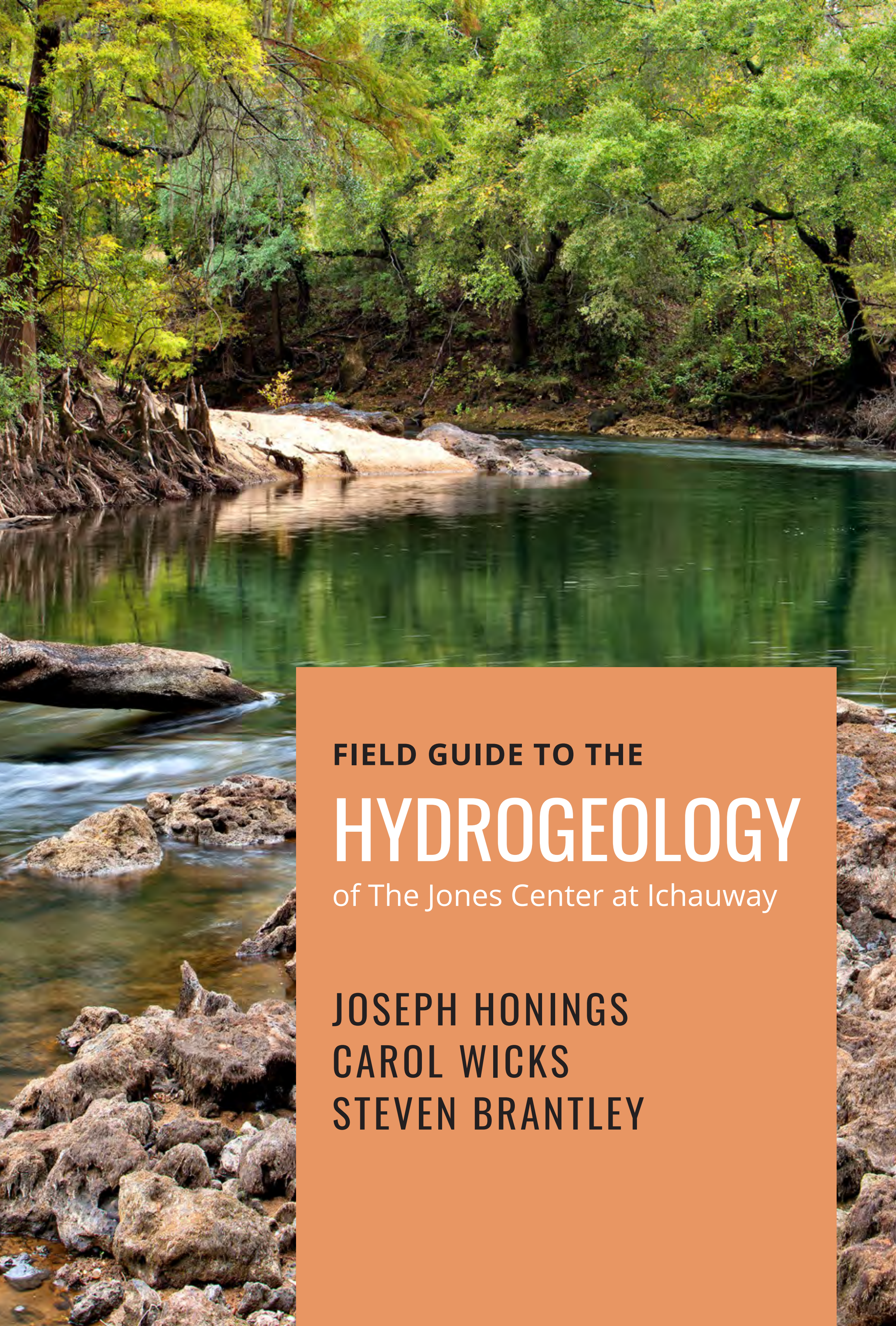

FIELD GUIDE TO THE

HYDROGEOLOGY

of The Jones Center at Ichauway

JOSEPH HONINGS
CAROL WICKS
STEVEN BRANTLEY

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JOSEPH HONINGS
CAROL WICKS

Department of Geology & Geophysics
Louisiana State University
Baton Rouge, LA 70802

STEVEN BRANTLEY

The Jones Center at Ichauway
3988 Jones Center Drive
Newton, GA 39870

Acknowledgements: Many individuals contributed to the production of this publication. We thank Dr. Honings' dissertation committee Dr. Karen Luttrell, Dr. Frank Tsai, and Dr. Eric Peterson, and Dean's Representative Dr. Y. Jun Xu for their critical input. We gratefully acknowledge internal reviews of this work by Dr. Lora Smith, Kevin McIntyre, Dr. Steve Golladay, and Dr. Kier Klepzig. We thank Jessica McCorvey for her work in formatting and producing the final publication. The Jones Center at Ichauway provided funding, housing, and research support for Dr. Honings. The LSU Department of Geology and Geophysics, Houston Energy LLP, and Chevron Corporation provided additional funding for Dr. Honing through scholarships and a teaching assistantship. Robert Ritger and Andrew Webb helped with data collection.

*Denotes key terms included in a glossary at the end of the guide

THE JONES CENTER AT ICHAUWAY

LSU

BACKGROUND

In the 1920s, Robert W. Woodruff, long-time chairman of The Coca-Cola Company, sought solitude within the longleaf pine and wiregrass of the Dougherty Plain in southwestern Georgia, and established Ichauway as his own hunting reserve (Figure 1). Woodruff was an avid outdoorsman who appreciated the aesthetics of the property as well as the game, especially the bobwhite quail. Following his death, the Robert W. Woodruff Foundation established what is now known as the Jones Center at Ichauway, an organization devoted to carrying on Woodruff's legacy of caring for people and the outdoors through natural resources research, conservation, and education.

Today, Ichauway (Figure 1b) is 29,000 acres of forests, wetlands, ecotones*, and streams, maintained as a living laboratory and working forest within a private nature preserve. In addition to its terrestrial wonders, Ichauway hosts a variety of rich aquatic habitats. Nearly 100 ponds and isolated wetlands dot the landscape. Ichawaynochaway Creek bisects the property flowing southward for 18 miles before its confluence with the Flint River. The Flint River, part of the greater Apalachicola-Chattahoochee-Flint (ACF) River Basin (Figure 1a) makes up the eastern boundary of the property for 13 miles. Ichauway and its terrestrial and aquatic habitats are home to over 1,100 vascular plant species and over 370 vertebrate species.

Ichauway now exists as an isolated island of carefully managed forests, fields, and wetlands in a sea of intensive irrigated agriculture (Figure 1b), which brings us to our current concern—water. Disputes have persisted for nearly four decades over water resources in the ACF Basin, where agricultural extraction of groundwater from the Upper Floridan Aquifer (UFA) increased exponentially starting in the 1970s, causing episodic water shortages including prolonged low-flow and no-flow durations in surface streams, with shifts from perennial to intermittent streamflow in some[1-4]. These changes have adversely impacted both natural and human systems that depend on that streamflow[5-8]. If the rate of groundwater recharge* equals the rate of groundwater extraction, then aquifer* sustainability can be ensured[9].

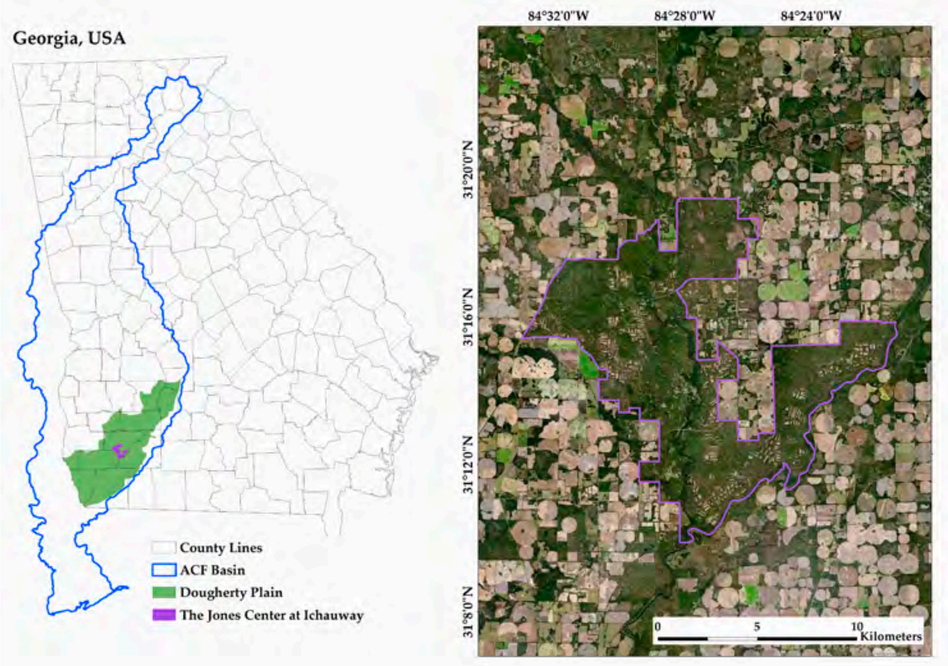

Figure 1. *a)* Georgia with locations of the ACF Basin (blue), Dougherty Plain (Green) and the Jones Center at Ichauway (Purple). *b)* The Jones Center at Ichauway (purple boundary) surrounded by the Flint River and center-pivot irrigated agricultural fields.

However, groundwater extraction in the ACF Basin is expected to increase from 3.9 million m^3/day (1,030 mgd) in 2020 to 4.3 million m^3/day (1,136 mgd) by 2050[10]. Current estimated extraction of the UFA in the Dougherty Plain is 1.7 million m^3/day, which exceeds the 0.9-1.2 million m^3/day (237-328 mgd) estimated sustainable yield range of the aquifer[10].

With the expected increase in agricultural demand and predicted changes in rainfall from climate change, there is an increased need to understand the groundwater-surface water interactions that link recharge areas to discharge areas[11-13]. Limited resources for irrigation reduction programs and water-centric forest restoration dictate that these activities be focused to maximize impacts on streamflow[14-16]. Certain areas in the landscape, for example geographically isolated wetlands* or areas with abundant sinkholes*, are thought to be locations of focused groundwater recharge to the UFA[13]. A visible clue to these subsurface features is the directional orientation of wetlands across the surface landscape. Many of the individual wetlands are located within larger wetland complexes oriented in either a NW-SE or NE-SW direction. Quantitative evidence of this pattern and its importance for predicting groundwater discharge and recent images from the National Ecological Observatory Network (NEON) aerial LiDAR* (neonscience.org) further support the existence of these large lineament* patterns[7, 17]. These lineaments run parallel to the down-gradient orientation of the UFA helping direct subsurface water towards Ichawaynochaway Creek. Validating the suspected structure of these potential subsurface flow features and embedded recharge hot spots and understanding how they connect to wetlands, streams, and groundwater is challenging. But accounting for the influence of these preferential flow paths across the broader Dougherty Plain region would improve local and regional groundwater modeling efforts. More importantly, it could help guide the implementation of restoration projects tasked with improving aquifer sustainability while minimizing impacts on the local economy around Ichauway and on the greater Dougherty Plain[14-16].

To fully understand the relationship of landscape features that impact the present flow of water, it is important to understand the evolution of the landscape over geologic time. This guide serves as an interactive, educational guide for both early-career geologists and non-geologists with some knowledge of hydrology that visit Ichauway to learn first-hand about the evolution of the geologic features that direct the flow of water. It covers fundamental geologic concepts as manifested in visible outcroppings*, sinkholes, and wetlands and relates these features to the overall karst* drainage of the Jones Center and greater Dougherty Plain. We describe key locations of hydrogeologic interest at Ichauway in which the visible geology is representative of what is common throughout the Dougherty Plain as a whole. We will describe each location and discuss how that landscape feature affects movement of water at or below the surface and its importance to the ACF watershed. The conceptualization of the overall landscape drainage pattern will help researchers at the Jones Center and their collaborators and students understand the hydrologic pathways and apply that knowledge to ongoing and future projects. We hope that these concepts also find applications in other, similar karst systems where subsurface geology influences the flow of water. A map of Ichauway with locations of the stops and a glossary of key terminology is provided in the appendix.

31°14'01.1"N, 84°28'04.2"W
(31.233645, -84.467841)

STOP
1

The Woodruff House & Historic Circle: Ichauway 100 Years and 36 Million Years in the Past

Our journey through Ichauway history begins at the Historic Circle, on the front lawn of the Woodruff House (Figure 2). Although the buildings around the Historic Circle give a glimpse of Ichauway as it may have looked one century into the past, we will venture much further back in time, between 34-56 million years ago, to a far different landscape. There are several rock outcroppings and large boulders in the front lawn and along the bluff that will take us back in time (Figure 3). A closer look at the texture of these boulders and outcroppings shows visible features such as bivalve fossils and holes where fossils have been removed (Figure 4). These shell fragments are remnants of one of Ichauway's earliest known "native species," saltwater mollusks. *What does finding a fossil of a saltwater organism within a rock in a landlocked terrain mean?* The nearest salt water is in the Gulf of Mexico, over 80 miles away from Ichauway. Preserved within these rocks are a landscape history and several important clues to the evolution of Ichauway, and the Southeastern Coastal Plain*, through time.

The bedrock formation nearest to the surface and outcropping at Ichauway is the Ocala Limestone Formation*, a 34- to 56-million-year-old rock layer, corresponding to the Eocene Epoch. Limestone is a rock comprised primarily of the mineral calcite, or calcium carbonate ($CaCO_3$). This mineral is typically formed by precipitation from solution or by organisms that utilize it for their shells or skeletal parts. The Ocala Limestone's origin is organic, specifically from reefs and other shallow marine environments.

Rock outcrops and fossilized mollusks within them are evidence that Ichauway was once part of a shallow marine landscape, specifically a marine platform that extended across what is now the southeastern United States before sea level retreated to its current position. Sea level once submerged

Figure 2. Location of Stop 1, indicated by the yellow star.

Figure 3. Example of a cherty Ocala Limestone exposure in the Historic Circle. *Photo: J Honings*

Figure 4. Example of cherty Ocala Limestone at Ichauway, with visible bivalve fossils. *Photo: J Honings*

what is now the continental United States to the extent of the Fall Line*, (Figure 5). As sea level retreated to its current position, the shoreline shifted with it, moving terrestrial depositional environments such as beaches, swamps, and river deltas seaward, and in this region southward (Figures 5 and 6). This shift facilitated the shallow burial of the former marine platform creating layers of similar rock from distinct periods (Figure 6), a process that continues today with modern rivers and swamps along the active Gulf of Mexico coastline. Over that 34-million-year period, the platform was cemented and hardened to become the Ocala Limestone we observe today in these surface exposures.

Although this type of stone is quite hard, limestone and carbonate minerals react readily with application of dilute hydrochloric acid (HCl), a concept that we will cover in more detail later. Apply a drop or two of the acid to the surface of the rock. Does it react (expect a "fizz")? Is it a violent fizz, or subdued? In the Historic Circle and nearby areas such as the skeet shooting range, the Ocala Limestone contains chert nodules, where silica in solution in seawater or groundwater precipitated within the limestone after deposition. Chert itself is more resistive to both physical and chemical weathering than calcite.

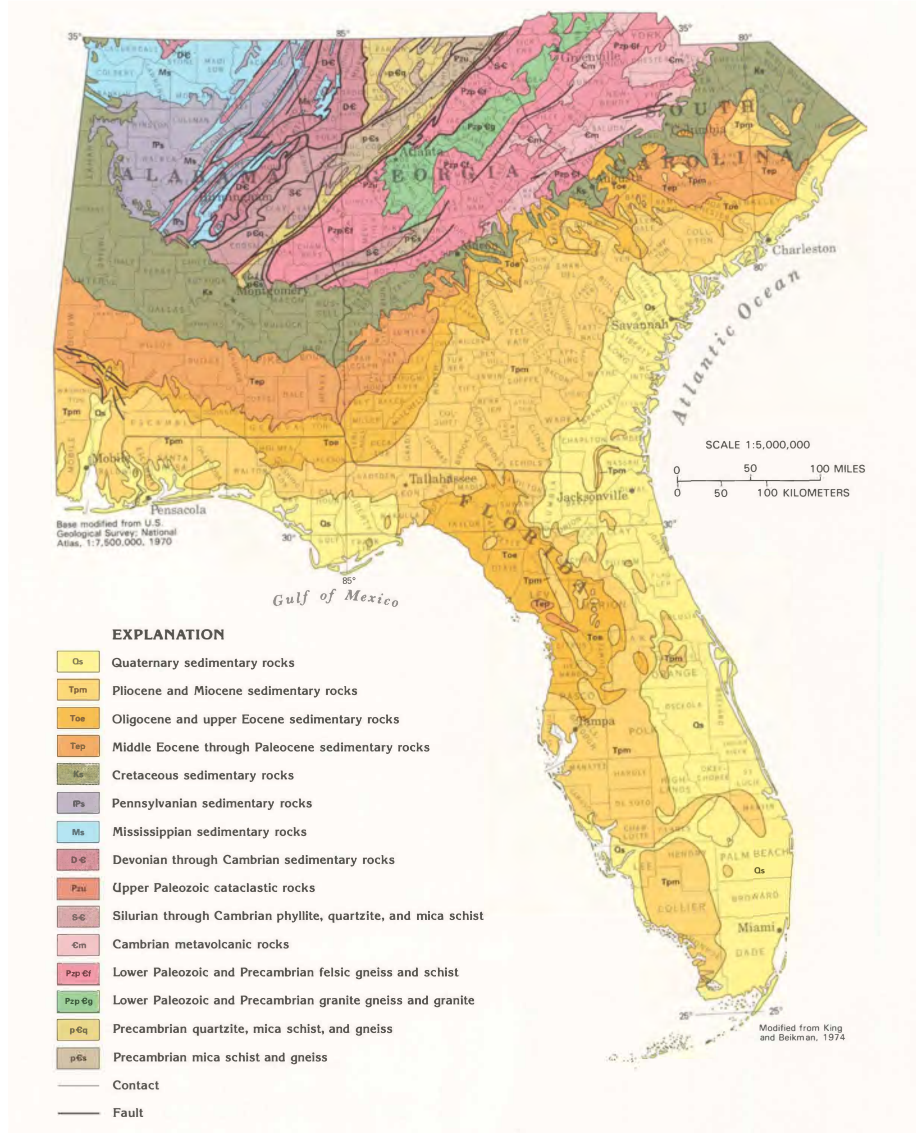

Figure 5. Simplified geologic map of the rock formations present in the Alabama-Georgia-Florida-South Carolina region. The Ocala Limestone is included in the Oligocene and upper Eocene sedimentary rocks. The other shades of yellow and orange indicate other rocks that were deposited during the Cenozoic as sea level gradually retreated to its current position since the late Cretaceous period. Coastward from the Fall Line (approximate position at the transition from pink to green), the transition from the older Cretaceous rocks (green) to the oranges and eventually yellow (Quaternary/modern) illustrates sea level regression and marine platform stands during those approximately 95 million years[18-20]. *Source: USGS Hydrologic Atlas 730-G*

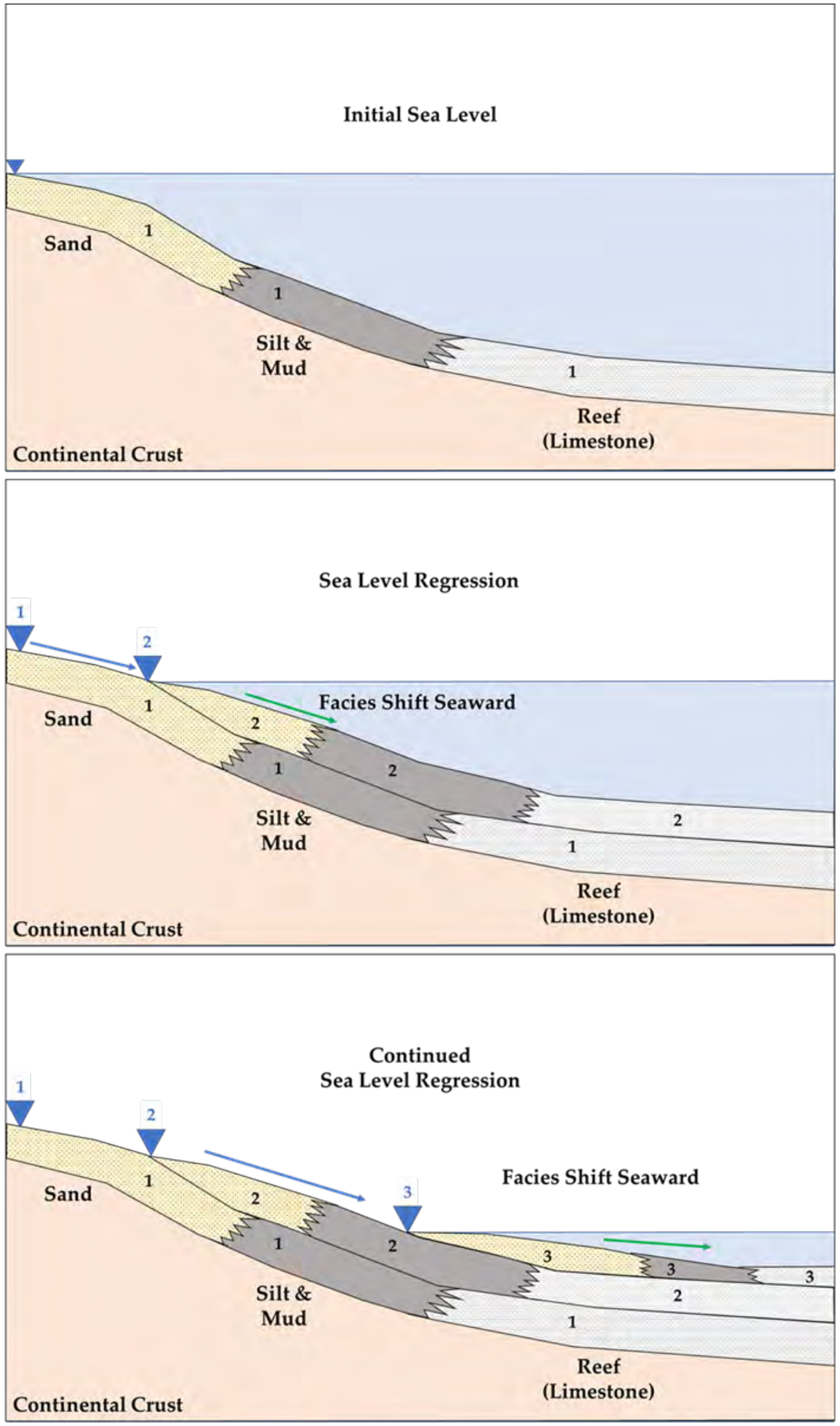

Figure 6. Conceptual depiction of Walther's Law of Facies. Depositional facies shift shoreward when sea level rises, and shift seaward when sea level falls.

These exposures of the Ocala Limestone in the Historic Circle are mostly boulder-sized and larger, and some are in-place as coherent bedrock. Where it isn't exposed as outcrop, ground-penetrating radar surveys reveal that the depth-to-bedrock of the Ocala Limestone at the Historic Circle is very shallow. The shallowness of the Ocala Limestone at Ichauway and the Dougherty Plain carries importance in the development of the Upper Floridan Aquifer within the sediments. Since these exposures are in-place, we can assume that the gently dipping formation would continue laterally until a it becomes thinner to a point in which it vanishes, known as a depositional pinch-out.

Looking to the east, toward Ichawaynochaway Creek, the Historic Circle forms a bluff that transitions into the stream valley of the creek. Ocala Limestone boulders here are scattered along the hillside and throughout the pasture. Small boulders were likely moved from cultivated fields for use in landscaping, but based on their size, we can infer that the largest boulders have not moved very far, and were likely displaced by either rapid water or collapse from stream undercutting at the paleo-position of the Ichawaynochaway Creek, which leads us to our next three stops.

31°14'58.0"N, 84°28'41.2"W
(31.249453, -84.478112)

STOP
2

The Paleo-Course of the Ichawaynochaway Creek

The route from the Historic Circle to where we now stand has traced the boundary between the uplands of Ichauway to the west and the Ichawaynochaway Creek stream valley to the east (Figure 7). Though there is not an active channel visible, the terrain contains several paleo-channels and stream meander cut-offs that once were the main channel. Looking to the east of the road reveals a winding depression that loops around a sandy mound of earth (Figures 7-9). This is a former meander of Ichawaynochaway Creek that is now disconnected from the creek, and the sandy mound is a point bar* deposit. The higher hydraulic conductivity* of sand relative to

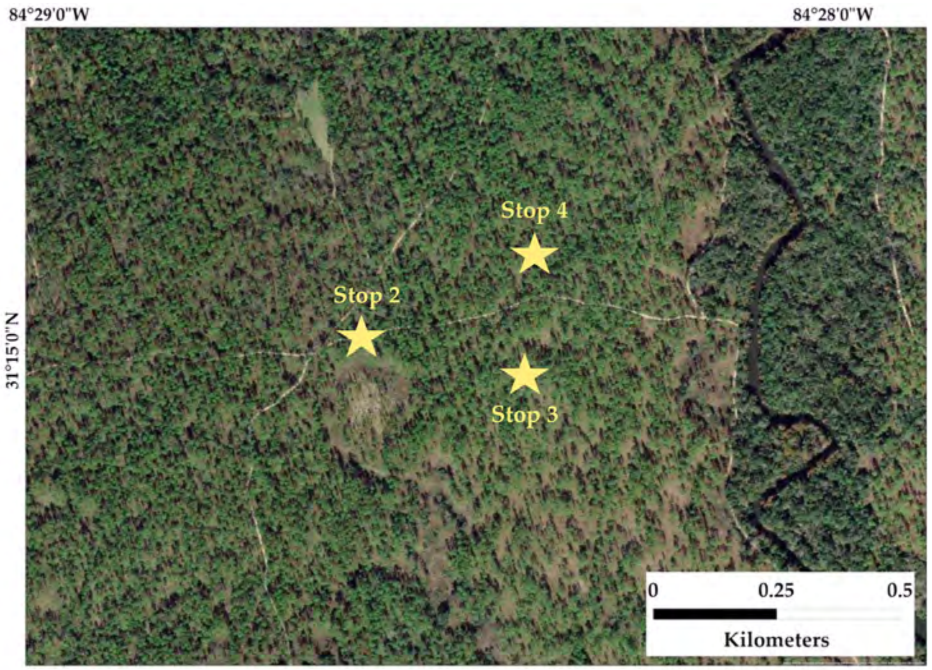

Figure 7. Approximate location of Stop 2. Stops 3 & 4 are to the east.

clay increases the vertical movement of water through the soil to the water table*. To the west, there is higher clay content in the soil, evidenced by the rusty color. Higher clay content in the upland soils reduces or slows vertical percolation* of rainwater. In high enough concentration, clay can serve as a confining layer* to the aquifer. As Ichawaynochaway Creek cut into the landscape both laterally and vertically, these clayey soils washed downstream, and sandy sediments like the ones forming the point bar were deposited within the valley. The removal of the low-permeability clay layer for sandy, permeable sediments developed a groundwater recharge hot spot within the floodplain of Ichawaynochaway Creek.

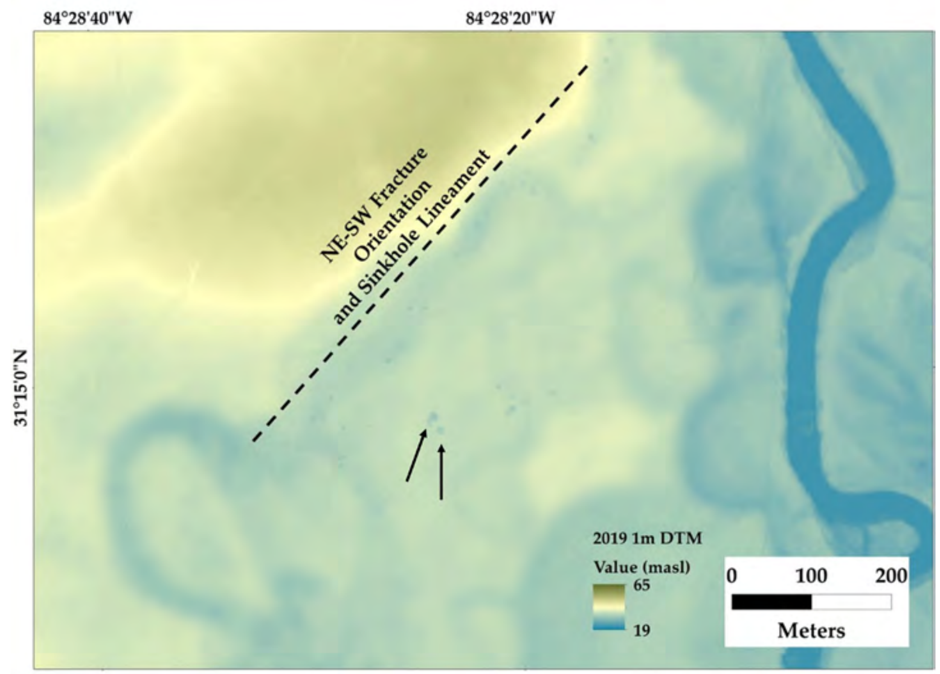

Figure 8. Zoomed view of Stops 2-4 with 1-meter resolution LiDAR Digital Terrain Model (DTM) as the basemap showing elevation in meters above sea level (masl) with Ichawaynochaway Creek on the right. A meander cutoff (paleo channel) of Ichawaynochaway Creek is clear in the southwest corner of the image. The small blue shapes in the center of the image are sinkholes (arrows highlight two larger examples), which visibly align along the prominent fracture orientation creating a draw over the sinkhole lineament (dashed line). The sinkhole cluster of Stop 3 and a similar cluster are visible to the east.

Figure 9. Looking east from the boundary of the Ichauway uplands toward the Ichawaynochaway Creek stream valley. The continuous, winding depression is the paleo-stream channel, and eastward from the depression is a series of point bar sand deposits. *Photo: J Honings*

31°14’57.7”N, 84°28’23.7”W
(31.249371, -84.473262)

STOP 3

The Sandy Sinkholes of the Turkey Woods

As at Stop 1, carbonate minerals (calcite) present in the Ocala Limestone dissolve with application of weak acid. Carbonic acid is formed when carbon dioxide from the atmosphere and soils mixes with rainwater. This solution moves vertically through the soil and reaches the water-rock interface (water table*) where speleogenesis* begins. At the landscape scale, acidic surface water and groundwater dissolve the host limestone bedrock to create cavities and enhance existing voids in the rock, developing what is referred to as karst topography. Landscapes with karst topography are dominated by solution as the key geomorphic agent. Typically, karst involves highly soluble rock, such as limestone. The limestone itself contains pore space between the sediment and fossil grains within it when it is formed. This percentage of void space within the bulk rock as a whole is referred to as primary porosity*. As the rock ages, karstic processes cause it to develop additional void space from dissolution. This is known as secondary porosity*. A pre-existing secondary porosity in the rock, such as a fracture system, will enhance speleogenesis due to exposure of more surface area.

Landforms indicative of karst terrain include dolines (sinkholes) and uvalas*, disrupted surface drainage (i.e. sinking streams), caves, and underground drainage systems. Sinkholes like the ones seen here are formed when a cavity develops in the limestone underground, and overlying sediment moves into the void causing the land surface to depress or collapse altogether (Figures 10 and 11).

Both the primary and secondary porosity within the Ocala Limestone allow the rock formation to serve as an aquifer, a rock formation that contains a sufficient porosity and permeability to transmit economically useful volumes of water[21–22]. The UFA is unconfined to semi-confined at Ichauway depending on location, meaning that the aquifer is connected to the surficial systems* in many places and can receive recharge from precipitation and losing stream reaches. In other areas, the aquifer may be capped by clay sediments. But overall, there is no regional, laterally continuous, impermeable soil or rock formation that prevents recharge to the UFA.

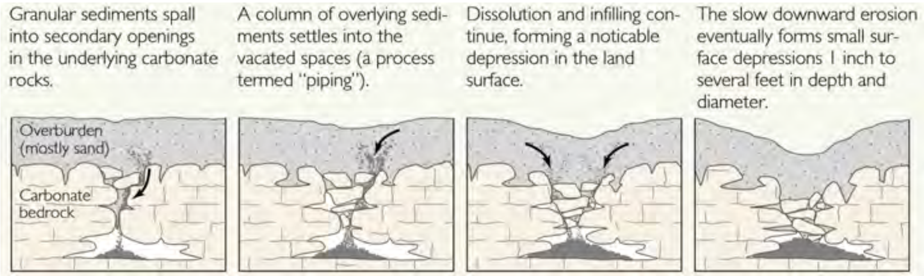

Figure 10. Generalized time-series of sinkhole formation in carbonate bedrock. *Source: United States Geological Survey (USGS). Available on the web via https://www.usgs.gov/special- topics/water-science-school/science/sinkholes*

Figure 11. View from the bottom of a large sinkhole within sandy soils of the Turkey Woods. Ground-penetrating radar equipment (yellow & black device) is included for scale.

These sinkholes are a precursor to much larger-scale features, observable at Stop 5. At both locations, these sinkholes are situated very close to each other, and as karst processes continue along the main fracture plane, these sinkholes will eventually coalesce into a much larger depression feature called a uvala (Figure 12).

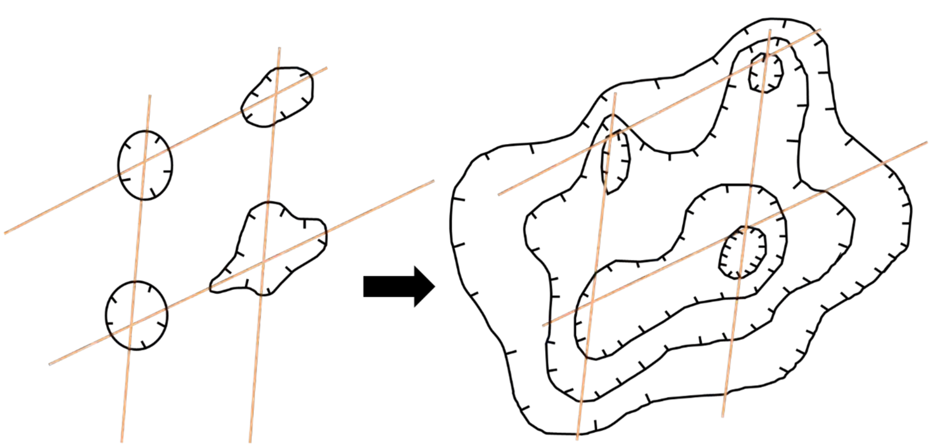

Figure 12. The evolution of compound sinkholes (left) into a uvala (right), through enhanced dissolution along pre-existing fracture planes (orange lines)[22].

31°15’05.2”N, 84°28’22.6”W
(31.251456, -84.472930)

STOP 4 The Turkey Woods Draw

This stop is a draw that contributes drainage to Ichawaynochaway Creek (Figures 8 and 13), though more inconspicuous than the location at Stop 2. Looking to the north from the road, there is a noticeable bluff, with large boulders of Ocala Limestone. Due to their size, it is assumed that these pieces are either in-place (the much larger ones) or “float,” a term used to describe large pieces of bedrock that have been eroded and left near their original location. By observing this, we can assume that the bedrock surface is at or near the surface, covered by a thin layer of soil and vegetation.

Toward the bluff, small areas of shrubs and small trees may be noticeable in the middle of the small valley, many of which the bottoms are not visible. Carefully approaching one of these clusters of brush leads to the realization that these have been growing from the bottom of a sinkhole that is 3-6 feet deep or more. Following the valley downstream (southwest) or upstream (northeast) will lead to several more sinkholes of similar size. The orientation of this lineament of sinkholes and the paleo-stream valley itself (Figure 8) is along a major fracture pattern within the Ocala Limestone[7, 24–25]. In karst processes, secondary porosity such as the fracture system in the host limestone will further concentrate dissolution. As this process continues, it will form sinkholes just like the bare, sandy ones at the previous stop and the ones observed here.

These surficial features are important clues to determining subsurface flow. As a general rule, in karstic aquifers >90% of groundwater flow occurs within the cave or conduit systems[25]. Because these sinkholes are oriented in a linear manner that matches a known regional fracture orientation in the Ocala Limestone, we hypothesize that an enhanced fracture exists between these sinkholes, connecting them, until truncated by a feature such as the creek itself. This enhanced fracture, or zone of enhanced dissolution, would serve as a preferential subsurface flow path.

Locating sinkhole lineaments and similar features allows us to approximate the location of preferential subsurface flow paths. We have completed extensive ground-penetrating radar (GPR) surveys in this area between known sinkholes, and perpendicular to the hypothesized orientation, to visualize and characterize the flow path. Comparing the subsurface imagery from the sinkhole lineament to the rock outside the flow path reveals that there is enhanced porosity, including some suspected cavities, along the hypothesized fracture.

Figure 13. Looking south-southeast from the hill at the lineament of sinkholes, oriented northeast-southwest, within the Turkey Woods.
Photo: J Honings

31°16'16.4"N, 84°29'49.6"W
(31.271213, -84.497103)

STOP
5

Rhexia Pond (Wetland 53)

Isolated wetlands in the Dougherty Plain are particularly abundant and form when clay layers accumulate over hundreds, or even thousands, of years within sandy depressions formed by cover collapse sinkholes in the underlying limestone[27-29]. Rhexia Pond, an open marsh (Figures 14 and 15), was formed by one or more cover collapse sinkholes, just like the features examined in the Turkey Woods at Stops 3 and 4, but this depression feature is much larger and much older. Such wetlands are filled by precipitation falling into the wetland catchment, and depending on the surrounding topography, some may receive water through overland flow from adjacent wetlands during larger rain events in a fill-and-spill manner[29]. Because these wetlands are formed by underlying sinkholes, there should exist some sort of vertical piping system within the epikarst* that acts as a funnel to the subsurface[29-30]. In this example, surface-groundwater interaction is dominated by seepage from the wetland into groundwater through the clay layer, into the vertical piping system, then into the conduit system. For mature wetlands like Rhexia Pond, the seepage rate may be very slow due to the thickness of the clay layer, making wetlands like this more hydrologically isolated. Still, although these wetlands are geographically and hydrologically isolated, they provide important ecosystem services like carbon sequestration and habitat for plants and wildlife that have adaptations for both wet and dry conditions.

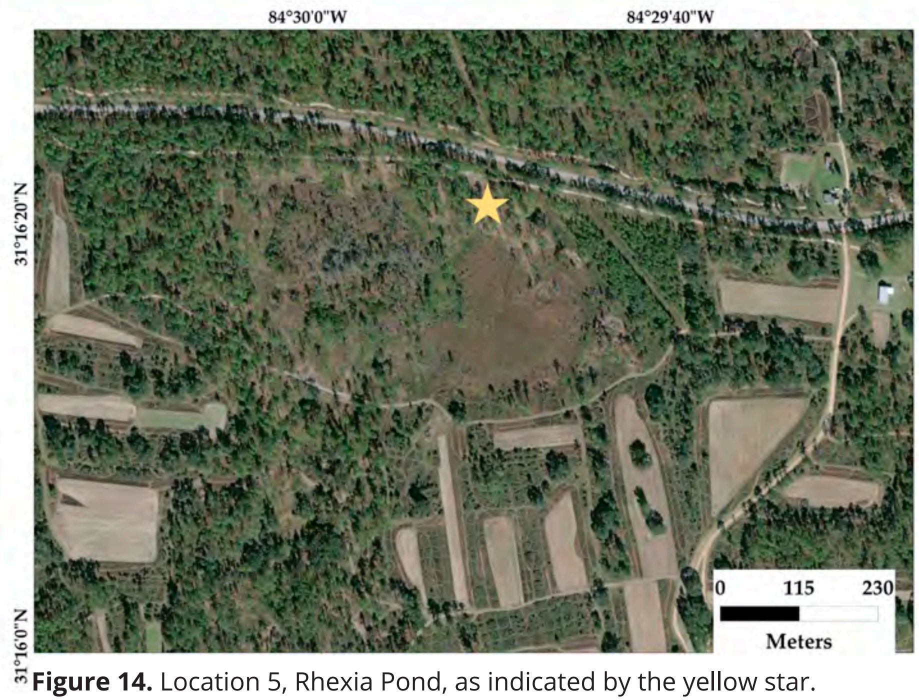

Figure 14. Location 5, Rhexia Pond, as indicated by the yellow star.

Figure 15. Rhexia Pond from the boardwalk looking toward the southwest. *Photo: S Golladay*

31°18’03.4”N, 84°26’19.2”W
(31.300930, -84.438661)

STOP 6

Balden Pond & Richardson Flat Concealed Feature

The next stop is an even larger wetland complex: Richardson Flat and Balden Pond (Figure 16). Prior to the center-pivot irrigation boom that began in the late 1970s, both Richardson Flat to the west and Balden Pond to the east may have been ponded year-round (Figure 17), or rarely dried completely. Extraction of groundwater throughout the Dougherty Plain, coupled with increased temperatures and longer growing seasons from climate change, has caused these wetlands to mostly dry up for much of the year. They now exist as grassy meadows surrounding small “gator holes*,” which may remain wet much longer than the surrounding wetland. Although surface water is intermittent at these locations, there are clues that groundwater movement occurs beneath the landscape.

As described at previous stops, there is a prominent fracture system in the limestone bedrock throughout the Dougherty Plain, with lineaments oriented northeast-southwest[7, 24-25]. When viewing the aerial image (Figure 16), the lowest points of Balden Pond and Richardson Flat align in the prevailing lineament orientation. Looking at the aerial photo (Figure 16), other shallow wetlands (visible as openings in the forest) appear to the west and to the north. At previous stops, we mentioned that development of karst is enhanced along secondary porosity features and that wetlands form by the infilling and ponding of sinkholes, which funnel water into the subsurface aquifer. As these processes continue, sinkholes will coalesce into much larger depressions called uvalas (Figure 12).

A uvala will contain a subsurface drainage system in which the sinkholes act as funnels to the groundwater. A recently completed small, gridded GPR survey in the depression (gator hole) in the southwest corner of Richardson Flat revealed the presence of a now-filled sinkhole that extends to a depth of ~20 feet below the ground surface (Figure 18).

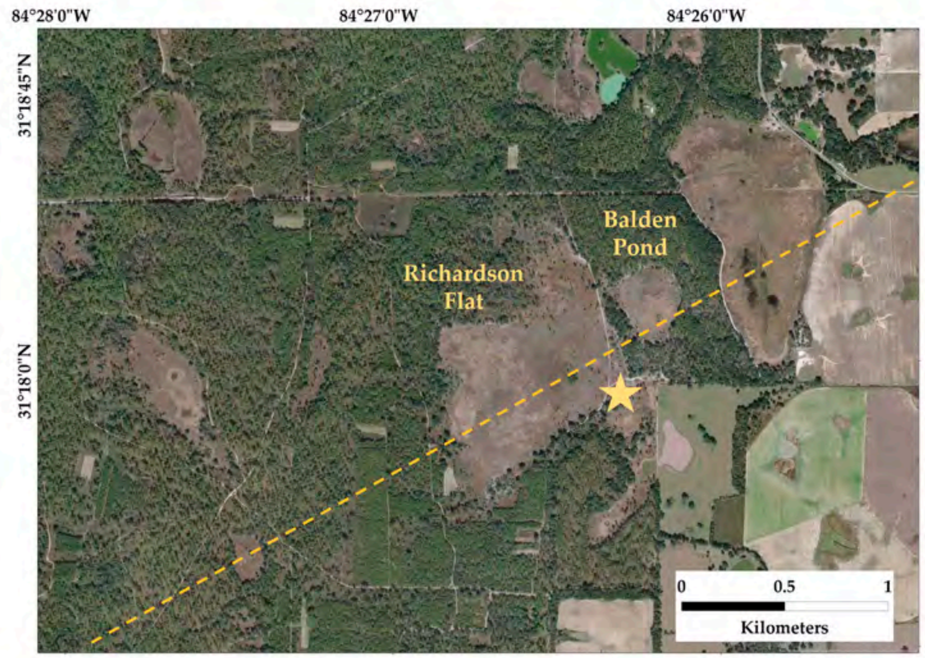

Figure 16. Location of Stop 6, indicated by the yellow star. The dashed yellow line shows the hypothesized location of the lineament.

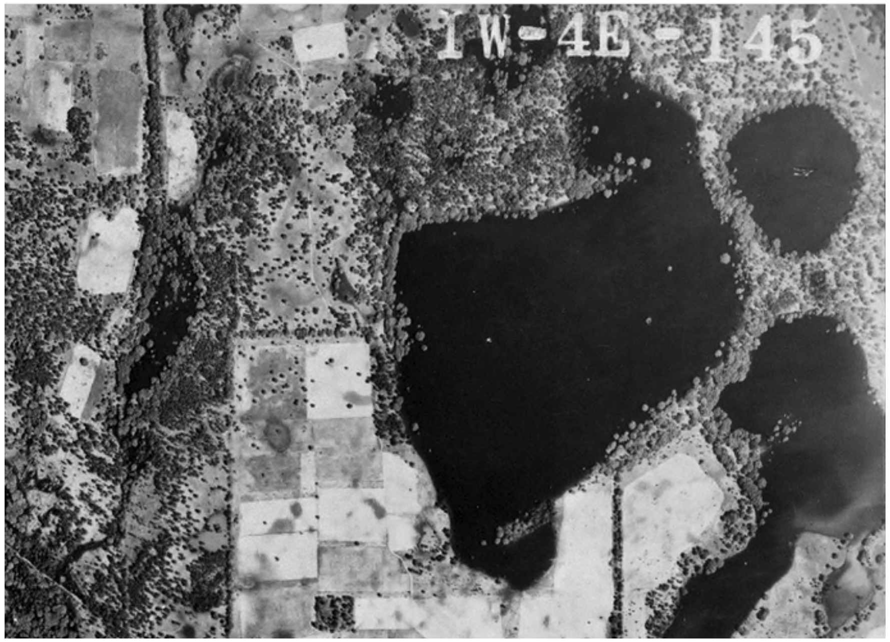

Figure 17. Richardson Flat and Balden Pond, 1948. Both ponds are fully inundated. *Source: Jones Center Archival Aerial Photography*

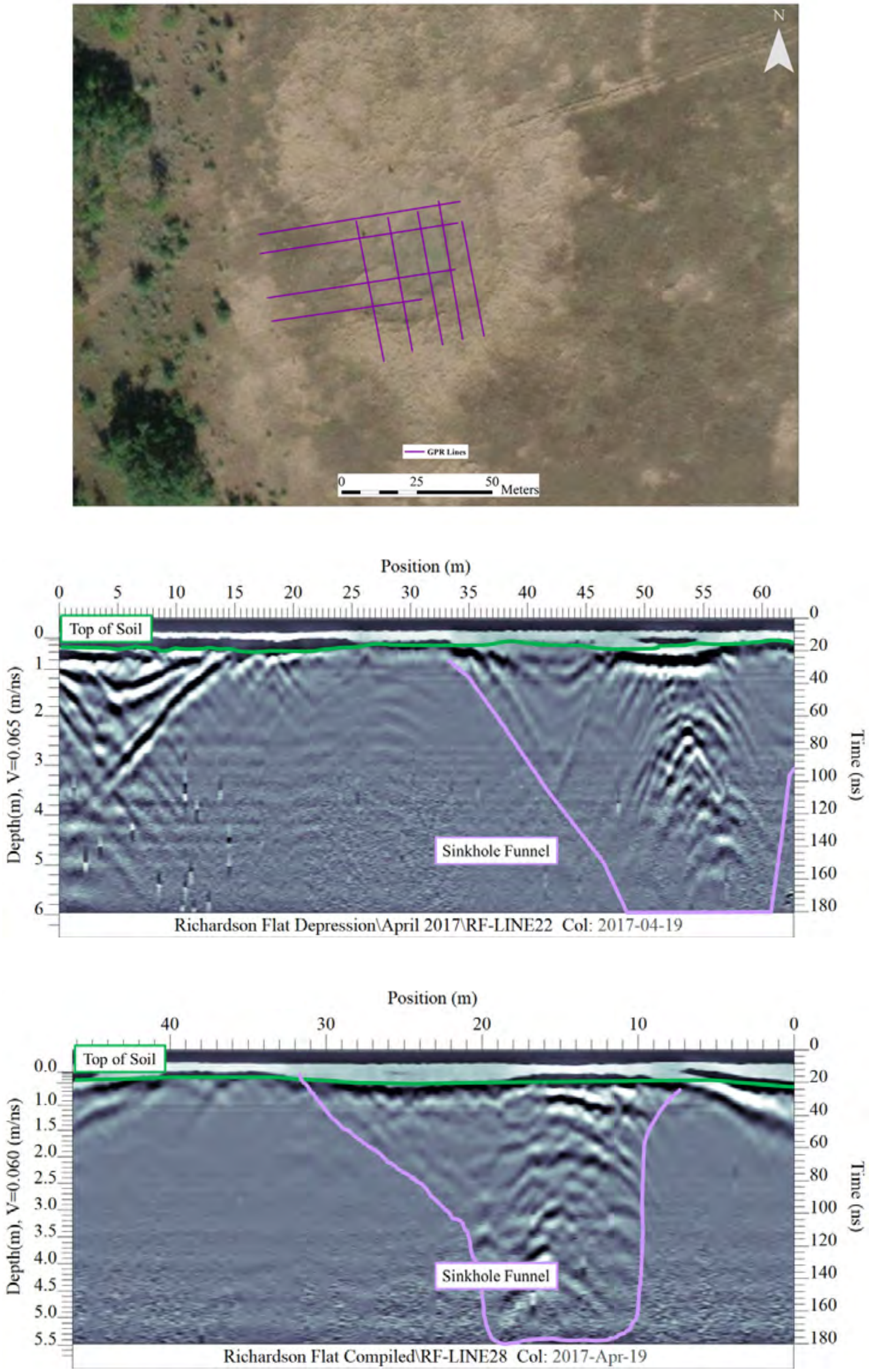

Figure 18. Select GPR images from the high-density grid over the sink point in Richardson Flat showing a high porosity zone (outlined in purple).

As in the Turkey Woods, a GPR survey was completed along the main road dividing Richardson Flat and Balden Pond, perpendicular to the documented fracture orientation. There are four zones of interest in the survey line (Figure 19) along the road. Numbered from the northern end of the survey line, zones 1, 2, 3, and 4 are approximately 60, 50, 120, and 110 m wide. Zones 1, 2, 3, and 4 have depths of approximately 3.5, 7, 5.5, and 7 m, respectively. Zones 1, 2, and 4 contain strong point reflectors* indicative of dry, high-porosity zones within the limestone. Zone 3 aligns with the lowest elevations in both Balden Pond to the east and Richardson Flat to the West (Figures 20 and 21), and point reflectors are subdued indicating the presence of water. This alignment matches the dominant fracture orientation and aligns with subsurface flow out of Balden Pond[32]. All zones identified in the cross section are karstic zones, with Zone 3 serving as the primary flow path.

The elevations of Zone 3, of the lowest point in the sinkhole in Richardson Flat, and the base level of the Ichawaynochaway Creek stream bed reveal a likely connection in the subsurface (Figure 20). Because these ponds are aligned with the orientation of fractures within the limestone, it can be inferred that a subsurface connection exists between the sequence of GIWs and Ichawaynochaway Creek. Additionally, because these karstic zones and related surficial expressions are hundreds of meters wide, this GIW sequence is on the scale of a uvala[23, 33] (Figure 21). These interpreted subsurface images provide insight on subsurface flow between the ponds and Ichawaynochaway Creek.

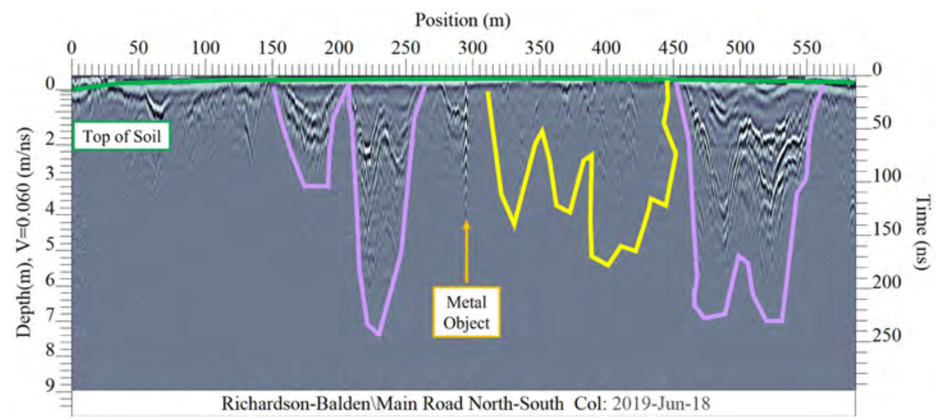

Figure 19. GPR survey along the road separating Richardson Flat and Balden Pond *(see Figure 16)*. The left side of the image is the north end of the survey. Zone 1 is located from 150 to 210 m, Zone 2 is located from 220 to 270 m, Zone 3 is 320 to 440 m, and Zone 4 is located 450 to 560 m. The green line is the top of the soil. The yellow and purple lines outline areas of reflectors indicative of high porosity indicated by weak (yellow) and strong (purple) reflectors.

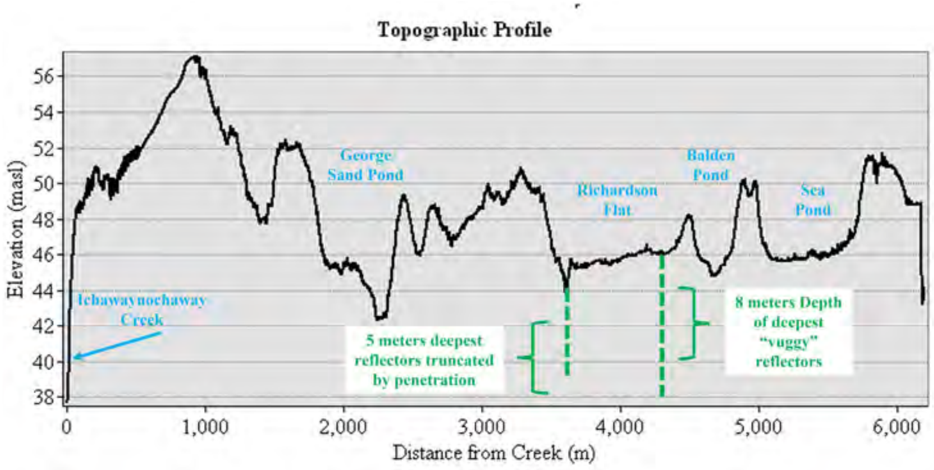

Figure 20. Topographic profile of the Sea Pond, Balden Pond, Richardson Flat, and George Sand Pond sequence toward Ichawaynochaway Creek. A consistent reflection pattern between 38 and 41 meters above mean sea level is evidence of a subsurface connection.

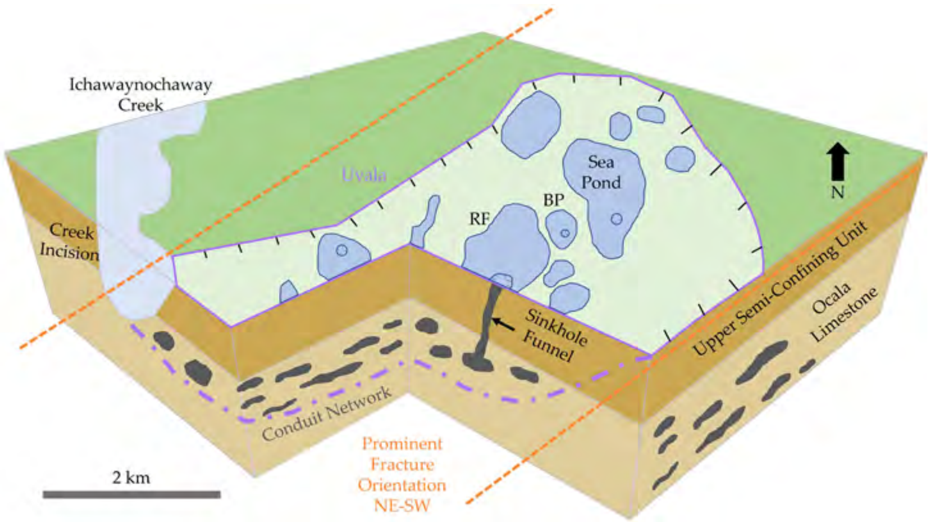

Figure 21. 3D diagram depicting the Balden Pond-Richardson Flat wetland sequence as a karst uvala. The purple line indicates the boundaries of the conceptualized uvala. The orange dashed lines are traces of the fracture system documented in the region.

The uvala represents the surface expression of the preferential subsurface flow path. As previously noted, approximately 90% of the groundwater flow is through conduits or other enlarged, continuous voids, implying that approximately 10% of the groundwater flow occurs through the primary porosity and the matrix of the Ocala Limestone. The spatial arrangement of these surface ponds and their deepest parts strongly suggest the extent of a subsurface conduit network. The application of geologic principles to the visible landscape allows the "best guess" as to the true nature of the system. However, the location and extent of a conduit is only truly known through extensive surveying or coring efforts, or mapping through one existing conduit that is physically traversable.

31°11'28.8"N, 84°28'23.7"W
(31.191340, -84.473248)

STOP
7

The Swimming Hole: The Upper Floridan Aquifer

The final stop is along the west bank of Ichawaynochaway Creek (Figure 22), near the confluence with the Flint River to the south. It is accessed by traveling east from the Crafton House, parking at the end of the path, and hiking down to the creek bank or viewing from the high ground. This side of the stream is the depositional bank, evidenced by the sandy beach. On the opposite east bank, there is a clear outcropping of the Ocala Limestone. Depending on creek stage, the outcrop forms an overhang due to a large cavity dissolved into it and the physical weathering from the creek flow itself (Figure 23).

Additionally, the Ocala Limestone has a different texture in this location as compared to locations in previous stops (Figure 24). There are several large cavities in the rock, with the rock structure often likened to Swiss cheese. These rocks represent one of the best visual examples of secondary porosity available at Ichauway.

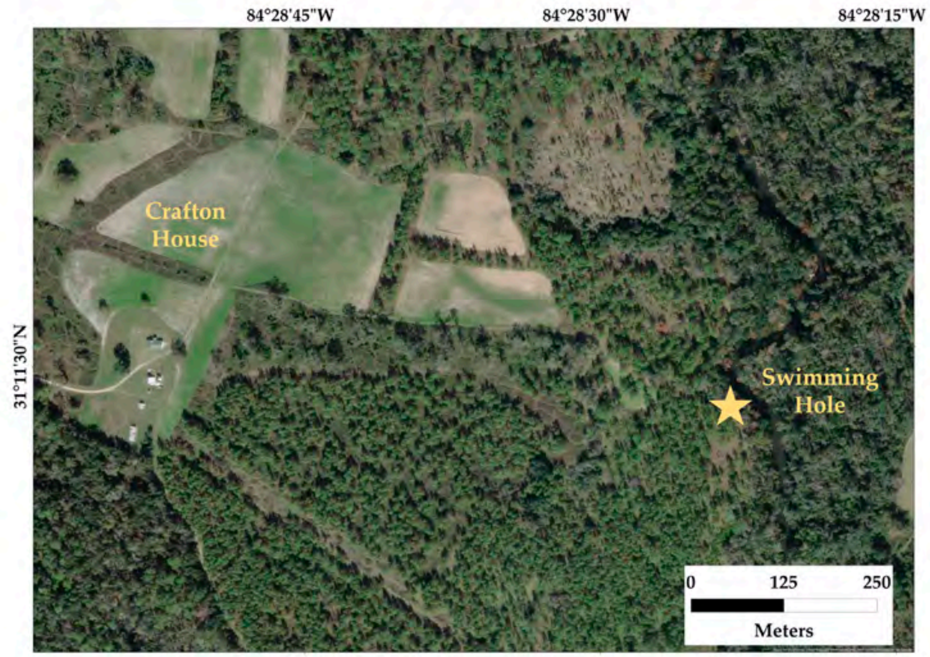

Figure 22. Approximate location of Stop 7, indicated by the yellow star.

Figure 23. Looking east from Swimming Hole bank at an Ocala Limestone outcrop that forms an overhang above the creek due to a solution cavity that continues into the bank. *Photo: S Golladay*

Figure 24. Looking west at an outcropping of the Ocala Limestone on the west bank of Ichawaynochaway Creek at the Swimming Hole. The large cavities in the rock are enlarged voids from acidic surface and groundwater. Rock hammer for scale. *Photo: J Honings*

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GLOSSARY

Aquifer: a rock formation that contains sufficient porosity and permeability to transmit economically valuable volumes of water.

Confining Layer: a body of material adjacent to an aquifer that prevents the flow of water due to its high density and/or lack of pore space.

Ecotone: a transitional area between two ecosystems along some environmental gradient, for example the area between a forest upland and wetland. They are often known for their high biodiversity.

Epikarst: a zone of highly weathered bedrock that sits atop karst bedrock and immediately under the soil.

Fall Line: the zone where coastal plain meets the piedmont or other upland.

Gator Hole: a local nickname for the lowest elevation spot or spots in isolated wetlands. These spots are often created, maintained, or enhanced by American alligators.

Geographically Isolated Wetland: a wetland with very limited or no surface water connectivity to nearby streams or rivers.

Hydraulic Conductivity: a measure of how easily water passes through a medium such as soil or rock.

Karst: a landscape type underlain by limestone bedrock and dominated by features resulting from the dissolution of rock, e.g. caves, sinkholes, and fissures.

LiDAR: Light Detection and Ranging; a remote sensing technique that uses laser pulses to measure distances.

Lineament: a linear feature in the surface of the ground that reflects some underlying geologic feature.

Ocala Limestone: a geologic formation ~35 million years old that serves as the vessel for the Upper Floridan Aquifer.

Outcrop/Outcropping: any rock formation visible at the surface.

Percolation: the passage of rainfall through the soil.

Point Bar: a deposit of soil formed on the inner side of a growing loop in a stream or river.

Point Reflectors: an underground object or feature such as a pipe, rock, or cavity, that reflects radar waves differently than the surrounding materials.

Primary Porosity: a term that describes the pore space, or voids, in rock that develop during initial rock formation, e.g. during sedimentation for sedimentary rocks.

Recharge: the replenishment of groundwater when water (e.g. rainfall) moves downward through the soil into the aquifer.

Secondary Porosity: a term that describes the pore space (or voids) in rock that develop after initial rock formation such as fracturing and channeling.

Sinkhole: a depression in the ground caused by the collapse of the surface material into an underground void.

Southeastern Coastal Plain: a region of eastern North America that extends from southern New Jersey to northeastern Mexico. It is generally characterized by relatively young sediments and low relief as it dips gradually into the Atlantic Ocean and Gulf of Mexico.

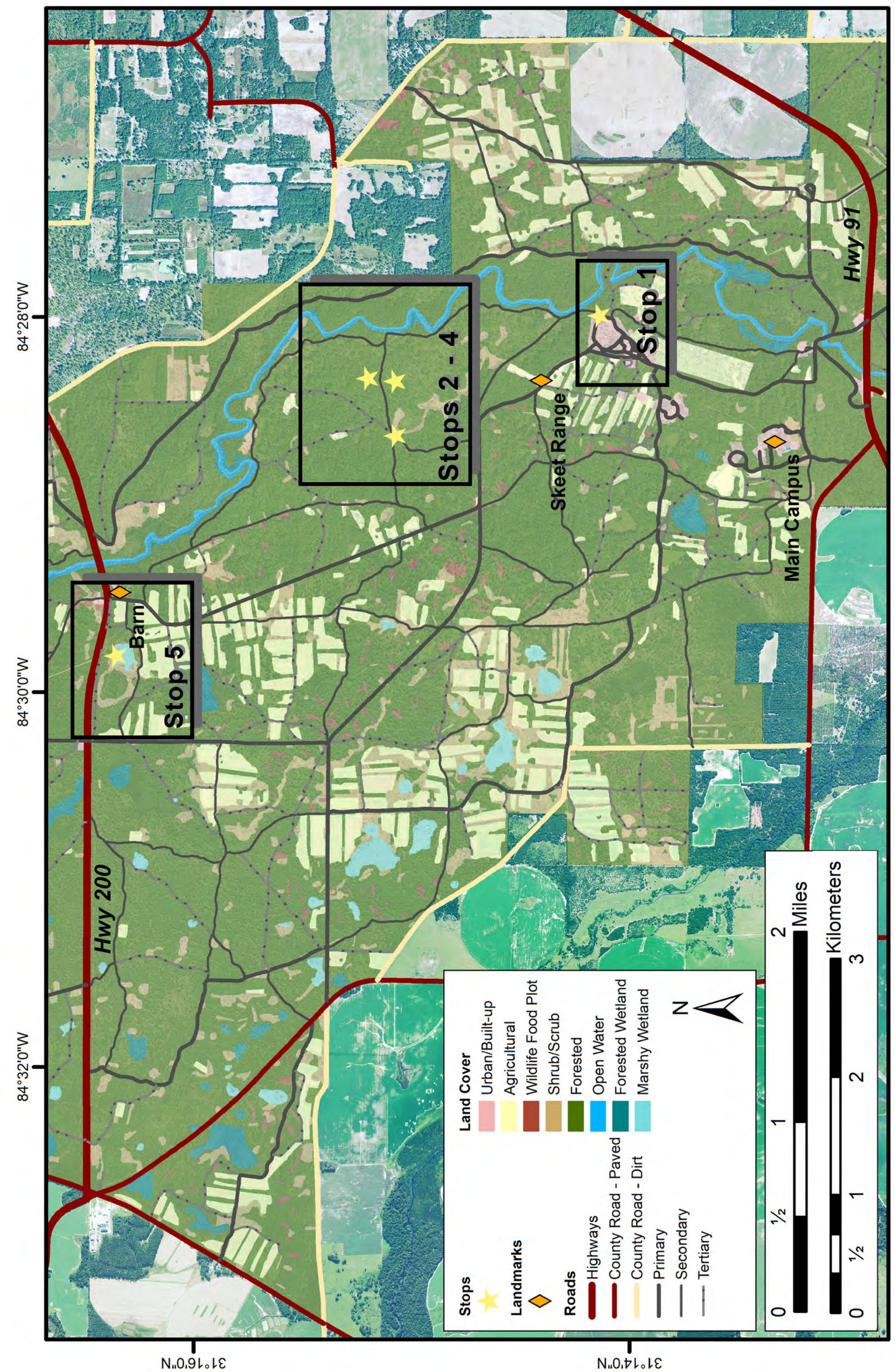
Speleogenesis: the process of dissolution of rock and formation landscape features of karst, e.g. the formation of sinkholes and caves.

Surficial Systems: water bodies that are exposed on the surface of the land including wetlands, ponds, lakes, streams, and rivers.

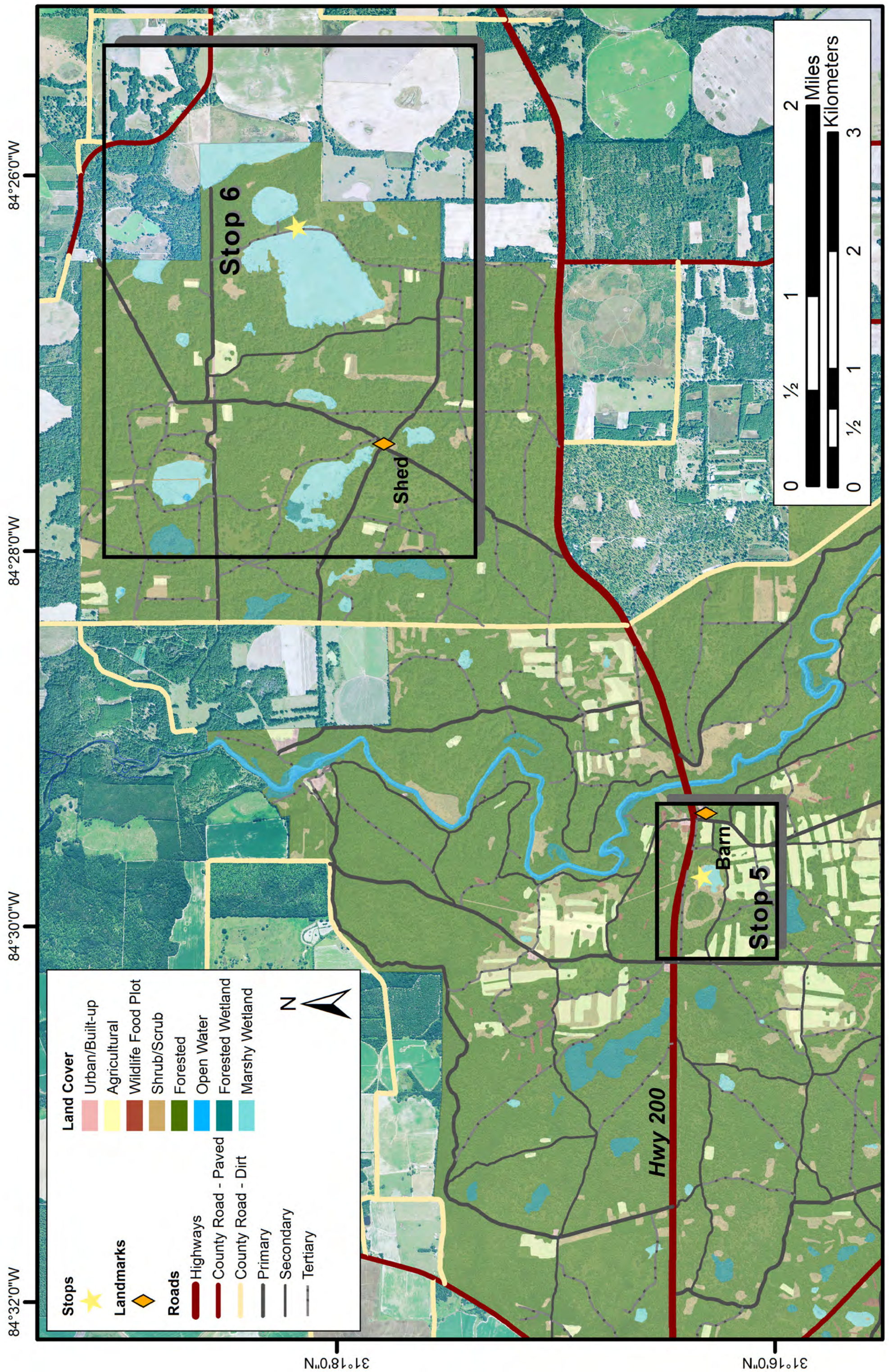
Water Table: the upper surface of saturated soil or other substrate.

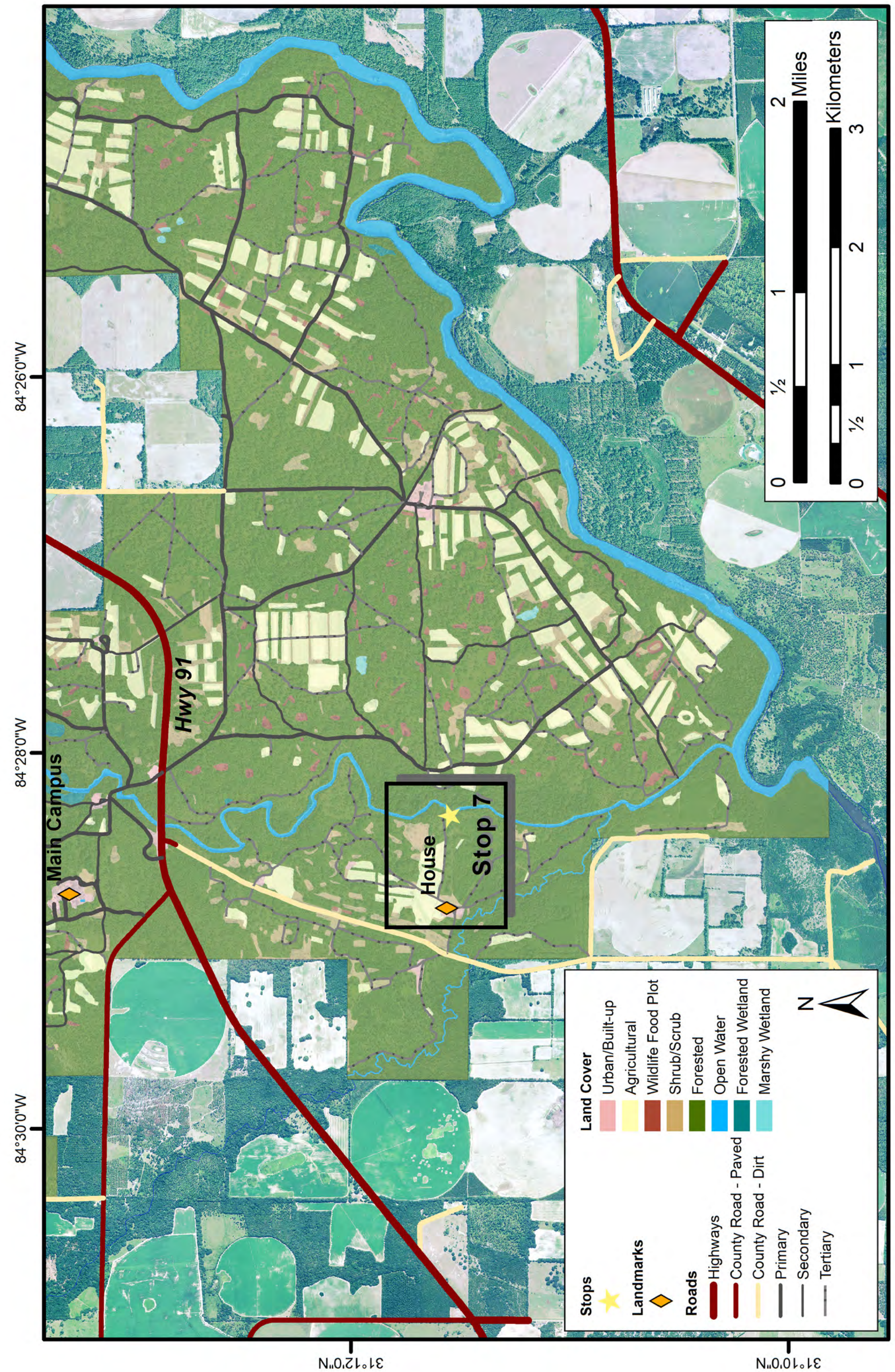
Uvala: a large depression, often linear, formed by the coalescing of a group of smaller sinkholes.

SITE MAPS



Site Maps with Stop Locations





Site Maps with Stop Locations