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State Corporation Commission
of Kansas

BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

In the matter of the petition of Daylight Petroleum, LLC (Operator) to open a docket pursuant to K.S.A. 55-605(a) regarding a fluid leak in Section 16, Township 30 South, Range 16 East, Wilson County, Kansas.	)	Docket No. 25-CONS-3040-CMSC CONSERVATION DIVISION License No. 35639

PRE-FILED REBUTTAL TESTIMONY OF

JULIE SHAFFER

ON BEHALF OF COMMISSION STAFF

JANUARY 31, 2025

Q. Are you the same Julie Shaffer that previously provided direct testimony in this matter on November 1, 2024?

A. Yes.

Q. What is the purpose of your rebuttal testimony in this matter?

A. The purpose of my rebuttal testimony is to address certain comments made in the prefiled direct and rebuttal testimony provided on behalf of Daylight Petroleum, LLC (Operator) in Docket 25-CONS-3040-CMSC (Docket 25-3040).

Q. In multiple places of her testimony, Ms. Wheeler states that KCC Staff has insisted that the building on top of the abandoned well be torn down. Is her testimony correct?

A. No, it is not. First, to my knowledge, Ms. Wheeler has not been a part of any conversations with the KCC that dealt with addressing the abandoned well beneath the building. Second, KCC Staff have never told anyone at Operator that the building needs to be torn down. The only suggestion that KCC Staff has made to Operator's staff regarding the building was about the possibility of removing a portion of the floor in a localized area of where the abandoned well is believed to be located. Ideally, the contractor would then be able to spool down the wellbore and not even have to make any modifications to the roof line. This was also our hope for locating the well bore from under the building, so as to avoid any damage to even the floor of the building. However, Operator instead chose to quit looking for the abandoned well and closed the monitoring pit next to the building.

Q. Would Staff have let Operator conduct various tests if it was adamant that the building needed to be torn down?

A. No. The fact that Staff attempted to work with Operator to find alternative methods of not only locating the well, but also plugging the well demonstrates that there is no basis for the narrative that Staff is adamant that the building needs to be torn down. Staff remains open to all non-invasive methods of locating and plugging the wellbore. For example, at the time Operator hired GSI to start geophysical exploration, several non-invasive methods for Operator to explore beneath the floor of the building were being discussed, such as ground penetrating radar, magnetic ranging, and thermal technologies. KCC Staff would have allowed injection into the Olhausen Farms #6 well in order to facilitate the precision of any of the proposed technologies. However, the only results shared by Operator with Staff were the results of the GPR survey. It is not known by Staff if the Operator chose to implement any of the other technologies.

Q. On page 3 line 22 through page 4 line 1 of her testimony, Ms. Wheeler states that further investigation will be necessary by KCC Staff to determine if in fact the source of the fluid is an abandoned well, and if so, who the responsible parties are for such a well. Do you agree with her testimony?

A. No, I do not. Staff is extremely confident that the source of the breakout is an abandoned well. As stated in my direct testimony on page 5, lines 4-8, “The fluid sampled from the monitoring pit had a chloride level of 41,000 ppm. The known produced fluid sample from the Olnhausen #4 contained a chloride level of 45,000 ppm. This alone appears to show a direct correlation between a nearby well from the same completion interval (within the Upper and Lower Bartlesville Sandstone, approximately 820 to 890 feet deep) due to the comparable chloride content.” Later in my direct testimony on page 6, lines 6-10 I conclude that “the Olnhausen Farms #6 well has channeled directly with an old wellbore beneath the footprint of the building on the Johnson Lease. The clear communication shown from the injection test linking the Olnhausen #6 to fluids surfacing from under the building into the monitoring pit not only link a channeled horizontal pathway but also a vertical pathway to the ground surface thus indicating an abandoned wellbore." For the correlation between the chloride levels of the formation and the produced fluids taken from the monitoring pit to be found here, there would have to be a direct conduit between the producing formation and the surface.

As far as who the responsible party is, the District Office will consult with the Legal Department for that determination to be made. Generally speaking, if an operator's completion or injection operations cause a well to breakout (flow at surface) that operator is the responsible party for the abandoned well. I believe that Director Hoffman addresses the responsible parties for the abandoned well in his testimony.

Q. On page 5 lines 5-6 of her testimony, Ms. Wheeler states that the groundwater is already impacted with chlorides, likely from past operations in the area. Do you agree with her assessment?

A. No. That statement in her testimony was made after being asked if plugging the abandoned well would prevent groundwater from being contaminated with chlorides. I am not sure how anyone can make such a comment without knowing the status of the wellbore beneath the building. The information available indicates that there are leaks in the wellbore that are impacting the fresh and usable water zones within Table I. The chloride level of water being injected into the formation was 45,000 ppm; however, the chloride level in the fluid taken from the monitoring pit next to the building measured 41,000 ppm. The produced fluid would not be diluted by 4,000 ppm of chlorides if it was not interacting with fresh water to some extent. Ms. Wheeler's statement that the groundwater was already impacted with that level of chlorides is not supported by the data. Neither GSI nor Ms. Wheeler can make that statement without prior knowledge or sampling in the area. As far as we know, they did not take any measurements before the breakout occurred. Thus, there is nothing that supports that statement.

Q. On page 5 lines 8-10 of her testimony, Ms. Wheeler states that the building will act as a "cap" preventing infiltration of chlorides beneath the building migrating down to groundwater. Does her comment make sense?

A. No, it does not. The communication of fluids that was witnessed at the building disproves this entire line of thinking. The building may prevent something like a minor spill from a vehicle's oil change from infiltrating groundwater. However, a large spill on the porous gravel outside of the building has a higher probability of making its way to a nearby open wellbore and down, than the probability of that building acting as a cap.

Q. On page 7 lines 13 through 19 of her testimony, Ms. Wheeler states that groundwater samples should be collected utilizing Hydrasleeve No-Purge samplers and left in place before being retrieved for sample collection. Did GSI ever raise any concerns about the sampling process before testimony was filed?

A. No. To my recollection, GSI has never expressed any concerns or issues with this manner of testing being conducted until Ms. Wheeler filed her testimony in this docket.

Q. On page 9 lines 15 through 18 of her testimony, Ms. Wheeler states that if produced water from Operator's Olnhausen Farms lease were flowing into the Table I interval, then the chloride levels in the groundwater samples would be several times higher. Do you agree with Ms. Wheeler's analysis?

A. No. For example, let's say that there is a cable tool hole drilled that is located under the building. It would have likely been about 8 inches in diameter at this 140 foot depth. Now take into account the surface area of the formations seen within Table I in general but also consider the formation pressure and surface tension of the pore space, fractures or bedding planes and the low porosity and permeability of likely microns in size where the ground water is traveling. Next, take into consideration the rate and pressure that was being injected and how far the produced fluids traveled during the short length of time there was allowed injection. The result is that you would have dilution, which is precisely what was found in the sample taken from the water being injected into the Olnhausen Farms lease (45,000 ppm Cl) versus the sample taken from the monitoring pit next to the building (41,000 ppm Cl). I do not expect for this short length of timeframe that there would be chloride values several times higher found in the water samples taken from the monitoring wells as she states. In all actuality it would be hard for anyone to estimate what the chloride concentrations should be that would be found in the groundwater.

Q. On page 10 lines 10 through 13 of her testimony, Ms. Wheeler states that upgradient wells PMW-3 and PMW-4 have both had detections of concentrations exceeding the secondary maximum contaminant levels for Chloride. Do you have any comment on the concentrations found in those wells?

A. Regarding the PMW-3 well which is upgradient from the other wells; it has shown very low chloride levels and the last 3 samplings from this well are more in line with "naturally occurring" chloride values that one would likely see from the formations in this area. The initial (earliest) sampling at depth was seen to have a chloride value of 262 ppm right around the MCL for chloride, while the 2nd quarterly sampling was down to 130 ppm and the last 3 quarters have averaged about 64 ppm. This well appears to be indicative of groundwater that is upgradient from the release with no real chloride impact leading one to believe that these values are what one would expect to see as indicated from the KGS Bulletin.

In addition, the PMW-4 well more closely resembles the PMW-2 well, lithologically speaking, but it has the largest screened interval whereas PMW-2 has the smallest screened interval. This causes the PMW-4 well to intercept more bedding planes and will likely have a higher water table, diluting chloride concentrations as Ms. Wheeler states in her testimony. However, the two uppermost samples collected from the PMW-4 well also indicate that the shallow zones were impacted as well as the deeper intervals within Table I.

Q. On page 10 lines 14 through 19 of her testimony, Ms. Wheeler references contamination from poor industry practices such as evaporation pits, surface releases of produced water, inadequate completion techniques and poor drilling practices and the slow infiltration of chlorides. Is there any evidence that would indicate such practices have caused the elevated level of chlorides on this lease?

A. With any historical oil lease this concern can be a possibility. In my experience of investigations within active oil fields, fluids within undocumented, abandoned wellbores will usually make their way to surface due to completion and injection activities conducted by nearby operators. However, these wells are then plugged within a timely manner, thus shortening the extent of impact to Table I. Additionally, if there were any evaporation pits or surface releases of produced water, the impact would be seen at surface for long periods of time after the fact with both soil and vegetative damage. There is no indication of such damage in this area in either recent or historical aerials.

Q. On page 10 line 22 through page 11 line 2 of her testimony, Ms. Wheeler states that Chlorides are very abundant in nature and would still be detected?

A. Naturally occurring brines are associated with many formations; however, the depth of the formation significantly impacts the abundance of brine that is associated with the geological formation. Deeper formations have higher potential for concentrated brine due to increased pressure and temperature conditions that facilitate the dissolution of salt minerals.

Chlorides are abundant in nature and District Staff witnesses this often. Comparing this information to the likely hundreds of past samples staff at KCC have sampled in creeks, rivers, streams, hand dug water wells and water wells alike, the average chloride values are below 100 ppm at shallow depths and typically show in the 30-60 ppm range.

Q. On page 11 of her testimony, Ms. Wheeler references a 1966 bulletin conducted by KGS. Do you see any issue with the correlation she tries to draw between that study and the information before the Commission?

A. Yes. Of the 42 wells sampled only 16 wells included the main formations encountered at the monitoring wells drilled through Table I for Operator. These formations are the Iola Limestone, Chanute Shale and Dennis Limestone. All of the other wells in the 1966 study sampled formations deeper than the Dennis Limestone. Attached to my testimony as ***Exhibit JS-4*** is an excel spreadsheet breaking down the samples included in the 1966 bulletin. I have highlighted the chloride levels found in each of the samples from formations encountered in Operator's monitoring wells. I believe it is important to note the median chloride levels taken from these samples. The median chloride level for the Iola Limestone was 165 ppm, the chloride median for the Chanute Shale was 30 ppm, and the median chloride level for the Dennis Limestone was 27 ppm. The average chloride level between all 16 wells within formations of relevance is 199 ppm. However, if you were to remove the two outlier samples included in the study, then the average chloride concentration is only 58 ppm. This value is more representative with what the KCC sees as naturally occurring chlorides in shallow formations. Additionally, please note the highlighted portion on page 4 of ***Exhibit JS-5***. The exhibit is from the Ground-Water Resources: Source, Occurrence, and Movement of Groundwater page of the 1966 KGS Bulletin. Under the section discussing the Sanitary Considerations the bulletin states "However, high concentrations of certain constituents such as nitrates or chlorides may indicate pollution of the water." District Staff believes the higher chloride levels seen in the samples included as part of the 1966 study are likely the result of contamination from localized oil and gas activities and not an indication of natural chlorides within these formations.

Q. On page 12 lines 1 through 3 of her testimony, Ms. Wheeler states that the higher chloride concentrations in the Table I groundwater do not come as a surprise and do not necessarily have anything to do with the release below the building. Do you think the higher chloride levels should be a surprise?

A. Yes. I think it is important for the Commission to take into account the type of bedrock in Eastern Kansas and why this part of the State does not have large fresh water producing aquifers. Eastern Kansas has mostly confining layers of rock at surface that continue at depth. At this site, the geoprobe hit a refusal point where it could not go any deeper at 10-12 feet below ground surface. This makes sense when you look at the cross sections referenced by Ms. Wheeler, the refusal point is about the same thickness as the clayey soil horizon, approximately 10 feet deep. Immediately below the soil horizon is a sandstone bed or a very thick shale bed, so the argument of surface to groundwater contamination does not make the most sense in this area.

If there was surface contamination, any brine pit/evaporation pit fluids would have been held up at the confining shale layer and any produced fluids would likely have traveled to the riverbank to the southwest along the top bedding plane and leached out the bank. This geology also prevents Ms. Wheeler's statement that rainfall can cause chlorides to sink deeper into the soils to groundwater from occurring. The data shows that the 2 upgradient geoprobe wells were dry. However, the 2 downgradient geoprobe wells were able to collect enough ground water for water sample collection, indicating produced fluids were intercepted flowing along the uppermost bedding plane from the site of the release.

Q. On page 13 line 22 through page 14 line 1 of her testimony, Ms. Wheeler states that the construction of the monitoring wells has predictably caused the chloride readings to be what they are. Later on page 14 lines 6 through 8 of her testimony, Ms. Wheeler stated that the monitoring wells at issue were not designed in accordance with industry best practices. What was Staff's main concern regarding the construction of the monitoring wells?

A. Our main concern was simply that the sampling from the monitoring wells needed to be representative of the entire Table I interval. We informed Operator that it could isolate any intervals it wanted as long as (1) those intervals in summation included the entire Table I interval and (2) that we were in agreement as to the locations of the wells. On page 14, Ms. Wheeler discusses being unable to identify where the groundwater is entering from. For our purposes, we are more concerned about identifying heightened levels of chlorides in Table I as opposed to specifically identifying where in Table I the heightened chlorides are entering the well from.

Q. On page 25 lines 1 through 4 of her testimony, Ms. Wheeler states that she believes that the chloride concentrations in the area are related to the many decades of oil production activities; possibly from poor well completion, surface discharge of produced water, or

even a pit used to hold brine water which could correlate with the multiple dark shadowed spots on the older arial images. Do you agree with her statement?

A. No, not necessarily. This area is part of historical oil production and the possibility exists for impacts both at surface and below ground. However, as seen on years of aerials, there is no vegetative impact at surface that is seen in the area of the immediate active leases at or to the east or south of the Johnson lease. Additionally, the chloride levels within groundwater seen from upgradient well PMW-3 displays evidence of groundwater that is not impacted by produced fluids while the immediate downgradient monitoring well from the release, PMW-2, has shown the highest levels of chlorides sampled within Table I.

Q. Did the testimony provided on behalf of Operator change your recommendation?

A. No. I agree with the recommendation made by Mr. Russell and still recommend that Operator be required to locate and plug the abandoned wellbore to prevent the further pollution of fresh and usable water.

Q. Does this conclude your testimony?

A. Yes.

1966 KGS Bulletin 183

Well number	Date of collection	Depth of well, feet	Geologic source	Temp. (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Pot. (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$ Carbonate	Non-carbonate	Specific conductance (micromhos at 25° C)
27-17-1dc	10/9/1961	**53**	**Chanute Shale**	64	17	0.16	51	18	108	439	36	**24**	1.1	1.5	473	201	0	820
27-17-11ad	10/10/1961	**46.8**	**Iola Limestone**		14	0.04	149	29	125	405	98	**165**	0.1	120	900	332	159	1.6
27-17-36bb	10/9/1961	**180**	**Chanute Shale**		10	0.03	16	8.8	132	381	2	**31**	0.7	3.1	391	76	0	690
27-18-24cc	10/9/1961	**44.1**	**Chanute Shale**		28	0.02	33	10	22	81	9.1	**29**	0.3	66	237	66	58	400
27-19-6da	8/30/1962	**18.7**	**Chanute Shale**	68	13	0.36	397	248	234	498	1,560	**210**	0.5	235	3,143	408	1,602	3,920
27-19-9da	8/29/1962	**17.7**	**Chanute Shale**	62	13	0.58	186	28	135	427	145	**169**	0.2	133	1,019	579	229	1,710
27-19-27bb	10/9/1961	75.8	Swope Limestone	61.5	10	0.62	47	18	444	437	28	540	2.2	1	1,305	191	0	2,470
27-19-30cd2	12/28/1960	105	Galesburg Shale		9	1.3	72	61	979	464	131	**1,440**	4	0.4	2,925	380	50	5,580
27-20-9dc	12/28/1960	150.6	Swope Limestone		4.5	0.07	22	17	821	527	18	**1,020**	8	0.9	2,171	125	0	4,130
27-20-31ad	10/10/1961	125	Swope Limestone	62	11	2.3	50	36	114	407	102	53	2	3.1	571	273	0	1,000
27-21-8cc	10/9/1961	**91.3**	**Dennis Limestone**	61	12	0.43	123	31	32	383	102	**27**	0.2	58	574	314	120	970
28-18-4cd	8/29/1962	**60**	**Dennis Limestone**	64	16	0.18	184	87	565	334	28	**1,250**	1.4	4.4	2,300	274	542	4,390
28-18-20ad1	12/28/1960	**145**	**Dennis Limestone**		12	0.1	453	222	260	578	2,000	**32**	0.7	9.3	3,274	474	1,568	3,900
28-18-27aa	8/29/1962	**16.8**	**Chanute Shale**		18	0.07	36	21	38	149	111	**5**	0.5	6.5	309	122	54	520
28-10-1ba	10/9/1961	**122.4**	**Dennis Limestone**	63	14	1.3	51	29	55	383	19	**18**	0.5	5.8	381	246	0	680
28-10-7cd	12/28/1960	106	Swope Limestone		12	0.03	87	45	78	432	27	62	0.5	124	648	354	48	1,090
28-10-14cd	10/9/1961	48	Wisconsinan alluvium		15	0.01	125	8.3	17	386	24	14	0.1	28	421	316	30	730
28-20-9da	12/28/1960	100	Tacket Formation		8	0.01	78	25	114	407	116	57	0.7	11	610	298	0	1,090
28-20-24ad	10/10/1961	35	Tacket Formation	59	5	0.18	237	25	71	429	210	106	0.1	159	1,024	352	342	1,730
28-20-30ca	8/29/1961	20	Wisconsinan alluvium		16	0.01	175	22	92	403	147	129	0.1	71	851	330	197	1,430
28-21-5bb1	10/9/1961	27.2	Tacket Formation	60.5	11	0.24	78	58	114	498	23	111	0.1	115	755	408	25	1,390
28-21-29aa	12/28/1960	54	Bandera Shale		10	0.08	148	50	46	400	35	61	0	279	826	328	246	1,270
28-21-34dd	10/10/1961	23.1	Bandera Shale	65	12	0.27	331	92	403	373	860	345	0.4	487	2,714	306	898	4,050
29-17-13cc	10/10/1961	**25.5**	**Chanute Shale**		21	1.4	227	83	111	429	748	**10**	0.3	4.2	1,415	352	556	1,900
29-18-20ac	10/10/1961	**14.9**	**Chanute Shale**		15	3.8	483	265	635	259	1,416	**1,115**	0.5	518	4,575	212	2,082	6,890
29-18-35dc	10/10/1961	137.5	Galesburg Shale		8.5	0.02	8	2	366	634	57	165	4	1.5	924	28	0	1,660
29-19-3ca	8/29/1962	**104.5**	**Dennis Limestone**	61	13	0.13	121	12	16	395	46	**12**	0.1	0.4	415	324	28	720
29-19-7dc	12/28/1960	**105**	**Dennis Limestone**		17	0.65	129	102	79	450	502	**12**	0.6	3.8	1,067	369	372	1,560
29-19-30bb	10/10/1961	**81.4**	**Dennis Limestone**		11	0.12	179	61	107	395	325	**71**	0.2	208	1,157	324	373	1,780
29-20-1dd	10/10/1961	27.4	Nowata Shale		12	0.02	82	26	50	459	4.9	25	0.2	3.1	429	312	0	780
29-20-20cc	12/28/1960	20	Hertha Limestone		13	0.7	182	24	26	210	158	77	0.4	204	788	172	380	1,230
29-21-32dd	8/29/1962	20	Wisconsinan alluvium	64	16	5.9	89	8.8	20	307	46	7	0.2	0.4	338	252	6	570
30-17-2dd	8/30/1962	240	Chanute Shale, Galesburg Shale		17	0.09	232	102	182	407	875	84	1.1	49	1,742	334	664	2,350
30-18-20ab1	12/28/1960	296	Tacket Formation		9	0.24	70	16	184	233	99	163	1.1	142	799	191	49	1,330
30-19-1da	8/30/1962	28.9	Hertha Limestone	60	15	2.3	140	58	75	256	318	50	0.4	150	933	210	378	1,410
30-19-4bb2	12/28/1960	65	Swope Limestone		9.5	5.6	201	19	93	295	234	89	0.3	212	1,003	242	338	1,510
30-19-19bb	10/10/1961	71.5	Galesburg Shale	61.5	15	0.91	636	206	332	266	1,218	430	0.5	1,319	4,288	218	2,216	6,040
30-19-24bb	8/30/1962	100	Tacket Formation	63	13	0.79	111	117	785	730	492	**910**	1.3	89	2,878	598	160	4,390
30-19-35bb	8/30/1962	66	Bandera Shale	63	12	0.94	125	50	115	425	360	36	0.5	0.4	908	348	170	1,390
30-20-13ac	12/28/1960	108.6	Bandera Shale		6	2.6	250	29	68	278	138	160	0.4	363	1,151	228	515	1,920
30-20-22dd	8/30/1962	21.6	Nowata Shale	63	11	0.04	175	43	99	415	237	90	0.3	137	997	340	273	1,610
30-21-22cd	12/28/1960	60	Bandera Shale		9.5	0.24	113	12	72	287	48	58	0.1	150	604	236	96	960

Total Wells Sampled **42**

Wells w/n Formations of relevance at the Johnson lease **16**

*See color-coded strat column to associate formations

Exhibit JS-4

Geohydrology of Neosho County

Prev Page--Subsurface and Outcropping rocks || Next Page--Utilization and Summary

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Ground-water Resources

Source, Occurrence, and Movement of Ground Water

The discussion of the occurrence of ground water in Neosho County is based partly on a detailed treatment by Meinzer (1923, 1923a). A general discussion of the principles of ground-water occurrence with special reference to Kansas has been given by Moore, et al. (1940).

Ground water is that water below the surface of the land in the zone of saturation. It is derived mainly from precipitation and reaches the zone of saturation by percolation downward through the soil and subsoil.

The rocks in the outer crust of the earth are not solid but contain many openings, or voids, that hold air, water, or other fluid. Generally, the rock formations below a certain level are saturated with water. The upper surface of the zone of saturation is neither a level surface nor a static surface, but one that has many irregularities, which are generally similar to the irregularities of the surface topography. Under natural conditions, the small part of the precipitation that reaches the zone of saturation moves slowly toward the streams and discharges into them or is lost by transpiration and evaporation in the valley areas.

Water in the zone of saturation, available to wells, may be confined or unconfined. Unconfined or free ground water does not have a confining or impermeable body restricting its upper surface. The upper surface of unconfined ground water is called the water table. The water in weathered limestone, sandstone, and shale, the alluvial deposits in Neosho River valley and other stream valleys, and colluvial slope deposits is unconfined in most localities. Ground water is said to be confined or artesian if it occurs in permeable zones between relatively impermeable beds that confine the water under pressure. Most of the wells constructed in the unweathered Pennsylvanian bedrock of Neosho County tap confined ground water.

Ground-water Recharge and Discharge

The addition of water to natural underground reservoirs is called recharge and may be effected in several ways. The most important source of recharge is local precipitation and this is the major source of recharge for weathered bedrock aquifers in the upland areas of Neosho County. Lesser amounts are contributed to these aquifers by influent seepage from streams and ponds and by subsurface inflow from adjacent areas. Locally, influent seepage from streams may contribute an important amount of recharge to adjacent alluvial deposits and to the bedrock aquifers where streams cut across permeable zones.

However, in the Neosho River valley the gradient of the water table, as indicated by water levels in test holes (Fig. 5). is toward the river. Therefore, it is unlikely that any recharge reaches the Wisconsinan and Recent deposits of the valley from the river except during periods of flooding.

Although no data on amounts are available, some recharge must be taking place in the Chanute Shale from the alluvial deposits or from the Neosho River in the area northeast of Chanute where Wisconsinan alluvium overlies northwestward-dipping sandstone beds in the Chanute Shale.

Recharge is seasonal in the Midwest. Generally the water levels of wells are lowered by natural drainage into streams during the winter, when the soil is frozen and precipitation is slight. During the spring precipitation is relatively abundant, temperature is moderately cool, and transpiration and evaporation are low, which results in the greatest amount of recharge during the year. Recharge may occur during other seasons whenever precipitation is sufficient to overcome the soil-moisture deficiency of a preceding dry period.

Ground water moves downward under the influence of gravity through the permeable rocks, in accordance with their character and structure, to points of lower elevation. It may discharge directly into a stream as a spring or seep or it may be discharged by evaporation or transpiration where the water table is near the surface. A part of the ground water is discharged from wells, but this amount is small in Neosho County compared with that discharged by other means.

Under natural conditions, over a long period of time, approximate equilibrium exists between the amount of water that is added annually to ground-water storage and the amount that is discharged annually.

Chemical Character of Ground Water

Various gases and minerals are taken into solution by water as it is precipitated and as it percolates through the rocks of the earth's crust. The type and quantity of impurities in ground water may be determined by chemical analysis. The corrosiveness, encrusting tendency, palatability, and other properties can be predicted from the results of a quantitative analysis of the water.

Analyses of 42 water samples from wells in Neosho County are shown in Table 1. Mineral concentrations are given in parts per million (ppm).

The samples of water from wells in Neosho County were analyzed by Howard A. Stoltenberg, Chief Chemist, in the Sanitary Engineering Laboratory of the Kansas State Department of Health. The analyses indicate only the dissolved mineral content of the water and do not indicate the bacteriological content.

Table 1--Analyses of water from selected wells in Neosho County, Kansas (in parts per million, except as otherwise indicated). One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water. (Samples analyzed by H. A. Stoltenberg)

Well number	Date of collection	Depth of well, feet	Geologic source	Temp. (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Ha
																Ca
27-17-1dc	10-9-1961	53	Chanute Shale	64	17	0.16	51	18	108	439	36	24	1.1	1.5	473	201
27-17-11ad	10-10-1961	46.8	Iola Limestone		14	.04	149	29	125	405	98	165	.1	120	900	332

27-17-36bb	10-9-1961	180	Chanute Shale		10	.03	16	8.8	132	381	2.0	31	.7	3.1	391	76
27-18-24cc	10-9-1961	44.1	Chanute Shale		28	.02	33	10	22	81	9.1	29	.3	66	237	66
27-19-6da	8-30-1962	18.7	Chanute Shale	68	13	.36	397	248	234	498	1,560	210	.5	235	3,143	408
27-19-9da	8-29-1962	17.7	Chanute Shale	62	13	.58	186	28	135	427	145	169	.2	133	1,019	579
27-19-27bb	10-9-1961	75.8	Swope Limestone	61.5	10	.62	47	18	444	437	28	540	2.2	1.0	1,305	191
27-19-30cd2	12-28-1960	105	Galesburg Shale		9.0	1.3	72	61	979	464	131	1,440	4.0	.4	2,925	380
27-20-9dc	12-28-1960	150.6	Swope Limestone		4.5	.07	22	17	821	527	18	1,020	8.0	.9	2,171	125
27-20-31ad	10-10-1961	125	Swope Limestone	62	11	2.3	50	36	114	407	102	53	2.0	3.1	571	273
27-21-8cc	10-9-1961	91.3	Dennis Limestone	61	12	.43	123	31	32	383	102	27	.2	58	574	314
28-18-4cd	8-29-1962	60	Dennis Limestone	64	16	.18	184	87	565	334	28	1,250	1.4	4.4	2,300	274
28-18-20ad1	12-28-1960	145	Dennis Limestone		12	.10	453	222	260	578	2,000	32	.7	9.3	3,274	474
28-18-27aa	8-29-1962	16.8	Chanute Shale		18	.07	36	21	38	149	111	5	.5	6.5	309	122
28-10-1ba	10-9-1961	122.4	Dennis Limestone	63	14	1.3	51	29	55	383	19	18	.5	5.8	381	246
28-10-7cd	12-28-1960	106	Swope Limestone		12	.03	87	45	78	432	27	62	.5	124	648	354
28-10-14cd	10-9-1961	48	Wisconsinan alluvium		15	.01	125	8.3	17	386	24	14	.1	28	421	316
28-20-9da	12-28-1960	100.0	Tacket Formation		8.0	.01	78	25	114	407	116	57	.7	11	610	298
28-20-24ad	10-10-1961	35	Tacket Formation	59	5.0	.18	237	25	71	429	210	106	.1	159	1,024	352
28-20-30ca	8-29-1961	20	Wisconsinan alluvium		16	.01	175	22	92	403	147	129	.1	71	851	330
28-21-5bb1	10-9-1961	27.2	Tacket Formation	60.5	11	.24	78	58	114	498	23	111	.1	115	755	408
28-21-29aa	12-28-1960	54	Bandera Shale		10	.08	148	50	46	400	35	61	0	279	826	328
28-21-34dd	10-10-1961	23.1	Bandera Shale	65	12	.27	331	92	403	373	860	345	.4	487	2,714	306
29-17-13cc	10-10-1961	25.5	Chanute Shale		21	1.4	227	83	111	429	748	10	0.3	4.2	1,415	352
29-18-20ac	10-10-1961	14.9	Chanute Shale		15	3.8	483	265	635	259	1,416	1,115	.5	518	4,575	212
29-18-35dc	10-10-1961	137.5	Galesburg Shale		8.5	.02	8	2.0	366	634	57	165	4.0	1.5	924	28
29-19-3ca	8-29-1962	104.5	Dennis Limestone	61	13	.13	121	12	16	395	46	12	.1	.4	415	324
29-19-7dc	12-28-1960	105	Dennis Limestone		17	.65	129	102	79	450	502	12	.6	3.8	1,067	369
29-19-30bb	10-10-1961	81.4	Dennis Limestone		11	.12	179	61	107	395	325	71	.2	208	1,157	324
29-20-1dd	10-10-1961	27.4	Nowata Shale		12	.02	82	26	50	459	4.9	25	.2	3.1	429	312
29-20-20cc	12-28-1960	20	Hertha Limestone		13	.70	182	24	26	210	158	77	.4	204	788	172
29-21-32dd	8-29-1962	20	Wisconsinan alluvium	64	16	5.9	89	8.8	20	307	46	7.0	.2	.4	338	252
30-17-2dd	8-30-1962	240	Chanute Shale, Galesburg Shale		17	.09	232	102	182	407	875	84	1.1	49	1,742	334
30-18-20ab1	12-28-1960	296	Tacket Formation		9	.24	70	16	184	233	99	163	1.1	142	799	191
30-19-1da	8-30-1962	28.9	Hertha Limestone	60	15	2.3	140	58	75	256	318	50	.4	150	933	210
30-19-4bb2	12-28-1960	65.0	Swope Limestone		9.5	5.6	201	19	93	295	234	89	.3	212	1,003	242

30-19-19bb	10-10-1961	71.5	Galesburg Shale	61.5	15	.91	636	206	332	266	1,218	430	.5	1,319	4,288	218
30-19-24bb	8-30-1962	100	Tacket Formation	63	13	.79	111	117	785	730	492	910	1.3	89	2,878	598
30-19-35bb	8-30-1962	66.0	Bandera Shale	63	12	.94	125	50	115	425	360	36	.5	.4	908	348
30-20-13ac	12-28-1960	108.6	Bandera Shale		6	2.6	250	29	68	278	138	160	.4	363	1,151	228
30-20-22dd	8-30-1962	21.6	Nowata Shale	63	11	.04	175	43	99	415	237	90	.3	137	997	340
30-21-22cd	12-28-1960	60	Bandera Shale		9.5	.24	113	12	72	287	48	58	.1	150	604	236

Chemical Constituents in Relation to Use

The following discussion of the chemical constituents of ground water has been adapted in part from publications of the U. S. Geological Survey, the State Geological Survey of Kansas, and the U. S. Public Health Service.

Dissolved Solids

When water is evaporated, the residue consists mainly of mineral constituents, but it may also include small quantities of organic matter and some water of crystallization. Water containing less than 500 ppm (parts per million) of dissolved solids is generally suitable for domestic use except for difficulties that may result from hardness or excessive iron or manganese. Water containing more than 1,000 ppm of dissolved solids is likely to have enough of certain constituents to impart a noticeable taste or otherwise render the water unsuitable or undesirable for use.

Hardness

The hardness of water is most commonly recognized by the scum or curd formed when soap is used with the water. Salts of calcium and magnesium cause nearly all the hardness of ordinary water. These salts also cause scale in steam boilers or other containers in which water is heated or evaporated. The total hardness of a water may generally be divided into carbonate hardness and noncarbonate hardness. The carbonate hardness is due to calcium and magnesium carbonates and may be almost completely removed by boiling. This type of hardness is often called temporary hardness. The noncarbonate hardness is caused by the sulfates and chlorides of calcium and magnesium and cannot be removed by boiling. This type of hardness is often referred to as permanent hardness. There is no difference between carbonate and noncarbonate hardness in regard to the reaction with soap.

Water with a hardness of less than 60 ppm is generally considered soft and, ordinarily, treatment for removal of hardness is unnecessary. Hardness ranging from 60 ppm to 150 ppm does not interfere with the use of water in most situations, but it does increase the consumption of soap. Laundries and other industries using large quantities of soap may profitably soften such water. Hardness greater than 150 ppm can be noticed by almost anyone, and if the hardness is 200 ppm or greater, the water is generally softened before use. When municipal supplies are softened, an attempt is usually made to reduce the hardness to about 80 to 100 ppm. Further softening of a public supply is not considered worth the additional expense. For purposes of discussion in this report, water with hardness ranging from 0-60 ppm is considered soft; 61-120 ppm, moderately hard; 121-180, hard; and greater than 180 ppm, very hard.

Nitrate

The use of water containing an excessive amount of nitrate in the preparation of a baby's formula may cause methemoglobinemia in the child, a condition of the blood which results in cyanosis or oxygen starvation. Some authorities specify that water containing greater than 45 ppm of nitrate should not be used in formula preparation for infants under 3 months (Metzler and Stoltenberg, 1950). Water containing 90 ppm is generally considered dangerous to infants and water containing as much as 150 ppm may cause severe cyanosis. Cyanosis is not produced in older children and adults by the concentrations of nitrate ordinarily found in drinking water. Boiling of water containing excessive nitrate does not render it safe for use by infants. Rather, boiling reduces the volume of the water by evaporation and increases the concentration of nitrate in the water. Therefore, only water known to be free of excessive nitrate should be used for preparing infant formulas.

The nitrate content of water from some wells is somewhat seasonal, being highest in winter and lowest in summer. In general, water from wells that are susceptible to surface contamination is likely to be high in nitrate concentration.

Nitrate was found in concentrations greater than 45 ppm in 23 of the 42 water samples analyzed for this report.

Fluoride

Fluoride is present in ground water generally in only small quantities. A knowledge of the fluoride concentration is important because use of water containing greater than 1.5 ppm of fluoride by children during the period of formation of permanent teeth may result in mottling of the enamel. If the fluoride concentration is as much as 4.0 ppm, about 90 percent of children using the water may have mottled enamel (Dean, 1936).

Whereas too much fluoride may have a detrimental effect, moderate concentrations of fluoride (1.0-1.5 ppm) help to prevent tooth decay (Dean, et al., 1941). The U. S. Public Health Service has established 1.5 ppm as the maximum concentration of fluoride permissible in drinking water used on interstate carriers.

Chloride

Chloride salts are very abundant in nature. Sea water and oil-field brines contain them in large quantities, and smaller amounts may be dissolved from rock materials by ground water. Water containing less than 250 ppm of chloride is satisfactory for most purposes. Water containing more than 250 ppm usually is objectionable for municipal supplies, while water containing more than 350 ppm can be unfit even for irrigation and industrial use. Water with as much as 500 ppm of chloride has a salty taste. However, cattle will often tolerate concentrations as high as 4,000 or 5,000 ppm. The removal of chloride is too difficult and costly to be economical for most water uses.

Iron

Next to hardness, iron is the constituent of natural waters that is generally most objectionable. The quantity of iron in the water may differ greatly, sometimes even in the same aquifer. If the water contains 0.3 ppm or more of iron in solution, the iron may settle out as a reddish sediment when the water is exposed to air. Iron at concentrations greater than about 0.3 ppm gives a disagreeable taste to water and stains laundry, cooking utensils, and plumbing fixtures. Iron can generally be removed by aeration and filtration, but some waters require chemical treatment for adequate removal of iron.

Manganese has the same effect as iron, except that the stain is black. Iron and manganese are considered together in evaluating the usefulness of water.

Sulfate

Sulfate in ground water is derived principally from gypsum and anhydrite (calcium sulfate), and from the oxidation of pyrite (iron disulfide). Magnesium sulfate (epsom salt) and sodium sulfate (glauber's salt), if present in concentrations greater than about 250 ppm, impart a bitter taste to water and have a laxative effect upon persons not accustomed to drinking it. More than 250 ppm of sulfate is considered undesirable.

Sanitary Considerations

The analyses of water given in Table 1 indicate only the amount of dissolved mineral matter in the water and do not show the bacteriological content of the water. However, high concentrations of certain constituents such as nitrates or chlorides may indicate pollution of the water.

No cities in Neosho County depend upon wells for their water supplies, but much of the rural population of the county rely upon private wells for water for domestic and stock use. Therefore, care should be taken to prevent pollution of these wells. Generally, wells should not be located downhill from such sources of pollution as barnyards, privies, septic tanks, or cesspools. Also, a well should be completely sealed at the top and around the casing to prevent contamination of the ground-water supply by dust, insects, vermin, debris, and surface water. Dug wells are relatively more vulnerable to contamination because the large diameters common among this type of well renders proper sealing more difficult.

Availability of Ground Water

In Neosho County fresh ground water is known to occur in consolidated rocks to a depth of nearly 300 feet and in unconsolidated rocks to a depth of 35 feet. The consolidated rock aquifers consist chiefly of limestones, shales, and sandstones of Pennsylvanian age. The sandstones constitute the most permeable consolidated rock aquifers.

The unconsolidated rock aquifers are alluvial deposits of silt, fine sand, and pebble-sized chert fragments of Pleistocene and Recent ages that occur in the stream valleys as valley fill and as low, highly dissected terraces.

Consolidated Rocks

Limestone and Shale Aquifers

The limestone and shale formations in the county possess a well-developed joint pattern which apparently persists at depth. Because of these joints and other fractures, yields of about 1 gpm may be obtained from wells to a depth of about 300 feet. Weathering processes have enlarged openings.along the joints, fractures, and bedding planes near the land surface. In these rocks, shallow dug or drilled wells may yield as much as 3 gpm. Dug wells, with a larger storage capacity, are generally more satisfactory than drilled wells in these aquifers.

The Bandera Shale is the oldest formation in the county from which fresh water is obtained. Well drillers report that water in rocks of the Pawnee Limestone and older Pennsylvanian rocks is highly mineralized and unfit for human or animal consumption.

Pre-Pennsylvanian Rocks

A well drilled in 1936 in SE SE sec. 13, T 29 S, R 20 E to a depth of 1,010 feet is reported to have produced highly mineralized, though potable, water from limestone of Mississippian age. The City of St. Paul used this well as a municipal supply for a short time in 1936 and 1937. In 1937, the static water level in this well was reportedly about 35 feet below the land surface. The well has subsequently been plugged, and no recent water-quality or water-level data are available.

The City of Walnut, Crawford County, Kansas, has a well 1,015 feet deep in SW SW sec. 20, T 28 S, R 22 E (about 3 miles east of the Neosho county line) which obtains water from a zone of saccharoidal dolomite and quartz sand informally called the "Swan Creek." The "Swan Creek," which is in the upper part of the Cotter Dolomite of Ordovician age, occurs in the interval between 990-1,010 feet in the well. Water from the overlying Mississippian and Pennsylvanian rocks, which contains high concentrations of chlorides and sulfates, is kept out of the well by steel casing that is cemented in place to a depth of 931 feet. In November 1964, the well was producing approximately 80 gpm. The chloride content of a water sample taken in 1956 soon after completion of the well was 570 ppm. Subsequent analyses performed in 1959 and 1964 have shown chloride concentrations of 640 ppm and 710 ppm, respectively. Although the water contains enough chloride to be objectionable, it is rendered usable by mixing it with water of much lower mineral content from shallow wells.

It is likely that wells penetrating the "Swan Creek" in Neosho County will encounter water with a much higher chloride content.

Tacket Formation

Wells obtaining water from the black shale of the Tacket Formation can generally be expected to yield at least 1 gpm. The highest yield reported from the Tacket is 1.5 gpm in wells 28-20-9da and 30-19-24bb. Water in sufficient quantity for domestic use is available from the Tacket to depths of 200 feet, as in wells 28-19-31cc and 30-17-35ab. In general, water of suitable quality for human consumption in quantities adequate for domestic use may be obtained from the Tacket throughout the county wherever the Formation outcrops (see Pl. 1) or wherever it may be penetrated at a depth of 200 feet or less (usually 5 to 8 miles west or northwest of the outcrop).

All wells except one (28-20-9da) obtaining water from the Formation that are 100 feet or more in depth reportedly yield water containing enough sodium chloride (more than 500 ppm) to have a discernibly salty taste. The quality of water in shallow dug wells penetrating the Tacket is reportedly suitable for human use.

The maximum yield of 1.5 gpm that can be expected from the Tacket indicates that it is not an aquifer that may be developed for irrigation, industrial, or municipal water supplies.

Swope Limestone

The Hushpuckney Shale Member of the Swope is one of the most productive shale aquifers in the county. Yields of 0.5 to 1.5 gpm may be expected from the black shale member in the area bounded on the east by the outcrop of the Swope Limestone and on the west by the west line of R 18 E (Pl. 1). Locally, yields from 2 to 5 gpm are obtainable from the Hushpuckney as indicated by wells 28-21-21bb and 30-19-6cd. Well drillers and well owners report that in most wells water enters the well bore throughout the full thickness of the black shale. However, in wells with relatively high yields such as 30-19-6cd (5 gpm) the water is encountered in the few inches of the shale just below the overlying Bethany Falls Limestone Member.

Water from wells in the Hushpuckney is generally of a quality suitable for domestic use, although very hard water is common. The sulfate concentration in water from this Member is generally low (less than 30 ppm), except for water from well 30-19-4bb2, which has a concentration of 234 ppm. This amount is

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still below the concentration of 250 ppm that the U. S. Public Health Service considers objectionable. Water slightly salty to the taste is reported in many wells penetrating the Hushpuckney at a depth of 75 feet or more, although water from well 30-18-25da2, which is 100 feet deep, reportedly has no detectable sodium chloride taste.

Dug or drilled wells penetrating the Bethany Falls Limestone Member of the Swope generally will yield 0.5 to 1.5 gpm of very hard water. The area in which these yields may be expected is bounded on the east by the outcrop of the base of the Swope Limestone and approximately on the west by the west line of R 19 E (Pl. 1).

The water from wells in the Bethany Falls is generally free from noticeable chloride concentrations. One well (27-20-7cb) reportedly yields some natural gas. This was the only well in the Bethany Falls found to yield gas and the condition is probably not common in the aquifer. The chemical quality of water from well 28-19-7cd (Table 1), except for the high nitrate concentration (124 ppm), is probably typical of water from the Swope Limestone.

Shallow dug and drilled wells obtaining water from the Bethany Falls and the Hushpuckney where the two members lie at or near the land surface have a tendency to go dry during periods of deficient rainfall. This dependency upon local rainfall for recharge, as well as the low yields common from the Hushpuckney and Bethany Falls, precludes the development of these two aquifers other than for small domestic or stock supplies.

Dennis Limestone

The Stark Shale Member of the Dennis Limestone is probably the most productive shale aquifer in the county. Dug or drilled wells penetrating the Stark generally yield from 0.3 to 4 gpm at or a few inches below the contact of the shale and the overlying Winterset Limestone. The marked variance in yields from wells in the shale is a reflection of local differences in permeability of the aquifer which, in turn, is directly related to the number of joints, cracks, and voids between bedding planes that are present in the shale. There seems to be no pattern to the occurrence of high or low yields throughout the area in which water is available from the Stark except that T 29 S, R 19 E (Centerville Township) appears to be an area in which as much as 4 gpm (well 29-19-1cd) may be generally available. Numerous small springs issue from this horizon at the outcrop of the Stark, which lies near the base of the Dennis Limestone, as shown on Plate 1.

The area in which water of usable quality is available from the Stark is bounded on the east by the base of the Dennis Limestone (Pl. 1) and approximately on the west by U. S. Highway 169. Near the western edge of this area slightly salty water is present locally in the shale as indicated by the analyses of water from well 28-18-4cd (1,250 ppm of chloride) and the report of brackish water in well 28-18-10abl. Hydrogen sulfide is commonly reported to be present in water from the Stark. Concentrations of sulfate greater than 250 ppm were found in 3 out of 5 water samples from the Stark (wells 28-18-20ad1, 29-19-7dc, and 29-19-30bb.). Indirect evidence of high sulfate concentrations, i. e. many reported instances of laxative effects on persons unaccustomed to drinking the water, indicates that excessive sulfate concentrations are common in water from the shale.

The upper, medium-bedded zone in the Winterset Limestone Member of the Dennis is the most productive limestone aquifer in Neosho County. Although most wells in the Winterset will reportedly yield from 0.2 to 1.0 gpm, locally yields as high as 2 or 3 gpm are possible (as in wells 27-19-24ba and 27-18-29cb, respectively). Nearly all wells (11 out of 13) found to be yielding water from the Winterset in usable quantities lie in the northern tier of townships in the county, i. e., T 27 S, R 18, 19, 20, and 21 E. Wells 28-19-1ba and 30-18-20ab2 both have reported yields of less than 1 gpm. Undoubtedly shallow dug or drilled wells located elsewhere in the county where the Winterset crops out or is near the land surface (Pl. 1) may obtain small amounts of water from the limestone especially during periods of ample rainfall.

Water from the Winterset is generally of good quality although reportedly very hard in most wells. Samples from two wells penetrating the Member were higher than 200 ppm total hardness (27-21-8cc and 28-19-1ba, Table 1). The iron concentrations in these samples were 0.43 ppm and 1.3 ppm respectively, both of which are greater than the 0.3 ppm considered objectionable by the U. S. Public Health Service.

The low yields obtainable from the Winterset and the Stark preclude their development as a supply other than for domestic needs.

Sandstone Aquifers

Bandera Shale

The Bandera Shale in Neosho County will yield 0.5 to 5 gpm from wells located in the area bounded on the north by the north line of T 28 S, R 21 E, on the east by the Crawford county line, on the south by the Labette county line, and on the west by the west lines of T 30 S, R 20 E, T 29 S, R 20 E, and T 28 S, R 21 E. Drillers report that water from the Bandera in other parts of the county is generally too highly mineralized to be used. Most wells in the Bandera in this area obtain water from sandstone beds in the middle of the formation. In local areas, some water is available from the sandy shale and clay shale in the upper part of the Bandera, i. e., wells 28-21-29aa and 28-21-29da. As much as 5 gpm is available from wells in T 30 S in the area between Labette Creek and the Crawford county line as indicated by wells 30-19-35bb and 30-21-22cd, which reportedly yield 5 gpm and 4 gpm respectively. The relatively high potential yield in this area is probably a reflection of the greater thickness of the sand bodies in the middle of the Bandera.

The quality of water from the formation is generally good, except that it is commonly very hard. Iron concentrations in 4 out of 5 water samples were greater or only slightly less than the 0.3 ppm considered objectionable. The nitrate content of all the samples except one (from well 30-19-35bb, Table 1) exceeds the limit recommended by the Public Health Service. There are insufficient data to determine if the high nitrate concentration is characteristic of water from the Bandera or merely isolated occurrences caused by local conditions.

The limited yields available from wells in the Bandera indicate that development of the aquifer for other than domestic and stock use is infeasible.

Nowata Shale

In southeastern Neosho County shallow wells dug or drilled into the Nowata Shale may produce as much as 1 gpm, although yields are generally less. In general, the Nowata yields usable quantities of water only from wells near the outcrop in areas where the formation is predominantly a sandy shale, such as south of the central part of T 28 S.

Analyses of samples from wells 29-20-1dd and 30-20-22dd (Table 1) indicate that water from the Nowata is of good quality although very hard. The relatively high concentrations of sulfate (237 ppm) and nitrate (137 ppm) in the sample from well 30-20-22dd may only reflect local conditions, such as contamination by surface water.

The fact that few wells yield water from the Nowata coupled with the reportedly low yields available from the two wells inventoried (0.3 gpm from well 29-20-1dd and 1.0 gpm from well 30-20-22dd) indicate that the formation is not a reliable aquifer for even domestic or stock supplies.

Hepler Sandstone Member

Shallow dug or drilled wells penetrating the Hepler Sandstone Member near its outcrop in the northern part of the county (Pl. 1) may yield 1 gpm or less of potable water. Because of the lateral variations in lithology and thickness of the Member it yields water only locally. Only two wells, 28-21-5bb1 and 28-21-5bb2, were inventoried that are definitely known to obtain water from the Hepler.

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The quality of water from well 28-21-5bb1 (Table 1) is probably representative of water from the Hepler. However, the excessive nitrate content (111 ppm) may only reflect local conditions.

The low yields available from the Hepler coupled with the somewhat local occurrence of ground water in the Member makes it unsuitable generally for development of even domestic and stock supplies.

Galesburg Shale

Wells penetrating the sandy shale and sandstone of the Galesburg Shale may be expected to yield from 0.5 to 2 gpm of potable water in the area bounded on the east by the outcrop of the base of the formation (located from a few tens of feet to a few hundred feet west of the outcrop of the Swope Limestone as shown on Pl. 1) and on the west by a line approximately parallel to and about 5 miles west of the outcrop of the overlying Dennis Limestone. A few small springs occur on the outcrop of the formation in the central portion of the county and at least one, 28-20-9da, has been enlarged and developed for a domestic water supply. In general, wells in the northern and southern portions of the county obtain water from the Dodds Creek Sandstone Member at the base of the formation, whereas wells in the central part of the county, especially T 29 S, R 19 E, yield water from sandy shale in the middle and upper part of the Galesburg.

High fluoride concentrations are apparently common in water from the Galesburg--3 out of 4 samples contained greater than 1.0 ppm and 2 of these 3 (27-19-30cd2 and 29-18-35dc) had concentrations of 4.0 ppm fluoride (Table 1). Nitrates in the two wells mentioned above were quite low, 0.4 ppm and 1.5 ppm respectively. However, the concentration in the sample from well 30-17-2dd was 49 ppm which is above that deemed objectionable by the Public Health Service. The nitrate content of the water from well 30-19-19bb was 1,319 ppm, which is more than two and one-half times higher than the nitrate content of any other sample analyzed (Table 1). This extremely high concentration is thought to be the result of some type of contamination by decaying vegetation or animal waste and cannot be considered representative of water from the Galesburg.

The low yields reported from wells penetrating the Galesburg indicate that it is unsuitable for development other than for domestic and stock supplies.

Chanute Shale

The Chanute Shale is the most productive consolidated-rock aquifer in the county. Two sandstone members, the Noxie at the base of the formation and the Cottage Grove at the top, yield 0.5 to 15 gpm of potable water to wells in the western quarter of the county.

East of Chanute, where the Noxie Sandstone Member overlies the Winterset Limestone Member of the Dennis Limestone or, locally, fills a channel eroded into the Dennis, yields up to 4 gpm (as in well 27-18-24cc) may be expected. West and south of Chanute and beneath the city itself, the Cottage Grove and Noxie Sandstone members are in contact or are separated only by a thin clay-shale zone. The sand composing the two members was apparently deposited in the deepest part of the channel described previously (see discussion of the stratigraphy of the Chanute Shale and Fig. 4). Wells penetrating the combined thicknesses of the two members in this area locally encounter as much as 110 feet of saturated, fine-grained sandstone. Some wells, such as 27-18-20ad, that obtain water from this sandstone reportedly yield as much as 10 gpm. In general, yields of 0.5 to 4 gpm may be expected. Permeability tests conducted under laboratory conditions upon core samples of the sandstones indicate that as much as 75 gpm may be obtained locally from properly developed wells (O. S. Fent, Hydraulic Drilling Co., Salina, Kansas, personal communication, 1965). South of the area underlain by the channel sandstone, in T 29 S, R 17 E, and T 30 S. R 17 E, yields as great as 15 gpm, as in well 29-17-24bd2, may be encountered.

The quality of water from wells in the Chanute is generally good, although the water-sample analyses (Table 1) showed very hard water to be common. Chloride content high enough to be objectionable (1,115 ppm) was found only in the sample from well 29-18-20ac. In five out of eight samples analyzed the chloride concentration was less than 40 ppm. Sulfate concentrations in three samples were greater than 700 ppm, but sulfates in the other samples were well below the 250 ppm considered objectionable. No physiological effects attributable to high sulfate concentrations were reported for other wells penetrating the Chanute. Nitrate content of the eight samples ranged from 1.5 to 518 ppm and was greater than 45 ppm in samples from four wells. Hydrogen sulfide gas, common in the bedrock aquifers in the county, was reported present in only one well yielding water from the Chanute. This well (30-17-2dd) penetrates both the Chanute and Galesburg shales. As the hydrogen sulfide is reportedly noticeable only after extended periods of pumping at about 2 gpm, it is probable that the gas is entering the well from the sandstone in the Galesburg.

In general, water from the sandstone beds in the Chanute contains lower concentrations of chlorides, sulfates, and nitrates than does water from sandstone and limestone aquifers stratigraphically lower than the Chanute.

In view of the 75 gpm that may be available, as reported by Fent, and the yields of as much as 15 gpm reported by well owners, it is possible that small industrial or municipal supplies may be developed in the Chanute. Any attempt to develop such supplies should, of course, be preceded by test drilling and pumping tests.

Other Aquifers

In addition to the limestone and shale aquifers discussed above, the well inventories showed that small amounts of water of usable quality are available locally from the Altamont, Lenapah, Hertha, and Iola limestones as well as from the Ladore and Cherryvale shales. These formations generally do not yield water in sufficient quantities for other than domestic and stock supplies.

Unconsolidated Rocks

Neosho River Valley

Although few wells exist in the Neosho River valley, this should not be construed as an indication that little water is available in the valley. Rather, it reflects a cultural adjustment to the danger of flood damage present in the valley, i.e., few landowners or tenants maintain homes in the valley and consequently few water-supply wells exist.

Illinoisan Terrace Deposits

No privately owned wells in the county that yielded water from the terrace deposits of Illinoisan age were inventoried. However, one test well (27-18-9bb), drilled in July of 1964, is probably representative of wells that may be developed in the terrace deposits. This well penetrated 30 feet of unconsolidated material, the lower 10.5 feet of which consisted of fine to coarse, rounded, chert gravel, and fine to coarse sand with about 10 percent of the material composed of silt and clay. The well yielded 20 gpm during a pumping period of 30 minutes with a total drawdown of 11.3 feet. The fact that the drawdown produced by a pumping rate of 20 gpm was more than 60 percent of the saturated thickness of the aquifer may indicate that a reduced pumping rate is necessary to obtain a sustained yield from wells in these deposits. A pumping rate of about 10 gpm is probably the maximum possible over an extended period from single wells in the terrace deposits.

Wisconsinan and Recent Alluvium

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Four wells obtaining water from Wisconsinan gravel deposits were inventoried in Neosho County. The minimum yield reported from these wells was 3 gpm (well 28-20-30ca) and the maximum yield was 8 gpm (well 29-20-3ab). Analyses of water samples from two of these wells, 28-20-30ca and 29-21-32dd (Table 1), indicate that water in the Wisconsinan deposits is generally of good quality. The excessive nitrate (71 ppm) in the sample from well 28-20-30ca renders the water dangerous for infants, but the concentrations of other ions in the water are well below those considered objectionable by the Public Health Service.

One test hole (29-20-15ad) drilled in the valley west of St. Paul in July of 1964 contained 4.5 feet of medium to coarse chert gravel in the interval from 20 to 24.5 feet. Total depth of the well was 25 feet with the bottom 0.5 foot penetrating light-gray Holdenville Shale. After installation of torch-perforated steel casing, the well was pumped for one hour at 20 gpm. Total drawdown at the end of the hour was 0.6 foot. In view of the performance of this well, it is likely that other properly developed wells on the flood plain (Pl. 1) penetrating sand and gravel deposits of similar lithology and thickness at the base of the Wisconsinan alluvium would yield comparable quantities of water. It is possible that properly developed wells in deposits of this type may yield as much as 50 gpm in local areas. As the saturated thickness of the material (that part of the deposit that lies below the water table) is generally about 10 feet during periods of normal rainfall, the available drawn down in wells and consequently the yields would vary with time. During periods of deficient rainfall, for example, it is quite likely that the water table would drop and as a result the available drawdown and yields would decrease.

In summary, it seems probable that 10 gpm is the maximum yield that may be expected from the Illinoisan terrace deposits for extended pumping periods. Yields of as much as 30 gpm are probably available for long periods of time from properly constructed and developed wells in the Wisconsinan alluvium. Wells producing as much as 50 gpm may be adversely affected by slight lowering of the water table and can be expected to decrease in yield over an extended pumping period.

Other Stream Valleys

The valleys of the smaller streams that are tributaries to the Neosho or Verdigris rivers contain alluvium of Pleistocene and Recent ages. These deposits are composed predominantly of very fine-grained material, but locally lenses of sand and chert pebbles are present in the basal part. The thickness of the alluvium ranges from 0 to as much as 30 feet.

Few wells obtain water from these deposits, but as much as 1 gpm is probably available everywhere the alluvium is more than 10 feet thick. One well (28-19-14cd) drilled into the alluvium of Canville Creek reportedly yields as much as 30 gpm for extended periods of time. The water from this well is of good quality (Table 1), although very hard (346 ppm total hardness), and is probably representative of water available from the alluvial deposits in the smaller valleys.

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CERTIFICATE OF SERVICE

25-CONS-3040-CMSC

I, the undersigned, certify that a true and correct copy of the attached Testimony has been served to the following by means of electronic service on January 31, 2025.

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