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Session 1A (Soils and Geology)

Kentucky Water Resources Research Institute, University of Kentucky

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Sudden and unpredictable collapse of unconsolidated earth material over soluble bedrock is referred to as cover collapse. Cover collapse in Kentucky frequently damages buildings, roads, utility lines, and farm equipment. It has killed livestock, including thoroughbred horses, and has injured people at an estimated annual cost near $20 million (Dinger and others, 2007). The Kentucky Geological Survey began developing a catalog of case histories in 1997 and receives roughly 24 reports annually (Currens, 2012). Yet the catalog is thought to represent only a fraction of the annual occurrences. The cover-collapse sites documented in the catalog are distributed across the state and total more than 354 individual occurrences.

The largest cover collapse in size recorded was the Dishman Lane collapse in Bowling Green, although it also included some bedrock collapse. The average dimensions of cover collapse reported here is 2.7 meters for the long axis and 1.9 meters for the short axis. The observable depth averages 2.4 meters. The parameters average diameter, asymmetry, and circularity were calculated from the length and width dimensions. There were no observations that suggested that asymmetry in the covering material is causing uneven development of the collapse.

Figure 1. The number of cover collapses that have occurred during a calendar month, regardless of year.
Only 7 percent of the cover-collapse sites occur within larger preexisting sinkholes determined from 1:24,000-scale topographic maps. Of a total of 216 observations that noted the presence or absence of buried trash, 10.7 percent of sinkholes had trash present, an indication the collapse had been previously filled. These results suggest that cover collapse initiates the development of doline sinkholes. But the cover-collapse process does not commonly repeat in more mature sinkholes (Currens and others, 2012).

The parameters for cover collapse, measured or calculated, were significantly skewed for most of the sample sets (Brinkmann and others, 2008). Variance and the student’s t-test suggest that there is little difference in the geometry between cover collapses that happen over Ordovician versus Silurian and Devonian carbonates. However, the collapses on Mississippian rocks have large differences in the variance of the mean for asymmetry, circularity, and diameter compared to the variance for Ordovician and Silurian-Devonian cover collapses. There is no statistical difference in mean depth between cover collapse over Mississippian rocks and over Ordovician rock or mean depth of cover collapse over Ordovician compared to over Silurian-Devonian rock. The count of cover collapses per calendar month follows a yearlong cycle that changes trend in mid-summer and again in mid-winter (Fig. 1). The number of collapses reported is at a minimum in February, but the number of collapses steadily increases, correlated with air temperature, through July. The air temperature reaches a peak in August, and as the temperatures begin to cool in the fall, the number of collapses decreases through December into January. Air temperature may be an important component of the cover-collapse process, possibly accelerating drying of the soil cover, either directly by evaporation or by evapotranspiration, resulting in subsequent collapse.

References Cited


Groundwater-level measurements taken in March 2012 indicate an increase in water levels of up to 40 feet in parts of the alluvial aquifer at Louisville, Kentucky, relative to measured groundwater conditions in May 1945, nearly doubling the volume of the aquifer. The rising trend in groundwater levels began in early 1945 as the demand on the area’s groundwater resources declined due in part to a decrease in war-time production and the administration of a new sewer use tax (Rorabaugh, 1949). Likewise, groundwater temperature measurements taken in May 2013 indicated a groundwater warming trend of up to 5 degrees Celsius over the period 1945 to 2013. Potential causes of increasing groundwater temperatures include climate change, land use change, leaky sewers, and groundwater flow. The result of these changing conditions is a present-day surficial alluvial aquifer with elevated temperatures forming a vast thermal energy reservoir for possible geothermal use.

Zhu and others (2010) developed a method to estimate the theoretical geothermal potential by quantifying the potential heat capacity in aquifers beneath urban land uses with elevated groundwater temperatures. This method was applied to calculate the potential heat content and available energy development capacity of the alluvial aquifer at Louisville. Results indicate that the estimated amount of extractable geothermal energy yielded from a simulated 2 degrees Celsius decrease in groundwater temperature in the alluvial aquifer beneath Louisville is approximately 20 to 50 times the estimated residential natural gas demand for space heating for the whole city in 2015.

References

Zhu, K., Blum, P., Ferguson, G., Balke, KD, and Bayer, P., 2010, The geothermal potential of urban heat islands: Environmental Research Letters, 5, article no. 044002
Curve numbers (CN) are used to estimate the amount of runoff that will occur for a given rainfall event. In urban landscapes, construction activities, pedestrian traffic, and the like can significantly increase soil compaction. The recommended CN values for these “open areas” may not accurately represent rainfall-runoff relationships due to differing levels of compaction which influence bulk densities and infiltration rates of soils. Over time, plant and animal activities, such as root development and burrowing, can restore soils to pre-construction conditions. The CNs currently available in engineering design manuals do not consider the effect of soil compaction, which can vary for the same land use. In parks, for example, areas with high foot traffic (e.g. paths) are expected to generate more runoff than areas with low levels of foot traffic. Supplying engineers with a better set of CNs will help in the design of structures to control stormwater.

This project is examining the effect of compaction on the soil’s ability to allow infiltration by 1) determining the bulk densities for residential lawns as related to age of the residence and hydrologic soil group (HSG), 2) determining representative infiltration rates for residential lawns as related to bulk density, age of the residence, and HSG, 3) evaluating the degree to which lab-constructed soil bulk density plots mimic in situ infiltration behavior, and 4) using soil plots to determine CNs for a range of bulk densities. Preliminary findings for the first objective will be presented.

All data were collected in Fayette County, Kentucky. The HSGs examined were B and C, which comprise about 48% and 43%, respectively, of Fayette County. The age classes (AGE) tested were NEW (<10 years), MEDIUM (25-35 years), and OLD (50+ years). A total of 18 lawns were examined (2 HSG x 3 AGE categories x 3 replications). For each lawn, bulk density measurements were obtained at five depths (DEPTH; 2, 4, 6, 8, and 10 inches from the surface) for three separate locations using a Troxler 3440 surface-moisture-density gauge. A three-way analysis of variance (ANOVA) was used to determine the presence of significant differences ($\alpha=0.05$). Factors were HSG, AGE, and DEPTH.

Preliminary bulk density results indicate that significant differences are present for AGE and DEPTH but not HSG. HSG B had a mean bulk density of 77.8 lb ft$^{-3}$ while HSG C had
a mean value of 80.6 lb ft$^{-3}$. For AGE, NEW (mean=87.1 lb ft$^{-3}$) was significantly different than MEDIUM (76.7 lb ft$^{-3}$) and OLD (73.9 lb ft$^{-3}$). These findings suggest that as lots age, bulk densities decline (i.e. compaction lessens) though this difference fades over time (no significant difference between MEDIUM and OLD). One hypothesis is that reductions in bulk density in older lots may be due to increases in macropores from tree roots, earthworms, and the like. For DEPTH, bulk density increased with increasing depth. A DEPTH of 2 inches was significantly different than a DEPTH of 4 inches. DEPTH values of 2 inches and 4 inches were significantly different than 6, 8, and 10 inches. No differences were noted between 6, 8, and 10 inches. We hypothesize that compaction in the upper 2 inches is alleviated to an extent by grass roots, which are typically shallow. No significant interactions between factors were noted.