Location Restrictions Demonstration Report
Area 2 Pond, Area 3 Pond, and Area 4 Pond (Inactive Units)
Lawrence Energy Center

Prepared for:

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Lawrence Energy Center
Lawrence, Kansas

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April 2020

TABLE OF CONTENTS

LIST OF FIGURES AND APPENDICES

FIGURES

APPENDICES

1.0 INTRODUCTION AND PURPOSE

The Disposal of Coal Combustion Residuals (CCR) from Electric Utilities Final Rule (CCR Rule) 40 CFR §257.100(e)(2) requires owner/operators of inactive CCR surface impoundments to comply with 40 CFR §257.60 through §257.64 and make demonstrations in the event a unit is located in certain areas. The purpose of this report is to demonstrate whether the inactive Area 2 Pond, Area 3 Pond, and Area 4 Pond (Units) at Evergy Kansas Central, Inc. (Evergy) Lawrence Energy Center (LEC) are located in any of those areas, and if so, to make certain demonstrations per the CCR Rule that will permit continued CCR disposal/management operations.

The Units, which are inactive CCR surface impoundments, are located at LEC in Lawrence, Kansas, as indicated in **Figure 1**. The Area 4 Pond underwent closure by removal and was infilled with soil, with closure construction certified complete in 2017. The Area 2 Pond and Area 3 Pond underwent closure by removal construction in 2017 through 2019. All CCR material and surrounding soils were excavated. The Units were redesigned, and the majority of internal berms that allowed excavation and removal of CCR were removed. The Units were then relined with a clay liner and repurposed as part of LEC's wastewater and/or stormwater conveyance systems. While these Units have not yet been certified closed pending final groundwater monitoring requirements, all CCR has been removed from the Units as part of clean closure construction. Area 2, Area 3, and Area 4 Ponds are no longer designed to hold an accumulation of CCR; no longer hold an accumulation of CCR; and do not treat, store, or dispose of CCR; therefore, they no longer fulfill the criteria that define a CCR Surface Impoundment:

> 40 CFR 257.2: *CCR surface impoundment* means a natural topographic depression, manmade excavation, or diked area, which is designed to hold an accumulation of CCR and liquids, and the unit treats, stores, or disposes of CCR.

As the Units are not currently certified closed pending groundwater monitoring, APTIM Environmental & Infrastructure, LLC (APTIM) has completed this evaluation of CCR surface impoundment location restrictions. APTIM has reviewed available historical reports provided in **Section 7.0** as well as undertaken a site visit in April 2019 to develop this report. This report provides the demonstrations necessary to document CCR Rule requirements outlined in 40 CFR §257.60 through §257.64 to determine if the Units are located in an area:

- with a base that is constructed no less than 5 feet above the upper limit of the uppermost aquifer (40 CFR §257.60);
- in wetlands (40 CFR §257.61);
- within 200 feet of the outermost damage zone of a fault which has been displaced in Holocene time (40 CFR §257.62);
- within a seismic impact zone (40 CFR §257.63); and
- in an unstable area (40 CFR §257.64).

The applicable CCR Rule requirement for each of the above is listed in the respective section in italics followed by an explanation of the review and determinations completed by APTIM.

2.0 PLACEMENT ABOVE UPPERMOST AQUIFER (§257.60)

§257.60 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must be constructed with a base that is located no less than 1.52 meters (five feet) above the upper limit of the uppermost aquifer, or must demonstrate that there will not be an intermittent, recurring, or sustained hydraulic connection between any portion of the base of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations (including the seasonal high water table). The owner or operator must demonstrate by the dates specified in paragraph (c) of this section that the CCR unit meets the minimum requirements for placement above the uppermost aquifer.

APTIM compared the location of the Units to the location of the upper limit of the uppermost aquifer by reviewing the site geology characterized by Haley & Aldrich in the CCR Groundwater Monitoring Network Description (Haley & Aldrich, 2020) and Golder Associates, Inc. in the Evaluation of Ash Pond Berm Stability (Golder Associates, 2009). As described in the reports, the generalized geology underlying the Unit includes the following, from the surface down:

1. Glacial Till Terrace Deposits (uppermost aquifer)
2. Shale (bedrock, aquitard)

The Units are underlain by clay, sand and gravel (maximum thickness of approximately 55 feet) and a shale bedrock (Haley & Aldrich, 2020). The geology is based on the borings drilled along the berm in 2017 and 2019 by Haley & Aldrich and the 2009 borings conducted by Golder Associates, Inc. The geology is overall consistent across the Units. Based on the boring results and the definition of aquifer in §257.53, the uppermost aquifer is located in the Glacial Till Terrace Deposits.

As previously discussed, the Area 4 Pond underwent closure by removal construction, was infilled with soil and closure construction was certified complete in 2017. As such, there is no unit base nor CCR material within five feet of the uppermost aquifer. The Area 2 Pond and Area 3 Pond underwent closure by removal construction in 2017 through 2019. All CCR material and surrounding soils were excavated. The Units were then redesigned and relined with a clay liner and repurposed as part of LEC's wastewater and/or stormwater conveyance systems. As such, there is no CCR material placed within five feet of the uppermost aquifer of these ponds. This demonstrates that there will not be an intermittent, recurring, or sustained hydraulic connection between the CCR material at the base of the Units and the uppermost aquifer.

In addition, the entire base of the Area 2 Pond and Area 3 Pond have been evaluated in comparison to seasonal groundwater fluctuations observed over a one-year period between 2018-2019 (Haley & Aldrich, 2019). Groundwater elevations were generally highest on a site-wide basis in January 2019, however, the highest groundwater elevation observed during routine monitoring is 825.96 ft MSL, observed during March 2019. Groundwater elevations observed in the location of the Units indicate that the base of the Units had, at a minimum, approximately 3 to 4 feet of separation from the uppermost aquifer during the seasonal high groundwater level, and greater than 5 feet separation during the remaining periods. This conclusion is drawn based on the base of the newly

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constructed liners ranging between elevations of approximately 824.5 – 830 ft MSL (Area 2 Pond) and 822.5 ft MSL (Area 3 Pond).

Based on this review, APTIM concluded that there is not an intermittent, recurring, or sustained hydraulic connection between CCR (nor any portion of the base of the Units) and the uppermost aquifer due to normal fluctuations in groundwater elevations (including the seasonal high-water table). The information presented above demonstrates the Units are in compliance with the requirements of §257.60. Pertinent documents and sections of documents reviewed are provided in **Appendix A**.

3.0 WETLANDS (§257.61)

§257.61 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located in wetlands, as defined in §232.2 of this chapter, unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that the CCR unit meets the requirements of paragraphs (a)(1) through (5) of this section."

A Certified Wetland Delineator visited the Unit on April 1, 2020 to determine if any area within the boundary of the Units is potentially located in an existing wetland area, as defined in 40 CFR §232.2. Details of the area inspected are presented in **Figure 2**. Based on the conclusions during the site visit and wetland inspection, APTIM determined that the Units are not located within an existing wetland area. Consequently, no additional demonstration is necessary.

4.0 FAULT AREAS (§257.62)

§257.62 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located within 60 meters (200 feet) of the outermost damage zone of a fault that has had displacement in Holocene time unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that an alternative setback distance of less than 60 meters (200 feet) will prevent damage to the structural integrity of the CCR unit.

APTIM compared the location of the Units to the location of faults from the Holocene time, as shown in the United States Geologic Survey (USGS) Quaternary Fault and Fold Database for the United States. The nearest fault area is indicated on **Figure 3**. Based on this review, APTIM determined the Units are not located within 200 feet of the outermost damage zone of a fault that has had displacement in the Holocene time. Consequently, no additional demonstration is necessary.

5.0 SEISMIC IMPACT ZONE (§257.63)

§257.63 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located in seismic impact zones unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that all structural components including liners, leachate collection and removal systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site.

APTIM compared the location of the Units to the location of seismic impact zones, as defined in §257.53, using the USGS map "Two Percent Probability of

Exceedance in 50 Years Map of Peak Ground Acceleration" shown in **Figure 4**. The location of the Units in relation to the nearest seismic impact zones (i.e. areas of at least 0.1g, shown in green) is shown on the Figure. Based on this review, APTIM determined the Units are not located within a seismic impact zone. Consequently, no additional demonstration is necessary.

6.0 UNSTABLE AREAS (§257.64)

§257.64 (a) An existing or new CCR landfill, existing or new CCR surface impoundment, or any lateral expansion of a CCR unit must not be located in an unstable area unless the owner or operator demonstrates by the dates specified in paragraph (d) of this section that recognized and generally accepted good engineering practices have been incorporated into the design of the CCR unit to ensure that the integrity of the structural components of the CCR unit will not be disrupted.

APTIM evaluated the location of the Units for the presence of on-site or local unstable areas as defined in §257.53. Evaluations of the conditions listed in §257.64(b)(1) through (3) were evaluated and are discussed below. Based on this review, APTIM determined the Units are not located within an unstable area as defined in §257.53. Consequently, no additional demonstration is necessary.

257.64 (b) The owner or operator must consider all of the following factors, at a minimum, when determining whether an area is unstable:

6.1 Unstable Factors Considered: Differential Settling (§257.64(b)(1))

On-site or local soil conditions that may result in significant differential settling;

APTIM has visited the Units and evaluated site-specific reports detailing the conditions of the on-site and local soils for conditions that could result in significant differential settling. The Units are located on a clay, sand and gravel that is up to approximately 55 feet thick (Haley & Aldrich, 2020). It was reported by APTIM that the foundation was found to be stable for the Units (APTIM, 2018 and APTIM, 2018). No significant differential settlement has been recorded since the original construction of the Units. Based on this information and a review of the available geotechnical data for the Units (Golder Associates, 2009 and Golder Associates, 2010), which show firm to stiff soils were used in the construction of the Units, APTIM's professional opinion is that the Units will not experience significant differential settlement and is not located within an area that may result in significant differential settling. Pertinent documents and sections of documents reviewed are provided in **Appendix B.1**.

6.2 Unstable Factors Considered: Geologic/Geomorphologic Features (§257.64(b)(2))

On-site or local geologic or geomorphologic features; and

APTIM visited the Units in April 2019 in addition to evaluating the most recent USGS Topographic Map; and reviewing site-specific reports characterizing the site geology (Golder Associates, 2009 and Haley & Aldrich, 2020), and structural stability (Black & Veatch, 2017 and APTIM, 2018 and AMEC Earth and Environmental, 2008) for the presence of on-site or local geologic and geomorphologic features such as karst terrain, steep slopes, and sinkholes. The Units are underlain by clay, sand and gravel (local maximum thickness of approximately 55 feet) and a shale bedrock. The groundwater flow is predominantly towards the North or Northwest, with the uppermost aquifer characteristics consisting of clay, sand and gravel (approximately 21 to 38 feet) (Haley & Aldrich, 2020). A review of the terrain at or near the Units indicated no steep slopes, terrain features, or other local geologic or geomorphologic features that could feasibly result in an unstable condition (Black & Veatch, 2017 and APTIM, 2018 and AMEC Earth and Environmental, 2008). The visit and references indicated that the Units are not underlain by near-surface or significant amounts of limestone and there are no known near surface karst terrain or sinkholes in the area, nor is this area of Kansas known to have near-surface karst terrain or sinkholes. Based on a review of this information and the site visit, APTIM has concluded that there are no steep slopes, terrain features, or other local geologic or geomorphologic features that could feasibly result in an unstable condition. Pertinent documents and sections of documents reviewed are provided in **Appendix B.2**.

6.3 Unstable Factors Considered: Human-made Features or Events (§257.64(b)(3))

On-site or local human-made features or events (both surface and subsurface).

APTIM visited the Units in April 2019 as well as evaluated published data and site-specific reports for the presence of on-site or local human-made features or events (both surface and subsurface), including surface and subsurface mining, extensive oil and gas extractions, and sources of rapid groundwater drawdown that could feasibly impact the Units. Documents and websites reviewed include:

- Kansas Geological Survey, Water Wells Interactive Map
- Kansas Geological Survey, Oil and Gas Wells and Fields Interactive Map
- Kansas Geological Survey, Industrial Minerals – Douglas County
- Haley & Aldrich (2020), CCR Groundwater Monitoring Network Description for the Lawrence Energy Center.

While there are records of oil and gas drilling in Douglas County, there are no known records of any surface or subsurface mining, oil and gas extractions and/or groundwater drawdowns near to the Units. APTIM concludes that, absent these features and events (both surface and subsurface), there will not be an unstable condition at the Units due to human-made activities. Pertinent documents and sections of documents reviewed are provided in **Appendix B.3** and indicate the location of the Units in relation to the known on-site or local human-made features or events (both surface and subsurface).

7.0 REFERENCES

AMEC Earth and Environmental (2008), Douglas County Multi-Jurisdictional Multi-Hazard Mitigation Plan.

APTIM (2018), Structural Stability Assessment, Inactive Units – Ash Pond Area 2, Ash Pond Area 3, and Ash Pond 4.

APTIM (2018), Initial Safety Factor Assessment, Lawrence Energy Center, Inactive Units – Ash Pond Area 2, Ash Pond Area 3, and Ash Pond 4.

Black & Veatch (2017), Lawrence Energy Center CCR Impoundment Closure Design 100% Design – January 26, 2017.

Golder Associates, Inc. (2009), Evaluation of Ash Pond Berm Stability, Westar Energy – Lawrence Energy Center.

Golder Associates, Inc. (2010), Results of Stability Analyses to Support Removal of Ash from Existing Ash Ponds at Westar Energy's Lawrence Energy Center.

Haley & Aldrich (2019), 2018 - 2019 Annual Groundwater Monitoring and Corrective Action Report, Area 2 Pond, Area 3 Pond, and Area 4 Pond.

Haley & Aldrich (2020), CCR Groundwater Monitoring Network Description for the Lawrence Energy Center.

U.S. Environmental Protection Agency (2015), Hazardous Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities, Federal Register Volume 80, No. 74 40 CFR Parts 257 and 261, April 17, 2015, unless otherwise noted.

8.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION (§§257.60(b), 257.61(b), 257.62(b), 257.63(b), 257.64(c))

The undersigned registered professional engineer is familiar with the requirements of the CCR Rule and has visited and examined the Units and/or has supervised examination of the Units and development of this report by appropriately qualified personnel. I hereby certify based on a review of available information within the facility's design, operating records, and observations, that the Units meet the requirements in §257.100(e)(2) and §§257.60(a)-257.64(a). The Units are being operated and maintained consistent with recognized and generally accepted good engineering standards and practices. This certification was prepared as required by 40 CFR Part §§257.60(b)- 257.63(b) and §257.64(c).

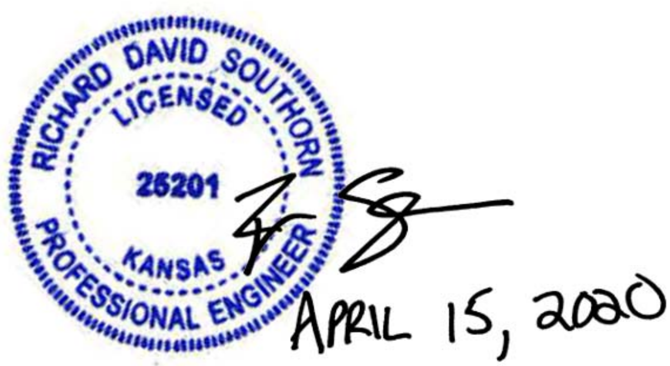
Name of Professional Engineer: Richard Southorn, P.E., P.G.

Company: APTIM

PE Registration State: Kansas

PE Registration Number: 25201

Professional Engineer Seal:



Richard Southorn

Digitally signed by Richard Southorn
Date: 2020.04.15 13:12:59 -05'00'

FIGURES

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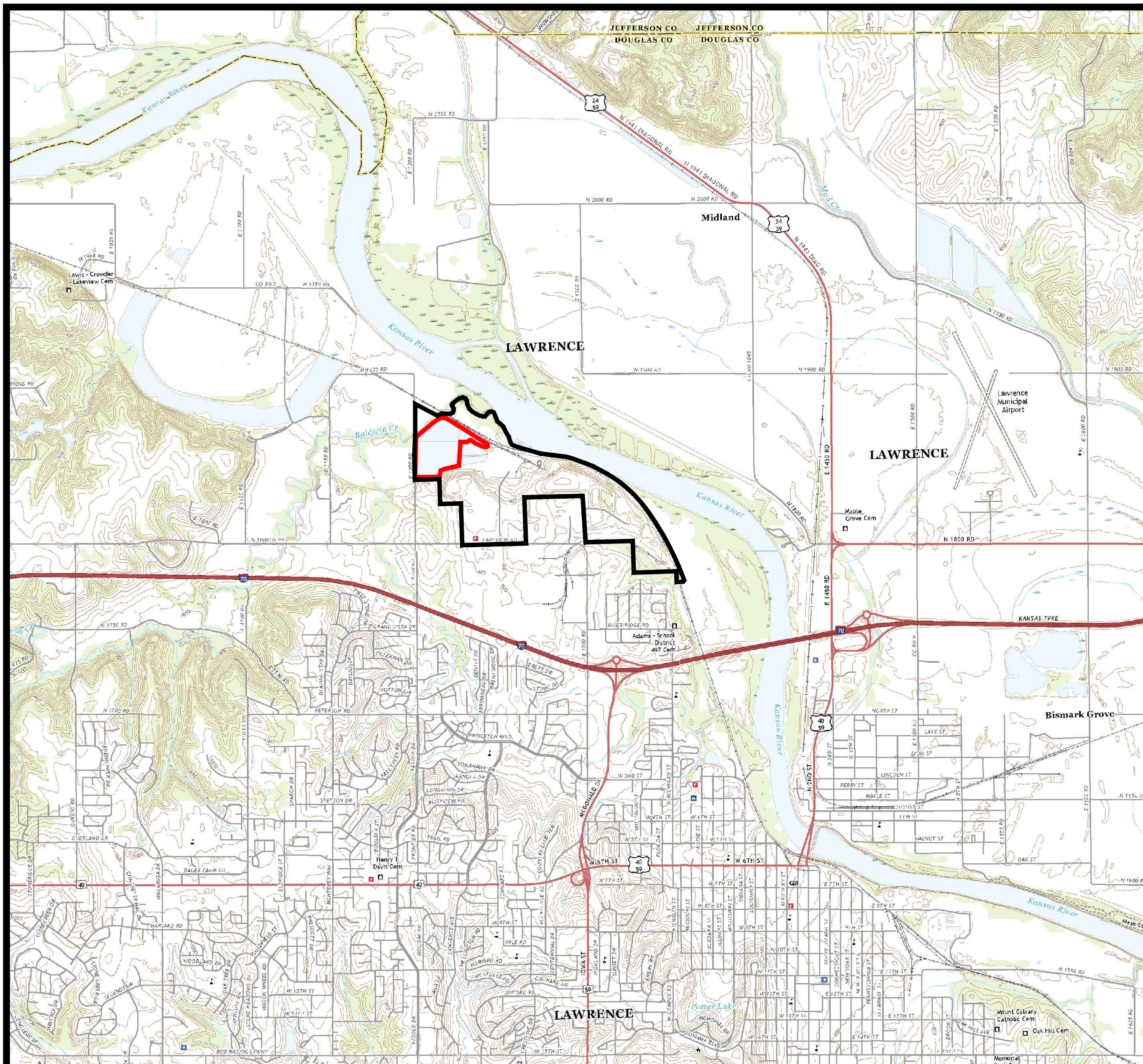

LEGEND

LAWRENCE ENERGY CENTER FACILITY BOUNDARY

UNIT BOUNDARY

N

0 5000'

GRAPHIC SCALE

NOTES

1. AERIAL TOPO OBTAINED FROM USGS 7.5-MINUTE SERIES, LAWRENCE EAST, LAWRENCE WEST, MIDLAND AND WILLIAMSTOWN QUADRANGLE, KANSAS, 2018.
2. ALL BOUNDARIES ARE APPROXIMATE.

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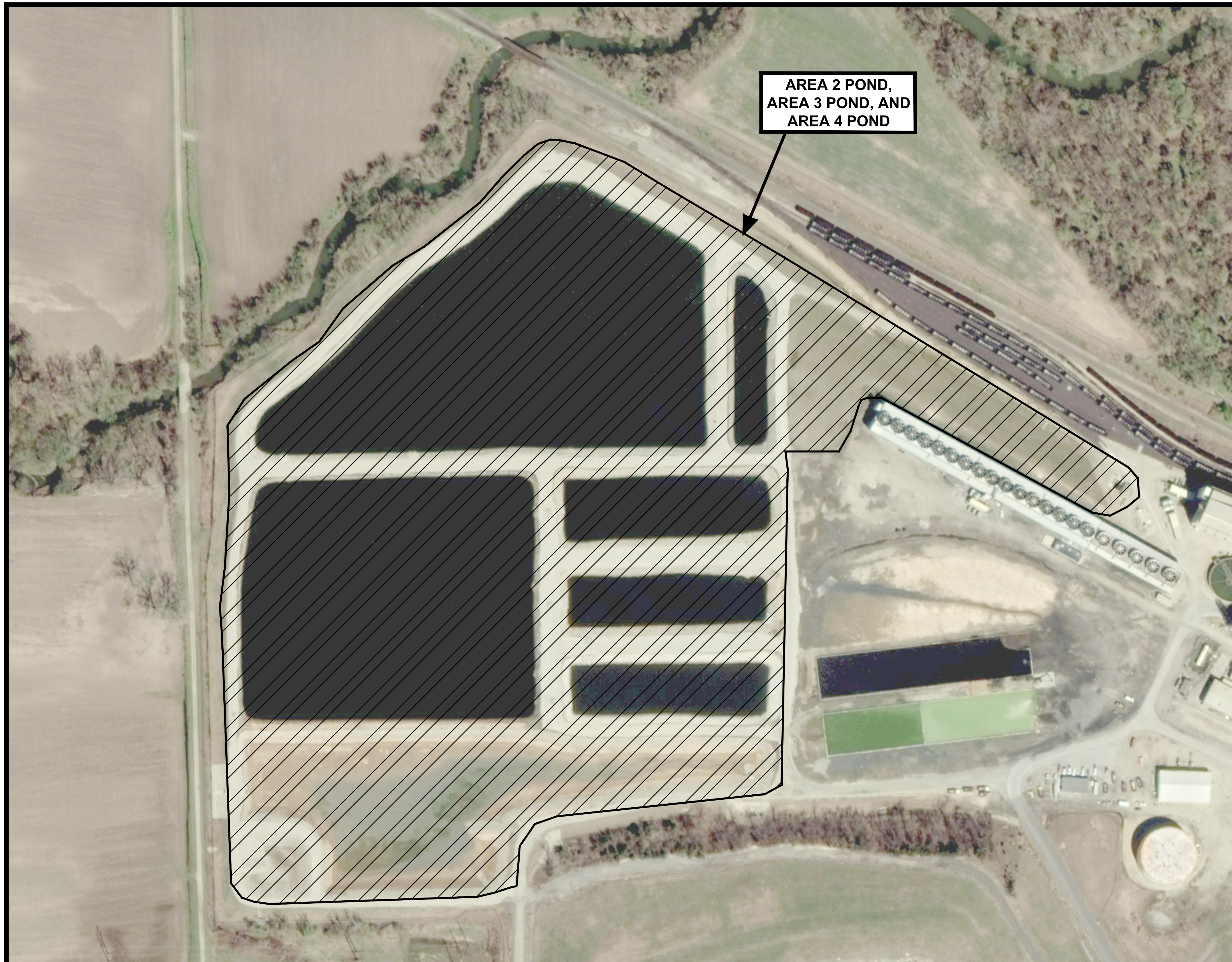
FIGURE 1
SITE LOCATION MAP

APPROVED BY:	RDS	PROJ. NO.:	631013710	DATE:	APRIL 2020



N

0 250'

GRAPHIC SCALE

LEGEND

AREAS FOUND NOT TO INCLUDE WETLANDS BASED ON INSPECTION

NOTES

1. GOOGLE EARTH IMAGE DATED APRIL 2019.
2. ALL BOUNDARY LOCATIONS ARE APPROXIMATE.
3. FOR CLARITY, NOT ALL SITE FEATURES MAY BE SHOWN.

REV. NO.	DATE	DESCRIPTION

evergy

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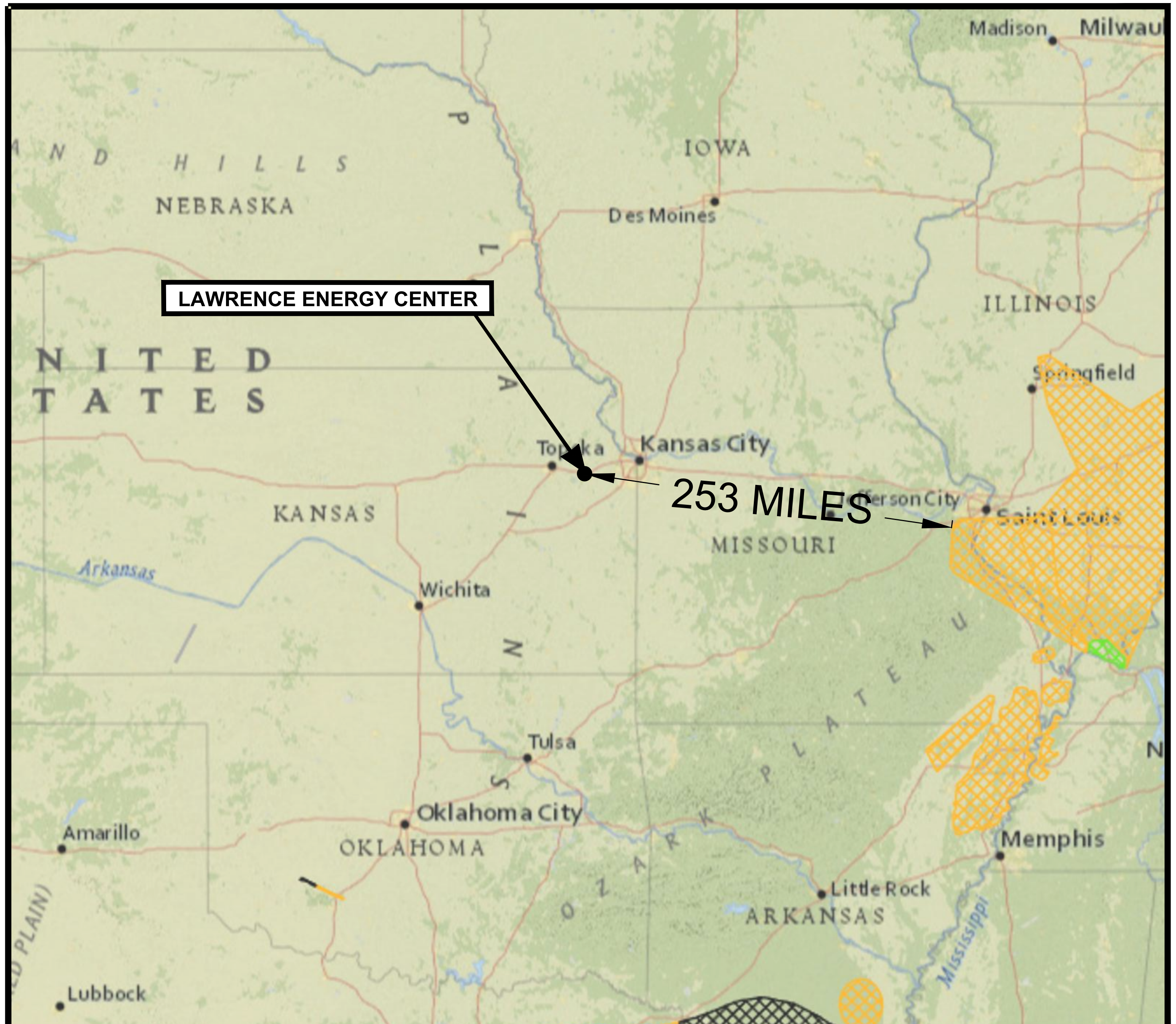
FIGURE 2
MAP OF WETLANDS INSPECTION AREA

DRAWN BY: ORC	APPROVED BY: RDS	PROJ. NO.: 631013710	DATE: APRIL 2020

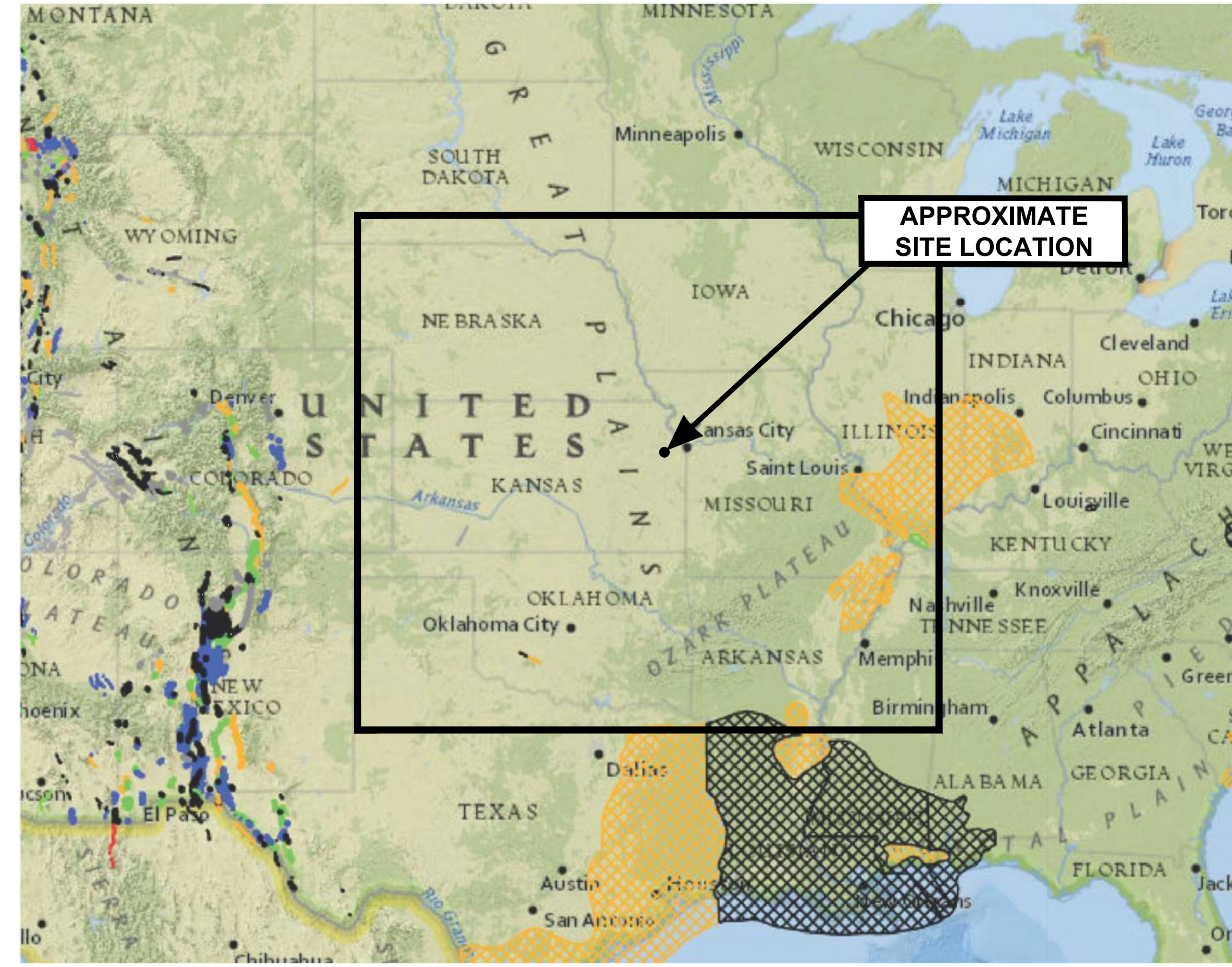
T:\AutoCAD\Projects\Westar Energy\Lawrence\Location - Inactive\Figure 2 - Wetlands V2.dwg, 4/3/2020 9:04:03 AM, AutoCAD PDF (General Documentation).pc3

USGS QUATERNARY FAULTS AND FOLDS DATABASE



0 100 MILES

GRAPHIC SCALE



0 250 MILES

GRAPHIC SCALE

Fault Areas

- Historic (< 150 years)
- Latest Quaternary (< 15,000 years)
- Late Quaternary (< 130,000 years)
- Middle and Late Quaternary (< 750,000 years)
- Undifferentiated Quaternary (< 1.6 million years)

N

NOTES

1. SOURCE: UNITED STATES GEOLOGIC SERVICE (USGS) U.S. QUATERNARY FAULTS AND FOLDS DATABASE, 2018.

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FIGURE 3
MAP OF FAULT AREAS

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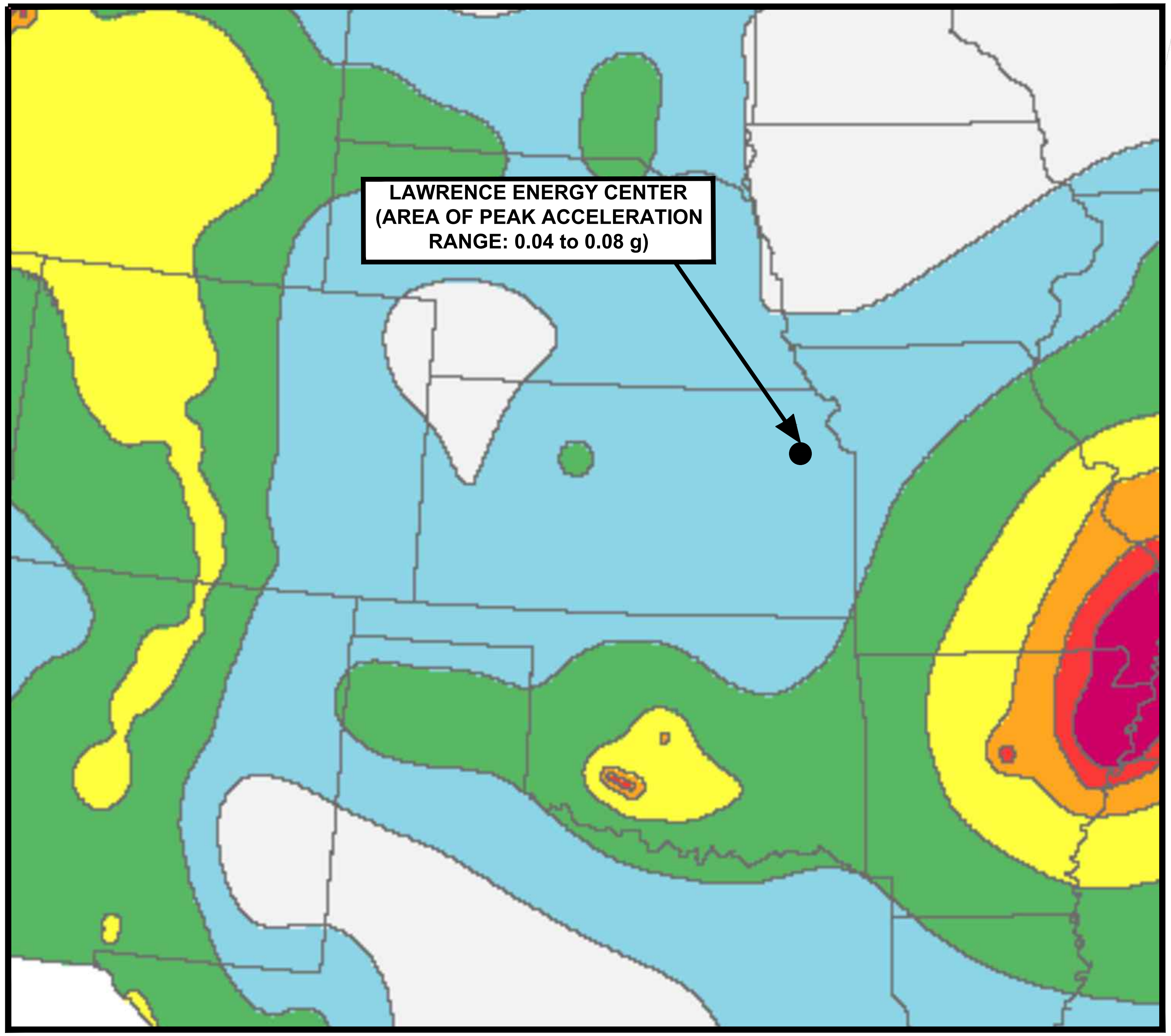
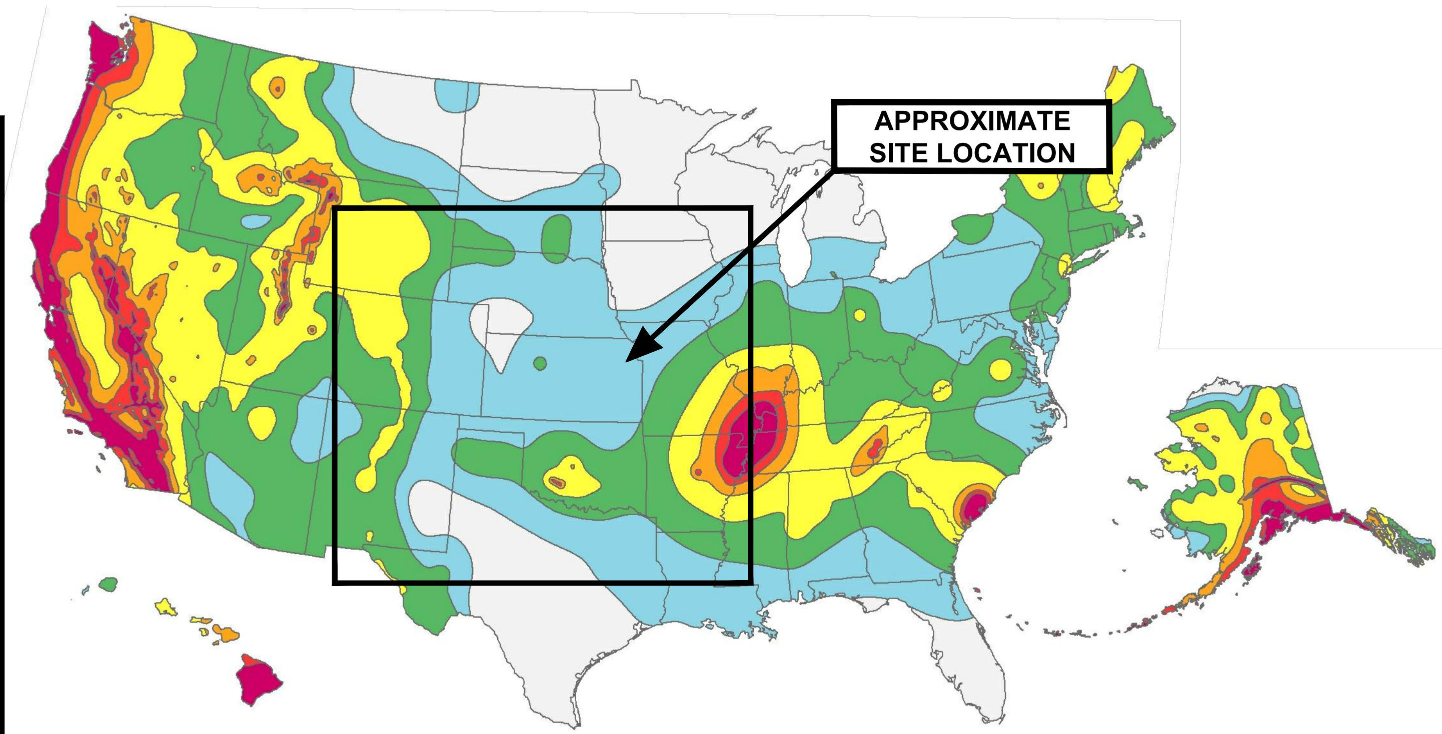
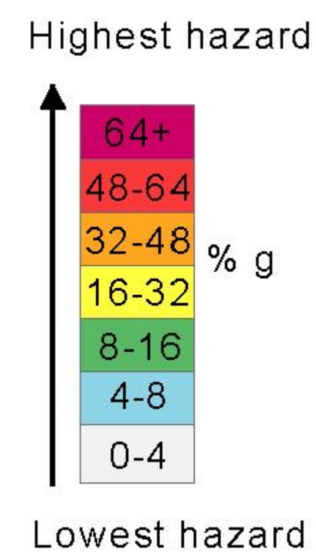
TWO-PERCENT PROBABILITY OF EXCEEDANCE IN 50 YEARS MAP OF PEAK GROUND ACCELERATION







NOTES

1. SOURCE: UNITED STATES GEOLOGIC SERVICE (USGS) WEBSITE, 2018.
2. AREAS WITH SUSPECTED NONTECTONIC EARTHQUAKES ARE NOT INCLUDED.

N

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FIGURE 4
MAP OF HORIZONTAL ACCELERATION

DRAWN BY: ORC	APPROVED BY: RDS	PROJ. NO.: 631013710	DATE: APRIL 2020

T:\AutoCAD\Projects\Westar Energy\Lawrence\Location - Inactive\Figure 4 - Seismic.dwg, 3/31/2020 1:12:54 PM, AutoCAD PDF (General Documentation).pc3

APPENDIX A

Aquifer Hydraulic Connection Demonstration

2.1.3 Confining Layer Below the Uppermost Aquifer

The Weston shale member is the confining unit underlying the Tonganoxie sandstone member. A core hole was drilled into the underlying shale and a falling head packer test was conducted at the monitoring well MW-31 location. The decision was made not to fully penetrate the underlying Weston shale member to prevent creation of a new potential pathway for downward vertical migration of fluids. Drilling was stopped when a sufficient thickness of competent shale had been intersected to facilitate completion of a representative falling head packer test. Based on observations made during drilling, the thickness of the underlying confining layer (aquitard) below the uppermost aquifer is greater than 5 feet in this area. Hydraulic conductivity of the underlying shale was calculated to be $8x10^{-7}$ cm/sec using data obtained from the falling head packer test conducted within the shale. The effective porosity was estimated to be less than 1 percent based on the falling head test data. The results of the falling head packer test indicate that the Weston shale member acts as an aquitard.

The hydrogeologic characterization data for the 847 Landfill described above are summarized in Table II.

2.1.4 847 Landfill Groundwater Monitoring System

The groundwater monitoring system at the 847 Landfill was designed to monitor the regionally extensive Tonganoxie sandstone member, which constitutes the uppermost aquifer beneath this CCR management unit. The monitoring system includes two up gradient monitoring wells and three down gradient monitoring wells. The up gradient monitoring wells, consisting of paired monitoring wells MW-32 and MW-35, are sited at locations that are representative of background groundwater quality. The down gradient monitoring wells (MW-31R, MW-33, and MW-34) are sited based on site-specific conditions at locations that are representative of groundwater flowing beneath the 847 Landfill. Published information indicates that the regional groundwater flow direction within the Tonganoxie sandstone member is toward the northeast. Although the groundwater gradient observed in the Tonganoxie sandstone member at the 847 Landfill is very shallow, the observed gradient and flow direction is towards the northeast, consistent with published information. The monitoring wells are sited at locations to detect migration of groundwater along representative flow paths in the uppermost aquifer beneath the 847 Landfill based on the groundwater flow direction. The locations of the 847 Landfill monitoring wells are shown on Figure 2. The monitoring wells were cased and the annular space sealed in conformance with KDHE water well construction standards. Monitoring well construction details are included in Table I. Monitoring well as-built diagrams and boring logs are included in Appendix A. In correspondence dated 5 July 2016, KDHE confirmed that the uppermost saturated sandstone beneath the 847 Landfill (Tonganoxie sandstone member) constitutes the uppermost aquifer beneath the 847 Landfill.

2.2 INACTIVE ASH PONDS HYDROGEOLOGIC UNITS

Geologic units that underlie the inactive Ash Ponds are roughly horizontal with a regional dip northwest and consist of poorly sorted terrace deposits consisting of reworked glacial till material that includes clay, sand, and gravel, and a shale member of the Tonganoxie member. The alluvium deposits represent Kansas River floodplain deposits and are underlain by interbedded shale and limestone strata representing transgressions and regression of marine and near-shore depositional environments. The uppermost aquifer beneath the inactive Ash Ponds consists of unconsolidated alluvium.

2.2.1 Unsaturated Material Overlying Uppermost Aquifer

The terrace deposits underlying the inactive Ash Ponds is unconfined; unsaturated material above the uppermost aquifer are composed of the same terrace deposit materials as the saturated aquifer. The thickness of the unsaturated materials observed at the inactive Ash Ponds is based on the observed static water level and corresponds to the linear distance from ground surface to the uppermost aquifer. Haley & Aldrich has made direct observation of the unsaturated material overlying the uppermost aquifer based on recent drilling (November 2017) conducted at the inactive Ash Ponds. Based on direct observations made during groundwater monitoring conducted between March 2018 and March 2019, the unsaturated material overlying the uppermost aquifer at the Site is up to 28 feet thick.

2.2.2 Uppermost Aquifer

Section 257.53 of the CCR Rule defines an aquifer as the geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of groundwater to wells or springs. The uppermost aquifer is defined in § 257.53 of the CCR Rule as the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility boundary.

The water-bearing geologic formation nearest the natural ground surface at the inactive Ash Ponds that is capable of yielding groundwater to wells or springs is the terrace deposits which consist of reworked glacial till material that includes poorly sorted clay, sand, and gravel. The terrace deposits have a local maximum thickness of approximately 55 feet. The saturated thickness of the uppermost aquifer beneath the inactive Ash Ponds is approximately 21 to 38 feet based on observations made during drilling conducted at the inactive Ash Ponds in January 2019.

Review of the Kansas Geological Survey (KGS) Water Well Completion Records (WWC-5) Database indicates that terrace deposit aquifer may be used for water supply in the vicinity of the inactive Ash Ponds. The nearest well (well #12107) listed in the KGS WWC-5 Database is a domestic well located approximately 0.6 mile to the southwest and is up gradient of the inactive Ash Ponds. Well #12107 is reported to be completed at a depth of 39 feet below ground surface, producing groundwater at a reported rate of 10 gallons per minute (gpm). The terrace deposit aquifer contains sufficient water to support low yield wells and springs and sufficient water to facilitate consistent groundwater monitoring of the saturated formation directly beneath the inactive Ash Ponds, and is therefore characterized as the uppermost aquifer beneath the inactive Ash Ponds.

The materials comprising the terrace deposits beneath the inactive Ash Ponds were observed directly during November 2017 drilling at monitoring wells MW-37 through MW-40. The drilling, completion, and testing of these monitoring wells yielded site-specific geologic data that were used in combination with other site-specific data developed during previous characterization activities and well installation activities to determine the appropriate number, depth, and spacing of the monitoring wells at the inactive Ash Ponds. Site-specific aquifer property values describing the alluvium and associated confining units developed during past and recent characterization activities are provided below.

Based on groundwater elevations measured between March 2018 and January 2019, the groundwater gradient in the upper aquifer unit is approximately 0.005 to 0.009 feet/foot and is unconfined. Groundwater flow direction is generally to the north/northwest.

Hydraulic conductivity of the uppermost aquifer was calculated using data generated from slug tests conducted on monitoring wells installed in the glacial deposits adjacent to the inactive Ash Ponds. The hydraulic conductivity of the clay deposits range from approximately $2.0x10^{-7}$ to $1.8x10^{-6}$ cm/sec (Black & Veatch, 2005). In comparison, the hydraulic conductivity within the sand and gravel deposits range from approximately $1.5x10^{-3}$ to $4.2x10^{-3}$ cm/sec (Black & Veatch, 2005). The groundwater flow rate was calculated using hydraulic conductivity values and effective porosity obtained from published sources and groundwater elevation data measured between March 2018 and January 2019. Based on estimates for similar material, effective porosity of the alluvium is estimated to be 0.1 to 0.2 percent (Fetter, 1980). The calculated groundwater flow velocity ranges from 11.6 to 182 feet/year.

The nearest gauge on the Kansas River is located at Bowersock Dam approximately 4.5 miles downstream from the inactive Ash Ponds at an elevation of 800.12 feet amsl. Flood stage at the Bowersock Dam gauge is at an elevation of 818.12 feet amsl. During 2015, the highest crest on the Kansas River at Lawrence was 20.29 feet. The historic maximum crest was 29.90 feet in 1951. The observed groundwater elevation at the inactive Ash Ponds is consistently between approximately 814 and 824 feet amsl. However, the groundwater elevations do not indicate influence by the Kansas River during flood stage. Changes in river stage are not expected to affect groundwater flow direction, groundwater gradient, or flow velocity in the glacial aquifer in response to typical season change conditions.

2.2.3 Confining Layer Below the Uppermost Aquifer

A shale unit of the Tonganoxie sandstone member comprises the confining unit underlying the uppermost aquifer at the inactive Ash Ponds. The reported thickness of the shale unit of the Tonganoxie sandstone member at other drill locations on the LEC Site is between 55 and 65 feet. The results of packer tests conducted during previous studies indicate that the hydraulic conductivity in the shale unit of the Tonganoxie sandstone member is $1x10^{-6}$ cm/sec. The effective porosity is estimated to be 1 percent. Based on the reported hydraulic conductivity, the shale unit of the Tonganoxie sandstone member is characterized as an aquitard.

The hydrogeologic characterization data for the inactive Ash Ponds described above are summarized in Table III.

2.2.4 Inactive Ash Ponds Groundwater Monitoring System

The groundwater monitoring system at the inactive Ash Ponds was designed to monitor the glacial aquifer, which constitutes the uppermost aquifer beneath this CCR management unit. The monitoring system includes one up gradient monitoring well and five down gradient monitoring wells. The up gradient monitoring well (MW-37) is sited at a location that is representative of background groundwater quality. The down gradient monitoring wells (MW-38, MW-39, MW-40, MW-K, and MW-L) are sited based on site-specific conditions at locations that are representative of groundwater flowing beneath the inactive Ash Ponds. Based on available groundwater elevation data, the groundwater flow direction is toward the north/northwest. The monitoring wells are sited at locations to detect migration of groundwater along representative flow paths in the uppermost aquifer beneath the inactive Ash Ponds based on the groundwater flow direction. The locations of the inactive Ash Ponds monitoring wells are shown on Figure 3. The monitoring wells were cased and the annular space sealed in conformance with KDHE water well construction standards. Monitoring well construction details are included in Table I. Monitoring well as-built diagrams and boring logs are included in Appendix A.

1.0 INTRODUCTION

1.1 Background

Golder Associates Inc. (Golder) has prepared this report to provide Westar Energy (Westar) with the results of Golder's site observations and stability evaluation of coal combustion product (CCP) storage facilities at Westar's Lawrence Energy Center (LEC) in Lawrence, Kansas. This report is in response to the United States Environmental Protection Agency's (EPA's) request for information under Section 104(e) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regarding impoundments storing liquid-borne CCPs. The report presents a general history of the CCP storage facilities at LEC and a description of Golder's geotechnical investigation (Section 1), the basis and results for Golder's stability analysis (Section 2), a summary of observations made by Golder while visually assessing the CCP storage facilities at LEC (Section 3), and a summary of Golder's conclusions and recommendations (Section 4).

1.2 Site History

Lawrence Energy Center is located in Douglas County, on the north edge of Lawrence, Kansas. Coal combustion products generated at LEC are temporarily staged in impoundments to facilitate dewatering. After the CCPs are dewatered, they are transported to on-site landfills for permanent disposal. Lawrence Energy Center has four staging areas that are separated by earthen embankments, as shown in Figure 1. Areas 1 and 2 were constructed in 1969, concurrent with construction of the energy generation facility, and Areas 3 and 4 were added in 1976. It is Golder's understanding that the staging areas were constructed to an engineered design. However, Westar is not in possession of the design drawings bearing a professional engineer's stamp or the construction records. The staging areas were constructed by excavation from existing grades and have not undergone engineered modifications since initial construction. Agricultural land surrounds the northwest, west, and south sides of the CCP storage facilities, and the energy generation facility and the Kansas River lie to the east and northeast.

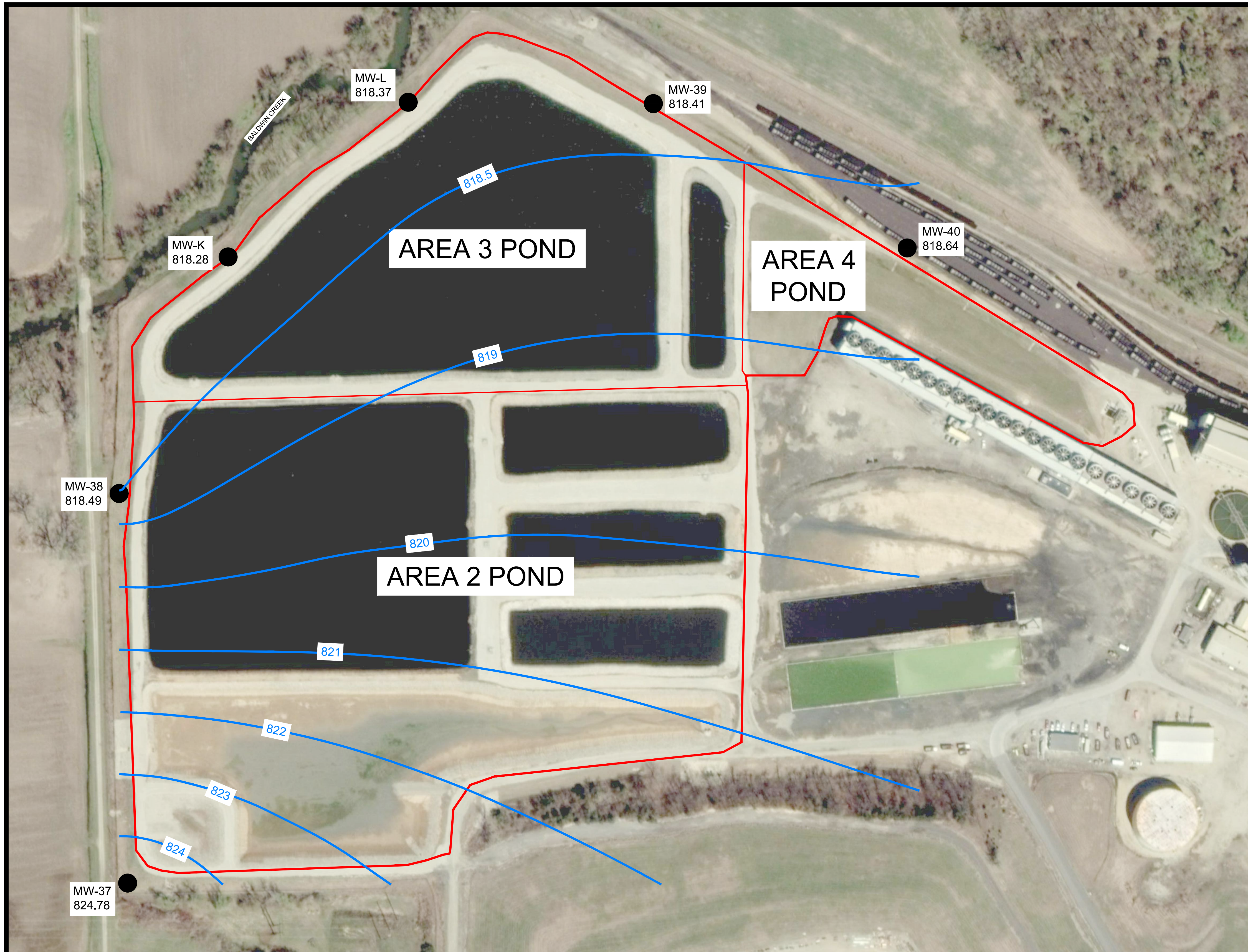
1.3 Geotechnical Investigation

Four soil borings, LEC-1, LEC-2, LEC-3, and LEC-4, were completed on October 26, 2009, at the locations shown in Figure 1 to support Golder's stability evaluation. The borehole locations were designated by Golder and Westar in areas where site topography indicated a downstream berm slope height of 12 feet or more, generally around the north and west sides of the CCP storage facilities. Boreholes were drilled near the downstream edge of the berm crest and were advanced with a truck-mounted CME drill rig using 6-inch-diameter hollow stem continuous flight augers. Relatively undisturbed samples were collected from each borehole using 2-inch-diameter thin-walled tube samplers (Shelby tubes). Soil samples were visually classified by Golder's geotechnical engineer in accordance with the Unified Soil Classification System (USCS). Berm stratigraphy was fairly consistent between boreholes and generally consisted of asphalt and bottom ash road base in the top 1 to 5 feet, underlain by low-plasticity clay (CL) and high-plasticity clay (CH) layers to the completed borehole depth. Borehole depths

ranged from 18 to 24 feet. Groundwater was not observed in boreholes drilled around the perimeter of the staging areas at LEC. The berm crest is at an elevation of 840 feet above mean sea level. Borehole logs based on field and laboratory soil classification are provided in Appendix A.

TABLE I
SUMMARY OF GROUNDWATER ELEVATIONS
Evergy Lawrence Energy Center
Inactive Area 2 Pond, Area 3 Pond, and Area 4 Pond
Lawrence, Kansas

Location		Measure Point Elevation (TOC)	Sample Date	Depth to Water (btoc)	Groundwater Elevation (ft AMSL)
Up Gradient	MW-37	833.29	3/7/2018	10.04	823.25
			5/9/2018	11.10	822.19
			7/2/2018	12.32	820.97
			8/14/2018	14.38	818.91
			10/3/2018	14.54	818.75
			11/19/2018	11.39	821.90
			1/11/2019	8.51	824.78
			3/18/2019	7.33	825.96
Down Gradient	MW-38	832.626	3/7/2018	16.11	816.52
			5/9/2018	15.98	816.65
			7/2/2018	16.43	816.20
			8/14/2018	16.84	815.79
			10/3/2018	16.69	815.94
			11/19/2018	14.56	818.07
			1/11/2019	14.14	818.49
			3/19/2019	14.29	818.34
	MW-39	830.615	3/8/2018	15.60	815.02
			5/9/2018	14.97	815.65
			7/2/2018	15.40	815.22
			8/14/2018	15.69	814.93
			10/3/2018	15.41	815.21
			11/19/2018	12.74	817.88
			1/11/2019	12.21	818.41
			3/19/2019	12.65	817.97
	MW-40	831.358	3/8/2018	16.17	815.19
			5/9/2018	15.6	815.76
			7/2/2018	16.01	815.35
			8/14/2018	16.25	815.11
			10/3/2018	16.01	815.35
			11/19/2018	13.43	817.93
			1/11/2019	12.72	818.64
			3/19/2019	13.25	818.11
	MW-K	842.600	5/10/2018	26.35	816.25
			7/2/2018	26.77	815.83
			8/14/2018	27.18	815.42
			10/3/2018	27.00	815.60
			11/19/2018	24.68	817.92
			12/12/2018	23.21	819.39
			1/11/2019	24.32	818.28
			3/19/2019	24.55	818.05
	MW-L	843.050	5/10/2018	27.24	815.81
			7/2/2018	27.63	815.42
			8/14/2018	27.96	815.09
			10/3/2018	27.73	815.32
			11/19/2018	25.17	817.88
			12/12/2018	23.64	819.41
			1/11/2019	24.68	818.37
			3/19/2019	25.08	817.97



N
0 225'
GRAPHIC SCALE

LEGEND

861 — APPROXIMATE GROUNDWATER ELEVATIONS (FT MSL) FOR 01-2019

● APPROXIMATE MONITORING WELL LOCATION

NOTES

1. GOOGLE EARTH IMAGE DATED APRIL 2019.
2. ALL PIEZOMETRIC LINES AND MONITORING WELL LOCATIONS ARE APPROXIMATE.
3. FOR CLARITY, NOT ALL SITE FEATURES MAY BE SHOWN.
4. AREA 2 POND LINER BASE ASSUMED TO BE AT 824.5 - 830 FT. MSL (BLACK & VEATCH, 2017).
5. AREA 3 POND LINER BASE ASSUMED TO BE AT 822.5 FT. MSL (BLACK & VEATCH, 2017).
6. AREA 4 POND UNDERWENT CLOSURE BY REMOVAL CONSTRUCTION, INFILLED WITH SOIL AND CLOSURE CONSTRUCTION WAS CERTIFIED COMPLETE IN 2017.

REV. NO.	DATE	DESCRIPTION

evergy

APTIM Environmental & Infrastructure, LLC

APTIM

LAWRENCE ENERGY CENTER
1250 N. 1800 RD. LAWRENCE, KANSAS

AREA 2 POND, AREA 3 POND, AND AREA 4 POND
JANUARY 2019 GROUNDWATER CONTOUR MAP

DRAWN BY:	ORC	APPROVED BY:	RDS	PROJ. NO.:	631013710	DATE:	APRIL 2020

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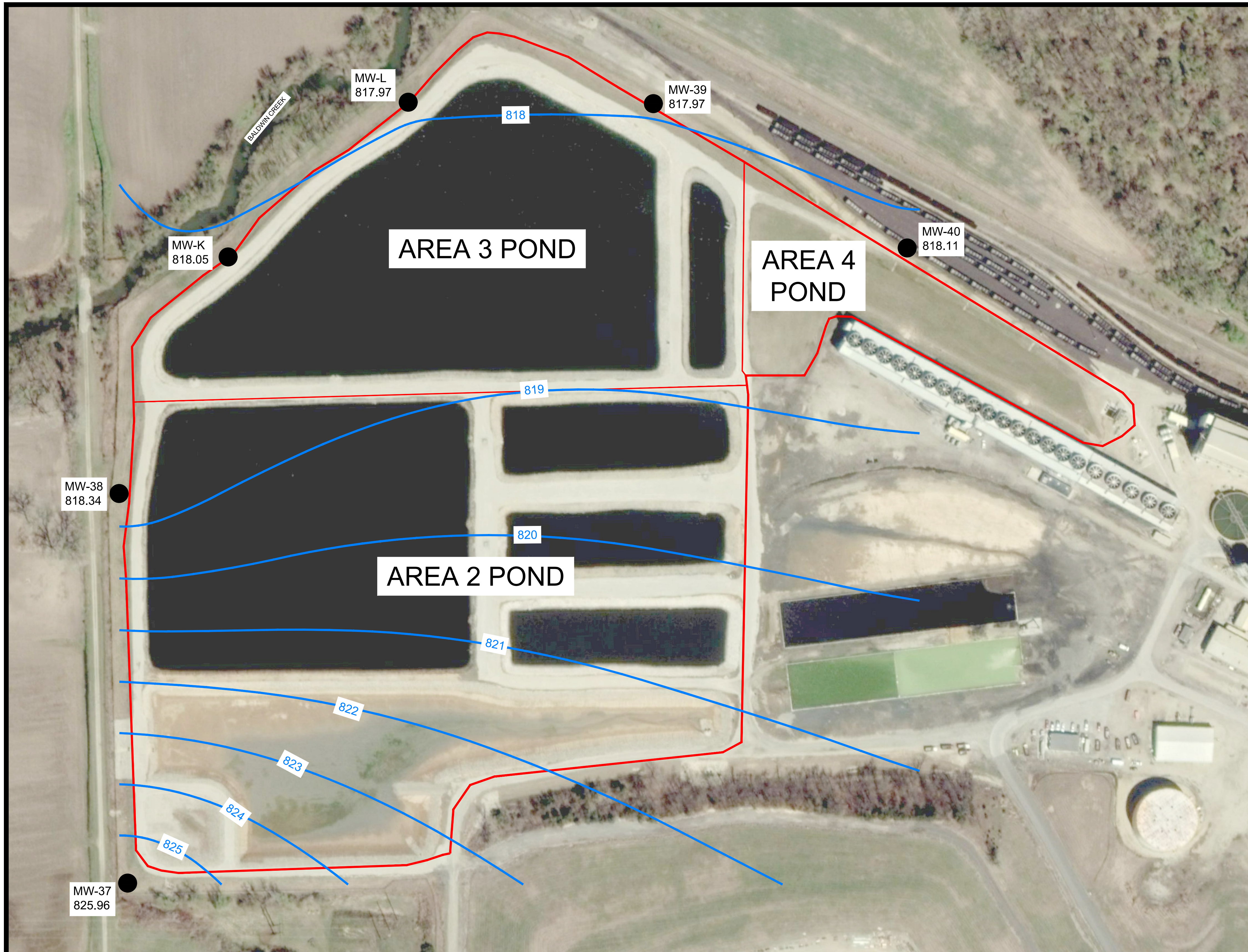

N

0 225'

GRAPHIC SCALE

LEGEND

861 — APPROXIMATE GROUNDWATER ELEVATIONS (FT MSL) FOR 03-2019

● APPROXIMATE MONITORING WELL LOCATION

NOTES

1. GOOGLE EARTH IMAGE DATED APRIL 2019.
2. ALL PIEZOMETRIC LINES AND MONITORING WELL LOCATIONS ARE APPROXIMATE.
3. FOR CLARITY, NOT ALL SITE FEATURES MAY BE SHOWN.
4. AREA 2 POND LINER BASE ASSUMED TO BE AT 824.5 - 830 FT. MSL (BLACK & VEATCH, 2017).
5. AREA 3 POND LINER BASE ASSUMED TO BE AT 822.5 FT. MSL (BLACK & VEATCH, 2017).
6. AREA 4 POND UNDERWENT CLOSURE BY REMOVAL CONSTRUCTION, INFILLED WITH SOIL AND CLOSURE CONSTRUCTION WAS CERTIFIED COMPLETE IN 2017.

REV. NO.	DATE	DESCRIPTION

evergy

APTIM

APTIM Environmental & Infrastructure, LLC

LAWRENCE ENERGY CENTER
1250 N. 1800 RD. LAWRENCE, KANSAS

AREA 2 POND, AREA 3 POND, AND AREA 4 POND
MARCH 2019 GROUNDWATER CONTOUR MAP

DRAWN BY: ORC	APPROVED BY: RDS	PROJ. NO.: 631013710	DATE: APRIL 2020

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APPENDIX B

Unstable Areas

APPENDIX B.1

Differential Settling

APTIM

2.2.1 Unsaturated Material Overlying Uppermost Aquifer

The terrace deposits underlying the inactive Ash Ponds is unconfined; unsaturated material above the uppermost aquifer are composed of the same terrace deposit materials as the saturated aquifer. The thickness of the unsaturated materials observed at the inactive Ash Ponds is based on the observed static water level and corresponds to the linear distance from ground surface to the uppermost aquifer. Haley & Aldrich has made direct observation of the unsaturated material overlying the uppermost aquifer based on recent drilling (November 2017) conducted at the inactive Ash Ponds. Based on direct observations made during groundwater monitoring conducted between March 2018 and March 2019, the unsaturated material overlying the uppermost aquifer at the Site is up to 28 feet thick.

2.2.2 Uppermost Aquifer

Section 257.53 of the CCR Rule defines an aquifer as the geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of groundwater to wells or springs. The uppermost aquifer is defined in § 257.53 of the CCR Rule as the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility boundary.

The water-bearing geologic formation nearest the natural ground surface at the inactive Ash Ponds that is capable of yielding groundwater to wells or springs is the terrace deposits which consist of reworked glacial till material that includes poorly sorted clay, sand, and gravel. The terrace deposits have a local maximum thickness of approximately 55 feet. The saturated thickness of the uppermost aquifer beneath the inactive Ash Ponds is approximately 21 to 38 feet based on observations made during drilling conducted at the inactive Ash Ponds in January 2019.

Review of the Kansas Geological Survey (KGS) Water Well Completion Records (WWC-5) Database indicates that terrace deposit aquifer may be used for water supply in the vicinity of the inactive Ash Ponds. The nearest well (well #12107) listed in the KGS WWC-5 Database is a domestic well located approximately 0.6 mile to the southwest and is up gradient of the inactive Ash Ponds. Well #12107 is reported to be completed at a depth of 39 feet below ground surface, producing groundwater at a reported rate of 10 gallons per minute (gpm). The terrace deposit aquifer contains sufficient water to support low yield wells and springs and sufficient water to facilitate consistent groundwater monitoring of the saturated formation directly beneath the inactive Ash Ponds, and is therefore characterized as the uppermost aquifer beneath the inactive Ash Ponds.

The materials comprising the terrace deposits beneath the inactive Ash Ponds were observed directly during November 2017 drilling at monitoring wells MW-37 through MW-40. The drilling, completion, and testing of these monitoring wells yielded site-specific geologic data that were used in combination with other site-specific data developed during previous characterization activities and well installation activities to determine the appropriate number, depth, and spacing of the monitoring wells at the inactive Ash Ponds. Site-specific aquifer property values describing the alluvium and associated confining units developed during past and recent characterization activities are provided below.

Based on groundwater elevations measured between March 2018 and January 2019, the groundwater gradient in the upper aquifer unit is approximately 0.005 to 0.009 feet/foot and is unconfined. Groundwater flow direction is generally to the north/northwest.

TABLE III
HYDROGEOLOGIC CHARACTERIZATION DATA FOR
THE INACTIVE ASH PONDS CCR MANAGEMENT UNIT
EVERGY KANSAS CENTRAL, INC.
LAWRENCE ENERGY CENTER
LAWRENCE, KANSAS

Unsaturated Material Overlaying Uppermost Aquifer Characteristics	
Lithology (Terrace Deposits)	clay, sand, and gravel
Unsaturated Thickness (Terrace Deposits)	Up to 28 feet
Hydraulic Conductivity (Terrace Deposits)	$1.5x10^{-3}$ to $4.2\ x10^{-3}$ cm/sec[b]
Uppermost Aquifer Characteristics	
Lithology (Terrace Deposits)	clay, sand, and gravel
Aquifer Thickness (Terrace Deposits)	21 to 38 feet
Groundwater Gradient (Terrace Deposits)	0.005 to 0.009 feet/foot[a]
Hydraulic Conductivity (Terrace Deposits)	$1.5x10^{-3}$ to $4.2\ x10^{-3}$ cm/sec[b]
Groundwater Flow Rate (Terrace Deposits)	11.6 to 182 feet/year
Groundwater Flow Direction (Terrace Deposits)	North/northwest
Effective Porosity (Terrace Deposits)	0.1 to 0.2
Confining Unit Below the Uppermost Aquifer Characteristics	
Lithology (shale unit of Tonganoxie sandstone member)	shale
Unit Thickness (shale unit of Tonganoxie sandstone member)	>5 feet
Hydraulic Conductivity (shale unit of Tonganoxie sandstone member)	$1x10^{-6}$ cm/sec[b]
Effective Porosity (shale unit of Tonganoxie sandstone member)	1

Notes:
[a] = Data based on March 2018 to January 2019 groundwater elevation data
[b] = Hydraulic conductivity value from Black & Veatch, 2005
cm/sec = centimeters per second

3.0 PERIODIC STRUCTURAL STABILITY ASSESSMENT (§257.73(d))

The available information for the Area 2, 3, and 4 Ponds was provided to and reviewed by APTIM for this Assessment:

- Annual Inspection Report Lawrence Energy Center Inactive Units – Ash Pond Area 2, Ash Pond Area 3, Ash Pond 4, CB&I, June 2017.
- Coal Combustion Waste Impoundment Round 7 – Dike Assessment Report, Dewberry & Davis, LLC, March 2011.
- LEC Survey, Professional Engineering Consultants (PEC), June 2016.
- NPDES Permit No. I-KS-31-PO09

Based on the available information and the site visit conducted May 15, 2017 by Richard Southorn, a professional engineer with APTIM, the following Assessment has been conducted to determine whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices in accordance with 40 CFR §257.73(d).

3.1 Foundation and Abutment Stability (§257.73(d)(1)(i))

Eight borings (LEC-1 through LEC-8) were drilled along the perimeter impoundment dike crest in October 2009 as part of the stability evaluation completed by Golder Associates in December 2009. The borings ranged from 13 feet to 24 feet below the ground surface. The borings show the perimeter dike consists of an asphalt and bottom ash road base underlain by clay and silty clay layers. Groundwater was not encountered in any of the borings.

The perimeter dike is has no abutments and is a continuous feature that ties into natural grades. Based on the results of analyses conducted by Golder Associates, boring logs, lab results, and the observations obtained during the 2017 site visit, it was determined that the perimeter dike is constructed of the same materials that underlay it. These materials include silty clays. Therefore, it is APTIM's professional opinion that the perimeter dike is located on a stable foundation. A Safety Factor Assessment, which is required under 40 CFR §257.73(e), was not completed as part of this Assessment and will be completed under a separate cover.

3.2 Slope Protection (§257.73(d)(1)(ii))

The Area 2, 3, and 4 Ponds are currently undergoing closure and are being repurposed. All pond side slopes will be lined with rip-rap for slope protection of the clay liner, with the exception of portions of the Clear Pond and Pond 404 which will remain vegetated. The rip-rap will extend from the top of the slope for a minimum of ten feet.

3.3 Dikes Compaction (§257.73(d)(1)(iii))

Based on borings obtained in 2009, it can be determined the perimeter dike is primarily constructed of silty clay. The silty clay was obtained from the excavation of the Area 2, 3, and 4 Ponds during the initial pond construction. It has been noted in a previous site investigation conducted by Golder Associates that the perimeter dike crest appears to be

4.4 Summary of Findings

Table 3 below summarizes the initial safety factor assessment results for the perimeter dike and Area 2, 3, and 4 Ponds. It confirms that the calculated factors of safety meet or exceed the required factors of safety by 40 CFR §257.73(e). All four cases were calculated for both circular and block slip surfaces.

The Area 2 and 3 Ponds are currently in the process of being dewatered and closed. The Area 2, 3, and 4 Ponds are not required by the CCR Rule to be assessed during closure conditions.

Table 3
Initial Safety Factor Assessment Results

Analysis	Calculated Minimum Factor of Safety		Required Minimum Factor of Safety (§257.73(e))
	Circular	Block	
Long-term, maximum storage pool loading	2.366	2.411	≥1.50
Maximum surcharge pool loading	2.208	2.242	≥1.40
Seismic Loading	2.115	2.065	≥1.00
Soil Liquefaction	N/A[1]	N/A[1]	≥1.20
Drawdown Conditions	2.115	2.128	N/A[2]

Notes:
(1) Perimeter dike is not constructed of soils that are susceptible to liquefaction (i.e. typically saturated granular soils).
(2) Analysis not required and therefore there is no minimum factor of safety that needs to be met, however it has been assumed that a factor of safety of 1.3 should be met based on industry standards.

1.0 INTRODUCTION

1.1 Background

Golder Associates Inc. (Golder) has prepared this report to provide Westar Energy (Westar) with the results of Golder's site observations and stability evaluation of coal combustion product (CCP) storage facilities at Westar's Lawrence Energy Center (LEC) in Lawrence, Kansas. This report is in response to the United States Environmental Protection Agency's (EPA's) request for information under Section 104(e) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regarding impoundments storing liquid-borne CCPs. The report presents a general history of the CCP storage facilities at LEC and a description of Golder's geotechnical investigation (Section 1), the basis and results for Golder's stability analysis (Section 2), a summary of observations made by Golder while visually assessing the CCP storage facilities at LEC (Section 3), and a summary of Golder's conclusions and recommendations (Section 4).

1.2 Site History

Lawrence Energy Center is located in Douglas County, on the north edge of Lawrence, Kansas. Coal combustion products generated at LEC are temporarily staged in impoundments to facilitate dewatering. After the CCPs are dewatered, they are transported to on-site landfills for permanent disposal. Lawrence Energy Center has four staging areas that are separated by earthen embankments, as shown in Figure 1. Areas 1 and 2 were constructed in 1969, concurrent with construction of the energy generation facility, and Areas 3 and 4 were added in 1976. It is Golder's understanding that the staging areas were constructed to an engineered design. However, Westar is not in possession of the design drawings bearing a professional engineer's stamp or the construction records. The staging areas were constructed by excavation from existing grades and have not undergone engineered modifications since initial construction. Agricultural land surrounds the northwest, west, and south sides of the CCP storage facilities, and the energy generation facility and the Kansas River lie to the east and northeast.

1.3 Geotechnical Investigation

Four soil borings, LEC-1, LEC-2, LEC-3, and LEC-4, were completed on October 26, 2009, at the locations shown in Figure 1 to support Golder's stability evaluation. The borehole locations were designated by Golder and Westar in areas where site topography indicated a downstream berm slope height of 12 feet or more, generally around the north and west sides of the CCP storage facilities. Boreholes were drilled near the downstream edge of the berm crest and were advanced with a truck-mounted CME drill rig using 6-inch-diameter hollow stem continuous flight augers. Relatively undisturbed samples were collected from each borehole using 2-inch-diameter thin-walled tube samplers (Shelby tubes). Soil samples were visually classified by Golder's geotechnical engineer in accordance with the Unified Soil Classification System (USCS). Berm stratigraphy was fairly consistent between boreholes and generally consisted of asphalt and bottom ash road base in the top 1 to 5 feet, underlain by low-plasticity clay (CL) and high-plasticity clay (CH) layers to the completed borehole depth. Borehole depths

ranged from 18 to 24 feet. Groundwater was not observed in boreholes drilled around the perimeter of the staging areas at LEC. The berm crest is at an elevation of 840 feet above mean sea level. Borehole logs based on field and laboratory soil classification are provided in Appendix A.

2.0 STABILITY EVALUATION

2.1 Slope Geometries

Golder developed two cross sections to evaluate the stability of the embankments surrounding the staging areas at LEC using site topography provided by Westar. The locations of the cross sections are shown in Figure 2. Based on site topography and visual assessment, Golder selected cross section locations to represent the critical slopes for stability analysis of the CCP storage facilities at LEC. Golder conservatively assumed that the staging areas were filled with CCPs to an elevation two feet below the berm crest and that ponded water reached the same elevation as the berm crest. The depth of CCP storage facilities was assumed to be 20 feet based on information provided by Westar (Terracon Consultants, Inc. 2009). Golder conservatively used a 0.5 (horizontal) to 1 (vertical) slope ratio for the upstream berm slopes.

2.2 Engineering Parameters

Golder collected relatively undisturbed soil samples from each borehole for geotechnical testing to determine engineering parameters for use in the slope stability analysis. Geotechnical test results are presented in Appendix B. For purposes of the stability analysis, Golder represented distinct soil layers and assigned engineering parameters based on field soil classification and laboratory test data, primarily plasticity index (PI), as shown in Figure 3. Golder assigned unit weights to each soil layer based on density testing of undisturbed soil samples collected at LEC. Golder assigned effective stress strength parameters to each soil layer based on the results of consolidated-undrained triaxial testing of undisturbed samples collected at LEC. Golder assigned a unit weight to CCPs based on previous experience and assumed that CCPs within the staging areas contribute no strength. Engineering parameters assigned to soil layers are summarized in Table 1.

TABLE 1

SUMMARY OF STABILITY ANALYSIS ENGINEERING PARAMETERS

Material	Unit Weight	Strength Parameters	
		Friction Angle	Cohesion
LEC-2 Sample 1 (PI=39)	116 pcf	26 degrees	260 psf
LEC-3 Sample 3 (PI=50)	116 pcf	28 degrees	410 psf
Coal combustion products	85 pcf	No strength	

2.3 Groundwater Information

Groundwater was not observed in any of the four boreholes drilled around the perimeter of the staging areas at LEC. Therefore, to develop phreatic surfaces within each cross section for stability analysis based on effective stresses, Golder used a straight line between the upstream edge of the berm crest and the static groundwater level at the approximate borehole location, as shown in Figure 3. The static

Golder Associates

TECHNICAL MEMORANDUM

Date: January 15, 2010 | **Project No.:** 093-81765.2

To: Andy Evans, PE | **Company:** Westar Energy

From: Jason Obermeyer, PE

cc: Ron Jorgenson | **Email:** jobermeyer@golder.com

RE: RESULTS OF STABILITY ANALYSES TO SUPPORT REMOVAL OF ASH FROM EXISTING ASH PONDS AT WESTAR ENERGY'S LAWRENCE ENERGY CENTER

Golder Associates Inc. (Golder) has prepared this technical memorandum to provide Westar Energy (Westar) with the results of stability analyses to support ash removal from existing ash ponds at Lawrence Energy Center in Lawrence, Kansas. Recommendations are provided herein for embankment geometries to be left in place, both temporarily and permanently.

1.0 GEOTECHNICAL INVESTIGATION

Eight soil borings, LEC-1 to LEC-8, were completed on October 26, 2009, at the locations shown in Figure 1 to support Golder's stability evaluation. The borehole locations were designated by Golder and Westar. Boreholes were advanced with a truck-mounted CME drill rig using 6-inch-diameter hollow stem continuous flight augers. Relatively undisturbed samples were collected from several boreholes using 2-inch-diameter thin-walled tube samplers (Shelby tubes). Soil samples were visually classified by Golder's geotechnical engineer in accordance with the Unified Soil Classification System (USCS). Borehole depths ranged from 13 to 24 feet. Borehole logs based on field and laboratory soil classification are provided in Attachment A.

The embankments consist primarily of silty clay and bottom ash. Golder also found soft saturated clay in LEC-7 and LEC-8. Photographs from the geotechnical investigation are presented in Attachment B.

2.0 STABILITY EVALUATION

Golder performed the stability analyses using SLIDE, a two-dimensional slope stability computer program developed by Rocscience Inc. (2009). Factors of safety for static conditions were computed for circular failure surfaces using Spencer's method for force and moment equilibrium.

2.1 Cross Sections

Golder developed cross sections for the stability analyses at locations where ash removal will result in an excavated slope approximately 20 feet in height, typically with impounded ash or water on the upstream side, based on Westar's phased ash removal sequence as provided in the Request for Proposal dated October 21, 2009 (Sketches #2 to #5). Golder performed stability analyses for the following cross sections, the locations of which are depicted in Figures 2 to 5:

Golder Associates Inc.
44 Union Blvd., Suite 300
Lakewood, CO 80228 USA
Tel: (303) 980-0540 Fax: (303) 985-2080 www.golder.com

- 1A, 1B, 1C, and 1D – These four cross sections are associated with the first phase of ash removal, as shown on Sketch #2
- 2A, 2B, 2C, and 2D – These four cross sections are associated with the second phase of ash removal, as shown on Sketch #3
- 3A, 3B, and 3C – These three cross sections are associated with the third phase of ash removal, as shown on Sketch #4.
- 4A, 4B, and 4C – These three cross sections represent the conditions to be left in place following completion of ash removal, as shown on Sketch #5

Golder assumed the depth of ash removal to be 20 feet, based on borehole logs provided by Westar (Terracon Consultants, Inc. 2009a). Golder conservatively assumed the upstream slopes of existing ash pond embankments to be sloped at 0.5 horizontal (H) to 1 vertical (V).

2.2 Engineering Parameters

Golder collected relatively undisturbed soil samples from several boreholes for geotechnical testing to determine engineering parameters for use in the slope stability analyses. Geotechnical test results are presented in Attachment C. For purposes of the stability analyses, Golder represented distinct material layers based primarily on the stratigraphy observed in nearby boreholes, as summarized in Table 1.

TABLE 1
BASIS FOR STRATIGRAPHY USED IN STABILITY ANALYSES

Cross Section	Basis for Assumed Stratigraphy
1A	Borehole LEC-6
1B	Borehole LEC-5
1C	Embankment material (temporary berm)
1D	Borehole LEC-7
2A	Borehole LEC-5
2B	Embankment material (temporary berm)
2C	Borehole LEC-8
2D	Embankment material (temporary berm)
3A	Borehole LEC-7
3B	Borehole LEC-7
3C	Borehole LEC-7
4A	Borehole LEC-6
4B	Borehole LEC-5
4C	Borehole LEC-7

Golder assigned engineering parameters to stratigraphic layers based on field soil classification and laboratory test data. Golder assigned unit weights and strength parameters to silty clay layers based on density testing and consolidated-undrained triaxial testing of an undisturbed soil sample collected at LEC. Golder assigned unit weights and strength parameters to clayey sand layers based on previous experience with similar materials. Golder assigned unit weights and strength parameters to layers consisting primarily of bottom ash based on the results of direct shear testing of recompacted bottom ash collected at LEC by others (Terracon Consultants, Inc. 2009b). Golder reinterpreted these results as appropriate for the relatively low normal stresses in the ash pond embankments, as shown in Attachment D. Golder assigned unit weights and strength parameters to competent ash layers based on previous experience with similar materials that have been placed using appropriate embankment construction techniques, including moisture conditioning and compaction to achieve at least 95 percent of the standard Proctor maximum dry unit weight. Strength characteristics of these materials can vary significantly, and project-specific strength testing should be performed to confirm the assumptions made in these analyses if a combination of bottom ash, fly ash, and/or soil will be used in embankment construction. Golder assigned a unit weight to soft saturated clay layers based on previous experience with similar materials and assigned an undrained strength based on published data for soft clays (e.g. Terzaghi and Peck 1967). Golder assigned a unit weight to impounded ash based on previous experience with similar materials and assumed that ash within the ash ponds is saturated and contributes no strength. Engineering parameters used in the slope stability analyses are summarized in Table 2.

TABLE 2

SUMMARY OF ENGINEERING PARAMETERS USED IN STABILITY ANALYSES

Material	Unit Weight	Strength Parameters			
		Total Stress (Undrained)		Effective Stress (Drained)	
		Friction Angle	Cohesion	Friction Angle	Cohesion
Silty clay	116 pcf	17 degrees	260 psf	26 degrees	260 psf
Clayey sand[1]	125 psf	--	--	35 degrees	0 psf
Bottom ash[1]	92 psf	--	--	37 degrees	0 psf
Competent ash[2]	92 psf	20 degrees	200 psf	30 degrees	200 psf
Saturated soft clay[3]	90 pcf	0 degrees	250 psf	--	--
Impounded ash	85 pcf	No strength			

2.3 Piezometric Line

Based on historic (Geotechnical Services Inc. 1999) and observed piezometric levels in and around the ash pond embankments, dewatering will likely be necessary to facilitate removal of ash to a depth of approximately 20 feet. Accordingly, Golder assumed the piezometric line during ash removal to be a straight line between the upstream edge of the berm crest and the downstream toe of the berm. Golder assumed ash ponds in operation to be filled with saturated ash to within 2 feet of the berm crest. Golder assumed areas containing water to be filled to within 2 feet of the berm crest.

[1] Based on visual observation, clayey sand and bottom ash layers are assumed to consist of free-draining materials that will exhibit drained strength during and after ash removal.

[2] Competent ash may consist of a mixture of bottom ash, fly ash, and/or clay that will achieve the strength parameters indicated in Table 1 when compacted. Golder is not aware of and has not performed strength testing to confirm the strength parameters used in the stability analyses. If ash will be used to construct temporary embankments, Golder recommends performing a consolidated-undrained triaxial test with pore pressure measurement on a reconstituted sample of the proposed ash mixture to confirm that the required strength parameters will be achieved.

[3] Saturated soft clay layers are assumed to consist of a material that drains slowly and will exhibit undrained strength during ash removal and throughout the relevant period of time following ash removal.

EVALUATION OF ASH POND BERMS AT WESTAR ENERGY'S LAWRENCE ENERGY CENTER
SUMMARY OF LABORATORY GEOTECHNICAL TEST DATA

Borehole	Sample	Depth	USCS	Dry Unit Weight	Moisture Content	Liquid Limit	Plasticity Limit	Plasticity Index	Friction Angle	Cohesion
LEC-1	1	13-15'	CL	94 pcf	28%	46	20	26		
LEC-2	1	8-10'	CH	93 pcf	25%	61	22	39	26 deg	250 psf
LEC-3	3	18-20'	CH	91 pcf	27%	74	24	50	28 deg	410 psf
LEC-4	1	8-10'	CL	106 pcf	21%	41	18	23		
LEC-4	2	13-15'			26%					
LEC-4	3	18-20'			27%					

APPENDIX B.2

Geologic/Geomorphologic Features Documentation

1.0 INTRODUCTION

1.1 Background

Golder Associates Inc. (Golder) has prepared this report to provide Westar Energy (Westar) with the results of Golder's site observations and stability evaluation of coal combustion product (CCP) storage facilities at Westar's Lawrence Energy Center (LEC) in Lawrence, Kansas. This report is in response to the United States Environmental Protection Agency's (EPA's) request for information under Section 104(e) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regarding impoundments storing liquid-borne CCPs. The report presents a general history of the CCP storage facilities at LEC and a description of Golder's geotechnical investigation (Section 1), the basis and results for Golder's stability analysis (Section 2), a summary of observations made by Golder while visually assessing the CCP storage facilities at LEC (Section 3), and a summary of Golder's conclusions and recommendations (Section 4).

1.2 Site History

Lawrence Energy Center is located in Douglas County, on the north edge of Lawrence, Kansas. Coal combustion products generated at LEC are temporarily staged in impoundments to facilitate dewatering. After the CCPs are dewatered, they are transported to on-site landfills for permanent disposal. Lawrence Energy Center has four staging areas that are separated by earthen embankments, as shown in Figure 1. Areas 1 and 2 were constructed in 1969, concurrent with construction of the energy generation facility, and Areas 3 and 4 were added in 1976. It is Golder's understanding that the staging areas were constructed to an engineered design. However, Westar is not in possession of the design drawings bearing a professional engineer's stamp or the construction records. The staging areas were constructed by excavation from existing grades and have not undergone engineered modifications since initial construction. Agricultural land surrounds the northwest, west, and south sides of the CCP storage facilities, and the energy generation facility and the Kansas River lie to the east and northeast.

1.3 Geotechnical Investigation

Four soil borings, LEC-1, LEC-2, LEC-3, and LEC-4, were completed on October 26, 2009, at the locations shown in Figure 1 to support Golder's stability evaluation. The borehole locations were designated by Golder and Westar in areas where site topography indicated a downstream berm slope height of 12 feet or more, generally around the north and west sides of the CCP storage facilities. Boreholes were drilled near the downstream edge of the berm crest and were advanced with a truck-mounted CME drill rig using 6-inch-diameter hollow stem continuous flight augers. Relatively undisturbed samples were collected from each borehole using 2-inch-diameter thin-walled tube samplers (Shelby tubes). Soil samples were visually classified by Golder's geotechnical engineer in accordance with the Unified Soil Classification System (USCS). Berm stratigraphy was fairly consistent between boreholes and generally consisted of asphalt and bottom ash road base in the top 1 to 5 feet, underlain by low-plasticity clay (CL) and high-plasticity clay (CH) layers to the completed borehole depth. Borehole depths

ranged from 18 to 24 feet. Groundwater was not observed in boreholes drilled around the perimeter of the staging areas at LEC. The berm crest is at an elevation of 840 feet above mean sea level. Borehole logs based on field and laboratory soil classification are provided in Appendix A.

2.2.1 Unsaturated Material Overlying Uppermost Aquifer

The terrace deposits underlying the inactive Ash Ponds is unconfined; unsaturated material above the uppermost aquifer are composed of the same terrace deposit materials as the saturated aquifer. The thickness of the unsaturated materials observed at the inactive Ash Ponds is based on the observed static water level and corresponds to the linear distance from ground surface to the uppermost aquifer. Haley & Aldrich has made direct observation of the unsaturated material overlying the uppermost aquifer based on recent drilling (November 2017) conducted at the inactive Ash Ponds. Based on direct observations made during groundwater monitoring conducted between March 2018 and March 2019, the unsaturated material overlying the uppermost aquifer at the Site is up to 28 feet thick.

2.2.2 Uppermost Aquifer

Section 257.53 of the CCR Rule defines an aquifer as the geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of groundwater to wells or springs. The uppermost aquifer is defined in § 257.53 of the CCR Rule as the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility boundary.

The water-bearing geologic formation nearest the natural ground surface at the inactive Ash Ponds that is capable of yielding groundwater to wells or springs is the terrace deposits which consist of reworked glacial till material that includes poorly sorted clay, sand, and gravel. The terrace deposits have a local maximum thickness of approximately 55 feet. The saturated thickness of the uppermost aquifer beneath the inactive Ash Ponds is approximately 21 to 38 feet based on observations made during drilling conducted at the inactive Ash Ponds in January 2019.

Review of the Kansas Geological Survey (KGS) Water Well Completion Records (WWC-5) Database indicates that terrace deposit aquifer may be used for water supply in the vicinity of the inactive Ash Ponds. The nearest well (well #12107) listed in the KGS WWC-5 Database is a domestic well located approximately 0.6 mile to the southwest and is up gradient of the inactive Ash Ponds. Well #12107 is reported to be completed at a depth of 39 feet below ground surface, producing groundwater at a reported rate of 10 gallons per minute (gpm). The terrace deposit aquifer contains sufficient water to support low yield wells and springs and sufficient water to facilitate consistent groundwater monitoring of the saturated formation directly beneath the inactive Ash Ponds, and is therefore characterized as the uppermost aquifer beneath the inactive Ash Ponds.

The materials comprising the terrace deposits beneath the inactive Ash Ponds were observed directly during November 2017 drilling at monitoring wells MW-37 through MW-40. The drilling, completion, and testing of these monitoring wells yielded site-specific geologic data that were used in combination with other site-specific data developed during previous characterization activities and well installation activities to determine the appropriate number, depth, and spacing of the monitoring wells at the inactive Ash Ponds. Site-specific aquifer property values describing the alluvium and associated confining units developed during past and recent characterization activities are provided below.

Based on groundwater elevations measured between March 2018 and January 2019, the groundwater gradient in the upper aquifer unit is approximately 0.005 to 0.009 feet/foot and is unconfined. Groundwater flow direction is generally to the north/northwest.

TABLE III
HYDROGEOLOGIC CHARACTERIZATION DATA FOR
THE INACTIVE ASH PONDS CCR MANAGEMENT UNIT
EVERGY KANSAS CENTRAL, INC.
LAWRENCE ENERGY CENTER
LAWRENCE, KANSAS

Unsaturated Material Overlaying Uppermost Aquifer Characteristics	
Lithology (Terrace Deposits)	clay, sand, and gravel
Unsaturated Thickness (Terrace Deposits)	Up to 28 feet
Hydraulic Conductivity (Terrace Deposits)	1.5×10^{-3} to 4.2×10^{-3} cm/sec[b]
Uppermost Aquifer Characteristics	
Lithology (Terrace Deposits)	clay, sand, and gravel
Aquifer Thickness (Terrace Deposits)	21 to 38 feet
Groundwater Gradient (Terrace Deposits)	0.005 to 0.009 feet/foot[a]
Hydraulic Conductivity (Terrace Deposits)	1.5×10^{-3} to 4.2×10^{-3} cm/sec[b]
Groundwater Flow Rate (Terrace Deposits)	11.6 to 182 feet/year
Groundwater Flow Direction (Terrace Deposits)	North/northwest
Effective Porosity (Terrace Deposits)	0.1 to 0.2
Confining Unit Below the Uppermost Aquifer Characteristics	
Lithology (shale unit of Tonganoxie sandstone member)	shale
Unit Thickness (shale unit of Tonganoxie sandstone member)	>5 feet
Hydraulic Conductivity (shale unit of Tonganoxie sandstone member)	1×10^{-6} cm/sec[b]
Effective Porosity (shale unit of Tonganoxie sandstone member)	1

Notes:
[a] = Data based on March 2018 to January 2019 groundwater elevation data
[b] = Hydraulic conductivity value from Black & Veatch, 2005
cm/sec = centimeters per second

3.0 PERIODIC STRUCTURAL STABILITY ASSESSMENT (§257.73(d))

The available information for the Area 2, 3, and 4 Ponds was provided to and reviewed by APTIM for this Assessment:

- ❑ Annual Inspection Report Lawrence Energy Center Inactive Units – Ash Pond Area 2, Ash Pond Area 3, Ash Pond 4, CB&I, June 2017.
- ❑ Coal Combustion Waste Impoundment Round 7 – Dike Assessment Report, Dewberry & Davis, LLC, March 2011.
- ❑ LEC Survey, Professional Engineering Consultants (PEC), June 2016.
- ❑ NPDES Permit No. I-KS-31-PO09

Based on the available information and the site visit conducted May 15, 2017 by Richard Southorn, a professional engineer with APTIM, the following Assessment has been conducted to determine whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices in accordance with 40 CFR §257.73(d).

3.1 Foundation and Abutment Stability (§257.73(d)(1)(i))

Eight borings (LEC-1 through LEC-8) were drilled along the perimeter impoundment dike crest in October 2009 as part of the stability evaluation completed by Golder Associates in December 2009. The borings ranged from 13 feet to 24 feet below the ground surface. The borings show the perimeter dike consists of an asphalt and bottom ash road base underlain by clay and silty clay layers. Groundwater was not encountered in any of the borings.

The perimeter dike is has no abutments and is a continuous feature that ties into natural grades. Based on the results of analyses conducted by Golder Associates, boring logs, lab results, and the observations obtained during the 2017 site visit, it was determined that the perimeter dike is constructed of the same materials that underlay it. These materials include silty clays. Therefore, it is APTIM's professional opinion that the perimeter dike is located on a stable foundation. A Safety Factor Assessment, which is required under 40 CFR §257.73(e), was not completed as part of this Assessment and will be completed under a separate cover.

3.2 Slope Protection (§257.73(d)(1)(ii))

The Area 2, 3, and 4 Ponds are currently undergoing closure and are being repurposed. All pond side slopes will be lined with rip-rap for slope protection of the clay liner, with the exception of portions of the Clear Pond and Pond 404 which will remain vegetated. The rip-rap will extend from the top of the slope for a minimum of ten feet.

3.3 Dikes Compaction (§257.73(d)(1)(iii))

Based on borings obtained in 2009, it can be determined the perimeter dike is primarily constructed of silty clay. The silty clay was obtained from the excavation of the Area 2, 3, and 4 Ponds during the initial pond construction. It has been noted in a previous site investigation conducted by Golder Associates that the perimeter dike crest appears to be

Douglas County Multi-Jurisdictional Multi-Hazard Mitigation Plan

December 2008

Developed by AMEC Earth and Environmental, Topeka, KS

Homeland Security and Emergency Management Programs

- **9/21/93:** The supercell thunderstorm that moved across parts of northeast Kansas hit the northern half of Douglas County including the City of Lawrence at late afternoon. Numerous and widespread reports of large hail and winds clocked at 66 knots caused significant and large scale damage from near Lecompton to Lawrence to Eudora. Many power lines were brought down along with trees and large limbs. Hail damage was common across Lawrence. Torrential rainfall in a short time flooded many roads. In some areas, winds were estimated at 100 mph. The storm briefly stalled across the northwest part of the county before regenerating and moving slowly east again. The NCDC reported $500,000 in property damage, and $500,000 in crop damage due to this hailstorm.

Probability of Future Occurrences

Based on data available from the NCDC, there have been 254 events in a 53 year period, producing an average of 4.8 hail events each year in Douglas County. When limiting the probability analysis to hail events producing hail 1.5 inches and larger, there have been 72 events in a 53 year period producing a greater than 100% chance in any given year that hail events of this size will occur. Even considering only the more significant events, this analysis produces a probability of highly likely.

Highly Likely: Level 4 – Event is probable within the calendar year.

Magnitude/Severity

Limited: Level 2 – 10 % to 25% of property severely damaged; shutdown of facilities for at least one week

Hazard Summary

Calculated Priority Risk Index	Planning Significance
3.10	High

3.2.11 Land Subsidence

Description

Subsidence is caused when the ground above manmade or natural voids collapses. Subsidence can be related to mine collapse, water and oil withdrawal, or natural causes such as shrinking of expansive soils, salt dissolution (which may also be related to mining activities), and cave collapses. The surface depression is known as a sinkhole. If sinkholes appear beneath developed areas, damage or destruction of buildings, roads and rails, or other infrastructure can result. The rate of subsidence, which ranges from gradual to catastrophic, correlates to its risk to public safety and property damage.

Areas of karst, a terrain or type of topography generally underlain by soluble rocks, such as limestone, gypsum, and dolomite, in which the topography is chiefly formed by dissolving the rock, are particularly prone to sinkholes.

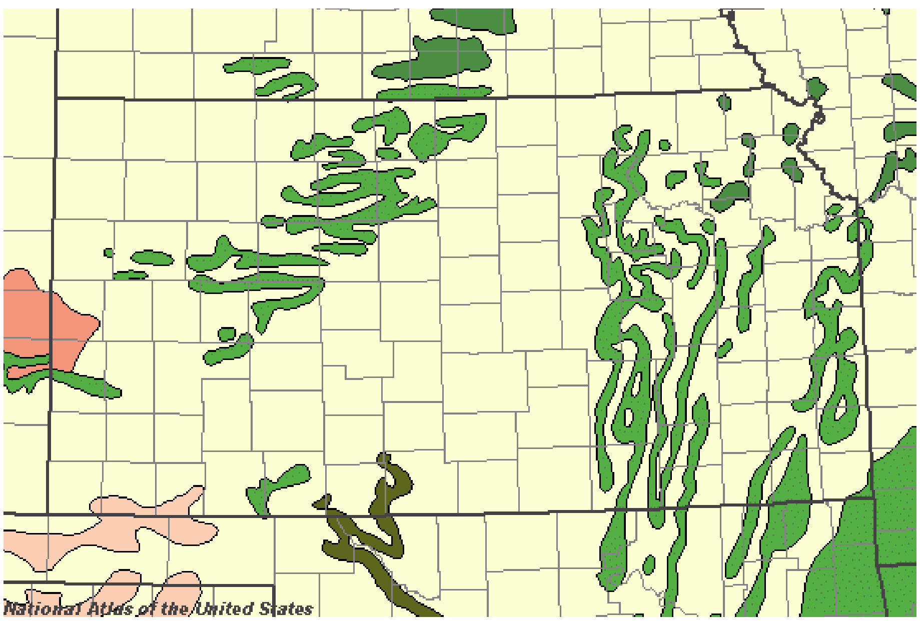
Warning Time: Level 4 – Less than 6 hours

Duration: Level 4 – More than 1 week

Geographic Location

There are limited documented problems associated with limestone subsidence and sinkholes in Kansas. Figure 3.12 illustrates the location of karst features in Kansas. The green areas shown in the map, which occur in northwest Douglas County, show fissures, tubes, and caves generally less than 1,000 feet (ft) long with 50 ft or less vertical extent in gently dipping to flat-lying carbonate rock. Brown areas have similar features in gently dipping to flat lying gypsum beds. Light pink colored areas are features analogous to karst with fissures and voids present to a depth of 250 ft or more in areas of subsidence from piping in thick unconsolidated material. Darker pink areas contain fissures and voids to a depth of 50 ft.

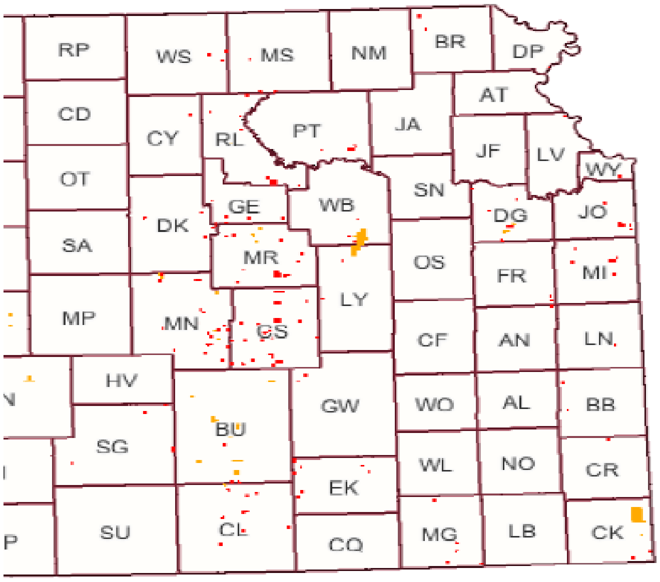
Figure 3.12 Karst Features in Kansas



Source: U.S. Geological Survey, mapped by the National Atlas of the United States, www.nationalatlas.gov

Figure 3.13 shows one-mile square sections of land in the eastern half of Kansas where sinkhole locations have been documented. There are several one-mile square sections of land in Douglas County where sinkholes have been documented. Sections in red indicate sinkhole occurrences (yellow indicates springs).

Figure 3.13 Sinkholes in Eastern Kansas



Source: Kansas Geological Survey

In 2006, the Kansas Department of Health and Environment prepared a report on "Subsurface Void Space and Sinkhole/Subsidence Area Inventory for the State of Kansas." This report inventoried subsurface void space from oil and gas exploration and production, natural sources, shaft mining and solution mining. According to this report, there are none of these particular subsurface void spaces in Douglas County.

Previous Occurrences

According to the Kansas Geological Survey, there have been several documented sinkholes in Douglas County. However, the HMPC did not have additional information regarding the locations or any associated damages of these events.

Probability of Future Occurrences

The HMPC determined that although subsidence incidents have reportedly occurred, subsidence does not occur often as this hazard is not generally considered to be particularly significant in the planning area.

Unlikely: Level 1 – Event is possible in the next 10 years

Magnitude/Severity

Although this hazard occurs occasionally, the HMPC is unaware of any associated damages. Therefore, the magnitude is considered "negligible".

APPENDIX B.3

Human-made Features or Events Documentation

STATE GEOLOGICAL SURVEY OF KANSAS

W. CLARKE WESCOE, M. D.,
Chancellor of the University, and ex officio Director of the Survey

FRANK C. FOLEY, Ph. D.,
State Geologist and Director

Division of Ground Water

V. C. FISHEL, B. S.,
Engineer in Charge

BULLETIN 148

GEOLOGY AND GROUND-WATER RESOURCES OF DOUGLAS COUNTY, KANSAS

By
HOWARD G. O'CONNOR
(State Geological Survey of Kansas)

Prepared by the United States Geological Survey and the State Geological Survey of Kansas with the co-operation of the Division of Sanitation of the Kansas State Board of Health, and the Division of Water Resources of the Kansas State Board of Agriculture.

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GEOLOGY AND GROUND-WATER RESOURCES OF DOUGLAS COUNTY, KANSAS

By Howard G. O'Connor

ABSTRACT

This report describes the geography, geology, and ground-water resources of Douglas County, Kansas, which has an area of about 474 square miles and in 1955 had a population of 32,067. The area lies within the Dissected Till Plain and the Osage Plain sections of the Central Lowlands physiographic province. Kansas River drains the northern three fourths, and tributaries of Marais des Cygnes River drain the southern fourth. The mean annual precipitation at Lawrence is 34.57 inches and the mean annual temperature 56.5° F. Farming, chemical manufacturing, and educational institutions employ many residents of the area. Oil and gas, sand, gravel, and limestone are mineral resources currently being produced.

In Douglas County the rocks above the Precambrian basement are 2,400 to 3,000 feet thick and are all of sedimentary origin. They include rocks of Quaternary, Pennsylvanian, Mississippian, Devonian, Ordovician, and Cambrian age. The exposed Pennsylvanian and Quaternary rocks are nearly 1,000 feet thick; their distribution is shown on a geologic map. The thickness, attitude, and sequence of the rock units are shown in cross sections.

The dominant regional structure is the Prairie Plains Monocline, which is chiefly post-Permian in age and which causes the outcropping Pennsylvanian rocks to dip northwestward about 20 feet per mile. Faulting and small sharp flexures in southern Douglas County affect the Pedee, Douglas, and lower Shawnee rocks. The faults and folds are believed to be chiefly nontectonic in origin. Extensive submarine slides and differential compaction suggest that the structures are penecontemporaneous and probably are restricted to the post-Stanton rocks.

Wisconsinan and Recent alluvial deposits 45 to 90 feet thick in the Kansas River valley yield large supplies of ground water and constitute the most important aquifer in the area, as more than four-fifths of the ground water pumped comes from an area of 6 square miles in the Kansas River valley. Illinoisan fluvial deposits and Kansan glacial and fluvial deposits locally yield small to moderate ground-water supplies. The Ireland Sandstone member of the Lawrence Shale and the Tonganoxie Sandstone member of the Stranger Formation are the most important bedrock aquifers; they provide water for domestic and stock requirements and small amounts for municipal water supplies.

Fresh ground water occurs locally to a depth of about 500 feet. Water from Quaternary deposits is generally good except for carbonate hardness and locally excessive iron content. The Ireland and Tonganoxie Sandstones yield calcium and magnesium bicarbonate water of good quality in water-table areas, and downdip or downgradient in the artesian areas they yield a sodium bicarbonate water, which is generally soft though high in dissolved solids.

Ground-water pumpage in 1955 was 2,266.4 million gallons, or 6,950 acre-feet, divided as follows: public supplies 1,610 acre-feet; industrial supplies 4,490 acre-feet; irrigation supplies 630 acre-feet; and other pumpage, 220 acre-feet. Industrial and irrigation use has greatly increased since 1950.

Field data upon which this report is based include records of 436 wells, test holes, and springs; logs of 196 wells and test holes; and chemical analyses of 113 water samples.

Kansas Geological Survey, Open-file Report 1973-5

Coal in Kansas

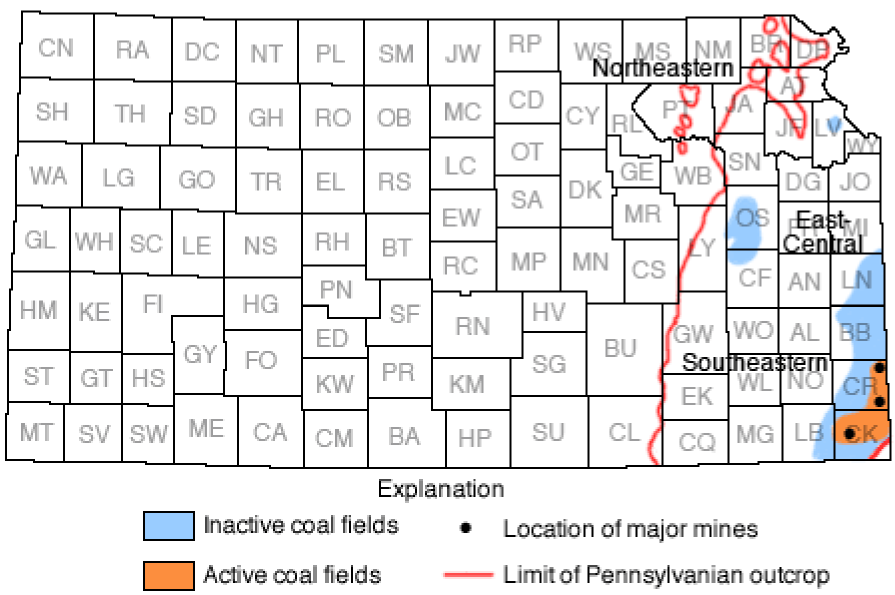
by
Linda A. Flueckinger and Lawrence L. Brady

KGS Open File Report 1973-5

Geology

Coal-bearing areas of Kansas cover approximately 18,800 square miles or 23 percent of the state. Coal-bearing rocks are limited to two general areas: (1) the bituminous coal bearing areas of eastern Kansas, and (2) the marginal Cretaceous lignite region of central and north-central Kansas (Figure 1).

Fig. 1--Location of Kansas mines and coal fields



The bituminous region forms the western edge of the western region of the Interior Coal Province. At least 53 bituminous coals have been recognized in Kansas of which 7 are presently being mined and 16 have been mined in the past or are considered in reserve estimates. The coal-bearing rocks containing the major reserves are Lower and Middle Pennsylvanian in age, although two seams have been recognized in Lower Permian rocks in northeastern and east-central Kansas (Schoewe, 1951). Bituminous coal-bearing beds are not limited to the Cherokee and Forest City Basins as previously thought (Schoewe, 1953), but are known from electrical logs to exist in the deeper subsurface over and west of the Nemaha Anticline.

The Pennsylvanian coal-bearing beds lie on the northwest flank of the Ozark Uplift and consequently the prevailing dip is to the northwest at 20 to 25 feet per mile. The regional strike is northeast. Kansas coals are predominantly flat-lying and relatively free of faulting. Deformation and faulting have been reported in coals of the lower Cherokee Group (Pierce, 1937), the Bevier (Hambleton, 1953), the Mulberry (Whitla, 1940), and the Nodaway coal (Whitla, 1940). The structural features range from rolls 2 to 3 feet across and local fractures filled with clay and pyrite in the upper seams; to the northwest plunging Pittsburg anticline with structural relief of 70 feet, closed depressions 10 to 80 feet deep, and normal faults from less than one to 2.5 miles in length and 15 feet throw in the Lower Cherokee seams.

Rank, Quality and Heating Value

Except for limited reserves of lignite and subbituminous coals in the central region, Kansas coals are mainly high volatile A bituminous in rank. In the commercial important coals of the Cherokee Group, the volatile matter decreases and fixed carbon progressively increases in coals successively lower stratigraphically in the group (Pierce, 1937).

On an as-received basis, moisture contents of Kansas bituminous coals range between 3 and 17%. The seven coals which are mined commercially have moisture contents ranging from, 4 to 12% with a range of average moisture values between 5 and 10%. Kansas bituminous coals are moderate to high in ash and high in sulfur.

As-received ash values for all Pennsylvanian coals range between 5 and 34% and for commercially-mined coals, 17 and 30%.

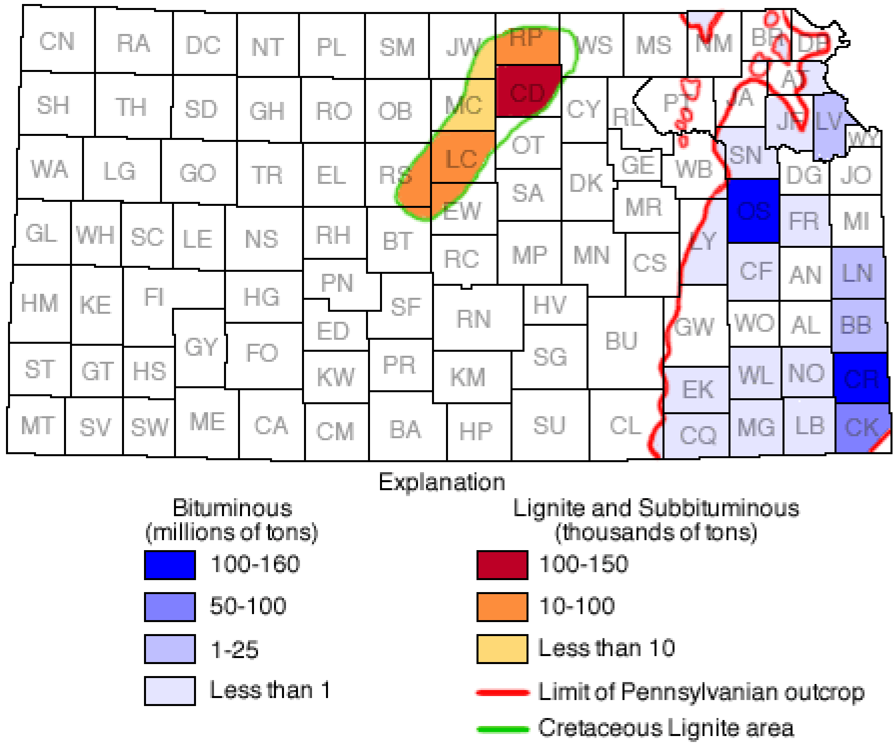
Sulfur in Kansas bituminous coals ranges between 2 and 6% for commercially-mined coals and 2 to 12% for other Pennsylvanian coals. Average sulfur values for seven commercially-mined coals range between 2.6 and 5.0%. An example of sulfur types for a commercial coal with 2.4% total sulfur is as follows: 0.05% sulfate sulfur; 1.21% organic sulfur; 1.11% pyritic sulfur.

Heat values for Kansas bituminous coals on a dry, ash-free basis average between 13,750 and 15,120 BTU/lb. Washing of blends of various proportions of the Mineral, Fleming and Croweburg coals mined in Cherokee County produces a uniform product with approximately 6.5% moisture; 12.5% ash, 3.3% sulfur, and 12,1300 BTU/lb. with a seam loss of 10%.

Production

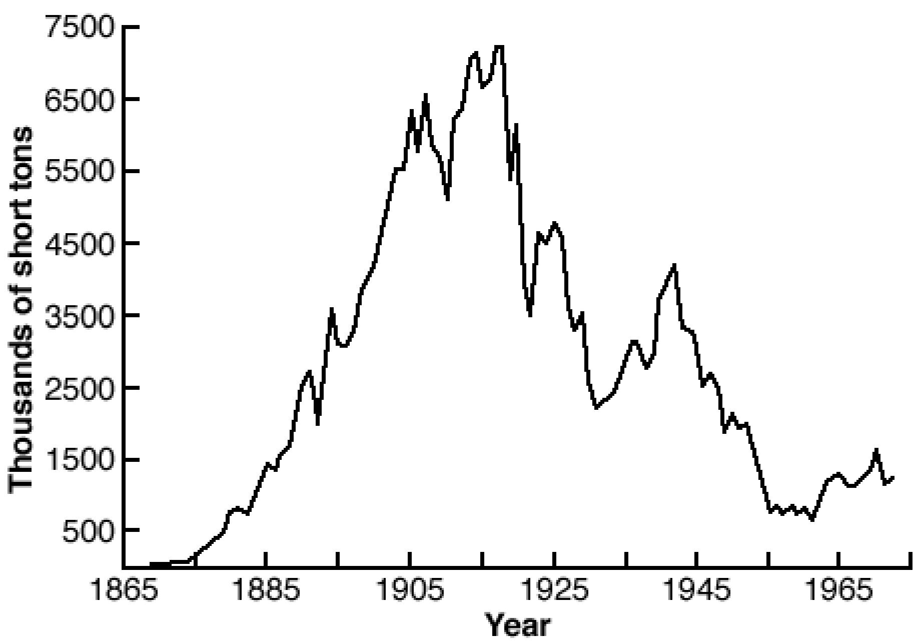
Kansas bituminous coal production has been centered in three regions: (1) the Southeastern Coal Field; (2) the East-Central Coal Field, and (3) the Northeastern Coal Field (Figure 1). However, since 1950, the Southeastern field, in particular Crawford, Cherokee, and Linn counties, has produced 99.5% of the coal mined in the state. Since 1969, when the last mine closed in the East-Central Coal 100% of recorded production has come from these 3 counties. Intermittent production in the East-Central field has been restricted to local trade. Total production from the 1860's through 1972 is 375,471,000 tons. Production by counties since 1869 is represented in Figure 2.

Fig. 2--Coal and lignite production since 1869



Peak Kansas coal production (7,250,000 tons) was recorded in 1917 and 1910 and with the exceptions of the years of World War II and 1962, to the present, has a declining trend (Figure 3). In 1970, coal production recorded a 17-year-high of 1.6 million tons which ranked Kansas 17th in bituminous coal production in the United States and 8th among states mining coal west of the Mississippi. In 1971, production dropped to 1.1 million tons due to a strike and then rose slightly in 1972 to 1.2 million tons valued at $6.6 million.

Fig. 3--Kansas coal production 1869-1972



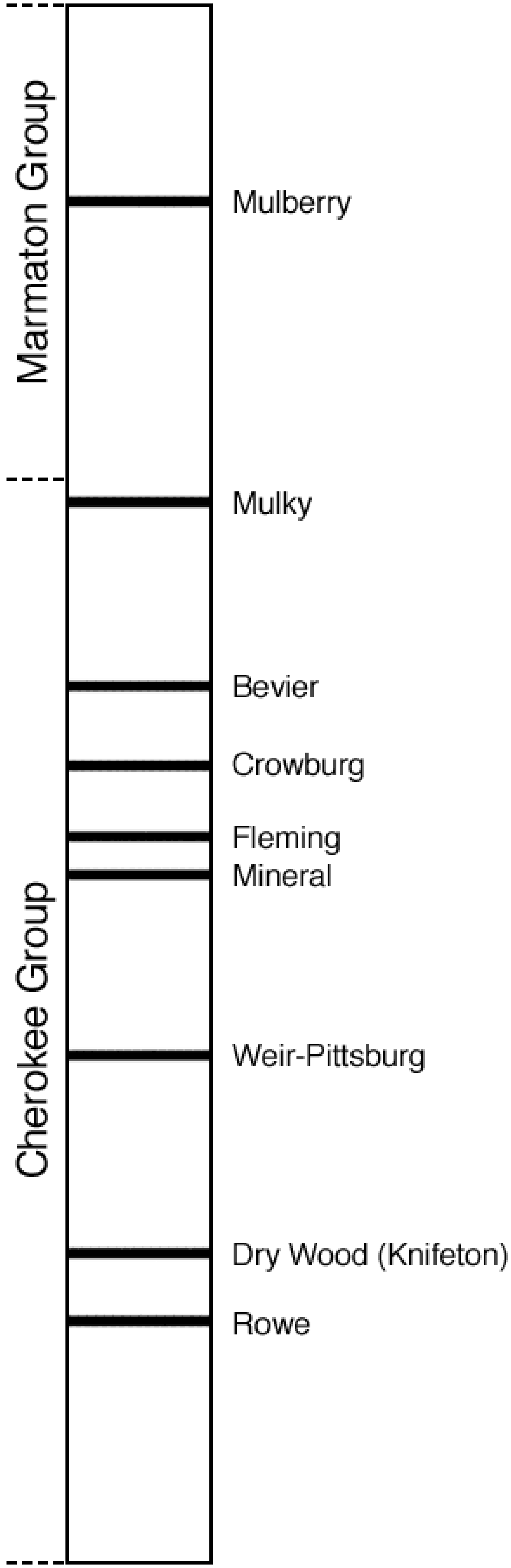
Seam Data

The nine coals of economic importance in southeastern Kansas (Figure 4) and the Nodaway coal with significant reserves in the East-Central Coal Field are characterized in Table 1.

Table 1--Characterization and reserves of major Kansas coals. Data compiled from Kansas State Geological Survey estimates, U.S. Bureau of Mines references, and the Pittsburg and Midway Coal Mining Co.; reserves refer to proven reserves without consideration of all economic limits.

Seam	Seam Thickness	(Av) or Range of Seam Thickness Mined	Range and (Av) % Moisture**	Range and (Av) % Ash**	Range and (Av) % Sulfur**	Range and (Av) % BTU/lb**
Nodaway	1-36	16-20 (18)	7.4-15.3 (10.2)	6.7-15.7 (10.0)	5.1-9.9 (7.6)	8,728-12,170 (11,093)
Mulberry	12-48	(27)	8-12 (10)	19-30 (23)	4-6 (5)	8,500-10,500 (9,600)
Mulky	8-22	12-14	(2.8)	(9.3)	(3.9)	(13,286)
Bevier	14-24	(15)	6-9 (6.5)	18-30 (24)	2.3-3.1 (2.6)	(10,100)
Croweburg	8-15	8-12	(6)	(26)	(2.5)	(9,800)
Fleming	1-26	(15)	(5)	(24)	(5)	(10,100)
Mineral	5-24	15-19	4-8 (5)	17-26 (21)	(4)	(10,500)
Weir-Pittsburg	34-60	(42)	3.8-7.4 (6.1)	6.5-13.1 (9.9)	2.2-5.3 (3.7)	12,110-13,210
Dry Wood (Knifeton)	3-20	10-12	(6)	(22)	(4)	(10,400)
Rowe	10-20	14-17	(6.5)	(26)	(4.7)	(10,100)
**As-received basis.						

Fig. 4--Coals of economic importance in the Southeastern Kansas Coalfield



Softening Temperature	Reserves (millions of	Comments

of Ash °F	tons)	
2,100	36.25--Osage County 1 or less--Coffey, Elk, Jefferson Cos.	Total production to date 12 million tons localized hardening and thickening; one of 12 seams in Wabaunsee Group
	129--Linn County 10--Bourbon County	2-3 foot rolls; clay tilled fractures; thin pyrite band near base
	7--Bourbon County 2.5--Crawford County	Fort Scott coal, not currently mined
2,300	10--Bourbon County 17--Cherokee County 21--Crawford County	Currently mined in Crawford and Cherokee counties: previously mined at 750 ft depths in Atchison and Leavenworth counties
2,200	1--(approx.) each in Crawford and Cherokee counties	Mined in Cherokee County with the Fleming and Mineral Seams; 1972 production of 130,000T
2,100	2.5 Crawford County 21 Cherokee County	
2,050	48.5--Cherokee County 126.5--Crawford County	Currently supplies greatest production (Cherokee and Crawford counties)
2,000-2,040	103.6--Cherokee County 100.5--Crawford County	Easily accessible reserves depleted
2,300		Mined in Crawford County with Rowe seam
2,300		Blocky with thin clay parting

Resources vs. Reserves

[Note: The term *resources* refers to identified coal deposits which may or may not be recoverable under present technologic and economic conditions; while the term *reserves* refers to coal deposits which are workable or probably workable and which meet certain stated geologic and economic limits.]

Kansas has estimated bituminous coal reserves of 18.7 billion tons (Averitt, 1969). However, only a small portion of this resource can be considered a minable reserve under current technologic conditions.

[Note: Resources in the ground including bituminous coal 10 inches or more thick; maximum overburden thickness 60 feet or an overburden-to-coal ratio not exceeding 35:1 for strippable coal. For underground mining methods the following criteria based on Abernathy, Jewett, and Schoewe (1947) were used:]

Max depth to coal (ft)	Min thickness of coal (inches)
100	16
150	18
200	22
600	32
1200	36

When resources are considered, Kansas has approximately 2% of the total estimated remaining coal resources for states west of the Mississippian (excluding Alaska). In total coal resources, Kansas is exceeded in order of increasing tonnages by Missouri, Utah, New Mexico, Colorado, Wyoming, Montana and North Dakota. When bituminous coals alone are considered, Kansas is exceeded in tonnages by Missouri, Utah, and Colorado.

Kansas' remaining coal reserves are estimated to be 895 million tons. [Note: 1973 Kansas Geological Survey estimate; proven reserves; all economic limits have not been considered.] The location and amounts of these reserves are shown on a county basin in Figure 5. Stripping coal reserves (Figure 6) are estimated to be 226 million tons from original resources of 500 million short tons stripping coal generally less than 100 feet below the surface (Averitt, 1970). [Note: 1973 Kansas Geological Survey estimate; bituminous coal of 12 inches minimum thickness and 100 feet maximum overburden thickness.] According to Pittsburg and Midway Coal Mining Co. estimates, Crawford, Cherokee, Linn, and Bourbon counties have strippable coal reserves of 165 million tons. U.S. Bureau of Mines estimates (1969, 1971) of recoverable reserves are 831 million tons [note: Conditions used to evaluate strippable and underground reserves not precisely stated.] with recoverable stripping coal estimates ranging from 215 [note: 1973 Kansas Geological Survey estimate; bituminous coal of 12 inches minimum thickness and 100 feet maximum overburden thickness.] to 375 [note: strippable reserves of 12 inches minimum thickness, 120 feet maximum overburden; economic stripping ratio 15:1 (feet to feet) or less; with deletion of reserves known to be unminable because of cultural or or topographic features, steep dips or oxidation at the outcrop, previous mining, unacceptable quality and because of coal which may never be leased or sold.] million tons. These stripping coal estimates include reserves which are contractually committed including approximately 30 million tons of Mulberry coal in Linn County and 14 to 15 million tons committed for mining in Cherokee and Crawford counties into the mid 80's.

Fig. 5--Estimated recoverable bituminous coal reserves

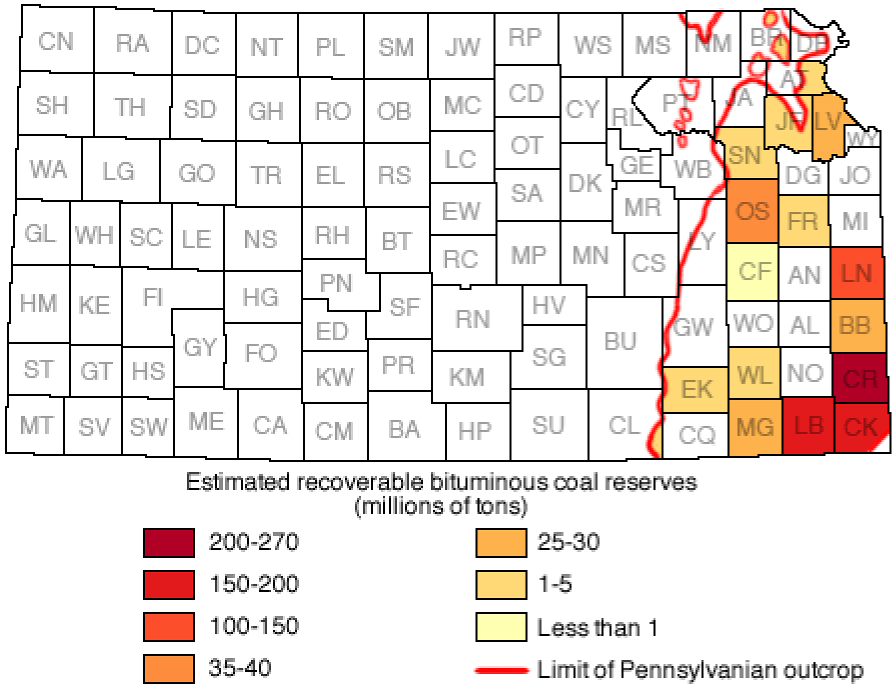
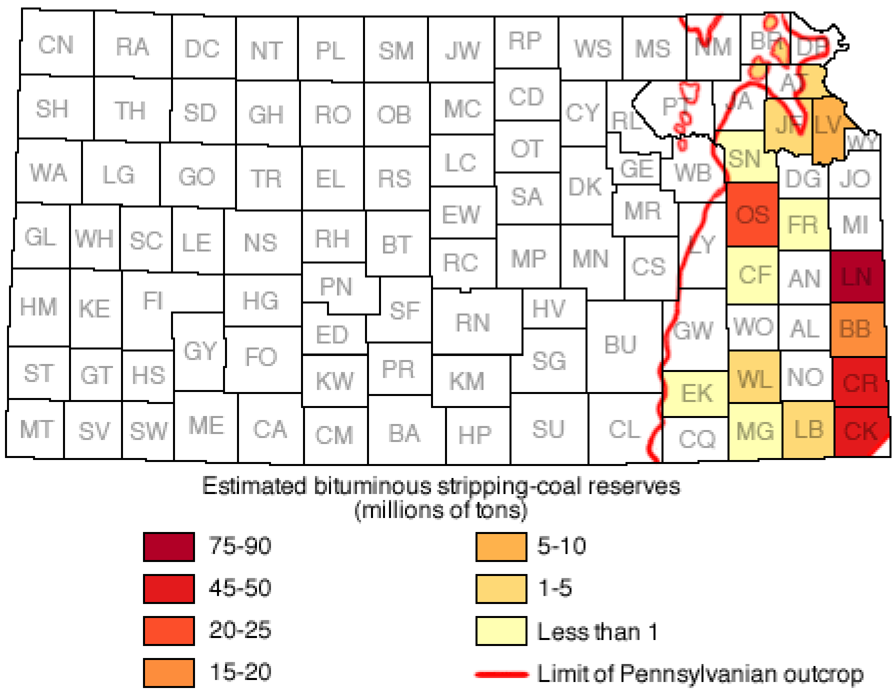


Fig. 6--Estimated bituminous stripping-coal reserves



The greatest reserves from a single Kansas seam are present in the Weir-Pittsburg coal. In 1925, these reserves were estimated to be 233,383,000 tons from original total reserves of 295,622,000 tons (Young, 1925). This seam is the thickest in Kansas (34 to 60 inches) and has supplied more coal, both by open-pit and underground mining methods, than any other coal bed in the state. More than 100 square miles of 42-inch or thinner Weir-Pittsburg coal were intensively mined until post-World War II in the Southeastern Coal Field by underground methods. The readily accessible Weir-Pittsburg coal is depleted but substantial deep reserves are present in Labette County at depths of 500 feet along the Kansas-Oklahoma border in Cherokee County; and possibly Montgomery County, and in the Northeastern Coal Field in Leavenworth County. All remaining reserves are high sulfur coals.

Mining Methods Utilized in Kansas

Strip mining exceeded deep mine production for the first time in 1931 and continued to increase until, in 1964, the last deep mine closed and open-pit mining accounted for 100% of Kansas' production.

In the Southeastern Kansas Coal Field, the Weir-Pittsburg coal seam was extensively mined by room and pillar methods. In Osage County, the Nodaway coal seam and in Leavenworth County the Cherokee coals were extensively mined using both room and pillar and longwall methods. Thickness of seams, coal quality, and economics of the remaining reserves have been instrumental in discontinuance of underground mining in Kansas.

In 1877, power equipment for strip-mining was first introduced to the industry in southeast Kansas. From this early start, the modern strip-mining of thin coals utilizing large electric shovels and draglines has evolved.

At two of -the three major coal mines in Cherokee and Crawford counties, multiple coal seams are worked. This multiple seam mining is necessary because the seams mined are generally less than 20 inches in thickness. Overburden to coal thickness ratios up to 35:1, the greatest recorded in the nation, are presently being mined in the state. This is possible because most of the strata overlying the coals consist of shale with only a few thin limestone beds.

Profiles of Kansas' Two Leading Coal Mining Companies

The Pittsburg and Midway Coal Mining Co., a wholly-owned subsidiary of the Gulf Oil Corporation, is the major coal producer in Kansas. P&M ranks as the 13th largest coal producing company in the United States and currently operates nine mines in five states from Kentucky to Colorado and New Mexico. In 1972, P&M produced more than 600 thousand tons of coal in Kansas. At P&M Mine #19 in Cherokee County, a Bucyrus-Erie 90-yard 1850-B shovel and a 35-yard 1250-B dragline are utilized in mining two or more thin coals. The most important seam that is mined is the Mineral seam, with mining of the Fleming and Croweburg coals in areas where their thickness justifies mining. Coal production from Mine #19 is hauled ten miles by truck to the company's preparation plant at Hallowell, Kansas. The washed coal is shipped subseauently via the MK&T Railroad to Lawrence, Topeka and Kansas City, Kansas, and Omaha, Nebraska.

In September of 1972, P&M produced the first coal from the company's Midway Mine in Linn County, Kansas, and Bates County, Missouri. At anticipated peak production in 1974, approximately 2.4 million tons of raw Mulberry coal will be hauled by truck to the mine-mouth power plant at LaCygne, Kansas, which is equipped with a Babcock & Wilcox environmental control system for both particulate and gaseous emissions. The coal is mined using a Bucyrus-Erie 2570-W 110-yard dragline. In the near future a Marion 8200 70-yard dragline also will be put into service at the mine. P&M initiated reclamation efforts in Kansas in 1938. With the more extensive reclamation required in recent years, P&M is making major studies to develop new equipment for better movement of the mine spoil in reshaping mined-land by reclaiming acreage strip-mined prior to enactment of the Kansas reclamation law.

Key personnel at corporate offices in Kansas City, Missouri, are shown in Figure 7.

Fig. 7--Officers in the Pittsburg & Midway Coal Mining Company

The Pittsburg & Midway Coal Mining Co.
A wholly owned subsidiary of Gulf Oil Corp.

President
J.A. Borders

Asst. to the President
F.H. Ales

Secretary
Walta Tappana

Finance & Services
Manager
E.T. Nave

Sales
Vice President
R.M. Holsten

Operations
Vice President
H.E. Knight

Research
Director
W.C. Bull

Community Relations & Civic Affairs
Director
F.J. Forseman

Engineering
Manager
Vacant

Land & Lease
Director
G.R. Stroud

Law
Divisional Attorney
D.E. Willson

Jan. 1, 1973

The Clemens Coal Co. with offices in Pittsburg, Kansas, is the second-largest coal mining company in the State. In 1972, Clemens Coal Co. mined in excess of 400 thousand tons of coal at two mines in Crawford County. By utilizing a smaller shovel and dragline at each mine, Clemens has worked multiple coal seams and maintained a continuing reclamation effort. At the Clemens mine #22, a 23-yard Marion 5560 shovel and a 11-yard Marion 7400 dragline are utilized in mining the Mineral and also the Bevier coal seams. At the Clemens mine #25, a 15-yard Marion 5322 shovel and a 1.1-yard Marion 7400 dragline are used to mine the Rowe and Dry Wood seams. By operating the shovel and dragline in tandem much of the soil is separated from shale for replacement in the reclamation effort.

Coal production from Clemens mines is hauled to the company's preparation plant north of Mulberry, Kansas, by both truck and rail. Mine #22 coal requires a 4 mile truck haul. Rowe and Dry Wood coal are transported approximately 18 miles on the St. Louis-San Francisco Railway, washed, and then returned to the same cars for further shipment.

In addition to reclamation of current mining acreage, the Clemens Coal Co. is reclaiming acreage strip-mined prior to enactment of the Kansas reclamation law. Officers in the company are:

- Chairman of the Board: George K. Mackie, Jr.
- President: John W. Mackie, Jr.
- Vice President: Jess M. Lee
- Treasurer: Flora DeVoss

Exploration and Manpower Base in Kansas

Since most land in Kansas is under private ownership, exploration for future mine development is limited to the standard permit, lease, or contract arrangements with the landowner. No filing of coal exploration logs with the State is required, and coal exploration in Kansas is basically a contractual matter between the landowner and coal company, arranged primarily by a good land-man.

Manpower in Kansas is more than adequate to supply any mining activity in the State. Persons with mining experience and skilled in the use of heavy equipment provide a ready work force in areas of potential mine development. The work staff of the recently opened P&M Midway Mine were mainly residents of the surrounding communities. James Borders, P&M President, has said these people have provided the new mine with very capable work force.

Reclamation Requirements in Kansas

With approximately 45 thousand acres of mined-land in Kansas attributed to previous strip-mining activities, a law covering surface mining of coal was enacted in 1968 to restore future mined-land to productive agricultural use. Reclamation in Kansas are governed by the Kansas Mined-Land Conservation and Reclamation Board. All surface coal mining activities in the state require a one-year permit from the Board and the posting of a performance bond to insure an adequate reclamation effort. The bond may not exceed $500 per acre.

Reclamation work must be conducted concurrently with the mining operation. The land must be shaped essentially to a rolling-type terrain with appropriate slopes to provide drainage for all portions of the permit area. Grading specifications for the land are as follows:

<table>
<tr><td>(1)</td><td colspan="2">Maximum slope--25 percent</td></tr>
<tr><td rowspan="5">(2)</td><td>Average Slope (%)</td><td>Maximum Slope Length (ft)</td></tr>
<tr><td>0-4</td><td>No Limit</td></tr>
<tr><td>4-8</td><td>300</td></tr>
<tr><td>8-15</td><td>150</td></tr>
<tr><td>15-25</td><td>75</td></tr>
<tr><td>(3)</td><td colspan="2">All exposed rocks that will not disintegrate in less than 3 years and larger than six inches in diameter are to be removed or buried with a minimum of six inches of soil.</td></tr>
</table>

Revegetation of the land is required following grading in order to minimize soil erosion and put the land into beneficial agricultural use. Reseeding at the present time is normally to legumes and/or grasses. However, the Board will consider the landowners' desires, expected future use of the land, and the physical and chemical properties of the soil. Inquiries about all State requirements on reclamation should be addressed to the chairman of the Kansas Mined-Land Conservation and Reclamation Board, Kansas Department of Labor, Topeka, Kansas.

Objections to Kansas reclamation requirements from the present coal producers have been concerned primarily with the grading of box cut spoil to meet the slope angle and length requirements stated above. The companies feel that the grading regulations should be modified for box cut spoils.

A favorable factor in Kansas strip-mining is the general absence of acid water problems. Where areas of low pH exist that could lead to an acid water drainage condition, corrective measures can be made simply.

A Look At Kansas' Coal Future By Its Major Producer

James Borders, President of the Pittsburg and Midway Coal Mining Company, is not optimistic about the future of coal mining in Kansas. According to Mr. Borders, future coal production in Kansas is limited by two major factors: (1) the presence of only thin coal seams, and (2) the high sulfur content of the coals. Sulfur content of Kansas coals restrict their use to major utility companies that can afford the necessary pollution control equipment required for their use.

Mr. Borders foresees only limited coal production in Cherokee County in particular and southeast Kansas in general, after 1985, and an end to P&M's major mining activities in Kansas near the end of this century. These dates are defined by the major contractual commitments of P&M with major area utility companies. With the opening of the new Midway Mine in Linn County, Kansas, and Bates County, Missouri, in September, 1972, P&M will supply, at full production 2.4 million tons of raw coal annually to a mine-mouth power station at LaCygne, Kansas. According to Mr. Borders, P&M has a commitment with the Kansas Gas and Electric Co. and Kansas City Power and Light Co. to supply the coal to the power plant until 2002. Approximately 30 to 35 million tons of an estimated 65 to 70 million tons of coal for the plant will be mined in Kansas. This will result in approximately 10,000 acres of Kansas land being mined. The remaining 30 to 35 million tons of coal necessary for the plant will be mined in Missouri.

Kansas' Changing Role as a Coal Producing State

The role of Kansas as a coal supplier has been favored in the past by its geographic position in the Midwest in conjunction with large supplies of readily accessible coal. Until the steam locomotive market was eliminated, eastern Kansas provided a convenient refueling stop for the railroads of the area. However, changing economic conditions have forced the closing of underground mines and the adoption of preparation plants to make strip-mined coal from thin seams suitable for power-plant use. Within the near future the delivered cost of imported low sulfur western coals will approach the price of coal from southeastern Kansas, and at that time, the market for Kansas coal will be very limited.

It is expected that coal production for the next five to six years will remain at approximately the present production of 1.2 to 1.5 million tons per year. In approximately 1978, the P&M Midway Mine will move most of its mining operations from Missouri into Kansas and Kansas coal production should rise to approximately 2.6 to 3 million tons a year. Probably in the mid-80's a decline in Kansas coal production will begin. Markets for Kansas coals in the near future will continue to be the electric utility companies in Kansas and portions of adjoining states.

Reserves in Southeast Kansas coal fields are still the important areas for future coal development. However, it is expected that future mining operations in Kansas will be smaller than at present with new mines working generally smaller reserve areas than those mines presently operating in the State. These smaller producers would supply small industrial and commercial operations and municipal electric plants.

Future Mining Methods

Strip-mining operations will probably continue to be the only economical way of coal mining in Kansas. Thickness of the coal seams limits the introduction of underground mining methods at the present market value of Kansas coal. The best potential strip-mine areas are in southeastern Kansas. Areas having the best potential for future underground mining are in the western and southern portion of the Southeastern Kansas coal field where the Weir-Pittsburg coal seam can be mined.

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Kansas Geological Survey
Placed online Sept. 26, 2010
Comments to webadmin@kgs.ku.edu
URL http://www.kgs.ku.edu/Publications/OFR/1973/OFR73_5/index.html

Kansas Geological Survey | Oil and Gas | Field Oil & Gas Production | Digital Petroleum Atlas

Forest City Coal Gas Area--Oil and Gas Production

Additional information on this field is available in the Digital Petroleum Atlas
Discovery currently listed:

> **Operator:**
> **Lease:** , Well
> **Location:** S-W:
> **Discovery Date:** 01/01/1873
> **Producing zone:** Forest City coal gas

Counties: Anderson, Atchison, Brown, Coffey, Doniphan, Douglas, Franklin, Jackson, Jefferson, Johnson, Leavenworth, Linn, Lyon, Miami, Morris, Nemaha, Osage, Pottawatomie, Shawnee, Wabaunsee, Wyandotte
View Field Boundary
Leases and Wells: View Production by Lease for this Field || View Wells Assigned to this Field
Producing Formations

Name	Depth (ft.)	Thickness (ft.)	Oil Grav	Produces	Temperature
COAL	-	-	-	Gas	-

Field Map (opens in new window): View Field Map

Flash Charts: Flash is no longer supported by most browsers, but may work in Microsoft Edge and Firefox. If the blue loading box does not go away in a few seconds, refresh the page.

Production Charts
View Flash chart

Year	Oil			Gas		
	Production (bbls)	Wells	Cumulative (bbls)	Production (mcf)	Wells	Cumulative (mcf)
1998	-	-	0	-	2	3,749
1999	-	-	0	2,344	2	6,093
2000	-	-	0	84,782	22	90,875
2001	-	-	0	95,402	24	186,277
2002	-	-	0	121,446	28	307,723
2003	-	-	0	158,593	47	466,316
2004	138	2	138	253,889	51	720,205
2005	251	6	389	273,126	68	993,331
2006	345	5	734	392,871	181	1,386,202
2007	2,242	10	2,976	417,663	237	1,803,865
2008	836	5	3,812	497,569	329	2,301,434

2009	424	12	4,236	353,341	282	2,654,775
2010	424	4	4,660	252,193	253	2,906,968
2011	286	4	4,946	161,384	232	3,068,352
2012	153	4	5,099	25,356	35	3,093,708
2013	184	6	5,283	1,047	1	3,094,755
2014	112	5	5,395	699	1	3,095,454
2015	254	3	5,649	762	1	3,096,216
2016	42	3	5,691	38,340	21	3,134,556
2017	-	-	5,691	131,786	33	3,266,342
2018	64	2	5,755	28,667	31	3,295,009

Updated through 6-2018.
Note: bbls is barrels; mcf is 1000 cubic feet.

Kansas Geological Survey
Comments to webadmin@kgs.ku.edu
URL=http://www.kgs.ku.edu/Magellan/Field/index.html
Programs Updated Aug. 28, 2014.
Data from Kansas Dept. of Revenue files monthly.

Kansas Geological Survey | Oil and Gas | County Oil & Gas Production

Douglas County--Oil and Gas Production

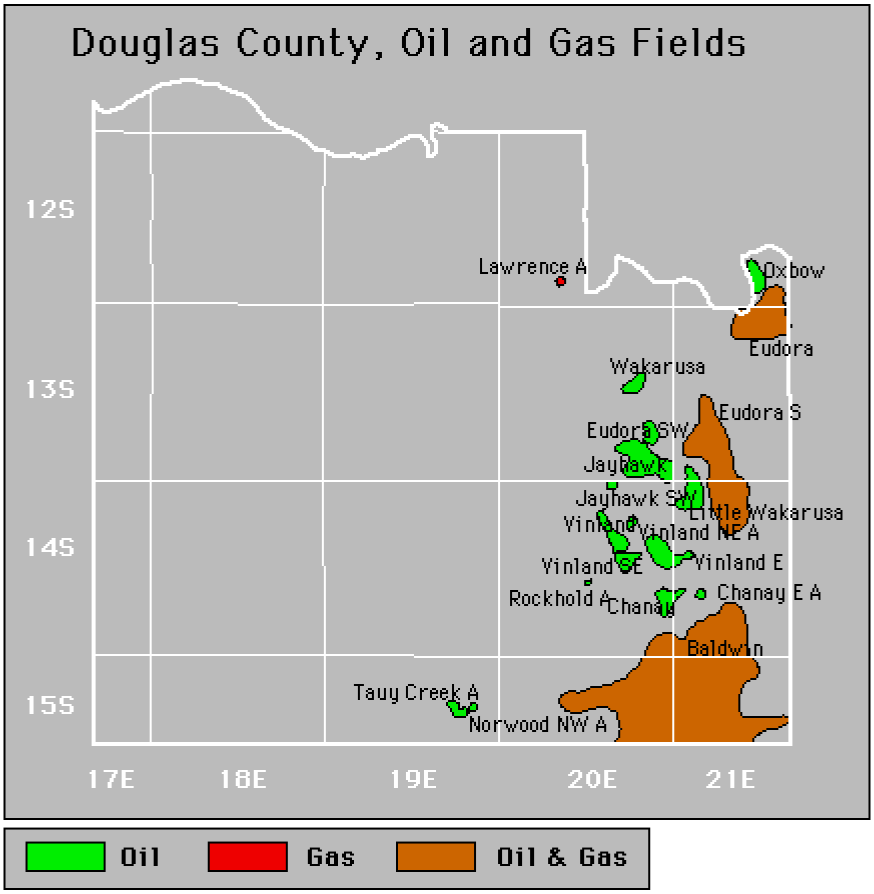
Production

Year	Oil			Gas		
	Production (bbls)	Wells	Cumulative (bbls)	Production (mcf)	Wells	Cumulative (mcf)
1995	73,927	156	2,072,298	-	-	135,033
1996	64,694	331	2,136,992	-	-	135,033
1997	59,389	317	2,196,381	-	-	135,033
1998	50,552	306	2,246,933	-	-	135,033
1999	41,913	271	2,288,846	-	-	135,033
2000	36,632	268	2,325,478	-	-	135,033
2001	32,671	260	2,358,149	-	-	135,033
2002	32,401	256	2,390,550	-	-	135,033
2003	31,705	261	2,422,255	-	-	135,033
2004	30,592	250	2,452,847	-	-	135,033
2005	29,193	261	2,482,040	-	-	135,033
2006	37,217	273	2,519,257	-	-	135,033
2007	37,515	274	2,556,772	-	-	135,033
2008	45,585	313	2,602,357	-	-	135,033
2009	56,461	336	2,658,818	-	-	135,033
2010	53,030	407	2,711,848	-	-	135,033
2011	46,134	399	2,757,982	-	-	135,033
2012	51,718	419	2,809,700	-	-	135,033
2013	64,134	440	2,873,834	-	-	135,033
2014	72,835	449	2,946,669	-	-	135,033
2015	59,281	460	3,005,950	-	-	135,033
2016	50,502	439	3,056,452	-	-	135,033
2017	45,591	477	3,102,043	-	-	135,033
2018	38,050	446	3,140,093	-	-	135,033
2019	30,858	347	3,170,951	-	-	135,033

Updated through 12-2019.
Note: bbls is barrels; mcf is 1000 cubic feet.

View interactive Flash chart of production

County Map



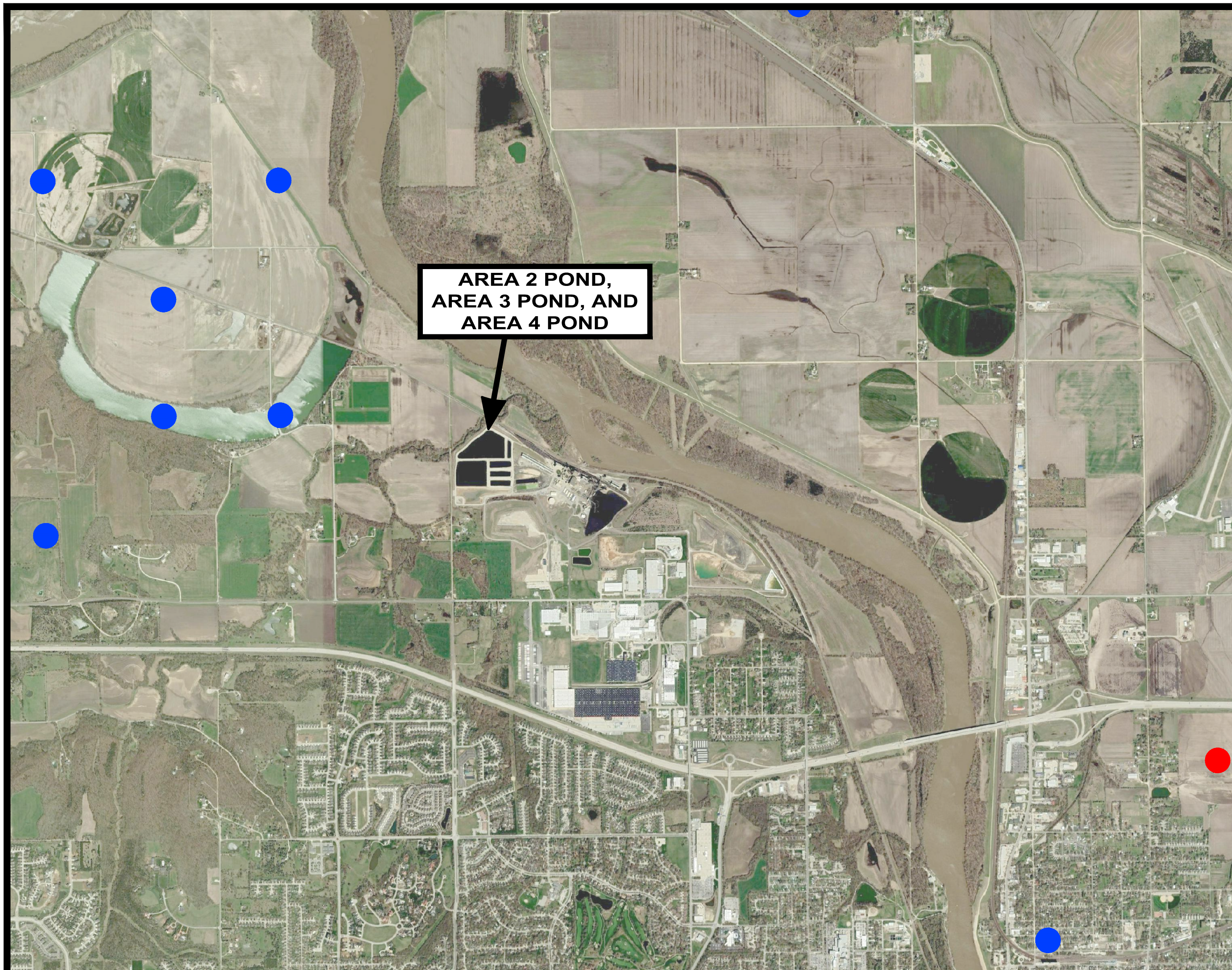
Fields

Also available is a text file containing field summary data for all fields in this county.

Active			
Baldwin	Forest City Coal Gas Area	Oxbow	Vinland Southeast
Chanay	Jayhawk	Rockhold	Wakarusa
Chanay East	Jayhawk Southwest	Tauy Creek	
Eudora	Lawrence	Vinland	
Eudora South	Little Wakarusa	Vinland East	
Eudora Southwest	Norwood Northwest	Vinland Northeast	

No Abandoned fields.

Kansas Geological Survey
Comments to webadmin@kgs.ku.edu
URL=http://www.kgs.ku.edu/PRS/County/def/douglas.html
Data from Kansas Dept. of Revenue files monthly.



N

0 0.7 MILE

GRAPHIC SCALE

LEGEND

- ACTIVE (red dot)
- ABANDONED (blue dot)

NOTES

1. AERIAL PHOTO FROM GOOGLE EARTH, APRIL 2019.
2. QUARRY LOCATIONS ARE APPROXIMATE.
3. FOR CLARITY, NOT ALL SITE FEATURES MAY BE SHOWN.

APTIM

APTIM Environmental & Infrastructure, LLC

LAWRENCE ENERGY CENTER
1250 N. 1800 RD., LAWRENCE, KS

QUARRIES NEAR
AREA 2 POND, AREA 3 POND, AND AREA 4 POND

DRAWN BY: ORC	APPROVED BY: RDS	PROJ. NO.: 631013710	DATE: APRIL 2020

T:\AutoCAD\Projects\Westar Energy\Lawrence\Location - Inactive\Quarries.dwg, 4/9/2020 9:06:15 AM, AutoCAD PDF (General Documentation).pc3

Kansas Geological Survey | Geology | Industrial Mineral Producers

Industrial Minerals--Douglas County; Both Active and Abandoned Quarries

106 records returned. **You may also choose to save this data to a file.**
Show Active Quarries || Show Abandoned Quarries || **Both Active and Abandoned Quarries Shown**

Coal

Company	Type	Location
Name Unknown	Abandoned	T13S, R20E, Sec. 26, SWNE Long: -95.15585, Lat: 38.89331

Limestone

Company	Type	Location
N.R. Hamm Quarries, Inc. P. O. Box 17 One Perry Plaza Perry, KS 66073-0017 785-597-5111	Surface Abandoned	T12S, R19E, Sec. 1, ALL Long: -95.25139, Lat: 39.03689
	Surface Active	T12S, R19E, Sec. 1, N2 Long: -95.2514, Lat: 39.04052
	Surface Active	T13S, R18E, Sec. 3, NW Long: -95.40453, Lat: 38.95316
	Surface Active	T13S, R18E, Sec. 3, E2NW Long: -95.40222, Lat: 38.95315
	Surface Active	T13S, R18E, Sec. 35, SW Long: -95.38589, Lat: 38.87331
	Surface Active	T13S, R18E, Sec. 35, SW Long: -95.38589, Lat: 38.87331
	Surface Active	T13S, R18E, Sec. 35, SW Long: -95.38589, Lat: 38.87331
	Surface Active	T13S, R21E, Sec. 15, SE Long: -95.06036, Lat: 38.91686
	Surface Active	T13S, R21E, Sec. 15, SW Long: -95.06982, Lat: 38.91686
	Surface Active	T13S, R21E, Sec. 15, N2 Long: -95.06508, Lat: 38.92414
	Surface Active	T13S, R21E, Sec. 15, S2SE Long: -95.06036, Lat: 38.91504
	Surface Active	T13S, R21E, Sec. 15, SW Long: -95.06982, Lat: 38.91686

Killough Quarries, Inc. P. O. Box 3729 Lawrence, Kansas 66046 913-843-5685	Surface Active	T13S, R18E, Sec. 1, SW Long: -95.36757, Lat: 38.94604
	Surface Active	T13S, R21E, Sec. 4, SE Long: -95.07932, Lat: 38.94596
	Surface Active	T13S, R21E, Sec. 4, NE Long: -95.07941, Lat: 38.95334
	Surface Abandoned	T14S, R20E, Sec. 27, SW Long: -95.18158, Lat: 38.80053
	Surface Active	T15S, R18E, Sec. 14, NW Long: -95.38526, Lat: 38.74973
	Abandoned	T15S, R18E, Sec. 14, NW Long: -95.38526, Lat: 38.74973
	Surface Active	T15S, R18E, Sec. 15, NE Long: -95.39455, Lat: 38.74976
Martin Marietta Agg.	Abandoned	T12S, R17E, Sec. 23, Long: -95.4915, Lat: 38.99307
	Abandoned	T12S, R17E, Sec. 26, Long: -95.49136, Lat: 38.97858
Penny'S Red-E Mix	Abandoned	T12S, R18E, Sec. 2, NE Long: -95.37699, Lat: 39.04039
Killough, Inc.	Abandoned	T14S, R20E, Sec. 20, SW Long: -95.2188, Lat: 38.8152
	Abandoned	T14S, R20E, Sec. 20, SE Long: -95.20953, Lat: 38.81516
	Abandoned	T14S, R20E, Sec. 21, SW Long: -95.20023, Lat: 38.81513
	Abandoned	T14S, R20E, Sec. 27, NW Long: -95.18158, Lat: 38.80779
N.R. Hamm Quarry, Inc.	Abandoned	T12S, R19E, Sec. 1, ALL Long: -95.25139, Lat: 39.03689
Killough Quarries, Inc	Abandoned	T14S, R20E, Sec. 27, SW Long: -95.18158, Lat: 38.80053
Hunt Midwest Mining Inc. Po Box 12659 Kansas City, Mo 64116 816-455-3876	Surface Active	T13S, R18E, Sec. 1, S2SW Long: -95.36758, Lat: 38.94423
	Surface Active	T13S, R21E, Sec. 4, NE Long: -95.07941, Lat: 38.95334
	Surface Active	T15S, R18E, Sec. 15, NE Long: -95.39455, Lat: 38.74976
Martin Marietta Materials Inc 11252 Aurora Street Des Moines, Ia 50322 515-254-0050	Surface Active	T12S, R17E, Sec. 22, E2 Long: -95.50542, Lat: 38.99313

Perry Jones	Abandoned	T13S, R19E, Sec. 20, SW Long: -95.33037, Lat: 38.90249
(Dale Bloom)	Abandoned	T15S, R17E, Sec. 13, SE Long: -95.46816, Lat: 38.74245
Martin Marietta Aggregates P. O. Box 5904 Topeka, Kansas 66605 913-267-5230	Surface Active	T12S, R17E, Sec. 23, Long: -95.4915, Lat: 38.99307
	Surface Active	T12S, R17E, Sec. 26, Long: -95.49136, Lat: 38.97858
	Surface Active	T13S, R19E, Sec. 4, NE Long: -95.30206, Lat: 38.95336
	Surface Active	T14S, R19E, Sec. 14, NW Long: -95.27408, Lat: 38.8369
Concrete Materials	Abandoned	T12S, R18E, Sec. 33, SW Long: -95.42308, Lat: 38.96035
	Abandoned	T12S, R19E, Sec. 1, NE Long: -95.24675, Lat: 39.04054
	Abandoned	T12S, R19E, Sec. 8, NE Long: -95.32118, Lat: 39.02602
	Abandoned	T13S, R18E, Sec. 34, NE Long: -95.39513, Lat: 38.8806
	Abandoned	T13S, R19E, Sec. 4, SW Long: -95.31155, Lat: 38.94617
	Abandoned	T13S, R19E, Sec. 34, SWNE Long: -95.28587, Lat: 38.87895
	Abandoned	T13S, R21E, Sec. 20, NW Long: -95.10705, Lat: 38.90959
	Abandoned	T14S, R18E, Sec. 22, SE Long: -95.39487, Lat: 38.81521
	Abandoned	T14S, R18E, Sec. 24, SW Long: -95.36699, Lat: 38.8152
	Abandoned	T14S, R19E, Sec. 14, NW Long: -95.27408, Lat: 38.8369
	Abandoned	T14S, R20E, Sec. 28, SE Long: -95.1909, Lat: 38.80054
Name Unknown	Abandoned	T12S, R17E, Sec. 11, SESW Long: -95.49406, Lat: 39.01669
	Abandoned	T12S, R18E, Sec. 32, SE Long: -95.43236, Lat: 38.96034
	Abandoned	T12S, R19E, Sec. 10, NW Long: -95.29303, Lat: 39.02596
	Abandoned	T12S, R19E, Sec. 16, SW Long: -95.31159, Lat: 39.00426
		T12S, R19E, Sec. 34, NW

	Abandoned	Long: -95.29266, Lat: 38.96787
	Abandoned	T13S, R18E, Sec. 1, SW Long: -95.36757, Lat: 38.94604
	Abandoned	T13S, R18E, Sec. 12, SE Long: -95.3582, Lat: 38.93153
	Abandoned	T13S, R18E, Sec. 15, SW Long: -95.40474, Lat: 38.91691
	Abandoned	T13S, R18E, Sec. 34, NE Long: -95.39513, Lat: 38.8806
	Abandoned	T13S, R19E, Sec. 16, SE Long: -95.30237, Lat: 38.91714
	Abandoned	T13S, R19E, Sec. 17, SW Long: -95.33038, Lat: 38.91707
	Abandoned	T13S, R19E, Sec. 35, NWNW Long: -95.27651, Lat: 38.88261
	Abandoned	T13S, R21E, Sec. 4, NE Long: -95.07941, Lat: 38.95334
	Abandoned	T13S, R21E, Sec. 15, SE Long: -95.06036, Lat: 38.91686
	Abandoned	T13S, R21E, Sec. 18, SESW Long: -95.12318, Lat: 38.91511
	Abandoned	T13S, R21E, Sec. 22, SE Long: -95.0604, Lat: 38.90229
	Abandoned	T14S, R19E, Sec. 19, SE Long: -95.33931, Lat: 38.81515
	Abandoned	T14S, R20E, Sec. 29, SE Long: -95.20953, Lat: 38.80061
	Abandoned	T15S, R18E, Sec. 1, NENE Long: -95.3552, Lat: 38.78061
	Abandoned	T15S, R18E, Sec. 15, NE Long: -95.39455, Lat: 38.74976
	Abandoned	T15S, R19E, Sec. 5, NE Long: -95.32053, Lat: 38.77872
Martin Marietta	Abandoned	T13S, R19E, Sec. 4, NE Long: -95.30206, Lat: 38.95336

Sand & Gravel

Company	Type	Location
Penny'S Concrete Co. Inc	Abandoned	T12S, R20E, Sec. 30, Long: -95.23248, Lat: 38.97881
	Abandoned	T12S, R20E, Sec. 31, Long: -95.23242, Lat:

		38.96428
	Abandoned	T12S, R20E, Sec. 32, Long: -95.21405, Lat: 38.96425
Lawrence Sand Company	Abandoned	T12S, R19E, Sec. 15, NW Long: -95.29295, Lat: 39.01151
	Pit or Lake Dredge Abandoned	T12S, R19E, Sec. 15, NW Long: -95.29295, Lat: 39.01151
	Pit or Lake Dredge Active	T12S, R20E, Sec. 20, SW Long: -95.21897, Lat: 38.98968
Penny'S Concrete Inc 23400 W 82nd Street Shawnee Mission, Ks 66227-2705 785-441-8781	Pit Active	T12S, R20E, Sec. 35, E2 Long: -95.1532, Lat: 38.96414
Lawrence Sand Co.	Abandoned	T12S, R19E, Sec. 15, NW Long: -95.29295, Lat: 39.01151
	Abandoned	T12S, R20E, Sec. 20, Long: -95.21438, Lat: 38.99331
Kaw Sand Inc	Abandoned	T12S, R20E, Sec. 29, Long: -95.21417, Lat: 38.97882
Bowersock Mills	Abandoned	T12S, R20E, Sec. 33, Long: -95.19538, Lat: 38.96421
Bowersock Mill & Power Co.	Abandoned	T12S, R20E, Sec. 30, SW Long: -95.23695, Lat: 38.97519
Penny'S Concrete Co. Inc.	Abandoned	T12S, R20E, Sec. 29, Long: -95.21417, Lat: 38.97882
Penny'S Sand 23400 West 82nd St. Shawnee Mission, Ks 66227 913-441-8781	River Dredge Active	T12S, R20E, Sec. 25, SW Long: -95.14407, Lat: 38.97501
Kaw Sand Inc.	Abandoned	T12S, R20E, Sec. 30, Long: -95.23248, Lat: 38.97881
	Abandoned	T12S, R20E, Sec. 32, Long: -95.21405, Lat:

		38.96425
Name Unknown	Abandoned	T12S, R19E, Sec. 9, SE Long: -95.30233, Lat: 39.01875
	Abandoned	T12S, R19E, Sec. 9, NW Long: -95.3118, Lat: 39.026
	Abandoned	T12S, R19E, Sec. 16, NE Long: -95.30228, Lat: 39.01151
	Abandoned	T12S, R20E, Sec. 20, SE Long: -95.20964, Lat: 38.98969
	Abandoned	T12S, R20E, Sec. 30, S2 Long: -95.23245, Lat: 38.97521
	Abandoned	T12S, R21E, Sec. 31, S2 Long: -95.12099, Lat: 38.96057
	Abandoned	T13S, R17E, Sec. 13, SW Long: -95.47746, Lat: 38.91693
	Abandoned	T13S, R18E, Sec. 21, NW Long: -95.42313, Lat: 38.90973
	Abandoned	T13S, R19E, Sec. 26, SW Long: -95.27419, Lat: 38.88808
	Abandoned	T13S, R19E, Sec. 26, SE Long: -95.26482, Lat: 38.88807
Penny'S Concrete Co., Inc.	Abandoned	T12S, R20E, Sec. 26, Long: -95.1581, Lat: 38.97863
Penny'S Concrete Company, Inc. 23400 W. 82nd Street Shawnee Mission, Kansas 66227 913-441-8781	River Dredge Active	T12S, R20E, Sec. 26, SE Long: -95.15333, Lat: 38.975
	River Dredge Active	T12S, R20E, Sec. 29, ALL Long: -95.21417, Lat: 38.97882
	River Dredge Active	T12S, R20E, Sec. 30, ALL Long: -95.23248, Lat: 38.97881
	River Dredge Active	T12S, R20E, Sec. 31, ALL Long: -95.23242, Lat: 38.96428
	River Dredge Active	T12S, R20E, Sec. 32, ALL Long: -95.21405, Lat: 38.96425

	River Dredge Active	T12S, R20E, Sec. 35, NW Long: -95.16243, Lat: 38.96776

Sandstone

Company	Type	Location
Name Unknown	Abandoned	T15S, R20E, Sec. 9, NW Long: -95.19975, Lat: 38.76408

Kansas Geological Survey
Comments or questions to webadmin@kgs.ku.edu
URL=http://www.kgs.ku.edu/Magellan/Minerals/index.html
Display Programs Updated Aug. 12, 2003
Data added periodically.