Mapping Florida Sinkholes using LIDAR and Field Verification

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Florida Geological Survey

Abstract

In 2012, Tropical Storm Debby dropped record-breaking amounts of rainfall across Florida, triggering the formation of hundreds of documented sinkholes within the State. The swarm of sinkhole activity resulted in tremendous damages to property, specifically in Suwannee and Hernando counties. Realizing these sinkhole hazards could exacerbate emergency situations, the Florida Division of Emergency Management (FDEM) and the Federal Emergency Management Agency (FEMA) contracted with the Florida Department of Environmental Protection's Florida Geological Survey (FDEP-FGS) to produce a map depicting which areas of the state may be more vulnerable to sinkhole formation.

The first year of the project was devoted to a pilot study in Columbia, Hamilton, and Suwannee counties, where project staff documented sinkhole occurrences and used them in the statistical modeling method Weights of Evidence (WofE). WofE generated a map yielding a 93 percent success rate for predicting areas where the geology was conducive to sinkhole formation. The two years following the pilot study have been devoted to mapping sinkholes in the remaining areas of Florida for input into the WofE model. Potential sinkholes were identified in the lab using Light Detection and Ranging (LiDAR) imagery and aerial imagery, and then validated in the field. Due to substantial increases in both volume and the types of data collected, the SINK team created a digital data form in ArcPad 10.2© for utilization in the field.

Subsidence Incident Reports Database

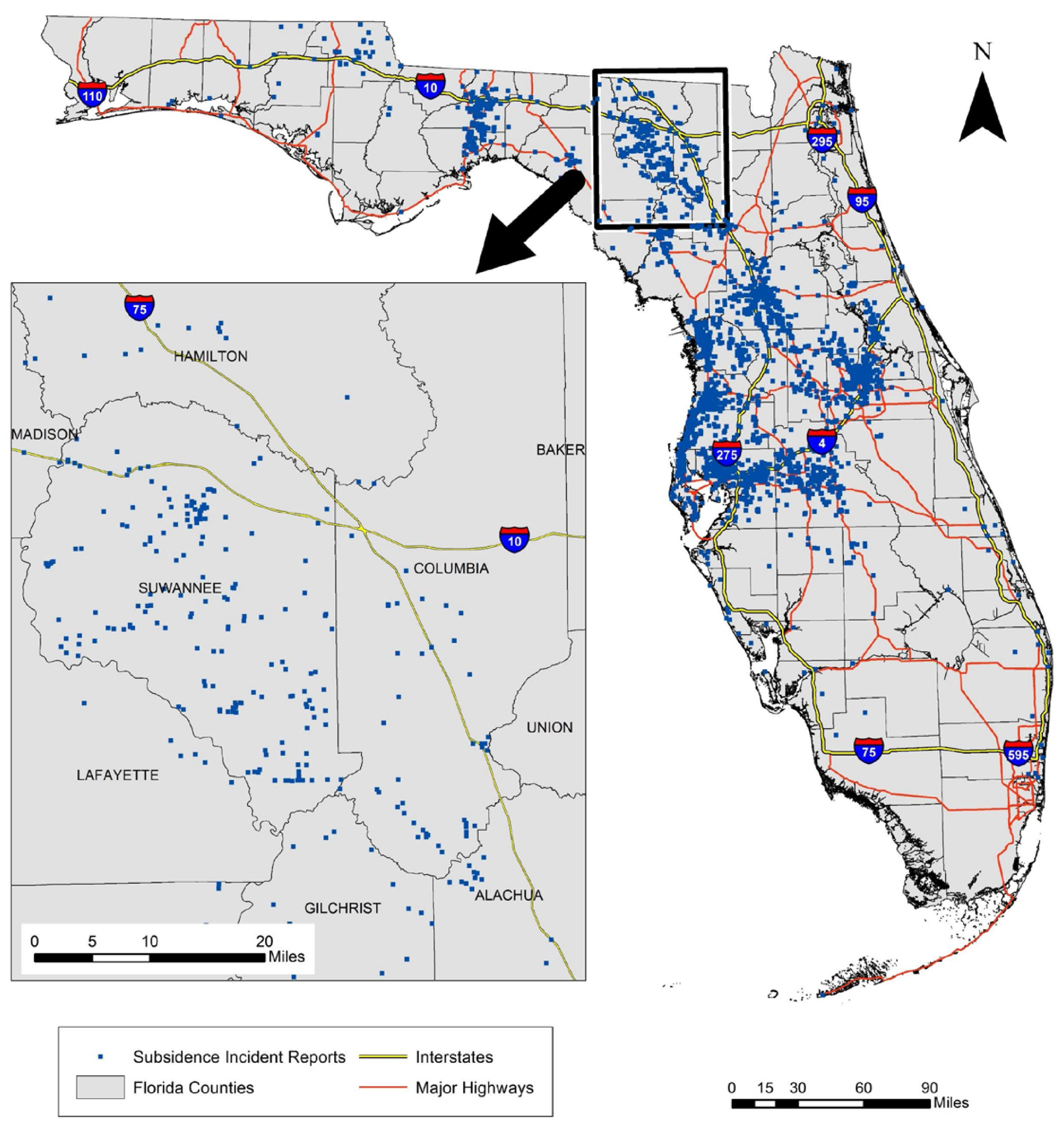


Figure 1. Map of Florida subsidence incidence reports from SIRs database.

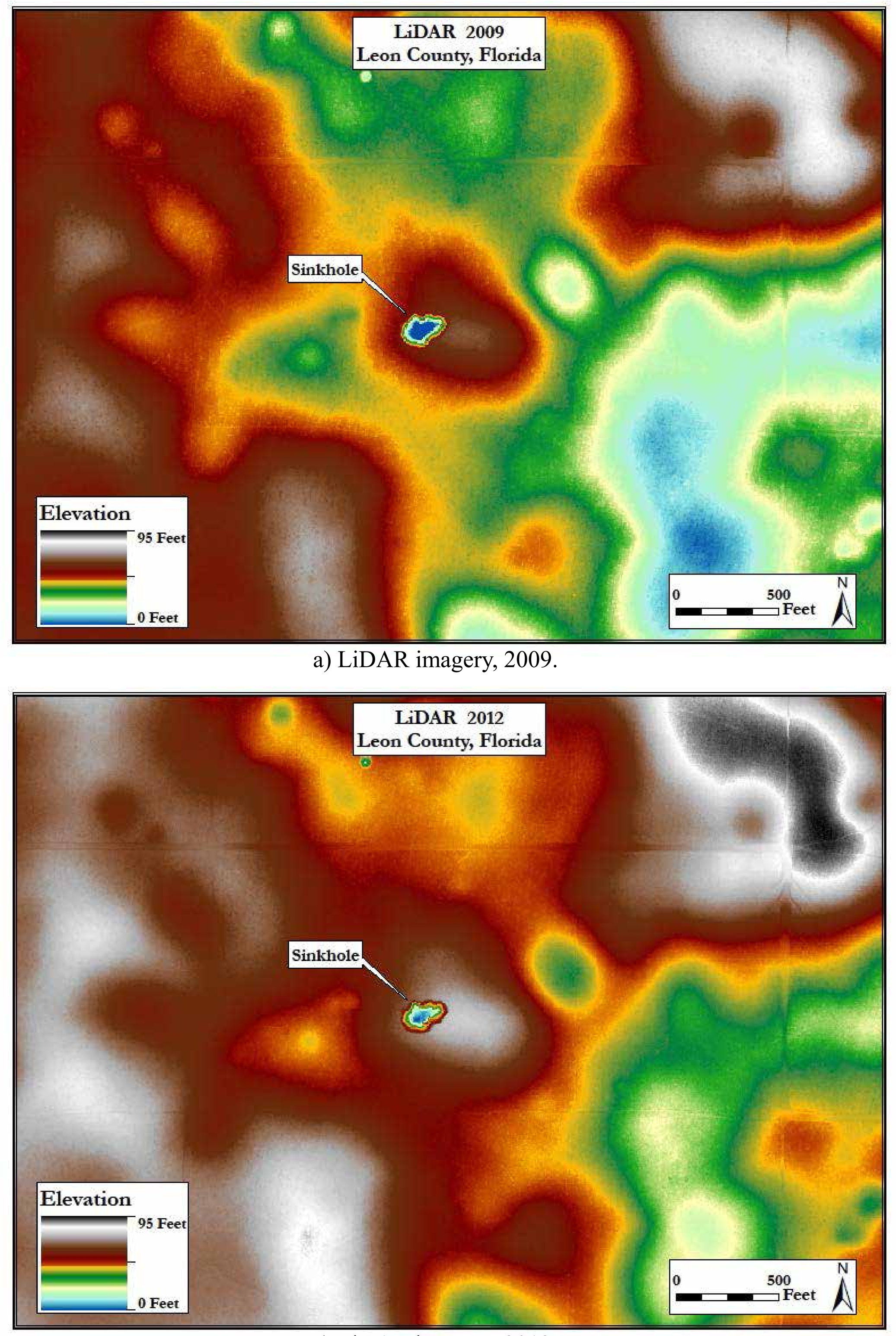
In 1982, the Florida Sinkhole Research Institute (FSRI) was created at the University of Central Florida. At that time, all of FGS's sinkhole data was transferred to the FSRI to be compiled and transferred to a computer database. Later, the Subsidence Incident Report Database (SIRs) was given back to the FGS when the Florida legislature discontinued FSRI's funding in the early 1990s (FGS, 2015).

The SIRs database contains a mix of historical data and recently reported subsidences with a date range from 1948 to 2016. Due to the large expanse in time over which this data was collected, many of the points cannot be field checked by a staff geologist to verify that the cause of the depression is in fact related to sinkhole activity. For this reason, the database is referred to as a 'subsidence' database and not a 'sinkhole' database, since a subsidence can refer to a subterranean void not related to karst.

The SIRs database was used to help check the DEM model to determine if it accurately predicts geologically vulnerable areas to sinkhole formation. This was done by verifying subsidence locations which had been documented using historical paper reports that were filled out by the FSRI, the public, or FGS staff. The reports were verified using a variety of methods that included: locating cadastral data, comparing aerial imagery, looking at hand drawn site maps, verifying latitude and longitude, and checking township, section and range to decipher location descriptions provided. Each point within SIRs is assigned a location accuracy statement that ranges from unknown accuracy, where not enough information was provided on the paper report, to a GPS accuracy, where the exact location is known with confidence.

Creation of Points of Interest using Imagery

Figure 2. Different types of elevation data and aerial imagery used to select points of interest; location in southern Leon County. Verified sinkhole location(s) indicated with text .



a) LiDAR imagery, 2009.

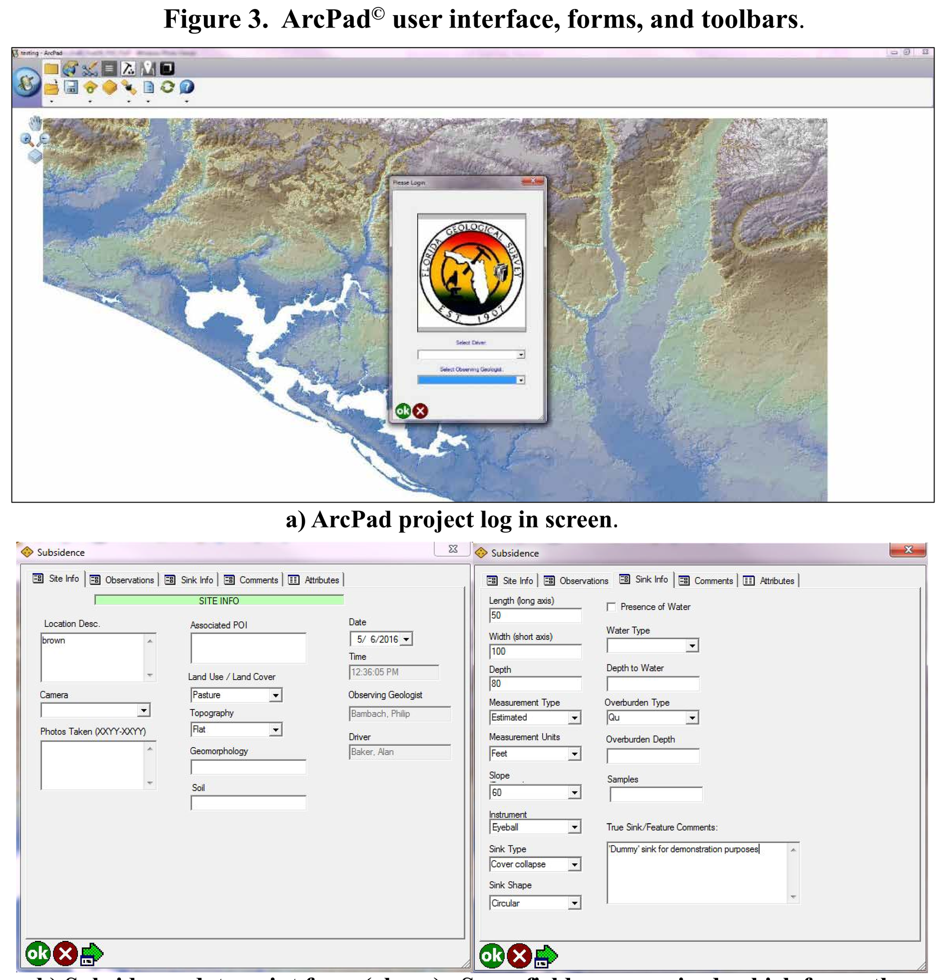
b) Digital Elevation Model (DEM), 2000.

c) LiDAR imagery, 2012.

d) Aerial imagery, 2015.

In pilot project areas, sinkholes were so prevalent and accessible that it was not necessary to predetermine potential features in the office. For the rest of the state, staff created feature classes called points of interest (POIs) and uploaded them onto field laptops for targeting sinkholes. Staff dropped POIs with a density of four per square km grid on both aerial and elevation imagery to cover the entire state without geographic bias. Whenever possible, staff dropped POIs on public land or in close proximity to public roads. Staff utilized a feature class of closed topographic depressions (CTDs) derived from a digital elevation model (DEM) to aid in selecting POIs. Existing cave and karst data, geologic maps, borehole data and SIRs data were also of use in selecting POIs.

Figure 3. ArcPad© user interface, forms, and toolbars.



a) ArcPad project log in screen.

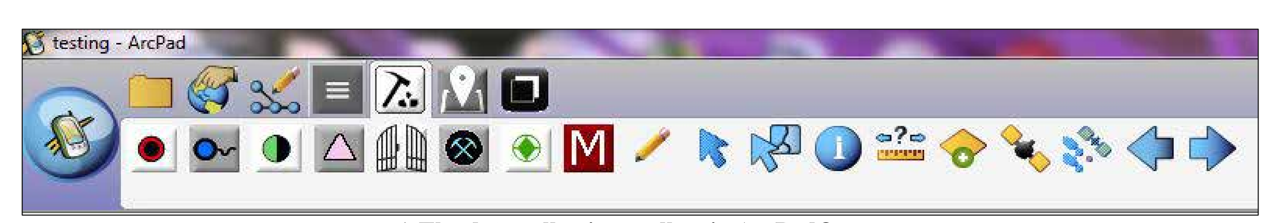
b) Subsidence data point form (above). Some fields are required, which forces the user to input a base minimum of information.

ArcPad© Data Collection

ArcPad© 10.2 was selected for use to meet this project's mobile GIS needs based on its ease of use for data collection and project customization. It was installed onto the Sink team's field laptops along with ArcGIS©. Data points were collected exclusively within the ArcPad© software.

Custom forms were created in ArcPad Studio© for the purpose of collecting and quantifying different types of data observed in the field. For staff that used the software, a login screen with user accounts was created; this enabled each data point collected to be associated with whomever was logged in during the collection period. Once the user logged in and connected ArcPad© to the GPS, they could choose between four custom menus: the 'toggle layers' menu, the 'data collection toolbar' menu, the 'quickdrops' menu, and the 'data management' menu.

The data collection menu was used to collect field observations; the user could select the type of data observed and then input more detailed information and comments into a corresponding form (Fig. 3b). The toggle layers menu allowed the user to turn imagery layers off and on within the project, and the quickdrops menu allowed users to collect points of various types when detailed information was not feasible or available for a location of interest. The data management toolbar allowed users to check on data layers being used, and to alter the visual display on raster features and background colors.



c) The data collection toolbar in ArcPad©.

Field Investigations and Model Preparation

Figure 4. Field photos and field data summaries.

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b

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d

Data Type	Subtype	#
Subsidence	Cover Collapse	115
	Cover Subsidence	176
	Rock Collapse	10
	Swallet	7
	Undetermined	313
Generic Karst	Cover Collapse	10
	Generic Depression	428
	Karstic Depression	394
	Lake (Possible Paleosink)	20
	Spring	7
	Subsidence	35
	Swallet	4
Anthropogenic	Borrow Pit	114
	Drainage Pond	267
	Quarry	25
	Sand Pit	8
	Test Pit	11
	Other	221
Access	Gate - No Access	938
	Gate - With Access	40
	Posted No Trespassing (or No Access)	1745
	Road - Does Not Exist	202
	Road - Impassable	94
	Other	10
Other	Cabbage Palm	299
	Data Quality Comment	89
	Feature of Interest - High Priority	78
	Feature of Interest - Low Priority	72
	Geologic Comment	111
	Uncategorized Comment	153
Outcrop	N/A	71
M Series	N/A	68

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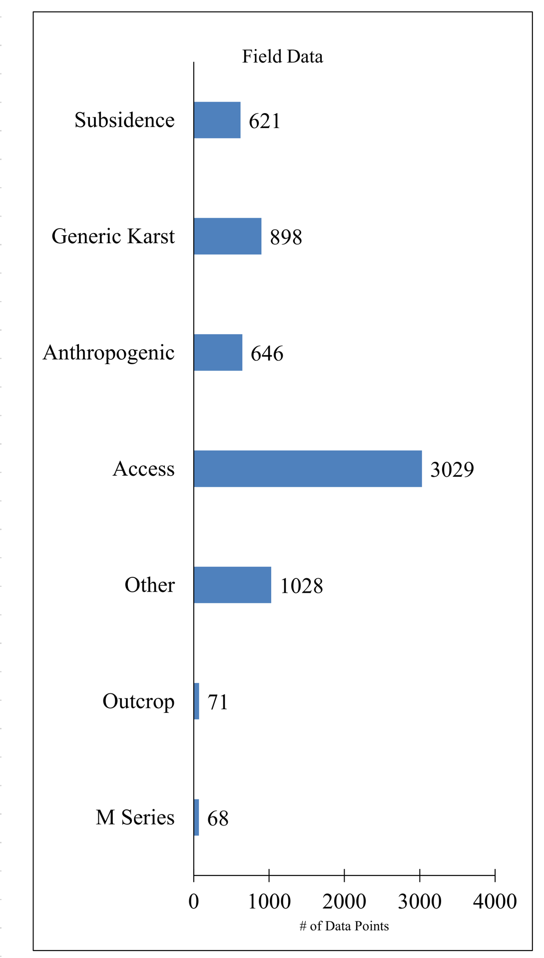

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Figures from top: a) Field crews measuring the diameter of a cover subsidence sinkhole in Manatee Springs State Park, Levy County; b) Anthropogenic point that looked like a sinkhole in LiDAR, Sarasota County; c) Cover subsidence sinkhole forming on Celosia Drive, Madison County; d) cover collapse sinkhole, Buck Lake, Leon County; e) summary table of field data subtypes; f) summary graph of field data points collected.

As of May 2016, field staff have covered an estimated 22,000 miles of roadway and visited every Florida county. At present, the SINK team is reviewing the field data before input into a Weights of Evidence Model.

Weights of Evidence measures the density of known phenomena, called "training points", within the bounds of spatial data, called "evidential themes" (Kromhout and Baker, 2015). The SINK project will use 'subsidence' points as training points and a variety of evidential themes to model which areas in the state of Florida are more or less favorable for sinkhole formation. By assigning positive and negative "weights" to each evidential theme and summing the weighted values, we will create a response grid that displays zones of high and low probability for where sinkholes may occur. The potential evidential themes for this study include: overburden type, soil type or soil pedality, overburden thickness, proximity to closed topographic depressions, subsidence incident reports, or other cave/karst data, potentiometric surface maps, soil hydraulic conductivity, and density of occupied or utilized land areas.

References

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