KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

July 14, 2008

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Dr. Mr. Gagné:

The Kansas Geological Survey was asked to review a proposed landfill for construction and demolition debris (C&D) with respect to its stability. The proposed landfill is located in SE ¼ of Section 21-T28S-R1W, approximately 3 miles due south of the Mid-Continent Airport on southwest side of Wichita (Figure 1). Unstable areas are defined in K.A.R. 28-29-302(h) as "areas susceptible to mass movement", which are defined as areas having active or substantial possibility of mass movement at, beneath, and adjacent to the landfill. Mass movement includes sinkholes, caves, and "karst terrain." Karst terrain is defined as topography resulting from dissolution of soluble rock (such as evaporites). Unstable areas would require information to verify engineering measures to be incorporated into the C&D landfill design to ensure that the integrity of the structural components of the C&D landfill will not be compromised.

Background Mapping

The proposed landfill is located on the eastern-most edge of the halite dissolution zone of the Hutchinson Salt Member of the Lower Permian Wellington Formation. The thickness of halite is depicted by an isopachous map of the net thickness of halite present in the Hutchinson Salt Member in the area around Wichita and the proposed landfill site (Figure 2, Watney and Paul, 1980; Watney, Berg, and Paul, 1988). The original contour map included central and western Kansas utilizing some 3,700 data points consisting of wireline logs, sample logs, and cores that covered the entire extent of the Hutchinson Salt in Kansas (Figure 3, regional net salt map of the Hutchinson Salt Member).

The dissolution zone defines the eastern edge of the Hutchinson Salt Member in central Kansas extending from southwest of Salina to southwest of Wichita (Figure 3). Between Hutchinson and south of Wichita the thickness of the net salt declines rapidly from over 200 ft in the undisturbed bedded salt west of the dissolution zone to an inferred zero halite line located east of Wichita (Figure 2). The well data selected are widely scattered along the dissolution zone including a relatively small amount of data available at the shallow depths of the salt (<200 ft) in the immediate area of the proposed landfill. Either the potential salt-bearing interval was not logged or the log types preclude determination of halite (Figure 4, Depth to Top of Hutchinson Salt Member). The zero salt line likely resides several miles to the east of the location of the proposed landfill.

The 1980 map was updated in 2006 in Sedgwick County by examining new wireline logs obtained from files at the Kansas Geological Survey in Lawrence. This update is incorporated in maps shown in Figure 3 and 4. Since few new wells were found, the change to the dissolution zone based on the new data is insignificant.

The closest well with sufficient data to the proposed landfill is the Frontier Chemical Company's Plant Site Disposal Well #2 (API: 15-173-03802) in T28S R1W, Sec. 27 SE NW SW shown in Figure 5. An unscaled gamma ray neutron log was used to estimate 20 ft of net halite present within a mile of the landfill. The top of the Hutchinson Salt is denoted at a bed with lower gamma ray and a low neutron count/high apparent porosity response that is similar to shale. In contrast, the interval between base of Hutchinson Salt and Top of Chase Group contains gypsum and dolomite beds that exhibit lower gamma ray and higher neutron county/lower apparent porosity. The low gamma ray and porous sections in the shallower interval (<150 ft) above the top of Hutchinson Salt in Figure 5 are believed to be porous Pliocene-Pleistocene-recent sands. This log response for halite is typical where salt beds have been heavily washed out around the wellbore during drilling. Different log suites call upon various levels of interpretation from quantitative to qualitative, but the key is consistency and validation when salt is present or when absent. Cores particularly have proved essential in establishing the presence of halite. As noted in Figure 2, the subsurface mapping of the net halite that remains at the site of the proposed landfill is estimated to be between 20 and 40 ft. thick.

A map of the Wellington Aquifer in Figure 6 (from Gogel, 1981) is based on areas of numerous sinks, undrained depressions, and folding of overlying strata. The aquifer is defined as the Permian bedrock interval lying above the Hutchinson Salt that underwent deformation and, in turn, porosity development as the underlying salt beds were dissolved. The Wellington Aquifer consists of broken and distorted strata as a result of the cumulative, long-term dissolution and subsidence. Rock layers between the salt and current ground surface in these highly distorted areas have minimal strength and are generally not capable of supporting a void space large enough to instigate catastrophic failure of the ground surface. Shallow-most Plio-Pleistocene and Recent sediments comprised mainly of sands and gravels lie above the Wellington Aquifer. The proposed landfill is located on the far eastern edge of the Wellington Aquifer and inferred "disturbed" strata, as might be anticipated in the context of the site within the remaining net halite (Figures 2 and 3).

Surface Subsidence

Seismic studies conducted within the dissolution zone suggest that subsidence histories extend at least as far back as mid-Tertiary. It is therefore unlikely that subsidence will end within the next millennium. Until the ground surface starts sinking, little if any evidence exists to allow prediction of sinkhole development. Long periods of inactivity followed by localized, rapid subsidence are common observations along the dissolution zone. Paleo-subsidence features, of varying dimensions from 10's of meters to km-scale, uniformly extend across the entire dissolution zone, indicative of this long history of dissolution and subsidence in this area. Salt will continue to be dissolved along the eastern edge of the Hutchinson Salt as long as the regional hydrodynamics remain reasonably consistent.

Seismic studies also indicate that reactivation of pre-existing subsidence features seems to be a key factor in active surface sinkholes, including partial reactivation of older features. Existing and suspected sinkholes in Wichita area represent 10s of 1000s of years of dissolution activity that can potentially impact infrastructure including pipelines (separation, rupture), highways (alignment or collapse), railroad (tilting, compromise of rail bed), buildings (realignment of drainage, foundation shift, utility disruption). Human induced subsidence may result from any activities changing the subsuface flow directions and rates.

Catastrophic formation of sinkholes over the Hutchinson Salt is rare, but any potential of instantaneous ground collapse represents an obvious risk to public safety. Considering the minimal strength left in the Upper Sumner Group after partial dissolution of the Hutchinson Salt along and in proximity to the dissolution zone in western Sedgwick County, catastrophic failure is exceedingly unlikely east of Goddard, Kansas, in Sedgwick County.

This residual salt at the proposed landfill site has minimal thickness compared to upwards of 200 ft immediately to the west. However, seismic imaging of the dissolution zone east of the city of Hutchinson has recognized local areas of abrupt thickening referred to here as salt "islands" (Miller, 2002, in KGS Open-File Report 2002-7 and as slide set available on the KGS website - http://www.kgs.ku.edu/Geophysics2/Pubs/2002-17%20US50%20ApdxB.pdf). A cross section in Figure 7 by Spinozola et al. (1985) depicts the main salt dissolution zone on the western edge and isolated areas of thick preserved salt that have been inferred to extend several miles east of the dissolution zone. These salt islands may become local sources for renewed subsidence as conditions change that could promote salt solution.

While it is highly likely that the residual salt will continue to slowly dissolve over geologic time, it is not possible with available information to determine when and how fast the dissolution will occur and, in turn, when and to what extent surface subsidence will occur that would be rapid and sufficient enough to affect man-made structures. One indication of relatively recent movement would be to establish evidence of surface deformation.
The land surface along this dissolution front is characterized by a relatively large number of gradually subsiding sinkholes, usually expressed as rather subtle, shallow, closed surface depressions reflecting current dissolution and recession and long-term recession of the shallow salt front to the west (Figure 8). Subsidence has been active along this front for millions of years with Permian shales that overlay the salt in Sedgwick County collapsing into voids left after progressive leaching of the salt interval. Subsidence provided space for younger surface deposits including sediment deposited by the Arkansas River. Thus, most of the surface expression left by the more than 200 ft of accumulated subsidence has been progressively filled in by younger late Tertiary and Quaternary deposition.

Potential for having active or substantial possibility of mass movement at, beneath, and adjacent to the landfill

The opportunity for further dissolution and subsidence in the context of "having active or substantial possibility of mass movement at, beneath, and adjacent to the landfill" is the key element address by this site review. To address this more precisely a recent assessment of potential for surface subsidence is summarized here that was focused on surface depressions identified by members of the Sedgwick County Commission. The assessment of these geomorphic features also serves to summarize the earlier discussion: *1) a majority of the closed surface depressions reside along the salt dissolution zone that has a relatively steep gradient between 200 ft and 60 feet of net halite; 2) strata above the dissolving salt has for the most part lost its strength as it behaves plastically and passively as it responds to further salt dissolution; 3) regional dissolution zones are developed in geologic time (millions of years), but are only locally active in human time (10's of years); 4) the nature of a dissolution zone is that it is irregular, but regionally consistent with isolated salt islands and minor dissolution behind the main dissolution along probable fracture systems; 5) human induced or assisted salt dissolution could occur to wellbore communication, changing flow of aquifer communicating with salt, or focused water flow into active sinkhole; 6) changes in rates of salt dissolution occurred through geologic time due to river incision, climate and water supply, and possibly human activities that change flow of water or providing access of water to salt and there may be variable lag times between causes and effects; and 7) aquifers and geologic features such as fractures/open joints providing access of salt to water.*

Conclusions and Assessment

The prediction of subsidence risk assessment with this evaporite karst is first to differentiate catastrophic vs. gradual surface subsidence. The Hutchinson Salt dissolution zone has experienced combinations of these styles through time as revealed in seismic data. Catastrophic subsidence would be more likely where the integrity of strata overlying salt can support cavity development. This appears not to be the case at the landfill site. Also contact of the halite with undersaturated groundwater could lead to high rates of dissolution and catastrophic subsidence in any location and precautions are needed with man-made surface and subsurface activities to prohibit dissolution. Local, gradual subsidence is more prone along and east of main dissolution zone including vicinity of the landfill since the strata overlying the remaining salt have been weakened structurally. The size of the area involved in this gradual subsidence based on areas of active and ancient subsidence (latter imaged with seismic profiling) ranges from 100's to 1000's feet wide. The duration of subsidence ranges from episodic to unknown, but is continuous in the area of dissolution.

The proposed landfill lies east of what appears to be more clearly defined expression of surface subsidence (Figure 8). Quick review of surface topography at and near the proposed landfill from the latest Google Earth imagery do not reveal any clearly defined areas of surface subsidence in the immediate vicinity of the landfill (Figure 9). While not precluding future subsidence, current active subsidence is not indicated based on this scale of observation.

Recommendation

Unstable areas are defined in K.A.R. 28-29-302(h) as "areas susceptible to mass movement", which are defined as areas having active or substantial possibility of mass movement at, beneath, and adjacent to the landfill. The possibility for instability at the proposed landfill site can not be eliminated due to the potential for further dissolution of shallow (200 to 250 ft) salt estimated to be at least 20 ft thick. Locally thick residual salt islands may also reside beneath the landfill site. Evidence for active surface subsidence is not suggested based a brief examination of surface morphology. A detailed geomorphic analysis is recommended at the proposed landfill site to identify and evaluate any potential areas of surface subsidence. Additional recommendations include acquisition of 1) a shallow borehole and accompanying wireline logs through the Hutchinson Salt Member and 2) a set of crossing high-resolution seismic lines to determine halite thickness and to eliminate the possible presence of a thick salt island. The latter may be less stable and prone to larger surface subsidence if salt dissolution occurs. If unstable areas are indicated, engineering measures need to be incorporated into the C&D landfill design to ensure that the integrity of the structural components of the C&D landfill will not be compromised.

References Cited

Gogel, T., 1981, Discharge of saltwater from Permian rocks to major stream-aquifer systems in central Kansas: Kansas Geological Survey Chemical Quality Series 9, 60 p.

Miller, R. D., 2002, High resolution seismic reflection investigation of the subsidence feature on U.S. Highway 50 at Victory Road near Hutchinson, Kansas; final report to Kansas Department of Transportation, District 5: Kansas Geological Survey Open-File Report 2002-7, 30 p., 6 pls., 3 appendixes.

Spinazola, J. M., Gillespie, J. B., and Hart, R. J., 1985, Ground-water flow and solute transport in the Equus Beds area, south-central Kansas, 1940-1979. U.S. Geological Survey, Water-Resources Investigations Report 85-4336, 68 p.

Watney, W. L.; and Paul, S. E., 1980, Maps and cross sections of the Lower Permian Hutchinson Salt Member in Kansas: Kansas Geological Survey Open-File Report 80-7, 11 p., 9 maps, 3 cross sections.

Watney, W. L.; Berg, J. A.; and Paul, S. E., 1988, Origin and distribution of the Hutchinson Salt Member (lower Leonardian) in Kansas, in Morgan, W. A.; and Babcock, J. A. (eds.), Permian rocks of the Mid-continent: Society of Economic Paleontologists and Mineralogists, Midcontinent Section, Special Publication 1, p. 113–135.

Please contact me if you have any questions.

Sincerely,

W. Lynn Watney
Senior Scientific Fellow
Kansas Geological Survey

RM — please advise this guy as to whether he's (a) in zone of dissolution or (b) elsewhere

Thanks - wh

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March 5, 2008

GAI Ref. No.: 083-81547

Kansas Geological Survey
1930 Constant Avenue
Lawrence, KS 66047-3726

To Whom It May Concern:

A Site Location Restrictions Demonstration is being prepared for a proposed landfill site in central Sedgwick County, Kansas. The proposed landfill would be for disposal of construction and demolition debris and similar materials. As the environmental consultant preparing the Site Location Restrictions Demonstration, Golder Associates Inc. is requesting the following determination as a requirement of K.A.R. 28-29-302(h):

> **(h) Unstable areas.**
> (1) For purposes of this subsection, the following definitions shall apply:
> (A) "Areas susceptible to mass movement" means those areas of influence, including areas characterized as having active, or a substantial possibility of, mass movement, where the movement of earth material at, beneath, or adjacent to the C&D landfill, because of natural or human-induced events, results in the downslope transport of soil and rock material by means of gravitational influence. Mass movement shall include the following:
> (i) Landslides;
> (ii) avalanches;
> (iii) debris slides and flows;
> (iv) solifluction;
> (v) block sliding; and
> (vi) rock falls.
> (B) "Karst terrain" means an area where karst topography, with its characteristic surface and subterranean features, is developed as the result of dissolution of limestone, dolomite, or other soluble rock. The physiographic features characteristic of karst terrains may include the following:
> (i) Sinkholes;
> (ii) sinking streams;
> (iii) caves;
> (iv) large springs; and
> (v) blind valleys.
> (C) "Poor foundation areas" means those areas where features exist that indicate that a natural or human-induced event could result in inadequate foundation support for the structural components of a C&D landfill. 121 (D) "Structural components" means liners, leachate collection systems, final covers, run-on systems, runoff systems, and any other component used in the construction and operation of the C&D landfill that is necessary for protection of public health, safety, and the environment.
> (E) "Unstable area" means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the C&D landfill structural components used to prevent releases from a landfill. This term shall include poor foundation areas, areas susceptible to mass movements, and karst terrains.
> (2) As part of the application, the applicant for each C&D landfill shall submit an assessment of the stability of the area and shall consider the following factors when determining whether or not an area is unstable:
> (A) On-site or local conditions that could result in significant differential settling;
> (B) on-site or local geologic or geomorphologic features; and

(C) on-site or local human-made features or events, both surface and subsurface.
(3) As part of the application, the applicant for each C&D landfill proposed to be located in an unstable area shall provide information verifying that engineering measures have been incorporated into the C&D landfill's design to ensure that the integrity of the structural components of the C&D landfill will not be compromised.
(4) *As part of the application, the applicant shall submit an approval or exemption for the siting of the new C&D unit with respect to stability from the Kansas geological survey* (my emphasis).

The property, which encompasses 160 acres located at the northwest corner of South Ridge Road and West 55th Street South, Wichita, Kansas (Section 21, Township 28 south, Range 1 west), is currently used for agricultural purposes. Location maps have been attached for your review.

Please send a determination on this matter to:

Golder Associates Inc.
2304 South Richfield
Wichita, Kansas 67207

Your help in this matter is greatly appreciated. If you have any questions or comments, please contact me at 316-250-2093 or via e-mail at mike_gagne@golder.com.

Sincerely,

GOLDER ASSOCIATES INC.

Michael P. Gagné

Michael P. Gagné, P.G.
Senior Geologist & Project Manager

Attachments

Additional Documentation
Not Scanned.

Available in Open-file.