Spring 2017

Analysis Of Big Creek Aquifer Alluvial Facies and Associated Phreatic Surface Contour Maps Hays, Ellis County, Kansas

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ANALYSIS OF BIG CREEK AQUIFER ALLUVIAL FACIES AND ASSOCIATED PHREATIC SURFACE CONTOUR MAPS
HAYS, ELLIS COUNTY, KANSAS

being

A Graduate Thesis Presented to the Geosciences Graduate Faculty of the Fort Hays State University in Partial Fulfillment of the requirements for The Degree of Master of Science

by

Kristopher John Neuhauser
B.S., Fort Hays State University

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ABSTRACT

Three contour maps of groundwater elevation levels below Hays, Kansas generated in 2016 show that the phreatic surface in eight monitoring wells declined 3.6 inches to 1 foot 9.6 inches over a three-month period of July, August, and September. They also indicate that groundwater flows in curvilinear directions toward Big Creek. Analyses of ten north-south oriented structural cross sections of the alluvial fill beneath the central region of Hays provide evidence of buried low-sinuosity and meandering streams, floodplains, and possibly adjoining tributaries and abandoned channels. Correlation of the more porous and permeable sand and gravel facies along a northwest to southeast flow direction suggests a possible subsurface paleochannel within the Big Creek alluvium. This information is useful in determining hydraulic connectivity within the alluvium, mobility of various contaminants, and future watershed analyses.
ACKNOWLEDGMENTS

I would like to extend a sincere thank you to Dr. Kenneth Neuhauser for his advice and guidance throughout this research. I also wish to thank Mr. Bill Heimann, Mr. Ned Marks, and Dr. Richard Lisichenko for supplying me with knowledge vital to this research. Thanks is also due to the Division of Water Resources Field Office in Stockton, Kansas for providing GIS data to locate private water wells throughout Hays, Kansas and to the Kansas Department of Health and Environment office in Hays for granting me access to private well logs and pumping rates of city wells. I wish to thank Fort Hays State University Department of Geosciences for providing me with equipment to complete my research.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF APPENDIXES</td>
<td>viii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>OBJECTIVES</td>
<td>2</td>
</tr>
<tr>
<td>LOCATION</td>
<td>3</td>
</tr>
<tr>
<td>PREVIOUS WORK</td>
<td>5</td>
</tr>
<tr>
<td>STUDY AREA GROUNDWATER AND PRECIPITATION</td>
<td>17</td>
</tr>
<tr>
<td>STUDY AREA GEOLOGY</td>
<td>19</td>
</tr>
<tr>
<td>METHODS</td>
<td>21</td>
</tr>
<tr>
<td>Water Table Method</td>
<td>21</td>
</tr>
<tr>
<td>Structural Cross Section Method</td>
<td>25</td>
</tr>
<tr>
<td>RESULTS</td>
<td>29</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Field Notes of Survey 1 July 7, 2015</td>
<td>53</td>
</tr>
<tr>
<td>2</td>
<td>Field Notes of Survey 2 August 19, 2015</td>
<td>54</td>
</tr>
<tr>
<td>3</td>
<td>Field Notes of Survey 3 September 16, 2015</td>
<td>55</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Upper: Kansas map with Ellis County highlighted in red and Hays represented by black dot. Lower: Location of study area within the black rectangle</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Structural cross sections (Latta 1948). North to left, south to right</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Structural cross section (Leanard and Berry, 1961). North to left, south to right. V=80</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Structural cross sections (Perez, 1986). A-A’: Northwest to left, southeast to right. B-B’: Southwest to left, northeast to right. V=25</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>Phreatic surface elevation contour maps by Schmidt (1997)</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>Perc isoconcentration map along Vine Street, Hays, Kansas (Staab, 2003)</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>Bedrock (Blue Hill Shale) elevation map beneath Hays, Kansas (Burns and McDonnell, 2013)</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>Sand and gravel thickness of alluvium below Hays, Kansas (Burns and McDonnell, 2013)</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>Taking GPS coordinates of monitoring well (41st Street and Post) on July 7, 2015. Photo by K.R. Neuhauser</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>Monitoring well gauging using Heron dipper-T water level meter. Photo by K.J. Neuhauser</td>
<td>16</td>
</tr>
<tr>
<td>12</td>
<td>Google Earth image overlain by LIDAR image (at 50% transparency). Retrieved from Kansas Data Access and Support Center (DASC)</td>
<td>29</td>
</tr>
<tr>
<td>13</td>
<td>Ten north-south, color-coded profile lines for structural cross sections in Hays, Kansas</td>
<td>30</td>
</tr>
<tr>
<td>14</td>
<td>July 7, 2015, 3D phreatic surface elevation contour map. Groundwater flow direction represented by black arrows and Big Creek by yellow line. Scale in Universal Transverse Mercator (UTM) coordinates</td>
<td>29</td>
</tr>
<tr>
<td>15</td>
<td>August 19, 2015, 3D phreatic surface elevation contour map. Groundwater flow direction represented by black arrows and Big Creek by yellow line. Scale in Universal Transverse Mercator (UTM) coordinates</td>
<td>30</td>
</tr>
</tbody>
</table>
September 16, 2015, 3D phreatic surface elevation contour map. Groundwater flow direction represented by black arrows and Big Creek by yellow line. Scale in Universal Transverse Mercator (UTM) coordinates ..............................................30

Lithology key for ten cross sections .............................................................................31

Structural cross section 1 (Peach, westernmost) ..........................................................32

Structural cross section 2 (Orange) ..............................................................................33

Structural cross section 3 (Pink) .................................................................................34

Structural cross section 4 (Dark Green) .....................................................................35

Structural cross section 5 (White) ..............................................................................36

Structural cross section 6 (Light Blue) ......................................................................37

Structural cross section 7 (Black) ...............................................................................38

Structural cross section 8 (Blue) .................................................................................39

Structural cross section 9 (Purple) .............................................................................40

Structural cross section 10 (Turquoise, easternmost) ..................................................41

Block diagram of lithofacies in a less sinuous stream (after Sutter, 2008) ...............43

Block diagram of lithofacies in a more sinuous stream (after Sutter, 2008) .............43

Ten structural cross sections aligned according to geospatial location .................44

Blue trend (interpreted from Burns and McDonnell basement map) represents the basal paleochannel and the yellow trend (interpreted from the ten cross sections) represents the more sinuous paleochannel in the upper zone ..................................45

Simulated DNAPL (red) and LNAPL (green) contamination plumes in cross section (peach). Phreatic surface represented by dashed line, water flow direction north to south (V=20) .................................................................................48
# LIST OF APPENDIXES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>White Cross Section Lithology Logs (in order from north to south, 14 total)</td>
<td>56-69</td>
</tr>
<tr>
<td>B</td>
<td>Legals of Wells Used</td>
<td>70-79</td>
</tr>
</tbody>
</table>
INTRODUCTION

Groundwater is one of the United States’ most important natural resources that provides about 40 percent of the nation’s public water supply (Alley, 1999). The quality of groundwater is equally as important because it is an important source of drinking water and is widely used for irrigation.

How groundwater flows is a function of the subsurface geology, which can include confined and unconfined aquifers. Directly below the topsoil of Hays, Kansas are Holocene and Pleistocene alluvial deposits of the unconfined Big Creek alluvial aquifer. The Big Creek aquifer provides nearly 40 percent of Hays’ water supply (Tessa Scheck, Hays Water Treatment Facility, personal communication). A determination of how groundwater flows through this aquifer can be better understood if the geometry of the alluvial facies is adequately described. This would allow for more effective tracking of groundwater contaminants. To date, there are very limited geologic cross sections that have been constructed of the Big Creek alluvium by previous researchers. These do not completely differentiate the undifferentiated facies, and therefore provide little information as to a more three-dimensional pathway of groundwater migration through the aquifer. Identifying certain facies within the alluvium can also reveal past stream channel patterns.

Having the knowledge of how groundwater flows through the Big Creek alluvial aquifer could help speed the remediation process of existing and future contaminant sources, thus providing safer water for Hays’ residents.
OBJECTIVES

The specific objectives of this study include:

1. Measure static phreatic surface elevations over a specified time frame, create Surfer-generated contour maps of this data, and approximate general flow directions.

2. Draft ten geologic cross sections of part of the Big Creek alluvial aquifer beneath Hays, Ellis County, Kansas.

3. Identify alluvial facies and potential permeable facies zones that could have an influence on groundwater movement.

4. Attempt to correlate these cross sections.

5. Hypothesize simplified movement of dense non-aqueous phase liquid (DNAPL) and light non-aqueous phase liquid (LNAPL) groundwater contaminants within the alluvium based on facies observed in one cross section.
LOCATION

The city of Hays is located in Ellis County in west-central Kansas. The study area is restricted to the central-most portion of Hays (Figure 1) within the confines of the following four points (starting in the southwest corner and rotating clockwise):

Latitude: 38° 54’ 21.56” N Longitude: 99° 20’ 50.67” W
Latitude: 38° 54’ 23.62” N Longitude: 99° 17’ 49.31” W
Latitude: 38° 50’ 47.81” N Longitude: 99° 17’ 54.14” W
Latitude: 38° 50’ 50.89” N Longitude: 99° 20’ 44.37” W

Water monitoring wells and selected water well logs within this region provide data for phreatic surface contour maps and alluvial analysis.

Big Creek flows southeastward across the study area and is a tributary of the Smoky Hill River. Two tributaries of Big Creek include Lincoln Draw and Chetolah Creek, each of which flow through the study area. The City of Hays obtains approximately 40% of its water supply from wells within this same study area.
Figure 1: Upper: Kansas map with Ellis County highlighted in red and Hays represented by black dot. (https://commons.wikimedia.org/wiki/File:Map_of_Kansas_highlighting_Ellis_County.svg)

Lower: Location of study area within the black rectangle (Kansas Department of Transportation website, 2016).
Previous work on groundwater-related research that relates to the objectives of this thesis included different emphases such as future ground-water supplies for Hays, Victoria, Walker, Gorham, and Russell, Kansas (Latta, 1948); geology and ground-water resources of Southern Ellis County, Kansas (Leonard and Berry, 1961); sedimentary analysis of alluvial fill (sand and gravel pits) along the Saline and Smoky Hill rivers, Ellis County, Kansas (Caprez, 1974); groundwater hydrology study Big Creek Area and Vicinity (Layne-Western, 1974); geohydrology of the Big Creek Alluvial Aquifer of Hays and vicinity, Ellis County, Kansas (Perez 1986); a morphometric and hydrogeologic survey of the Saline River paleovalley and valley fill, Ellis County, Kansas (Heimann 1987); geochemistry of groundwater and gas in the vadose zone in selected parts of Hays, Kansas (Satya Sinha, 1992); static water level fluctuations of the Big Creek Alluvial Aquifer in the Vine street area, Hays, Ellis County, Kansas, 1993-1994 (Schmidt, 1997); potential sources of nitrate-nitrogen affecting the city of Hays, Big Creek, well field (Townsend, 2002); an evaluation of the source area for the former Norges Cleaners tetrachloroethylene plume near Centennial Boulevard and Vine Street, Hays, KS, over a 20-year span using past data to estimate the plume concentration reduction (Staab 2013); and an evaluation of the long-term viability of the Big Creek Aquifer, Hays, Kansas (Burns F & McDonnell, 2013).

Latta’s 1948 work on the future ground-water supplies for Hays, Victoria, Walker, Gorham, and Russell, Kansas provided two geologic cross sections of part of the Big Creek Alluvial Aquifer. The report refers to most of the alluvial fill as
“undifferentiated”, and did not clearly distinguish different facies within the alluvium (Figure 2).

Figure 2: Structural cross sections (Latta, 1948). South to left, north to right. V=40.

Figure 2: Structural cross sections (Latta, 1948). South to left, north to right. V=40.
Leanard and Berry’s 1961 research discusses geology and groundwater resources in Kansas, and contributed information on groundwater in relation to geologic formations in southern Ellis County, as well as parts of Trego and Rush counties. The Big Creek terrace and alluvium was shown along the north end (between arrows) of a structural cross section (Figure 3). Again, little differentiation is given on facies.

Figure 3: Upper: Structural cross section (Leanard and Berry, 1961). North to left, south to right. V=80. Lower: Zoomed in view of study area within cross section.
Data in an unpublished Fort Hays State University (FHSU) thesis (Caprez, 1974) covering the sedimentary analysis of alluvial fill (sand and gravel pits) along the Saline and Smoky Hill rivers, Ellis County, provided quartz and feldspar percentages found in the alluvium. It was determined that feldspar content is reduced slowly in low-gradient streams. Average feldspar content ranged from 15-20% within both alluvial deposits, thus indicating that the ancestral Smoky Hill and Saline Rivers were low gradient, non-turbulent streams, similar to those of the present day. Caprez indicated that the Ogallala Formation gravels contain the same percentage of feldspar, thus suggesting that it was the immediate source for both alluvial fills. Although this research was useful with respect to mineralogy, no information was provided regarding aquifer facies conditions.

A groundwater hydrology study of Big Creek Area and Vicinity (Layne-Western, 1974) included test hole logs, water level information, and water quality data. Twenty-three test holes were drilled to the west of Hays, and seven more to the southeast, to determine which areas could produce a significant yield of groundwater. Only eight test holes were determined to be unsatisfactory, leaving a success percentage of 73%. Natural recharge and infiltration from Big Creek were determined to be the essential factors for sustaining high yields from the aquifer. Test holes closer to Big Creek itself were estimated to have a much higher yield than those further away, due to the infiltration recharging the aquifer. No cross sections were provided showing alluvial facies.

In a FHSU masters thesis evaluating the Big Creek Alluvial Aquifer in Hays and its vicinity (Perez, 1986) two geologic cross sections of the alluvium were provided. Like Latta, Perez used the term “undifferentiated” to describe the alluvial fill. In one cross
section, a sand lens was present within a layer of unconsolidated silt and clay, located in the southeast corner of Hays. One profile was oriented southwest to northeast and was constructed using nine well logs, while the second was oriented northwest to southeast, having been constructed with twelve well logs. Both were generalized representations of the alluvium, (Figure 4) but did not provide a broader correlation of facies.

Figure 4: Structural cross sections (Perez, 1986). A-A’: Northwest to left, southeast to right. B-B’: Southwest to left, northeast to right. V=25.
A morphometric and hydrogeologic survey of the Saline River paleovalley and valley fill, Ellis County, Kansas (Heimann, 1987) focused on both the geomorphologic and hydrologic makeup of the river valley. Both the Saline River and Big Creek are major tributaries of the Smoky Hill River and exhibit similar subsurface geology. Twenty-five geologic cross sections were produced along the valley, showing surface and subsurface topography. Five of these cross sections displayed alluvial material deposited on an erosional unconformity over Upper Cretaceous bedrock.

Johnson and Martin (1987) conducted alluvial-stratigraphic studies of Holocene deposits from Kansas and adjoining states of the east-central Plains. Radiocarbon data was used to interpret floodplain stability periods evidenced by soil development. They focused on various terrace systems, the development of which they attributed to Pleistocene climatic fluctuations.

Sinha’s (1992) study had the primary purpose of detecting and describing chloride and nitrate concentrations in the groundwater. It did likewise with volatile organic chemicals (VOCs) concentrations in the vadose zone in selected parts of Hays. The study also described the subsurface behavior of those contaminants.

An unpublished thesis by Schmidt (1997) focused on the relationship between precipitation and phreatic surface fluctuations of the aquifer along Vine Street in Hays. Seventeen wells were surveyed bimonthly using a Powers Well Sounder instrument to obtain static water level measurements. Phreatic surface elevation contour maps with flow lines were also created for four separate days in 1993 and 1994 (Figure 5).
A report (Townsend, 2012) determined the source of nitrate contamination of the southern portion of Hays Big Creek well field was animal waste from the Kansas State University farm complex south of the city. A description of the soils, alluvium, and well depths on the southern edge of Hays were also given.

Another unpublished thesis (Staab, 2013) evaluated a source area for a tetrachloroethylene plume in Hays over a 20-year span. Staab used past data to assess this tetrachloroethylene (perc) plume’s concentration reduction. Fourteen perc isoconcentration maps were produced, displaying the reduction of perc concentration level over 20 years. One of the maps is shown in Figure 6.
An evaluation of the long-term viability of the Big Creek Aquifer, Hays, Kansas (Burns & McDonnell, 2013) was conducted for the city of Hays to determine the operating condition of the Big Creek Well Field public water supply (PWS) wells at the time. Borehole records were assessed to determine the extent and depth of the aquifer. Hays’ water rights and usage data were also evaluated. It was concluded that the Big Creek PWS are located in higher yielding areas of the aquifer and well conditions were
currently good. Available tools however were not applied for evaluating the long-term viability of the aquifer. But Burns & McDonnell did provide a bedrock contour map (Blue Hill Shale) surface elevation (Figure 7), and an isopach map of sand and gravel (Figure 8). One of Vilma Perez’s 1986 geologic cross sections of the Big Creek alluvium was also used in the report (Figure 9). Again, no alluvial facies interpretations were provided.
Figure 7: Bedrock (Blue Hill Shale) elevation map beneath Hays, Kansas. (Burns and McDonnell, 2013).
Figure 5: Sand and gravel thickness map of alluvium below Hays, Kansas, 2013.
Figure 9: Structural cross section (Burns & McDonnell, 2013). Reproduction of Perez (1986). Southwest to left, northeast to right. V=25.

Explanation
- Surface Soil - Silty Loams
- Cretaceous - Blue Hill Shale Member
- Aquifer Material
- Sand & Gravel Aquifer Material
- Quaternary - Alluvium, Floodplain & Low-Terrace Deposits
- Alluvium - Terraces, Silt & Clay
- Alluvium - Terrace Deposits, Silt & Clay
- Source: Modified from Perez, 1986, page 38, Geohydrology of the Big Creek Alluvial Aquifer of Hays and Ellis Counties, Kansas.

Figure 2: Big Creek Aquifer Cross Section A-A'
STUDY AREA GROUNDWATER AND PRECIPITATION

When there is precipitation, the first water that enters the soil is held by capillarity, which replaces water that has been evaporated or taken up by plants. After the soil and plants are saturated and the precipitation continues, the remaining water will penetrate the soil via gravitational forces to reach the phreatic surface. The phreatic surface is the top of the zone in which the openings in the rock or soil are saturated. During precipitation events surface runoff can be the main source of water for certain streams, including Big Creek. Anthropogenic, impermeable surfaces in Hays create a high amount of surface runoff, which can account for a large percentage of the flow in Big Creek (Schmidt, 1997).

Groundwater will flow through an aquifer toward natural discharge points, which in the case of the study area, are areas of seepage into Big Creek. Relative to groundwater movement, permeability (or hydraulic conductivity) is the ability of an aquifer to allow fluid to flow through it (Brassington, 1988). Porosity, on the other hand, simply describes the quality of a material being porous. This can be given as a measurement of the empty space in a material, sand and gravel included.

Uncompacted clay is common in the alluvium of the study area, and constitutes an aquitard. An aquitard is a material that does not transmit groundwater at a significant rate. The clay has a high porosity, but a low permeability, and therefore does not yield water to wells. The sand and gravel present in the alluvium, however, has a higher permeability and will yield water. Very few natural materials are completely isotropic and most contain aquitard materials (Brassington, 1988).
In the study area, the phreatic surface will fluctuate due to the annual variations of precipitation. The Big Creek alluvial aquifer is recharged principally by precipitation. It is depleted mainly by seepage into Big Creek, evapotranspiration, and water well pumping. As of 2015, up to five of Hays PWS wells pump water each day within the city limits. Each well pumps at a rate ranging from 70 to 182 gallons per minute (GPM). Over one thousand private water wells are estimated to exist within the city, and any number of them may be pumping during the day. This pumping causes a lowering of the phreatic surface in the alluvium. As water is pumped out of a well, the phreatic surface in the immediate vicinity tends to be lowered in a cone of depression (Jones, 1997).
STUDY AREA GEOLOGY

This research is confined within the city limits of Hays, situated in the Big Creek Valley, within the Great Plains Region. The surface elevation in Hays varies from 1,980 feet to 2,050 feet above mean sea level. Big Creek is a major tributary of the Smoky Hill River, and flows in a southeasterly direction, along the southern edge of Hays. Its two tributaries in the area are Chetolah Creek and Lincoln Draw. The present flow pattern of Big Creek is almost entirely a result of events that occurred during the Pleistocene Epoch (Frye and Leonard, 1952). Groundwater in the Big Creek Valley alluvial fill is supplied by precipitation infiltrate, influent drainage directly from Big Creek, and seepage from pipes and sewer lines. Groundwater occupies Pleistocene and Holocene alluvial deposits, which underlie terrace surfaces and the floodplain in the Big Creek Valley. These terrace surfaces flank the Big Creek Valley and are remnants of the former floodplains in the area. The deposits are primarily unconsolidated sand, silt, clay, and gravel, which overlie and fill ancient stream channels that have incised into the Blue Hill Shale. Like other alluvial deposits, the unconsolidated material shows an upward-fining sequence. The course of Big Creek has changed many times, which has resulted in peaks and valleys on the paleosurface of the Blue Hill Shale, in addition to variations in sand grain size and discontinuous lenses of alluvial material (Perez, 1986).

The Blue Hill Shale is a member of the Upper Cretaceous Carlile Shale, and makes up the bedrock beneath Hays. It has a very low permeability and hydraulic conductivity. Since there are essentially no other impermeable soils above the alluvial deposits, the Big Creek alluvium constitutes an unconfined aquifer. An unconfined aquifer is a body of permeable rock that can transmit groundwater, which has permeable
material extending from land surface down to the confining base layer (Jones, 1997). Therefore the phreatic surface beneath Hays can vary in elevation depending on how much groundwater is within the Big Creek alluvium.
METHODS

Phreatic Surface Method:

Data was collected on three separate surveys on dates as follows: July 7th, 2015, August 19th, 2015, and September 16th, 2015. On each day, measurements of the water table were taken from 8 monitoring wells throughout the city. GPS coordinates of each monitoring well were also recorded using a handheld Garmin GPS 38 Personal Navigator (Figure 10). A Heron dipper-T water level meter was used to calculate phreatic surface elevations as well as the total depth of each well (Figure 11). Monthly tables were kept in a field notebook for each survey (See tables 1-3 in back of thesis).

Figure 10: Taking GPS coordinates of monitoring well (41st Street and Post) on July 7, 2015. Photo by K.R. Neuhauser.
Monitoring wells were opened using a socket wrench to remove two bolts and a screwdriver to pry the metal lid off. After removed, the well cap was taken off to allow the phreatic surface in the well to equilibrate with the barometric pressure. Then measurements were taken ten minutes after the well cap was removed. In the first survey, a measuring tape with a weighted bolt attached to the end was run down each monitoring well to insure the well casing had not been obstructed or destroyed. This was intended to avoid damage to the meter. Each well was noted as viable and useful for data collection. After using the measuring tape, the water level meter was deployed down into the middle of the well casing. The meter was slowly unwound downward until a high pitch sound was omitted. This indicated the water-sensing probe attached to the end had reached
water. The depth from the well vault (surface elevation) to the phreatic surface was recorded and then that value was subtracted from the elevation of the well vault to determine the elevation of the phreatic surface.

Ground surface elevations of each of the 8 well locations were calculated by integrating a Google Earth image and LiDAR image in ArcMap Version 10.3 (Figure 12). ArcMap is the main component of ESRI’s ArcGIS suite of geospatial processing programs, and is used to view, edit, create, and analyze geospatial data. LiDAR stands for Light Detection and Ranging and is a technique for remotely sensing the shape of surfaces, typically using lasers, which can produce high-resolution maps (Weaver, 2015).

Each of the wells was spatially located on this Google Earth image of Hays. The LiDAR data image within ArcMap indicated the elevations in meters that are accurate to the third decimal place. These surface elevations were then converted to feet (also to the third decimal place) and subsequently used to calculate the elevation of the phreatic surface in all 8 wells.
Figure 12: Google Earth image overlain by LIDAR image (at 50% transparency). Retrieved from Kansas Data Access and Support Center (DASC).
UTM Northing and Easting coordinates taken during each field survey and the LiDAR elevations of the phreatic surface calculated above were manually entered into the computer program Surfer 8. Easting values served as the X coordinates, Northing values served as the Y coordinates, and the phreatic surface elevation values (in feet) served as the Z coordinates. Groundwater contour maps for the July, August, and September surveys were created in Surfer 8 using the Kriging algorithm because it generated more realistic-looking contours. Surfer 8 is a contouring and 3D surface mapping program created by Golden Software.

**Structural Cross Sections Method:**

A shapefile showing the location of private water wells throughout Kansas was obtained from the Division of Water Resources Field Office in Stockton, Kansas. A shapefile is an ESRI vector data format that stores the location, shape, and attribute for geographic features. This shapefile, along with the satellite image and LIDAR data file covering Hays, were loaded into ArcMap. Next, north to south profile lines for ten cross sections were determined (Figure 13). Between ten and twenty water wells were used in a single cross section with a total of 149 wells overall. The Identify button was utilized to access a web address for the driller’s log. All wells in the shapefile had access to the original driller’s logs via the Water Well Completion Records (WWC5) Database on the Kansas Geological Survey website. The driller’s logs were saved in ten separate, personal folders, to be later used in drawing each cross section.
Figure 13: Ten north-south, color-coded profile lines for structural cross sections in Hays, Kansas.

The Interpolate Line tool on the 3D Analyst Toolbar was next used to create ten profile lines. After a line was drawn, the profile graph option was selected to create a two-dimensional cross sectional view of the surface elevation for that specific area in Hays. All ten profile lines ran in a north to south direction; each spanning different lengths. The graphs (by program default) were created using a scale in meters for both surface distance and elevation. All graphs were converted to feet (in order to match the driller’s logs). Although there is no such thing as a ‘perfect’ cross section (Kenneth R. Neuhauser, personal communication, 2016), the most accurate cross sections are constructed along straight lines and are oriented perpendicular to a major trend (LeRoy
and LeRoy, 1982; and Tearpock and Bischke, 1991), and will depend on the best available data.

Attempting to match lithologic logs proved difficult due to driller’s occasional use of lay terminology. Correlating stratigraphy was challenging because there were inconsistent terminologies used by different private water well drillers. It became apparent that different terms were used to describe the same lithologies. One such example is gumbo, which is a driller’s term for a sticky clay or mud. Furthermore, Mr. Bill Heimann, geologist for the Kansas Department of Health and Environment (KDHE) in the Hays office and an adjunct professor in the Geosciences Department of Fort Hays State University, noted that some drillers routinely classify silts as clays in their drillers’ logs (personal communication, 2015). These descriptions led to making judgment calls when labeling some lithologies in the cross section. Color and consistency were also used to describe a majority of the lithologies.

It should also be noted that the driller’s logs do not include useful bedding structure information such as cross beds, ripples, parting lineation, load casts, flame features, mudcracks, tool marks, channel scours; as well as burrows, tracks, and trails which are common to clastic facies. Furthermore, there are no surface outcrops present in the study area for further analyzing bedding structure.

Ten cross sections were hand drawn on large sheets of graph paper, each beginning at surface elevation and ending on the upper surface of the Upper Cretaceous Blue Hill Shale. It was determined that drawing the data by hand was the best way to create the detailed geometries of the alluvium. Also, a vertical exaggeration of 20 was
used for each cross section in order to emphasize the low relief features or thin beds within the facies.

When completed, each cross section was scanned and converted to a jpeg image. These images were scaled down and printed off, and a light table was used to trace them onto clean white paper in ink. Symbols and colors were used to distinguish the different lithology and a scale bar (in feet) was also included.

For one cross section (peach profile line), a phreatic surface and arrows representing hypothetical groundwater movement were included. Measurements of the phreatic surface under Hays (collected during July 7, 2015) were used to draw an estimated equipotential line. Two contaminant spills were then simulated, one being a LNAPL and the other a DNAPL. Two plumes of each contaminant were drawn into the cross section. Common forms of each contaminant, which could likely be spilled in Hays, were selected for this; the LNAPL being gasoline and the DNAPL being tetrachloroethylene (a dry cleaning fluid, also known as PERC).

The sinuosity of present day Big Creek and two interpreted paleochannels within the study area were calculated using the sinuosity ratio (Sinuosity = l/d). This ratio is given by the distance along a stream between two points (l) divided by the straight-line distance between these two points (d). To measure the stream distances, a string was used to overlay each on a map and then a ruler was used to measure the string. Next, the ruler was used to measure the straight-line distance (Leopold, et al., 1964). Several terminology schemes exist for sinuosity. Terminology by Sarkar et al. (2012) was utilized to describe the stream sinuosity indices.
RESULTS

Phreatic Surface Results:

Surfer 8.0 3D contour maps of phreatic surface elevation data taken on July 7\textsuperscript{th}, 2015, August 19\textsuperscript{th}, 2015, and September 16\textsuperscript{th}, 2015 are shown in Figures 14, 15, and 16. White represents highest measured phreatic surface elevation while dark blue represents lowest elevation. The maps indicate that the phreatic surface dropped anywhere from 3.6 inches to 1 foot 9.6 inches over this three-month period. Monthly rainfall values for July, August, and September of 2015 were 4.28 inches, 0.44 inches, and 0.48 inches respectively (U.S. Climate Data.com, KSU Agriculture station).

Figure 14: July 7, 2015, 3D phreatic surface elevation contour map. Groundwater flow direction represented by black arrows and Big Creek by yellow line. Scale in Universal Transverse Mercator (UTM) coordinates.
Figure 15: August 19, 2015, 3D phreatic surface elevation contour map. Groundwater flow direction represented by black arrows and Big Creek by yellow line. Scale in UTM coordinates.

Figure 16: September 16, 2015, 3D phreatic surface elevation contour map. Groundwater flow direction represented by black arrows and Big Creek by yellow line. Scale in UTM coordinates.
Structural Cross Sections Results:

Review of the ten structural cross sections (Figures 18-27) indicates that the Big Creek alluvium generally consists of two distinct zones. They are enlarged in order to emphasize detail and are presented in order from westernmost (peach) in Figure 18 to easternmost (turquoise) in Figure 27. See Figure 17 for the lithology key in these figures.

The basal contour map (Figure 7) of the Blue Hill Shale (Burns and McDonnell, 2013) suggests a larger, central axis of a main paleochannel along the southern margin of the study area. Further, the basal contour exhibits paleotributary channels that flowed southerly towards the main channel. The lowest or basal alluvial zone contains mostly amalgamated fine- to medium-grained sand and gravels. The gravels in this lower zone also contain small, localized lenses of clay and silt. Above this zone lies the uppermost alluvial zone, which exhibits a mixture of mainly clay and some fine to medium grained sand. This upper zone contains localized lenses of coarser sands and gravels. A silt and silt-clay loam topsoil overlies the uppermost alluvial zone.

![Lithology key for ten cross sections.](image)

Figure 17: Lithology key for ten cross sections.
Figure 18: Structural cross section 1 (Peach, westernmost).
Figure 19: Structural cross section 2 (Orange)
Figure 20: Structural cross section 3 (Pink).
Figure 21: Structural cross section 4 (Dark Green)
Figure 22: Structural cross section 5 (White)
Figure 23: Structural cross section 6 (Light Blue)
Figure 24: Structural cross section 7 (Black)
Figure 25: Structural cross section 8 (Blue)
Figure 26: Structural cross section 9 (Purple)
Figure 27: Structural cross section 10 (Turquoise, easternmost)
CONCLUSIONS

Phreatic Surface Conclusions:

The drop in elevation of the water table over three months directly reflects the amount of precipitation that fell in the Hays area. The transition from July, to August, to September saw decreased amounts of monthly rainfall, and each monthly survey saw a drop in the water table. The contour maps also indicate that the general flow of groundwater is, as expected, southerly towards Big Creek.

Structural Cross Sections Conclusions:

Interpretation of the cross sections of the basal sand and gravel zone suggests the presence of winding, low-sinuosity (sinuosity index=1.20) alluvial paleochannels on the paleosurface of the Blue Hill Shale. Figure 28 represents what this may have looked like in a three-dimensional diagram. Clay lenses within this zone are interpreted as possible abandoned channel fills.

The sand and gravel lenses in the uppermost younger zone are interpreted as twisty, more sinuous (sinuosity index=1.29) paleochannels and the finer facies in the upper zone are interpreted as floodplain deposits. Figure 29 represents an interpretation of the facies in a three-dimensional diagram. Based on WWC5 logs, the larger sand lenses near the southern edge of the upper zone within many cross sections exhibit a vertical lithology trend that are interpreted as the point-bar channel deposits or crevasse splays. Smaller sand lenses further to the north of many cross sections are interpreted as deposits from paleotributaries of Big Creek. The larger sand lenses were targeted on Figure 30 and these points were then projected onto an aerial photo of the study area.
(Figure 31). A line representing the paleochannel was constructed by connecting these lense locations (Figure 31). The calculated sinuosity index of present day Big Creek within the study area is 1.65, which is classified as meandering.

Figure 28: Block diagram of lithofacies in a less sinuous stream (after Sutter, 2008).

Figure 29: Block diagram of lithofacies in a more sinuous stream (after Sutter, 2008).
Figure 30: Ten structural cross sections aligned according to geospatial location.
Figure 31: Blue trend (interpreted from Burns and McDonnell basement map) represents the basal paleochannel and the yellow trend (interpreted from the ten cross sections) represents the more sinuous paleochannel in the upper zone.

Although not an objective of this thesis, a speculation as to possible past fluvial and climate conditions is proffered. One explanation of the change of sinuosity of Big Creek over time could be related to the transitional climate changes from a wetter Pleistocene to a drier Holocene. Johnson and Martin (1987) used radiocarbon data to interpret floodplain stability periods and corresponding soil development. The data used in this thesis did not have any radiocarbon information that would allow the correlation of their stream stability periods to the paleochannel and present Big Creek sinuosity.
changes. It is herein only speculated that a drop in precipitation amounts would be one factor in the sinuosity change. It is speculated that the basal paleochannel existed during a time with higher precipitation and stream flow rates, which could have contributed to a lower sinuosity stream channel pattern. It is further speculated that the upper zone paleochannel flowed during a time with lower precipitation and stream flow rates, which could have contributed to a higher sinuosity stream channel pattern.

It must be noted that although this thesis does not focus on modern fluvial conditions, there have been numerous studies that did. Examples are described by Heimann (1987), Galloway (1981), and Schumm (1968). No natural system is in a steady state; tectonics, fluctuations in river discharge, temperature, glaciations, tidal variations, and storm surge are some of the major factors that result in shifts in channel form (Miall, 2014). This thesis strictly uses two-dimensional views of the subsurface, though Friend (1983) states that it is unwise to infer channel form from limited two-dimensional exposure. This thesis, however, does provide evidence of more details of the Big Creek alluvial facies than in previous work.

Additionally, research beyond the scope of this thesis for studying modern fluvial systems is being conducted. Bridge and Lunt (2005) propose that depositional models by previous workers do not meet significantly accurate requirements to interpret ancient river deposits. They suggest the use of ground-penetrating radar, the study of frozen rivers, and short-time aerial photograph sequencing. They proposed that by developing new models of modern fluvial systems, one could have better means to investigate ancient subsurface deposits.
A simplified contaminant simulation (Figure 32) shows an LNAPL migrating down through the subsurface, before settling atop the phreatic surface. Here it is shown flowing with the groundwater in a general north to south direction. A DNAPL is shown migrating into the subsurface where it sinks past the phreatic surface down to the upper surface of the Blue Hill Shale. Here it also flows in a north to south direction with the groundwater within the cross section. In some areas the DNAPL pools in deeper pockets on the shale surface and atop clay lenses within the sand and gravel zone.

Contaminant migration is more complex than this simplified simulation. Lateral connectivity of the Big Creek aquifer can only be inferred by ten two-dimensional cross sections. If a small amount of NAPL is released, it will migrate downward through the unsaturated zone where a fraction of the hydrocarbon will be retained by capillary forces as residual globules in the soil pores, eventually depleting the NAPL mass until movement ceases (Newell et al., 2015).

If a larger release of a LNAPL occurs, it will migrate downward until it reaches a physical barrier (such as strata with low permeability) or is affected by buoyancy forces near the phreatic surface. Once the capillary fringe is reached, the LNAPL may move laterally as a continuous, free-phase layer along the upper boundary of the saturated zone due to gravity and capillary forces (Newell et al., 2015). If a larger supply of DNAPL is released and is sufficient to overcome the fraction depleted by the residual saturation in the vadose zone, it will reach the phreatic surface and contaminate the groundwater directly. It will continue to migrate through the saturated zone until the residual saturation process exhausts the volume, or until it reaches a low permeable formation (Example;
Blue Hill Shale), where it will begin to move laterally along the contact of the low permeable formation with the flow of groundwater (Huling and Weaver, 1991).

Figure 32: Simulated DNAPL (red) and LNAPL (green) contamination plumes in cross section (peach). Phreatic surface represented by dashed line, water flow direction north to south (V=20).

If a contaminant were to enter the groundwater system beneath Hays, it would flow in a southwest, south, or southeast direction depending upon the phreatic surface gradient and inter-connectivity of the permeable alluvial facies. The most important control on aquifer or reservoir performance is sand-body connectivity, also referred to as the “sand fairway”. Paleochannel density and stacking pattern, regardless of the style of the channels, are the key controls of connectivity (Miall, 2014). Further, more detailed research would be needed at a contaminant site to more accurately predict where the contaminants would migrate.
FUTURE RESEARCH

If further spatial detail of the alluvial facies is to be determined, one could attempt to use 3D seismic techniques. That approach, however, is impractical because of that technology, the urban setting, and cost. Seismic energy sources such as Vibroseis trucks, explosives, or an array of geophones would not be easily set up or permitted within the city limits. Further, seismic signals would experience interference by sewer lines, water lines, basements, electrical infrastructure, and steel pilings.

If a three-dimensional picture of the alluvial fill is not attainable, then another possibility to improve and expand on this research would be to create two to three times the number of structural cross sections. It is suggested that in addition to more N-S cross sections, that an equivalent number of E-W cross sections be generated. One could then attempt to create and possibly correlate a “fence diagram” of the same or expanded area of the Big Creek Aquifer. However, WWC5 logs alone may not necessarily provide enough viable data. If enough workable private water well logs or other archived City well logs could be accessed, then a quality fence diagram could be constructed. This method would involve additional time equivalent to another thesis.

Another research project could involve simulating other types of contaminants in the cross sections. One could attempt to simulate contaminants of differing densities to show their flow paths through the alluvium. To make this attempt more realistic would depend on creating many more cross sections as suggested above. Another project could focus on geochemistry and model how the different contaminants react with the sediments or how they might break down in the groundwater.
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### APPENDIX A

White Cross Section Lithology Logs (in order from north to south, 14 total)

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- **LOCATION OF WATER WELL:**
  - NE 1/4 Section 11 Township 1S Range 1E

- **WATER WELL OWNER:**
  - **David L. Jensen**

- **LOCATION OF WATER WELL:**
  - **Screen-Perforated Interval:** From, To
  - **Gravel Pack Interval:** From, To
  - **Perforation Openings:**
    - **Character:**
      - **PVC:** 8
      - **Concrete:** 12
      - **ABS:** 12
      - **None:** 12
  - **Screen or Perforation Openings:**
    - **Character:**
      - **Concrete:** 8
      - **Gravel:** 8
      - **Wire:** 8
      - **Drilled:** 8
  - **Gauge:**
    - **Character:**
      - **Steel:** 8
      - **Galvanized:** 8

- **WATER WELL RECORD Form WWO-5, KSA 1968:**
  - **District:**
    - **Board of Agriculture, Division of Water Resources**

- **LOCATION AND DISTANCE:**
  - **Distance and direction from nearest town or city street address:**
    - **205 W 41st St. Hays, KS 67601**

- **INSTRUCTIONS:**
  - **Lithology Logs (in order from north to south, 14 total)**
  - **Plugging Intervals**
    - **ONCE USE ONLY**
**WATER WELL RECORD** Form WW-5

1. **LOCATION OF WATER WELL:**
   - Fraction: 28
   - M: 15
   - S: 16
   - E: 18
   - G: 6
   - H: 2

   Global Positioning System (GPS) Information:
   - Latitude: (in decimal degrees)
   - Longitude: (in decimal degrees)

2. **WATER WELL OWNER:** Rondy Seahander
   - RR#: 113 W 34th
   - City: Hays, KS
   - ZIP Code: 67601

3. **LOCATE WDLL WITH AN "X" IN: X
   - SECTION BOX:
   - N
   - NW
   - W
   - SW
   - S

4. **DEPTII OF COMPLETED WELL:**
   - Depth(s) Groundwater Encountered:
     1. ft.
     2. ft.
     3. ft.

   Well's static water level:
   - ft. below land surface measured on month/day/year.

5. **TYPE OF CASING USED:**
   - Steel
   - PVC
   - Other (HDDP, H-20)

   Casings:
   - Diameter:
     1. in. to 240 ft.

   - Weight:
     1. lbs/ft.

   - Wall thickness or gauge:
     1. 0.080

6. **GROUT MATERIAL:**
   - Cement
   - Sand
   - Other (Specify)

   Grout:
   - From:
     1. 5 ft.

7. **CONTRACTOR'S OR LANDOWNER'S CERTIFICATION:**
   - This water well was constructed, reconstructed, or plugged under my jurisdiction and was completed on (month/year) 9/14/09, and this record is true to the best of my knowledge and belief.

   Kansas Water Well Contractor's License No. 5-6 or 783.

   **INSTRUCTIONS:** Please fill in blanks and check the correct answer. Send three copies (public, blue, pink) to Kansas Department of Health and Environment, Bureau of Water, Geology Section, 1000 SW Jackson St., Suite 410, Topeka, Kansas 66612-3347. Telephone: 785-296-5225. Send one to WATER WELL OWNER and retain one for your records. Include fee of $3.00 for each completed well. Visit us at [http://www.kdhe.state.ks.us].
WATER WELL RECORD

LOCATION OF WATER WELL:

- County: Chase
- Township: 15
- Range: 16
- Section: 20

Distance and direction from nearest town or city street address of well if located within city?

312 Skyline Court
Hays, Kansas 67601

WATER WELL OWNER

- Name: Rick Finney
- Address: 312 Skyline Court
- City: Hays
- State: Kansas
- ZIP: 67601

Water Well Owner's Certification: This water well was (1) constructed, (2) reconstructed, or (3) plugged under my jurisdiction and was completed on (month/year) 7/15/92.

Board of Agriculture, Division of Water Resources

LOCATION OF WELL'S LOCATION WITH AN "X":

WELL'S STATIC WATER LEVEL:

- Pump test data: Well water was 37 ft. below land surface measured on mon. 7/15/92.
- Est. Yield: 10 gpm
- Hours pumping: 10
- Hours pumping: 10

Bore Hole Diameter: 10 in.

Screen-Perforated Openings are:

- Screen-Perforated: Steel
- Gravel-Cored: None

Gravel-Cored sewer lines: 6

WELL WATER TO BE USED AS:

- 1. Domestic
- 2. Irrigation
- 3. Sewage disposal
- 4. Industrial
- 5. Lawn and garden only
- 6. Other (specify below)

OTHER (specify below):

- Septic tank
- Septic tank
- Septic tank

LOCATION:

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WATER WELL RECORD

LOCATION OF WATER WELL

County: Ellis
City, St., Zip Code: Hays, Kansas 67601

WATER WELL OWNER: Carol Brin

State, Address Box #: 107 W. 38th

WELL NO.: 0298

Distance and direction from nearest town of city street address of well if located within city:

107 West 35th Hays, Kansas

WELL NUMBER LOCATION WITH AN "X" IN SECTION BOX:

- Depth of Committed Well: 50 ft.
- Elevation: 1117.095
- Depth of Groundwater Encountered: 1 ft.
- Pump test data: Well water was 24 ft. after 1 hour pumping, 6 gpm
- Est. Yield: 6 gpm
- WELL WATER TO BE USED AS: 7 Domestic
- Water well was tap tested and found to be free from contamination of livestock manure, septic pollutants, sewage, lagoon effluent, soil-gas, and well drilling or servicing fluids.
- Was the water well disinfected? Yes, No: Yes

TYPE OF BLANK CASING USED:
- 1 Steel
- 3 RMP (SP)
- 6 Asbestos-Cement
- 0 Other (specify below)
- 0 Other

TYPE OF SCREEN OR PERFORATION MATERIAL:
- 0 Steel
- 3 Stainless steel
- 0 RMP (SR)
- 0 Concrete
- 0 Asbestos-cement
- 0 Other (specify below)
- 0 Other

SCREEN PERFORATION OPENINGS ARE:
- 8 Continuous slot
- 0 Mill slot
- 0 Wire wrapped
- 0 Drilled holes
- 0 None (open hole)

SCREEN PERFORATED INTERVALS:
- From 50 ft. to 30 ft.
- From 30 ft. to 50 ft.

GRAVEL PACK INTERVALS:
- From 20 ft. to 50 ft.
- From 50 ft. to

CIRCUIT MATERIAL:
- 3 Next cement
- 2 Cement grout
- 3 Bentonite
- 4 Other

GROUT INTERVALS:
- 0 ft. to 20 ft.
- 20 ft. to

WHAT IS THE NEAREST SOURCE OF POSSIBLE CONTAMINATION:
- None
- 10 Livestock pens
- 14 Abandoned water well
- 15 Soil-gas/Gas well
- 16 Other (specify below)

INSTRUCTIONS: Use typewriter or ball point pen; PLEASE PRINT NAME and PRINT clear. Please fill in all blanks, underline or cross the correct answers. Send copy to Kansas Department of Health and Environment, Bureau of Water and Physical Resources, Topeka, Kansas 66609. Telephone 913-268-4240. Send one of WATER WELL DRILLING & SERVICE, INC. and original for your records.
**LOCATION OF WATER WELL:**

- **County:** Ellis
- **Type:** NE 1/4 SW 1/4 SE 1/4
- **Section Number:** 28
- **Township Number:** 13
- **Range Number:** 18

- **Distance and direction from nearest town or city street address of well if located within city?** 2613 Fort Street Hays, Kansas
- **用途:**
  - Board of Agriculture, Division of Water Resources
- **Application Number:** 2613 Fort Street

**WATER WELL OWNER:** Alfred Ruder

**Para. St. Address, Box #** 2613 Fort Street

**City, State, ZIP Code:** Hays, Kansas 67601

**WELL LOCATION:**

- **Location:** Upland

**DEPTH OF COMPLETED WELL:** 87 ft.

- **Elevation:** Upland

**WELL'S STATIC WATER LEVEL:** 35 ft.

- **Below land surface measured on:** 4/17/39

**Pump test data:**
- **Well water:** 60 ft. after
- **1 hour pumping:** 20 gpm

**Estimated Yield:** 20 gpm

**Well water:** 60 ft. after

**Hours pumping:** 1

**Bore Hole Diameter:** 10 in.

**WELL WATER TO BE USED AS:**
- **7** Public water supply
- **8** Air conditioning
- **11** Injection well

**Injection well:**
- **1 Domestic**
- **3 Feeder**
- **9 Oil field water supply**
- **12 Other (Specify below)**

**2 Imagination**

**7 Lawn and garden only**

**1 Observation well**

**Was a chemical/bacteriological sample submitted to Department? Yes... No.**

- **No.**

**If yes, monthly/weekly sample was submitted:** Water well disinfected? Yes... No.

- **Yes.**

**TYPE OF BLANK CASING USED:**
- **1 Steel**
- **2 PVC**
- **3 Reinforced RRM (SR)**
- **4 ABS**
- **5 Wrought iron**
- **6 Concrete tile**
- **7 Fiberglass**
- **8 Other (Specify below)**

**Block casing diameter:** 5 in. to 6 ft.

**Height above land surface:** 10 ft.

- **Casing weight:** 160 lbs.
- **Wall thickness or gauge No.:** 26

**TYPE OF SCREEN OR PERFORATION MATERIAL:**
- **1 Steel**
- **2 Brass**
- **3 Stainless steel**
- **4 Galvanized steel**
- **5 Fiberglass**
- **6 Concrete tile**
- **7 PVC**
- **8 RMP (SR)**
- **9 Other (Specify)**
- **10 Asbestos cement**
- **11 Other (Specify)**
- **12 None used (open hole)**

**SCREEN OR PERFORATION OPENINGS ARE:**
- **5 Gauzed wrapped**
- **6 Wire wrapped**
- **7 Torch cut**
- **8 Saw cut**
- **9 Drilled holes**
- **11 None (open hole)**

**SCREEN PERFORATED INTERVALS:**
- **From:** 67 ft.
- **To:** 87 ft.

**GRAVEL PACK INTERVALS:**
- **From:** 87 ft.
- **To:** 100 ft.

**Cement:**
- **2 Cement ply**
- **3 Bentonite**
- **4 Other**

**GROUT MATERIAL:**
- **1 Next cement**
- **2 Cement ply**
- **3 Bentonite**
- **4 Other**

**Cement ply:**
- **From:** 0 ft.
- **To:** 20 ft.

**Cement:**
- **From:** 20 ft.
- **To:** 40 ft.

**NATURAL SOURCES OF POTENTIAL HAZARD:**
- **1 Septic tank**
- **2 Sewer lines**
- **3 Waterline sewer lines**
- **4 Septic pipe**
- **5 Septic tank**
- **6 Septic pipe**
- **7 Septic pipe**
- **8 Septic tank**
- **9 Septic pipe**
- **10 Lewiston pond**
- **11 Lewiston pond**
- **12 Lewiston pond**
- **13 Lewiston pond**
- **14 Lewiston pond**
- **15 Lewiston pond**
- **16 Lewiston pond**
- **17 Lewiston pond**
- **18 Lewiston pond**
- **19 Lewiston pond**
- **20 Lewiston pond**

**LITHOLOGIC LOG:**

- **LITHOLOGIC LOG:**
- **FROM:**
- **TO:**

**GROUT INTERVALS:**
- **From:** 0 ft.
- **To:** 20 ft.

**HORIZON:**
- **Trend:**
- **Strike:**
- **Distance:**

**PHYSICAL OR MECHANICAL DATA:**
- **Porosity:**
- **Permeability:**
- **Temperature:**
- **Fluorescence:**
- **Acidity:**
- **Color:**
- **Clarity:**
- **Taste:**
- **Odor:**
- **Radioactivity:**
- **Toxicity:**
- **Other:**

**HOW MANY FEET?**

**CONTRACTOR'S OR LANDOWNER'S CERTIFICATION:**

- **This water well was:**
  - **1 Constructed**
  - **2 Reconstructed**
  - **3 Plugged under jurisdiction and was**
    - **completed on:** 4/17/39
    - **and the record is true to the best of my knowledge and belief. Kansas**
  - **Water Well Contractors License No.:**
  - **(Completed on month/year)**
  - **This Water Well Record was completed on:**
  - **(Month/year)**

**INSTRUCTIONS:** Use typewriter or ball point pen. PLEASE PRESS PRINT AND PRAY. Please include or state the answers. Send to Kansas Department of Health and Environment, Office of Oil Field and Environmental Geology, Regulation and Permitting Section, Topeka, Kansas 66620-7500, Telephone 719-862-3376. Send one to WATER WELL OWNER and retain one for your records.
**WATER WELL RECORD**

**Kansas Department of Health and Environment**
Division of Environment
Water Well Contractor
Topeka, Kansas 66620

<table>
<thead>
<tr>
<th>1. Location of well</th>
<th>2. Distance and direction from nearest town or city:</th>
</tr>
</thead>
<tbody>
<tr>
<td>County</td>
<td>Street address of well location if in city:</td>
</tr>
<tr>
<td>Ellis</td>
<td>2928 William Hays, E 800 S 30th, Topeka, KS 66604</td>
</tr>
<tr>
<td>Township number</td>
<td>Range number</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
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<tr>
<td>Section number</td>
<td>28</td>
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<tr>
<td>Township number</td>
<td>8</td>
</tr>
<tr>
<td>Range number</td>
<td>18</td>
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<tr>
<td>Location of well</td>
<td>Section number</td>
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<tr>
<td>1</td>
<td>28</td>
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<th>Sketch map</th>
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<tr>
<td>Willow</td>
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<tr>
<td>30th</td>
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<tr>
<td>House</td>
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<tr>
<td>N-well</td>
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</tbody>
</table>

4. Locate with "X" in section below:

<table>
<thead>
<tr>
<th>Type and color of material</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>topsoil</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>clay</td>
<td>4</td>
<td>38</td>
</tr>
<tr>
<td>fine to medium sand</td>
<td>38</td>
<td>57</td>
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<tr>
<td>blue shale</td>
<td>57</td>
<td>62</td>
</tr>
</tbody>
</table>

5. Type and color of material

| Topsoil                   |         |
|-------------------------------------------------|
| Clay                                        |        |
| Fine to medium sand                      |        |
| Blue shale                                |        |

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<tr>
<th>6. Bore hole dia.</th>
<th>6. Completion date</th>
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<tr>
<td>62 in.</td>
<td>5-17-79</td>
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<th>7. Cable test</th>
<th>8. Horse test</th>
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<tr>
<td>Battery</td>
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<tr>
<td>62</td>
<td>14</td>
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<tr>
<th>9. Casing material</th>
<th>Length Below Ground</th>
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<td>X</td>
<td>18</td>
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<tr>
<th>10. Screen Material</th>
<th>11. Screen Material</th>
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<tr>
<td>X</td>
<td>Screen pack</td>
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<td></td>
<td>Size: range of material:</td>
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<th>12. Well depth below ground:</th>
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<tr>
<td>62 ft.</td>
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<th>13. Water level:</th>
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<td>62 ft. below land surface:</td>
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<td>Date: 5-17-79</td>
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<th>14. Wall head completion:</th>
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<td>12 inches above grade</td>
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<th>15. Well grouted?</th>
<th>Yes</th>
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<th>16. Screen material:</th>
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<tr>
<td>X</td>
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<tr>
<th>17. Pump</th>
<th>18. Motor</th>
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<td>FSW</td>
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<th>19. Remarks</th>
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<th>20. Water well contractor's certification:</th>
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<td>This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.</td>
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<th>21. Water Well Well</th>
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<th>22. Address</th>
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<td>108 W 40th St, Topeka, KS 66604</td>
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<th>23. Authorized representative</th>
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*Forward the white, blue and pink copies to the Department of Health and Environment*
### LOCATION OF WATER WELL:

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<thead>
<tr>
<th>County</th>
<th>Township</th>
<th>Range Number</th>
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<tr>
<td>2603</td>
<td>13</td>
<td>18 NW</td>
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</tbody>
</table>

**Address:** Hays, Kansas

**Owner:** Bruce Kratzer

**Address:** Hays, Kansas 67601

**Application Number:** Board of Agriculture, Division of Water Resources 2003 Fort

**ZIP Code:** 67601

### DEPTH OF COMPLETED WELL:

<table>
<thead>
<tr>
<th>Depth</th>
<th>Elevation</th>
<th>Location</th>
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<tbody>
<tr>
<td>70 ft</td>
<td>45 ft</td>
<td>Below land surface measured on May 7, 1994</td>
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**Est. Yield:** 30 gpm

**Depth of Completed Well:** 70 ft

**Location:** Below land surface measured on May 7, 1994

### SCREEN OR PERFORATION INTERVALS:

<table>
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<tr>
<th>Type</th>
<th>Specification</th>
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<tr>
<td>1</td>
<td>Continuous</td>
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<tr>
<td>2</td>
<td>Wrought iron</td>
</tr>
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<td>3</td>
<td>Stainless steel</td>
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<td>5</td>
<td>Fiber glass</td>
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</table>

**Material:** 7 PVC

**Screen:** 8 RMP (SR)

**Porosity:** 10 Asbestos-cement

**Gauge:** 18 Saw cut

**Perforation:** 11 None (open hole)

### SOIL Material:

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<th>To</th>
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### LITHOLOGIC LOG:

- Topsoil
- Gumbo
- Gumbo, traces of sand
- Brown clay
- Sand, clay mix
- Good gravel
- Clay
- Shale

### WATER WELL RECORD:

**Number:** 2003 Fort

**Location:** Hays, Kansas

**Owner:** Bruce Kratzer

**Address:** Hays, Kansas 67601

**Application Number:** Board of Agriculture, Division of Water Resources

**ZIP Code:** 67601

**Depth:** 70 ft

**Location:** Below land surface measured on May 7, 1994

**Est. Yield:** 30 gpm

**Depth of Completed Well:** 70 ft

**Location:** Below land surface measured on May 7, 1994

**Screen:** 8 RMP (SR)

**Porosity:** 10 Asbestos-cement

**Gauge:** 18 Saw cut

**Perforation:** 11 None (open hole)

**Material:** 7 PVC

**Screen:** 8 RMP (SR)

**Porosity:** 10 Asbestos-cement

**Gauge:** 18 Saw cut

**Perforation:** 11 None (open hole)
### Location of Water Well

**County:** Ellis  
**City, State, ZIP Code:** Hays, Kansas 87601

**Application Number:**

**WATER WELL OWNER:** Simon Roth

**RFM, St. Address, Box #:** 108 West 25th

**Board of Agriculture, Division of Water Resources:**

**WELL'S STATIC WATER LEVEL:** 1.8 ft. below land surface measured on 9/15/89.

**Pump test data:**
- **Est. Yield:** 20 gpm
- **Well water:** 50 ft. after 1 hour pumping
- **50 ft. after 1 hour pumping:** 20 gpm

**Type of Blank Casing Used:**
- **Steel:** 7 in.
- **RMP (SR):** 7 in.
- **ABS:** 7 in.

**Screen or Perforation Material:**
- **Fiberglass:** 7 in.
- **Interlocking laminates:** 7 in.
- **Wrought iron:** 7 in.
- **Concrete tile:** 7 in.

**Screen-Perforated Intervals:**
- From 55 ft. to 75 ft.
- From 75 ft. to 95 ft.
- From 95 ft. to 115 ft.
- From 115 ft. to 135 ft.

**GROUT MATERIAL:**
- **Cement:** 7 in.
- **Grout:** 7 in.
- **Barite:** 7 in.
- **Other:** 7 in.

**DIRECTION FROM WELL:**
- Topsoil
- Clay
- Clay and sand
- Clay
- Clay
- Clay
- Clay
- Sand
- Clay
- Sand
- Shale

**CONTRACTOR'S OR LANDOWNER'S CERTIFICATION:** This well was constructed, reconstructed, or plugged under my jurisdiction and was completed on 9/15/89. The record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. 198 This Water Well Record was completed on 9/15/89 under the business name of Hart's Water Well Drilling & Service Inc.

**INSTRUCTIONS:** Use typewriter or ball-point pen. PLEASE PRINT NAME AND PRINT CLEARLY. Please fill in blanks, underline or circle incorrect answers. Send three copies to Kansas Department of Health and Environment, Bureau of Water Protection, 222 S. Kansas, Topeka, Kansas 66614; Telephones 913/296-6769 or 913/296-7585; Fax 913/296-7564. Thank you for your service.
### WATER WELL RECORD Form WWC-5 KSA 62a-1212

<table>
<thead>
<tr>
<th>Location of Water Well</th>
<th>Location</th>
<th>Fraction</th>
<th>SM</th>
<th>ME</th>
<th>Section Number</th>
<th>Township Number</th>
<th>Range Number</th>
<th>Range</th>
<th>LITHOLOGIC LOG</th>
<th>LITHOLOGIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>County:</td>
<td>Ellis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City, State, Zip Code</td>
<td>Hays, Kansas 67660</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Distance and direction from nearest town or city?**
Street address of well if located within city?

**WATER WELL OWNER:** Jacob Amhold

**WATER WELL OWNER:**

<table>
<thead>
<tr>
<th>FIRE, &amp; St. Address, Box #</th>
<th>105 S. 22nd, Hays, Kansas 67601</th>
</tr>
</thead>
</table>

**City, State, Zip Code:**

<table>
<thead>
<tr>
<th>City, State, Zip Code</th>
<th>Hays, Kansas 67601</th>
<th>Application Number:</th>
</tr>
</thead>
</table>

**DEPT OF COMPLETED WELL:**

<table>
<thead>
<tr>
<th>DEPT OF COMPLETED WELL</th>
<th>Bore Hole Diameter</th>
<th>19 ft. Bore Hole Diameter</th>
<th>19 ft. and 14 ft. and</th>
<th>H</th>
</tr>
</thead>
</table>

**Well Water to be used as:**

<table>
<thead>
<tr>
<th>Well Water to be used as</th>
<th>1 Domestic</th>
<th>2 Sewage Line</th>
<th>3 Irrigation</th>
<th>4 Industrial</th>
</tr>
</thead>
</table>

**Water to be used as:**

<table>
<thead>
<tr>
<th>Water to be used as</th>
<th>5 Public water supply</th>
<th>6 Irrigation</th>
<th>7 Malaysian Supplier</th>
<th>8 Insecticide</th>
</tr>
</thead>
</table>

**Surface of Perforation Material:**

<table>
<thead>
<tr>
<th>Surface of Perforation Material</th>
<th>1 Steel</th>
<th>2 PVC</th>
<th>3 Stainless steel</th>
<th>4 Galvanized steel</th>
<th>5 Fiber Glass</th>
</tr>
</thead>
</table>

**Screen/Diameter/Perforation Details:**

<table>
<thead>
<tr>
<th>Screen/Diameter/Perforation Details</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Screen/Perforation Intervals:**

<table>
<thead>
<tr>
<th>Screen/Perforation Intervals</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Gravel Intake Intervals:**

<table>
<thead>
<tr>
<th>Gravel Intake Intervals</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Casing Height Above Land Surface:**

<table>
<thead>
<tr>
<th>Casing Height Above Land Surface</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Casing Height Above Land Surface:**

<table>
<thead>
<tr>
<th>Casing Height Above Land Surface</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Screen or Perforation Opening Size:**

<table>
<thead>
<tr>
<th>Screen or Perforation Opening Size</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
</table>

**Perforation Details:**

<table>
<thead>
<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Type of Blank Casing Used:**

<table>
<thead>
<tr>
<th>Type of Blank Casing Used</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Well Water Test Data:**

<table>
<thead>
<tr>
<th>Well Water Test Data</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Pump Test Data:**

<table>
<thead>
<tr>
<th>Pump Test Data</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Location of Water Well:**

<table>
<thead>
<tr>
<th>Location of Water Well</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Locate Wells Location:**

<table>
<thead>
<tr>
<th>Locate Wells Location</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Elevation:**

<table>
<thead>
<tr>
<th>Elevation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**Instructions:** Use typewriter or ball point pen, please print neatly and PRINTER clearly. Please fill in blanks, underline or circle the correct answers. Send by three
# WATER WELL RECORD

**Location of Water Well**

<table>
<thead>
<tr>
<th>County</th>
<th>Township</th>
<th>Range Number</th>
<th>Section Number</th>
<th>Township Number</th>
<th>Range Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>X11T</td>
<td>13S</td>
<td>13W</td>
<td>33</td>
<td>13T</td>
<td>1B</td>
</tr>
</tbody>
</table>

- **Distance and direction from nearest town or city:** 2109 Oak Street, Hays, Kansas 67601
- **Well water test data:**
  - Well water was ... 
  - Hours pumping: 20 gpm

## Well Information

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water to be used</td>
<td>7</td>
</tr>
<tr>
<td>Well diameter</td>
<td>7 ft</td>
</tr>
<tr>
<td>Depth of well</td>
<td>76 ft</td>
</tr>
<tr>
<td>Screen or perforation</td>
<td></td>
</tr>
<tr>
<td>Location of water well</td>
<td></td>
</tr>
<tr>
<td>Pump test data</td>
<td></td>
</tr>
<tr>
<td>Est. Yield</td>
<td>20 gpm</td>
</tr>
</tbody>
</table>

## Well Material

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>3 RMP (SR)</td>
</tr>
<tr>
<td>PVC</td>
<td></td>
</tr>
<tr>
<td>Screen</td>
<td></td>
</tr>
<tr>
<td>Screen material</td>
<td></td>
</tr>
<tr>
<td>Casing</td>
<td></td>
</tr>
<tr>
<td>Casing material</td>
<td></td>
</tr>
<tr>
<td>Screen perforation</td>
<td></td>
</tr>
<tr>
<td>Screen perforation material</td>
<td></td>
</tr>
<tr>
<td>Well perforation</td>
<td></td>
</tr>
<tr>
<td>Well perforation material</td>
<td></td>
</tr>
</tbody>
</table>

## Grout Material

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>1</td>
</tr>
<tr>
<td>Grout</td>
<td>2</td>
</tr>
<tr>
<td>Barite</td>
<td>4</td>
</tr>
</tbody>
</table>

## Other Information

- **Owner:** John Karrin
- **Address:** 2109 Oak Street
- **City, State, Zip Code:** Hays, Kansas 67601
- **Application Number:** Board of Agriculture, Division of Water Resources

---

**INSTRUCTIONS:** Use typewriter or ball point pen, please print and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three sheets only.
**WATER WELL RECORD**

<table>
<thead>
<tr>
<th>Field</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOCATION OF WATER WELL:</strong></td>
<td>Ewing NE 1/4 NW 1/4 SE 1/4 35 S T 13 R 18 E</td>
</tr>
<tr>
<td><strong>WATER WELL OWNER:</strong></td>
<td>John McFetland</td>
</tr>
<tr>
<td><strong>RAP, St. Address, Box:</strong></td>
<td>209 S 19 th</td>
</tr>
<tr>
<td><strong>City, State, ZIP Code:</strong></td>
<td>Application Number:</td>
</tr>
<tr>
<td><strong>DEPTH OF COMPLETED WELL:</strong></td>
<td>ft. ELEVATION</td>
</tr>
<tr>
<td>Depth(s) Groundwater Encountered</td>
<td>ft. 48 ft. 48 ft. 48</td>
</tr>
<tr>
<td>WELL'S STATIC WATER LEVEL</td>
<td>ft. below land surface measured on moist day</td>
</tr>
<tr>
<td>Pump test data: Well water was</td>
<td>gpm</td>
</tr>
<tr>
<td>Est. Yield</td>
<td>gpm</td>
</tr>
<tr>
<td>Bore Hole Diameter</td>
<td>in.</td>
</tr>
<tr>
<td>WELL WATER TO BE USED AS:</td>
<td>8 in.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **TYPE OF BLANK CASING USED:** | CASING JOINTS: 
1 Continuous slot 3 Mill slot 5 Wrought iron 8 Concrete tile 8 Steel
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS
47 Louvers 4 Key punched 10 Steel
57 Trench cut 10 Other (specify)
| **SCREEN OR PERFORATION OPENINGS ARE:** | 5 Gauzed wrapped 11 None (open hole)
| | 9 Other (specify) |
| **SCREEN-PERFORATED INTERVALS:** | ft. From | ft. To |
| From | ft. To |
| From | ft. To |
| From | ft. To |
| From | ft. To |
| From | ft. To |
| From | ft. To |

**GROUT MATERIAL:**
- Neat cement
- Bentonite
- Other

**GROUT INTERVALS:**
- From ft. 10 to ft. 0
- From ft. 10 to ft. 0
- From ft. 10 to ft. 0
- From ft. 10 to ft. 0
- From ft. 10 to ft. 0

**WHAT IS THE NEAREST SOURCE OF POSSIBLE CONTAMINATION:**
- Sptic tank
- Lateral lines
- Pit pipe
- Septic field
- Sewerage lagoon
- Other storage
- Water tower sewer lines
- Seepage pit
- Feedlot
- Other (specify below)

**DIRECTION FROM WELL:**
- West
- East
- North
- South

**LITHOLOGIC LOG:**
<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 27</td>
<td>Blew off</td>
</tr>
<tr>
<td>30</td>
<td>Fine sand interbedded with clay</td>
</tr>
<tr>
<td>40</td>
<td>Medium sand interbedded with clay</td>
</tr>
<tr>
<td>50</td>
<td>Loose sand interbedded with clay</td>
</tr>
<tr>
<td>60</td>
<td>Silt and clay</td>
</tr>
<tr>
<td>70</td>
<td>Loose gravel</td>
</tr>
<tr>
<td>72 73</td>
<td>Arctic gravel</td>
</tr>
</tbody>
</table>

**CONTRACTORS OR LANDOWNERS CERTIFICATION:**
This water well was (1) constructed (2) reconstructed, or (3) plugged under my jurisdiction and was completed on (month/year) 8/28/85. This record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. 9745. This water well was completed on (month/year) 8/28/85. Signed by James Beier.

**INSTRUCTIONS:** Use typewriter or ball point pen. PRINT clearly. Please fill in blank underscore lines or circle the correct answers. Send top of page to Kansas Department of Health and Environment Division of Environmental Quality Control Trace |

**OFFICE USE ONLY**
From: 0 ft. to 10 ft. From: 0 ft. to 10 ft. From: 0 ft. to 10 ft. From: 0 ft. to 10 ft. From: 0 ft. to 10 ft.
To: 0 ft. To: 10 ft. To: 10 ft. To: 10 ft. To: 10 ft. To: 10 ft. To: 10 ft. To: 10 ft. To: 10 ft. To: 10 ft.

LITHOLOGIC LOG

FROM TO LITHOLOGIC LOG

0 3 Topsoil
3 38 Brown clay
38 47 Gray clay
47 56 Sand
56 60 Shale

INSTRUCTIONS: Use typewriter or ball point pen, PLEASE PRESS FAMILY and PRINT clearly. Please fill in blank, underline words to circle the correct answers. Send top
lines written to Kansas Department of Health and Environment. Division of Environmental Health, Environmental Sanitation Services, Topeka, KS 66603. Send via WATER WEB.
**WATER WELL RECORD**

**Location of Water Well:**
- **County:** Ellis
- **Township Number:** 13
- **Range Number:** 18

**Water Well Owner:** Agitation Leifer

**Locate Well's Location with An "X" in Section Box:**

**Depth of Completed Well:** 70 ft.

**Well's Static Water Level:** 14 ft. below land surface measured on 1-24-1984

**Pump Test Data:**
- Well water was pumped for 20 hours pumping 20 gpm
- Well water was pumped for 20 hours pumping 10 gpm

**Bore Hole Diameter:** 9 in. to 10 in.

**Well Water to Be Used As:**
- 5 Public water supply
- 1 Air conditioning
- 1 Injection well

**Screen or Perforation Openings Are:**
- 7 PVC
- 7 Fiber glass
- 8 RMP (SR)
- 11 Other (specify)

**Screen or Perforation Material:**
- 5 Gauged wrapped
- 8 Saw cut
- 11 None (open hole)

**Screen or Perforation Intervals:**
- From 60 ft. to 70 ft.
- From 70 ft. to 80 ft.
- From 80 ft. to 90 ft.
- From 90 ft. to 100 ft.

**Gravel Pack Intervals:**
- From 35 ft. to 45 ft.
- From 45 ft. to 55 ft.
- From 55 ft. to 65 ft.
- From 65 ft. to 75 ft.
- From 75 ft. to 85 ft.

**Lithologic Log:**

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>Top soil</td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>Brown clay</td>
</tr>
<tr>
<td>26</td>
<td>66</td>
<td>Sand</td>
</tr>
<tr>
<td>66</td>
<td>70</td>
<td>Shale</td>
</tr>
</tbody>
</table>

**Contractors or Landowner's Certification:**
- This water well was constructed on January 24, 1984
- This water well record was completed on January 31, 1984

**Instructions:** Use typewriter or ballpoint pen. Please press firmly and print clearly. Please fill in blanks, underline or circle the correct answers. Send copy to Kansas Department of Health and Environment, Division of Water Resources.
1. **LOCATION OF WELL**

<table>
<thead>
<tr>
<th>Township</th>
<th>Range</th>
<th>Section</th>
<th>Quarter Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>12</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

   **Precise Location:**
   - **Elevation:** 50 ft above mean sea level
   - **Distance from Street:** 403 E 14th

2. **WATER WELL OWNER:**
   - Roger G. Oebel

3. **LOCATION OF WATER WELL:**
   - **Depth of Completed Well:** 50 ft
   - **Elevation:** Valley
   - **Borehole Diameter:** 10 ft
   - **Water Level:** 25 ft
   - **Static Water Level:** 25 ft
   - **Type of Water:** Public water supply
   - **Use:** Air conditioning, injection well

4. **TYPE OF BLANK CASING USED:**
   - 2: Wrought iron
   - 3: RWP (SP)
   - 4: ABS
   - 5: Concrete tile

5. **SCREEN AND PERFORATION MATERIALS:**
   - **Type:** 7: PVC
   - **Material:** 10: Asbestos cement
   - **Other:** 4: Galvanized steel

6. **GROUT MATERIAL:**
   - 3: Neat cement
   - 2: Cement grout
   - 3: Grout

7. **CONTRACTOR'S OR LANDOWNER'S CERTIFICATION:**
   - This water well was constructed, reconditioned, or plugged under my jurisdiction and was completed on 7/11/01.
   - The person signing this form is responsible for the accuracy of the information provided.

**Additional Information:**
- **Owner:** Roar Rock Wl Drilling & Services, Inc.
- **Licence Number:** 199
- **Address:** 403 E 14th, Hays, KS 67601
- **Application Number:** 102-012345
- **Date:** 7/11/01

---

**Notes:**
- **Groundwater:** Sand
- **Water Level:** 15 ft
- **Drilled Holes:** 3
- **Water Use:** Domestic, Feedlot, Oil field water supply, Domestic, Injection well
- **Water Well:** Disinfected:
  - Yes
  - No

---

**Additional Details:**
- **Screen Perforation Openings Are:**
  - 5: Slanted wrapped
  - 8: Slit
  - 11: None

---

**Lithologic Log:**

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Lithologic Log</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>Topsoil</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>Gambino/clay</td>
</tr>
<tr>
<td>17</td>
<td>40</td>
<td>Sand</td>
</tr>
<tr>
<td>40</td>
<td>46</td>
<td>Clay</td>
</tr>
<tr>
<td>46</td>
<td>50</td>
<td>Sand</td>
</tr>
<tr>
<td>50</td>
<td>98</td>
<td>Shale</td>
</tr>
</tbody>
</table>
APPENDIX B

Legals of Wells Used

Peach Cross Section (1)

<table>
<thead>
<tr>
<th>Water wells (north to south)</th>
<th>Legal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NW, SW, SE, Section 20, T 13 S, R 18 W</td>
</tr>
<tr>
<td>2</td>
<td>SW, SW, SE, Section 20, T 13 S, R 18 W</td>
</tr>
<tr>
<td>3</td>
<td>NW, NW, NE, Section 29, T 13 S, R 18 W</td>
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