NCKRI REPORT OF INVESTIGATION 13

ELECTRICAL RESISTIVITY SURVEY OF A PSEUDOKARST SINKHOLE HAZARD, VILLAGE OF SAN MATEO, CIBOLA COUNTY, NEW MEXICO

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Electrical Resistivity Survey of a Pseudokarst Sinkhole Hazard, Village of San Mateo, Cibola County, New Mexico

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Cover photo: Sinkhole during the electrical resistivity survey. A white measuring tape extends over the sinkhole and electrodes are connected into the yellow cable on each side of the sinkhole. NCKRI staff photo by George Veni.

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NCKRI Organization and Mission

NCKRI was created by the US Congress in 1998 in partnership with the State of New Mexico and the City of Carlsbad. NCKRI is administered by the New Mexico Institute of Mining and Technology (aka New Mexico Tech or NMT).

NCKRI's enabling legislation, the National Cave and Karst Research Institute Act of 1998, 16 USC, §4310, identifies NCKRI's mission as to:

1) further the science of speleology;
2) centralize and standardize speleological information;
3) foster interdisciplinary cooperation in cave and karst research programs;
4) promote public education;
5) promote national and international cooperation in protecting the environment for the benefit of cave and karst landforms; and
6) promote and develop environmentally sound and sustainable resource management practices.

NCKRI Report of Investigation Series

NCKRI uses this report series to publish the findings of its research projects. The reports are produced on a schedule whose frequency is determined by the timing of the investigations. This series is not limited to any topic or field of research, except that they involve caves and/or karst. All reports in this series are open access and may be used with citation. To minimize environmental impact, few or no copies are printed. They may be downloaded at no cost from the NCKRI website at www.nckri.org.

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Electrical Resistivity Survey of a Pseudokarst Sinkhole Hazard, Village of San Mateo, Cibola County, New Mexico

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Background

In mid-April 2021, Cibola County management personnel reported the occurrence of what appeared to be a small sinkhole ~1.5 m in diameter and 1 m deep, located on the north shoulder of County Road 605 in the village of San Mateo, New Mexico (Figures 1 and 2). The sinkhole was filled quickly with compacted soil to a mound several centimeters above grade. A site inspection on 29 June 2021 found that over the past two months the soil mound had subsided and the space was now occupied by a depression roughly 10 cm below ground level (Figure 1). Features such as this often form in urban settings when aging utility lines in the shallow subsurface collapse. However, a careful examination of the records by Cibola County personnel indicates that the main water line for the village is located 17 m to the south on the other side of CR 605. There are no records of utility lines underlying the sinkhole itself (Figure 2), thus the feature appears to be naturally caused and not of human origin.

The sinkhole is formed in soil and alluvial material ~8 to 25 m thick overlying upper Cretaceous bedrock of the Menefee Formation (Dan Koning, 2021, personal communication). Lithology of the Menefee Formation consists of non-marine sandstone, shale and coal beds, and is generally not consistent with the formation of typical karst features such as sinkholes. There is a history of coal and uranium mining in the area, but consultation with local mine operators did not reveal any mine activity beneath the village of San Mateo itself. This feature may be the result of soil piping, wherein individual particles of soil can be eroded and transported by the subsurface flow of groundwater that is focused along preferential flow paths (Allison and Shipman, 2007). However, without a more detailed investigation this hypothesis could not be proven. After consultation with Cibola County managers, NCKRI personnel proposed conducting an electrical resistivity survey of the sinkhole to determine if there were any underlying cavities that could cause additional subsidence or catastrophic collapse.

Figure 1. *San Mateo sinkhole, located on the north shoulder of CR 605. NCKRI staff photo by Lewis Land.*

Methods

Electrical resistivity (ER) surveys are a very reliable method for identifying subsurface voids (e.g., Land, 2012; Land and Veni, 2012; Land et al., 2018). The basic operating principal for an ER survey involves generating a direct current between two metal electrodes implanted in the ground, while measuring the ground voltage between two other implanted electrodes. Given the current flow and voltage drop between the electrodes, differences in subsurface electrical resistivity can be determined and mapped. Modern resistivity surveys employ an array of multiple electrodes (45-cm long stainless steel stakes) connected with electrical cable. Over the course of a survey, pairs of electrodes are activated by means of a switchbox and resistivity

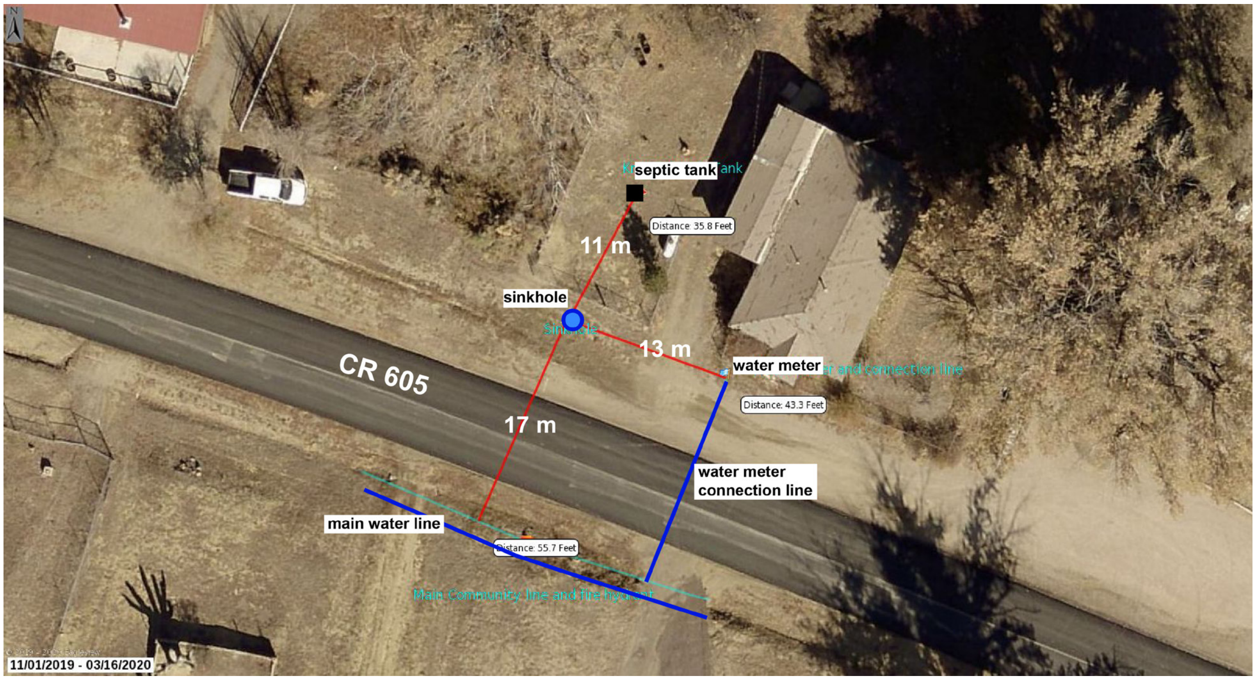

Figure 2. *Map of buried water lines (blue lines) in the vicinity of the San Mateo sinkhole. Red lines show distances from anthropogenic features.*

meter. The depth of investigation for a typical ER survey is approximately one-fifth the length of the array of electrodes. Specialized software is used to process the raw data and generate resistivity profiles, which illustrate vertical and lateral variations in subsurface resistivity. Because air has near-infinite resistivity, the presence of air-filled cavities will strongly affect the results of an ER survey, displaying as zones of higher resistivity on ER profiles relative to the surrounding bedrock.

A SuperSting R8/IP electrical resistivity system manufactured by Advanced Geosciences, Inc. (AGI) was used to collect resistivity data, employing a dipole-dipole array configuration. While resistivity data were collected, a Topcon GR3 GPS instrument package was used to collect survey-grade GPS coordinates for each electrode in the arrays. Elevation data collected during the GPS survey were used to correct the resistivity data for variations in topography. ER data were processed using EarthImager-2D™ (EI) software.

Upon arrival at the sinkhole on 21 August 2021, we found it had widened to 1.5 by 1.7 m and deepened to 1.3 m over the past two months. We assumed that the sinkhole was underlain by a subsurface void or air-filled rubble, however the depth of the void was uncertain. We therefore conducted three ER surveys over and adjacent to the San Mateo sinkhole on the north shoulder of CR 605 (Figure 3). Lines SM2 and SM3 were deployed approximately one and two meters south of the sinkhole using a 28-electrode array at 1 m electrode spacing, for a target exploration depth of ~5 m. Line SM4 used a 28 electrode array at 2 m electrode spacing, for a target depth of ~11 m. The center of line SM4 crosses directly over the center of the sinkhole. The survey numbering system was determined by field conditions, which required that the initial SM1 survey line be eliminated.

Results and Discussion

ER lines SM2 and SM3 (Figures 4 and 5) achieved exploration depths of approximately7 m. Both profiles display mostly low resistivity (~100 ohm-m), indicated by blue and green shading, which is typical of relatively fine-grained alluvium. The center of the SM2 profile shows a pod of slightly higher resistivity coinciding with the position of the sinkhole, extending from the surface to about 1-2 m below grade. That pod of higher resistivity is not visible on line SM3, which is offset 2 m south of the sinkhole. Another shallow region of higher resistivity is visible at the west end of both profiles, and probably represents air-filled porosity in soil and alluvium. Both profiles are dominated by two low resistivity (<10 ohm-m) layers shown by blue shading. These layers probably reflect lower resistivity clay and silt material within the alluvium. There is a slight dip in the upper layer on line SM2 directly beneath the sinkhole that coincides with a slight upward bulge in the lower layer, which may result from downward seepage of more electrically conductive groundwater.

Figure 3. Aerial view of electrical resistivity surveys SM2, SM3 and SM4 over and adjacent to the San Mateo sinkhole. Red, blue and green filled circles show locations of each electrode used in the ER surveys. The large red filled circle shows the location of the sinkhole relative to the ER survey lines.

ER line SM4 (Figure 6) crosses directly over the sinkhole and achieved an exploration depth of ~14 m. The maximum resistivity shown on this profile is only 100 ohm-m, and includes a pod of slightly higher resistivity between electrodes 14 and 15, coinciding with the position of the sinkhole. This higher-resistivity zone extends to a depth of ~1.5 m below ground level and is underlain by more electrically conductive material. Higher resistivity zones at greater depth at the west end of the profile probably represent air-filled porosity within coarser-grained sand and gravel in the alluvium.

Conclusions and Recommendations

The results of these surveys are unremarkable. The sinkhole itself is visible as a near-surface pocket of higher resistivity at the center of ER lines SM2 and SM4, extending ~1.5 to 2 m below ground level. There is no indication of a large subsurface cavity beneath the sinkhole that could cause catastrophic collapse. The fact that the sinkhole has continued to subside shows that some soil piping is occurring. It is possible that some anthropogenic feature, such as an abandoned septic tank, may be contributing to this continued subsidence; or lateral flow from a leaking water line washing soil into enlarged fractures below, although no such features are indicated on the ER profiles.

While no cause for the sinkhole is apparent, and the cavity that resulted in the collapse may now be filled and thus does not appear in the ER imagery, prudence suggests continuing to investigate its origin. This can be accomplished during remediation. A backhoe should excavate the sinkhole down to undisturbed alluvium, soil, or bedrock. Based on the ER images, this will probably be found within about 5 m of the surface. A geologist should be present on site during the excavation to identify the undisturbed materials and determine what caused the collapse. The ER survey indicates such excavation can be conducted safely.

Most sinkholes form by groundwater transporting sediment to create a void. If this is confirmed by excavation and the base of the sinkhole is found, the excavated material should be replaced with a graded back-fill. The basal 25% of the excavation should be filled with large cobbles, the next 25% with course gravel, above that pea-size gravel, and then the top 25% with soil. This sequence of fill will allow natural and artificially induced groundwater to flow through the material without displacing it, preventing development of future voids and sinkholes in that location.

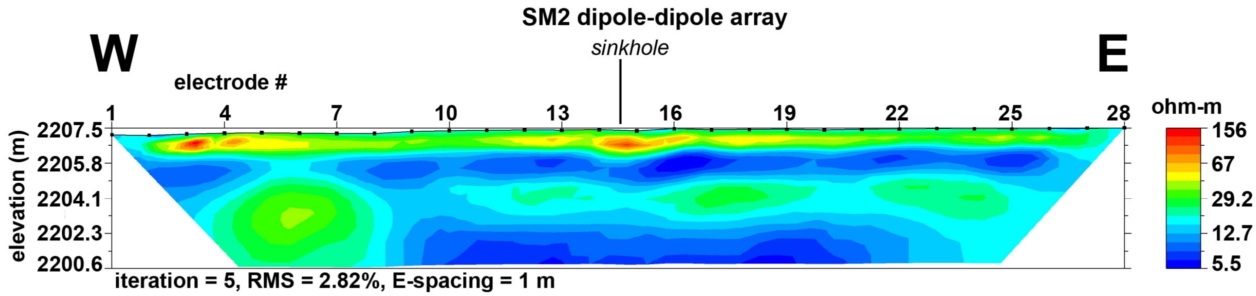

Figure 4. *ER profile from survey SM2.*

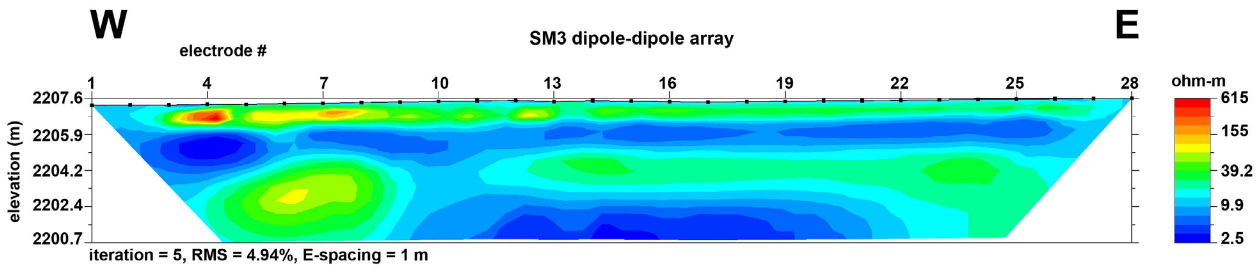

Figure 5. *ER profile from survey SM3.*

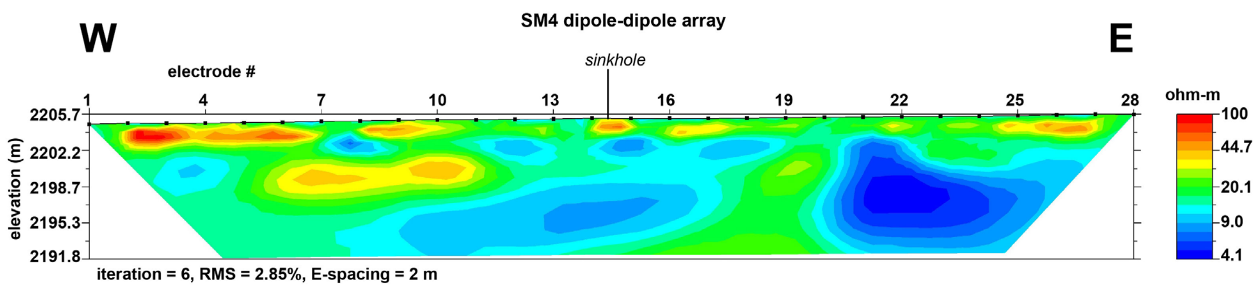

Figure 6. *ER profile from survey SM4.*

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Dr. Land places protective covers over the electrodes to prevent accidental electrical shock if touched while active. NCKRI staff phot by George Veni.

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