Technical Fact Sheet SJ2019-FS3

Elevation and Thickness of the Intermediate Aquifer or Intermediate Confining Unit in the St. Johns River Water Management District and Parts of Peninsular Florida

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Executive Summary

The St. Johns River Water Management District (SJRWMD) develops hydrogeologic surfaces based on borehole data derived from in-house drilling projects, data from other agencies, and publications. This report provides an overview of results and methods used to construct the elevation estimation of the intermediate aquifer or intermediate confining unit (ICU) within SJRWMD and adjacent parts of peninsular Florida. A master table was developed that identifies the top of the ICU for each borehole. A total of 5,021 boreholes was included for the entire project. These elevation values were used in a geostatistical analysis to calculate a surface elevation estimation in a gridded format. The process accounts for short- and long-term variations that are characteristic of the karst of Florida.

Where present, the ICU acts as a confining unit between land surface and the top of the Floridan Aquifer System (FAS). The report shows areas (primarily west and northwest) of SJRWMD where the ICU is very thin or absent and therefore provides no confinement. The thickness of the ICU ranges from 0 to 875 feet within the total area of the grid estimation. Within SJRWMD the ICU ranges from 0 to 519 feet thick.

INTRODUCTION

A hydrostratigraphic unit is composed of sediments or rocks that have similar lithologic and hydrogeologic characteristics, with each unit having distinct hydraulic conductivity characteristics that effect the potential for water supply. The primary hydrostratigraphic units that comprise the hydrogeologic framework in SJRWMD include the surficial aquifer system (SAS), the intermediate aquifer system or intermediate confining unit (ICU), and the units within the FAS. The FAS includes the Upper Floridan aquifer (UFA), the middle confining units, and the Lower Floridan aquifer. The ICU separates the SAS from the FAS and slows the flow of water between those aquifers. This publication presents the surface elevation estimation of the ICU created in 2017 (Davis and Boniol). The resulting grid is incorporated in SJRWMD's hydrogeologic mapping project and provides input to groundwater models. A single, regional mapping provides consistency between various end users throughout the extent of the grid. The location of the total grid extent, the SJRWMD boundary, and the location of data points used for the ICU grid estimations are shown in Figure 1. There is a high density of points within SJRWMD, which helps increase the certainty of the estimation. Areas within the Northwest Florida Water Management District and the Suwannee River Water Management District have significantly fewer points due to the lack of borehole data or there is no ICU present in the boreholes. More borehole data may be needed in the "white" areas to increase the certainty of the characteristics of the ICU especially in the most northern counties.

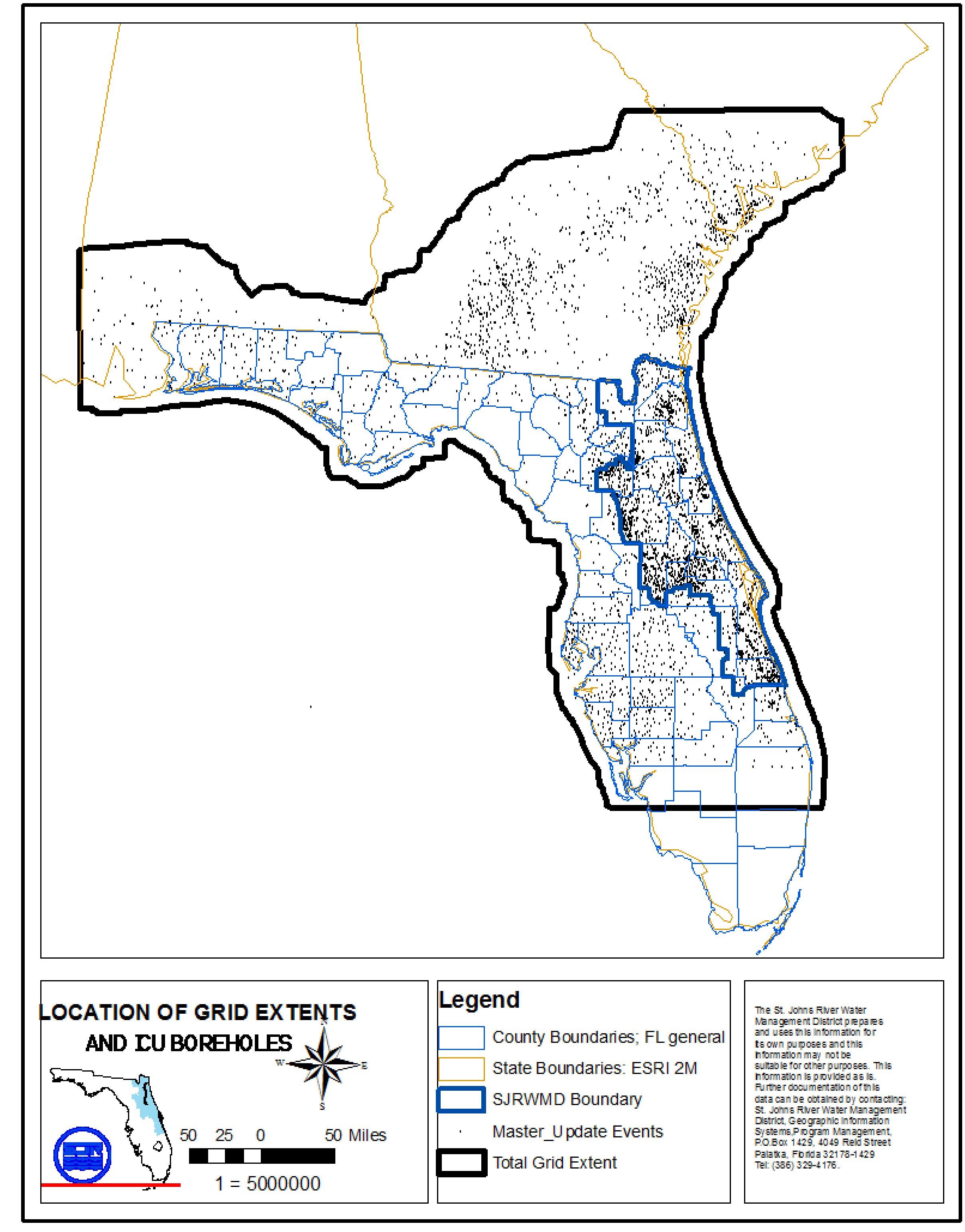

Figure 1. Location of the total extent of grid estimations, SJRWMD, and boreholes used for the ICU estimations.

BACKGROUND

The ICU was called the upper confining unit by Miller (1988) and included beds of Miocene age and locally low permeability beds of post-Miocene age. Updates in the form of a Florida Geological Survey Special Publication 28 (Revised) (Copeland and others, 2010) to the original Southeastern Geological Society SEGS ad hoc committee (1986) has labeled it the intermediate aquifer system or intermediate confining unit (IAS/ICU) and provided additional guidance for defining and identifying the unit. The name is in lower case since it has not been formalized yet. The updated Special Publication 28 provides a conceptual relationship of aquifers and confining units in the IAS/ICU (Figure 2). Since the entire interval between the base of the SAS and the top of the FAS collectively provide confinement to the FAS, this report does not differentiate between areas where there are aquifer(s) present locally within the IAS/ICU, or the unit is all confining material (ICU) as in the center panel of Figure 2. Within the district there are localized intervals within the ICU that may act as an aquifer, but these have not been regionally mapped due to poor lateral continuity.

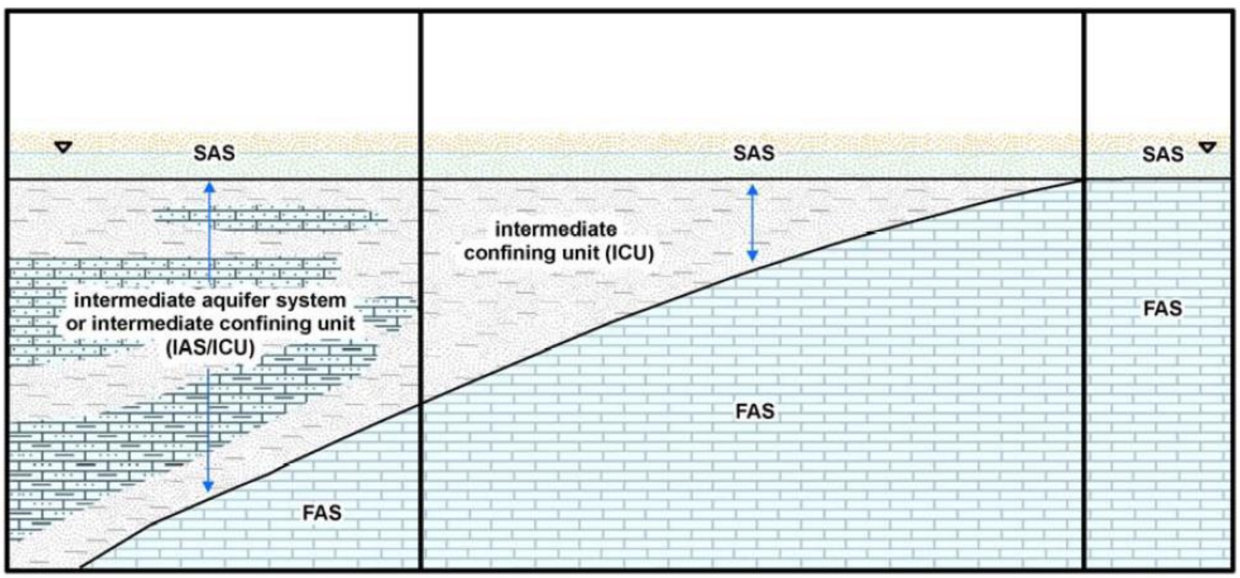

Figure 2. Generalized cross section of Florida's three uppermost aquifer systems (note that no direction is implied). (Modified from Copland and others [2010]).

The geologic structure and lithostratigraphy of peninsular Florida control the nature and distribution of the hydrostratigraphic units and have a direct influence on the storage, movement and quality of groundwater. The Hawthorn Group is the primary lithostratigraphic unit that comprises the ICU in SJRWMD (Scott, 1988, Scott, 1991) but other units in the panhandle may also be included (Copeland and others, 2010). Many previous reports have provided detailed descriptions of the lithology and occurrence of the Hawthorn Group and the reader is referred to (Scott, 1988) as a good starting point. It should be noted that the Florida Geological Survey has an active field mapping project for near surface sediments. The STATEMAP (www.dep.state.fl.us/geology/programs/statemap.htm) project is attempting to map the entire state based on 100,000 topographic quadrangle areas. This detailed mapping effort includes both borehole and outcrop data for very high-resolution mapping. Data collected from the STATEMAP project has been used in this report wherever available.

The SAS consists of the permeable siliciclastic and carbonate sediments that extend from land surface downward to the top of the ICU, or to the top of the FAS where the ICU is not present. In SJRWMD, the surficial aquifer is composed of the Holocene undifferentiated sediments and the Pliocene to Pleistocene formations (post-Hawthorn Group sediments). The shell and sand beds of the Anastasia Formation and the sands beds of the Okeechobee, Nashua, Cypresshead, and late Tamiami formations comprise the water-producing zones of the surficial aquifer.

The ICU includes the fine-grained, low permeability clastic sediments that lie between and that collectively retard the movement of water between the overlying SAS and the underlying FAS (Copeland and others, 2010). This study identifies and maps the top of this hydrostratigraphic unit as the uppermost, laterally extensive, and vertically persistent sediments of lower permeability below the SAS. The Hawthorn Group is generally used as a surrogate for the ICU if specific hydrologic data are unavailable to include additional units above or below. SJRWMD uses either 1) information interpreted from lithologic and geophysical logs that fit a regional interpretation of the unit to pick the top of the ICU, or 2) in the rare case where there is specific hydrogeologic data such as distinct water levels tied to a specific interval to identify the ICU above the top of the Hawthorn Group. The top of the Hawthorn Group may be identified at a certain elevation in a lithologic description, but a natural gamma or induction log can indicate the presence of low permeable (clay rich) material that is in direct contact above the Hawthorn Group. There are many examples of gamma log response in the Hawthorn Group (Davis and others, 2001) that demonstrate how the geophysical logs are used to identify the Hawthorn Group and therefore the ICU. The additional sediments must be traced laterally to be considered sub-regional before the interval can be included. The base of the ICU occurs at the top of the vertically persistent, permeable carbonate section that comprises the FAS.

The ICU sediments are extremely heterogeneous in lithologic and hydrologic properties, that can be variable in vertical and lateral extent. Depending on the hydraulic properties of the sediments, or their ability to store and transmit water, zones within this hydrostratigraphic unit can act as confining zones or permeable zones. At some locations, there may be a continuous section of low permeability, poorly yielding to non-water-yielding strata down to the top of the FAS. In other areas, low to moderate yielding permeable zones inter-layered with the confining zones may supply water to wells (SEGS 1986). In any case, the ICU sediments, as a whole, act as a confining to semi-confining unit above the FAS where present.

The sediments that comprise the SAS and intermediate confining hydrostratigraphic units in SJRWMD are referred to as overburden. They directly overlie the FAS carbonates. The overburden deposits vary in thickness due to geologic structure, depositional history, differential erosion, and infilling of karst features as the overlying sediments settle into the irregular carbonate surface and into voids within the highly soluble carbonate rocks beneath them. The geologic structure and surface elevation of the FAS controls the resulting thickness of the overburden sediments and can impact the hydrogeologic characteristics of the overburden. Where the overburden is thickest there is greater confinement to the FAS. Where it is thin or absent, the FAS has experienced enhanced dissolution resulting in enhanced hydraulic conductivity (Bush and Johnson, 1988).

A table of elevation values for the top of the ICU (picks) was developed from reviewing borehole geophysical and lithologic logs, published reports, data values provided by other water management districts, the Florida Geological Survey STATEMAP program, and the United States Geological Survey. After reviewing the borehole data, picks for the top of the ICU were made and used as input for a geostatistical analysis to create an elevation grid of the top of the ICU. The base of the ICU is the top of the FAS (Boniol and others, 2014).

METHODS–GEOSTATISTICAL ANALYSIS AND FINAL ELEVATION ESTIMATION

Geostatistical analysis techniques were used to create an estimation of the elevation of the top of the ICU. The geostatistical data analysis procedures used herein were the same as for SJRWMD's mapping of the FAS (Boniol and others, 2014). More detailed documentation of the estimation process can be found in the Geovariances peer review report (Geovariances, 2011).

The ICU surface is influenced by the regional structural trends of the FAS, as well as local features such as karst development, infilling of underlying depressions, and reworking of Hawthorn Group sediments during periods of high sea level stands. The estimation process accounts for the regional long-range variability and the local short-range variability. Exploratory variogram analysis is done to derive a model for each of these conditions. During the process, a global trend surface was generated to identify the effects of short-range variability. The global trend was subtracted from the true elevation of the ICU at each location. The variogram analysis of these residuals resulted in an exponential model structure.

The ISATIS software by Geovariances (2011), has a Local GeoStatistics (LGS) procedure that was used to analyze the local, short-range spatial structure. The study area was partitioned into 100 by 100 kilometer grids to refine the mapping of the ICU in areas of geologic structural highs and lows and in areas where the top of the ICU varies locally due to karst features. The ISATIS local automatic variogram fitting algorithm tests different variogram model and neighborhood variants, and stores the optimal structural and computational parameters based on the input data for each partition area. The optimal local parameters are those with the lowest absolute mean error based on the local cross-validation scores. LGS kriging is performed on the global trend residuals, re-interpolated at each 150-meter grid cell used for the ICU elevation map. The final ICU elevation map is calculated by adding the LGS residuals kriging estimation result to the long-range trend variable at each 150-meter grid cell. The geostatistical data analysis procedures used were the same as for the SJRWMD mapping of the FAS (Boniol and others, 2014).

A final step in the process is to constrain the top to be five feet below land surface. This is done to account for the fact that there is generally some soil formation where the unit is that close to land surface and the need for groundwater flow models to have a minimum thickness for the overlying SAS. This also prevents the estimation from rising above land surface. The initial digital elevation model (DEM) of the land surface was a 10-meter cell size but it was upscaled to 150-meter grid to match the ICU cell size before the constraint was added.

ELEVATION AND THICKNESS OF THE ICU

The elevation of the top of the ICU in the mapped area ranges from approximately 200 feet NAVD88 (North American Vertical Datum of 1988) in northern peninsula Florida to more than -260 ft NAVD88 in the Okeechobee Basin of southern Florida (Figure 3). The depth to the top of the ICU from land surface was determined, then the ICU elevation relative to mean sea level (NAVD88, feet) was calculated using the land surface elevation at each site. The ICU elevation data exhibit long-range trends due to geologic structural features, short-range variability related to karst and erosional processes, or clustering of data points in some areas.

The elevation and thickness of the ICU are directly related to the geologic structural features present locally and to karst development. The ICU data exhibit long-range trends of increasing depth to the top of the unit and increasing thickness toward the Jacksonville basin to the north and toward the Okeechobee Basin to the south. The deepest occurrence of the ICU within the total mapped area occur in Alabama. In central peninsular Florida, the ICU surface exhibits short-range variability due to karst development and erosional processes.

The thickness of the ICU ranges from 0 to 875 feet within the total area of the grid estimation. Within SJRWMD it ranges from 0 to 519 feet thick. The ICU is absent due to erosion or is thin (less than 50 feet in thickness) over the crest and on the flanks of the Ocala Platform in west-central and northwestern parts of the mapped area. In central Florida the ICU is present but is relatively thin (25 to 75 feet in thickness) and can be breached by karst features. Over the structural highs in east-central Florida, reworked erosional remnants of the Hawthorn Group and discontinuous Pliocene sediments of low permeability form the ICU. Reworked Hawthorn sediments may be rich in clay or fine-grained material in direct vertical contact with the Hawthorn Group and though they provide confinement, they are younger sediments. These are the type of sediments identified in gamma and induction geophysical logs that may be included in the ICU.

The thickness of the ICU is presented in Figure 3. Notice how the thickness is greatest in the northeast (red/brown) where the Jacksonville Basin has provided a deep area for sediment infill and thin or absent in the west where the Floridan aquifer is close to the land surface. In east-central Florida (green-blue) the ICU is generally less than 100 feet thick and may be absent in areas.

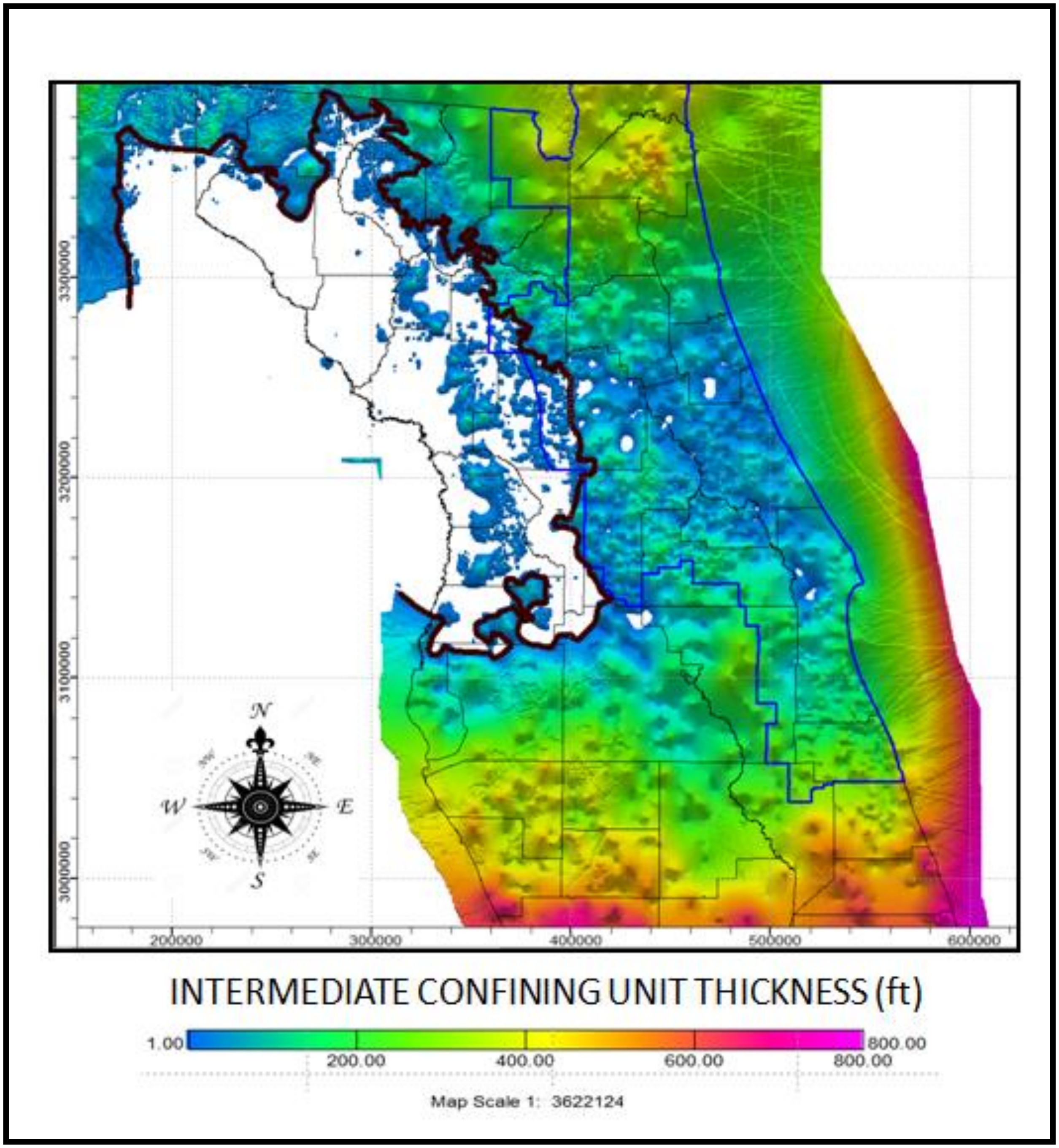

Figure 3. Thickness of the ICU greater than 20 feet thickness and demarcated with a black line to approximate where the FAS is essentially unconfined. SJRWMD boundary is delineated in blue.

A black line is drawn in Figures 3 and 4 to show the general area (primarily in the central western portion of the state) where the FAS is unconfined based on having a thickness less than 20 feet for the ICU. The location was determined by using the ArcGIS aggregate function to smooth the edges of the raster and manually draw the line at the boundary. The colored areas represent areas with some confinement. Because this is a regional conceptualization, this approximation does not address localized areas where the ICU may have relatively high vertical hydraulic conductivity and therefore would be considered leaky in that area. The unconfined area is hydraulically important in that there can be direct recharge to the FAS and there is little protection from pollution at land surface. These areas are also more susceptible to the development of sinkholes.

The elevation of the top of the ICU is shown in Figure 4. Within SJRWMD it ranges from a high of 174 feet NAVD88 to a low of -168 feet (NAVD88). For the total grid extent, the elevation ranges from -1,308 to 491 feet NAVD88 with the highest elevations occurring in north Georgia and the lowest in the western panhandle of Florida and Alabama.

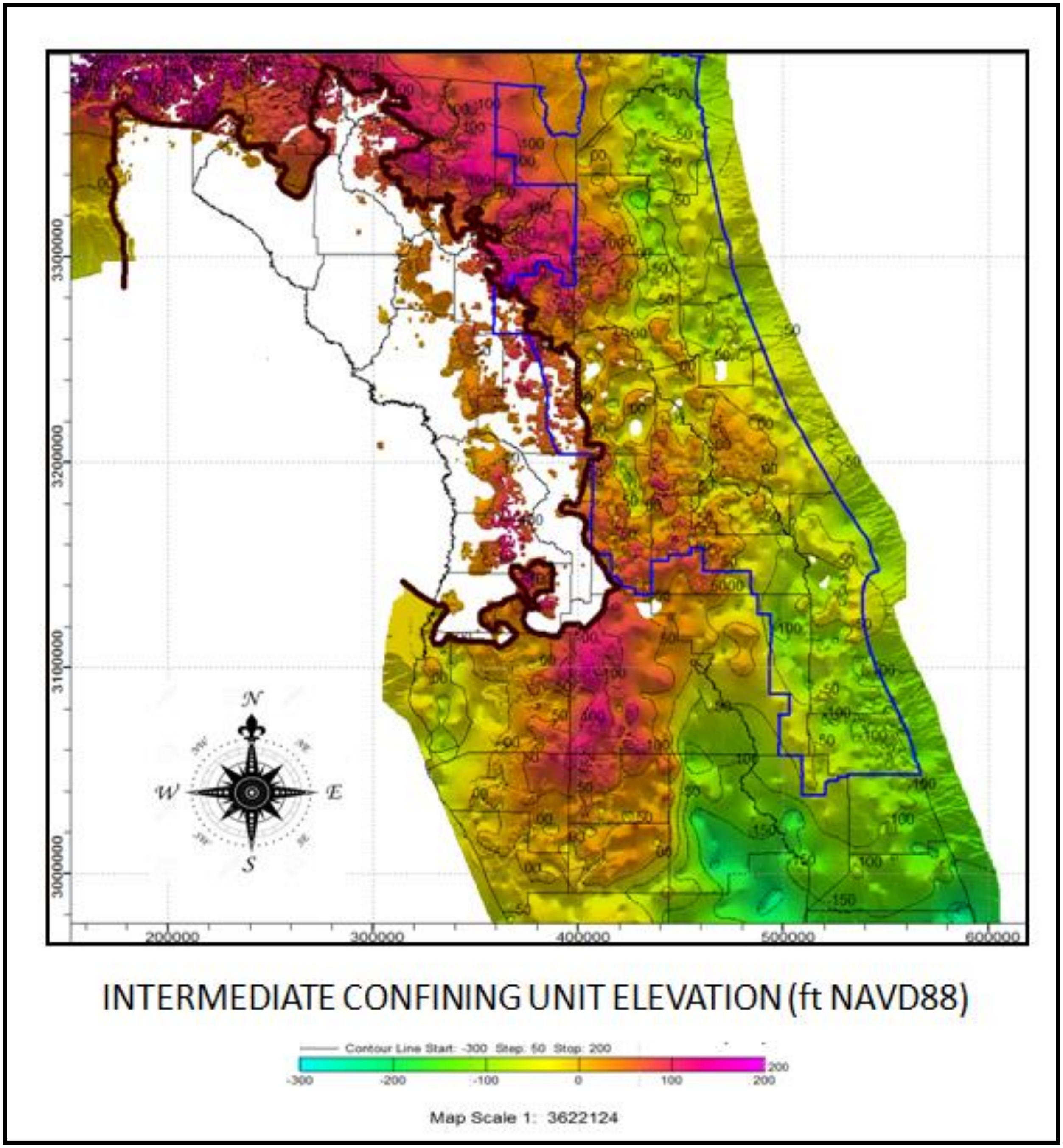

Figure 4. Elevation of top of the ICU (colored) showing where the thickness is greater than 20 feet. A black line is drawn to approximate where the FAS is essentially unconfined. SJRWMD boundary is delineated in blue.

The extent of this map extends beyond SJRWMD's boundary to emphasize the areas where the ICU is thin or absent. The surface (colored area) shows where the thickness is greater than 20 feet. This thickness was chosen since with only 20 feet of ICU thickness, there is minimal confinement.

The series of cross sections (Figures 5-8) illustrate the configuration of the ICU in relation to the overlying and underlying hydrogeologic units. Section A-A' (Figure 5) cuts west to east through the northern part of peninsular Florida. This shows that in the west even though there is some ICU present it is exceedingly thin and therefore provides minimal confinement. In the east, the thick ICU is prominent in the Jacksonville Basin. There is very good confinement and there is minimal risk of sinkhole formation.

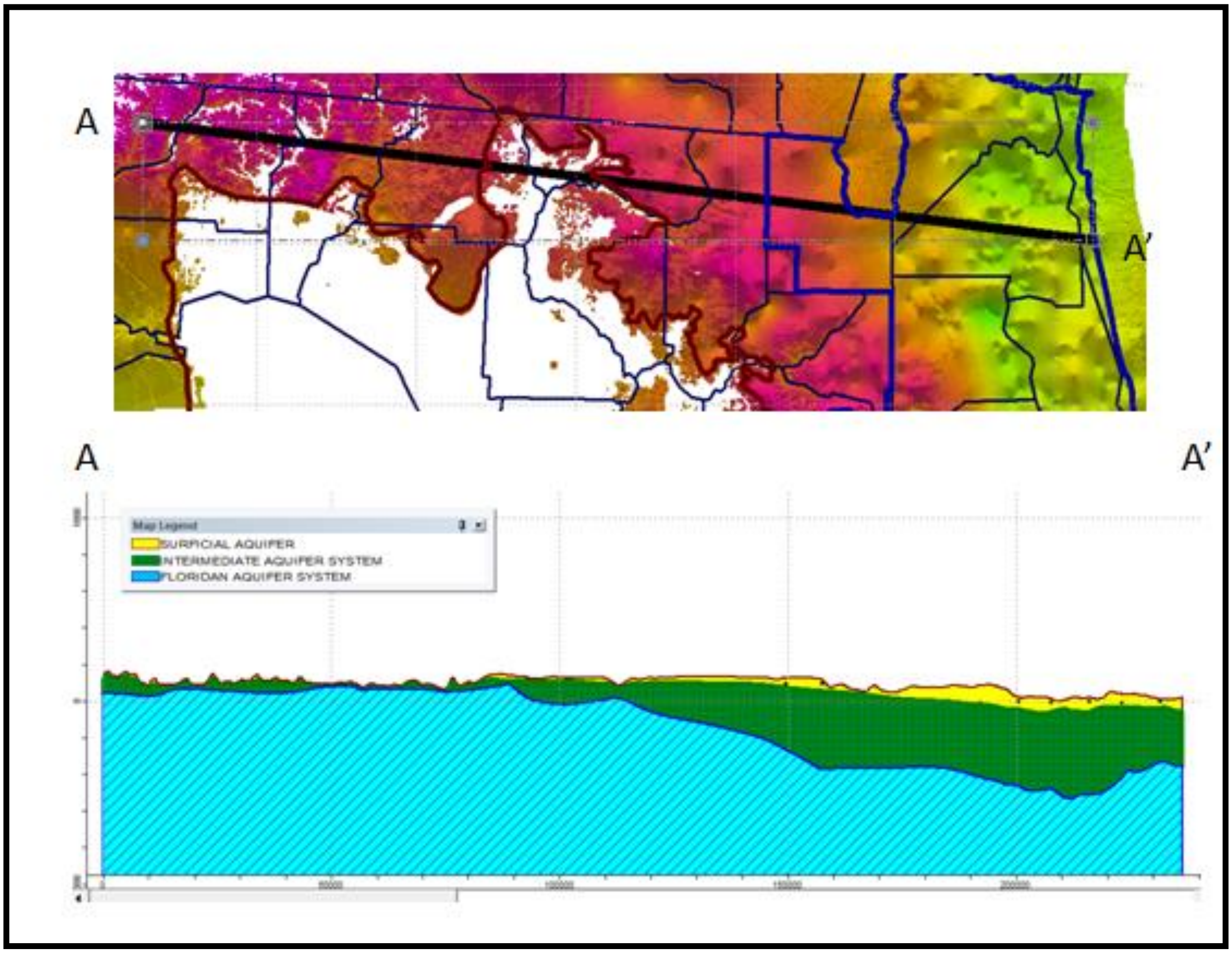

Figure 3. Hydrogeologic cross section A-A' west to east in northern peninsular Florida.

Section B-B' cuts through the entire SJRWMD from north to south. As in A-A' the thick section in the Jacksonville Basin is seen in the north and the elevated area of the Ocala Platform is prominent in the central region. The unit thickens to the south and continues to dip further south.

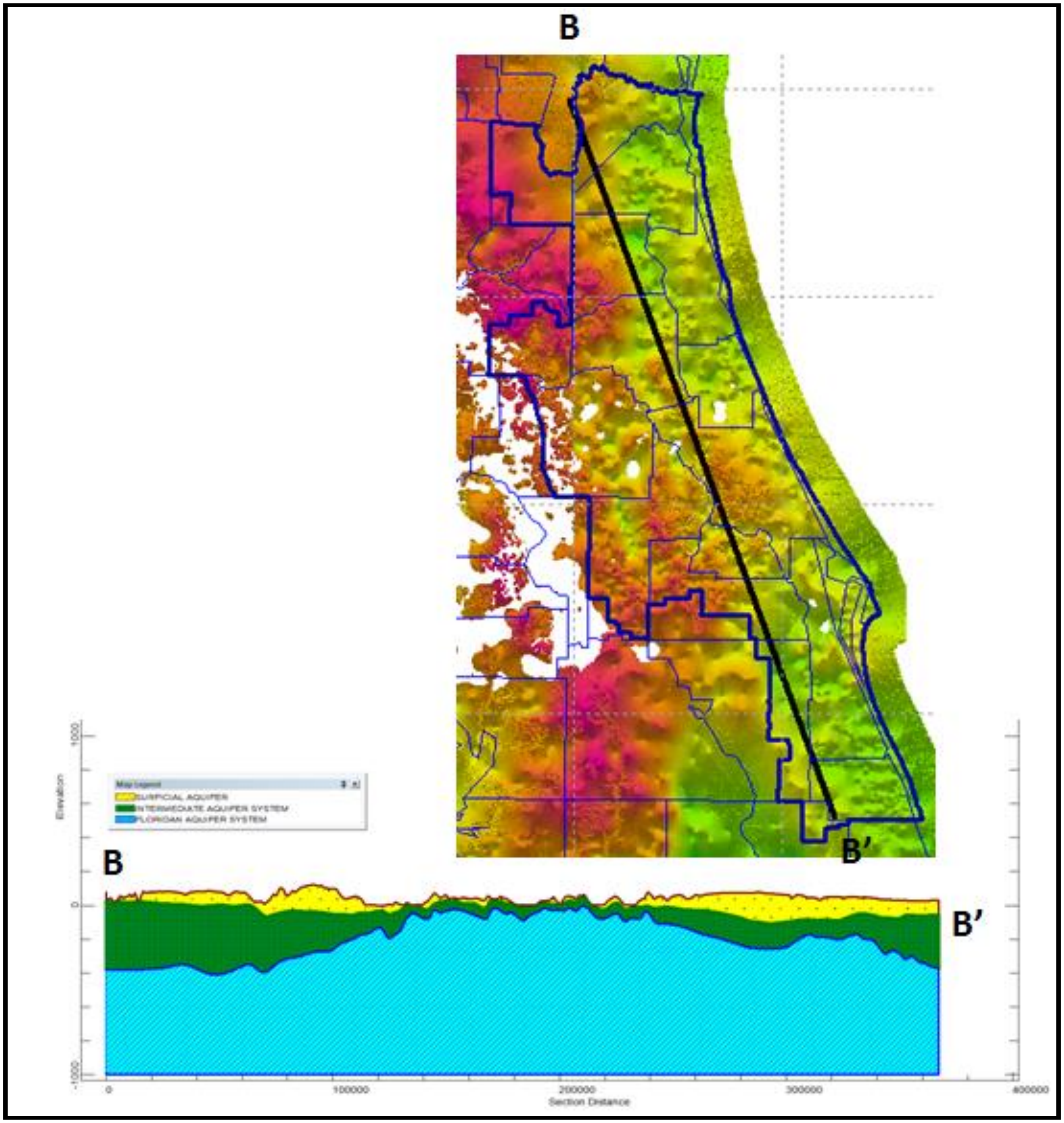

Figure 4. Hydrogeologic cross section B-B' north to south through SJRWMD.

East to west cross section C-C' cuts through the center of SJRWMD. The unit is very thin in the west and thickens and dips to the east. Evidence of paleo-sea levels can be seen in peaks and terraces on the land surface.

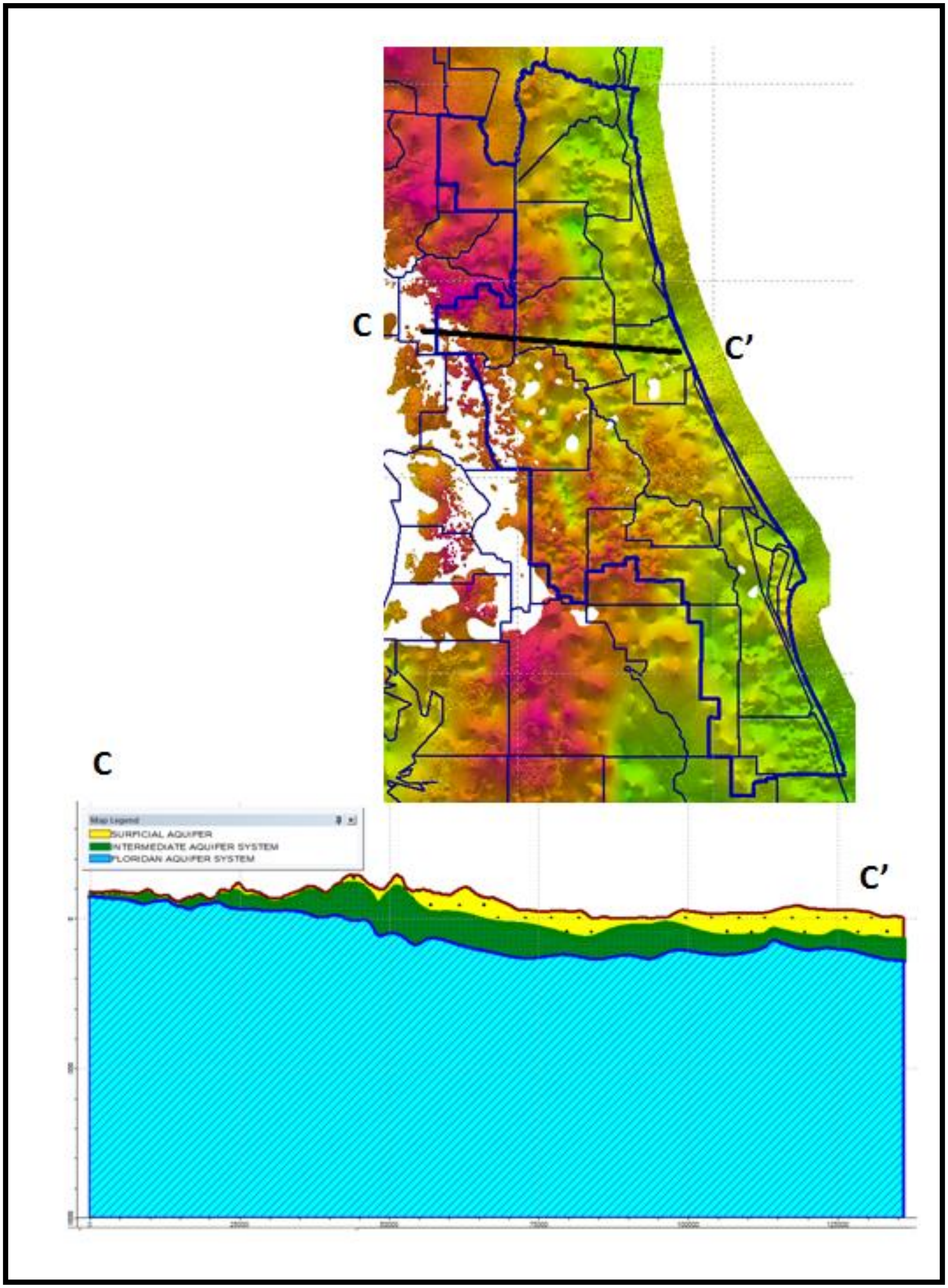

Figure 5. Hydrogeologic cross section C-C' west to east in central peninsular Florida.

Section D-D’ is similar in character to C-C’ with the exception of the large trough feature in the west. The trough is cut into both the FAS and ICU whereas the land surface does not reflect this morphology at all. This is likely a paleo-drainage feature that was incised on the Ocala Limestone when it was exposed. This may have continued after the Hawthorn Group sediments were deposited. Infilling with the SAS sediments created the present-day landforms. Multiple large lakes (see inset) are located within the trough suggesting the lakes origins may be related to the trough possibly due to enhance karstification.

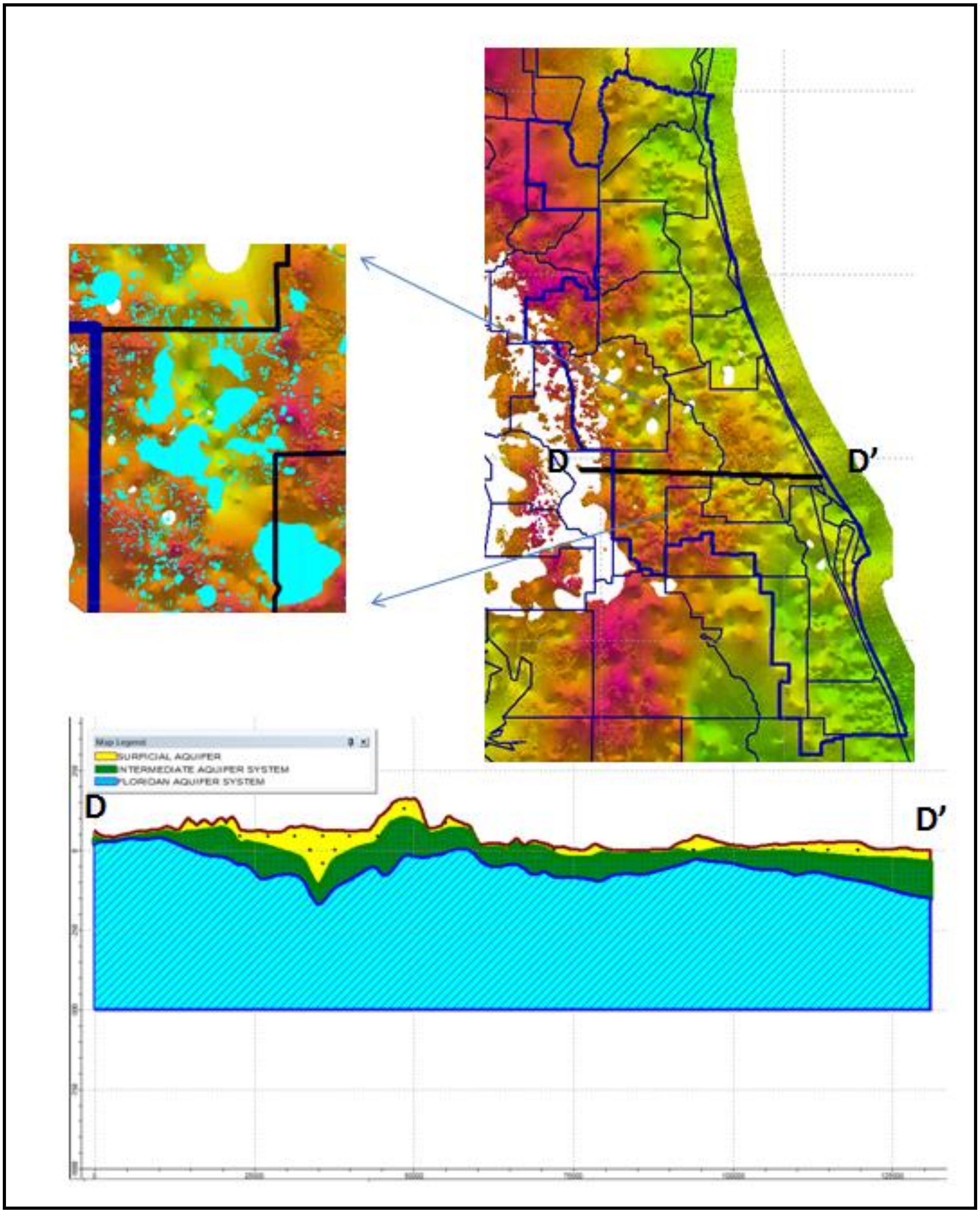

Figure 6. Hydrogeologic cross section D-D' west to east in south central peninsular Florida. Note the large trough feature in central Lake County.

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Acknowledgements

The St. Johns River Water Management District gratefully acknowledges the data, comments through the years, and hydrogeologic information provided by the South Florida Water Management District (Emily Richardson), the Southwest Florida Water Management District (Jason LaRoche, Ron Basso, Jerry Mallums), the Suwannee River Water Management District (Dale Jenkins), the Florida Geological Survey (David Paul, Clint Kromhout, Rick Green), and the U.S. Geological Survey (Lester Williams, Rick Spechler, Nicolas Sepulvada, Lou Murray).