2022 KARST ANNUAL REPORT:

UPDATED KARST MAPPING OF HAMILTON COUNTY, OHIO

by Douglas J. Aden and Brittany D. Parrick

OHIO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

OHIO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

Graphic design & layout: Jeremy E. Gladden
Editing: Anthony J. Bresnen
Front cover: A sinkhole found in a woodland, Hamilton County, Ohio.

Recommended citation: Aden, D.J., and Parrick, B.D., 2022 Karst annual report—Updated karst mapping of Hamilton County, OH: Columbus, Ohio Department of Natural Resources, Division of Geological Survey, 17 p.

2022 Karst annual report: Updated karst mapping of Hamilton County, Ohio

by
Douglas J. Aden and Brittany D. Parrick

STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
D. Mark Jones, Chief

Columbus 2022

PREFACE

The 2022 Karst Annual Report describes the 2021–2022 study area and continues the ODNR Division of Geological Survey's efforts to comprehensively map the karst features in Ohio. This includes characteristics of the study area and an updated summary of the statewide status from 2009 until 2022 (table 1). This dataset is now available as a modern interactive web map that is continually updated. The Karst Interactive Map is available for viewing on the Survey's website at **ohiodnr.gov/karst**. Karst feature descriptions and photos (for many features) can be found on the interactive map. For their preservation, details regarding caves and other sensitive features are omitted in this report and on the interactive map. Interested scientists may obtain detailed location information for cave research by contacting the ODNR Division of Geological Survey at **geo.survey@dnr.ohio.gov**.

CONTENTS

FIGURES

TABLES

WHAT IS OHIO KARST?

Over 480 million years ago, Ohio was covered by a vast, tropical sea full of life—similar to the modern-day Bahamas. As marine organisms living in this ancient sea died and were buried, parts of their skeletons slowly cemented together into vast quantities of limestone and dolostone. Following the formation of these rock layers on Earth's surface, millions of years of weathering has helped shape the karst terrain found in Ohio (fig. 1). Karst features are found in zones throughout the Devonian-, Silurian-, and Ordovician-aged bedrock in the central and western portions of the state (Hobbs, 2009), where glacial deposits are thinner than about 25 ft (7.6 m).

FIGURE 1. Three sinkholes in a pasture in Hamilton County, Ohio. The sinkhole in the lower right of the photo is partly filled with concrete rubble.

Sinkholes, disappearing streams, caves, and springs form from dissolution of carbonate rocks (fig. 2), such as limestone and dolostone, or evaporites, such as gypsum or salt, and can be found in many areas of Ohio. Sinkholes are enclosed depressions often found with a natural drain that allows water to flow into fractures in the subsurface. Because of this, sinkholes rarely hold water but can become clogged with debris. Sinkholes can vary from currently inactive (without a drain, fig. 3) to very active (with ongoing erosion into a drain, fig. 4). Unique surface-water features called *disappearing streams* or *ponors* are waterways that flow into sinkholes. As water flows underground, caves may form because dissolution causes fractures to enlarge into passages and chambers. In some places, these underground flows can reemerge from the subsurface as springs.

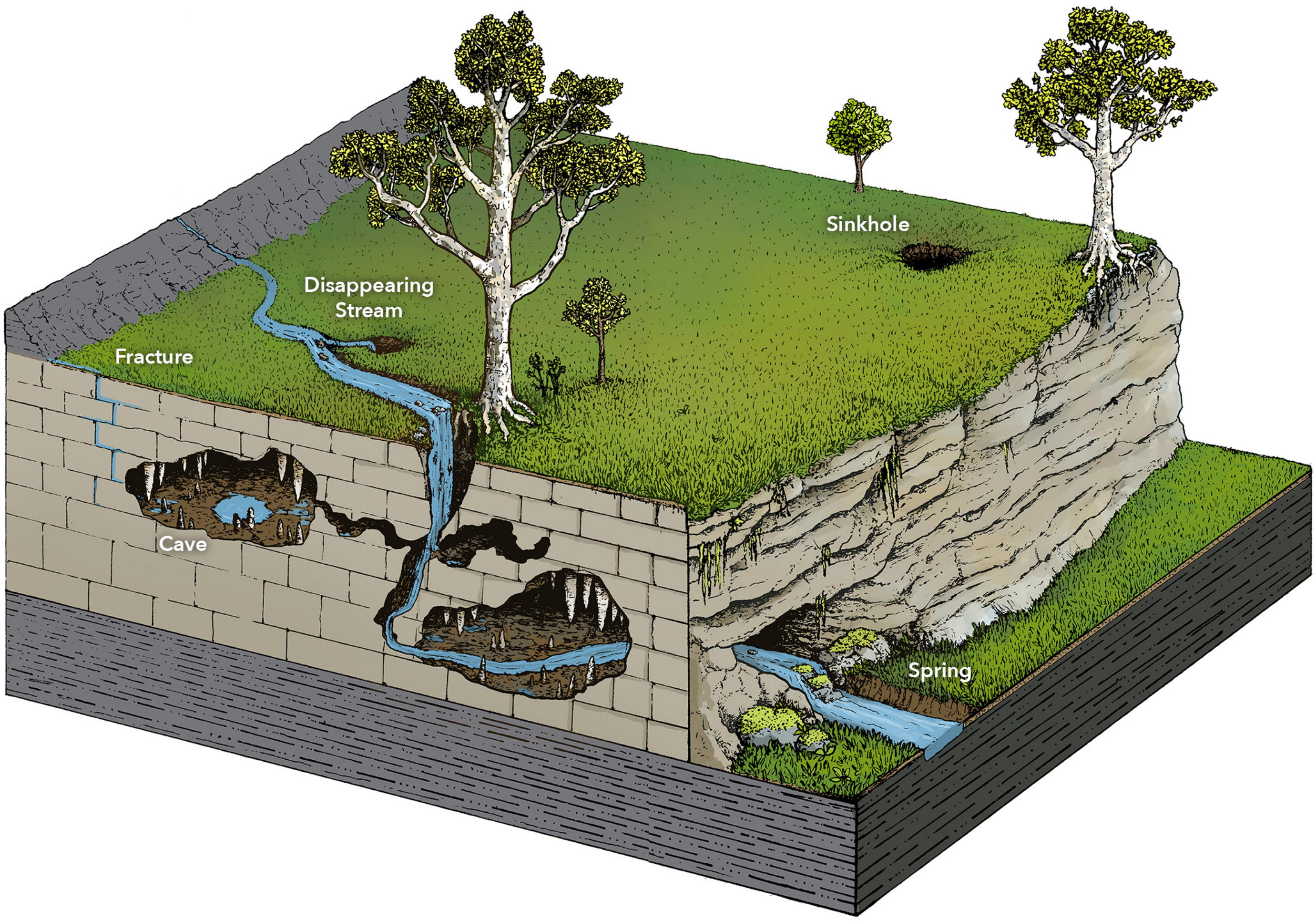

FIGURE 2. Block diagram showing the relationships between karst features. Illustration by Madison Perry.

FIGURE 3. Recently cleared, currently inactive sinkhole in Hamilton County, Ohio.

FIGURE 4. Active sinkhole with grass sod still partly suspended by tree roots in Hamilton County, Ohio.

IMPORTANCE OF RESEARCH

Knowing the locations of karst features is important for a variety of reasons. Fractures, joints, and dissolution paths present in bedrock (fig. 5) provide a direct connection from the land surface to the water table, bypassing soil and rock layers that normally would filter water of contaminants. Consequently, when compounds such as fertilizers, pesticides, and waste enter sinkholes, they are rapidly transported to the water table and can quickly pollute water wells, streams, springs, and rivers. Karst is often classified as a geologic hazard because roads, buildings, utilities, and other structures built on karst terrain may be subject to damage from sinking (fig. 6), collapse, or flooding. Documenting the locations of caves in the state also helps wildlife biologists track bat species and monitor the spread of diseases, such as white-nose syndrome.

FIGURE 5. Solutionally enlarged pathways in the grayish limestone rock (center top of photo; rock is about 2 ft long) enable greater surface-to-groundwater connectivity in Hamilton County, Ohio.

FIGURE 6. Sinkhole located adjacent to a buried natural gas pipeline clear-cut in Hamilton County, Ohio. Subsidence caused by karst features can threaten infrastructure.

LOCATING KARST FEATURES

The locations of karst features are confirmed using computer mapping software and field verification. Geologists use ESRI ArcGIS mapping software to look for enclosed depressions. These depressions can be found on a LiDAR (Light Detection and Ranging)-derived Digital Elevation Model (DEM; OGRIP, 2006–2008) of Ohio's topography using a fill-and-subtract method (see appendix 1 and Aden, 2018, for details). Geologists utilize the DEM, bedrock geology (Slucher and others, 2006), glacial drift thickness (Powers and Swinford, 2004), past karst mapping (Pavey and others, 1999), and available aerial imagery (OGRIP, 2018) to determine the likelihood of sinkholes in an area. Human-made structures, such as culverts, old foundations, ponds, or anything that can be mistaken as an enclosed depression, such as slopes disturbed by landslides (fig. 7), are identified by geologists and not listed as karst features. Features that cannot be eliminated remotely are field checked. During field verification, previously unidentified sinkholes, caves, and springs are often discovered or pointed out by residents. Fieldwork is especially useful for locating filled sinkholes that are not visible on the DEM, but easy to identify on site (fig. 8).

FIGURE 7. A landslide unrelated to karst in Hamilton County, Ohio.

FIGURE 8. A sinkhole mostly filled in with concrete and gravel debris in Hamilton County, Ohio.

KARST 2021–2022 STUDY AREA

During the 2021–2022 field season, fieldwork was completed in Hamilton County (fig. 9) by finishing the area that was remaining from the 2019-2020 field season (see fig. 11, Parrick and Aden, 2021). The motive for this mapping was to determine the extent of karst in this populous yet understudied region. A relatively small area of about 100 acres (40 hectares) of dense karst terrain with 71 sinkholes was mapped by Applegate (2003) in Mt. Airy Forest, and three karst features were located by the late Dr. Paul Potter of the University of Cincinnati in the Miami Whitewater Forest. There were also a few known features located on the west end of Winton Woods, but otherwise very little was known for southwestern Ohio before initial karst mapping efforts in 2019.

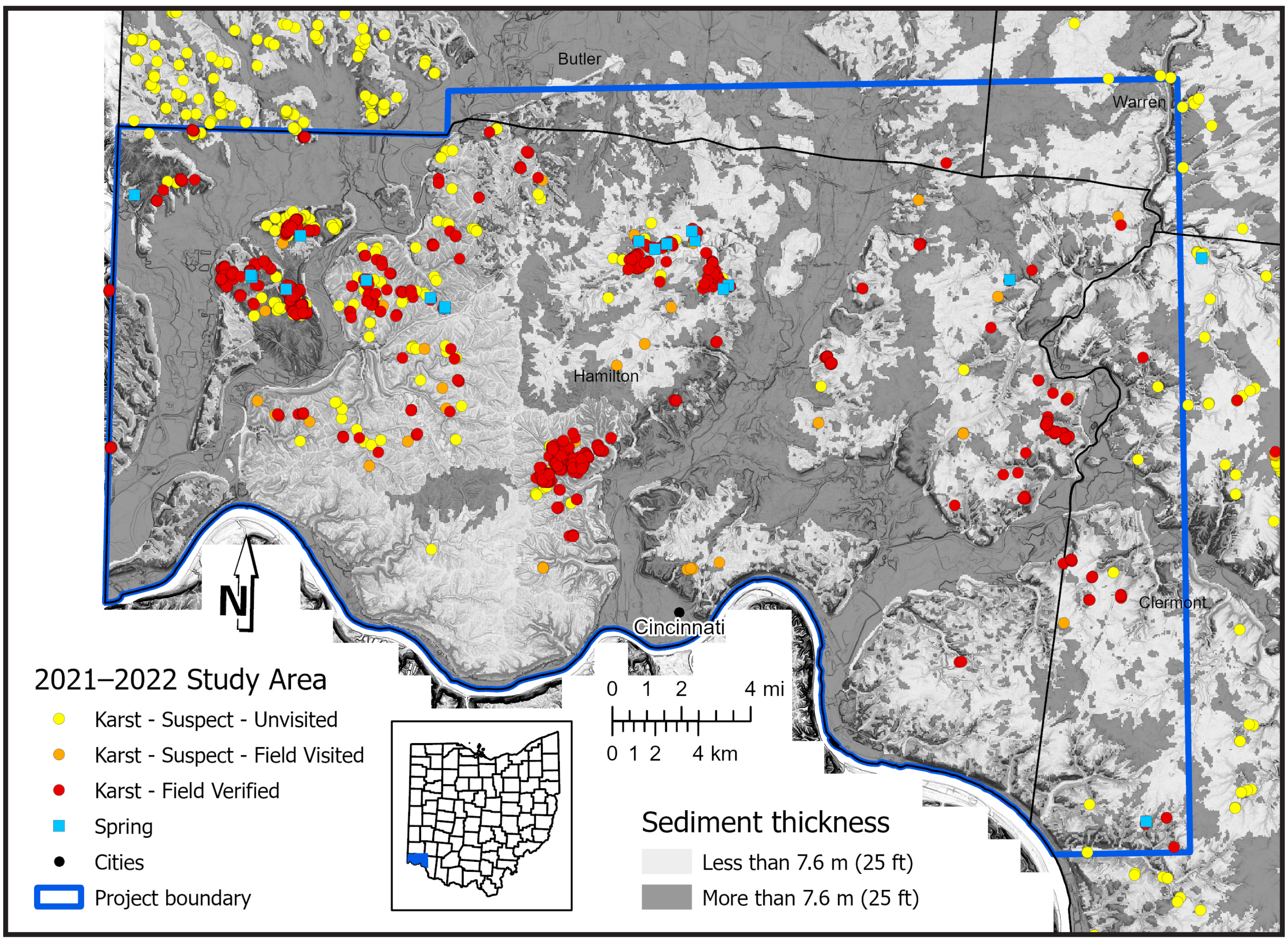

FIGURE 9. Map depicting the 2021–2022 study area (blue outline) in southwestern Ohio. Dark-gray areas are covered by more than 7.6 m (25 ft) of glacial material at the surface, and light-gray areas are covered by less than 7.6 m (25 ft) of glacial material at the surface. Note that the karst points are found almost exclusively in the light-gray areas where the glacial material is thin. The concentration of yellow points in the northwestern portion of the map shows where the next field season will continue in Butler County.

DEM analysis of this region unearthed 1,849 potential karst points, many more than expected. In addition, some of these points are located in areas of very thick glacial material. However, since sinkholes do not typically form in till thicker than about 25 ft (7.6 m), these points may represent localized glacial material thickness map inaccuracies. This field season, 268 karst points were reviewed (table 1), resulting in a total of 1,332 points within this project area when combined with the 2019–2020 data. Field work is crucial for confirming potential karst points, adding newly located sinkholes, and measuring depths of features. Sinkholes that were measured in the field were often deeper than what remote sensing data shows—adding as much as 8 ft (2.4 m) this year and a record of 42 ft (12.8 m) in 2017. Approximately 30% of the total karst points were discovered during this season's field mapping, even though they were not captured on the DEM (fig. 10). One interesting type of sinkhole noted in this area are small sinkholes that form alongside of a stream, but not connected on the surface to the stream. These are likely young sinkholes that may eventually erode enough to capture the adjacent stream (fig. 11). This area also included a few sinkholes that are unusually large for the area (fig. 12).

TABLE 1. ***Summary of karst points found in the 2021–2022 field season and cumulative statewide status.***

Karst Point Type	2022 Total	Statewide Total*
Karst – Field Verified	246	8,122
Karst – Suspect – Field Visited	11	2,239
Karst – Suspect – Unvisited	2	9,244
Springs	9	506
Total Karst Points	**268**	**20,111**

***The inventory of statewide karst points was first created in 2009.**

FIGURE 10. Active sinkhole that did not appear on the DEM but was located by field work in Hamilton County, Ohio.

FIGURE 11. Small, mossy sinkhole adjacent to a stream in Hamilton County, Ohio. It's likely that water from the stream running diagonally across the photo is draining into bedrock fractures upslope (left) and washing away material in the subsurface here, creating and enlarging this sinkhole. This demonstrates the sometimes complex and concealed nature of karst since this sinkhole is not forming from surface water erosion from above, but from water removing material below causing collapse

FIGURE 12. This very large sinkhole is the deepest (24 ft (7.3 m)) and in the top ten largest (280 ft (85 m) long) in Hamilton County, Ohio.

This project area is also notable because sinkholes are forming in Ordovician-age rock that is dominated by shale. The majority of these sinkholes occur in the Grant Lake Formation (62%) or the Miamitown Shale - Fairview Formation Undivided (35%), with the remaining three percent in other formations. These formations are 50 to 90 percent shale and contain typically thin limestone interbeds (fig. 13). The predominance of shale within these formations was expected to largely impede karst formation; however, occasional sinkholes up to 24 ft (7.3 m) deep are found in this area. It has been proposed that these sinkholes are formed as the poorly lithified shales collapse and physically weather into the underlying solutioned limestones (Applegate, 2003). In general, very little limestone was seen within sinkholes, and only 1 in 50 field-checked sinkholes had exposed limestone, compared to about 1 in 4 in past mapping in southern Ohio. It's possible that little limestone is visible here because it's been covered by slumped shale colluvium.

FIGURE 13. Typical outcrop in a stream bank, Hamilton County, Ohio. The majority of the exposure is comprised of thinly bedded shales with a smaller portion of somewhat thicker limestone beds. Red dashed lines indicate contacts between rock types.

STATEWIDE STATUS AND FUTURE WORK

Most of the known, very dense, karst areas in Ohio have been mapped in detail, apart from Adams and Brown Counties, where field work is incomplete because of the large number of features and ongoing data processing. However, there are large areas of southwestern and potentially central Ohio where remote sensing data indicates that there are hundreds of sinkholes (fig. 14). In fact, field work in Hamilton County has shown a significant occurrence of karst in the Ordovician bedrock which likely extends to surrounding counties. Field mapping will continue in the 2022–2023 field season in Butler County, where additional karst features are suspected and impacts on urban development are potentially significant. Preparation for future mapping this year included processing the DEM for Logan County and the remaining portion of Highland County (fig. 14).

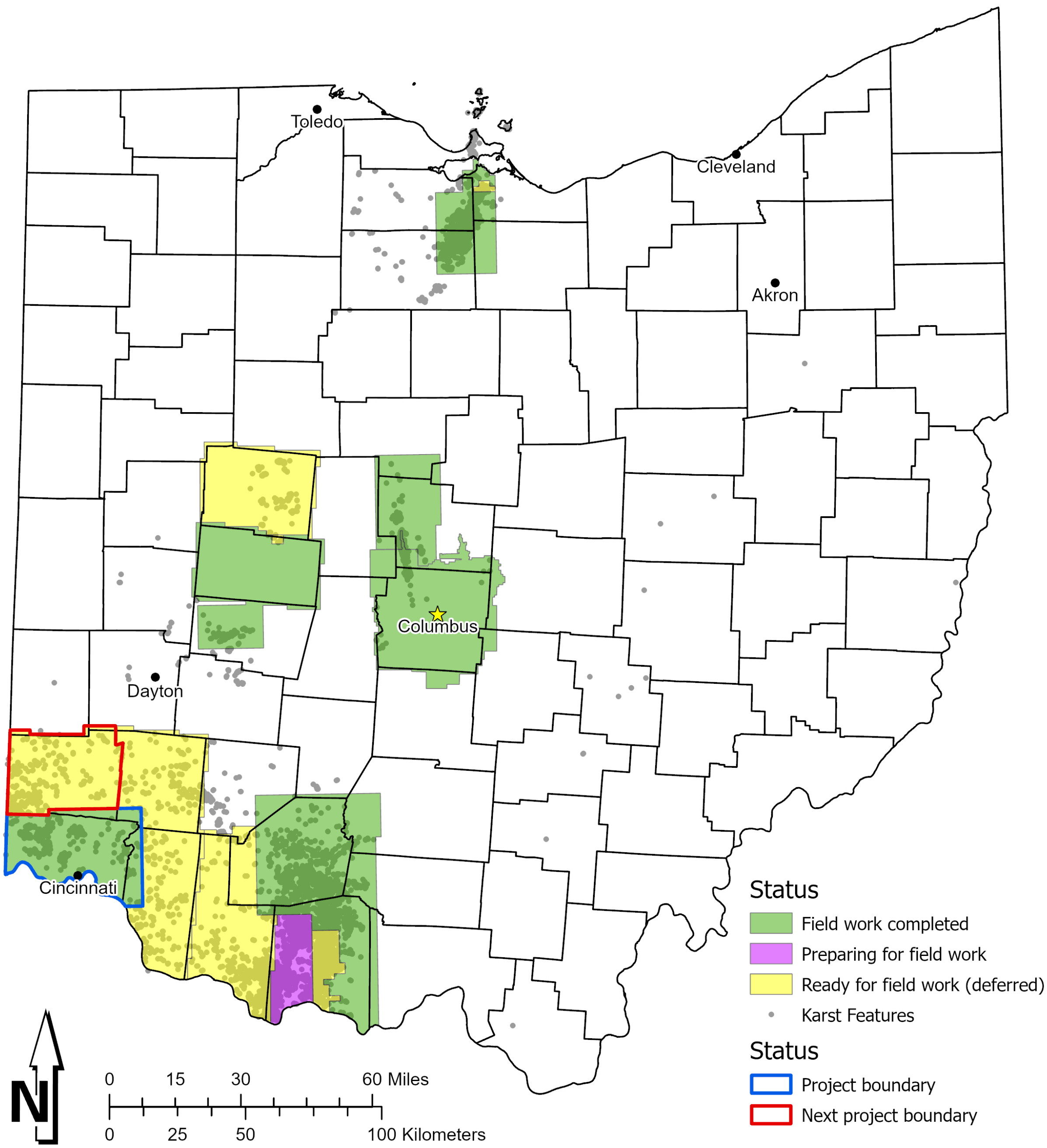

FIGURE 14. Karst mapping statewide status map. Green shading shows areas where data processing and field work are complete; yellow shading shows areas where data processing is complete and the area is ready for field work; and purple shading shows areas where data is currently being processed for potential future field work.

REFERENCES

Aden, D.J., 2018, Quantitative comparison of sinkhole geomorphology of four karst regions in Ohio, *in* Sasowsky, I.D., Byle, M.J, and Land, L., eds., NCKRI Symposium 7—Proceedings of the 15th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst and the 3rd Appalachian Karst Symposium, April 2–6, 2018, Shepherdstown, W. Va.: Carlsbad, N. Mex., National Cave and Karst Research Institute, p. 259–267, last accessed August 27, 2021, at <http://scholarcommons.usf.edu/sinkhole_2018/ProceedingswithProgram/Formation_of_Karst_and_Sinkholes/2/>.

Aden, D.J., Powers, D.M., Pavey, R.R., Jones, D.M., Martin, D.R., Shrake, D.L., and Angle, M.P., 2011, Karst of western Delaware County, Ohio, region: Columbus, Ohio Department of Natural Resources, Division of Geological Survey OFR 2011-4, 2 p., 35 pl.

Applegate, P., 2003, Detection of sinkholes developed on shaly Ordovician limestones, Hamilton County, Ohio, using digital topographic data—Dependence of topographic expression of sinkholes on scale, contour interval, and slope: Journal of Cave and Karst Studies, v. 65, no. 2, p. 126–129.

Hobbs III, H.H., 2009, The Glaciated Central Lowlands—Ohio, chap. 4 *of* Palmer, A.N., and Palmer, M.V., eds., Caves and Karst of the USA—A Guide to the Significant Cave and Karst Areas of the United States of America: National Speleological Society, p. 136–140.

Ohio Geographically Referenced Information Program (OGRIP), 2006–2008, State of Ohio, ESRI GRID DEM Mosaic [digital elevation model derived from digital LiDAR data collected March–May, 2006–2008]: State of Ohio, Office of Information Technology, Statewide Imagery Program, last accessed February 3, 2022, at <https://gis5.oit.ohio.gov/geodatadownload/>.

Ohio Geographically Referenced Information Program (OGRIP), 2012–2020, State of Ohio, 1FT MrSID County Mosaics (30x) [digital orthoimagery]: State of Ohio, Office of Information Technology, Statewide Imagery Program, last accessed February 3, 2022, at <https://gis5.oit.ohio.gov/geodatadownload/>.

Pavey, R.R., Hull, D.N., Brockman, C.S., Schumacher, G.A., Stith, D.A., Swinford, E.M., Sole, T.L., Vorbau, K.E., Kallini, K.D., Evans, E.E., Slucher, E.R., and Van Horn, R.G., 1999, Known and probable karst in Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Map EG-1, scale 1:500,000. [Revised 2002, 2004, and 2007.]

Powers, D.M., and Swinford, E.M., 2004, Shaded drift- thickness map of Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Map SG-3, scale 1:500,000.

Schumacher, G.A., Mott, B.E., and Angle, M.P., 2013, Ohio’s geology in core and outcrop–A field guide for citizens and environmental and geotechnical investigators: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Information Circular 63, 191 p.

Slucher, E.R., (principal compiler), Swinford, E.M., Larsen, G.E., and others, with GIS production and cartography by Powers, D.M., 2006, Bedrock geologic map of Ohio: Columbus, Ohio Division of Geological Survey Map BG-1, version 6.0, scale 1:500,000.

APPENDIX

Instructions for deriving karst depressions from an approximately 20 mi^2 (32 km^2) or smaller sized Digital Elevation Model (DEM), at a resolution of 2.5 ft^2 (0.76 m^2) per pixel, using ArcGIS Pro 2.8.0 and the spatial analysis extension. Similar steps can be applied for those using QGIS or ArcGIS Desktop.

1. Prepare the DEM.
   a. Locate the DEM data that covers the project area.
   b. ***Extract by mask*** needed segments from each area.
   c. Create a seamless DEM for your project area by using ***mosaic to new raster***, or ***clip*** from an existing regional DEM. If tiled data is available, it is much quicker to use a ***mosaic dataset*** rather than producing a single raster mosaic.

2. Identify depressions on the DEM.
   a. On the new area DEM use the ***fill tool*** to fill enclosed lows.
   b. Use ***minus*** to subtract the unfilled DEM from the filled DEM to identify enclosed low spots.

3. Convert the DEM into polygons.
   a. Use ***reclassify*** on the subtracted DEM to create a gridcode. If you get datum conflicts, run the process in a new blank project.
   b. Assign a gridcode using 'equal interval' to set each range to one foot (or one decimeter). This creates bins where ranges of values are set to one value. For example, set the range of 0.00001–1 = 1, 1–2 = 2, 2–3 = 3, etc. Do not use zero in the lowest range or you will get a polygon that is too complex to be generated.
   c. Use ***raster to polygon*** to create a polygon feature class of depressions. The advantage of the feature class over a raster is that individual depressions can be deleted from the dataset.

4. Symbolize the polygons based on gridcode using a color ramp. Depressions with substantial elevation change may require a repeating color ramp to improve visualization. (See figure A1-1 for an example image of polygons resulting from steps 1–4.)

5. Delete shallow isolated polygons: steps 1–4 will produce an excessive number of polygons when run on a 20 mi^2 (32 km^2) sized area at 2.5 ft^2 (0.76 m^2) per pixel resolution. Isolated polygons less than 1 ft (~0.3 m) deep can be deleted, as these are unlikely to be sinkholes.
   a. Start with the results of step 4: a polygon feature class with all the depressions in the study area.
   b. Select all gridcode 1 polygons and export to a new feature class using the ***definition query: gridcode = 1***. Isolated polygons below a given minimum size can also be deleted here if desired using a similar ***definition query***.
   c. Select all gridcode 2 polygons and export to a new feature class using the ***definition query: gridcode = 2***.
   d. Select all gridcode 1 polygons that touch the boundary of gridcode 2 polygons using ***select by location***. Export this selection of the touching gridcode 1 polygons (non-isolated) to a new feature class.
   e. Use a ***definition query*** on the full depression layer (results of step 3) to set ***gridcode to not equal (<>) 1***. Export all the polygons except for the gridcode 1 polygons to a new feature class.
   f. Use ***load data*** in catalog to add the touching gridcode 1 polygons (non-isolated) to the full depression layer without the gridcode 1 polygons.
   g. This will produce a feature class of depressions without isolated polygons.

6. Verify step 5: compare the output from step 5 (feature class with shallow, isolated polygons removed) to output from step 4 (full feature class with all polygons). The step 5 output should not show any of the isolated 1 ft (~0.3 m) deep depressions present in the results of step 4.

7. Begin manually deleting extraneous polygons by reviewing best available aerial imagery, DEM + slope shade, and culvert data if available (see fig A1-2 for an example output with possible sinkhole depressions).
   a. The polygons in quarries, large lakes, and rivers can be deleted first, this will trim the data set and may improve drawing speed.
   b. Sort the attribute table by gridcode to locate the deepest depressions, these are usually human-made depressions and can be deleted.
   c. Bridges and culverts often generate large non-karst depressions
   d. Streams and ditches often produce series of shallow linear depressions from pools and gravel bars. These very rarely represent karst.
   e. If a probable sinkhole is located, carefully check the surrounding areas for less obvious features especially at similar elevations.

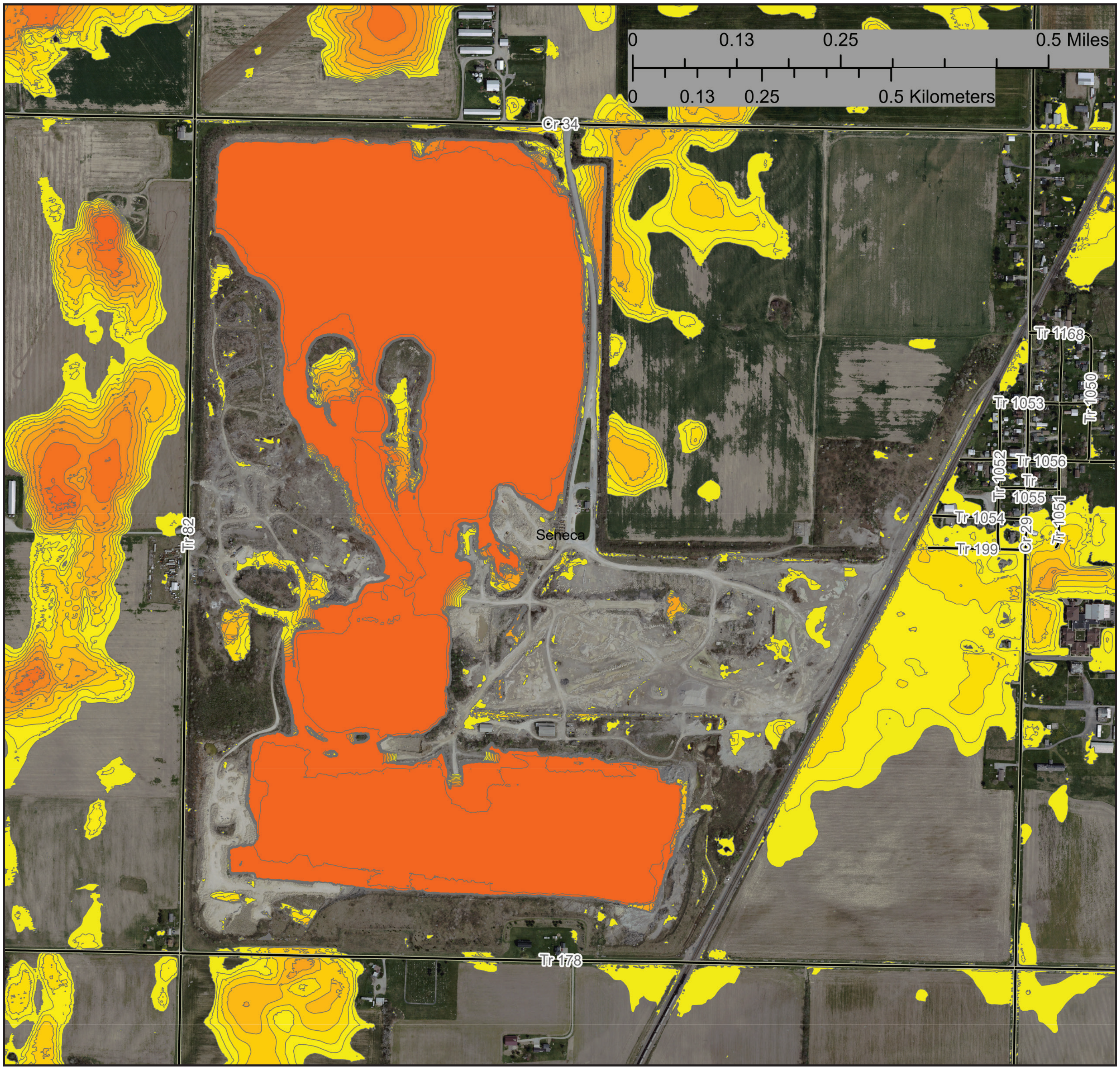

FIGURE A1-1. Polygons representing an example set of raw depressions, extracted from the DEM by completing steps 1–4 of the instructions in Appendix 1.

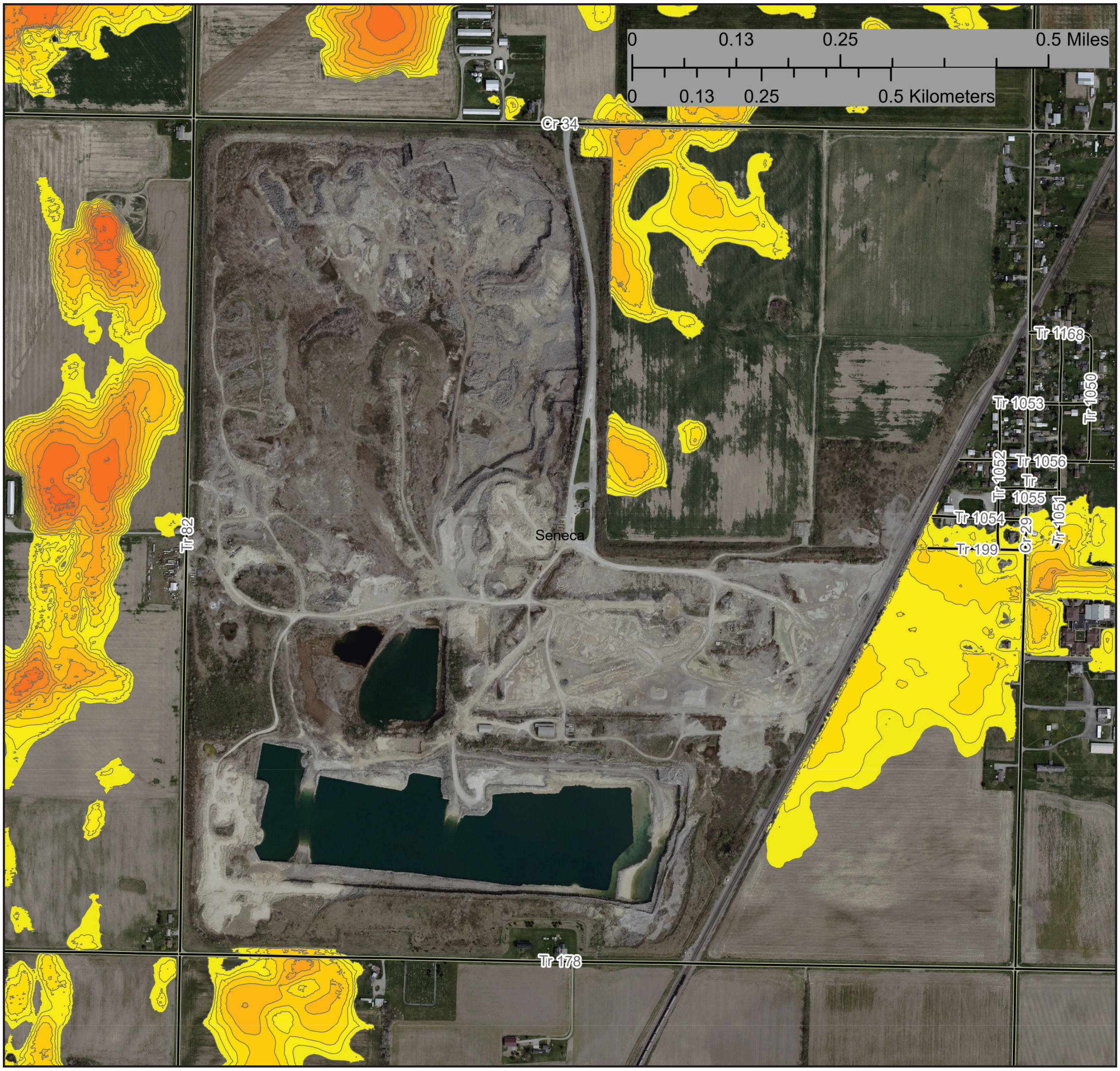

FIGURE A1-2. Numerous polygons are automatically removed during step 5 of the instructions in Appendix 1. During step 7, other non-karst–related polygons are manually removed—such as those in this quarry and along roads—until only the depressions that are likely to be sinkholes remain.

OHIO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

(614) 265-6576 • geo.survey@dnr.ohio.gov
geology.ohiodnr.gov