	1.43	7.6
21	19	7.4	22	15.5	1140	578	365	1650	2.68	7.7
102	511	34	63	16.0	1414	714	497	1850	2.65	7.6
46	104	35	66	15.0	1407	642	407	1850	3.28	7.7

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
174	711	0.8	16	14.0	665	396	26	1020	1.64	7.9
1500	104	0.5	12	13.0	618	377	28	955	1.48	7.8
20	1.2	0.2	5.7	19.0	325	156	0	475	1.26	7.7
25	1.4	0.1	5.9	18.5	341	165	0	490	1.25	8.0
1720	365	10	67	16.0	772	452	28	1290	1.90	7.7
2790	701	4.6	35	14.0	653	378	26	1000	1.72	7.5
1080	563	4.3	36	14.5	555	311	0	860	1.60	7.6
12	4.6	9.0	48	17.0	548	334	12	855	1.26	7.7
13	2.6	0.0	6.0	19.0	310	155	0	455	1.15	7.6
29	0.8	2.1	3.2	19.0	311	150	0	440	1.10	7.9
17	3.7	3.6	24	18.0	291	147	0	450	1.15	8.2
30	6.3	3.6	25	18.0	425	236	73	640	0.88	7.9
75	16	8.0	25	16.5	812	504	185	1190	1.22	7.6
15	1.8	3.4	18	15.0	359	216	5.0	540	0.74	7.7
12	1.3	1.3	15	18.0	312	176	0	450	0.79	7.8
26	1.2	1.3	17	17.5	318	162	0	460	1.02	8.0
20	5.8	1.6	16	20.5	319	166	0	465	0.98	7.9
16	6.0	3.2	22	16.0	389	250	4.6	640	0.93	7.5
29	5.6	1.5	15	19.5	267	149	0	425	1.03	7.7
36	13	3.6	15	20.5	279	153	0	430	0.95	7.7
66	3.2	4.3	11	16.0	313	181	0	470	0.78	7.7
30	4.9	2.3	13	16.0	479	310	73	730	0.62	7.4
60	4.8	4.6	28	16.0	511	306	56	790	1.07	7.5
45	2.2	3.3	22	17.5	336	155	0	495	1.61	7.9
45	1.2	2.5	19	17.5	317	154	0	455	1.24	8.0

●<u>Sheridan County</u>

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
6-27W-3DCD	QA	a	51	82	17	17	8.9	0.7		317	36	16	0.5	7.4	0.5
6-27W-27BCC	TO		57	53	20	15	7.5	0.9		260	22	9.6	0.9	9.5	0.2
6-29W-10DBC	TO		59	52	22	18	8.0	1.0		243	34	15	1.4	11	0.1
6-29W-24ABB	TO	a	58	56	20	18	7.4	1.0		229	34	18	1.4	22	
6-30W-2BCA	QA, TO		56	52	14	25	7.2	0.7		217	31	13	1.6	17	
6-30W-14CCD	TO	a	58	51	21	16	7.5	1.0		254	17	9.7	1.3	11	
7-26W-12BAC	TO		56	72	20	12	6.9	1.0		264	30	16	0.6	36	
7-26W-15CCB	TO		54	50	15	14	6.3	0.7		243	15	3.6	0.9	11	
7-26W-19BBC	TO		53	48	19	17	6.4	0.8		229	18	17	1.2	14	
7-27W-15BAD	TO		58	42	17	17	6.3	0.7		229	16	5.3	1.3	11	
7-27W-16BAA	TO		48	43	19	16	6.7	0.8		226	15	5.5	1.3	12	
7-28W-19BBA	TO		56	43	17	18	6.1	0.7		226	17	7.2	1.5	12	0.1
7-28W-23BAD	TO		52	47	15	18	6.1	0.6		221	23	9.4	1.3	14	
7-28W-36ABA	TO		49	54	16	16	5.9	0.7		232	24	12	0.7	16	
7-29W-3BBB	QA, TO		54	49	18	22	6.3	0.8		247	26	7.8	1.3	16	
7-29W-17BBB	TO		53	48	18	14	6.1	0.8		228	14	7.6	1.1	20	0.2
7-29W-21ABB	TO		58	46	18	20	6.2	0.8		222	24	12	1.6	14	0.1
7-29W-27CCC	TO		50	50	14	18	5.2	0.6		225	20	6.6	1.1	11	
7-29W-30ABA	TO	a	59	44	18	23	6.0	0.7		213	27	14	1.7	16	0.1
7-30W-30DAB	TO		60	48	19	22	7.6	0.7		216	29	16	1.9	16	0.3
7-30W-36BBD	TO		53	45	17	20	6.1	0.7		226	22	6.7	1.6	12	0.1
8-26W-14DAA	QA		40	96	23	37	6.8	1.2		412	53	13	0.7	9.5	0.2
8-27W-22BDB	QA		49	99	30	53	9.7	1.5		386	116	25	1.0	16	0.2
8-28W-27BBB	TO		48	53	17	12	6.2	1.0		249	15	6.1	0.7	8.8	
8-29W-1DBC	TO		60	42	17	22	5.9	0.9		220	24	8.3	1.5	12	
8-29W-20ABB	TO		53	46	18	20	6.3	1.0		219	30	10	1.2	16	
8-29W-29BAA	TO		49	63	20	14	6.1	0.8		240	39	14	0.8	14	0.1
8-30W-11CBC	TO		55	43	17	24	6.2	0.7		223	26	6.1	1.3	10	
8-30W-30ABC	TO	a	52	51	21	25	6.9	1.2		219	44	20	1.3	22	
9-28W-4BCC	QA, TO		36	71	20	26	8.0	1.2		297	40	18	1.1	2.1	0.2
9-28W-24BAD	QA, TO		42	54	20	14	5.9	1.2		221	33	21	1.0	12	
9-29W-17BAB	TO	a	30	50	18	21	5.7	1.0		230	30	20	1.2	11	
9-29W-29BBB	TO		35	39	17	23	5.5	1.0		226	19	7.7	1.5	7.6	0.1
9-30W-4AAB	TO		43	52	24	21	6.8	1.2		226	37	18	1.6	28	
9-30W-20ACC	TO		32	53	16	12	5.6	0.9		234	15	4.3	1.0	13	
9-30W-35BBB	TO	a	31	38	16	26	5.7	0.8		222	22	7.6	1.4	8.0	
10-26W-32ACD	TO		43	149	37	28	12	1.4		404	187	50	0.7	3.6	0.4
10-27W-20CBC	TO	a	43	107	26	27	13	0.9		386	90	28	0.8	2.5	0.4
10-28W-5DDB	TO		32	50	20	12	5.3	1.0		232	22	11	1.0	12	
10-28W-29DAA	QA, TO		34	61	17	19	5.5	0.8		246	36	15	1.0	10	0.1
10-30W-12BBD	TO		35	50	20	24	6.0	1.2		224	31	24	1.1	24	
10-30W-17DAD	TO	a	35	69	25	31	7.2	1.4		248	81	35	1.2	18	

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
11	1.6	1.6	14	14.5	379	275	16	610	0.45	7.4
12	0.3	1.4	13	16.0	302	216	2.5	490	0.44	7.4
12	2.3	0.8	8.2	17.5	333	218	19	500	0.52	7.7
18	2.0	0.8	10	16.5	329	224	36	515	0.50	7.8
13	2.9	1.7	10	17.0	308	188	10	460	0.79	7.7
16	4.7	0.9	9.2	15.0	301	215	6.6	460	0.47	7.8
3.9	0.1	1.1	8.9	15.0	370	263	47	570	0.32	7.6
1.7	0.4	0.8	8.2	15.0	268	187	0	430	0.45	7.8
2.9	0.6	0.8	11	16.0	289	199	11	460	0.52	8.0
2.3	0.6	0.7	6.7	15.0	270	176	0	415	0.56	7.8
-	-	-	-	15.0	280	186	1.1	415	0.51	7.7
18	0.9	1.7	13	15.0	283	178	0	430	0.59	7.8
4.5	0.5	0.7	7.7	16.0	279	180	0	440	0.58	7.6
6.7	0.9	0.8	7.0	15.0	298	201	11	470	0.49	7.6
1.7	0.3	0.5	9.9	15.0	332	197	0	480	0.68	7.8
1.1	0.3	0.4	8.3	15.0	293	195	7.9	430	0.44	7.7
1.4	0.3	0.4	10	15.5	315	190	7.8	450	0.63	7.8
8.8	0.6	0.2	3.9	15.0	287	183	0	430	0.58	7.5
6.2	0.4	0.6	5.0	15.0	306	185	10	460	0.74	7.7
1320	2.0	1.4	13	17.5	310	199	22	460	0.68	,8.2
6.3	0.8	0.5	6.3	22.0	294	183	0	430	0.64	7.8
12	2.2	1.5	11	13.0	494	335	0	760	0.88	7.6
16	26	1.3	14	16.5	588	372	56	890	1.20	7.4
5.5	1.9	0.4	4.9	18.0	280	203	0	440	0.37	7.5
5.4	0.3	0.5	4.5	16.0	299	176	0	430	0.72	7.9
25	5.3	0.3	5.3	16.0	300	190	10	460	0.63	7.8
7.8	2.8	0.4	5.2	16.5	334	240	44	510	0.39	7.6
22	3.6	0.5	5.8	17.0	281	178	0	425	0.78	7.8
9.4	1.2	0.2	5.7	16.0	348	215	36	530	0.74	7.7
27	81	1.4	7.2	17.0	348	261	17	595	0.70	7.5
18	1.6	1.3	7.5	18.0	311	222	40	500	0.42	7.6
64	6.6	1.1	6.3	17.0	294	200	11	480	0.65	7.8
9.7	2.5	0.8	1.2	17.0	262	168	0	420	0.77	7.8
18	4.4	0.5	7.0	16.5	351	230	45	540	0.60	7.6
11	1.4	0.6	4.6	16.0	275	199	7.3	425	0.37	7.7
21	0.8	2.2	1.1	18.0	266	161	0	420	0.90	7.7
450	191	0.1	8.6	18.0	704	526	194	1070	0.53	7.3
864	428	0.5	6.0	16.0	540	375	59	830	0.61	7.4
56	2.5	2.8	4.0	17.5	292	206	16	460	0.38	7.6
25	7.3	0.9	5.5	18.0	324	223	21	510	0.55	7.6
19	2.5	1.8	3.6	17.5	337	212	28	530	0.70	7.8
50	12	0.5	10	17.0	439	277	73	685	0.81	7.6

●Sherman County

Well Location	Geological Unit [1]	Historical Data [2]	SiO_2 ppm [3]	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	Ortho PO_4 ppm [4]
6-37W-7BBA	QA		47	37	16	28	6.2	0.7		222	25	5.4	1.4	12	
6-37W-16CDD	TO		55	33	14	37	6.0	0.6		212	26	8.4	2.0	15	
6-37W-34DCD	TO		61	30	14	34	5.7	0.7		211	23	6.4	2.0	13	
6-38W-20ACC	QA, TO		54	52	19	28	6.8	0.7		235	48	7.3	1.0	24	0.1
6-39W-1BBB	TO		57	30	12	37	5.8	0.6		199	24	4.4	1.5	13	
6-39W-33BDD	TO		60	33	11	21	4.7	0.6		176	16	4.5	1.0	11	0.1
6-40W-10AAC	TO		60	36	19	33	6.9	0.7		184	30	21	1.6	36	0.2
6-40W-21ACC	TO		62	27	11	31	5.5	0.5		185	18	3.2	1.2	12	
6-41W-1ABB	TO		60	50	17	38	6.0	0.7		191	52	20	1.1	52	
6-41W-19DBD	TO		55	34	13	29	4.6	0.6		211	16	2.9	1.4	10	
6-41W-27DBD	TO		55	26	13	33	4.8	0.6		185	23	5.5	1.4	11	
6-42W-8CBB	TO		58	36	12	23	4.7	0.6		175	28	8.2	1.3	20	
6-42W-22DCC	TO		61	30	14	25	4.7	0.7		185	21	6.3	1.5	12	
6-42W-30ADA	TO		61	32	13	24	4.8	0.6		184	20	5.4	1.3	12	
7-37W-12CCB	TO		58	37	13	40	5.4	0.7		200	26	14	1.7	40	0.1
7-37W-17BDA	TO		60	40	17	40	5.7	1.0		200	38	23	1.9	38	
7-37W-31DCC	TO		59	34	12	34	4.7	0.7		200	23	8.1	1.8	15	
7-38W-25BBC	TO		68	38	15	39	5.1	0.9		204	29	11	1.9	37	
7-39W-9BBB	TO		59	51	10	19	4.8	0.6		177	39	8.9	1.2	24	
7-39W-24BAA	TO		62	34	14	34	4.9	0.8		205	25	11	1.9	18	
7-39W-30CCB	TO	a	57	53	26	41	5.7	1.8		184	56	32	1.7	96	
7-40W-6ADB	TO	a	63	32	11	26	4.3	0.6		189	17	3.5	1.0	11	
7-40W-23BDC	TO		60	36	8.7	19	4.1	0.6		166	15	6.0	1.3	14	
7-40W-29BBA	TO		56	37	8.5	13	3.6	0.4		161	13	3.1	1.1	13	
7-41W-5BBD	TO		64	26	13	37	4.8	0.6		190	25	6.5	1.5	15	
7-41W-10BBA	TO		60	30	9.1	28	4.3	0.5		177	17	4.3	0.9	11	
7-41W-28DBB	TO	a	59	31	9.2	25	4.2	0.4		178	16	3.4	1.2	10	
7-42W-7DAA	TO		56	25	10	36	4.4	0.5		189	15	4.5	1.4	12	
7-42W-27AAB	TO	a	52	31	8.7	24	3.8	0.4		169	14	3.0	0.8	14	
8-38W-24AAB	TO	a	57	46	16	33	4.6	0.7		188	49	21	1.4	25	
8-38W-28ACC	TO		48	36	12	27	4.0	0.6		187	23	5.6	1.3	19	
8-39W-2BBA	TO		56	43	18	38	4.8	1.0		201	55	20	1.8	19	
8-39W-13AAB	TO		59	31	11	34	4.0	0.5		200	18	3.9	1.6	11	
8-39W-17DCD	TO		58	51	18	39	4.7	0.9		179	49	31	1.4	57	0.1
8-39W-27AAB	TO		57	37	13	32	4.1	0.6		190	31	9.8	1.4	19	
8-40W-5DBB	TO		51	28	13	36	3.9	0.6		198	21	10	2.0	12	
8-40W-14DCB	TO		47	33	12	34	4.0	0.6		186	20	12	2.2	27	
8-40W-18DBB	TO		53	26	11	40	4.0	0.6		203	20	3.9	2.1	9.5	
8-40W-35CCB	TO		27	38	11	29	3.7	0.6		186	27	7.5	1.1	18	0.1
8-41W-17CBA	TO		48	36	8.5	13	3.4	0.5		160	11	4.3	1.0	12	0.1
8-42W-2DAB	TO		48	33	7.6	23	3.7	0.5		178	13	2.6	1.1	10	
8-42W-19ABB	TO		42	37	9.0	23	3.9	0.5		173	15	9.0	1.3	16	
8-42W-34DCB	TO		31	29	15	31	4.0	0.6		200	19	8.3	2.1	12	
9-39W-17BBA	TO		27	33	9.0	28	3.4	0.5		176	22	4.6	1.0	13	0.1
9-39W-19CCC	TO		23	39	10	25	3.5	0.5		178	27	9.3	1.2	15	
9-40W-8CCB	TO		24	31	8.9	31	3.3	0.5		186	17	5.1	1.0	14	
9-41W-5DCC	TO		26	33	13	33	3.7	0.6	1.7	172	19	13	2.0	38	
9-41W-11DCB	TO		38	52	17	22	4.2	0.8		194	38	18	1.0	43	
9-42W-11CCC	TO	a	24	37	14	30	3.5	0.6		171	23	18	2.0	36	
9-42W-29BDA	TO		22	44	13	26	3.5	0.6		163	42	17	1.5	35	
9-42W-35ABB	TO		19	31	9.8	26	3.0	0.4		176	15	5.8	1.6	14	
10-37W-23ABB	TO		25	48	24	33	6.0	1.2		206	59	27	1.6	32	
10-39W-25CCA	QA	a	40	74	16	86	9.2	0.8		425	80	11	1.2	3.6	0.3
10-40W-8BAA	TO		21	41	9.5	18	3.2	0.4		173	21	9.5	1.1	13	
10-40W-10ADC	QA, TO		22	94	22	72	5.1	1.0		309	183	15	1.0	20	
10-41W-15CAD	QA, TO	a	19	39	8.2	10	4.2	0.4		169	8.9	2.2	1.0	14	0.1
10-41W-35CAC	TO		21	35	14	26	4.3	0.8		185	25	13	1.0	14	
10-42W-24BBA	TO		18	35	7.8	16	3.1	0.4		164	13	3.2	1.2	11	

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
5.7	1.6	0.8	11	13.5	295	159	0	425	0.97	7.8
34	10	0.7	11	16.0	300	141	0	430	1.36	8.0
35	1.6	0.4	10	16.5	294	133	0	420	1.28	7.8
12	0.6	0.8	12	14.5	350	209	16	510	0.84	8.0
11	5.1	0.7	10	16.5	275	125	0	395	1.44	8.0
9.3	0.3	0.4	2.9	16.0	258	128	0	540	0.81	7.9
371	22	0.3	7.3	18.0	336	169	18	480	1.10	8.2
7.4	0.4	0.3	6.3	16.5	265	113	0	355	1.27	8.1
48	0.8	0.5	10	16.5	408	195	39	565	1.18	7.7
15	0.1	0.9	1.1	17.0	274	139	0	385	1.07	7.7
14	0.0	1.1	2.9	16.0	263	119	0	370	1.32	8.0
19	0.2	0.3	1.2	17.0	281	140	0	385	0.85	8.2
17	0.1	0.9	1.2	16.5	254	133	0	365	0.94	8.1
13	0.2	1.7	1.2	17.0	257	134	0	360	0.90	8.0
25	2.8	2.4	28	17.0	343	147	0	480	1.44	7.8
27	4.1	2.4	24	20.0	369	171	7.0	530	1.33	7.8
10	0.3	2.9	0.8	16.0	277	135	0	415	1.27	7.9
21	0.3	0.3	4.1	16.5	330	158	0	485	1.35	7.9
6.3	0.1	0.2	3.9	16.0	303	169	24	430	0.64	7.7
6.9	0.2	0.2	2.8	16.0	294	143	0	435	1.24	7.8
7.3	1.2	0.1	2.8	15.0	449	241	90	680	1.15	7.9
20	1.2	0.5	2.1	16.0	253	126	0	350	1.01	8.0
8.3	0.8	0.4	2.8	15.5	241	126	0	330	0.74	7.9
35	1.5	0.5	1.6	14.5	227	128	0	310	0.50	7.9
13	0.4	0.4	2.1	16.0	271	119	0	390	1.48	8.1
28	0.4	0.4	1.7	16.5	254	113	0	345	1.15	8.0
18	0.2	0.3	1.8	15.5	242	116	0	340	1.01	8.0
34	1.6	0.3	1.8	16.0	255	104	0	360	1.54	7.8
15	0.6	0.4	2.0	16.5	233	114	0	325	0.96	7.9
22	0.6	0.2	3.3	16.0	356	181	26	510	1.06	7.8
39	0.8	3.2	5.9	17.0	251	140	0	390	0.99	7.8
12	1.2	0.3	3.8	15.0	364	182	18	515	1.22	7.7
14	0.4	0.2	2.9	17.0	271	123	0	380	1.33	7.8
13	0.1	0.1	3.5	17.0	405	202	56	580	1.19	8.0
15	0.1	1.1	4.2	16.0	305	146	0	420	1.15	8.0
17	1.5	0.5	2.6	17.0	273	124	0	390	1.41	8.0
45	0.7	2.1	3.1	15.0	277	132	0	410	1.29	8.1
8.8	0.5	0.7	3.1	16.0	262	111	0	380	1.65	8.1
5.1	0.2	0.5	2.4	17.0	249	141	0	395	1.06	8.0
15	1.1	0.6	1.8	16.0	216	125	0	305	0.51	7.8
18	1.7	0.3	2.0	16.0	222	114	0	320	0.94	8.2
5.2	0.6	0.2	2.0	17.0	239	130	0	350	0.88	8.0
8.0	0.6	0.4	3.0	17.0	252	135	0	390	1.16	8.3
25	1.4	2.0	10	16.0	223	120	0	355	1.11	7.9
37	1.4	2.6	6.8	17.0	243	139	0	390	0.92	8.2
3.8	0.4	1.1	2.8	16.0	223	115	0	360	1.26	8.0
10	0.4	2.8	2.7	17.0	257	136	0	420	1.23	8.4
16	0.7	2.4	5.1	15.0	326	201	42	505	0.70	8.0
14	0.3	1.1	2.2	17.0	280	151	10	430	1.06	8.2
14	1.5	1.4	3.0	16.0	288	164	30	450	0.88	7.9
15	0.4	0.7	2.1	16.0	215	118	0	340	1.04	8.2
50	2.7	2.1	10	17.0	346	220	51	590	0.97	8.0
8.6	0.8	5.9	14	15.0	522	250	0	835	2.35	7.4
5.4	0.2	0.8	1.9	17.0	227	142	0.1	360	0.66	8.1
7.4	0.5	3.9	4.0	15.0	579	326	73	880	1.73	7.7
16	1.4	1.9	10	14.0	166	131	0	310	0.38	7.9
43	1.9	2.2	16	15.0	229	146	0	405	0.94	7.9
13	3.6	1.2	11	15.0	196	120	0	310	0.64	7.8

●Thomas County

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
6-31W-3ADB	TO	a	58	47	16	19	7.0	0.8		234	22	9.5	1.1	10	0.1
6-31W-33CCD	QA, TO		51	76	21	17	7.8	1.0		290	30	11	0.9	41	0.1
6-32W-29CDB	TO	a	57	40	19	30	7.6	0.7		228	36	12	1.7	17	
6-33W-7BBB	TO		60	38	17	33	7.2	0.7		219	29	11	1.4	19	
6-33W-32DBB	QA, TO	a	53	64	19	35	7.8	1.0		253	58	17	1.4	33	0.1
6-34W-17CBC	TO	a	61	42	15	31	6.4	0.8		216	28	10	1.4	23	
6-34W-22CBC	TO		62	40	17	30	7.3	0.8		216	28	13	1.4	23	
6-35W-2CDD	TO		66	35	15	41	6.7	0.7		223	33	8.6	2.1	18	
6-35W-26ACD	TO	a	64	44	16	27	6.5	0.8		227	21	8.8	1.2	21	
6-36W-11CDD	TO		62	34	15	39	6.7	0.7		211	29	10	2.1	24	
6-36W-34DDB	TO		58	42	16	38	6.2	0.8		207	47	15	1.8	24	0.1
7-31W-1DCA	TO		58	48	23	26	7.7	1.0		230	47	18	1.7	22	
7-31W-26CCC	TO	a	53	42	18	24	6.8	0.9		218	23	11	1.8	17	0.1
7-32W-8ABB	TO		60	41	16	28	6.6	0.8		223	29	10	2.3	17	
7-32W-13AAA	TO		56	55	23	24	7.1	1.2		218	55	26	1.8	21	
7-32W-25ACC	TO		54	41	17	23	6.1	0.8		224	21	6.9	1.9	13	
7-33W-7BDA	TO		61	41	17	24	5.9	0.8		203	25	10	1.8	29	0.1
7-33W-21DBC	TO		59	43	16	26	6.1	0.7		210	37	12	1.8	18	
7-33W-35ADD	TO	a	52	50	19	22	6.2	1.0		229	29	13	1.7	23	
7-34W-27DBB	TO		56	46	16	22	5.5	0.7		218	26	6.4	1.6	14	
7-35W-10CCC	TO	a	60	35	15	33	6.2	0.7		206	35	9.6	2.0	18	0.1
7-35W-27BDC	QA, TO		57	43	19	26	6.4	0.8		235	33	9.3	1.5	20	0.1
7-36W-14BCB	TO		60	44	13	29	5.4	0.7		216	24	9.0	1.6	24	
7-36W-17CCC	TO		60	48	13	23	5.2	0.7		223	21	8.2	1.1	18	
8-31W-1DCA	TO		49	47	17	20	6.4	0.7		225	23	11	1.5	12	0.2
8-31W-4ACB	TO		48	48	20	16	6.7	0.8		240	20	7.2	1.4	10	0.1
8-31W-27BAB	TO		51	50	20	29	7.0	1.0		216	49	20	1.4	21	
8-32W-12DBC	TO		45	50	18	26	6.2	0.7		227	29	15	1.5	17	0.1
8-32W-16BBA	TO		38	49	16	23	6.0	0.7		236	22	9.0	1.4	14	
8-32W-27CBC	TO		43	36	17	33	6.1	0.9		219	30	14	1.6	15	
8-33W-2CDA	TO		50	40	17	24	5.6	0.8		221	21	7.6	1.8	13	0.1
8-33W-14CAA	TO		39	41	19	23	6.3	0.8		234	21	5.7	1.6	10	
8-33W-18CCA	TO	a	48	40	19	24	6.1	0.8		218	24	11	1.5	14	
8-33W-34BBC	TO		34	48	19	36	6.3	0.9		217	56	21	1.4	21	
8-34W-6CBC	TO	a	54	40	18	23	5.4	0.8		201	30	11	1.7	23	
8-34W-23CBD	TO		50	41	18	19	5.8	0.8		228	18	4.6	1.4	11	
8-34W-24BAD	TO		54	46	20	19	6.2	0.6		227	33	9.3	1.4	13	0.2
8-35W-36DAA	TO		45	38	18	34	6.0	0.9		225	31	9.1	1.5	14	
8-36W-4DDC	TO		54	44	14	26	5.0	0.7		204	28	7.0	1.6	18	0.1
8-36W-20DBB	TO		54	54	21	33	5.6	1.2		236	66	18	1.4	22	
9-31W-10BBB	TO		33	56	26	18	6.4	1.0		230	58	19	1.3	25	
9-31W-19BCA	TO		23	42	15	19	5.5	0.7		224	17	5.9	1.2	7.9	
9-31W-36BBB	TO		26	38	15	26	6.1	0.8		226	19	6.8	1.3	8.6	0.1
9-32W-9BDA	TO		24	52	20	23	6.7	1.0		245	31	18	1.5	17	
9-32W-27BCD	TO	a	19	56	19	21	6.2	1.2		239	36	19	0.7	17	
9-33W-6AAA	TO		31	43	17	28	5.6	0.9		228	27	9.3	1.4	13	
9-33W-9CCC	TO		25	40	17	27	5.3	0.9		231	22	8.1	1.3	9.2	
9-33W-15ACC	TO		29	43	16	29	5.2	0.9		227	23	10	1.2	11	
9-33W-30CAA	TO		24	41	14	27	5.4	0.7		242	13	4.1	1.6	7.1	
9-33W-35AAD	TO		18	62	20	20	5.9	1.2		224	46	26	0.9	32	
9-34W-2BDA	TO		26	41	19	19	5.8	0.8		235	15	4.5	1.2	8.9	
9-34W-17BBA	TO		31	46	16	22	5.5	0.8		241	16	5.8	1.2	16	
9-35W-32DAA	TO	a	25	38	16	29	5.4	0.7		225	24	8.0	1.5	9.5	
10-31W-6DCA	TO		22	43	16	27	6.2	0.8		228	20	9.3	1.5	17	
10-31W-13BAD	TO		32	47	18	25	5.8	1.0		227	34	12	1.2	12	
10-31W-29AAB	TO		28	43	17	29	5.9	0.9		226	31	13	1.4	9.0	0.3
10-32W-6CAB	TO		20	41	14	30	5.7	0.9		229	22	11	1.2	9.4	
10-32W-11BAA	TO		28	54	18	31	6.8	1.1		231	53	23	1.2	15	0.1
10-32W-29DCB	TO		26	56	21	18	5.3	1.1		251	33	13	0.8	16	
10-32W-30ABB	TO		31	56	20	21	5.6	1.1		248	34	17	0.8	16	

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
32	2.0	6.0	16	16.0	300	184	0	435	0.61	7.9
20	1.8	2.8	17	15.5	392	277	40	595	0.44	7.7
37	1.8	3.1	18	16.0	328	179	0	490	0.98	7.8
27	1.0	1.7	17	18.0	323	166	0	465	1.12	8.0
1260	2.4	4.0	24	15.0	401	239	32	625	0.98	7.7
34	1.6	0.3	12	16.0	319	167	0	450	1.04	7.9
14	1.4	0.2	9.8	16.0	319	171	0	465	1.00	7.9
42	3.6	0.1	12	17.0	327	150	0	460	1.46	7.8
26	2.2	0.5	11	16.5	321	177	0	440	0.88	7.8
19	1.2	0.7	14	17.5	349	147	0	450	1.40	8.0
27	1.5	0.6	12	17.0	361	172	1.9	505	1.26	7.9
16	1.5	1.7	14	15.5	349	216	27	550	0.77	7.9
31	7.7	1.6	17	15.5	292	180	1.2	460	0.78	7.9
35	2.4	1.5	15	14.5	308	169	0	465	0.94	7.8
43	8.6	3.0	19	15.5	382	233	54	580	0.64	8.0
17	4.8	2.4	17	16.5	290	173	0	435	0.76	7.8
37	3.4	2.0	16	18.0	300	173	6.8	460	0.79	7.9
14	1.5	1.4	14	16.0	322	174	1.8	470	0.86	7.8
18	4.2	1.7	11	15.5	324	204	16	500	0.67	7.8
34	0.4	2.2	4.1	15.0	293	181	2.7	430	0.71	7.7
11	3.1	2.2	23	16.0	331	150	0	450	1.17	8.1
71	4.5	4.8	27	15.0	333	186	0	480	0.83	8.0
25	2.4	2.8	22	17.0	323	164	0	450	0.98	7.9
8.8	4.3	2.9	23	16.0	295	174	0	435	0.76	7.6
125	3.5	3.7	10	15.5	316	188	3.6	450	0.63	7.7
67	9.6	1.7	11	15.5	284	203	6.3	450	0.49	7.7
9.3	1.7	0.2	6.0	16.0	350	208	31	530	0.87	7.7
34	11	3.2	12	16.0	299	200	14	490	0.80	7.8
8.8	1.2	2.0	6.3	15.5	298	188	0	460	0.73	7.8
6.3	1.4	1.2	6.5	16.0	290	161	0	470	1.13	7.9
21	2.0	1.7	15	16.0	277	171	0	440	0.78	8.0
25	0.1	0.6	1.0	15.0	278	181	0	430	0.74	7.7
24	0.0	3.0	1.3	15.0	306	179	0.6	445	0.76	7.6
27	0.1	3.3	1.4	15.0	357	199	21	550	1.11	7.9
14	1.6	1.9	11	15.5	304	176	11	450	0.76	7.7
18	0.4	0.5	6.0	17.0	276	175	0	420	0.62	7.6
-	-	-	-	16.0	293	198	12	480	0.59	7.7
13	0.3	1.4	4.0	16.0	299	170	0	460	1.13	7.8
20	1.6	1.8	13	16.5	304	166	1.8	420	0.90	7.8
128	7.6	1.9	15	16.0	383	222	29	580	0.96	8.0
30	3.7	3.7	16	15.0	353	248	59	580	0.50	7.8
28	2.1	4.2	15	16.0	250	167	0	420	0.64	7.8
25	2.3	2.9	17	16.0	246	157	0	420	0.90	7.8
17	2.1	2.8	18	15.0	316	213	12	520	0.69	7.8
40	2.8	3.2	19	16.0	302	219	23	530	0.62	8.1
12	0.2	0.7	3.1	15.0	288	178	0	460	0.91	8.0
13	0.8	2.0	2.9	15.0	270	171	0	440	0.90	7.7
48	0.7	1.7	3.5	15.0	267	174	0	445	0.96	7.8
8.0	0.4	2.8	5.4	15.0	255	161	0	420	0.93	8.1
12	1.6	3.1	9.8	15.0	348	238	55	570	0.56	7.8
2.8	0.4	2.4	5.8	15.0	261	181	0	415	0.61	7.8
20	0.7	1.6	3.6	15.5	276	184	0	450	0.70	7.6
35	0.9	1.6	4.1	16.0	274	161	0	440	0.99	7.6
37	2.1	3.4	17	17.0	256	174	0	450	0.89	7.8
32	8.8	1.3	6.0	17.0	296	192	6.4	480	0.78	7.8
13	2.8	41	4.7	17.5	289	178	0		0.94	7.7
11	0.4	2.5	8.0	15.0	268	161	0	445	1.03	8.0
78	2.5	3.4	19	15.0	336	210	21	560	0.93	8.0
21	4.0	6.3	4.2	18.0	311	227	22	520	0.52	7.6
18	3.0	39	3.9	18.5	315	223	20	530	0.61	7.6

●Thomas County Cont'd

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
10-33W-10DAA	TO		18	44	13	33	5.7	0.9		228	26	12	1.0	16	
10-33W-17AAA	TO		20	89	24	22	6.3	1.6		233	77	37	0.8	64	
10-33W-19CBD	TO		26	67	16	12	5.3	0.9		247	29	13	0.5	22	
10-34W-1ABA	TO	a	23	44	12	30	5.2	0.8		225	23	8.6	1.3	11	0.1
10-34W-12BCD	TO		23	60	19	19	5.6	1.0		217	28	25	1.2	40	
10-35W-9AAB	TO		29	52	14	20	4.9	0.7		229	23	8.3	0.9	17	
10-36W-7ACC	TO		27	47	23	18	5.5	1.0		229	30	13	1.0	21	

●Wallace County

Well Location	1 Geological Unit	2 Historical Data	3 SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	4 Ortho PO_4 ppm
11-38W-5BBC	QA, TO	a	26	92	21	91	10	1.1		372	156	34	1.1	17	0.2
11-39W-26CCD	QA		28	77	27	69	9.8	0.9		401	111	13	1.2	0.5	0.8
11-41W-35BBD	TO	a	47	42	17	51	5.7	0.7		281	35	9.9	2.2	4.0	0.1
11-42W-5CBB	TO		17	33	11	16	3.7	0.6		163	13	8.8	1.6	13	
11-42W-8DDC	TO		21	36	13	21	4.1	0.6		180	18	9.2	1.6	12	
11-42W-10AAD	TO		19	37	14	20	4.1	0.8		176	23	12	1.7	12	
13-39W-20CCC	QA		26	87	20	77	10	1.3		254	222	20	0.9	18	
13-40W-10ABB	QA		21	118	30	70	9.9	1.6		233	334	22	0.7	4.7	0.1
13-41W-12DDD	QA		21	69	15	35	7.3	1.1		278	73	13	0.8	6.1	0.1
14-39W-36BCB	TO	a	26	36	11	26	3.6	0.7		182	26	6.8	1.9	13	0.1
14-40W-23ACC	TO		20	36	11	21	3.3	0.6		166	19	7.5	1.0	18	
14-41W-23BBB	TO		19	36	11	23	3.4	0.7		168	23	8.6	1.0	13	
14-42W-2AAB	TO	a	23	34	9.4	15	3.1	0.6		165	12	4.3	0.8	10	

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
8.4	0.6	2.4	8.2	15.0	283	164	0	470	1.12	7.7
12	1.1	4.6	3.5	16.0	458	323	132	730	0.53	7.6
13	2.1	1.6	7.0	17.0	325	234	32	515	0.34	7.4
8.5	1.5	1.2	2.0	15.0	268	160	0	430	1.03	7.7
7.4	1.0	1.8	2.0	15.0	326	229	51	540	0.55	7.9
21	0.5	2.7	7.7	15.0	273	188	0.5	455	0.63	7.8
28	1.3	1.9	9.1	15.0	292	213	25	500	0.54	7.8

5 Fe ppb	Mn ppb	Cu ppb	Ni ppb	Temp. °C	Dis. Solids 180°C ppm	Hardness as $CaCO_3$ Total ppm	Non-Carbonate ppm	Specific Conductance µmho at 25°C	SAR	pH
49	11	4.0	32	15.0	614	317	12	980	2.22	7.5
3239	598	1.6	25	15.0	527	304	0	830	1.72	7.8
994	14	2.1	18	16.0	332	176	0	540	1.67	7.7
30	5.8	3.2	12	14.0	185	128	0	330	0.61	7.8
26	3.1	2.0	11	15.0	213	144	0	370	0.76	8.0
18	3.3	1.7	12	15.0	239	151	6.6	380	0.71	8.0
44	4.6	5.3	37	16.0	620	301	93	910	1.93	8.0
25	8.8	2.2	20	18.0	729	420	229	1060	1.49	7.7
10	2.8	2.5	20	15.0	377	235	7.3	620	0.99	7.7
34	5.8	3.1	20	15.0	243	136	0	385	0.97	8.0
44	3.7	4.8	15	18.5	202	136	0	360	0.78	8.0
34	8.3	3.8	18	17.0	206	136	0	370	0.86	8.0
23	3.8	2.8	11	17.0	169	124	0	320	0.59	8.1

Chemical Quality of Irrigation Waters in Northwestern Kansas   Hathaway & Others   KGS

Chemical Quality Series 8
Kansas Geological Survey
The University of Kansas
Lawrence, Kansas 66044