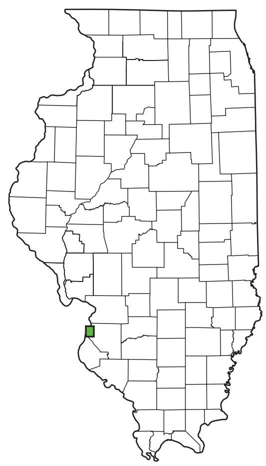
Illinois Geologic Quadrangle Map
IGQ Cahokia-SD

Sinkhole Density and Distribution of Cahokia Quadrangle

St. Clair County, Illinois

Samuel V. Panno, Donald E. Luman, and Julie C. Angel

2009



ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Institute of Natural Resource Sustainability
William W. Shilts, Executive Director
ILLINOIS STATE GEOLOGICAL SURVEY
E. Donald McKay III, Interim Director
615 East Peabody Drive
Champaign, Illinois 61820-6964
(217) 244-2414
http://www.isgs.illinois.edu

Introduction

Sinkhole Density and Distribution of Cahokia Quadrangle, St. Clair County, Illinois, is part of a series of maps published by the Illinois State Geological Survey (ISGS) that portrays the geology of quadrangles in the Metro East Illinois area of greater St. Louis at 1:24,000 scale (fig. 1). Most of the area, including adjacent Monroe County, is experiencing rapid population growth and increasing environmental concerns. Although the population of St. Clair County has declined 2.6% between 1990 and 2000 (U.S. Census Bureau 2000), about one quarter of the Cahokia Quadrangle lies within Illinois' sinkhole plain (fig. 1).

Previous work (Panno 1996, Panno et al. 1998, Bade et al. 2002) showed approximately 10,000 sinkholes concentrated in three distinct clusters (fig. 1). The northernmost cluster in western St. Clair County and northern Monroe County is associated with a single relatively long, large-diameter cave and associated groundwater basin. A second cluster in northwestern Monroe County is associated with numerous small caves and conduit systems (Panno et al. 2007a). The third sinkhole cluster (mostly within the Renault Quadrangle) is located in the south-central third of Monroe County, an area known for its relatively long, large-diameter cave systems and relatively large groundwater basins (Panno et al. 2007b).

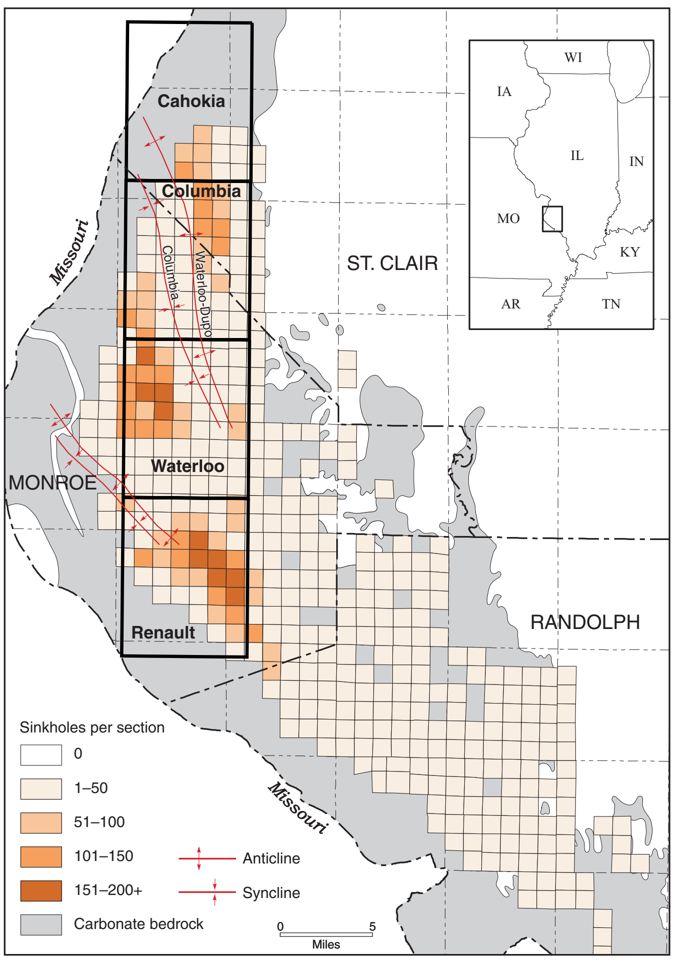


Figure 1 Map of sinkhole density within the sinkhole plain determined at the section level, showing the location of the Cahokia, Columbia, Waterloo, and Renault Quadrangles and major structural features. Sinkhole counts were derived from U.S. Geological Survey 7.5-minute quadrangle maps (modified from Panno et al. 1998).

The density and distribution of sinkholes in the area are being documented to aid in urban planning (e.g., for location and type of wastewater treatment facilities), land use planning (e.g., for roadways and landfills), and water resource management (Magdalene and Alexander 1995). These maps may be useful for planning by state and local governments, utilities, developers, and home buyers. Maps of sinkhole density, distribution, and area can identify those places with the most potential for geological hazards and/or contaminated groundwater problems associated with karst and sinkhole formation.

Geology of the Sinkhole Plain

In the Cahokia Quadrangle, bedrock units regionally dip gently a few degrees to the east. Geologic structures in the quadrangle include the northwest-southeast–trending Waterloo-Dupo Anticline and the Columbia Syncline (Nelson 1995, unpublished mapping by J.A. Devera). The Waterloo-Dupo Anticline is an asymmetric fold that dips 2 to 4° on its western limb and can exceed 45° on its eastern limb. The anticline was named after the two oil fields in the area with traps associated with the Waterloo-Dupo Anticline (Nelson 1995).

Bedrock in the sinkhole plain consists mostly of calcite-rich, Mississippian limestone that either crops out (fig. 2) or is less than 15 m (50 feet) below the surface (Herzog et al. 1994). In most places, the upland area is covered with as much as 15 m (50 feet) of Pleistocene Glasford Formation till and outwash, bedrock residuum, and loess (wind-blown silt). Sinkholes are partially filled with redeposited glacial till, residuum, and loess. The bedrock surface is predominantly St. Louis Limestone with minor exposures of the Ste. Genevieve and Salem Limestones (e.g., fig. 3). Sinkholes and caves in the study area form predominantly in fine-grained sediments overlying and within bedrock of the St. Louis and Ste. Genevieve Limestones. Karst formation is controlled by lithology (especially in calcite-rich limestone), poor primary porosity coupled with well-developed secondary porosity (e.g., vertical fractures and dilated bedding planes), the presence of overlying fine-grained sediments, and a deep water table.

The Ste. Genevieve Limestone is light gray and fossiliferous with some very distinctive beds of white, oolitic limestone. The St. Genevieve is relatively thin in this area (3 to 6 m [9 to 18 feet]) and is exposed in Columbia Quarry where it can be seen overlying the St. Louis Limestone. The St. Louis

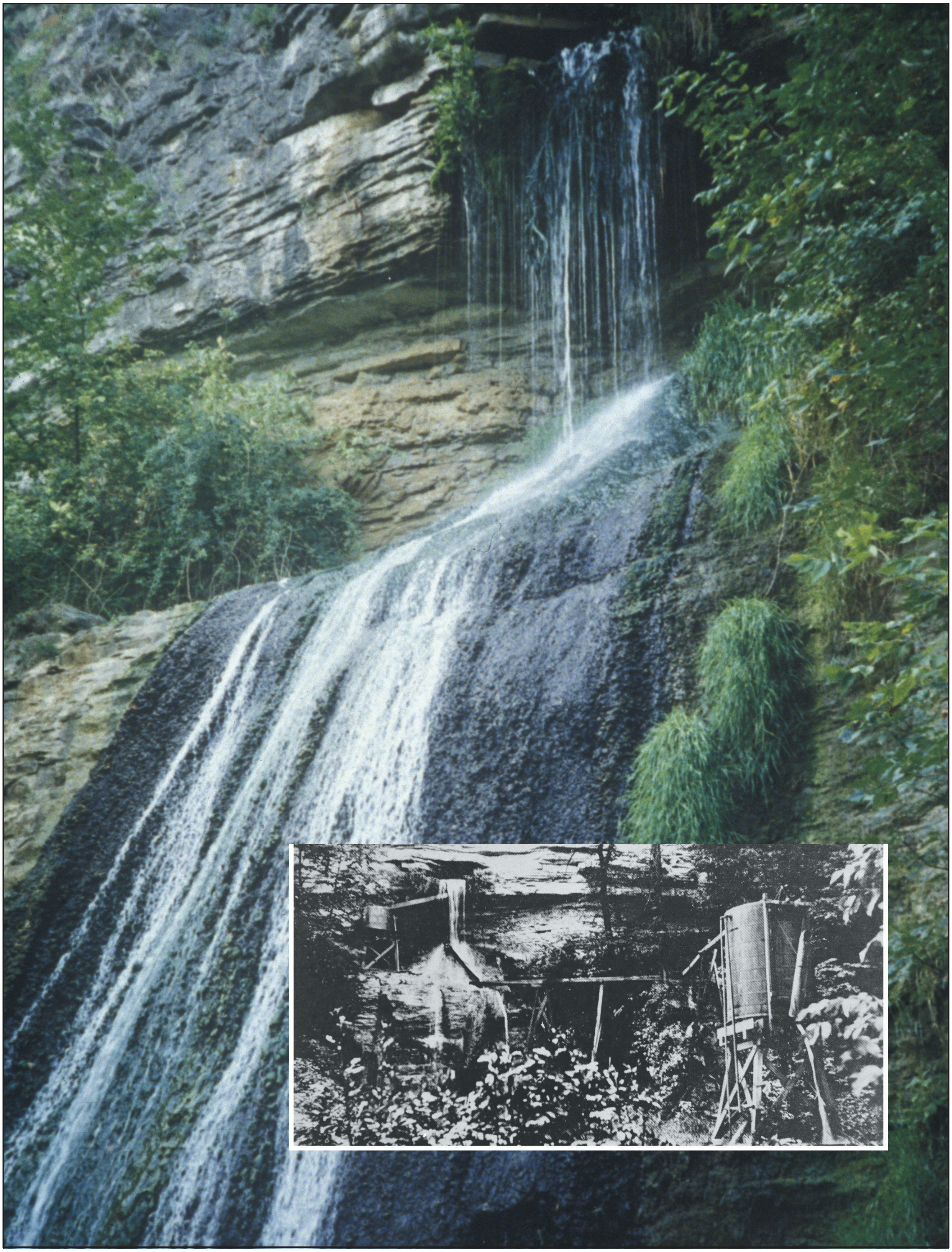


Figure 2 Falling Springs, a small cave spring near Dupo, Illinois, is shown as it appeared in 1998 and 1900 (inset photograph from Panno and Weibel 1997b). The spring discharges from a bedding-plane cave in the St. Louis Limestone and was originally used as a water supply for domestic use and for steam locomotives (water towers). The water towers disappeared with the steam locomotives, and the spring now provides water for a nearby fishing pond. (Photograph by Samuel V. Panno.)

Limestone in the study area is a more fine-grained, micritic limestone and is well-known for sinkholes developed in the sediments that overlie it (Willman et al. 1975). The Salem Limestone is a fossiliferous grainstone used extensively as building stone (Willman et al. 1975). Although the Salem is calcite-rich and thick-bedded and possesses the requisite secondary porosity, this unit appears to be less susceptible to karstification than the St. Louis and Ste. Genevieve Limestones, based on bedrock geology and sinkhole distribution (Thornbury 1969). These formations are well represented in an exposure at the base of a sinkhole that formed following the "blow-out" of a sediment plug of a sinkhole pond (fig. 4).

The majority of the caves in the sinkhole plain are branchwork type and formed along bedding planes within the St. Louis Limestone (Panno et al. 2004). Because they typically formed by groundwater dissolution between bedding planes, the caves are sinuous in map view (reminiscent of meandering streams). The main "trunk" of Stemler Cave, a 1.8-km- (1.1-mile-) long cave (Webb et al. 1998) just outside the map area in the adjacent Columbia Quadrangle trends northwest-southeast and parallel to the Waterloo-Dupo Anticline axis.

Sinkholes in the St. Louis area in the northwestern corner of the quadrangle are often larger than those of Illinois' sinkhole plain. One of the sinkholes measures more than 914 m (3,000 feet) in length. Cover-collapse sinkholes and caves in this area were formed in Mississippian (Ste. Genevieve and St. Louis) and Pennsylvanian limestones (Knight and Koenig 1957).

Sinkhole Origin and Morphology

Sinkholes in the sinkhole plain are predominantly cover-collapse features. Sinkholes are circular or ovoid surficial depressions in unconsolidated materials originating from solution-enlarged crevices in underlying carbonate bedrock. Crevices in the bedrock are typically about 15 cm (5.9 inches) or wider at the bedrock surface (Panno and Weibel 1998). A typical crevice along Three Lakes Road in Section 26 is shown in figure 3. Soil and overlying unconsolidated materials can move via soil piping and collapse into such crevices, forming large cylindrical holes that later become transformed into the bowl-shaped surface depressions referred to as sinkholes (fig. 5). Rarely, a sinkhole forms as a result of a cave ceiling collapse, forming a relatively deep, steep-walled, nearly circular hole that can provide entrance to the cave.

Within the Cahokia Quadrangle, sinkhole morphology ranges from simple circles to ellipses with a single closed contour to complexly shaped (in places branching) compound sinkholes with multiple separated closed contours. Groundwater basins of the longest caves in the sinkhole plain are characterized by very large sinkholes, the size of

Figure 3 The excavation of a sinkhole reveals a long crevice in the exposed St. Louis Limestone bedrock that leads to a somewhat wider crevice. The wider crevice led down, about 15 feet, into a small cave about 0.3 m (1 foot) high and 0.6 m (2 feet) wide through which runoff from rainwater and snowmelt can flow. (Photographs by Samuel V. Panno.)

which appears closely related to the size of the conduits in the subsurface (Panno and Weibel 1999a). The reason for this sinkhole-conduit relationship is that the larger-diameter conduits are capable of removing very large volumes of runoff through the sinkhole during and following large rainfall events. The smaller conduits tend to quickly reach their drainage capacity, and the water levels may rise above the throats of sinkholes feeding the conduits, resulting in the formation of temporary ponds within the sinkholes. Temporary ponding creates a low-energy environment that promotes sedimentation that may plug or partially plug the bottom of the sinkhole with sediment and debris. Where ponding occurs, sinkholes tend to remain relatively small. Conversely, sinkholes that form over large-diameter conduit systems rarely, if ever, pond; those sinkholes represent high-energy environments where continued erosion of sinkhole flanks causes the sinkholes to enlarge (Panno and Weibel 1999a).

The presence of sinkholes in karst topography indicates an underlying karst aquifer system. The sinkholes themselves act as small watersheds, collecting runoff and snowmelt and funneling water into the aquifer via bedrock crevices. Because of this open pathway, shallow groundwater in karst regions is typically contaminated with surface pollutants such as agrichemicals, lawn chemicals, road salt, industrial waste, and wastes from livestock, humans (effluent from private septic systems), pets, and wildlife (White 1988). The formation of sinkholes near infrastructure can cause major damage to roads, structural foundations, and utilities. Sinkhole distribution can also yield clues to the location of groundwater basin boundaries and potentially caves (Panno and Weibel 1999a).

Mapping Methods

Sinkhole density is the number of sinkholes per unit area (fig. 6). For this investigation, a unit area equals one section of a 7.5-minute quadrangle map, which is usually one square mile. The sinkhole density and distribution map was compiled from U.S. Geological Survey (1991) 7.5-minute quadrangle maps at a scale of 1:24,000. The aerial photographs from which this map was compiled were taken in 1986. Initially, sinkholes and sinkhole ponds (naturally occurring sinkhole depressions that retain water) on the map were counted by hand for each section and summed to the nearest 0.25 sinkhole. Counts were later rounded to the nearest whole number for each section. To quantify the number of sinkholes in each section, sinkholes were defined as any closed-contour topographic depression or sinkhole pond. Thus, if a compound sinkhole had two or more separate closed-contour depressions, each depression was counted as a sinkhole. Each sinkhole pond was counted as one sinkhole. Partial sections that lay on the boundaries of the map were counted in full using the adjacent quadrangle map.

Figure 4 This cover-collapse sinkhole, 5.5 m (18 feet) in diameter and 7 m (23 feet) deep, occurs in Pleistocene-age loess overlying Mississippian-age limestone in the southwestern Illinois' sinkhole plain. The sinkhole formed during a 22.9 cm (9-inch) rainfall over a two-day period in April 1996 and rapidly drained a 0.2-ha (0.5-acre) sinkhole pond. The snow-white, teeth-like projections of the epikarst are fossiliferous oolitic limestone of the Ste. Genevieve Limestone that, along with the underlying red-brown and gray, fine-grained St. Louis Limestone, are responsible for sinkhole densities of up to 230 sinkholes per township section in the sinkhole plain. (Photograph by Samuel V. Panno.)

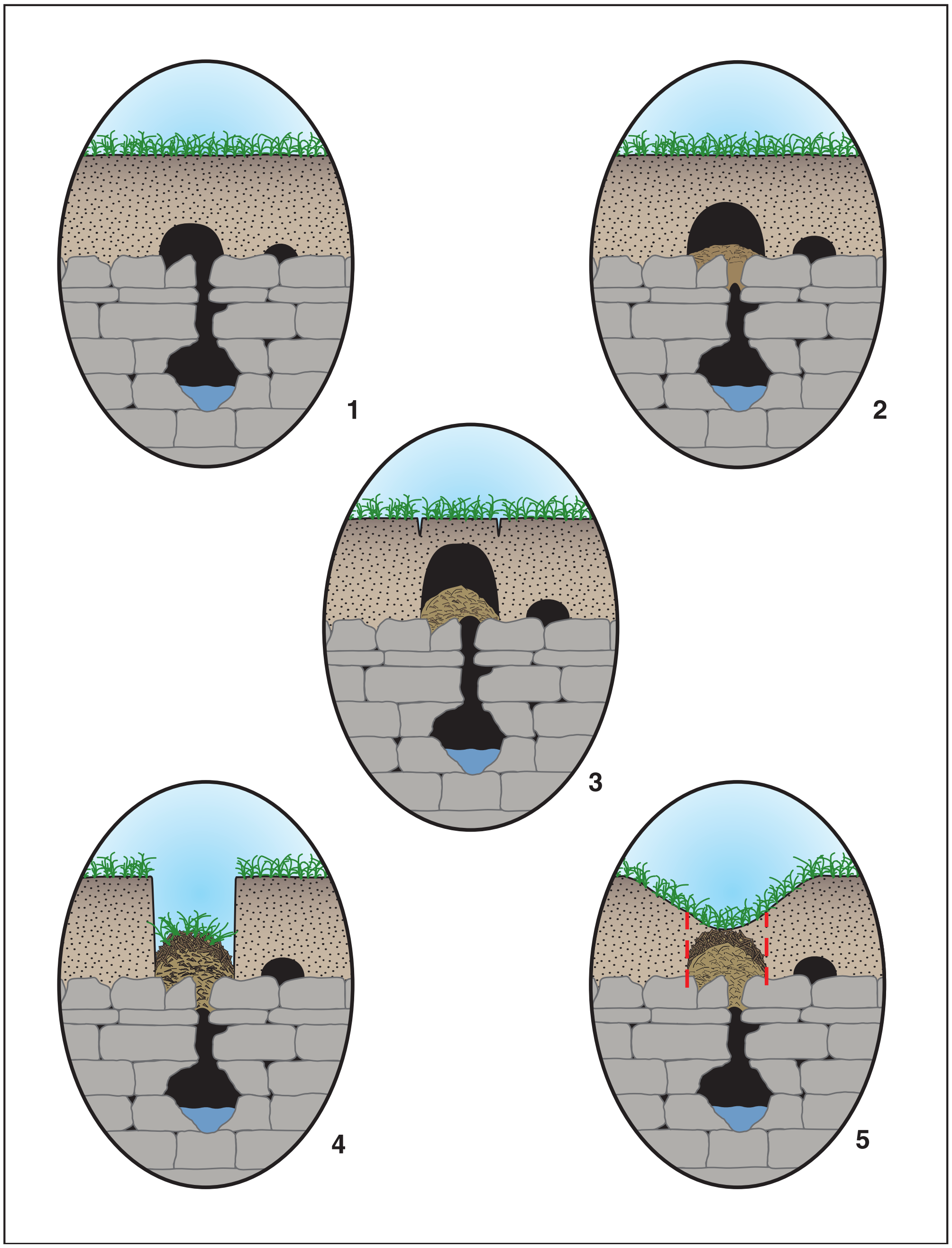


Figure 5 Sinkholes develop where the soil overlying creviced bedrock collapses into a crevice, forming a hemisphere-shaped void in the soil (1 and 2). Groundwater flows through the bedrock to remove the material in the crevice during formation. As soil collapse continues, the void grows upward toward the surface (3), resulting in the eventual collapse of the surface material into a nearly circular hole (4). Erosion smooths out the land surface, forming a bowl- or cone-shaped depression (5). The sinkhole then functions as a small drainage basin, focusing runoff and snowmelt into a conduit system in bedrock (Panno et al. 2004).

These hand counts were tested against digitally automated counts made with a Geographic Information Systems (GIS) technique developed by Angel et al. (2004). The results of these two techniques were statistically equivalent with a difference of 0.25%. Using similar GIS techniques also developed by Angel et al. (2004), the area of each sinkhole was determined and summed for each section. The area within each closed depression was summed for each complete section of the quadrangle map. Sinkhole areas within a partial section at the quadrangle edges were not determined.

Density and Distribution

Color-enhanced sinkhole fill-ins on the Cahokia Quadrangle map show the non-random distribution of sinkholes across the uplands (fig. 1 and map). We mapped 525 sinkholes within boundaries of the Cahokia Quadrangle. Concentrations of sinkholes in the 15 sections within and intersected by the Cahokia Quadrangle are 35 (mean) and 17 (median) sinkholes per section. Density within the quadrangle ranges from 0 to 144 sinkholes per square mile or per section (0 to 56 sinkholes/km²). Sinkhole density is greatest in the highlands along the bluffs overlooking the Mississippi River valley (see map) where the Ste. Genevieve and St. Louis Limestone bedrock displays abundant and widespread dissolution features, typically exposed in sinkhole excavations (fig. 3) and a pond collapse (fig. 4).

In general, map areas with densities of 25 or more sinkholes per square mile and sinkhole areas exceeding 5% of the total area of a section may indicate that at least part of the underlying bedrock contains numerous and well-developed karst features. Where such conditions are present, the land should be carefully examined prior to development. However, even in areas with relatively low sinkhole density, care should be taken when building on properties possessing at least one sinkhole.

Maps of sinkhole density, distribution, and area, when used with dye-tracing results and estimated groundwater basin boundaries (Aley et al. 2000), may be useful in predicting the subsurface pathway of contaminants in the event of a surface spill. In karst terrain, spills of toxic materials can flow directly into sinkholes and caves that provide direct access to groundwater in the shallow karst aquifer and eventually discharge to surface waters at springs. In Illinois' sinkhole plain, these springs flow into streams that eventually enter the Kaskaskia and Mississippi Rivers. Knowledge of underground pathways taken by toxins following a spill or intentional dumping is thus necessary to intercept contaminants (within a cave or at the mouth of a spring) to prevent a more widespread problem.

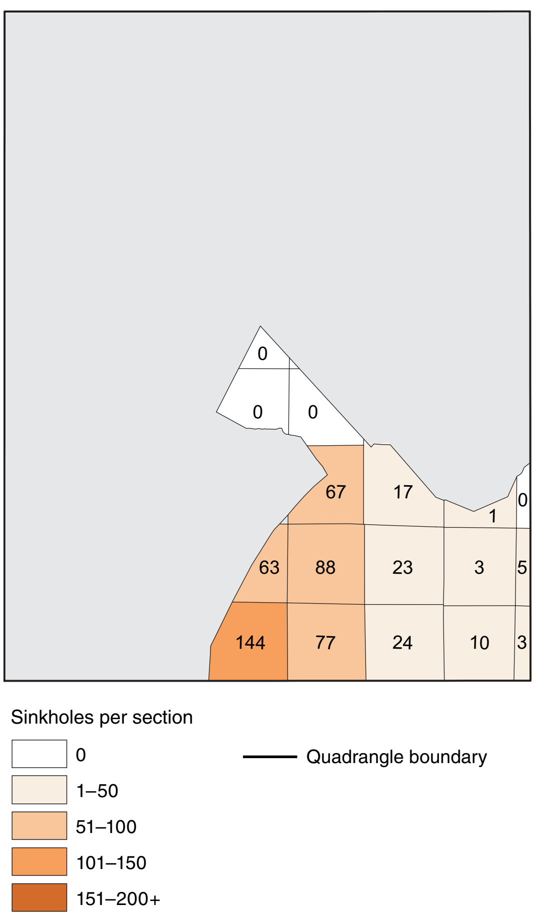


Figure 6 Sinkhole density of the Columbia Quadrangle determined at the section level. The sinkhole density values for the partial section at the margins of the map represent the sinkhole density of the entire section.

Acknowledgments

This map was prepared by a multidisciplinary team of geologists from the Illinois State Geological Survey and was significantly improved through review, suggestions, and comments by Keith Hackley and Donald Keefer of the ISGS.

References

Aley, T., P. Moss, and C. Aley, 2000, Delineation of recharge areas for four biologically significant cave systems in Monroe and St. Clair Counties, Illinois: Ozark Underground Laboratory unpublished report for the Illinois Nature Preserves Commission and the Monroe County Soil and Water Conservation District, 254 p.

Angel, J.C., D.O. Nelson, and S.V. Panno, 2004, A comparison of manual and GIS-based methods for determining sinkhole distribution and density: An example from Illinois' sinkhole plain: Journal of Cave and Karst Studies, v. 66, no. 1, p. 9–17.

Bade, J., J.J. Lewis, S.J. Taylor, D. Tecic, D.W. Webb, D. Brand, S.V. Panno, K. Hartman, Jr., and P. Moss, 2002, Illinois cave amphipod (Gammarus acherondytes) recovery plan: Ft. Snelling, Minnesota, U.S. Fish and Wildlife Service, 63 p.

Herzog, B.L., B.J. Stiff, C.A. Chenoweth, K.L. Warner, J.B. Sieverling, and C. Avery, 1994, Buried bedrock surface of Illinois: Illinois State Geological Survey, Illinois Map 5, 1:500,000.

Knight, R.D., and J.W. Koenig, 1957, Guide book, Field trip of the forty-second Annual Meeting of the American Association of Petroleum Geologists, St. Louis, Missouri, April 5, 1957, 31 p.

Magdalene, S., and E.C. Alexander, 1995, Sinkhole distribution in Winonca County, Minnesota revisited, in B.F. Beck, ed., Proceedings of the Fifth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, Karst Geohazards, Gatlinburg, TN, April 2–5, 1995, p. 43–51.

Nelson, J.W., 1995, Structural features in Illinois: Illinois State Geological Survey, Bulletin 100, 144 p.

Panno, S.V., 1996, Water quality in karst terrane: The Karst Window, v. 2, no. 2, p. 2–4.

Panno, S.V., J.C. Angel, D.O. Nelson, C.P. Weibel, D.E. Luman, and F.B. Denny, 2007a, Sinkhole distribution and density of Waterloo Quadrangle, Monroe County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle Map, IGQ Waterloo-SD, 1:24,000.

Panno, S.V., J.C. Angel, D.O. Nelson, C.P. Weibel, D.E. Luman, and J.A. Devera, 2007b, Sinkhole distribution and density of Renault Quadrangle, Monroe County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle Map, IGQ Renault-SD, 1:24,000.

Panno, S.V., S.E. Greenberg, C.P. Weibel, and P.K. Gillespie, 2004, Guide to the Illinois Caverns State Natural Area: Illinois State Geological Survey, GeoScience Education Series 19, 106 p.

Panno, S.V., W.R. Kelly, C.P. Weibel, I.G. Krapac, and S.L. Sargent, 1998, The effects of land use on water quality and agrichemical loading in the Fogelpole Cave groundwater basin, southwestern Illinois: Proceedings of the Eighth Annual Conference of the Illinois Groundwater Consortium Research on Agricultural Chemicals in Illinois Groundwater: Status and Future Directions VIII, Makanda, IL, April 1–2, 1998.

Panno, S.V., and C.P. Weibel, 1998, Karst landscapes of Illinois: Dissolving bedrock and collapsing soil: Illinois State Geological Survey, Geobit 7, 4 p.

Panno, S.V., and C.P. Weibel, 1999a, The use of sinkhole morphology and distribution as a means of delineating the groundwater basins of four large cave systems in southwestern Illinois' sinkhole plain: Proceedings of the Karst Modeling Symposium, Charlottesville, VA, February 24–29, 1999, p. 244. (Abstract)

Panno, S.V., and C.P. Weibel, 1999b, Geology, hydrology, and water quality of the karst regions of southwestern Illinois and southeastern Missouri: Geological field trip 2: April 24–25, 1999, North-Central Section, Geological Society of America, 33rd Annual Meeting, Champaign-Urbana, Illinois, April 22–23, 1999: Illinois State Geological Survey, Guidebook 27, 38 p.

Thornbury, W.D., 1969, Principles of geomorphology, 2nd ed.:New York, Wiley and Sons, 594 p.

U.S. Census Bureau, 2000, State and county quickfacts. http://quickfacts.census.gov/qfd/index.html.

U.S. Geological Survey, 1991, Columbia, IL. U.S. Geological Survey 7.5 minute quadrangle map: Denver, Colorado, U.S. Geological Survey, 1:24,000.

Webb, D.W., L.M. Page, S.J. Taylor, and J.K. Krejca, 1998, The current status and habitats of the Illinois cave amphipod, Gammarus acherondytes Hubricht and Mackin (Crustacea: Amphipoda: Journal of Cave and Karst Studies, v. 60, p. 172–178.

White, W.B., 1988, Geomorphology and hydrology of karst terrains: New York, Oxford University Press, 464 p.

Willman, H.B., E. Atherton, T.C. Buschbach, C. Collinson, J.C. Frye, M.E. Hopkins, J.A. Lineback, and J.A. Simon, 1975, Handbook of Illinois stratigraphy: Illinois State Geological Survey, Bulletin 95, 261 p.