2023 KARST ANNUAL REPORT:

KARST MAPPING OF BUTLER COUNTY, OHIO

by Douglas J. Aden and Brittany D. Parrick

OHIO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

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Graphic design & layout: Jeremy E. Gladden
Editing: Anthony J. Bresnen
Front cover: A sinkhole in a field, Butler County, Ohio. Bedrock is exposed within this collapse.
Back cover: A small cave, field verified during the 2022–2023 field season at an undisclosed location.

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STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
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PREFACE

The 2023 Karst Annual Report describes the 2022–2023 study area and continues the Ohio Department of Natural Resources (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 through September 2023 (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**.

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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. Photograph of a sinkhole filled with trees in a field in Butler County, Ohio.

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.

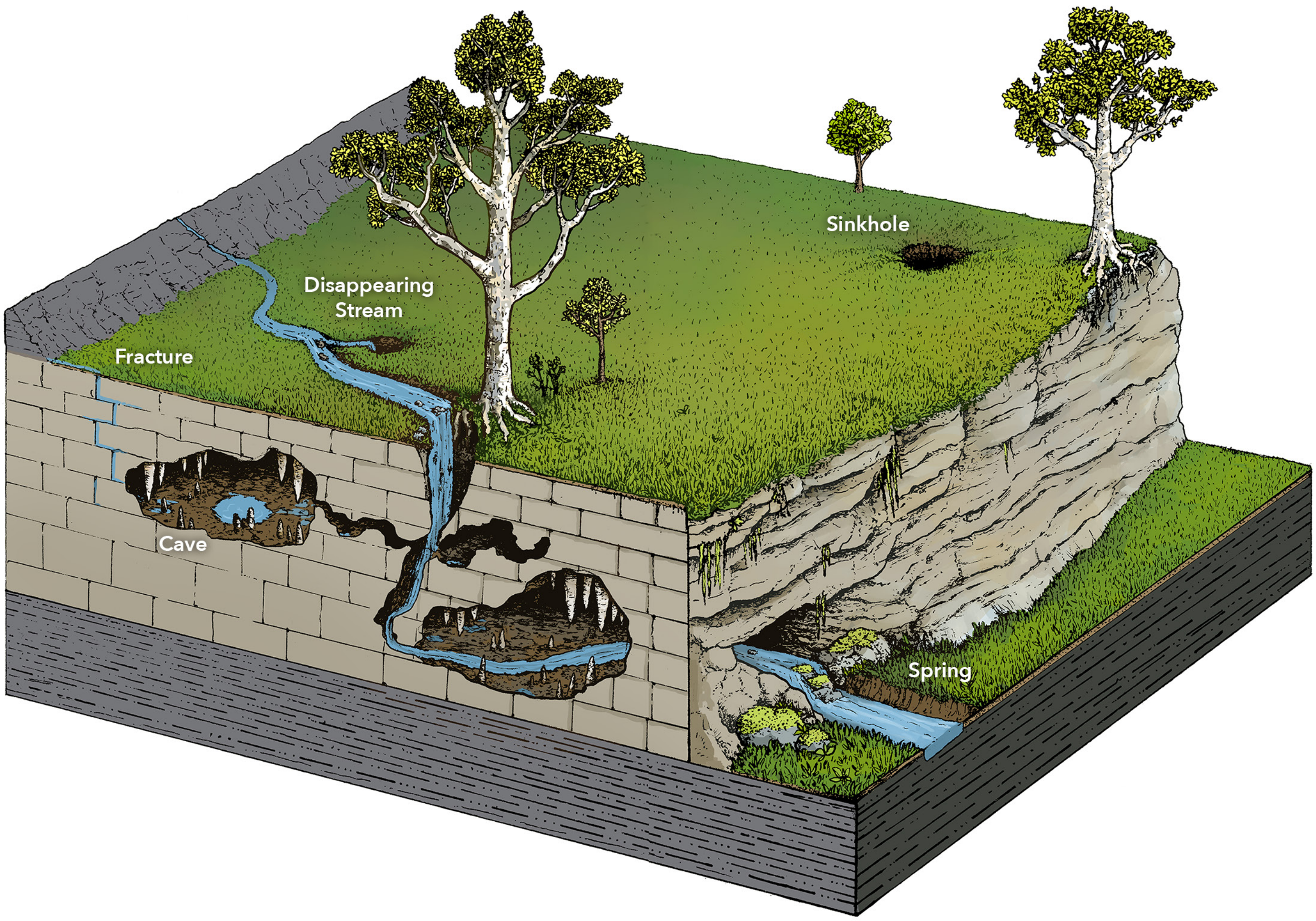

FIGURE 2. Block diagram showing the relationships between karst features. Illustration by Madison Perry.

FIGURE 3. This sinkhole in a homeowner's yard in Butler County, Ohio, appears inactive, but some recent fill may indicate that suffosion is ongoing.

FIGURE 4. Active sinkhole with soil suspended from tree roots in Butler 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 contaminants from water. 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 (fig. 6). 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, 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 this limestone rock found in Butler County, Ohio, enable greater surface-to-groundwater connectivity. Three-inch (8-cm) pocketknife for scale.

FIGURE 6. A tire-filled sinkhole in Butler County, Ohio. Tires leach many contaminants when not disposed of properly.

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, 2018) 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 sediment 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, wells (fig. 7), old foundations, ponds, or anything that can be mistaken as an enclosed depression, such as slopes disturbed by landslides, 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 very small or filled sinkholes (fig. 8) that are not visible on the DEM but easy to identify on site.

FIGURE 7. An old collapsing well unrelated to karst in Butler County, Ohio.

FIGURE 8. A previously filled sinkhole located during fieldwork in Butler County, Ohio.

KARST 2022–2023 STUDY AREA

During the 2022–2023 field season, fieldwork was completed in Butler County (fig. 9). This area was chosen because it is one of the top-10 fastest-growing counties in Ohio, ties into karst mapped the previous year in Hamilton County (Aden and Parrick, 2022), and had not yet been assessed for karst.

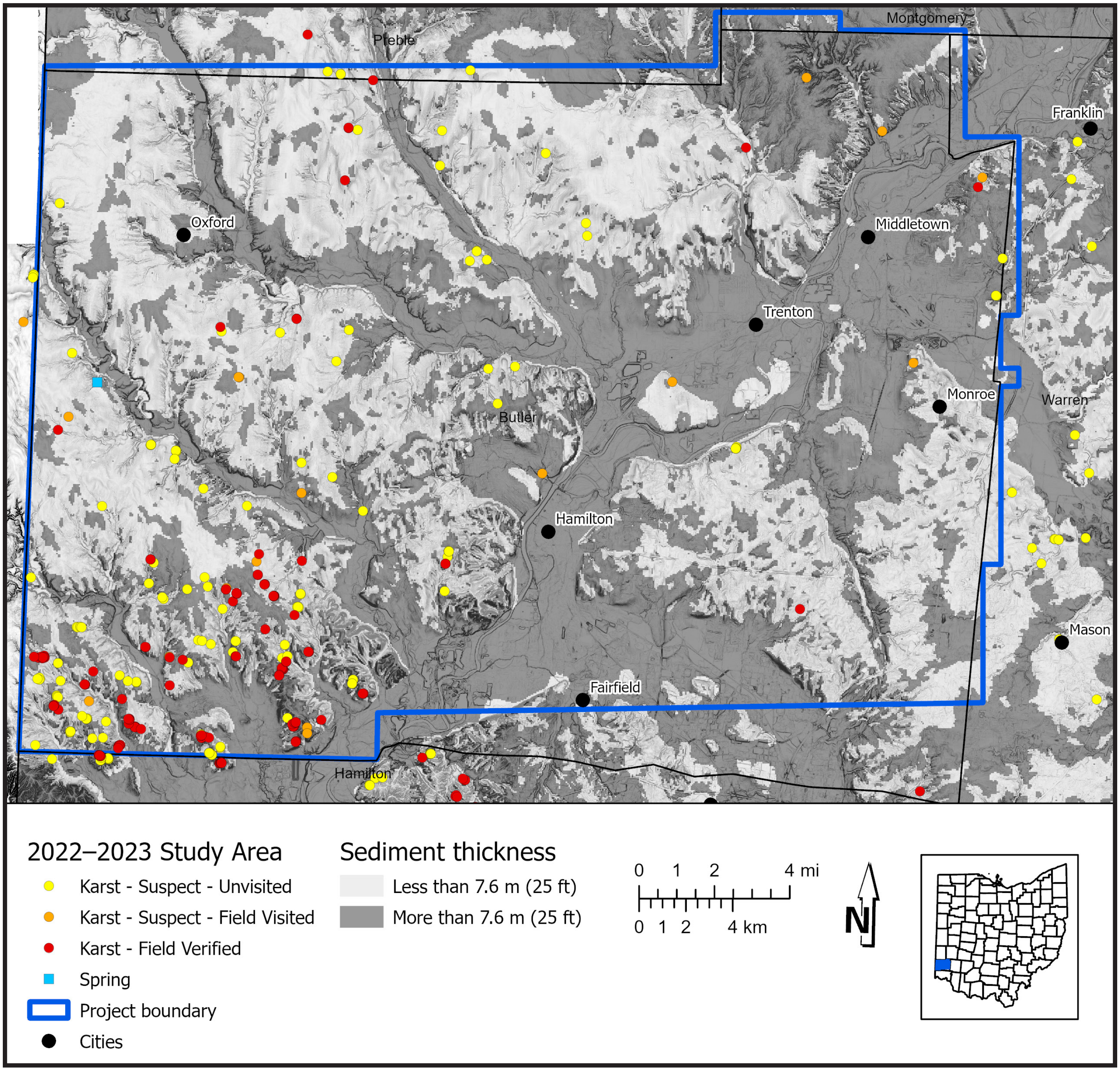

FIGURE 9. Map depicting the 2022–2023 study area (blue outline) in southwestern Ohio. Dark-gray areas are covered by more than 25 ft (7.6 m) of glacial material at the surface, and light-gray areas are covered by less than 25 ft (7.6 m) of glacial material at the surface. Note that the karst points are found almost exclusively in the light-gray areas where the glacial material is thin. The concentration of points in the southwestern portion of the map occurs where the ridges are more dissected compared to other portions of the county. The blue project boundary line is determined by the extent of the new DEM data and previously completed projects.

No verified karst points existed in the ODNR karst database for Butler County prior to this project. Initial DEM analysis identified 611 potential points and 343 remained when the project was complete (table 1). Fieldwork is crucial for confirming potential karst points and distinguishing them from purely erosional features, adding newly located sinkholes, measuring the depth of features, and monitoring changes (fig. 10). Sinkholes that were measured in the field were often deeper than remote sensing data suggested—adding as much as 10 ft (3.0 m). Sinkholes do not typically form in sediments thicker than about 25 ft (7.6 m) and the few points mapped on Figure 9 that do may represent localized mapping inaccuracies of glacial material thickness.

TABLE 1. ***Summary of karst points found during the 2022–2023 field season and cumulative statewide status.***

Karst Point Type	2023 Total	Statewide Total*
Karst – Field Verified	187	8,328
Karst – Suspect – Field Visited	24	2,260
Karst – Suspect – Unvisited	125	10,217
Springs	7	525
Total Karst Points	**343**	**21,330**

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

The availability of a higher-resolution, 2-ft (0.6-m)-per-pixel DEM for Butler County necessitated more computer processing time and resulted in more false positives, but the benefit was detecting smaller karst features than in previous years. This resulted in Butler County having half as many field-added points (14%) as Hamilton County (data collected during the 2021–2022 field season; see Aden and Parrick, 2022) due to many of them being detected during computer processing work before fieldwork began. Examples of false positives include the collapse shown in Figure 11a which is about 200 ft (61 m) away from six confirmed sinkholes but was found to be floored by failing drain tile and unrelated to karst. Similarly, Figure 11b was determined to be a network of washed-out drain tiles in easily eroded silt along the edge of a farm field. Failing drain tiles are typically indistinguishable from karst on a DEM, and they often form enclosed sinking areas but can generally be identified in person by the presence of broken tile. Both steep-sided and narrow features can also appear to be sinkholes on a DEM, and Figure 11c shows an example that ended up being a meandering stream channel cutting into farm pasture. This type of landform can be especially tricky to identify remotely if the channel is narrower than the LiDAR point spacing. Similarly, Figure 11d shows significant erosion in a field caused by surface runoff. LiDAR is an invaluable tool for initially locating potential features, but fieldwork will continue to be required to distinguish between karst and other landscape features.

Over the last 50 years, the Midwest has experienced a five to ten percent increase in average annual precipitation, and the increase in total rainfall on the wettest days of the year (USEPA, 2016) is exacerbating erosion in this region (Soil and Water Conservation Society, 2003). The significant erosion seen in Figures 11a–11d represent areas that were farmed in the past but are now too steep or irregular to be farmed. This is especially clear in Figure 11d, which shows erosional degradation of a field in as little as one year since it was planted. Furthermore, as glacial sediments continue to be removed through erosional processes, sinkholes may be more likely to form in Butler County and other areas in Ohio as bedrock is exposed closer to the surface.

FIGURE 10. This sinkhole (a) was found during the 2021–2022 field season very close to the Hamilton-Butler County border. It was revisited one year later (b). Note how much more the roots are exposed in the center as this sinkhole has continued to erode. Arrows mark the two matched trees in both photos.

FIGURE 11. Four dramatic examples of erosion in farm fields in Butler County, Ohio, that are false positives identified by LiDAR and are unrelated to karst. The hole seen in Figure 11a was found to be floored by failing drain tile. The elongated ditch seen in Figure 11b was determined to be a network of washed-out drain tiles in easily eroded silt along the edge of a farm field. The channel seen in Figure 11c was found to be a meandering stream cutting into farm pasture. The long erosional depression seen in Figure 11d was created by surface runoff.

This project area continues the trend documented during the 2021–2022 field season in Hamilton County (Aden and Parrick, 2022), where sinkholes are forming in Ordovician-age rock that is dominated by shale. The sinkholes occur in a variety of formations including the Grant Lake Formation (37%); the Waynesville Formation (27%); the Miamitown Shale - Fairview Formation undivided (13%); the Arnheim Formation (11%); and the Drakes, Whitewater, and Liberty Formations undivided (7%) with the remaining five percent in other formations. These formations are 50–90 percent shale and contain typically thin limestone interbeds (fig. 12). The predominance of shale within these formations was expected to largely impede karst formation; however, occasional sinkholes up to 10 ft (3.0 m) deep are found in this area and even a single cave (back cover photo). It has been proposed that these sinkholes form 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 86 (versus 1 in 50 in Hamilton County) field-checked sinkholes had exposed limestone, compared to about 1 in 4 in past mapping in southern Ohio. It is possible that little limestone is visible here because it has been covered by slumped shale colluvium.

FIGURE 12. Typical outcrop in a stream bank in Butler County, Ohio. The majority of the exposed bank is comprised of thinly bedded shales with a smaller portion of somewhat thicker limestone beds. Bedrock trends are similar to what is seen in Hamilton County but in Butler County, bedrock exposures are generally covered by glacial sediments or colluvium. Red dashed lines indicate contacts between rock types.

UPDATES TO PREVIOUSLY MAPPED AREAS

A volunteer for the Friends of French Park in Hamilton County reached out to ODNR during the Butler County project and reported having located sinkholes in Hamilton County. These features were not located during previous Hamilton County mapping (Aden and Parrick, 2022), but since fieldwork was ongoing in Butler County, a visit was arranged. In total, 22 sinkholes and one spring not apparent on the DEM were added to the statewide karst inventory (figs. 13 and 14). Collaborating with local groups is an important way to provide educational information, better understand groundwater movement in the area, discuss mitigation options, and to improve detailed mapping. Furthermore, improvements in the resolution of available DEM data (such as what was used in Butler County during the 2022–2023 field season) improve the ability to locate potential karst points. Utilizing improved DEM data, additional points were added to the statewide karst inventory in Erie, Huron, Sandusky, and Seneca Counties.

STATEWIDE STATUS AND FUTURE WORK

While many significant karst areas have been mapped in Ohio, there are also extensive areas where mapping is incomplete. This is especially true in western Adams and eastern Brown Counties where fieldwork has been deferred because of the high density of probable karst points and pending availability of updated DEM data. There are also many other areas of western Ohio where carbonate bedrock is present and the glacial sediment is thin; many of these areas remain unassessed. Recent fieldwork in Hamilton and Butler Counties has shown a significant occurrence of karst in the Ordovician bedrock which DEM analysis suggests extends to surrounding counties. In order to validate these points, field mapping will continue for the 2023–2024 field season just to the east in Warren and Clinton Counties where additional karst features are suspected. Preparation for future mapping this year included completing DEM processing for Logan and Clinton Counties and the remaining portion of Adams County, as well as processing an updated DEM for the karst region in north central Ohio (fig. 15).

ACKNOWLEDGMENTS

Special thanks to Scott Putthoff and the Friends of French Park Volunteers for the tour of the sinkholes they found, and to all the landowners in the region who provided access to potential karst features.

FIGURE 13. An active sinkhole undetected on the DEM in French Park, Hamilton County, Ohio.

FIGURE 14. A historically developed spring in French Park, Hamilton County, Ohio.

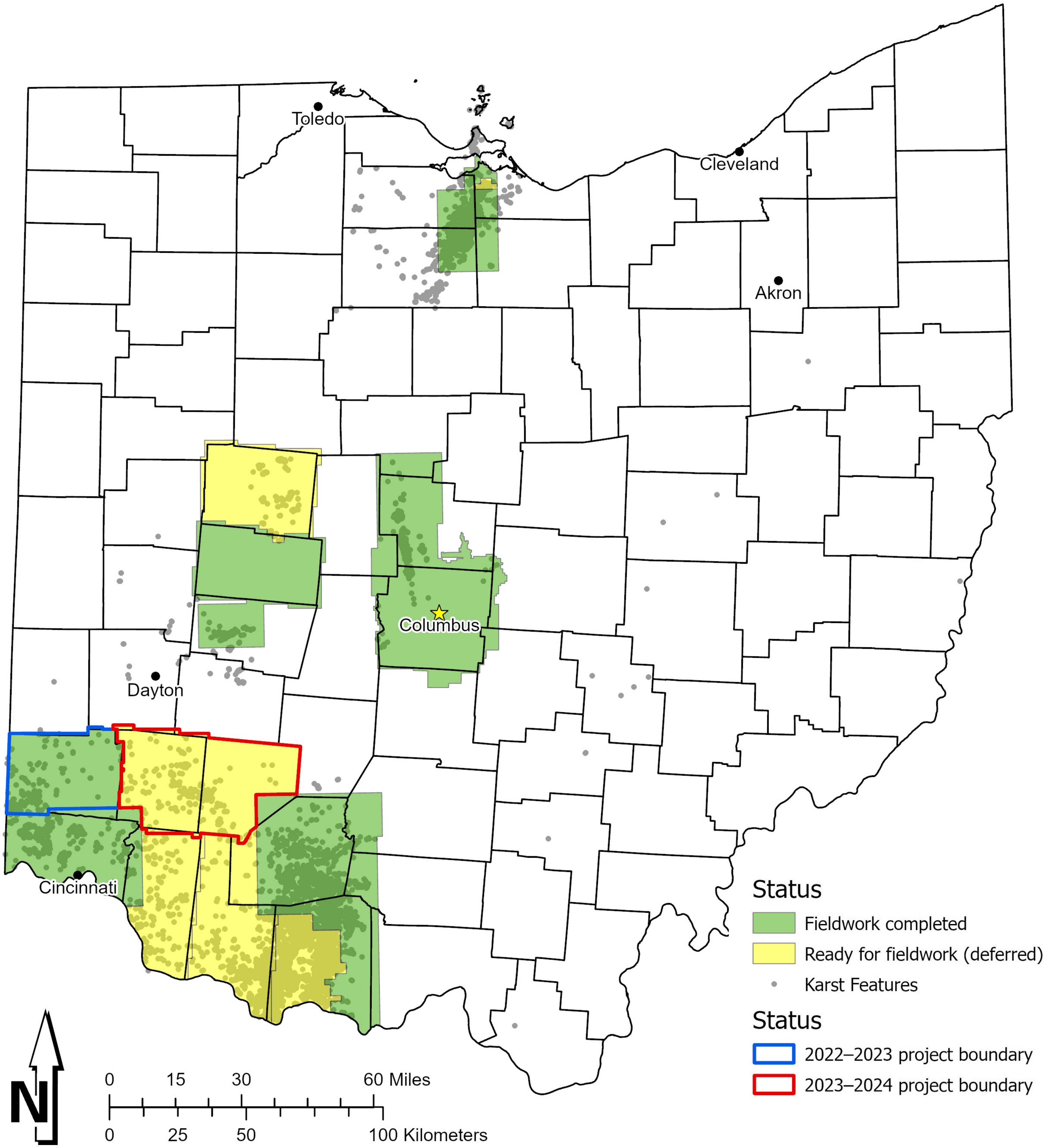

FIGURE 15. Karst mapping statewide status map. Green shading shows areas where data processing and fieldwork are complete; yellow shading shows areas where data processing is complete and the areas are ready for fieldwork.

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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. Use 'defined interval' and set the interval size to 1 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. Make the lowest range 0–0.00001 = NODATA to avoid 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.

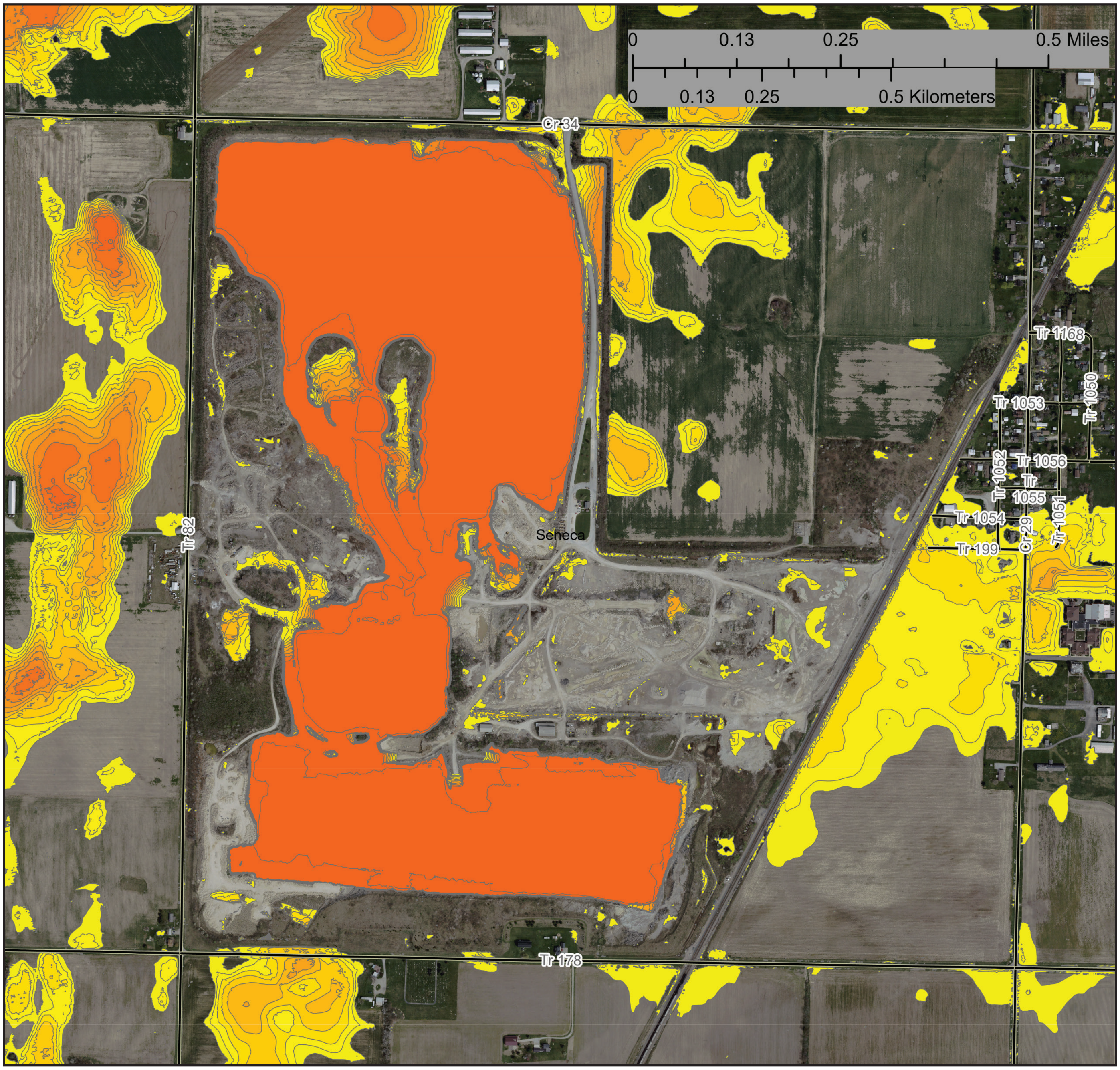

FIGURE A1-1. Polygons representing an example set of raw depressions, extracted from the DEM by completing steps 1–4 of the instructions in Appendix 1.

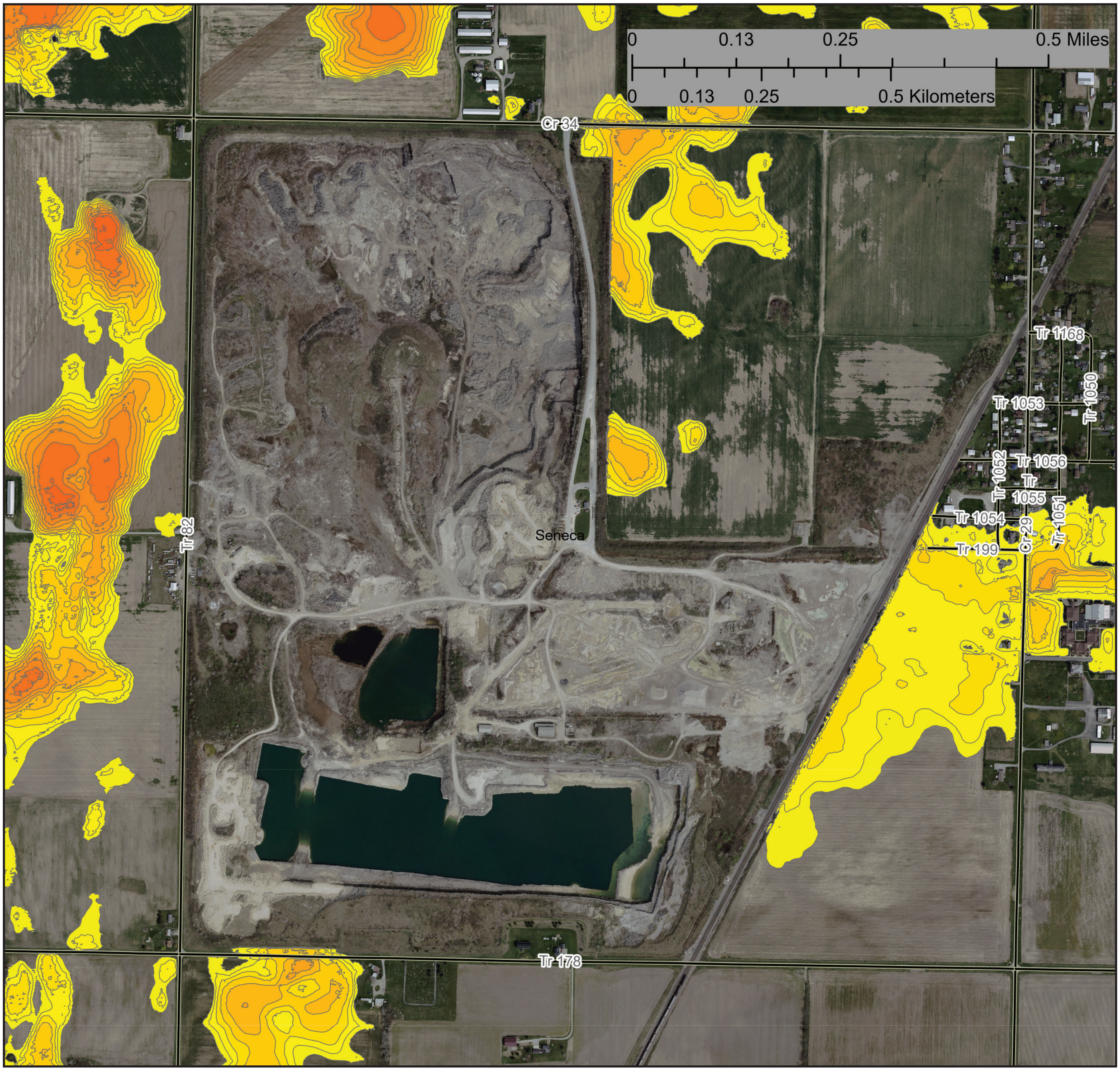

FIGURE A1-2. Numerous polygons are automatically removed during step 5 of the instructions in Appendix 1. During step 7, other non-karst–related polygons are manually removed—such as those in this quarry and along roads—until only the depressions that are likely to be sinkholes remain.

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