

THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

BEFORE COMMISSIONERS: Pat Apple, Chairman
Shari Feist Albrecht
Jay Scott Emler

In the Matter of the Application of Quail Oil
& Gas, LC to authorize injection of saltwater
Into the Arbuckle formation at the Sly 2-6
SWD well, located in the NE NE SE of
Section 6, Township 17S, Range 6E in
Morris County, Kansas

Docket No. 17-CONS-3484-CUIC

CONSERVATION DIVISION

License No. 33185

TESTIMONY OF JAMES ABERS, Ph.D.

ON BEHALF OF PROTESTANTS

May 22, 2017

1 Q. Please state your name:

2 A. James Aber.

3 Q. Where do you reside?

4 A. Emporia, Kansas.

5 Q. Are you presently employed? If so, by whom and in what capacity?

6 A. At the time of this written testimony I am employed by Emporia State University as a Distinguished
7 Professor.

8 Q. Do you anticipate that your employment status may change during this case? If so, in what way(s)?

9 I will retire at the end of May 2017.

10 Q. What are your academic qualifications?

11 A. Ph.D. in Geology plus nearly four decades as a geology professor.

12 Q. Please summarize your relevant employment history.

13 A. Chadron State College, Nebraska (1978-80) and Emporia State University, Kansas (1980-2017).

14 Q. Do you have particular research interests that you consider relevant to your testimony in this docket?

15 A. I have taught structural geology and tectonics at undergraduate and graduate levels for nearly four
16 decades. For further detail about my qualifications and background please refer to the curriculum vita
17 attached hereto and designated as Ex.1.

18 Q. For whom are you providing testimony in this docket?

19 A. The five individuals designated "protestants" in this docket.

1 Q. Are you being compensated for your services?

2 A. I am not receiving any fee for my services. However, protestants have agreed to pay my travel
3 expenses.

4 Q. Have you previously testified before the Commission?

5 A. No.

6 Q. Are you familiar with the geology of the area of the wastewater injection well in this docket? Please
7 describe.

8 A. Yes. I have conducted detailed mapping of surficial geology in the Flint Hills region, specifically for
9 Butler County and parts of Chase and Morris counties.

10 Q. Are you familiar with the structure and function of the type of wastewater injection well in this
11 docket? If so, upon what is your familiarity based?

12 A. Yes. General knowledge of injection practices, including the Tertiary Oil Recovery Project when I was
13 a graduate student at the University of Kansas.

14 Q. Please designate the location of the wastewater injection well in this docket.

15 A. Based on the application, the well is located in Sec. 6-T17S-R6E in southern Morris County. Exhibit 2,
16 attached hereto, includes a map of the area in question.¹ I have designated the approximate location of
17 the well with a red "X".

18 Q. Approximately how far from Diamond Creek is the wastewater well in this docket?

¹ Exhibit 2 is a summary of information concerning the proposed injection well. In addition to the map designated as Figure 1, it includes a list of references that also support my testimony in this docket.

1 A. Section 6 includes Threemile Creek, a tributary of Diamond Creek and directly aligned with main
2 trend of Diamond Creek valley.

3 Q. What are the characteristics of the geology implicated by the wastewater injection well in this
4 docket?

5 A. The well location directly overlies a buried basement uplift known as the Nemaha Ridge. On the
6 eastern side of the Nemaha Ridge is the Humboldt Fault zone. The Humboldt Fault zone is characterized
7 by multiple, parallel faults that trend north-northeast. Ex. 2 shows the location the wastewater injection
8 well in this docket (designated by red "x" on Fig.1), the Nemaha Ridge and the Humboldt Fault zone.

9 The Nemaha Ridge is a buried basement uplift. What is that?

10 A. Ridge of basement (granite) rock uplifted by displacement along the Humboldt Fault zone.

11 Q. What is a fault zone?

12 A. A series of more-or-less parallel faults that display similar offset or sense of movement.

13 Q. Describe the relevant characteristics of the Humboldt Fault zone.

14 A. A series of NE-SW trending faults in southern Morris and northern Chase counties that are offset by
15 NW-SE trending faults of the Lost Springs trend. The site in question is bounded by these faults. These
16 are considered to be ancient (Precambrian) faults that were reactivated during the Paleozoic (Berendsen
17 and Blair 1986).

18 Q. Is there a relationship between the Nemaha Ridge and Humboldt Fault zone that causes you concerns
19 about the wastewater injection well in this docket? Please explain.

1 A. Yes. The faults of the Humboldt zone have been active historically. The largest earthquake in Kansas
2 (Modified Mercalli VII)² took place along this fault zone in the Manhattan-Wamego vicinity in 1867
3 (Steeple and Brosius 2014). Under the Modified Mercalli measure the 1867 earthquake would be
4 considered “very strong”.

5 Q. Are there other geologic characteristics that raise concerns about earthquakes in this area?

6 A. Yes. The Nemaha-Humboldt Ridge north-northeast trend is cross-cut by faults of the Bourbon Arch
7 complex (Lost Springs trend) that run toward the northwest. The Bourbon Arch complex intersection
8 with the Nemaha-Humboldt Ridge creates a complicated network of faults in Morris and Chase counties
9 and in the vicinity of the wastewater injection well in this docket.

10 Q. What are lateral strike-slip faults?

11 A. Faults that experience primarily horizontal displacements.

12 Q. Please describe the lateral strike-slip faults present in the NNE-trending Humboldt zone and the NW-
13 trending Bourbon Arch complex

14 A. The NNE-trending Humboldt zone is characterized by left-lateral strike-slip faults. The NW-trending
15 Bourbon arch complex includes right-lateral strike-slip faults. The geologic consequence of the
16 intersection of these left-lateral and right-lateral strike-slip is a complex web of faults in the area of
17 southern Morris and northern Chase counties. This is the area of the wastewater well in this docket.

18 Q. Are you familiar with recent geological field work and structural analysis at Emporia State University
19 concerning this region?

² The Modified Mercalli Intensity Scale is used by the U.S. Geological Survey.
<https://earthquake.usgs.gov/learn/topics/mercalli.php>

1 A. Yes. Based on the recent Emporia State University research effort and other pertinent research, it is
2 reasonable to conclude that this region is riddled with faults. Further, these faults offset basement rock,
3 project upward through the sedimentary sequence, and some faults are exposed at the surface in the
4 vicinity of Diamond Creek.

5 Q. What is the geological significance of basement rock that is offset by faults?

6 A. Faults in the basement represent tectonic scars that may be reactivated by later tectonic stress
7 and/or human activities that may cause the faults to slip again, sometimes in directions different from
8 previous displacements of the faults.

9 What is the geological significance of faults that project upward through the sedimentary sequence?

10 A. Some basement faults are considered to be quite ancient (Precambrian), but they have been
11 reactivated later and, thus, cut through overlying and younger sedimentary strata.

12 Q. What is the geological significance of the exposure of faults in the vicinity of Diamond Creek related
13 to the wastewater well in this docket?

14 A. Exposed faults are the surficial expression of faults that extend into the subsurface and are well
15 known from previous geophysical investigations of this region.

16 Q. Why does the presence of the fault complex raise concerns about the wastewater injection well in
17 this docket?

18 A. The U.S. Geological Survey has concluded that wastewater disposal is the primary source of the
19 recent increase in earthquakes in the central United States. (USGS 2017). I have reviewed the reports of
20 this survey and its conclusions are reasonable and based on sound geological interpretations of the
21 interactions between wastewater and faults.

1 Q. Can you elaborate on the nature of the relevant interactions between wastewater fluids and faults?

2 A. Fluids injected under high pressure naturally tend to migrate along existing fractures and faults in the

3 subsurface. The effect of such high-pressure fluid is to reduce the stress necessary for fault movement

4 and resulting earthquakes. In effect, fluid lubricates the fault.

5 Q. Upon what do you base your answer concerning the interactions between wastewater fluids and

6 faults?

7 A. Numerous studies of the effects of high-pressure fluid for fault displacement going back to the classic

8 work of Hubbert and Rubey (1959).

9 Q. But doesn't the depth of the wastewater well in this docket affect the probability of increased

10 earthquake frequency and/or intensity? Explain.

11 A. High-pressure fluids would migrate along pre-existing fractures outward as well as upward and

12 downward from the spot of injection. Deeper injection does have the possibility of reaching basement

13 faults.

14 Q. Has the U.S. Geological Survey determined whether earthquakes may be triggered at distances that

15 are remote from the site of a wastewater injection well?

16 A. Yes. The U.S.G.S. has reported that wastewater injection-well-caused earthquakes may occur as much

17 as 10 miles or more from the well's location.

18 Q. Do you have an opinion, within a reasonable degree of scientific certainty, concerning the probability

19 of whether the wastewater well at issue in this docket might induce earthquakes that would likely not

20 occur in the absence of the fluids disposed of in the subject well?

1 A. Yes. In my opinion the area where the wastewater well in this docket is located is particularly
2 vulnerable to interactions between numerous, nearby, known faults and fluids disposed of in
3 wastewater injection wells.

4 Q. Does this conclude your testimony?

5 A. Yes.

6 VERIFICATION

7
8
9 STATE OF KANSAS)
10) ss:
11 COUNTY OF LYON)

12 James Aber, of lawful age, being first duly sworn upon oath, deposes and states: That he
13 is responsible for the testimony to which this verification is attached, that he has read the above
14 and foregoing and that the statements therein contained are true and correct according to his
15 knowledge, information and belief.

16
17 _____
James Aber, Ph.D.

18 Subscribed and sworn to before me this ____ day of _____, 2015.

19

20 My appointment expires: _____
21 _____
Notary Public

JAMES SANDUSKY ABER — FULL RÉSUMÉ

February 2017

Roe R. Cross Distinguished Professor
Physical Sciences Department
Emporia State University
(jaber@emporia.edu)

DEGREES

B.S. in Geology. State University of New York at Binghamton (now Binghamton University), 1974. Ralph E. Digman Award for outstanding academic performance.
M.S. in Geology. University of Kansas, Lawrence, Kansas, 1976. Thesis: *Upland glacial stratigraphy in the Binghamton-Montrose region of New York and Pennsylvania*. Sun Oil Tuition Scholarship; Erasmus Haworth Award, outstanding master's student.
Ph.D. in Geology. University of Kansas, Lawrence, Kansas, 1978. Dissertation: *Erratic-rich drift in the Appalachian Plateau: Its nature, origin, and conglomerates*. Graduate School Summer Fellowship; Doctoral Comprehensive Examination passed with Honors; University Dissertation Fellowship; Erasmus Haworth Award, outstanding doctoral student.

ACADEMIC EMPLOYMENT

Assistant Professor: Chadron State College, Nebraska, 1978-80.
Assistant Professor: Emporia State University, Kansas, 1980-84.
Associate Professor: Emporia State University, Kansas, 1984-90.
Professor: Emporia State University, Kansas, 1990-2017.

CURRENT COURSES

Ice Age/Quaternary Environments, Field Geomorphology, Wetland Environments, Introduction to Geospatial Analysis, Computer Mapping Systems, Small Format Aerial Photography, Remote Sensing, Advanced Image Processing, Plate/Global Tectonics, History of Geology, Advanced Tectonics, Earth Science Research/Thesis.

INTERNATIONAL EXPERIENCE

Fulbright-Hays Student Award: Department of General Geology, University of Copenhagen, Denmark. January-August, 1979. For postdoctoral study of Scandinavian glacial geomorphology and geoarchaeology. Funded by the Institute for International Education.
Faculty Exchange: Department of Geography, University of Regina (Saskatchewan), Canada. July-December, 1984. For teaching geography—remote sensing and glacial geomorphology, and for research in glacial geomorphology. Funded by U.S. Information Agency.
Marshall Award/ESU sabbatical: Department of Geology, University of Bergen, Norway. February-July, 1987. For study of Scandinavian glacial geology and glaciotectionics. Norwegian Marshall Fund.
Fulbright Scholar Award/ESU sabbatical: Institute of Geology, University of Warsaw, Poland. July-December, 1993. For study of Polish glacial geomorphology and for teaching short course on satellite remote sensing of glaciated terrain. Funded by Council for International Exchange of Scholars.

Exhibit 1

Scandinavian research course: Geographical Institute, University of Copenhagen; field course taught in Iceland. August, 1994. Guest teacher for glaciotectonics and remote sensing of glaciated terrain. Funded by NorFA (*Nordisk Forskerutdanningsakademi*).

Faculty Exchange: Department of Geology, University of Tartu, Estonia. August-December, 2000. For remote sensing of glacial geomorphology and wetland environments in eastern Baltic region. Funded by U.S. National Research Council, Baltic twinning program with Estonia.

Field investigations in Slovakia: Alpine and fluvial geomorphology of Tatra Mountains and major river valleys. Institute for Geosciences, Technical University of Košice; funded by Slovak Academic Information Agency. July-August 2007.

Faculty exchange grant with the Technical University of Košice, Slovakia. Full funding for travel and accommodation for a faculty exchange, May-June 2016.

LANGUAGE PROFICIENCY

- Fair comprehension: Danish and Norwegian.
- Basic knowledge: Estonian, Polish, Slovakian, Spanish, Swedish.
- Reading ability: French.

PROFESSIONAL AFFILIATIONS AND SERVICE

- INQUA (International Union for Quaternary Research). Vice-president (1987-1995) Commission on Glaciation; founder and President (1995-2003) work group on geospatial analysis of glaciated environments (<http://www.emporia.edu/earthsci/gage/gage.htm>).
- Sigma Xi, The Scientific Research Society—Life Member.
- History of Earth Sciences Society.
- Suoseura, the Finnish Peatland Society.
- Kansas Academy of Science: past President of the academy and past Co-editor of the *Transactions*.
- Editorial board, *Boreas*, an international journal devoted to Quaternary science.
- Co-editor for *Emporia State Research Studies*

HONORS, GRANTS AND AWARDS

- Eagle Boy Scout.
- Sigma Xi Grants-in-Aid of Research (3), 1975-1977.
- Institutional Grants, Chadron State College, Nebraska, 1978-80.
- Institutional Grants, Emporia State University, 1980-2012.
- Travel Grant, U.S. INQUA Committee, XI INQUA Congress, Moscow, USSR, 1982.
- Special Merit Awards (3) for exceptional scholarly accomplishment, College of Liberal Arts and Sciences, Emporia State University: 1985, 1987, and 1989.
- Best *Hertitage of the Great Plains* article of the year for 1988 (see Aber 1988, The glaciation of Kansas).
- Kansas Geological Survey: interagency contract for mapping surficial geology of Butler County, Kansas, 1989-91.
- NASA JOint Venture (JOVE) grant to ESU for 1991-94: use of satellite imagery for mapping and analysis of glacial landforms, in cooperation with Goddard Space Flight Center, MD.

- North Dakota Geological Survey and North Dakota State Department of Health and Consolidated Laboratories: grant for purchase of satellite data for geologic and hydrologic investigation of Devils Lake vicinity, North Dakota, 1991-94.
- NASA JOVE awards (4): for curriculum and program development of geospatial analysis at Emporia State University, 1992-95.
- Kansas Dept. of Wildlife and Parks: interagency contract for study of gravel resources and hydrologic behavior of the Neosho River in southeastern Kansas, 1993-95.
- NASA JOVE Augmentation Grant for use of space-shuttle photographs and satellite imagery for mapping and analysis of glacial landforms, in cooperation with Johnson Space Center, Houston, 1994-96.
- Roe R. Cross Distinguished Professor, Emporia State University, 1994-95. Highest faculty award at Emporia State University, given for a record of sustained academic achievement, excellent teaching, and university service.
- Danish Natural Science Research Council, 1995-97. Multinational investigations of Myrdalsjökull ice cap, Iceland (led by J. Krüger). Co-principal investigator for use of satellite imagery and ground-based observations to document glacier dynamic activity.
- NSTA/NASA Mission to Planet Earth contest. National **first prize** for space-science project by 8th-grade students from Holy Trinity Catholic School, Paola, Kansas. Faculty consultant. 1995.
- INQUA grant for central European glaciotectonic map project, 1996-99.
- NASA EPSCoR award in connection with Kansas State University and the University of Kansas. Co-principal investigator for remote sensing of rural resources, focus on glaciated terrain of northeastern Kansas. 1996-2001.
- President's Award for Research and Creativity, Emporia State University, 1996-97.
- ESU Technology Award, in recognition of the use of technology to improve teaching or support the university, 1999.
- Kahola Park Cabin Owners Association, Kansas: Kite aerial photography and creation of image database for cabin properties around lake perimeter. Consulting with financial donations to earth science department, 2001-2004.
- NASA EPSCoR award in connection with Kansas State University and the University of Kansas. Co-principal investigator for remote sensing of rural resources, focus on wetland sites in central Kansas. 2002-2004. See <http://www.geospectra.net/cheyenne/bottoms.htm>
- Award for "Innovative use of KAP" at the international conference on Kite Aerial Photography in California, KAPiCA/02. 2002.
- Kemper Foundation, Commerce Bank of Kansas City, Missouri: Satellite imagery and kite aerial photography of Missouri River bottomland forest from St. Louis to North Dakota, in connection with Lewis and Clark bicentennial atlas, 2002-2003. See http://www.geospectra.net/lewis_cl/
- Bureau of Reclamation, Pueblo, Colorado. On-site training sessions for kite aerial photography in 2003 and continuing consultation (2006).
- NSF/AAAS 2005 Science and Engineering Visualization Challenge. *Autumn color; Estonian bog* won **first place** in the photography category. The winning image and a short description were published in *Science* (vol. 309, p. 1991). This award represents the ultimate recognition for scientific visual imagery. See <http://www.sciencemag.org/cgi/content/full/309/5743/1991b>
- Kansas View grant related to small-format aerial photography in Kansas. Student support and travel expenses, 2006-08.
- Best kite aerial photograph taken during KAPiCA06 conference in Pacific Grove, California, November 2006.

JOURNAL PUBLICATIONS

- Aber, J.S. 1979. Glacial conglomerates of the Appalachian Plateau, New York. *Quaternary Research* 11, p. 185-196.
- Aber, J.S. 1979. Kineto-stratigraphy at Hvideklint, Møn, Denmark and its regional significance. *Geological Society Denmark, Bulletin* 28, p. 81-93.
- Aber, J.S. 1980. Nature and origin of exotic-rich drift in the Appalachian Plateau. *American Journal of Science* 280, p. 363-384.
- Aber, J.S. 1982. Two-ice-lobe model for Kansan glaciation. *Nebraska Academy Sciences, Transactions* 10, p. 25-29.
- Aber, J.S. 1982. Model for glaciotectionism. *Geological Society Denmark, Bulletin* 30, p. 79-90.
- Aber, J.S. 1984. History of Kansas glacial geology. *Earth Sciences History* 3, p. 134-142.
- Aber, J.S. 1985. Definition and model for Kansan glaciation. *Ter-Qua Symposium Series* 1, p. 53-60.
- Aber, J.S. 1985. Quartzite-bearing gravels and drainage development in eastern Kansas. *Ter-Qua Symposium Series* 1, p. 105-110.
- Aber, J.S. 1985. The nature of glaciotectionism. *Geologie en Mijnbouw* 64, p. 389-395.
- Aber, J.S. 1988. West Atchison drift section. *Geological Society America, Centennial Field Guidebook* 4, p. 5-10.
- Aber, J.S. and Aarseth, I. 1988. Glaciotectionic structure and genesis of the Herdla Moraines, western Norway. *Norsk Geologisk Tidsskrift* 68, p. 99-106.
- Aber, J.S. and Lundqvist, J. 1988. Glaciotectionic structures in central Sweden and their significance for glacial theory. *Géographique Physique et Quaternaire* 42/3, p. 315-323.
- Aber, J.S. 1988. Ice-shoved hills of Saskatchewan compared with Mississippi delta mudlumps—Implications for glaciotectionic models. In Croot, D.G. (ed.), *Glaciotectionics: forms and processes*, p. 1-9. A.A. Balkema, Rotterdam.
- Aber, J.S. 1988. Upland chert gravels of east-central Kansas. *Kansas Geological Survey, Guidebook Series* 6, p. 17-19.
- Aber, J.S. 1988. Spectrum of constructional glaciotectionic landforms. In Goldthwait, R.P. and Matsch, C.L. (eds.), *Genetic classification of glacial deposits*, p. 281-292. A.A. Balkema, Rotterdam.
- Aber, J.S. 1988. The glaciation of Kansas. *Heritage of the Great Plains* 21/4, 36 p.
- Aber, J.S. 1988. Bibliography of glaciotectionic references. In Croot, D.G. (ed.), *Glaciotectionics: forms and processes*, p. 195-210. A.A. Balkema, Rotterdam.
- Aber, J.S. 1991a. The glaciation of northeastern Kansas. *Boreas* 20, p. 297-314.
- Aber, J.S. 1991b. Surficial geology of Butler County, Kansas. *Kansas Geological Survey, Open-File Report* 91-48, 31 p.
- Wayne, W.J. and Aber, J.S. 1991. Quaternary geology of the northern Great Plains: High Plains and Plains Border sections in Nebraska, Kansas, and Oklahoma. In Morrison, R.B. (ed.), *Quaternary Nonglacial Geology: Conterminous U.S.*, *Geological Society America, The Geology of North America*, vol. K-2, p. 462-469. Geological Society of America, Boulder, Colorado.
- Aber, J.S. 1992. Glaciotectionic structures and landforms. *Encyclopedia of Earth System Science*, vol. 2, p. 361-378. Academic Press, San Diego.
- Aber, J.S. 1992. Chert gravel, drainage development, and sinkholes in the Walnut basin, south-central Kansas. *Kansas Academy Science, Transactions* 95, p. 109-121.
- Aber, J.S. 1993. Geomorphic and structural genesis of the Dirt Hills and Cactus Hills, Saskatchewan. In Aber, J.S. (ed.), *Glaciotectionics and mapping glacial deposits*. *Canadian Plains Research Center; Canadian Plains Proceedings* 25, vol. 1, p. 9-35. Regina, Canada.

- Aber, J.S. 1993. Expanded bibliography of glaciotectonic references. In Aber, J.S. (ed.), Glaciotectonics and mapping glacial deposits. *Canadian Plains Research Center; Canadian Plains Proceedings* 25, vol. 1, p. 99-137. Regina, Canada.
- Aber, J.S., Bluemle, J.P., Brigham-Grette, J., Dredge, L.A., Sauchyn, D.J. and Ackerman, D.L. 1993. Glaciotectonic data base and mapping of North America. In Aber, J.S. (ed.), Glaciotectonics and mapping glacial deposits. *Canadian Plains Research Center; Canadian Plains Proceedings* 25, vol. 1, p. 177-200. Regina, Canada.
- Aber, J.S., Spellman, E.E. and Webster, M.P. 1993. Landsat remote sensing of glacial terrain. In Aber, J.S. (ed.), Glaciotectonics and mapping glacial deposits. *Canadian Plains Research Center; Canadian Plains Proceedings* 25, vol. 1, p. 215-225. Regina, Canada.
- Aber, J.S. 1993. Glaciotectonic landforms and structures. In Sauchyn, D.J. (ed.), Quaternary and Late Tertiary landscapes of southwestern Saskatchewan and adjacent areas. *Canadian Plains Research Center; Canadian Plains Proceedings* 25, vol. 2, p. 20-26. Regina, Canada.
- Aber, J.S., Ruszczynska-Szenajch, H. and Krzyszkowski, D. 1995. Landsat interpretation of glaciotectonic terrain and regional lineaments in Poland. *Quaestiones Geographicae*, Special Issue 4, p. 1-11.
- Aber, J.S., Spellman, E.E., Webster, M.P. and Rand, L.L. 1997. Applications of Landsat imagery in the Great Plains. *Kansas Academy of Science, Transactions* 100, p. 47-60.
- Aber, J.S. and Ruszczynska-Szenajch, H. 1997. Glaciotectonic origin of Elblag Upland, northern Poland, and glacial dynamics in the southern Baltic region. *Sedimentary Geology* 111, p. 119-134.
- Aber, J.S. 1997. Chert gravel and Neogene drainage in east-central Kansas. *Kansas Geological Survey, Current Research in Earth Sciences, Bulletin* 240, p. 29-41.
- Aber, J.S., Nang, K.N., Wilkins, N.H., Ye, H., Harrington, J. and Nowak, M.C. 1998. Remote sensing of forest growth and response to climatic variations in northeastern Kansas, U.S.A. *Proceedings for 27th International Symposium on Remote Sensing of Environment*, Tromsø, Norway, p. 709-714.
- Aber, J.S., Webster, M.P., Garmon, B.B. and Krüger, J. 1998. Landsat MSS remote sensing and GIS analysis of glacier change and dynamics for Myrdalsjökull, Iceland. *Proceedings, Pecora 13 Symposium—Human interactions with the environment: Perspective from space*, p. 536-540 (CD-ROM). *American Society for Photogrammetry and Remote Sensing*.
- Aber, J.S., Sobieski, R., Distler, D.A. and Nowak, M.C. 1999. Kite aerial photography for environmental site investigations in Kansas. *Kansas Academy Science, Transactions* 102, p. 57-67.
- Aber, J.S., Harrington, J. and Nowak, M.C. 1999. Kite aerial photography for forest assessment at Fort Leavenworth, Kansas. *Proceedings—From image to information*, p. 484-490 (on CD-ROM). *American Society of Photogrammetry and Remote Sensing*.
- Aber, J.S. 1999. Pre-Illinoian glacial geomorphology and dynamics in the central United States, west of the Mississippi. In Mickelson, D.M. and Attig, J.W. (eds.), *Glacial processes past and present. Geological Society of America, Special Paper* 337, p. 113-119.
- Aber, J.S. and Galazka, D. 2000. Kite aerial photography for Quaternary investigations in Poland. *Geological Quarterly* 44/1, p. 33-38.
- Aber, J.S., Aber, S.W. and Leffler, B. 2001. Challenge of infrared kite aerial photography. *Kansas Academy Science, Transactions* 104, p. 18-27.
- Aber, J.S. and Aber, S.W. 2001. Limestone xenoliths in Hills Pond lamproite, Woodson County, Kansas. *Kansas Academy Science, Transactions* 104, p. 120-125.
- Aber, J.S. and Aber, S.W. 2001. Potential of kite aerial photography for peatland investigations with examples from Estonia. *Suo* 52/2, p. 45-56.
- Aber, J.S., Kalm, V. and Lewicki, M. 2001. Geomorphic interpretation of Landsat imagery for western Estonia. *Slovak Geological Magazine* 7/3, p. 237-242.

- Aber, J.S. and Kalm, V. 2001. Remote sensing of eskers from Vormsi and Väinameri vicinity, northwestern Estonia. *Geological Quarterly* 45, p. 365-372.
- Aber, J.S., Wallace, J. and Nowak, M.C. 2002. Response of forest to climatic events and human management at Fort Leavenworth, Kansas. *Kansas Geological Survey, Current Research in Earth Sciences, Bulletin* 248, part 1 (<http://www.kgs.ku.edu/Current/2002/aber/aber1.html>).
- Aber, J.S., Aaviksoo, K., Karofeld, E. and Aber, S.W. 2002. Patterns in Estonian bogs as depicted in color kite aerial photographs. *Suo* 53/1, p. 1-15.
- Pavri, F., Aber, J.S., Wallace, J. and Novak, M. 2003. Monitoring forest cover trends in northeastern Kansas through historical and multi-temporal satellite-image analysis. *Kansas Academy of Science, Transactions* 106, p. 2-10.
- Aber, J.S. and Aber, S.W. 2003. Applications of kite aerial photography: Property survey. *Kansas Academy Science, Transactions* 106, p. 107-110.
- Aber, J.S., Zupancic, J. and Aber, S.W. 2003. Applications of kite aerial photography: Golf course management. *Kansas Academy Science, Transactions* 106, p. 211-214.
- Pavri, F., Aber, J. and Banman, C. 2003. Landscape change detection analyses for wetland environments. *Papers of the Applied Geography Conferences* 26, p. 276-285.
- Aber, J.S. 2004. Historical changes of the Missouri River in vicinity of Fort Leavenworth, Kansas. *Heritage of the Great Plains* 37/1, p. 4-26.
- Aber, J.S. 2004. Lighter-than-air platforms for small-format aerial photography. *Kansas Academy Science, Transactions* 107, p. 39-44.
- Pavri F. and Aber, J.S. 2004. Characterizing wetland landscapes: Multitemporal and multispatial analysis of remotely sensed data at Cheyenne Bottoms, Kansas. *Physical Geography* 25/1, p. 86-104.
- Aber, J.S. and Apolzer, K. 2004. Pre-Wisconsinan glacial database and ice limits in the central United States. In, Ehlers, J. and Gibbard, P. (eds.), *Quaternary Glaciations - Extent and Chronology, Part II: North America*. Developments in Quaternary Science, Vol. 2b, p. 83-88. Elsevier, Amsterdam.
- Aber, J.S., Eberts, D. and Aber, S.W. 2005 Applications of kite aerial photography: Biocontrol of saltcedar (*Tamarix*) in the western United States. *Kansas Academy of Science, Transactions* 108, p. 63-66.
- Aber, J.S., Aber, S.W., Pavri, F., Volkova, E. and Penner, R.L. 2006. Small-format aerial photography for assessing change in wetland vegetation, Cheyenne Bottoms, Kansas. *Kansas Academy of Science, Transactions* 109, p. 47-57.
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Proposed injection of wastewater in Morris County, Kansas

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A wastewater injection well has been proposed in Sec 6-T17S-R6E, southern Morris County, Kansas. This location raises serious concerns for its potential to induce earthquakes along one or more known faults of the vicinity. The site directly overlies a buried basement uplift known as the Nemaha Ridge, which is flanked on its eastern side by the Humboldt Fault zone with multiple, parallel faults trending generally north-northeast (Fig. 1). Faults of the Humboldt zone have been active historically. The largest earthquake in Kansas (Modified Mercalli VII) took place along this fault zone in the Manhattan-Wamego vicinity in 1867 (Steeple and Brosius 2014). Buchanan et al. (2015) have thoroughly reviewed the potential for induced earthquakes in Kansas, and they specifically identified the Nemaha Ridge and Humboldt Fault zone as structures associated with Kansas earthquakes.

The Nemaha-Humboldt trend is cross-cut by faults of the Bourbon Arch complex, which run toward the northwest. This intersection creates a complicated network of faults in Morris and Chase counties. Based on recent geological field work and structural analysis at Emporia State University, it is reasonable to say this region is riddled with faults (Peterson 2016). These faults offset basement rock, project upward through the sedimentary sequence, and some are exposed at the surface in the vicinity of Diamond Creek.

The U.S. Geological Survey has concluded that *wastewater disposal is the primary cause of the recent increase in earthquakes in the central United States* (USGS 2017). Furthermore, such earthquakes may occur *at distances of 10 miles or more* from the injection site as fluids migrate underground. Thus, all of southern Morris and northern Chase counties should be considered at risk for induced earthquakes regardless of the exact location or depth of wastewater injection.

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Exhibit 2

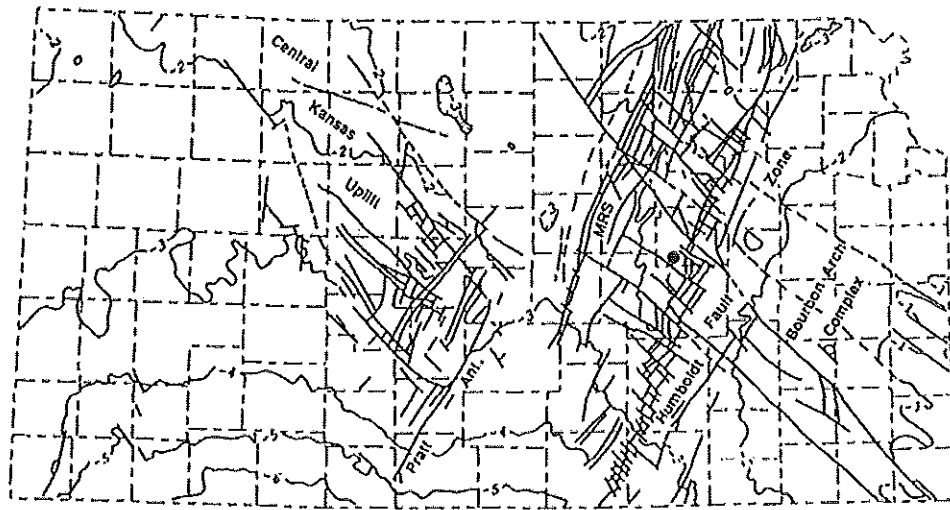


Figure 1. Kansas basement faults. The NNE-trending Humboldt Fault zone is interpreted as left-lateral strike-slip faults, and the NW-trending Bourbon arch complex includes right-lateral strike-slip faults (Baars 1995). Red dot indicates approximate location of proposed injection site. Contours show elevation of basement in thousands of feet (below sealevel). Map adapted from Baars and Watney (1991, fig. 3).