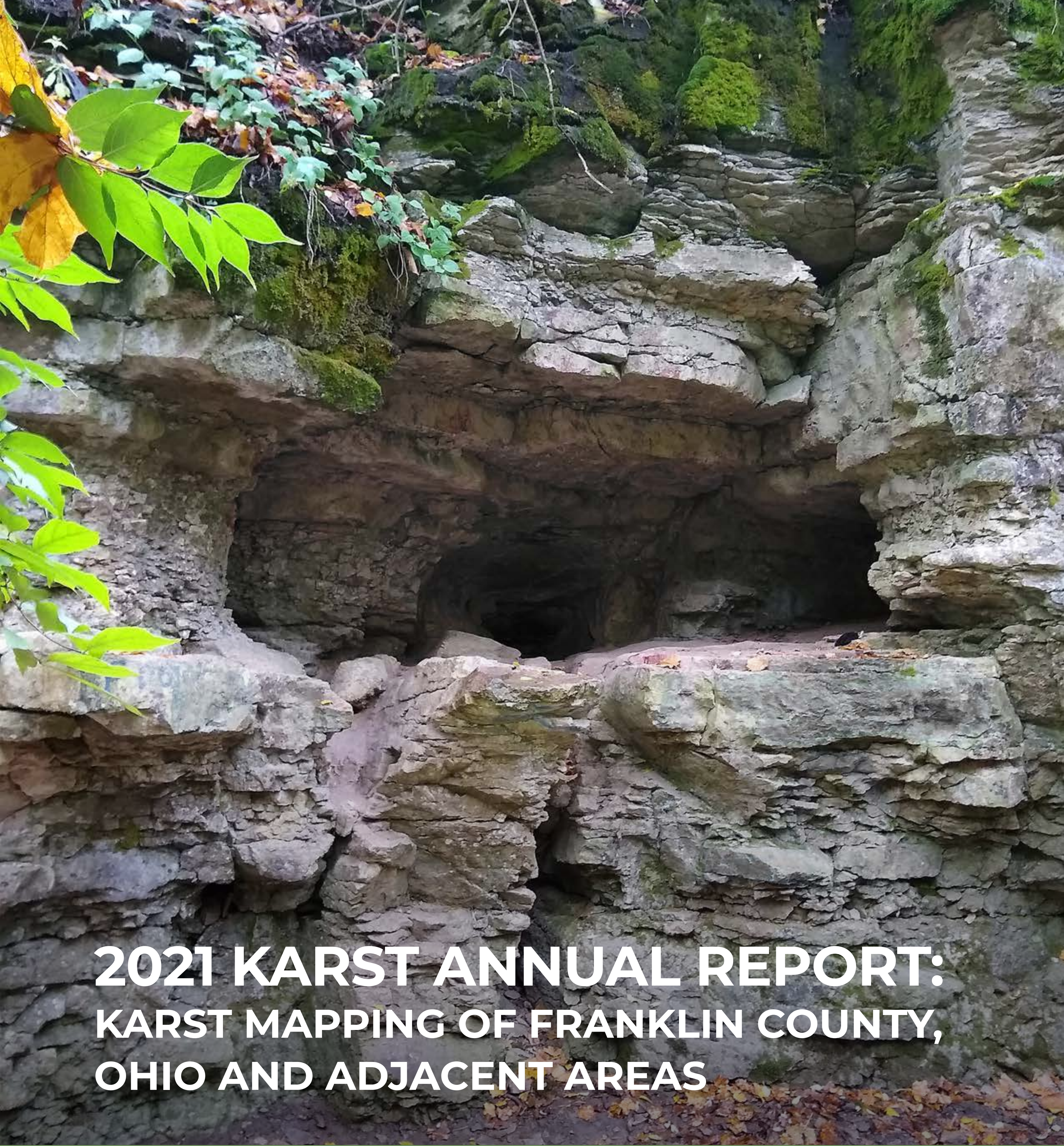

2021 KARST ANNUAL REPORT:
KARST MAPPING OF FRANKLIN COUNTY, OHIO AND ADJACENT AREAS

by Douglas J. Aden and Brittany D. Parrick

OHIO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

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2021 Karst annual report: Karst mapping of Franklin County, Ohio and adjacent areas

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

The 2021 Karst Annual Report describes the 2020–2021 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 2021 (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. A stream disappearing into a sinkhole near the contact of the Olentangy Shale and the Delaware Limestone, Delaware 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, see 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.

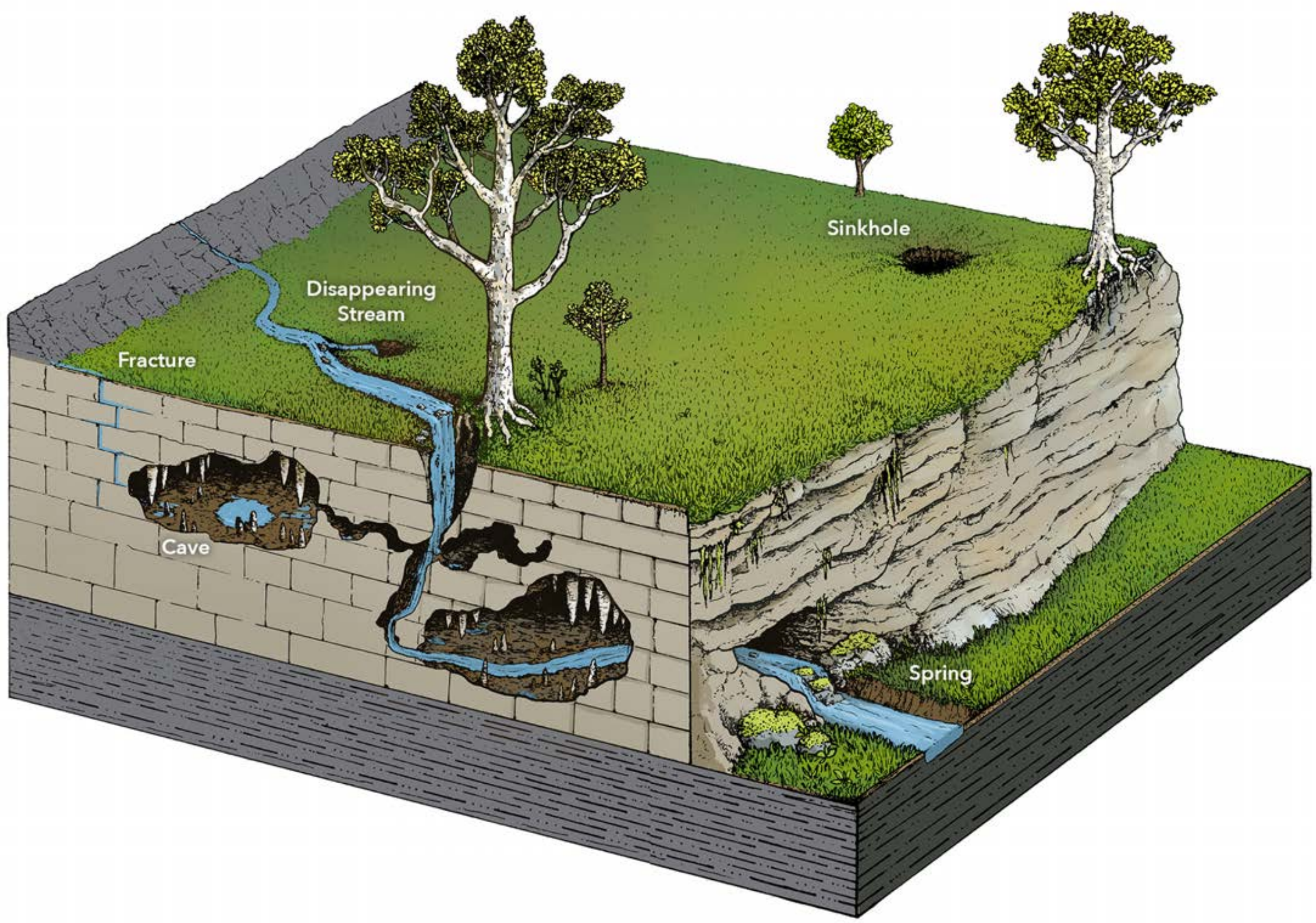

FIGURE 2. Block diagram showing the relationships between karst features. Illustration by Madison Perry.

FIGURE 3. Currently inactive sinkhole recently altered into a retention pond holding water in Delaware County, Ohio.

FIGURE 4. Active sinkhole posing a challenge to farming in Delaware 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 (fig. 6), 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. 7), 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 fractures in Delaware Limestone in Franklin County, Ohio. Inset image shows a silicified rugose coral fossil within one of the fractures that is more resistant to chemical weathering. These solutionally enlarged pathways within the limestone enable greater surface-to-groundwater connectivity and may allow groundwater to be contaminated by surface pollution.

FIGURE 6. Trash-filled sinkhole in Delaware County, Ohio.

FIGURE 7. Large, active sinkhole with exposed bedrock in the drain; located in a new residential area under development as of 2021 in Delaware County, Ohio.

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 Distance and Ranging)-derived Digital Elevation Model (DEM; OGRIP, 2006–2008 and OGRIP, 2015) 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, 2012–2020) to determine the likelihood of sinkholes in an area. Human-made structures, such as culverts, old foundations (fig. 8), ponds, or anything that can be misidentified 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.

FIGURE 8. An abandoned house foundation in Franklin County, Ohio. This location, determined to be unrelated to karst during field work, was originally identified during DEM processing.

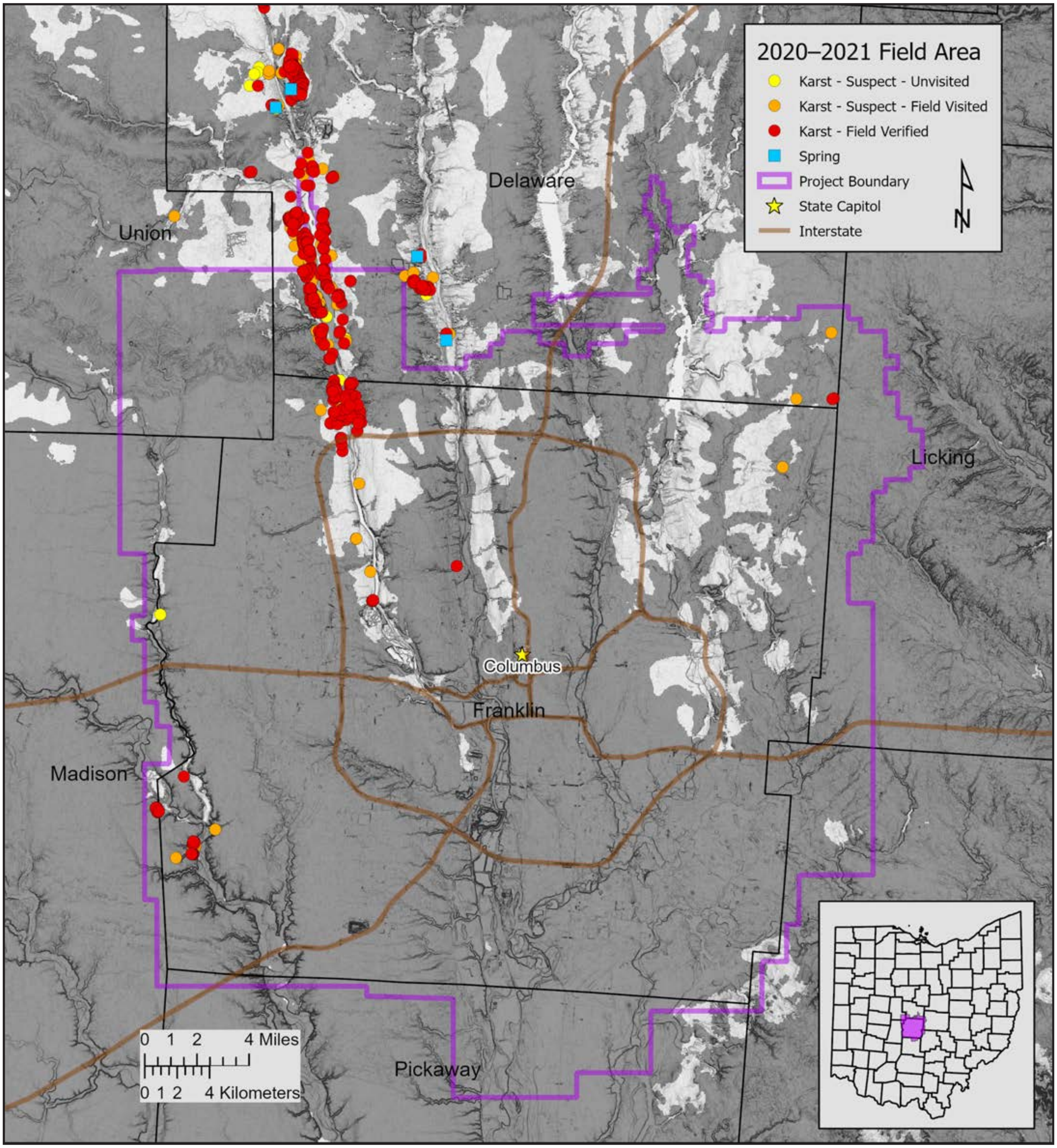

FIGURE 9. Map depicting the 2020–2021 study area (purple outline) in central Ohio where new 2015 LiDAR data was used. Dark gray areas (majority) are covered by more than 25 ft of glacial material at the surface and light gray areas are covered by less than 25 ft of glacial material at the surface. Note that the karst points are found almost exclusively in the light gray areas where the glacial material is thin.

KARST 2020–2021 STUDY AREA

During the 2020–2021 field season, the karst mapping project area included Franklin and southwestern portions of Delaware County (fig. 9) and preliminary work in other counties (see next section). The motive for this mapping was to determine the extent of karst in a region which is residentially developing faster than any other area in Ohio.

Parts of Delaware and northern Franklin Counties were also mapped ten years ago (Aden and others, 2011), but new higher-resolution DEM data and improved processing methods have led to the discovery of additional sinkholes in this area. In addition, some previously mapped areas were updated outside of the purple boundary in southwestern Delaware County along the Scioto River and north of Olentangy Indian Caverns (located in the southwestern corner of Delaware County near the project boundary in figure 9) to better understand how some of these features are changing. There is also new LiDAR data (fig. 9 purple boundary) that was processed into a very high-resolution 1-ft-(0.3 m-) per-pixel bare-earth DEM—the highest resolution ever used in Ohio for locating sinkholes (see fig. 10 for a comparison). It is also interesting to note that large swaths of this mapping area do not have surficial karst because of thick, competent glacial till deposits and shale bedrock. However, there is significant subsurface karst in the buried limestone in known locations such as the voids encountered while drilling geothermal wells at The Ohio State University (Bair, 2018) and while workers were tunneling the deep sewage bypass system on the south side of Columbus (Spiteri and others, 2014).

DEM analysis of this region identified 394 new potential karst points. After field work, which is crucial for confirming potential karst points, adding newly located sinkholes, recording changes over time (fig. 10 and 11), and measuring the depths of features, 214 total karst points had been located (table 1), making a total of 668 identified in the Delaware and Franklin County karst area. Approximately 18% of the 214 new karst features were discovered during this season's field mapping, even though they were not captured on the DEM (i.e., fig. 5 and 12).

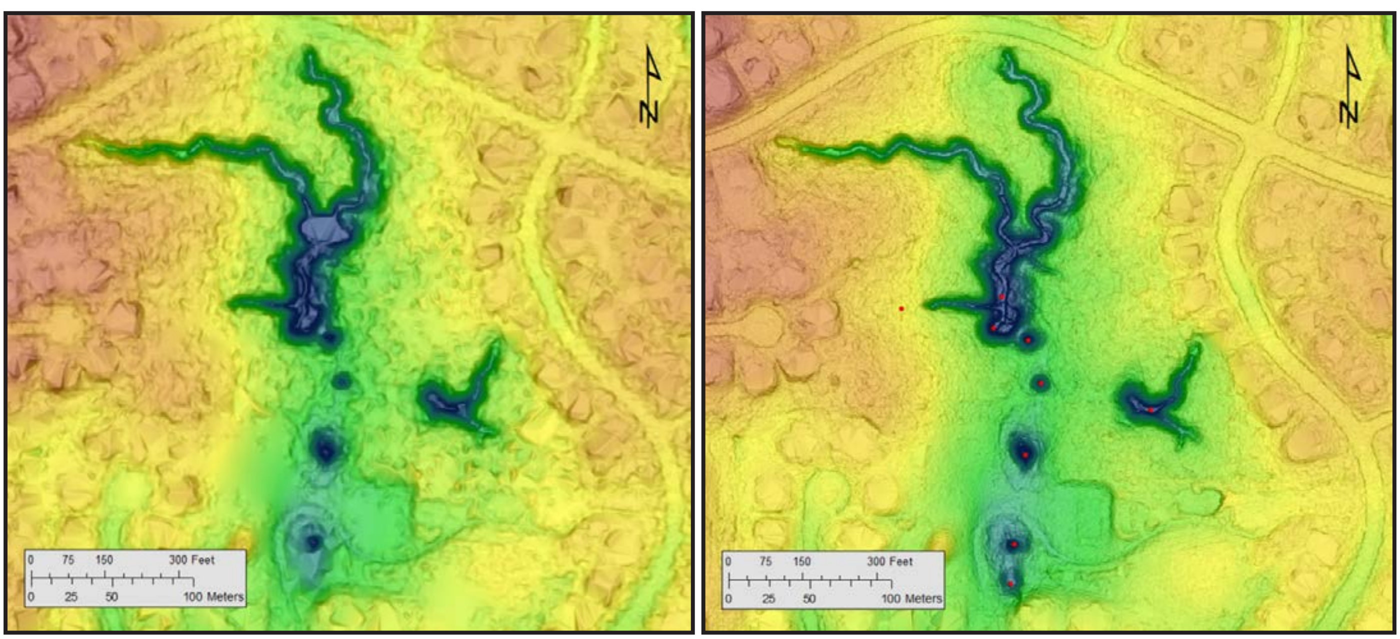

FIGURE 10. Comparison of the old (left) 2.5-ft-per-pixel DEM and the new (right) 1-ft-per-pixel DEM in Wellington Park, Franklin County, Ohio. Note the improved smoothing and the additional karst feature that is now visible (southernmost red dot). The polygonal areas all around the sinkholes are houses in close proximity to these sinkholes.

FIGURE 11. This disappearing stream in Franklin County, Ohio, has changed dramatically over the last 10 years. A: In 2011, it was a large, actively eroding pit that undercut a tree until it collapsed into the sink. B: When revisited on November 12, 2020, the sink was almost entirely filled in with sediment. However, the stream was still draining into the subsurface (yellow arrows) and was completely dry beyond this point.

FIGURE 12. Small cave near the contact of the Columbus and Delaware Limestones at an undisclosed location within the project area.

Sinkholes that were measured in the field were often significantly deeper than what remote sensing data shows—adding as much as 24 ft (7.3 m) this year and a record of 42 ft (12.8 m) in 2017. Virtually all karst features occur in the Devonian-age Columbus and Delaware limestones with a few outliers in a localized Mississippian limestone to the east. Approximately 1 in 20 sinkholes in this two-county area have exposed limestone, compared to 1 in 50 in Hamilton County and 1 in 4 in eastern Adams County.

TABLE 1. ***Summary of karst points found in the 2020–2021 field season and cumulative statewide status.***

Karst Point Type	2021 Total	Statewide Total*
Karst – Field Verified	160	7,831
Karst – Suspect – Field Visited	45	2,227
Karst – Suspect – Unvisited	8	8,414
Springs	1	494
Total Karst Points	**214**	**18,966**

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

STATEWIDE STATUS AND FUTURE WORK

Until recently it was thought that most of the known dense karst areas in Ohio had been mapped in detail, apart from Adams and Brown Counties (where field work is incomplete because of the large number of features). However, there are large swaths of Ohio with high karst potential but little information on the extent or occurrence of the karst. In fact, the significant number of karst features identified during the 2020 field season in Hamilton County highlighted the significant occurrence of karst in the Ordovician bedrock which extends to surrounding counties, such as Butler County to the north.

The complete mapping of karst areas in Hamilton County was the original goal for this field season but was postponed to another year. With fewer points to field check this season, more time was available for preliminary DEM processing of other potential karst areas. To this end, DEM processing was completed in Warren, Clermont, and Champaign Counties and is in progress for the remaining portions of Highland and Adams Counties (see fig. 13).

Preliminary work last year in Butler County indicated the likelihood of scattered features in Warren and Clermont Counties and a review of the DEM supports this observation. Brown County also has a significant number of features, especially in the east, and field work is needed to confirm these features. Much of Champaign County has thick glacial deposits that occlude subsurface karst that is likely present, but there are some potential sinkholes in a small region in the northern portion of the county.

Field mapping will continue in the 2021–2022 field season in southwestern Ohio (if health and safety guidelines allow), where additional karst features are suspected and impacts on urban development are potentially significant. Karst mapping in Champaign County and other portions of Ohio will follow in later years.

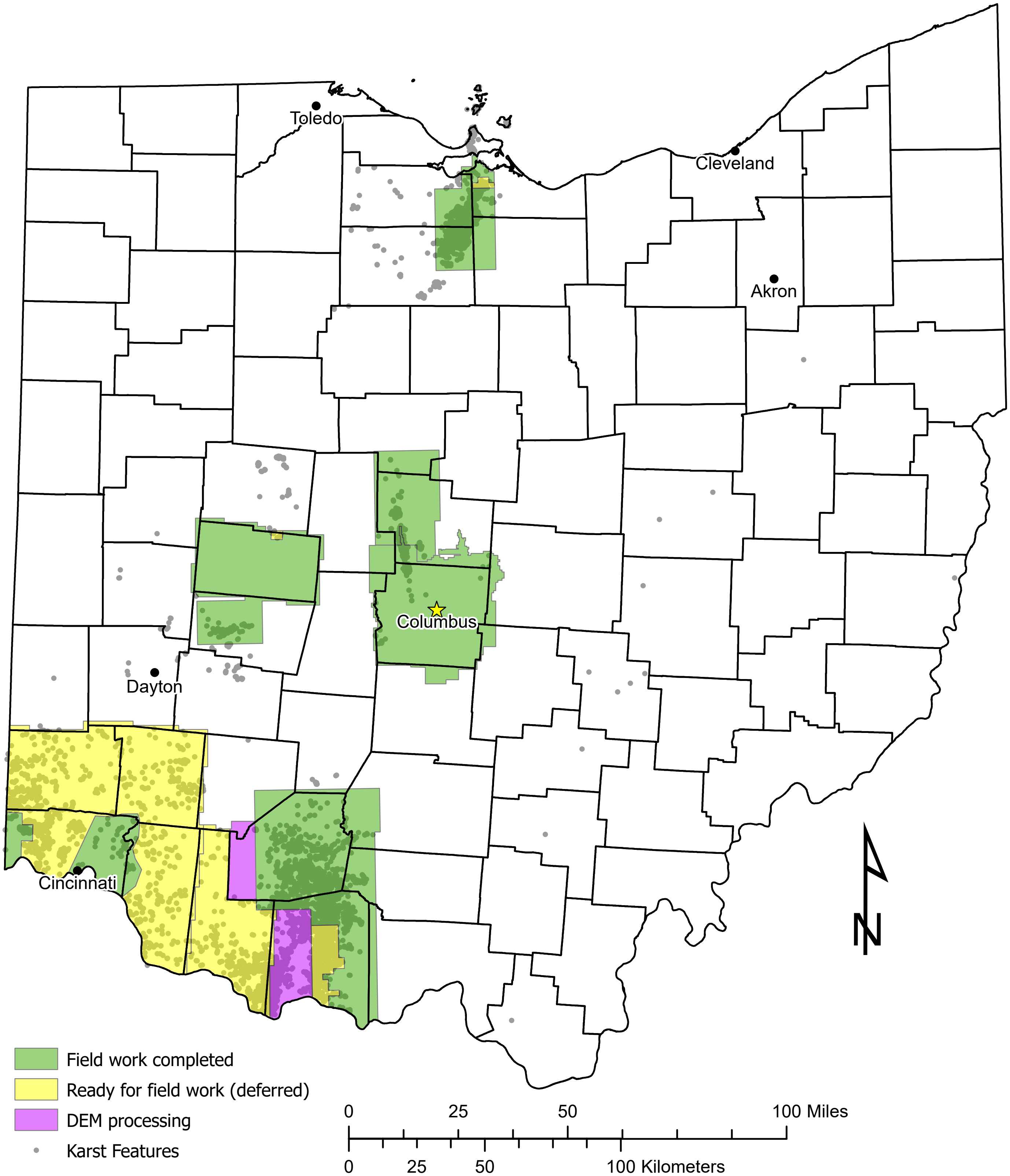

FIGURE 13. Karst mapping statewide status map. Green shading shows areas where data processing and field work are complete; yellow shading shows areas where data processing is complete and the area is ready for field work; and purple shading shows areas where data is currently being processed for potential future field work.

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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. 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.

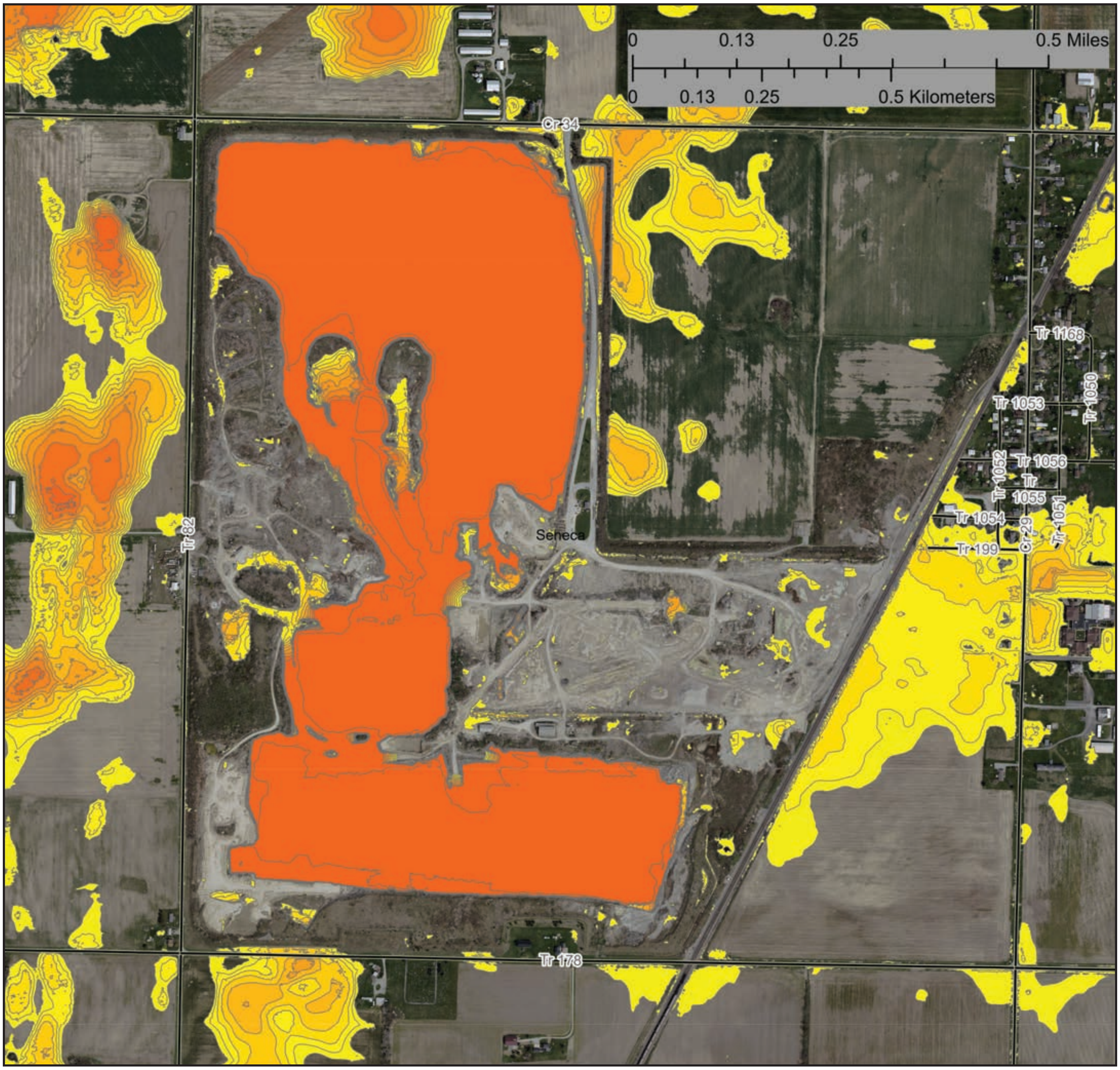

FIGURE A1-1. Polygons representing an example set of raw depressions, extracted from the DEM by completing steps 1–4 of the instructions in Appendix 1.

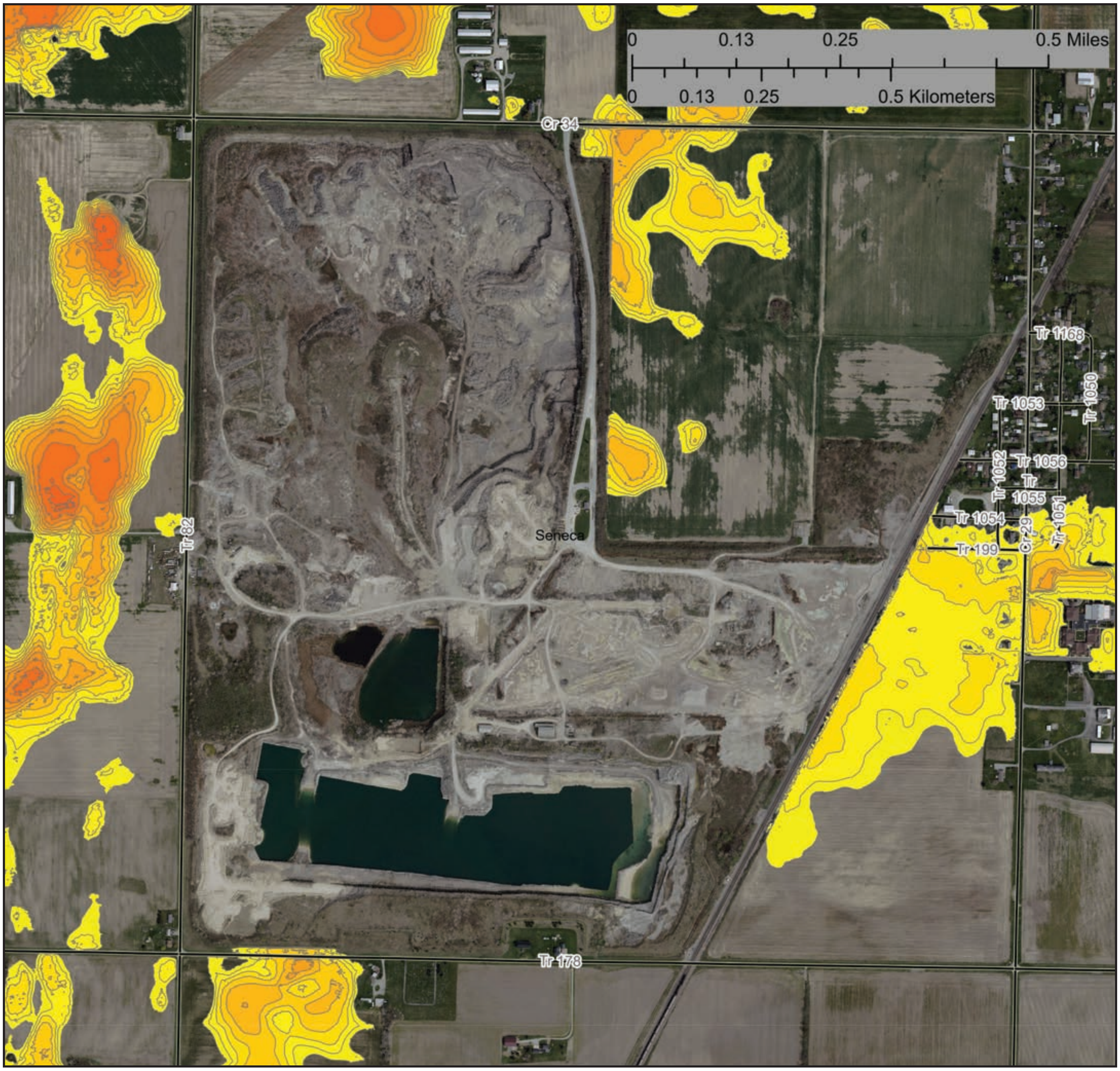

FIGURE A1-2. Numerous polygons are automatically removed during step 5 of the instructions in Appendix 1. During step 7, other non-karst–related polygons are manually removed—such as those in this quarry and along roads—until only the depressions that are likely to be sinkholes remain.

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