ATTACHMENT A-7

GROUNDWATER ANALYSIS REPORT

U.S. Army Corps of Engineers

Mobile Harbor Channel Deepening

Groundwater Evaluation

Prepared by

U.S. Army Corps of Engineers

Philadelphia District

April 2019

1 Introduction

The U.S. Army Corps of Engineers (USACE), Mobile District (SAM) is conducting a Feasibility Analysis to evaluate modifications to the Mobile Harbor Navigation Channel. The modifications include a deepening of the channel from the existing -47 ft MLLW to as deep as -56 ft MLLW and a widening of up to 150 feet. These modifications will extend from the Choctaw Pass Turning Basin to the mouth of Mobile Bay, south of Dauphin Island. Concern over the dredging impacts to the aquifer underlying the channel were raised during the review of the Tentatively Selected Plan (TSP). These concerns primarily relate to potential increases in saltwater intrusion resulting from the thinning or removal of a confining layer underlying the channel as a result of the deepening. The City of Dauphin Island currently uses the brackish water zone below this confining unit as its primary drinking water supply source.

The modeling tasks were a combined effort between USACE Mobile District (SAM) and USACE Philadelphia District (NAP). SAM compiled all available data and helped define the hydrogeologic framework, while NAP developed, calibrated and performed design simulations using the model to investigate the potential impacts of channel deepening on the existing groundwater flow system.

The objectives of this modeling effort are to:

- Develop a better understanding of the complex groundwater flow system in the vicinity of Dauphin Island.
- Evaluate the proposed deepening plan to determine where the clay at the base of the channel may be penetrated.
- Qualitatively evaluate the impacts of the proposed deepening on groundwater flow to the water supply wells at Dauphin Island.
- Conduct a sensitivity analysis to determine the uncertainty in the model results.

2 Modeling Approach

The first step in the modeling process is to define clear, achievable goals and objectives for the model based on the desired purposes. Both the modeling team and the end user must begin with the end goal in mind and understand the abilities and limitations of the model. The purpose of the Mobile Harbor groundwater model is to evaluate potential changes in Dauphin Island municipal water supply well capture zones due to proposed modifications to the Mobile Harbor Navigation Channel and assess if changes could impact the extent of saltwater intrusion experienced by Dauphin Island in the future.

Prior to developing the groundwater model, data was collected from a variety of sources to improve the Conceptual Site Model (CSM) in the area of interest. Data sources included regional studies of the Coastal Lowlands Aquifer System (Geological Survey of Alabama, 2018; Gillett et al. 2000; Martin and Whiteman 1989/90; Moore, 1977; Weiss, 1992) and local studies conducted in Mobile County, Mobile Harbor and in the vicinity of Dauphin Island (Kidd, 1988; Murgulet, 2009; and Rich 2006).

This CSM was used as a basis for a 3-dimensional finite difference groundwater model. The Groundwater Modeling System v10.1 (GMS) developed by Aquaveo was used to develop both the CSM and MODFLOW numerical groundwater model (Harbaugh, 2005) for this project. Due to limitations in the available calibration data, a coarse, steady state calibration was performed. Once a reasonable calibration was achieved, the model was used to evaluate groundwater flow pathways with and without deepening the Mobile Harbor Shipping Channel to assess if the deepening may result in changes to water supply well capture zones. Since there was some uncertainty in model input parameters due to the coarse calibration, a sensitivity analysis was performed in order to bracket the range of potential model solutions.

2.1 Model Extents and MODFLOW Grid

The horizontal extents of the model were established along drainage divides or in areas where the groundwater flow conditions could be reasonably assumed. The model boundaries were selected such that they were located away from the Dauphin Island area of interest to minimize any boundary effects on the model solution. The western edge of the model was selected along the approximate edge of the Escatawpa River (see Figure 1), which represented a reasonable specified head boundary condition at the mudline and a drainage divide in the underlying aquifers. The eastern edge of the model was selected along the approximate edge of the Fish River, which represented a reasonable specified head boundary condition at the mudline and a drainage divide in the underlying aquifers. Based on regional groundwater studies (Martin and Whiteman, 1989), these eastern and western boundaries are parallel to regional groundwater flow from the mainland to the outcrops in the Gulf of Mexico. The southern boundary was located south of the outcrop of the A2 aquifer (as described in Section 2.4) where the specified head was assumed to be sea level. Figure 1 shows the horizontal extents of the model domain (approximately 1,725 square miles) and well as the primary channel features incorporated into the calibration and design simulations.

Figure 2 shows the horizontal resolution for the computational grid elements, which varied from 100 ft at Dauphin Island and along the shipping channel to 2,500 ft along the model boundaries. This higher resolution at Dauphin Island and along the shipping channel was needed to accurately compute the sharp gradients that exist due to the cones of depression at the Dauphin Island pumping wells and the details of the existing and proposed channel. Vertically, the model extended from the ground surface to the aquitard at the base of the A2 aquifer. In the vicinity of Dauphin Island the A3 aquifer is artesian in nature and limited flow is believed to occur between the A3 and the overlying A2 aquifer. As such, no-flow boundary conditions were assumed along the base of the model. Although the depth of the model varies, the topographic high is at approximately 190 ft NAVD88. The deepest point of the A2 aquitard interface is at approximately elevation -510 ft NAVD88. The 3D grid contains 5 vertical element layers and is comprised of 624,020 computational cells.

2.2 Model Datum

Numerous data sources were compiled to generate the conceptual model and model input parameters. All data sets were converted to a common horizontal and vertical datum. The horizontal datum used for this model was the North American Datum of 1983 (NAD 83), State Plane Alabama West. The North American Vertical Datum of 1988 (NAVD 88) was used as the vertical datum. Data received in mean lower low water (MLLW) was converted to NAVD 88 using the datum equivalency provided by the National Oceanic and Atmospheric Association (NOAA) for tide gauges 8735180 (Dauphin Island, AL) and 8736897 (Coast Guard Sector Mobile, AL) as shown on Figure 3 (NOAA, 2019). Elevation in feet NAVD 88 was approximated to be MLLW + 0.5 ft across the model domain based on these two gauges.

2.3 Topography

Topographic and bathymetric information across the area of interest was used to define the surface of the 3-D computational grid. Topographic/bathymetric data for this study was taken from the NOAA Topobathymetric Model of the Northern Gulf of Mexico 2014. Figure 4 shows the topographic relief across the model domain. The model includes a topographic high of 190 ft NAVD 88 in the northern portion of the model domain to a bathymetric low of -107 ft NAVD 88 at the southern end of the model.

2.4 Geology and Hydrogeology

Mobile Bay lies near the southeastern boundary of the Coastal Lowlands Aquifer System, which extends across portions of Texas, Louisiana, Mississippi, and Alabama. The aquifer system is comprised of five permeable zones (Permeable Zones A through E) and terminates at the Vicksburg-Jackson Confining Unit (Martin and Whiteman, 1990; Weiss, 1992; Martin and Whiteman, 1999). Each permeable unit outcrops to the surface, and Figure 5 depicts the outcrop areas in the vicinity of the model domain. Permeable Zones B and C outcrop in the Mobile Bay region and are the primary hydrogeologic units of interest in this study. In Mobile and Baldwin Counties, these permeable zones have been subdivided into Aquifers A1, Upper A2, Lower A2, and A3, based on the presence of lower permeability aquitards, as shown on Figure 6 (Chandler et al., 1985; Gillett et al., 2000; Murgulet and Tick, 2008). The primary focus of this study is analysis of the flow pathways within Aquifers A1, Upper A2, and Lower A2, so the model was constructed to incorporate the hydrogeologic units from the ground surface vertically downward to the aquitard that divides the Lower A2 aquifer from Aquifer A3, which serves as the bottom boundary of the model.

The elevations and thicknesses of the local geology (Aquifers A1, A2, and intermediate confining or semi-confining units) were better defined within the model domain using geologic boring data compiled from investigations conducted by the USACE and well records maintained by the Geological Survey of Alabama (GSA). Investigations conducted by the USACE were mainly in the vicinity of the Mobile Harbor Navigation Channel and included Mobile Harbor Improvements (1985) and Proposed Improvements to the Theodore Channel (1977). Boring logs from additional SAM investigations are compiled in *Mobile Harbor Integrated GRR and Supplemental EIS - Engineering Appendix*. GSA maintains well records across the state of Alabama, which were accessible through their website <https://www.gsa.state.al.us/gsa/groundwater/wellrecords> at the time of this modeling effort. Selected borings from Mobile and Baldwin Counties from the GSA were useful in defining the geology in the vicinity of Dauphin Island as well as mainland areas. The locations of the boreholes used to define the modeled geology are shown on Figure 7. Boreholes pictured on Figure 7 were selected out of a larger dataset of available borehole data because they were of adequate depth and included detailed geologic descriptions that could be used to define the modeled stratigraphy. A compilation of the boring logs shown on Figure 7 is presented in Appendix A.

After the major stratigraphic units were identified in each boring, the geologic contacts were interpolated/extrapolated across the model domain to create the conceptual geologic model which serves as the basis for the numerical model. Figure 8 shows cross sections from the geologic model. Note that the unconfined sands of Aquifer A1 on the mainland are disconnected from the A1 aquifer on the barrier islands. The confining or semi-confining clay is exposed at the surface within Mobile Bay and in areas of lower elevation surrounding the bay as shown on Figure 9. The thickness of the confining or semi-confining clay beneath Aquifer A1 is at a maximum of approximately 170 ft in the higher elevation areas in the northwestern quadrant of the model. In the southern portion of the model, this clay confinement is non-existent, leaving Aquifer A2 exposed at the surface. Previous dredging has also cut through the clay in portions of the navigation channel. On Dauphin Island, the thickness of the clay separating Aquifers A1 and A2 ranges from 12 ft to 35 ft. Top elevations of the clay layer range from 74 ft NAVD 88 in the mainland areas to -108 ft NAVD 88 where the clay pinches out in ocean (see Figure 10 for top elevations of the clay across the model).

The A2 Aquifer has a top elevation ranging from -2.5 ft NAVD 88 at the northern boundary of the model to -132 ft NAVD 88 (-50 to -62 ft NAVD 88 on Dauphin Island; see Figure 11). A review of the boring logs indicated the presence of alternating layers of higher and lower permeability materials (i.e. layers including but not limited to sand, clayey sand, sandy clay, clay, marl, and sometimes rock) within Aquifer A2. While there is a great deal of variation in how these materials were deposited across the area of interest, similarities were noted in a number of boring logs that indicated the upper and lower portions of Aquifer A2 are generally more permeable while clays are more prevalent in the middle portion of the aquifer. This is consistent with previous conceptualizations of the subsurface stratigraphy in Baldwin and Mobile counties which includes an aquitard dividing Aquifer A2 into upper and lower units (Chandler et al., 1985; Gillett et al., 2000; Murgulet and Tick, 2008). The zone of lower permeability interbedded sand and clay begins at elevations between -50 and -280 ft NAVD 88, and extends to the top of Lower Aquifer

A2 with top elevations ranging from -166 to -464 ft NAVD 88. See Figures 12 and 13 for the top elevations of the interbedded sand/clay layer and Lower Aquifer A2.

The bottom of the model was set at the top of clay which divides Lower Aquifer A2 from Aquifer A3. The deepest point in the model is -510 ft NAVD 88. Figure 14 depicts the elevations of the bottom of the model/bottom of Lower Aquifer A2.

2.5 Boundary Conditions

Since the primary purpose of this model is to simulate the potential impacts of dredging on the shallow sand (A2) confined aquifer, constant head boundary conditions were used over the majority of the upper layer of the model, which allows the model to define the recharge that will provide the expected groundwater heads in the lower aquifers. In the mainland areas, the constant head applied to the model surface was based on the potentiometric surface for aquifer recharge areas develop by the GSA (Gillett et al., 2000). In areas where the topographic surface is covered by the Mobile Bay or the Gulf of Mexico, an average tidal surface of mean sea level (approximately 0 ft NAVD88) was assumed. Figure 15 shows the constant head boundary condition applied to the model surface. This mean sea level approximation was also assumed for the vertical model faces on the southern model boundary where the A2 aquifer outcrops into the Gulf of Mexico. In order to evaluate the impact of surficial recharge along the barrier islands to the A2 aquifer, a high and low recharge rate was applied to the model surface on both Dauphin Island and the peninsula from Gulf Shores to Fort Morgan. These recharge rates varied between 6 in/yr and 20 in/yr (Kid, 1988). For the final model sensitivity analysis a conservatively low recharge of 6 in/yr was utilized since this minimizes infiltration from surface recharge. As such the water withdrawn from the deeper Dauphin Island water supply wells will conservatively pull water from within the A2 aquifer.

The primary sinks to groundwater are from pumping wells installed on both the mainland and Dauphin Island. For the mainland wells in Mobile and Baldwin County, GSA data for public water supply wells was used to approximate average groundwater withdrawals. Where withdrawal data was not available, the pumping rate was estimated based on nearby wells. The three water supply wells on Dauphin Island that are screened in the A2 aquifer were also modeled. The average 2018 groundwater pumping rates were used in the model based on data provided by Dauphin Island. Figure 16 shows the location and rate used for the Dauphin Island pumping.

3 Calibration

Model calibration is the process of varying model input parameters within a reasonable range in order to match simulated output to observed conditions within acceptable error criteria. The data available for this phase of the study was limited and water levels taken across decades were used in the calibration process. Since many of the wells were likely impacted by nearby pumping or seasonal changes, only a coarse calibration was performed to establish regional groundwater flow patterns. Due to the uncertainties in this calibration a robust sensitivity analysis was performed to quantify the uncertainty in the model and evaluate groundwater flow based on conservative assumptions.

3.1 Steady State Calibration

The coarse steady state calibration performed for this study was a combination of both a qualitative and quantitative evaluation. The USGS Regional Aquifer System Analysis (RASA) modeling encompasses the model domain for this study. Based on the geologic descriptions in RASA study, Permeable Zone C correlates to the A2/A3 aquifer system used in this study. The RASA model results show that infiltration from the upland areas of the mainland recharge this confined aquifer system and groundwater is ultimately discharged at the outcrop in the Gulf of Mexico or beneath Mobile Bay. Figure 17 shows the computed water level elevations in the RASA model in the vicinity of the model domain. These flow patterns were used as a qualitative guide for the regional aquifer head trends for the current study. Water level data in the A2 aquifer was also compiled based on GSA data. Figure 18 shows the regional water levels in the A2 aquifer compared to the computed aquifer heads. These water levels were taken over the course of several decades and may be impacted by regional pumping in the vicinity of the wells. However, the overall trend of these observed water levels are consistent with the regional trends in the RASA model where the aquifer is recharged in the upland area of Mobile and Baldwin counties and flows towards Mobile Bay and southward towards the Gulf of Mexico. The intent of this groundwater comparison is not to accurately replicate local groundwater heads on the mainland but rather to ensure the model has a reasonable groundwater flow trend from the recharge areas towards Dauphin Island.

Groundwater flow patterns on the barrier islands were also evaluated. Recent modeling by the University of Alabama (Murgulet, 2009) provides regional groundwater flow trends in south eastern Baldwin County. The A2 groundwater flow patterns depicted in the University of Alabama modeling effort were consistent with the current modeling effort in the Baldwin County area. Water level data collected in the A2 aquifer on Dauphin Island ranged from approximately 3.2 ft to 1.2 ft, with a general trend of higher water levels on the northern side of the island and lower water levels on the southern side of the island. It is believed that these water levels were taken prior to the commencement of the Dauphin Island water supply withdraws from the A2 aquifer. As shown in Figure 19, the computed heads with no pumping in the A2 aquifer on Dauphin Island vary between 1.5 and 2.0 ft. This represents a slightly flatter regional gradient than observed; however, the gradient is reasonable given the uncertainty in the data. This slightly flatter regional gradient is also expected to be conservative, since the modeled source of fresh water to the A2 aquifer from the upland areas is less than that believed to be occurring naturally.

In addition to evaluating the A2 aquifer, the computed water levels in the water table aquifer at Dauphin Island were evaluated during the coarse calibration. The USGS performed extensive monitoring and modeling of the water table aquifer on Dauphin Island in the 1980s (Kidd, 1988). This study concluded that the water table aquifer was highly sensitive to recharge from precipitation, with a higher water table elevations towards the center of the island and groundwater flow generally from the center of the island to the surrounding surface water bodies. Figures 20 and 21 show the simulated heads in the water table aquifer under high and low recharge conditions, respectively. The insets in these figures show the simulated heads from the USGS study, which are quite similar to those computed by the current model. Although the variations in recharge made a significant difference in the computed heads in the water table aquifer, the corresponding variations in computed water level in the upper portion of the A2 aquifer were less than 0.05 ft, indicating that recharge to the water table aquifer is not a primary source of water to the underlying A2 aquifer.

Figure 9 and 22 show the spatial distribution of materials in layers 1 and 2 of the model, respectively. This distribution of materials was based on the location of permeable zone outcrops defined in the RASA modeling, location of Bay sediments and location of A2 aquifer outcrops in the Gulf of Mexico. Model layers 3, 4, and 5 correspond to the upper, interbedded and lower potions of the A2 aquifer, respectively. Table 1 shows the calibrated hydraulic conductivity values for each material type used in the model, which were based on literature data compiled for this study (Kidd, 1988; Martin and Whiteman 1989/90; Murgulet, 2009; and Rich 2006). Little data is available related to the confining/semi-confining unit within the A2 aquifer. Since the geologic logs indicated that this was generally an interbedded sand/clay sequence, the vertical hydraulic conductivity of this interbedded layer was assumed to be 10 times less permeable that the portions of the A2 aquifer without the interbedded clays.

Table 1: Calibration Values for Hydraulic Conductivity (K). All K values are in ft/d. These hydraulic conductivity values remained constant in all runs.

Material	Horizontal Hydraulic Conductivity (ft/day)	Vertical Hydraulic Conductivity (ft/day)
Barrier Island Water Table Aquifer (A1)	55	5.5
Clay (between A1/A2)	0.0025	0.00025
Upper Shallow Sand (Upper A2)	75	7.5
Interbedded A2	75	0.75
Lower Shallow Sand (Lower A2)	75	7.5
Mainland Water Table Aquifer (A1)	55	5.5
Clay (Permeable Zone C Outcrop)	0.01	0.001

4 Design/Sensitivity Simulations

The coarsely calibrated model was used to evaluate the proposed deepening of the Mobile Harbor Shipping Channel. For this effort particle tracks to the pumping wells and from the channel were evaluated using the USGS MODPATH program for each of the design/sensitivity simulations.

4.1 Design Simulation Results

Prior to performing long term particle tracking, a qualitative assessment of the coarse calibration was made by comparing the capture zones of the regional pumping wells in the model to Well Head Protection Areas (WHPAs) and the Source Water Assessment Areas (SWAAs) developed by the GSA (Gillett et al., 2000) at the same wells. Figure 23 shows that the modeled capture zones from the regional public water supply wells are reasonably consistent if not larger than the WHPAs and SWAAs, indicating that the model may be slightly conservative.

Since the coarsely calibrated model appeared to reasonably depict the capture zones of the regional public water supply wells, particle tracking was performed for the Dauphin Island wells assuming current canal conditions, dredged conditions (clay below channel remained if proposed dredging did not fully penetrate), and fully penetrating conditions (clay assumed to be fully removed in the proposed channel). Figures 24 to 26 show the particle tracking results for each of these simulations respectively. At each well 1,000 particles were released in the model within the screened interval of each of the A2 aquifer pumping wells on Dauphin Island. These particles were tracked back to their source to define the capture zone for the well.

Under existing conditions the primary source of water to the Dauphin Island water supply wells appears to be from recharge on the mainland. Under both with project conditions, the capture zones extend further to the south and east (towards the channel) with selected particles passing under the channel. This southeastward expansion of the capture zone results from the lowering of the heads in the A2 aquifer as a results of the deepening south of Dauphin Island. It should be noted that these particle tracks trace the flow paths back to the water source, regardless of time.

The insets on Figures 24 to 26 shows the lateral extent of the capture zones after 1,000 years. Particle track timing was computed using a porosity of 30% which is consistent with other studies performed in the area and a reasonable approximation for the unconsolidated depositions within the model (Murgulet, 2009; Rich 2006). All three scenarios show that the capture zone for the Dauphin Island wells extend to the south toward the Gulf of Mexico. It is anticipated that the salinity of the A2 aquifer south of the island increases due to natural seawater intrusion. Although the salinity profile in the A2 aquifer is not known, the pumping of the Dauphin Island wells likely induces some seawater encroachment under current conditions. The red line on the inset figures under deepened conditions (Figures 25 to 26) shows the existing 1,000 year capture zone without the deepening. A comparison of this existing condition capture zone to the predicted capture zone under deepened conditions indicates only a marginal increase in the capture zone due to the deepening. Since the salinity profile of the A2 aquifer to the south and east of Dauphin Island is not currently known, additional data would need to be collected to better quantify any increase in salinity due to the deepening. However, based on this capture zone analysis, any increases in salinity at the Dauphin Island wells in excess of existing pumping induced seawater intrusion are expected to be low in magnitude and occur over an extended period of time.

The flux of water from the channel into the aquifer was also compared under existing and deepened conditions. Under existing conditions, water from the mainland discharges into Mobile Bay, resulting in upward flow from the aquifer into the bay along the entire length of the channel. This is consistent with recent groundwater studies into submarine groundwater discharges (SGD) and their ecological impacts within the Mobile Bay (Montiel et al., 2018). These upward flow patterns are maintained even under deepened conditions assuming either partial or full cut-through of the clay underlying the channel. Flow reversal could occur during high-tide events, but these events would be of relatively short duration and not expected to have a significant contribution to long-term groundwater flow patterns.

Although regional flow patterns do show that most of the shipping channel will remain a discharge area even if deepened, removal of the clay beneath the channel has the potential to allow some seawater into the A2 aquifer system due to density effects. Denser saltwater will sink within the water column and could create a saltwater wedge beneath the channel. This saltwater wedge is expected to remain local to the channel and far from the Dauphin Island well capture zones over the 50-year design life of the project if groundwater pumping on Dauphin Island is not increased significantly from 2018 pumping rates. Significant increases in pumping will increase the capture zone radius, which is discussed further in Section 4.2.3, but impacts on water quality from increased pumping cannot be quantified with this model.

4.2 Sensitivity Analysis

The sensitivity of the particle tracks and extraction well capture zones to several model input parameters was explored with a series of sensitivity simulations in order to bracket the uncertainty in the model solution. Hydraulic conductivity, ocean level, and Dauphin Island well pumping rate were varied during the sensitivity analysis. The sensitivity analysis was conducted on simulations that assumed the clay layer had been removed due to channel dredging over the entire length of the navigation channel.

4.2.1 Hydraulic Conductivity

To test the sensitivity of the model results to hydraulic conductivity, the hydraulic conductivity of one material type was adjusted to be higher or lower than the calibrated value in each sensitivity simulation. Both high end values and low end values were tested in order to bracket the range of possible solutions. In most cases, the ratio of horizontal conductivity (K_h) to vertical conductivity (K_v) was kept the same as the calibrated value. Adjustments to this ratio were explored for the Interbedded A2 material in addition to testing higher and lower conductivity values. Table 2 lists the ranges of hydraulic conductivities used in the sensitivity analysis.

Table 2: Comparison of Calibrated Horizontal (K_h) and Vertical (K_v) Conductivities to Sensitivity Simulation Conductivities

Material	Calibrated K_h/K_v (ft/day)	High End K_h/K_v Sensitivity (ft/day)	Low End K_h/K_v Sensitivity (ft/day)
Barrier Island Water Table Aquifer (A1)	55/5.5	100/10	10/1
Clay (between A1/A2)	0.0025/.00025	0.025/0.0025	0.00025/0.000025
Upper Shallow Sand (Upper A2)	75/7.5	200/20	20/2
Interbedded A2	75/0.75	200/2 and 75/7.5	20/0.2 and 75/.075
Lower Shallow Sand (Lower A2)	75/7.5	200/20	20/2
Clay (Permeable Zone C Outcrop)	0.01/0.001	0.1/0.01	0.001/0.0001

In most instances, the hydraulic conductivity adjustments resulted in little to no change in the direction of particle tracks or the extent of the 1,000 year capture zone, which was used as a very conservative timeframe for comparison purposes between model simulations. It is important to note that particles traced back to their origin have been used to analyze differences between model simulations, regardless of the time it would take those particles to ultimately reach a well, which could be tens of thousands of years. The most notable differences in particle tracks due to changes in hydraulic conductivity occurred under the following conditions:

Increased hydraulic conductivity of Clay: The sensitivity simulation where the horizontal conductivity of the clay between the A1 and A2 aquifers was increased to 0.025 ft/day (vertical conductivity set to 0.0025 ft/day) resulted in some of the particles from the Dauphin Island water supply wells originating from the navigation channel and towards the outcrop of the A2 aquifer in the ocean. The 1,000-year capture zone appears to have shifted slightly southeast as compared to the capture zone predicted by the calibrated model, but the overall capture zone footprint has not noticeably expanded. The 1,000 year capture zone and particle tracks for this sensitivity simulation are shown on Figure 27.

Decreased hydraulic conductivity of Interbedded A2: When the horizontal hydraulic conductivity of the Interbedded A2 Aquifer is decreased to 20 ft/day (vertical conductivity set to 0.2 ft/day), some of the particles that reach the pumping wells on Dauphin Island originate along the outcrop of the A2 aquifer in the ocean and from the extreme southern end of the navigation channel. Additionally, a significant number of particles track back to originate in the higher elevation areas of Baldwin County. The 1,000-year capture zone has shifted slightly to the south and the overall footprint is slightly smaller than the capture zone footprint produced using the calibrated model parameters. Figure 28 shows the particle tracks for this sensitivity simulation.

Decreased hydraulic conductivity of the Clay underlying the outcrop of Permeable Zone C: Both an increase and a decrease in the hydraulic conductivity of the clay in the outcrop region of Permeable Zone C by an order of magnitude produces notably different particle track configurations (See Figure 22 for location of the outcrop). The decrease in hydraulic conductivity produces particle tracks which extend towards the navigation channel and ocean outcrop, resulting in a worst-case-scenario. However, this change in conductivity produces water levels in the mainland outcrop areas over 20 or 30 ft lower than their calibrated levels, which is unrealistic. Particle track results for this simulation are unreliable because of the unrealistic flow field. However, even under these extreme and unrealistic conditions, the 1,000-year capture zones for the Dauphin Island wells, shown on Figure 29, do not reach the navigation channel and have a similar footprint to results using the calibrated conductivity values.

Flow into the aquifer below the channel was also computed for each hydraulic conductivity sensitivity simulation. In most of the sensitivity simulations, the shipping channel remained an area of groundwater discharge to the surface. Minor inflows from the channel to the aquifer to the east and southeast of Dauphin Island were noted during a few of the sensitivity simulations including when the hydraulic conductivity of the clay was increased and when the hydraulic conductivity of the interbedded A2 aquifer was decreased. The total downward flow within the shipping channel did not exceed 0.032 MGD in these simulations, which is only a fraction of the 0.785 MGD average groundwater withdrawals made from the Dauphin Island wells in 2018. Additionally, flat hydraulic gradients in the vicinity of the shipping channel result in velocities that are very slow. Water entering the aquifer at the shipping channel may take thousands of years to reach the wells on Dauphin Island. The hydraulic conductivity sensitivity analysis confirms that any seawater intrusion that might occur on Dauphin Island is expected to be low in magnitude and occur over an extended period of time.

4.2.2 Sea Level Rise

The sensitivity of the model to sea level was tested by adjusting the boundary conditions representing the ocean along the top and southern model boundaries to be 1.2 ft NAVD 88. Previously, the ocean boundary had been set to an elevation of 0 ft NAVD 88 to approximate average tidal conditions (see Section 2.5). A 1.2 ft increase in ocean level corresponds to the approximate change in sea level that is expected to occur over the course of 100 years based on the relative sea level trend at the Dauphin Island tide gauge (3.61 mm/year) determined by NOAA. Tides on Dauphin Island can often exceed 1.2 ft NAVD88, but high water tidal events are transient in nature and are balanced by the occurrence of low water events. Impacts to the movement of saline or brackish water through the aquifer due to extreme tidal events would be short-term and would have little impact on the long term effects to water quality on Dauphin Island. Therefore, assessing the impact from sea level rise on the average ocean level was considered more appropriate than assessing the impacts from short-term extreme events.

Figure 30 shows particle tracks for a model simulation that includes the deepened channel fully penetrating the clay layer and a 1.2 ft increase in sea level. Under the increased ocean level, there is a minor shift in the particle tracks to the Dauphin Island wells, showing the potential for water entering the Dauphin Island wells to originate at the A2 Aquifer outcrop in the ocean where more saline water could exist. However, it would take more than 1,000 years to draw in water from the ocean outcrop, and the 1,000-year capture zone under the increased sea level is almost identical to the capture zone using the lower ocean level of 0 ft NAVD 88.

4.2.3 Dauphin Island Pumping

The final sensitivity analysis tested the impact of the Dauphin Island well pumping rate on the model results. Previous simulations assumed that the pumping rate for the three operational Dauphin Island water supply wells (Well 2, Well 4, and Well 6) were equal to the average pumping rate for 2018, or a total withdrawal of 0.785 MGD. In order to assess the impacts from additional pumping, the pumping rate for each well was increased to the peak rate recorded in any year from 2003 to 2018, resulting in a total extraction rate of 2.125 MGD from Dauphin Island (well over two times the average pumping rate from 2018). Under these increased pumping conditions, some particles from the Dauphin Island wells extend back to an origin at the navigation channel as well as the A2 Aquifer outcrop, as shown on Figure 31. Under deepened conditions, the amount of flow entering the aquifer from the channel is approximately 0.26 MGD, or 12% of the total peak pumping rate from Dauphin Island, representing only a small portion of the total water supply. The 1,000-year capture zone is also noticeably larger than the capture zone of the Dauphin Island wells pumping at lower rates. The inset image of the 1,000-year capture zone on Figure 31 includes a yellow outline of the capture zone from the model simulation with the Dauphin Island wells pumping at their average rates.

The particle tracks produced by a simulation including increased Dauphin Island pumping with existing (non-deepened) channel conditions were assessed and are shown on Figure 32. This simulation illustrates that there is a potential for increased pumping on Dauphin Island to increase the risk of saltwater intrusion even if the channel is not deepened. Under the non-deepened conditions, the greatest risk for saltwater intrusion is from the A2 Aquifer outcrop into the ocean whereas deepening the channel may increase the risk for saltwater intrusion from the southern end of the shipping channel.

5 Conclusions and Recommendations

The proposed deepening of the Mobile Bay shipping channel has the potential to cut through clay that separates the seawater from the brackish water within the A2 aquifer used for water supply on Dauphin Island. Removal of the clay would result in a direct hydraulic connection between the surface water of the bay and the brackish water in the aquifer below, potentially exposing Dauphin Island to increased saltwater intrusion. In order to evaluate the potential increased risk for saltwater intrusion on Dauphin Island due to deepening of the channel, a series of groundwater flow modeling simulations were performed. Although the deepening of the shipping channel may expose the aquifer below the channel to increased levels of salinity, the modeling simulations indicated that the impact to the Dauphin Island water supply wells is expected to be low in magnitude and occur over an extended period of time but will also be highly dependent on future groundwater usage rates on Dauphin Island.

Under existing conditions, the model shows that the wells on Dauphin Island are primarily capturing groundwater that originally entered the aquifer system in the mainland areas of Mobile County but also pull brackish water from areas south and east of the island. Modeling simulations along with a comprehensive sensitivity analysis have shown that the majority of Mobile Bay along with the navigation channel is a discharge area for regional groundwater flow. Even if the clay layer is removed in these discharge areas, groundwater will flow out of the aquifer and into the bay under average conditions, although there could be short-term reversals of flow during high-tides. A few simulations exploring the sensitivity of the model to hydraulic conductivity indicated a potential for water in the shipping channel to enter the A2 Aquifer to the east and/or southeast of Dauphin Island. However, the quantity of water entering the aquifer from the shipping channel is very small compared to the average daily pumping rate on Dauphin Island (4% at most). Movement of saltwater due to density effects has not been quantified with this model but may result is some additional flux of saltwater into the aquifer in the immediate vicinity of the shipping channel. Over the long-term, increases in groundwater withdrawals from the A2 aquifer on Dauphin Island or sea level rise pose a risk to saltwater intrusion whether or not the Mobile Bay shipping channel is deepened.

Hydraulic gradients in the vicinity of locations where seawater could enter the A2 Aquifer (shipping channel and ocean outcrop) are small, resulting in low groundwater flow velocities. Model simulations suggest that it may take thousands of years for water that enters the aquifer system at the shipping channel or the A2 Aquifer ocean outcrop to make its way to the Dauphin Island wells. Minor shifts in particle track capture zones due to channel deepening will likely have little impact on the water quality of the Dauphin Island wells over the 50-year design life of the deepening project. However, some consideration must be given to the potential for shifts in capture zones to the south of Dauphin Island to reach areas that may have been previously impacted by saltwater intrusion due to historical pumping. Since little is known about the location of the interface between the seawater and brackish water used for water supply, the impact from shifts in capture zones due to the deepening cannot be quantified. Although this capture zone analysis predicts insignificant impacts of the proposed deepening on the capture zones of the Dauphin Island pumping wells, additional salinity data in the aquifers is needed to fully quantify the potential migration of saline water. Conversely, the model-predicted impacts to the capture zones from future Dauphin Island pumping changes and sea level rise were notable; however, prediction of future sea level and pumping rates is uncertain. Even if saltwater intrusion has impacted a portion of the capture zone, particle tracking indicates that under all conditions, the Dauphin Island wells pull in water radially, with a significant portion of the capture zone extending to the north of Dauphin Island, where water is expected to be lower in salinity. Due to the low likelihood of Dauphin Island experiencing increased saltwater intrusion due to the Mobile Harbor channel deepening, no additional investigation is recommended at this time. Although additional salinity data would result in a more quantitative analysis of salinity movement due to the various aquifer stresses, substantial uncertainty would remain and the cost of this additional analyses is not warranted.

6 REFERENCES

Anderson, Mary P., Woessner, William P., and Hunt, Randall J. Applied Groundwater Modeling, Second Edition. Elsevier Inc, 2015.

Geological Survey of Alabama, 2018, Assessment of groundwater resources in Alabama, 2010-16: Alabama Geological Survey Bulletin 186, 426 p., plus separately bound volume of 105 plates.

Gillett, B., D.E. Raymond, J.D. Moore, and B.H. Tew, 2000. Hydrogeology and Vulnerability to Contamination of Major Aquifers in Alabama: Area 13.

Harbaugh, A.W., 2005, MODFLOW-2005, the U.S. Geological Survey modular ground-water model -- the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16.

Kidd, Robert E., 1988. Hydrogeology and Water Supply Potential of the Water Table Aquifer on Dauphin Island, Alabama, U.S. Geological Survey Water Resources Investigation Report 87-4283.

Martin, Angel, Jr. and C.D. Whiteman, Jr., 1989. Geohydrology and Regional Groundwater Flow of the Coastal Lowlands Aquifer System in Parts of Louisiana, Mississippi, Alabama and Florida. U.S. Geological Survey Water Resources Investigation Report 88-4100.

Martin, Angel, Jr. and C.D. Whiteman, Jr., 1990. Calibration and Sensitivity Analysis of a Groundwater Flow Model of the Coastal Lowlands Aquifer System in Parts of Louisiana, Mississippi, Alabama and Florida. U.S. Geological Survey Water Resources Investigation Report 89-4189.

Martin, Angel, Jr. and C.D. Whiteman, Jr., 1999. Hydrology of the Coastal Lowlands Aquifer System in Parts of Alabama, Florida, Louisiana, and Mississippi. U.S. Geological Survey Professional Paper 1416-H.

Moore, James D., Hinkle, Frank, and Barksdale Henry C., 1977. Geohydrology of the Proposed Theodore Ship Channel, Mobile County, Alabama.

Montiel, Daniel, 2018. Is Submarine Groundwater Discharge (SGD) Important for the Historical Fish Kills and Harmful Algal Bloom Events of Mobile Bay?, Coastal and Estuarine Research Federation.

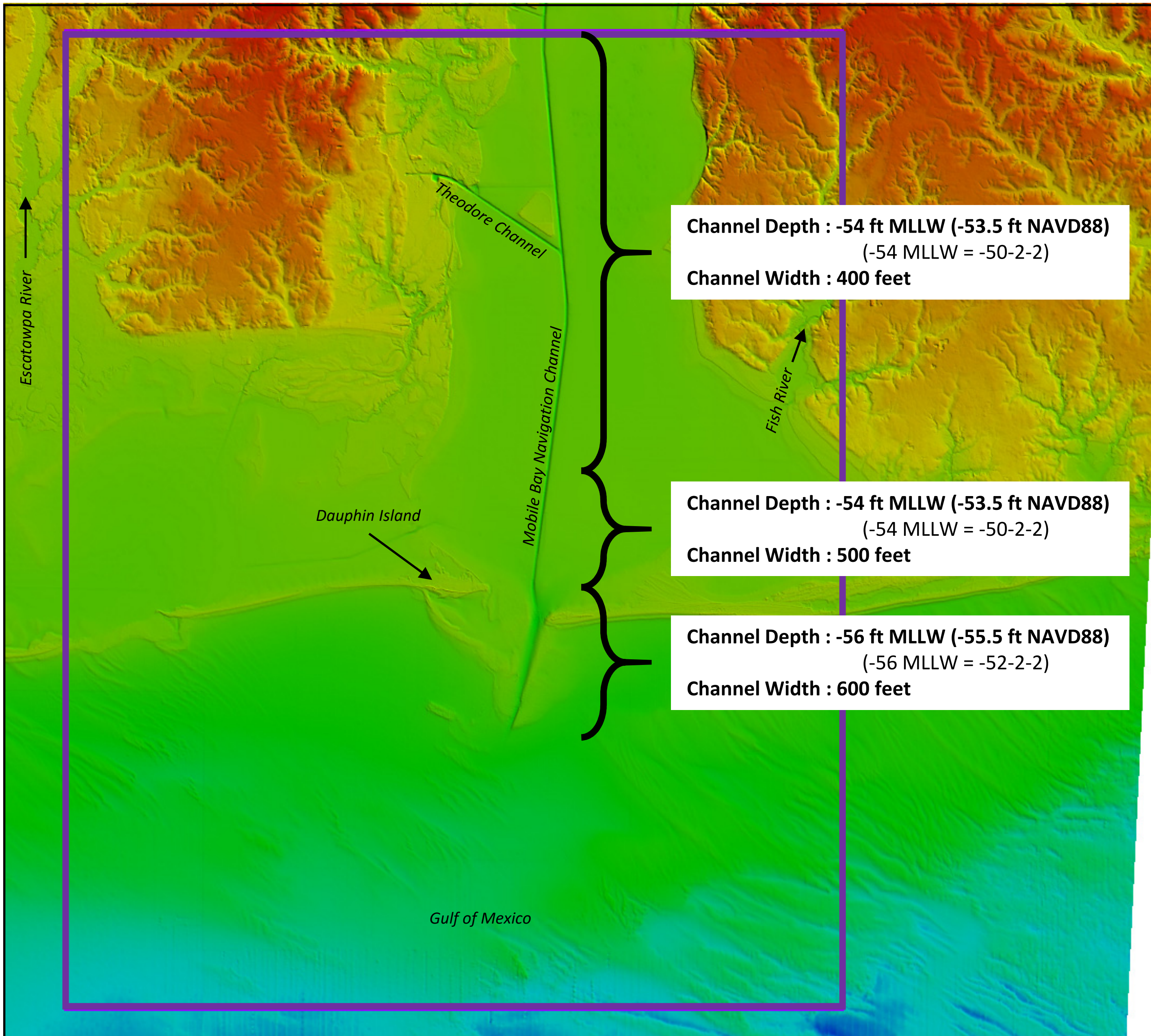
Murgulet, Dorina, 2009. Groundwater Flow Dynamics and Contaminant Transport to the Coastal Waters under Low Recharge Conditions: Regional Scale Study of the Aquifer System Underlying Southern Baldwin County.

Murgulet, Dorina and Tick, Geoffrey R., 2008. Assessing the extent and sources of nitrate contamination in the aquifer system of southern Baldwin County, Alabama.

National Oceanic and Atmospheric Association (NOAA), 2019. Tides and Currents, online resource: https://tidesandcurrents.noaa.gov/map/index.html?region=Alabama

Rich, Kendal A., 2006. Hydrogeology of Fort Morgan Peninsula: Modeling Capture Zone Assessment.

Weiss, Johathan S., 1992. Geohydrologic Units of the Coastal Lowlands Aquifer System, South-Central United States. U.S. Geological Survey Professional Paper 1416-C.



Legend

Elevation (feet NAVD88)

250

50

-150

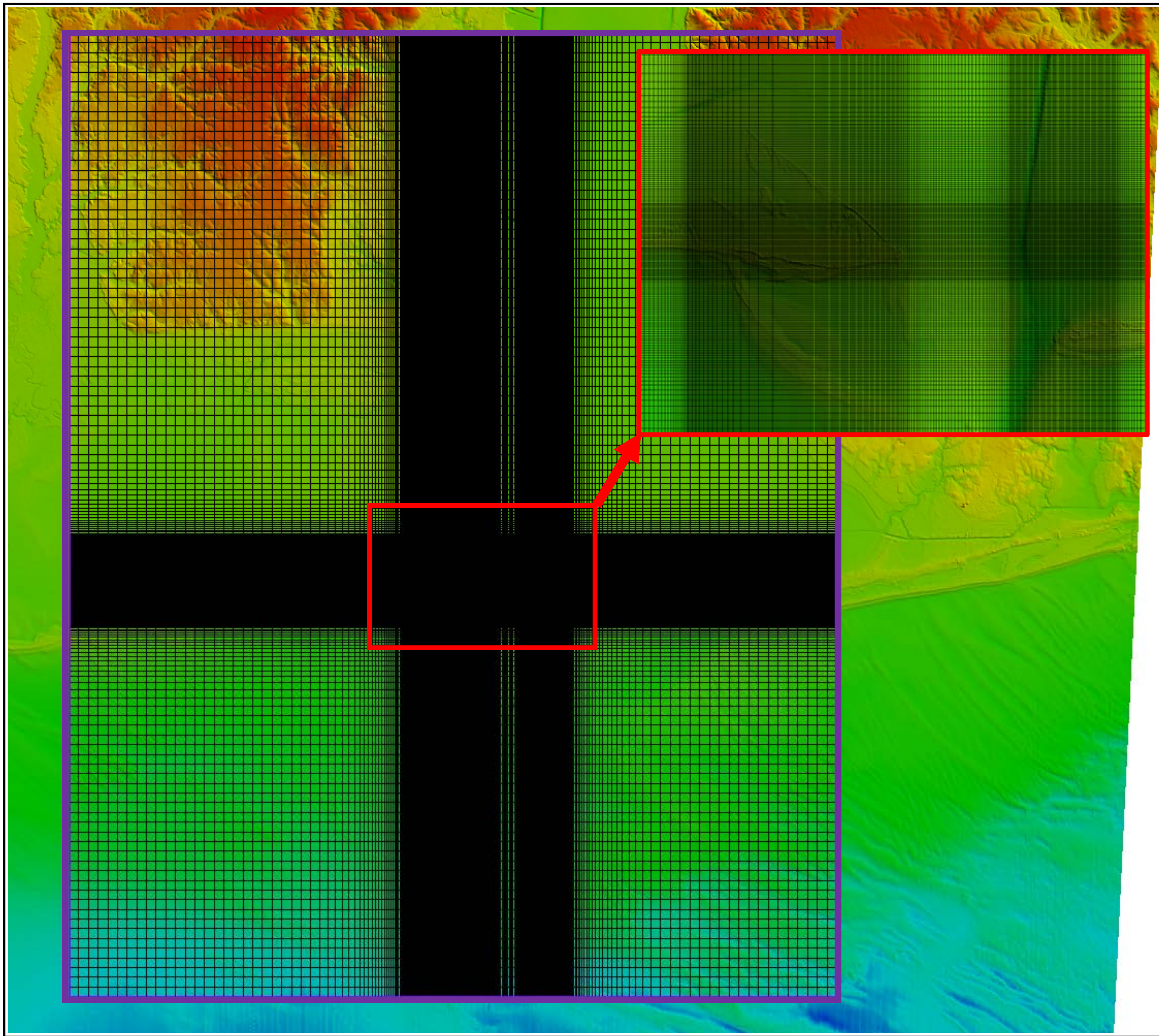
Model Domain

Notes:
Topography/Bathymetry based on NOAA Coastal Lidar for Northern Gulf of Mexico

Model Domain

Figure 1

March 2019

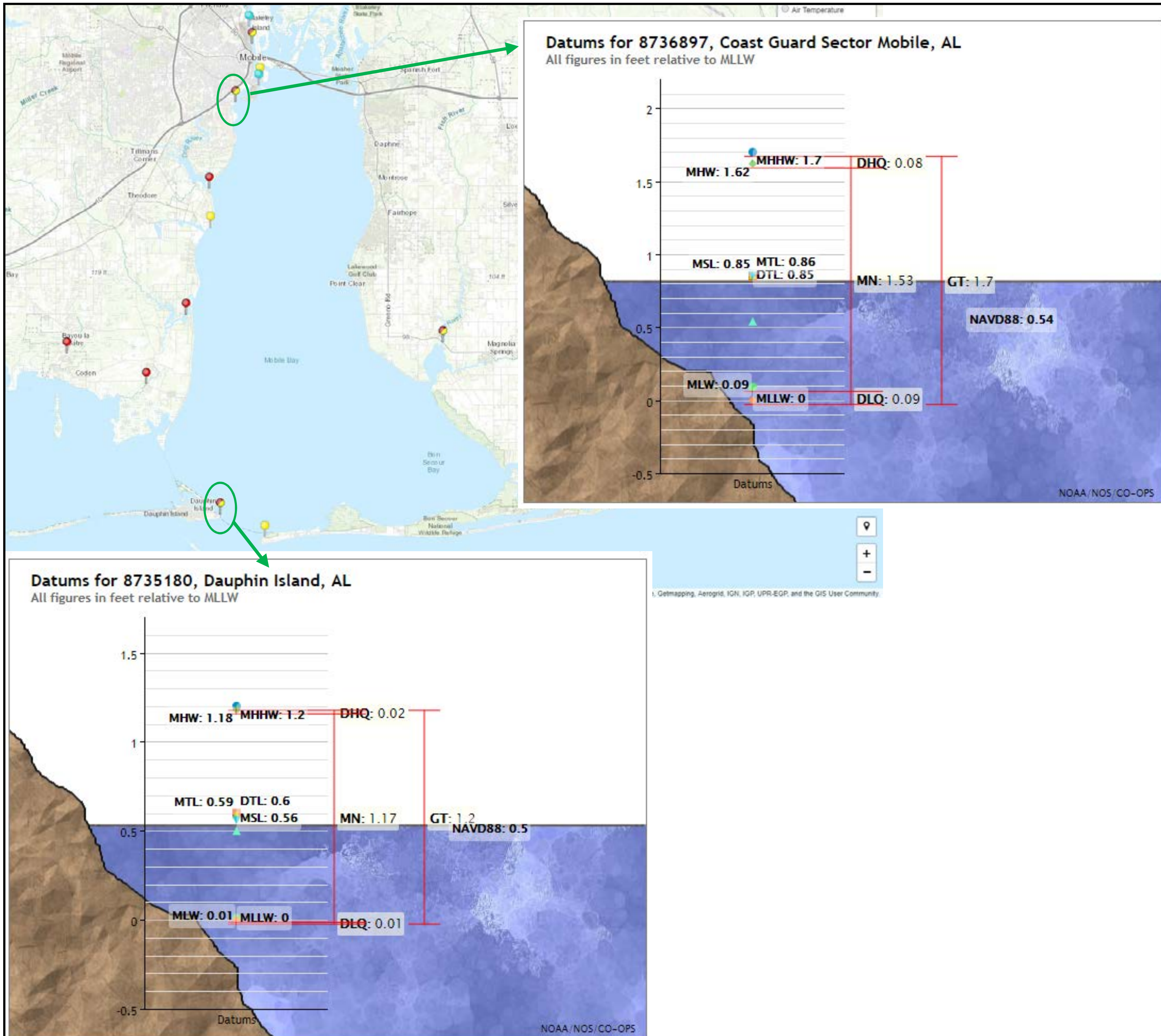


Notes:
Resolution along the channel and at Dauphin Island 100 ft.
Resolution at model extents 2,500 ft.

Model Resolution

Figure 2

March 2019



Notes:

Data received in various datums was converted to ft NAVD88 for modeling purposes.

NAVD88 = MLLW + 0.5

References:

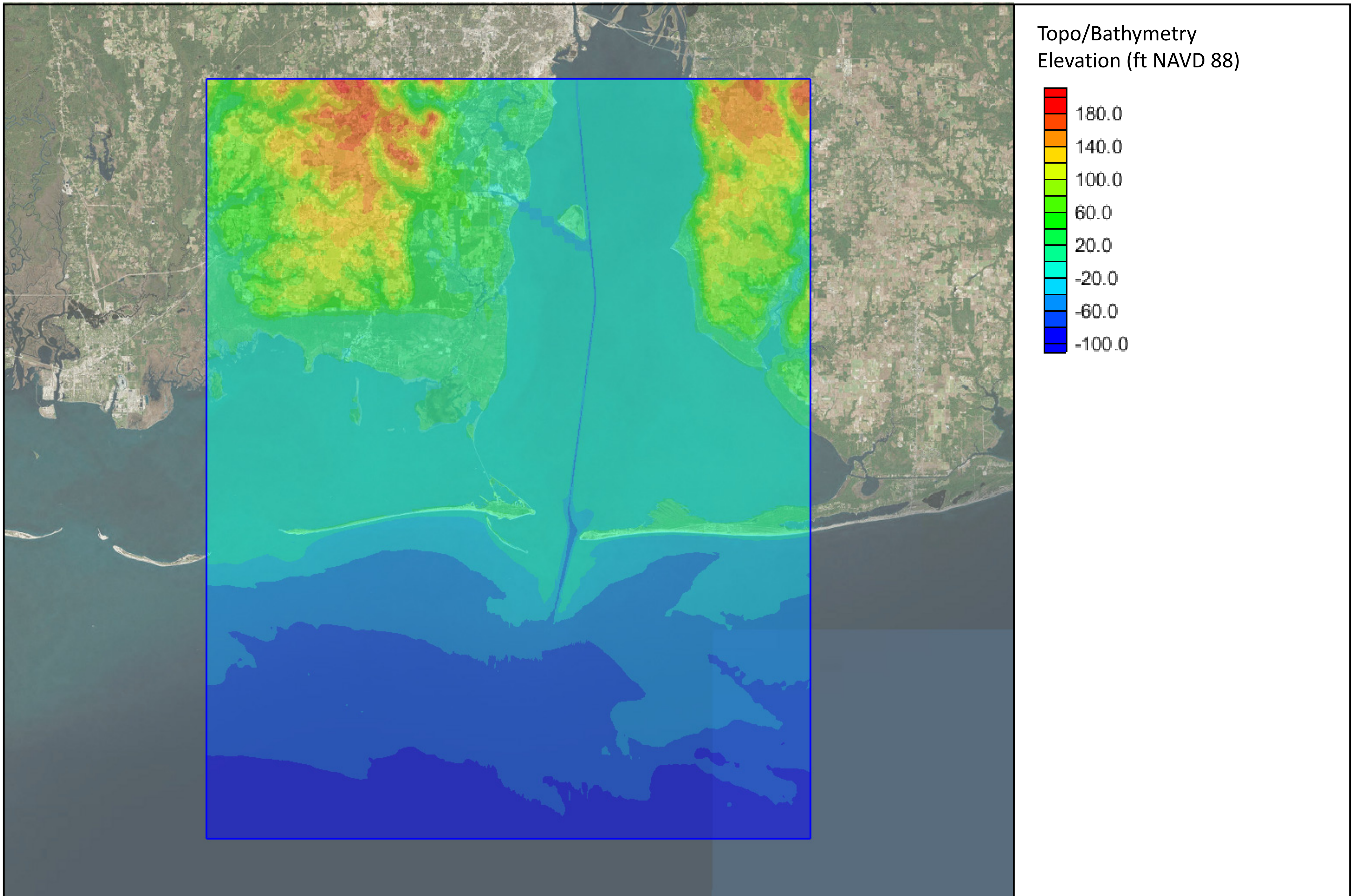
https://tidesandcurrents.noaa.gov/datums.html?id=8735180

https://tidesandcurrents.noaa.gov/datums.html?id=8736897

Datum Conversion

Figure 3

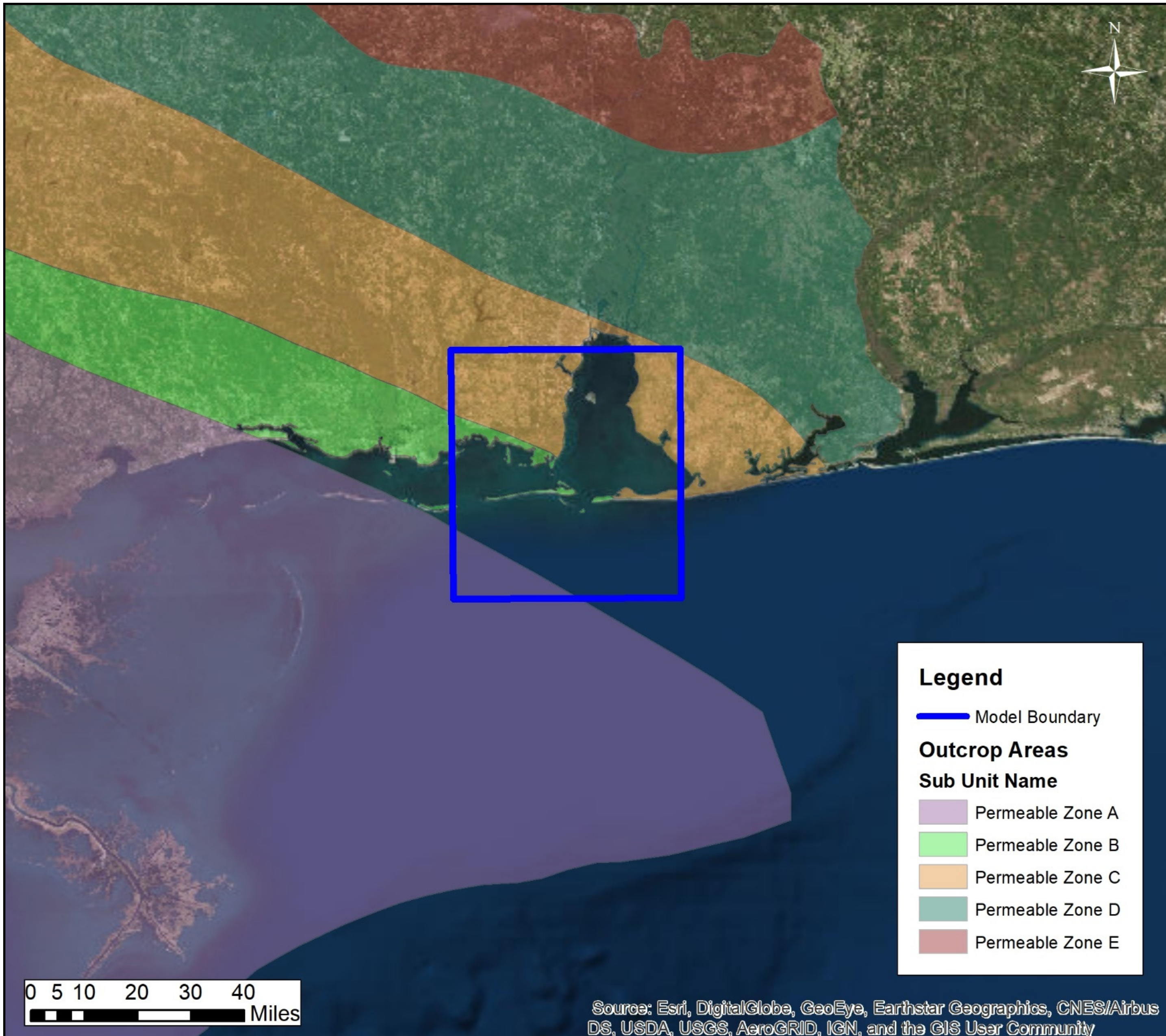
March 2019



Topography/Bathymetry within Model Domain

Figure 4

March 2019

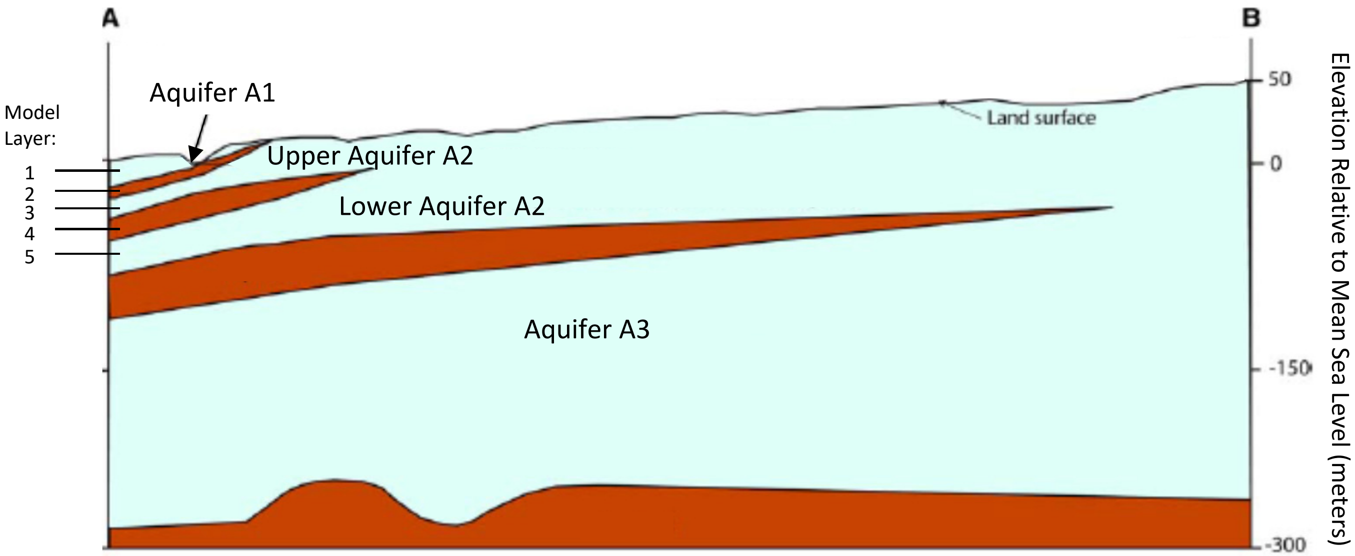


<u>Notes:</u>
Outcrops of major hydrogeologic units of the Coastal Lowlands Aquifer system have been adapted from *Geohydrologic Units of the Coastal Lowlands Aquifer System South-Central United States, Regional Aquifer System Analysis-Gulf Coastal Plain*, U.S. Geological Survey Professional Paper 1416-C (Weiss, 1992)

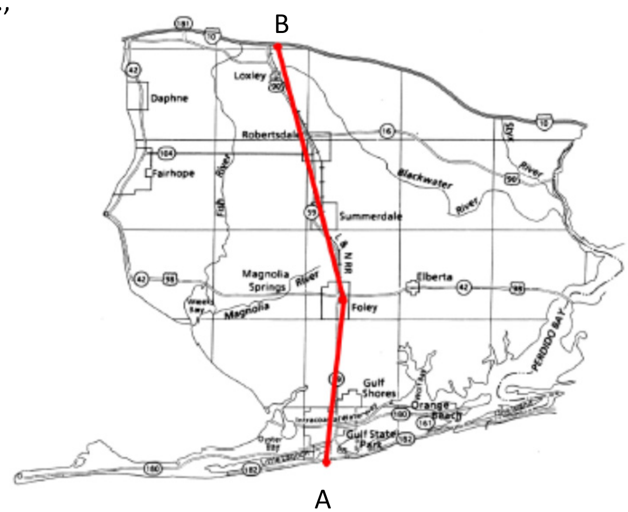
Regional Geology from Previous Studies

Figure 5

March 2019



Adapted from Chandler et al., 1985; Gillett et al., 2000; Murgulet and Tick, 2008.



Legend

- Aquifer
- Aquitard

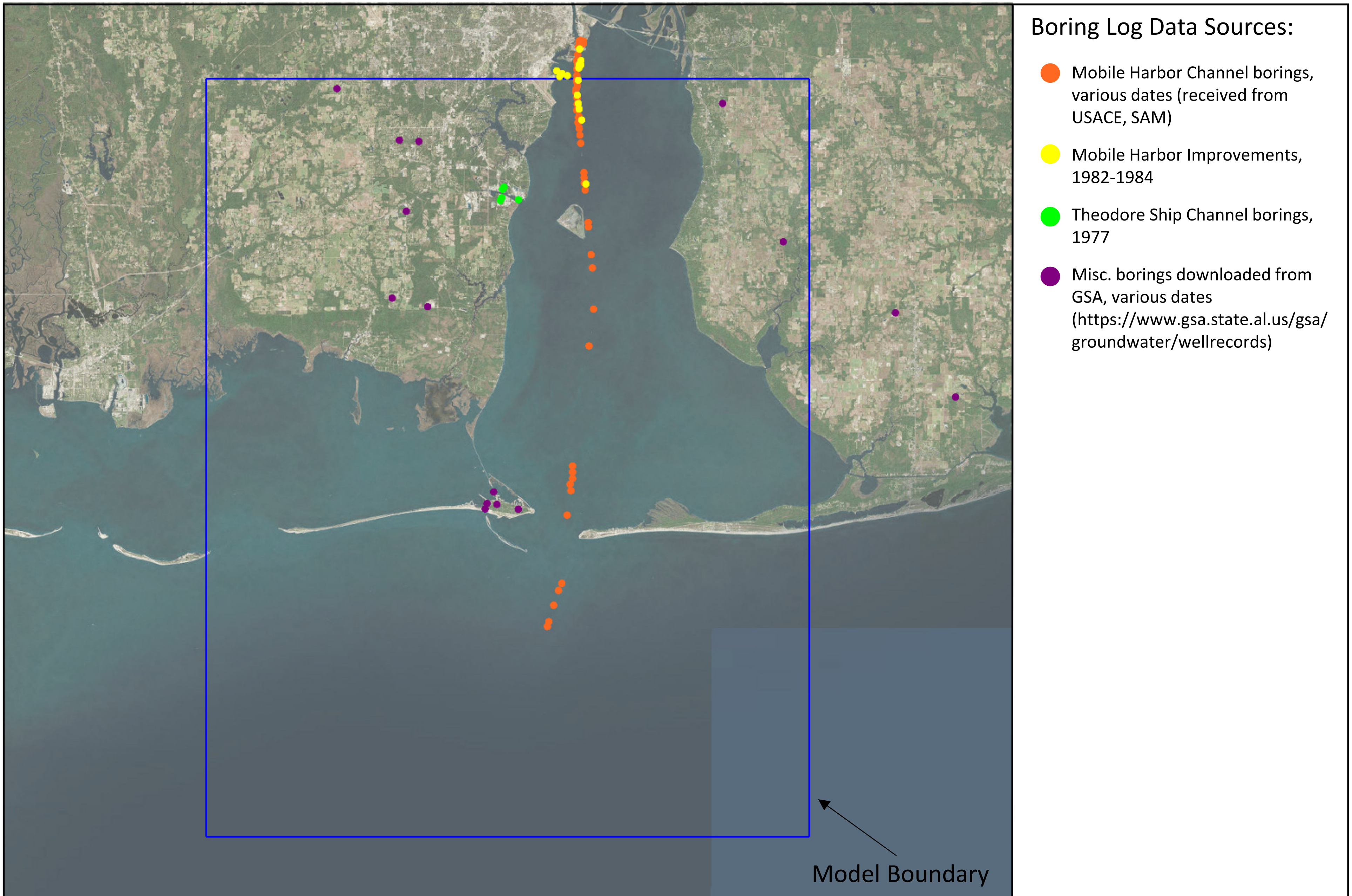
Notes:

The cross section shows a conceptual depiction of the hydrogeologic units in Mobile and Baldwin Counties. The model includes aquifers A1, Upper A2, Lower A2 and the zones of lower permeability in between the aquifers. The bottom boundary of the model coincides with the aquitard that separates Lower Aquifer A2 from Aquifer A3.

Regional Geology Depicted in the Model

Figure 6

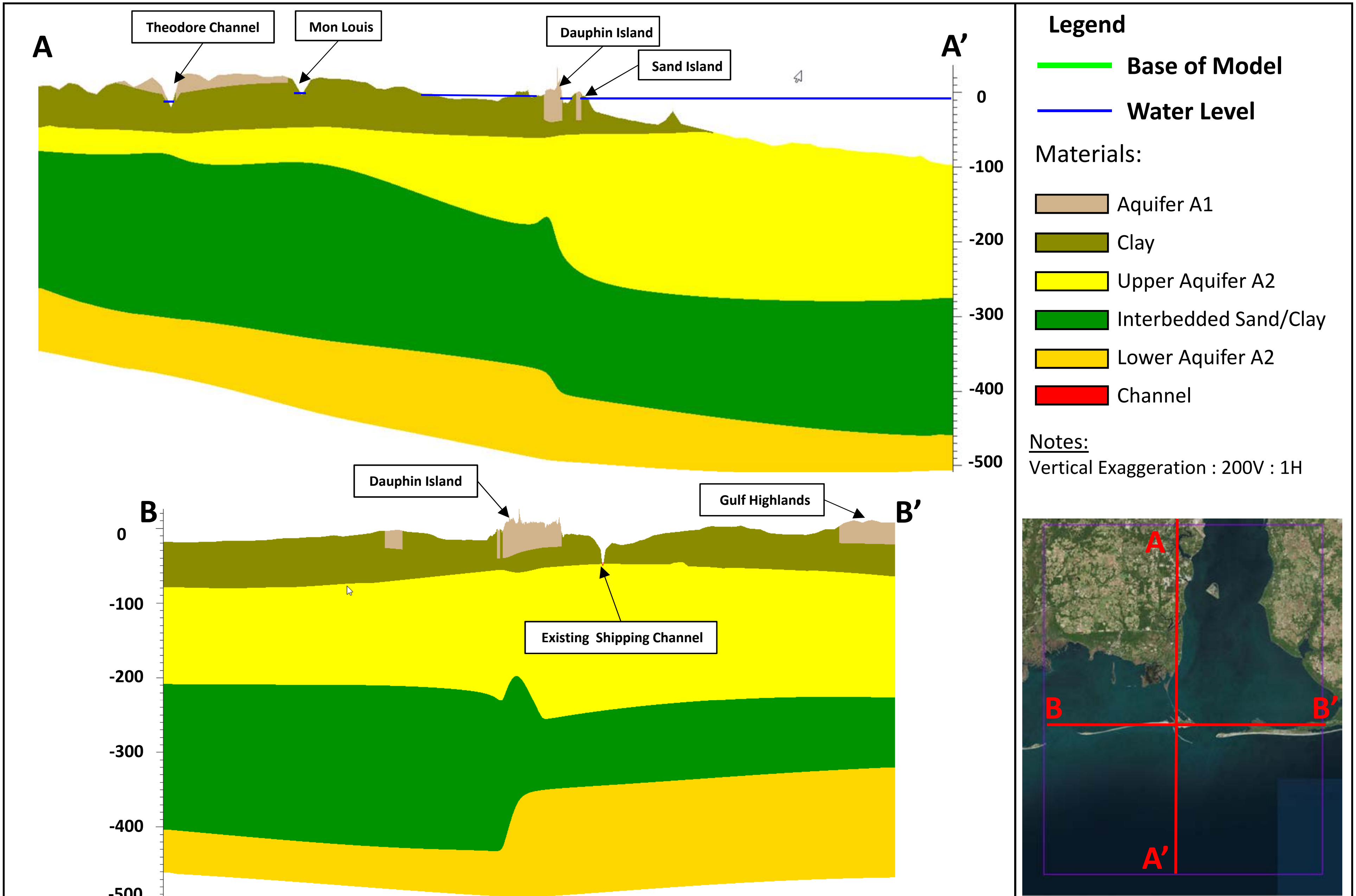
March 2019



Locations of Boreholes Used for Geologic Model

Figure 7

March 2019



Conceptual Geologic Model

Figure 8

March 2019

Materials:

Aquifer A1

Clay

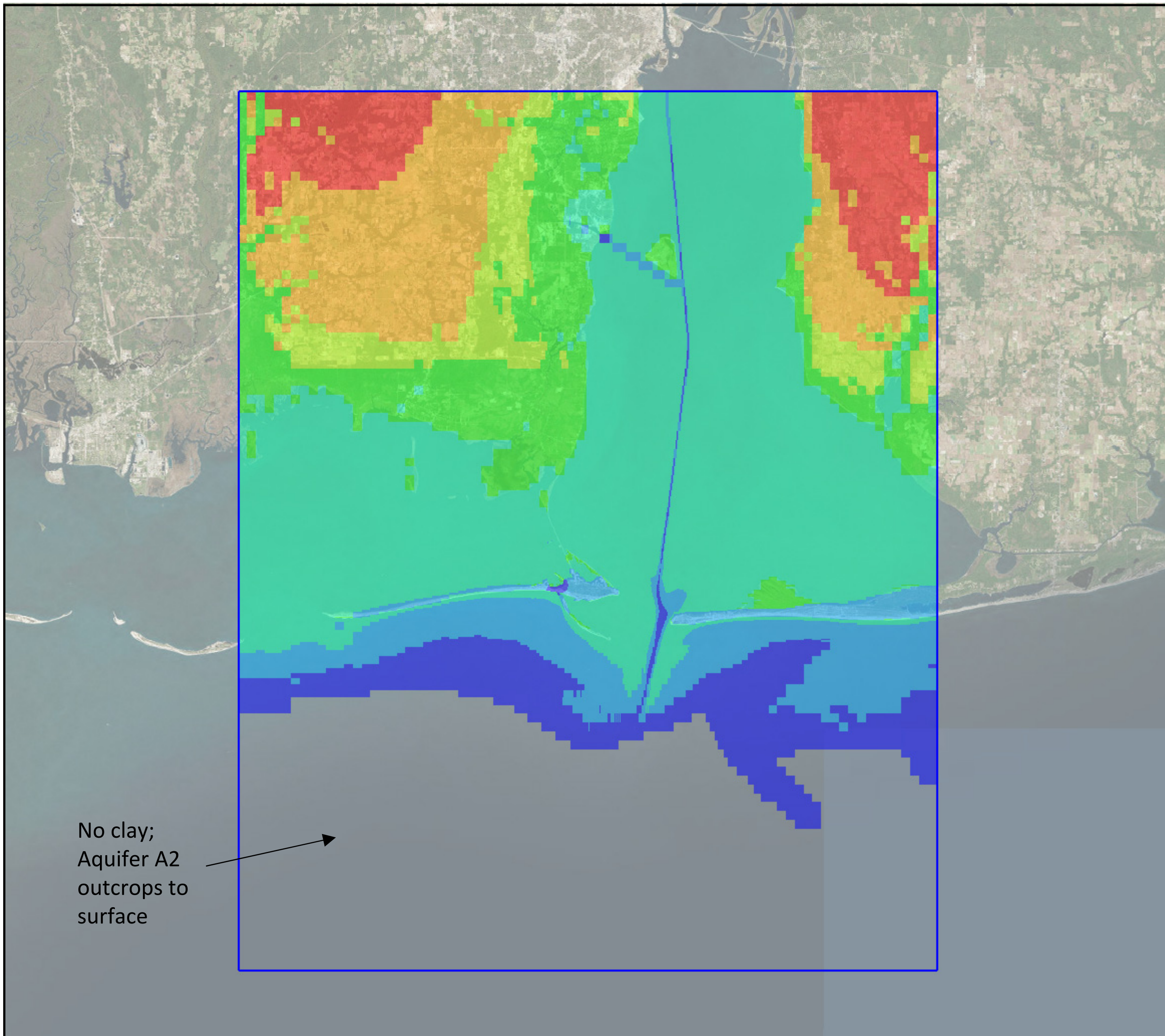
Upper A2 Aquifer

Channel

Surface Materials

Figure 9

March 2019



Legend

Top of Clay Elevation, ft NAVD 88

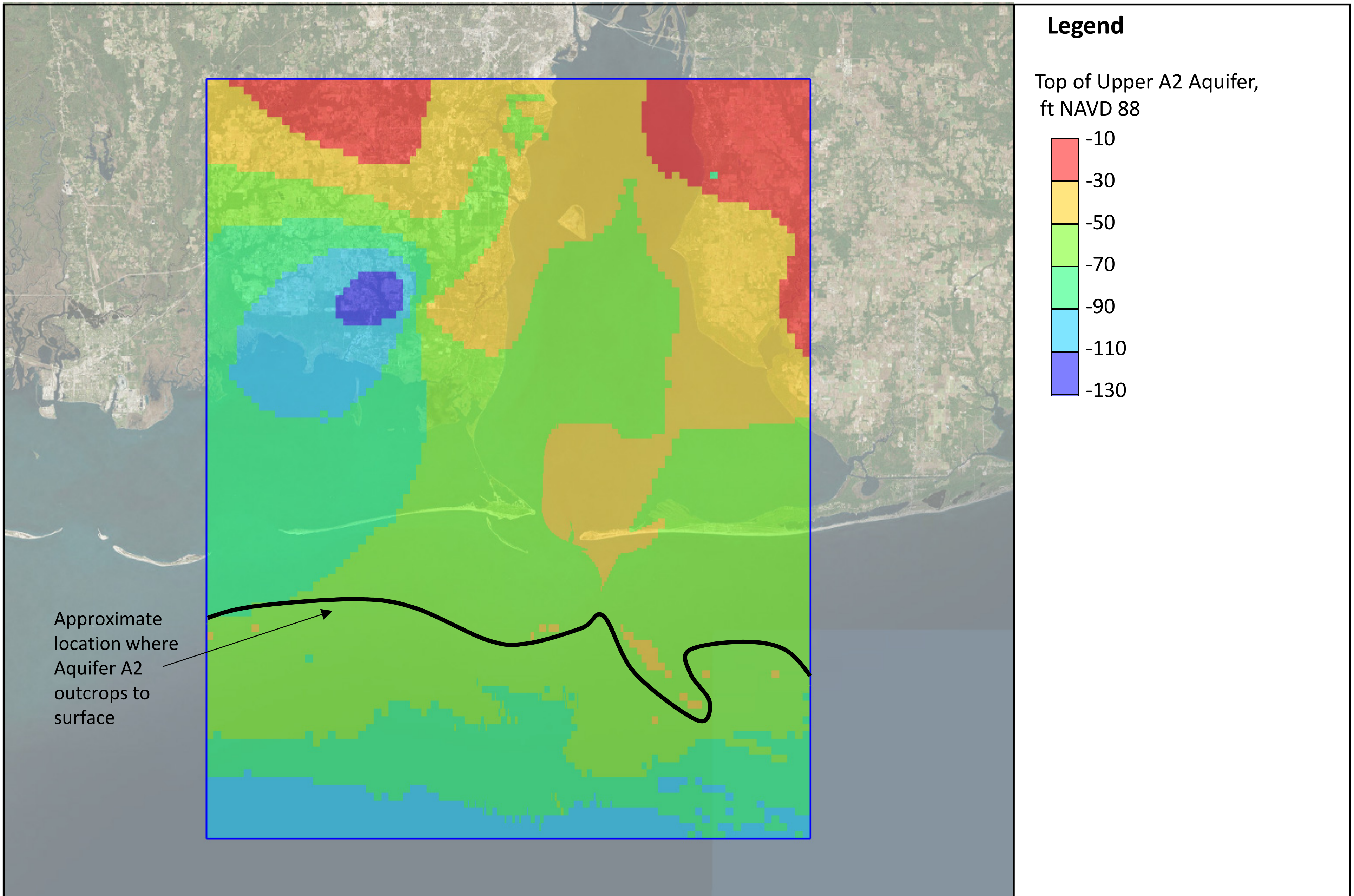
80
60
40
20
0
-20
-40
-60

Notes:
This figure shows the top of the clay unit between aquifers A1 and A2. This clay unit does not exist in the southern portion of the model where Aquifer A2 outcrops to the surface.

Top Elevation of Clay

Figure 10

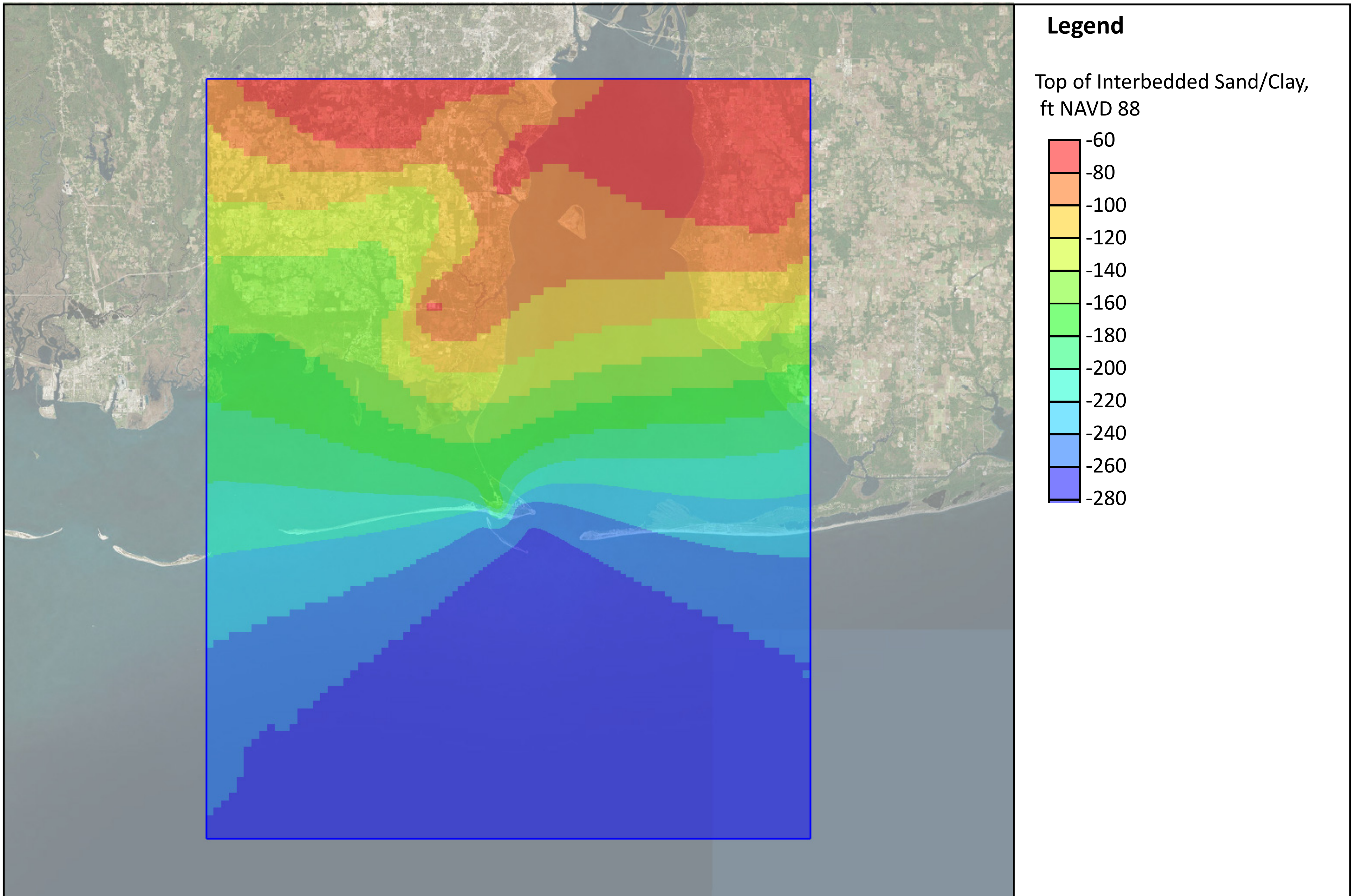
March 2019



Top Elevation of Upper Aquifer A2

Figure 11

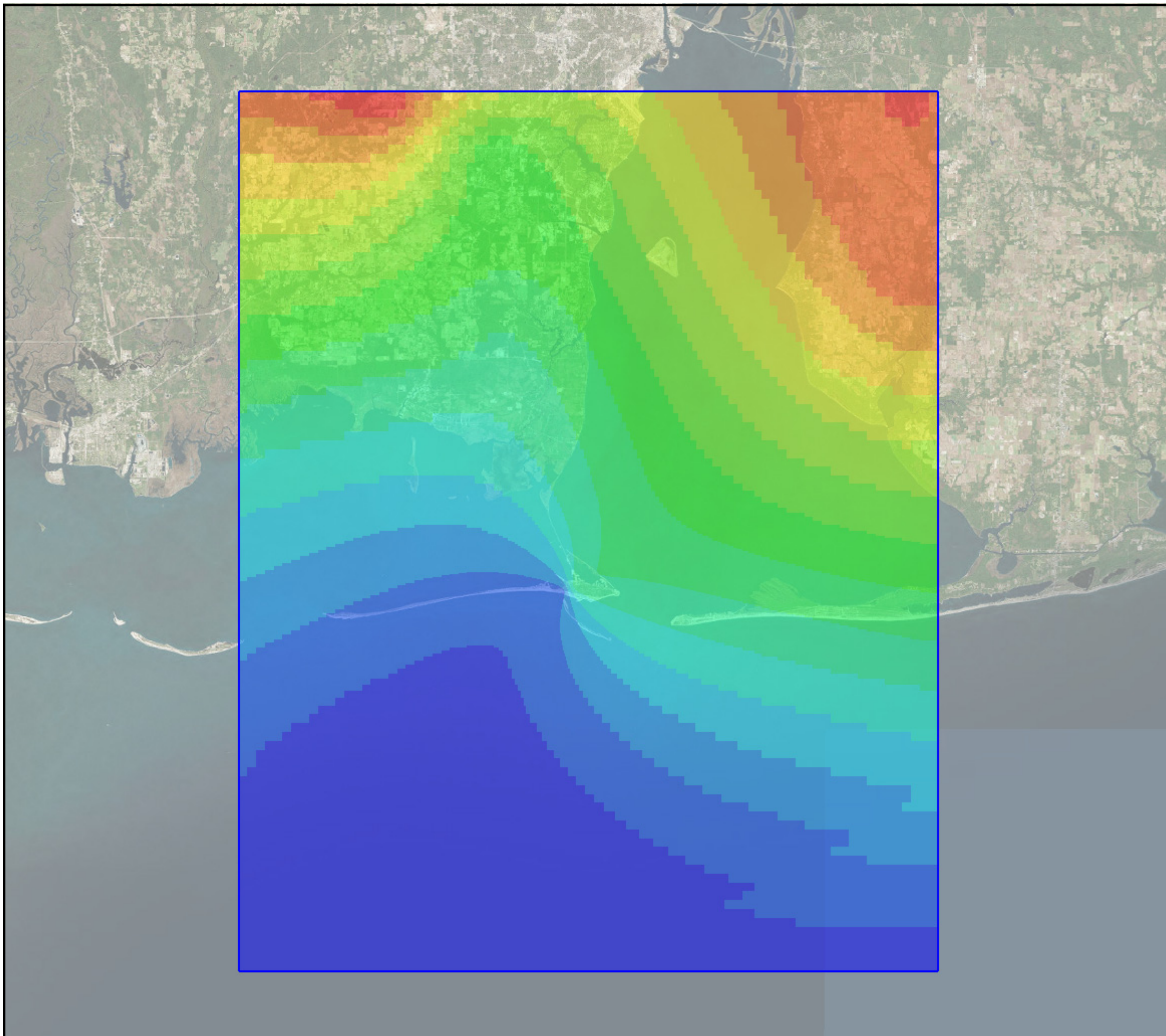
March 2019



Top Elevation of Interbedded Sand/Clay

Figure 12

March 2019



Legend

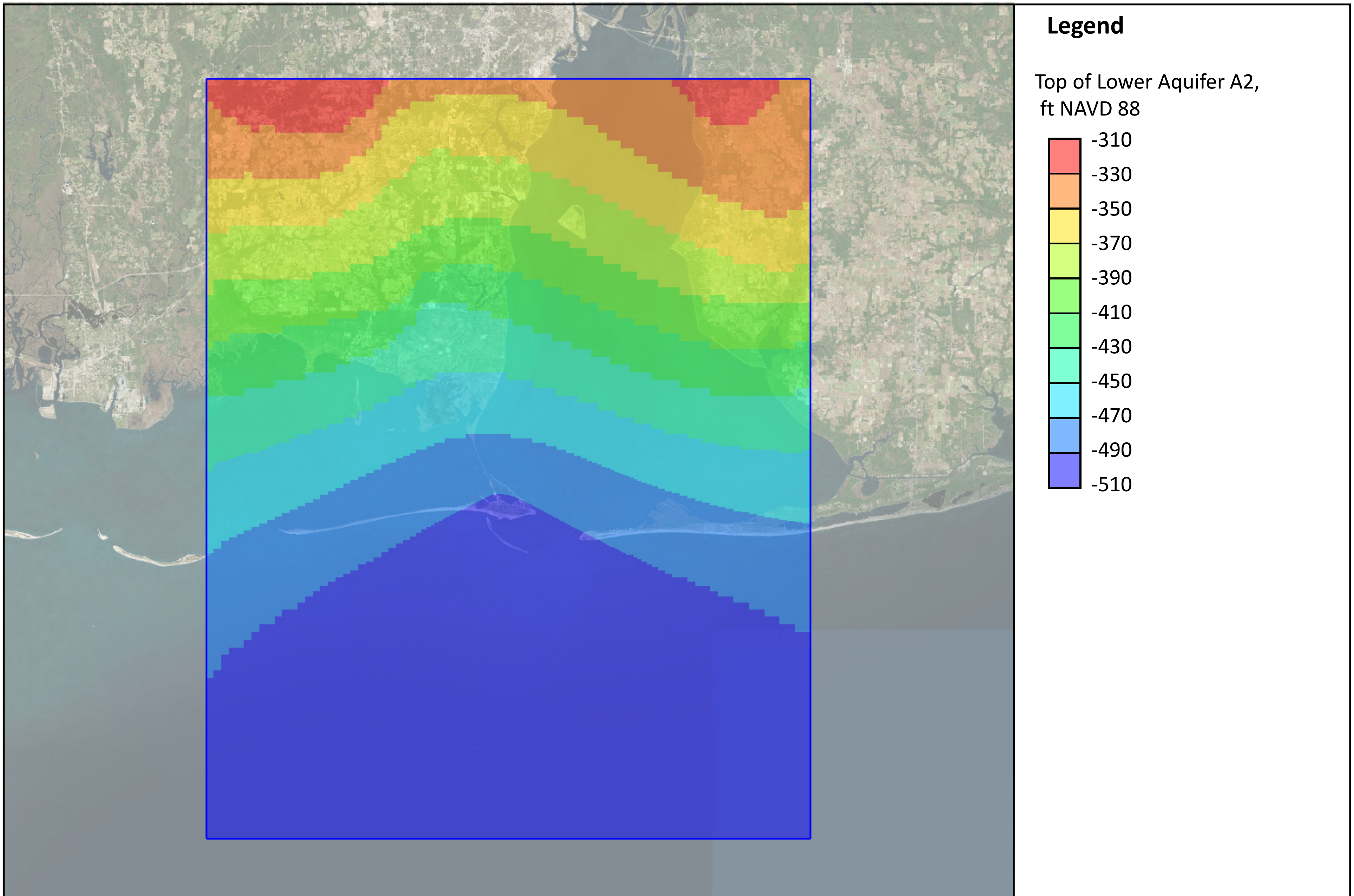
Top of Lower Aquifer A2,
ft NAVD 88

-160
-180
-200
-220
-240
-260
-280
-300
-320
-340
-360
-380
-400
-420
-440
-460

Top Elevation of Lower Aquifer A2

Figure 13

March 2019

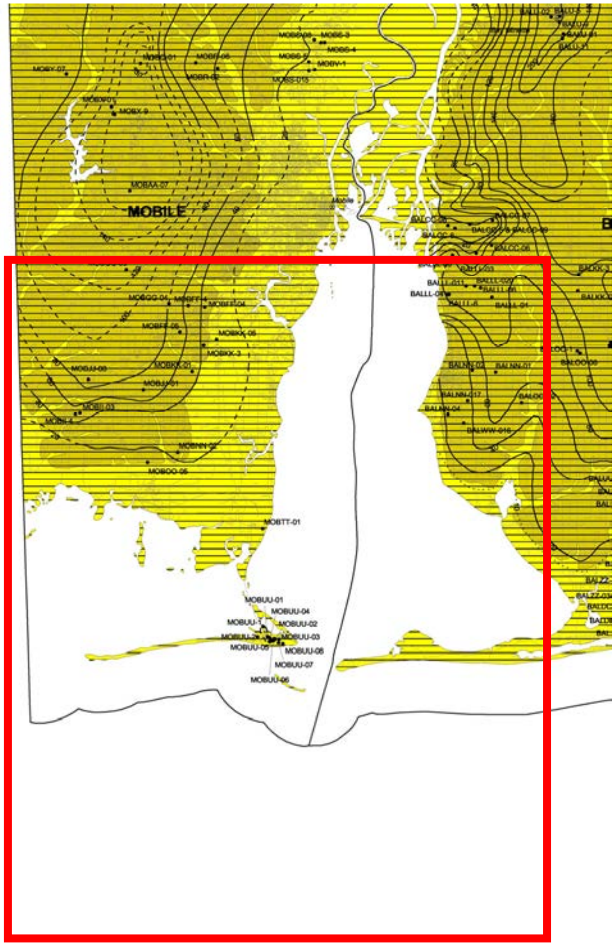


Bottom Elevation of Lower Aquifer A2

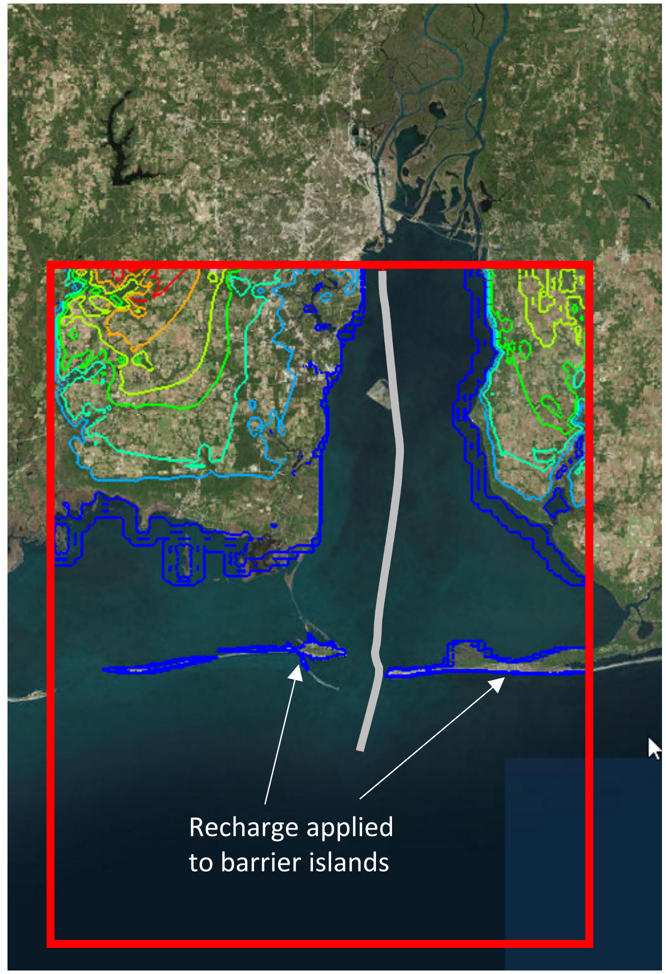
Figure 14

March 2019

Gillett et al. (2000)



Modeled Boundaries



Legend

Elevation (feet NAVD88)

120

60

0

Model Domain

Notes:

Contours interval is 20 ft and depict surface boundary conditions.

Surface boundary conditions on mainland based on potentiometric surface in “Hydrogeology and Vulnerability to Contamination of Major Aquifers in Alabama_Area 13”, Plate 1 by Gillett et al. (2000).

Bay and ocean assumed to be sea level.

Barrier islands assumed to have between 6 and 20 in/year recharge based on Kidd (1988)

Downstream boundary assumed to be mean sea level.

Boundary Conditions

Figure 15

March 2019

YEAR	WELL 2		WELL 4		WELL 6	
	YEAR AVG (MGD)	PEAK (MGD)	YEAR AVG (MGD)	PEAK (MGD)	YEAR AVG (MGD)	PEAK (MGD)
2018	0.143	0.274	0.125	0.248	0.517	1.093
2017	0.123	0.265	0.116	0.305	0.371	0.838
2016	0.102	0.314	0.106	0.284	0.389	0.971
2015	0.069	0.126	0.089	0.160	0.471	0.832
2014	0.000	0.000	0.000	0.000	0.596	1.000
2013	0.000	0.000	0.000	0.000	0.527	0.953
2012	0.000	0.000	0.000	0.000	0.559	0.858
2011	0.161	0.309	0.22	0.246	0.628	1.123
2010	0.173	0.319	0.214	0.299	0.000	0.000
2009	0.142	0.327	0.205	0.289	0.000	0.000
2008	0.138	0.327	0.166	0.252	0.000	0.000
2007	0.149	0.332	0.194	0.269	0.000	0.000
2006	0.138	0.329	0.223	0.320	0.000	0.000
2005	0.183	0.484	0.256	0.427	0.000	0.000
2004	0.184	0.482	0.222	0.518	0.000	0.000
2003	0.153	0.355	0.173	0.328	0.000	0.000

Legend

Shipping Channel

Notes:

Pumping data provided by Dauphin Island

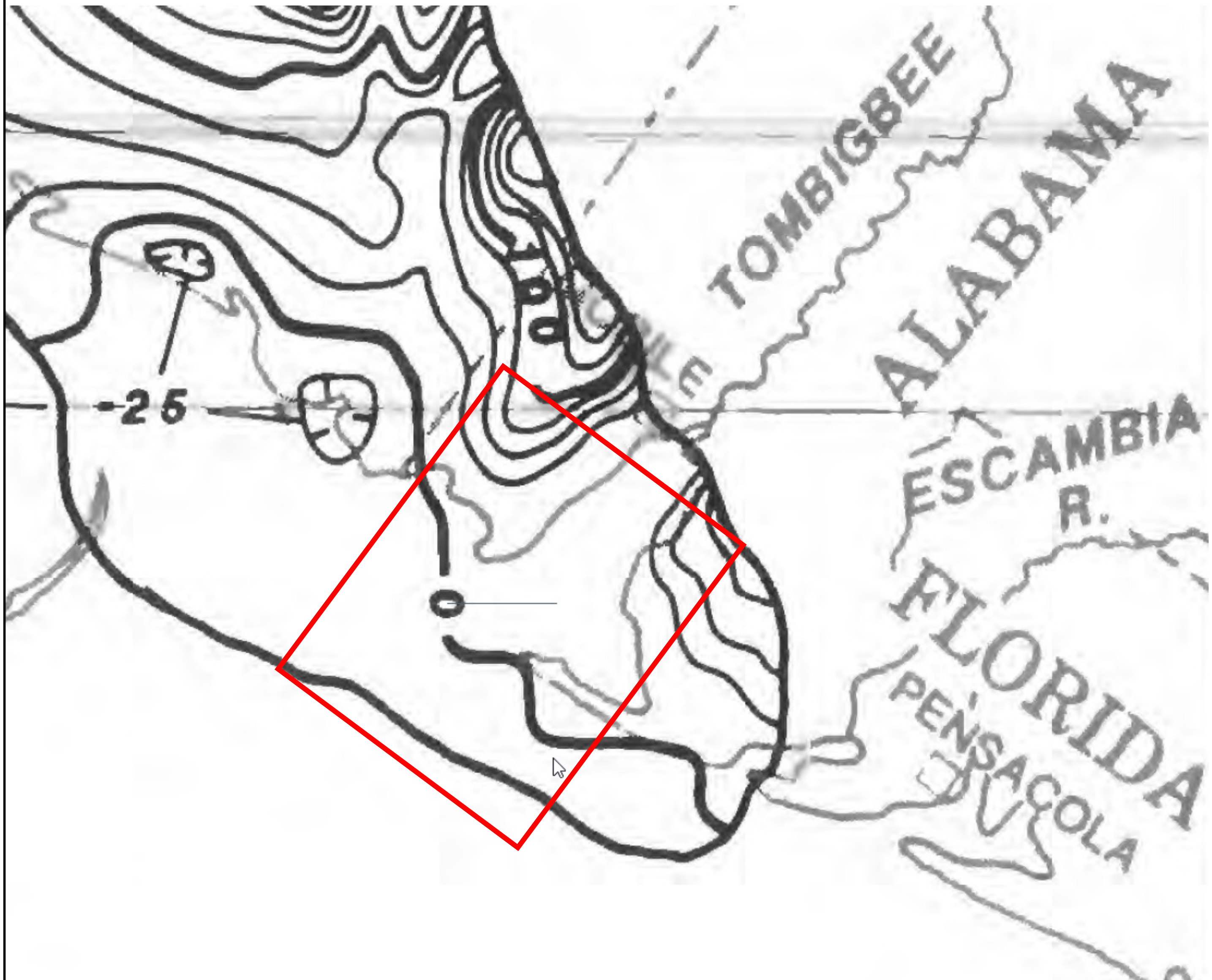
Pumping is assumed to be at average 2018 rates.

Based on well logs depths, the Dauphin Island wells are screened in the interbedded sand/clay layer (model layer 4)

Dauphin Island Pumping in Shallow Sand Aquifer

Figure 16

March 2019



Model Domain

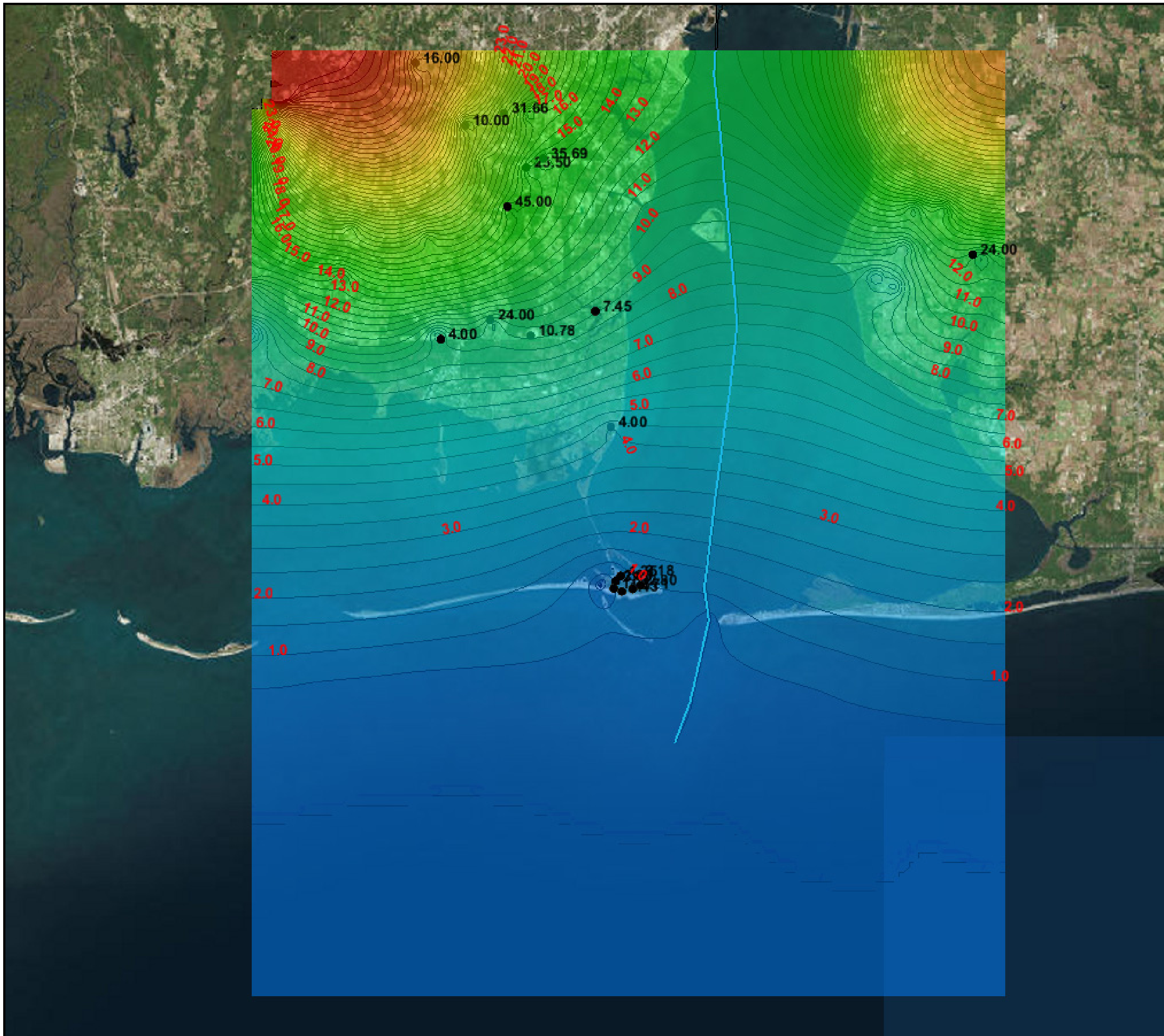
Notes:
Data from USGS Water-Resources Investigations Report 88-4100 by Martin and Whiteman (Figure 31)

Contour interval = 25ft

Regional Water Levels in Shallow Sand Aquifer
(Zoom in Area of Interest)

Figure 17

March 2019



Legend

Water Level (feet NAVD88)

35

15

-5

Shipping Channel

Notes:

Contours are simulated heads in the shallow sand aquifer.

Point values are water levels in the confined aquifer taken from drilling logs.

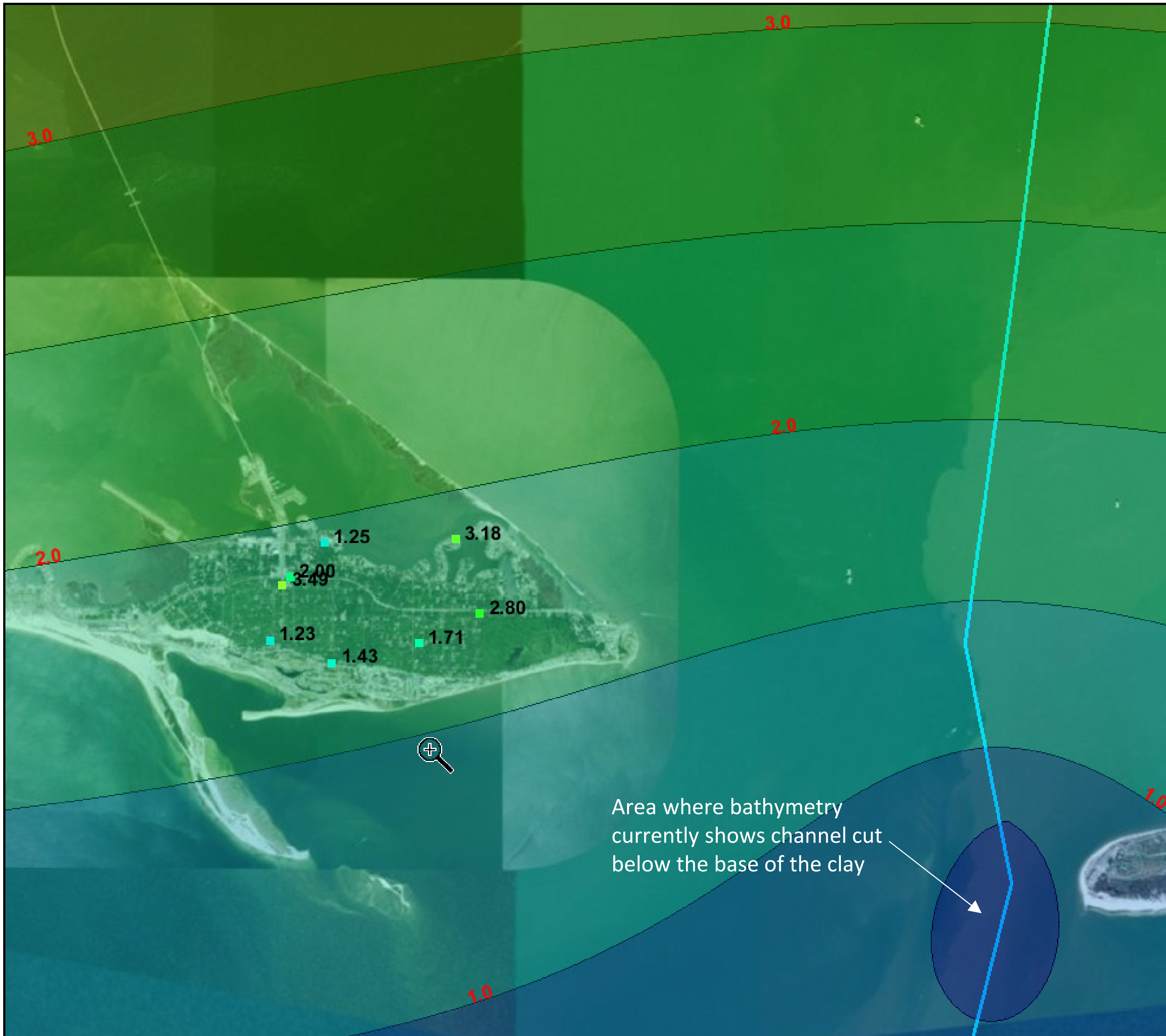
Several of the water levels appear to be impacted by pumping.

Intent to simulate approximate regional trend in water level from mainland source to ocean discharge.

Computed Regional Water Levels in Shallow Sand Aquifer

Figure 18

March 2019



Legend

Water Level (feet NAVD88)

5

2.5

0

Shipping Channel

Notes:

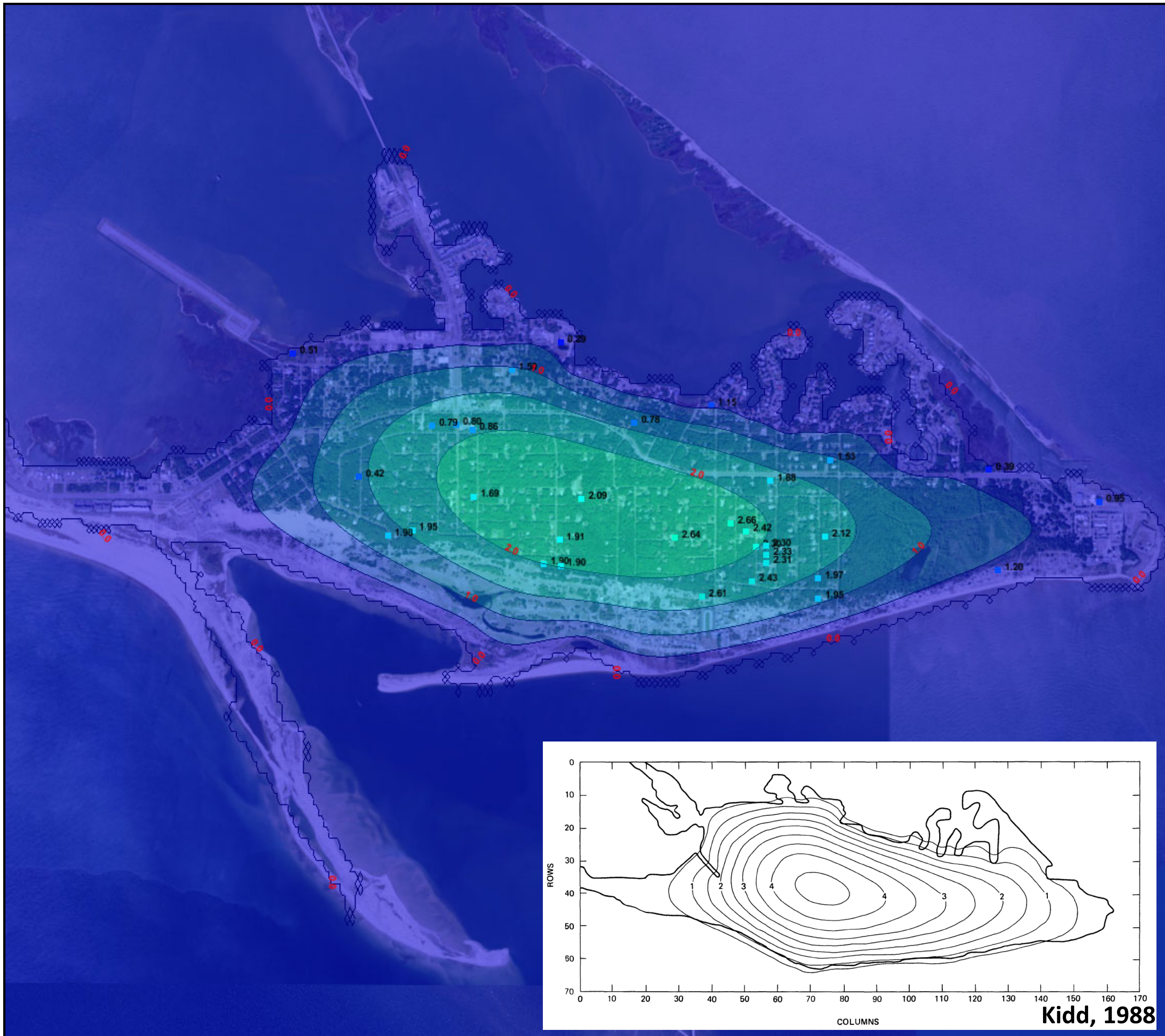
Contours are simulated heads in the shallow sand aquifer.

Point values are water levels in the confined aquifer taken from drilling logs.

Computed Dauphin Island Water Levels
in Shallow Sand Aquifer

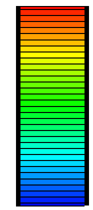
Figure 19

March 2019



Legend

Water Level (feet NAVD88)



Notes:

Contours are simulated heads in the water table aquifer.

Point values are water levels in the water table aquifer taken from Kidd 1988.

No pumping is assumed.

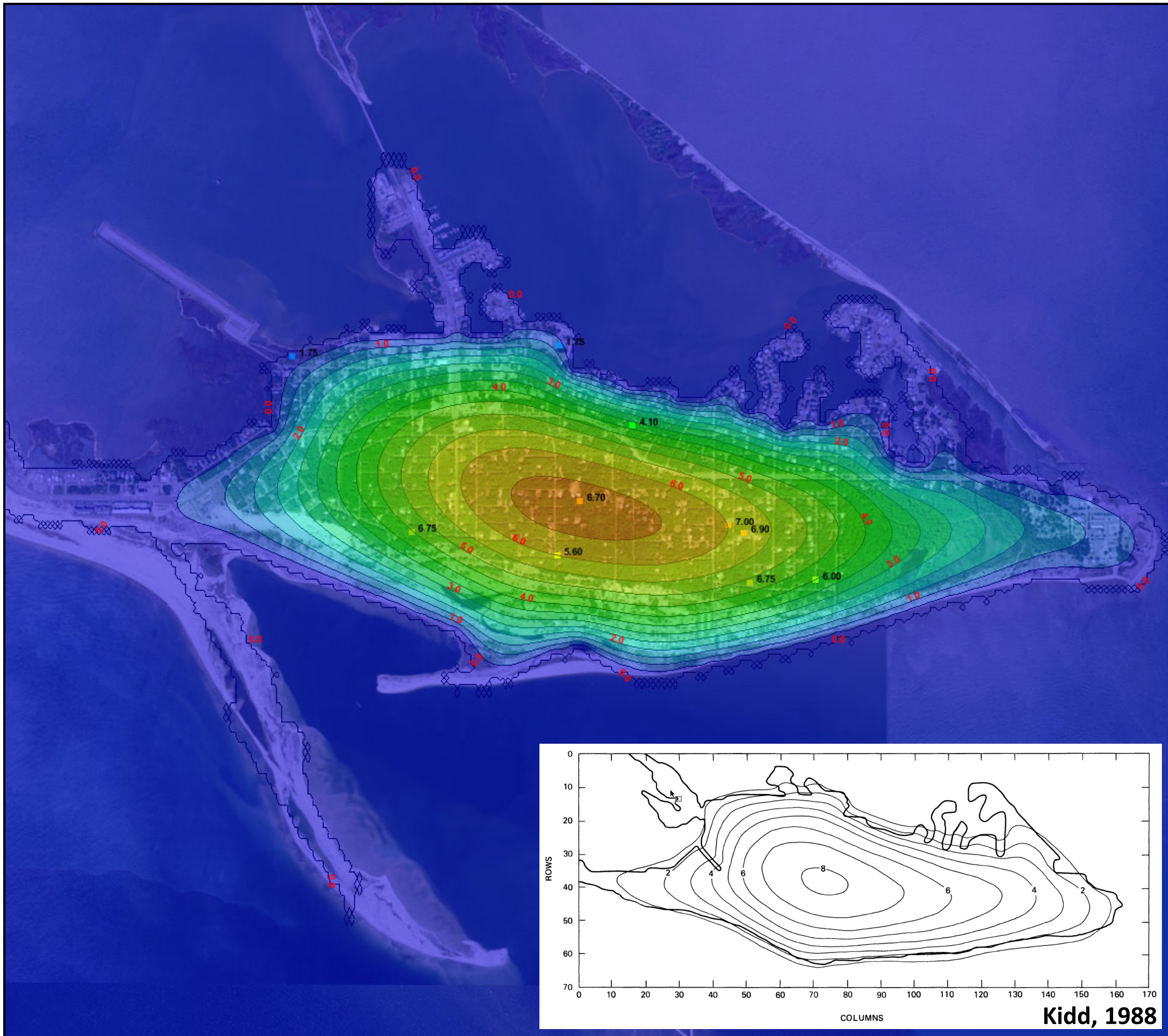
Water levels are consistent with observed data and Kidd 1988.

Changes in recharge to water table aquifer have a negligible impact on shallow sand aquifer water levels.

Dauphin Island Water Levels in Water Table Aquifer
(Low Recharge of 6 in/year)

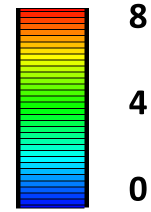
Figure 20

March 2019



Legend

Water Level (feet NAVD88)



Notes:

Contours are simulated heads in the water table aquifer.

Point values are water levels in the water table aquifer taken from Kidd 1988.

No pumping is assumed.

Water levels are consistent with observed data and Kidd 1988.

Changes in recharge to water table aquifer have a negligible impact on shallow sand aquifer water levels.

Dauphin Island Water Levels in Water Table Aquifer (High Recharge of 20 in/year)

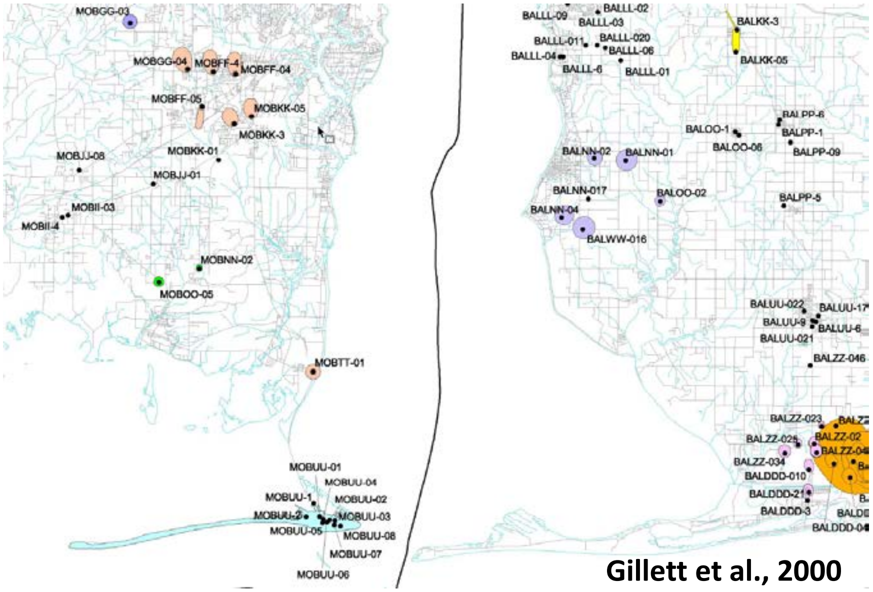
Figure 21

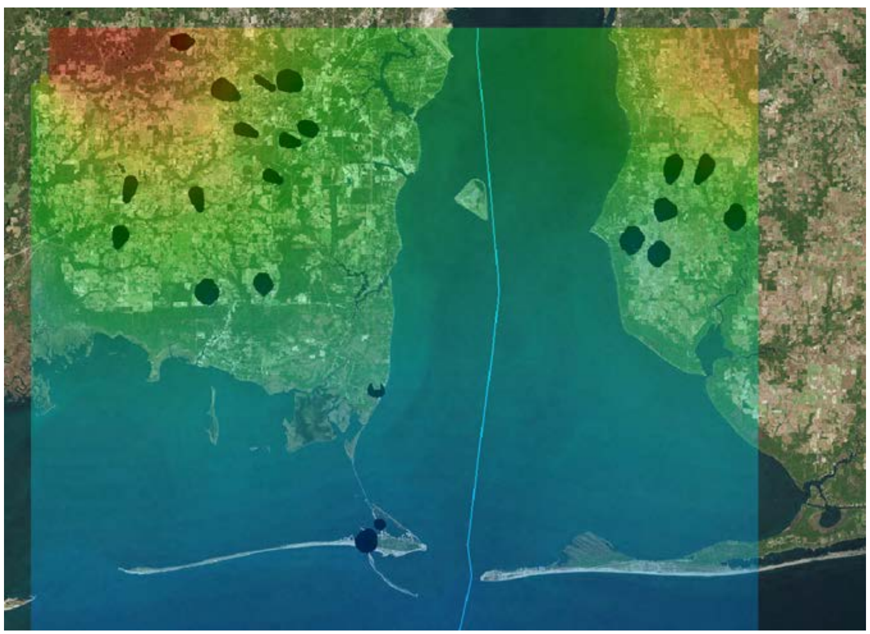
March 2019

Layer 2 Materials

Figure 22

March 2019





Legend

Water Level (feet NAVD88)

35

15

-5

Shipping Channel

Computed 100 yr Capture Zone

Notes:

Upper figure shows Well Head Protection Areas (WHPAs) and the Source Water Assessment Areas (SWAAs) develop by the GSA (Gillett et al., 2000).

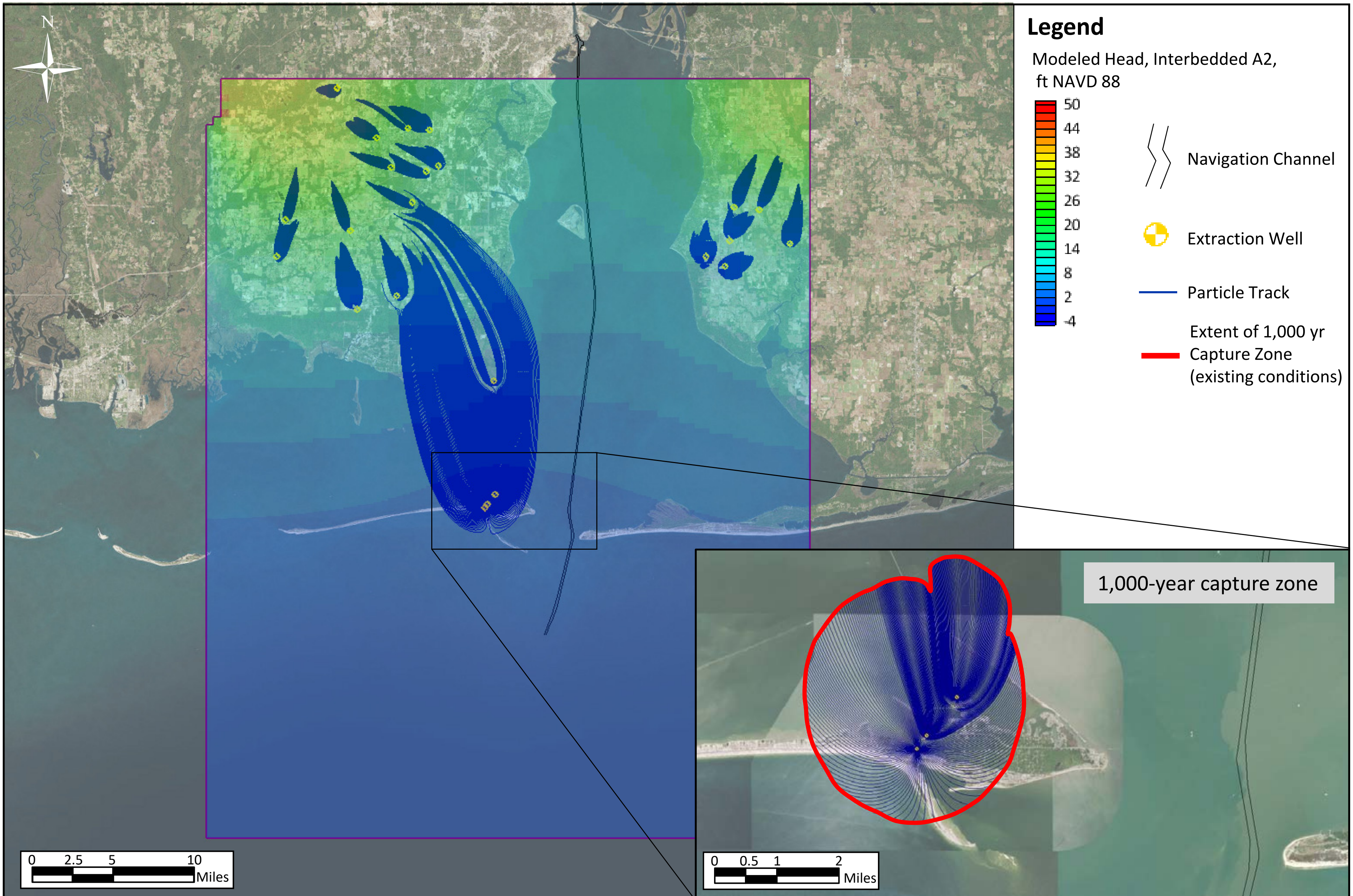
Lower figure shows the 100 year capture zones computed in the model.

Contours are simulated heads in the shallow sand aquifer.

Computed Regional Water Levels in Shallow Sand Aquifer

Figure 23

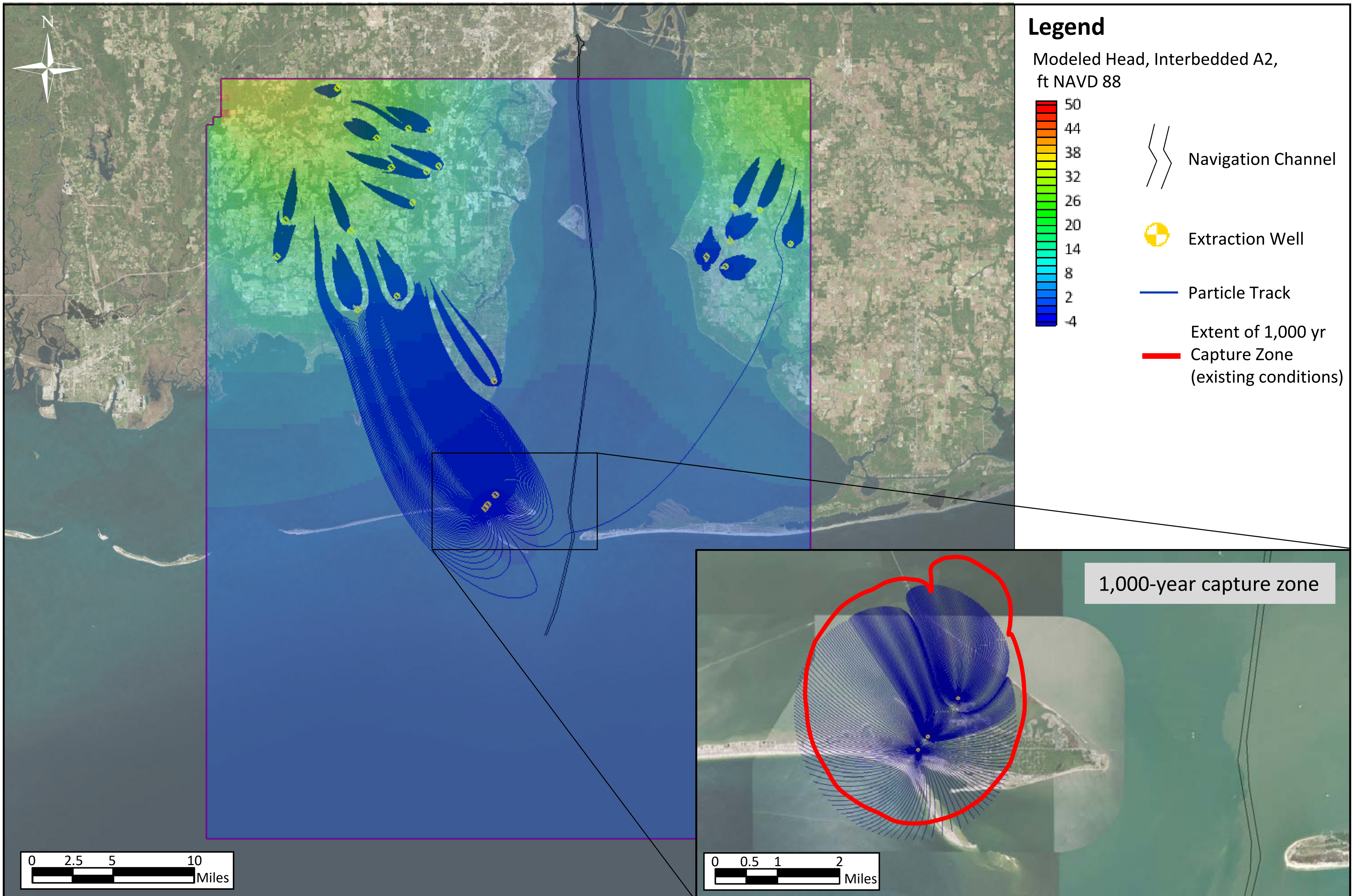
March 2019



Backward Particle Tracks
Existing Conditions

Figure 24

March 2019

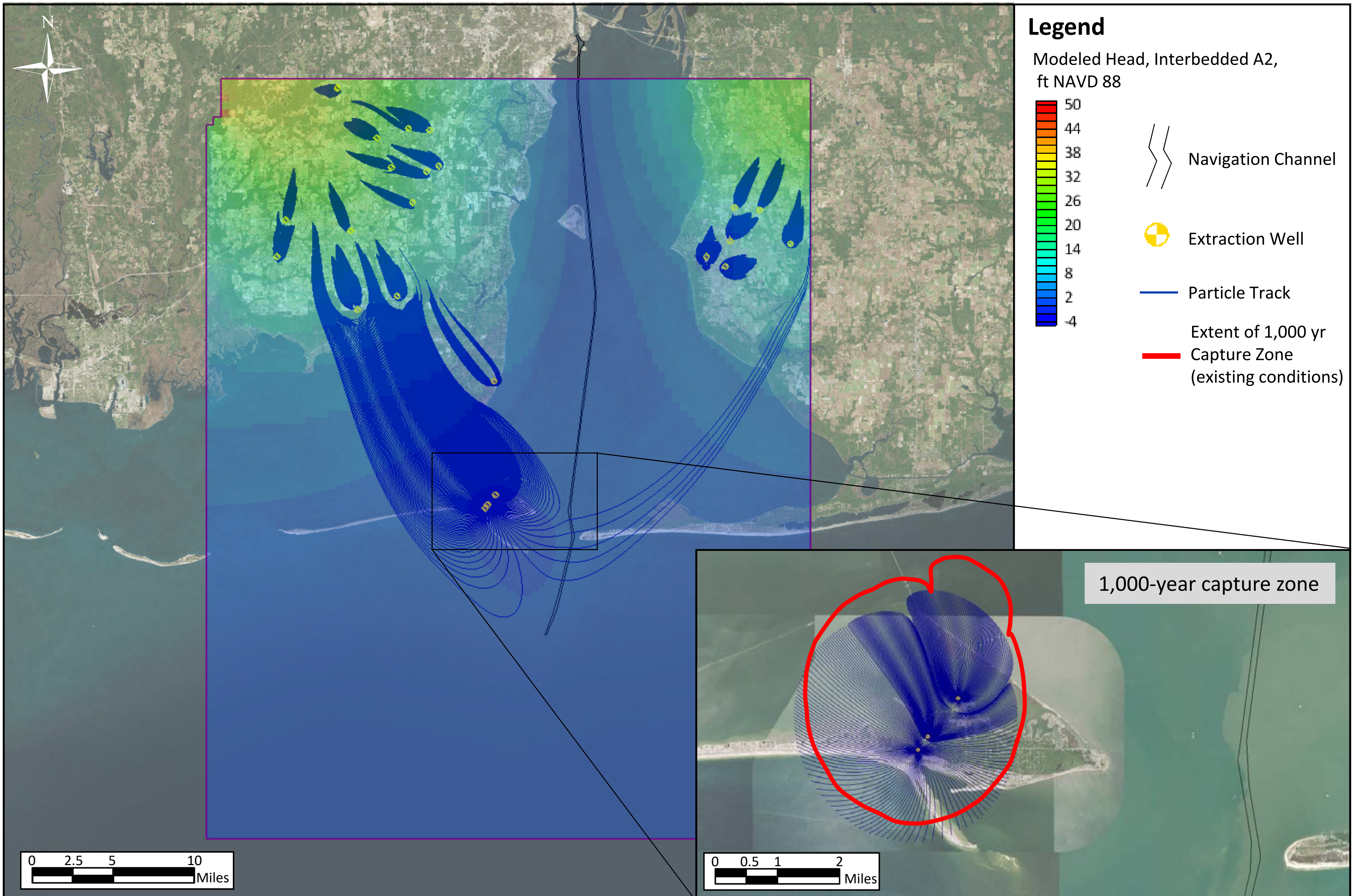


Backward Particle Tracks

Deepened Channel Assuming Partial Cut-through of Clay

Figure 25

March 2019

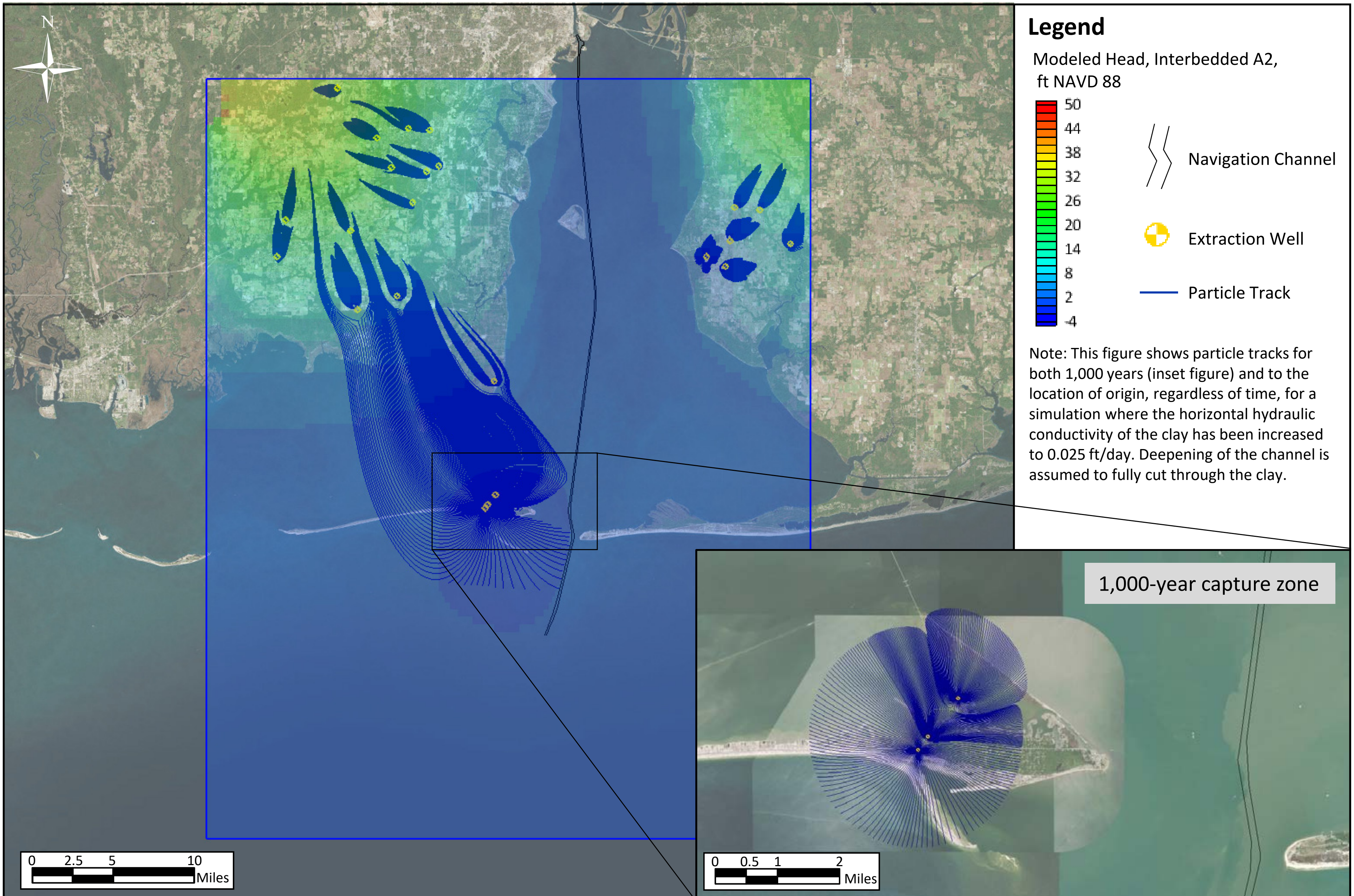


Backward Particle Tracks

Deepened Channel Assuming Full Cut-through of Clay

Figure 26

March 2019

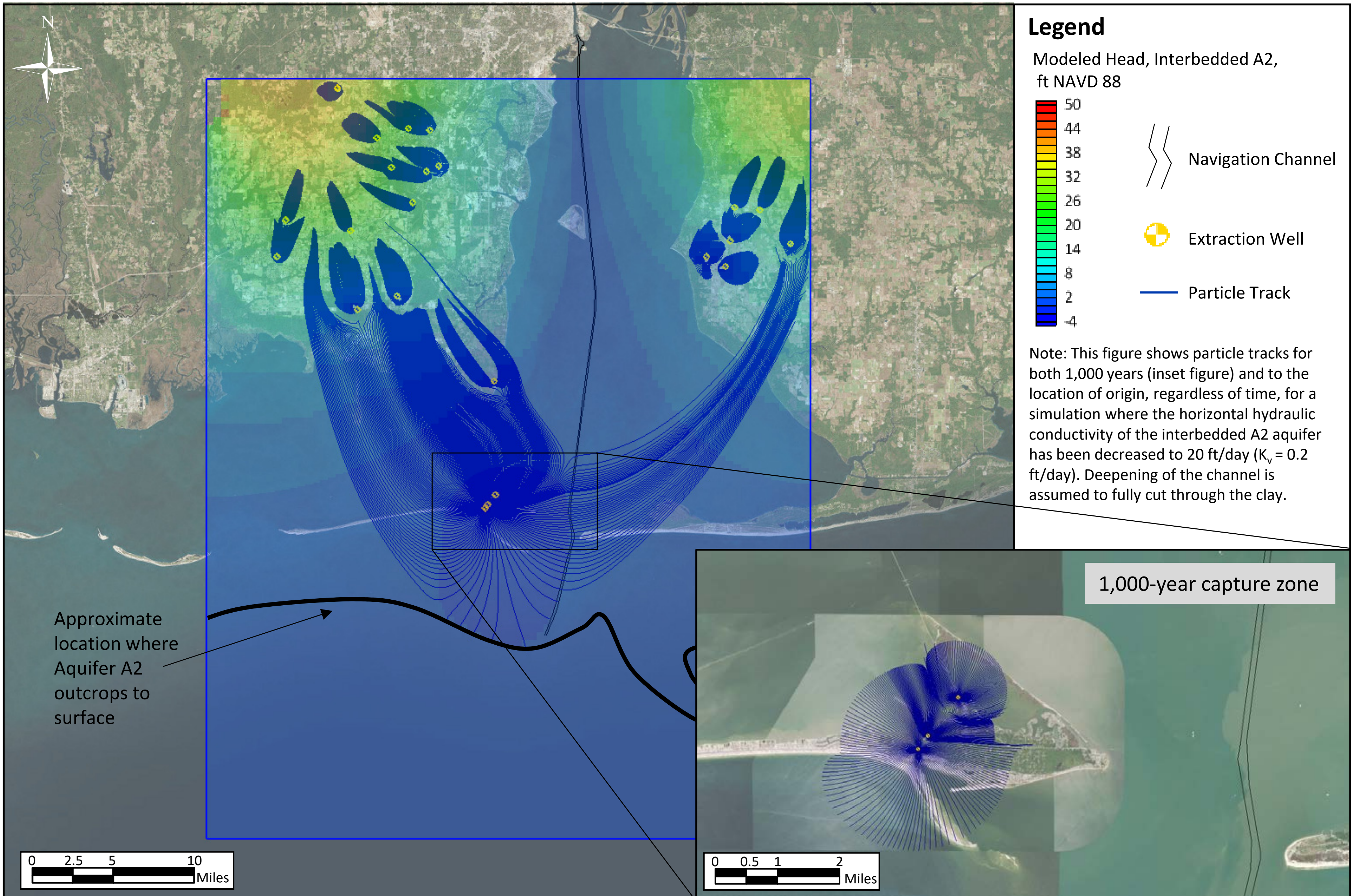


Backward Particle Tracks

Sensitivity Analysis: Increased Conductivity of Clay

Figure 27

March 2019

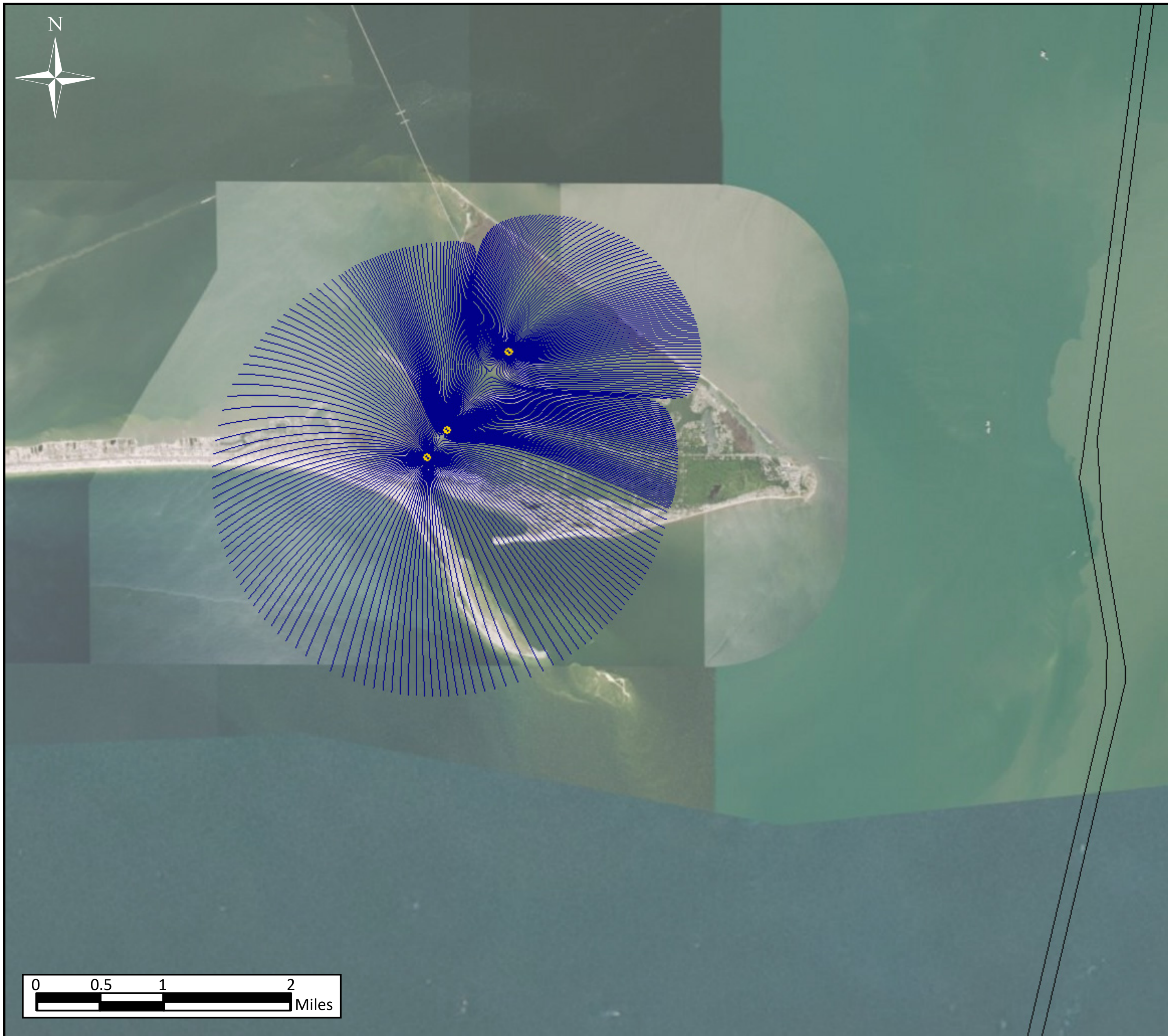


Backward Particle Tracks

Sensitivity Analysis: Decreased Conductivity of Interbedded A2

Figure 28

March 2019



Legend

Modeled Head, Interbedded A2, ft NAVD 88

50
44
38
32
26
20
14
8
2
-4

Navigation Channel

Extraction Well

Particle Track

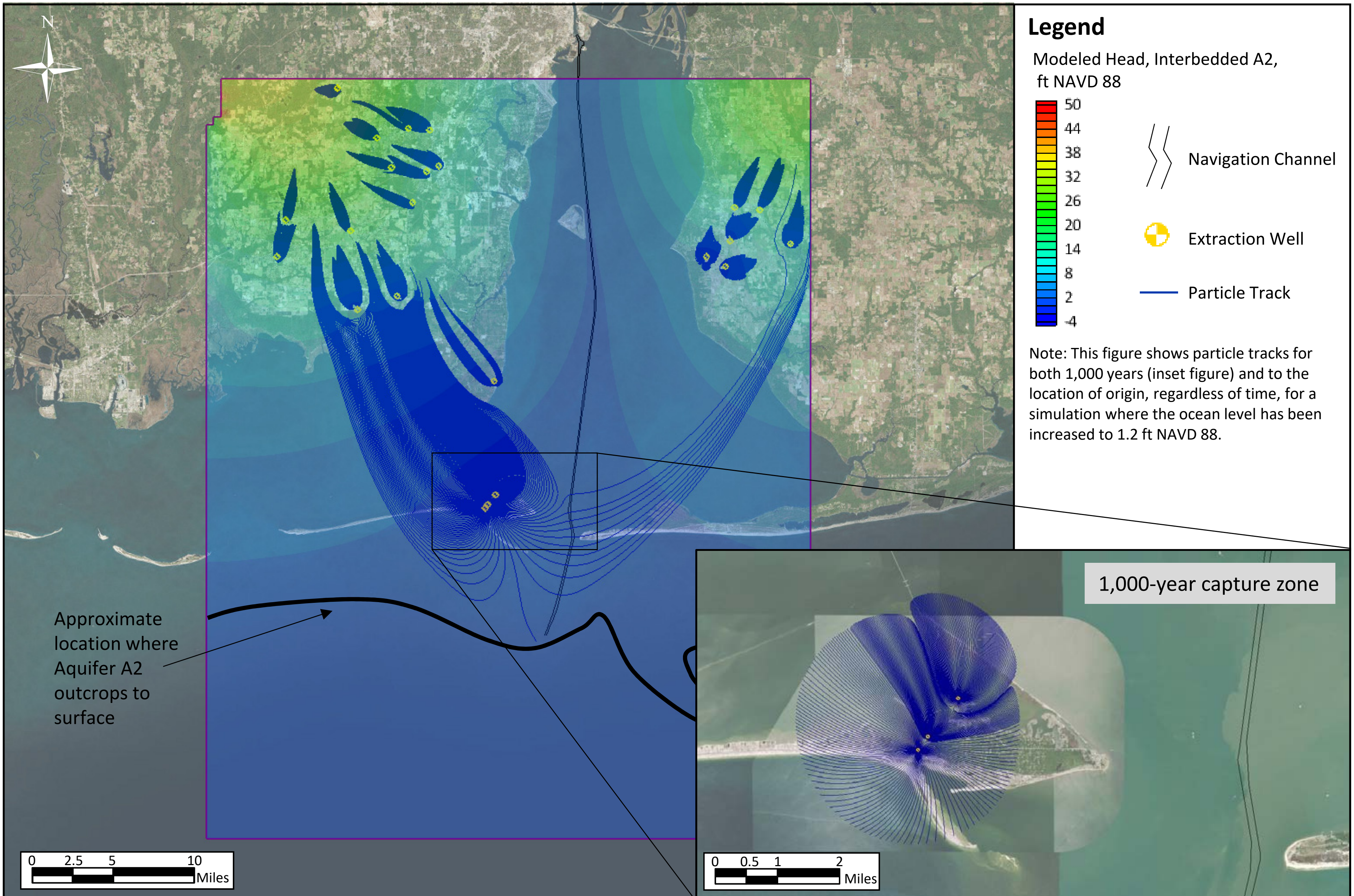
Note: This figure shows particle tracks for 1,000 years for a simulation where the horizontal hydraulic conductivity of clay below the Permeable Zone C outcrop area has been decreased by an order of magnitude to 0.001 ft/day (K_v = 0.0001 ft/day). Deepening of the channel is assumed to fully cut through the clay.

1,000-year Capture Zone

Sensitivity Analysis: Decreased Conductivity of Outcrop Area

Figure 29

March 2019

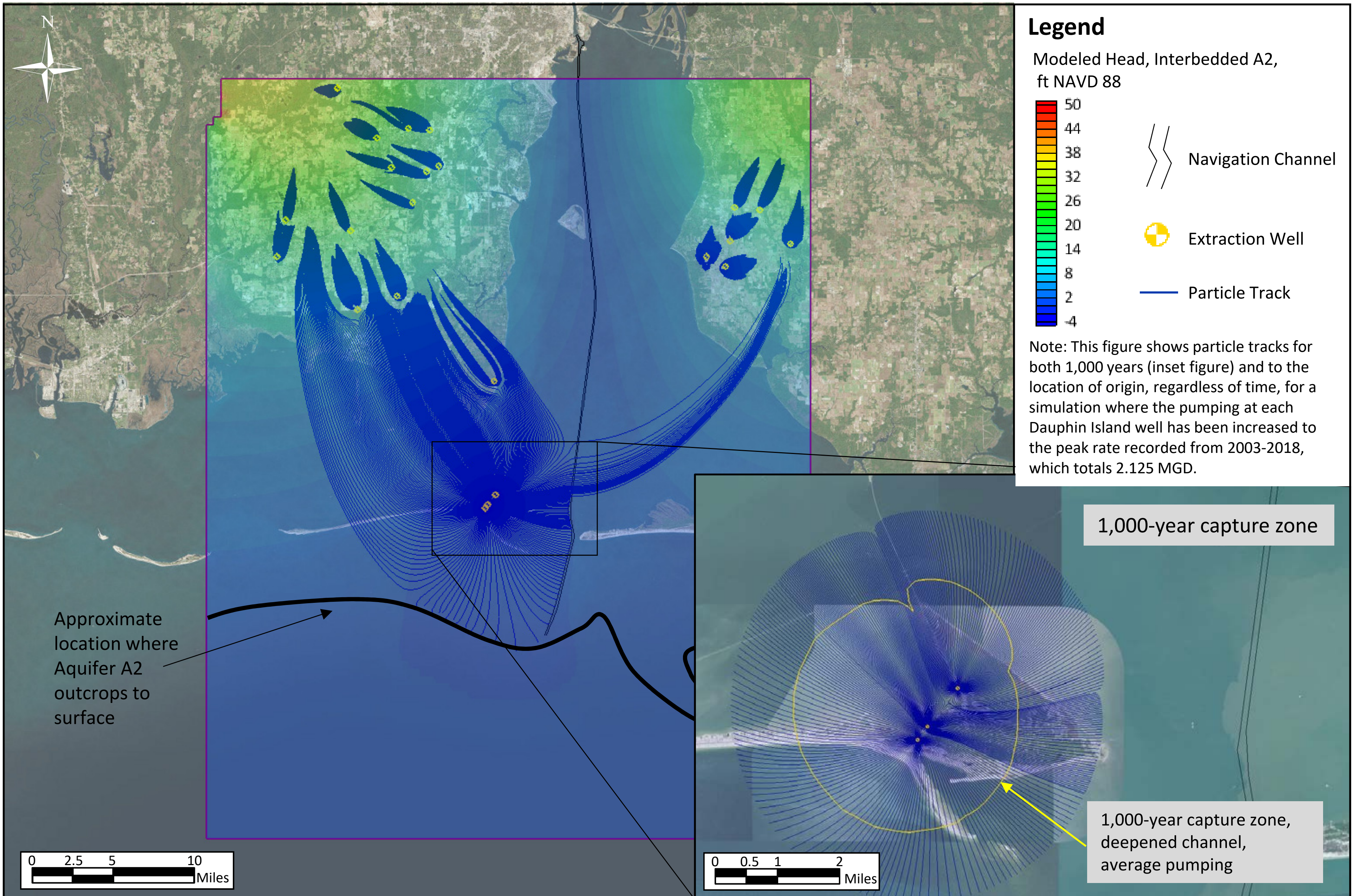


Backward Particle Tracks

Sensitivity Analysis: Increase in Ocean Level

Figure 30

March 2019

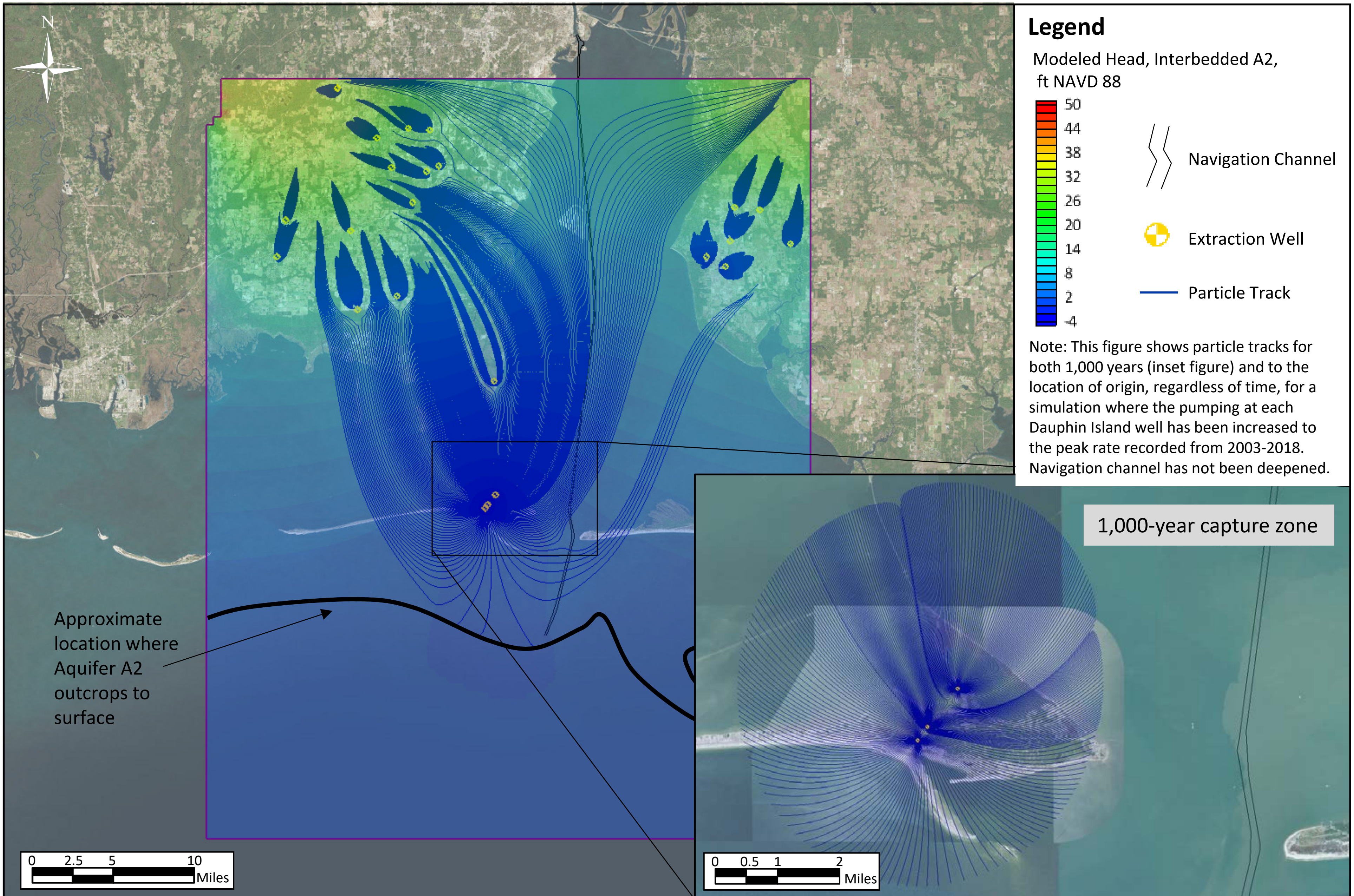


Backward Particle Tracks

Sensitivity Analysis: Increased Dauphin Island Pumping, Deepened Channel

Figure 31

March 2019



Backward Particle Tracks

Sensitivity Analysis: Increased Dauphin Island Pumping, Existing Channel Conditions

Figure 32

March 2019

Appendix A
Boring Logs used in Model Construction

Well ID	NAD 83 State Plane Alabama West		Contact Elev	Model Layer	Data Source
	Easting	Northing	(ft NAVD 88)		
W-1	1776954	194769	20	2	Geohydrology of the Proposed Thedore Ship Channel
W-1	1776954	194769	-50	3	Geohydrology of the Proposed Thedore Ship Channel
W-1	1776954	194769	-66	4	Geohydrology of the Proposed Thedore Ship Channel
W-1	1776954	194769	-81.5	4	Geohydrology of the Proposed Thedore Ship Channel
P-5	1782183	191381	3	2	Geohydrology of the Proposed Thedore Ship Channel
P-5	1782183	191381	-37	3	Geohydrology of the Proposed Thedore Ship Channel
P-5	1782183	191381	-92	4	Geohydrology of the Proposed Thedore Ship Channel
P-5	1782183	191381	-105	4	Geohydrology of the Proposed Thedore Ship Channel
P-6	1777452	195461	4	1	Geohydrology of the Proposed Thedore Ship Channel
P-6	1777452	195461	-16	2	Geohydrology of the Proposed Thedore Ship Channel
P-6	1777452	195461	-56	3	Geohydrology of the Proposed Thedore Ship Channel
P-6	1777452	195461	-112.5	3	Geohydrology of the Proposed Thedore Ship Channel
P-7	1776733	191989	12.5	1	Geohydrology of the Proposed Thedore Ship Channel
P-7	1776733	191989	-2.5	2	Geohydrology of the Proposed Thedore Ship Channel
P-7	1776733	191989	-52.5	3	Geohydrology of the Proposed Thedore Ship Channel
P-7	1776733	191989	-92.5	4	Geohydrology of the Proposed Thedore Ship Channel
P-7	1776733	191989	-104	4	Geohydrology of the Proposed Thedore Ship Channel
P-8	1776235	191132	13.3	1	Geohydrology of the Proposed Thedore Ship Channel
P-8	1776235	191132	-4.7	1	Geohydrology of the Proposed Thedore Ship Channel
P-8	1776235	191132	-34.7	2	Geohydrology of the Proposed Thedore Ship Channel
P-8	1776235	191132	-59.7	3	Geohydrology of the Proposed Thedore Ship Channel
P-8	1776235	191132	-97.7	3	Geohydrology of the Proposed Thedore Ship Channel
SA-6-82	1801764	235077.9	-7.5	2	Mobile Harbor Improvements
SA-6-82	1801764	235077.9	-57	3	Mobile Harbor Improvements
SA-6-82	1801764	235077.9	-58.5	3	Mobile Harbor Improvements
SA-7-82	1801714	234077.9	-7.5	2	Mobile Harbor Improvements
SA-7-82	1801714	234077.9	-52.5	3	Mobile Harbor Improvements
SA-7-82	1801714	234077.9	-55.5	3	Mobile Harbor Improvements
SA-1-82	1802384	236477.9	-7	2	Mobile Harbor Improvements
SA-1-82	1802384	236477.9	-58.5	3	Mobile Harbor Improvements
SA-1-82	1802384	236477.9	-88.5	4	Mobile Harbor Improvements
SA-1-82	1802384	236477.9	-90	4	Mobile Harbor Improvements
SA-10-82	1802334	235077.9	-7	2	Mobile Harbor Improvements
SA-10-82	1802334	235077.9	-56	3	Mobile Harbor Improvements
SA-10-82	1802334	235077.9	-90.5	3	Mobile Harbor Improvements
SC-11-83	1794526	233129.9	-4.2	2	Mobile Harbor Improvements
SC-11-83	1794526	233129.9	-49.7	3	Mobile Harbor Improvements
SC-11-83	1794526	233129.9	-51.2	3	Mobile Harbor Improvements
SC-12-83	1796254	232289.9	-2.8	2	Mobile Harbor Improvements
SC-12-83	1796254	232289.9	-37.8	3	Mobile Harbor Improvements
SC-12-83	1796254	232289.9	-39.3	3	Mobile Harbor Improvements
SC-13-83	1797986	231594.9	-1.8	2	Mobile Harbor Improvements
SC-13-83	1797986	231594.9	-49.2	3	Mobile Harbor Improvements
SC-13-83	1797986	231594.9	-49.3	3	Mobile Harbor Improvements
SC-14-83	1795512	231309.9	-4.6	2	Mobile Harbor Improvements
SC-14-83	1795512	231309.9	-51.6	3	Mobile Harbor Improvements

Appendix A
Boring Logs used in Model Construction

Well ID	NAD 83 State Plane Alabama West		Contact Elev	Model Layer	Data Source
	Easting	Northing	(ft NAVD 88)		
SC-14-83	1795512	231309.9	-53.1	3	Mobile Harbor Improvements
SC-24-83	1801520	230082.8	12.3	2	Mobile Harbor Improvements
SC-24-83	1801520	230082.8	-29.7	3	Mobile Harbor Improvements
SC-24-83	1801520	230082.8	-32.2	3	Mobile Harbor Improvements
SS-201-84	1801954	240227.9	-14.4	2	Mobile Harbor Improvements
SS-201-84	1801954	240227.9	-42.2	3	Mobile Harbor Improvements
SS-201-84	1801954	240227.9	-64.2	3	Mobile Harbor Improvements
SS-203-84	1801205	225277.8	-15.7	2	Mobile Harbor Improvements
SS-203-84	1801205	225277.8	-43.7	3	Mobile Harbor Improvements
SS-203-84	1801205	225277.8	-63.7	3	Mobile Harbor Improvements
SS-203A-84	1801539	222559.8	-13.6	2	Mobile Harbor Improvements
SS-203A-84	1801539	222559.8	-48	3	Mobile Harbor Improvements
SS-203A-84	1801539	222559.8	-65	3	Mobile Harbor Improvements
SS-204-84	1801800	220773.7	-12.6	2	Mobile Harbor Improvements
SS-204-84	1801800	220773.7	-44	3	Mobile Harbor Improvements
SS-204-84	1801800	220773.7	-65.5	3	Mobile Harbor Improvements
SS-205-84	1802644	217196.7	-9.6	2	Mobile Harbor Improvements
SS-205-84	1802644	217196.7	-50	3	Mobile Harbor Improvements
SS-205-84	1802644	217196.7	-65.5	3	Mobile Harbor Improvements
SS-217-84	1804005	196477.5	-11.4	2	Mobile Harbor Improvements
SS-217-84	1804005	196477.5	-53.4	3	Mobile Harbor Improvements
SS-217-84	1804005	196477.5	-64.4	3	Mobile Harbor Improvements
10-D301-06	1802491	242683	-8.5	2	USACE Investigations conducted by SAM
10-D301-06	1802491	242683	-29.5	3	USACE Investigations conducted by SAM
10-D301-06	1802491	242683	-60.5	3	USACE Investigations conducted by SAM
11-D301-06	1802799	242584	-8.5	2	USACE Investigations conducted by SAM
11-D301-06	1802799	242584	-29.5	3	USACE Investigations conducted by SAM
11-D301-06	1802799	242584	-60.5	3	USACE Investigations conducted by SAM
13-D301-06	1801858	242405	-21.5	2	USACE Investigations conducted by SAM
13-D301-06	1801858	242405	-29.5	3	USACE Investigations conducted by SAM
13-D301-06	1801858	242405	-59.5	3	USACE Investigations conducted by SAM
14-D301-06	1802074	242381	-13.5	2	USACE Investigations conducted by SAM
14-D301-06	1802074	242381	-25.5	3	USACE Investigations conducted by SAM
14-D301-06	1802074	242381	-59.5	3	USACE Investigations conducted by SAM
15-D301-06	1802500	242385	-9.5	2	USACE Investigations conducted by SAM
15-D301-06	1802500	242385	-33.5	3	USACE Investigations conducted by SAM
15-D301-06	1802500	242385	-60.5	3	USACE Investigations conducted by SAM
16-D301-06	1803182	242395	-16.5	2	USACE Investigations conducted by SAM
16-D301-06	1803182	242395	-40.5	3	USACE Investigations conducted by SAM
16-D301-06	1803182	242395	-60.5	3	USACE Investigations conducted by SAM
17-D301-06	1802103	242193	-12.5	2	USACE Investigations conducted by SAM
17-D301-06	1802103	242193	-36.5	3	USACE Investigations conducted by SAM
17-D301-06	1802103	242193	-59.5	3	USACE Investigations conducted by SAM
18-D301-06	1802512	242203	-10.5	2	USACE Investigations conducted by SAM
18-D301-06	1802512	242203	-33.5	3	USACE Investigations conducted by SAM
18-D301-06	1802512	242203	-60.5	3	USACE Investigations conducted by SAM

Appendix A
Boring Logs used in Model Construction

Well ID	NAD 83 State Plane Alabama West		Contact Elev (ft NAVD 88)	Model Layer	Data Source
	Easting	Northing			
20-D301-06	1803206	242203	-8.5	2	USACE Investigations conducted by SAM
20-D301-06	1803206	242203	-39.5	3	USACE Investigations conducted by SAM
20-D301-06	1803206	242203	-62.5	3	USACE Investigations conducted by SAM
22-D301-06	1802101	241991	-14.5	2	USACE Investigations conducted by SAM
22-D301-06	1802101	241991	-32.5	3	USACE Investigations conducted by SAM
22-D301-06	1802101	241991	-59.5	3	USACE Investigations conducted by SAM
23-D301-06	1802802	241995	-14.5	2	USACE Investigations conducted by SAM
23-D301-06	1802802	241995	-34.5	3	USACE Investigations conducted by SAM
23-D301-06	1802802	241995	-60.5	3	USACE Investigations conducted by SAM
24-D301-06	1803201	241940	-13.5	2	USACE Investigations conducted by SAM
24-D301-06	1803201	241940	-34.5	3	USACE Investigations conducted by SAM
24-D301-06	1803201	241940	-60.5	3	USACE Investigations conducted by SAM
25-D301-06	1802010	241744	-23.5	2	USACE Investigations conducted by SAM
25-D301-06	1802010	241744	-35.5	3	USACE Investigations conducted by SAM
25-D301-06	1802010	241744	-59.5	3	USACE Investigations conducted by SAM
28-D301-06	1801836	241612	-26.5	2	USACE Investigations conducted by SAM
28-D301-06	1801836	241612	-37.5	3	USACE Investigations conducted by SAM
28-D301-06	1801836	241612	-60.5	3	USACE Investigations conducted by SAM
29-D301-06	1801878	241275	-24.5	2	USACE Investigations conducted by SAM
29-D301-06	1801878	241275	-45.5	3	USACE Investigations conducted by SAM
29-D301-06	1801878	241275	-60.5	3	USACE Investigations conducted by SAM
2-D301-06	1802137	243035	-18.5	2	USACE Investigations conducted by SAM
2-D301-06	1802137	243035	-38.5	3	USACE Investigations conducted by SAM
2-D301-06	1802137	243035	-59.5	3	USACE Investigations conducted by SAM
7-D301-06	1802110	242799	-15.5	2	USACE Investigations conducted by SAM
7-D301-06	1802110	242799	-30.5	3	USACE Investigations conducted by SAM
7-D301-06	1802110	242799	-61.5	3	USACE Investigations conducted by SAM
8-D301-06	1803214	242753	-8.5	2	USACE Investigations conducted by SAM
8-D301-06	1803214	242753	-37.5	3	USACE Investigations conducted by SAM
8-D301-06	1803214	242753	-61.5	3	USACE Investigations conducted by SAM
9-D301-06	1802098	242596	-15.5	2	USACE Investigations conducted by SAM
9-D301-06	1802098	242596	-34.5	3	USACE Investigations conducted by SAM
9-D301-06	1802098	242596	-59.5	3	USACE Investigations conducted by SAM
CHEM-1-06	1801859	242805	-24.5	2	USACE Investigations conducted by SAM
CHEM-1-06	1801859	242805	-37.5	3	USACE Investigations conducted by SAM
CHEM-1-06	1801859	242805	-54.5	3	USACE Investigations conducted by SAM
CHEM-3-06	1802804	242249	-11.5	2	USACE Investigations conducted by SAM
CHEM-3-06	1802804	242249	-39.5	3	USACE Investigations conducted by SAM
CHEM-3-06	1802804	242249	-54.5	3	USACE Investigations conducted by SAM
M-4	1802499	241998	-14.5	2	USACE Investigations conducted by SAM
M-4	1802499	241998	-31.5	3	USACE Investigations conducted by SAM
M-4	1802499	241998	-40.5	3	USACE Investigations conducted by SAM
m-5	1802499	242518	-16.5	2	USACE Investigations conducted by SAM
m-5	1802499	242518	-38.5	3	USACE Investigations conducted by SAM
m-5	1802499	242518	-43.5	3	USACE Investigations conducted by SAM
SG-16-83	1796200	67039	-35.5	2	USACE Investigations conducted by SAM

Well ID	NAD 83 State Plane Alabama West		Contact Elev (ft NAVD 88)	Model Layer	Data Source
	Easting	Northing			
SG-16-83	1796200	67039	-54.5	3	USACE Investigations conducted by SAM
SG-16-83	1796200	67039	-55.5	3	USACE Investigations conducted by SAM
SG-17-83	1795137	64740	-43.5	2	USACE Investigations conducted by SAM
SG-17-83	1795137	64740	-53.5	3	USACE Investigations conducted by SAM
SG-17-83	1795137	64740	-59.5	3	USACE Investigations conducted by SAM
SG-19-83	1793534	59960	-28.5	2	USACE Investigations conducted by SAM
SG-19-83	1793534	59960	-52.5	3	USACE Investigations conducted by SAM
SG-19-83	1793534	59960	-59.5	3	USACE Investigations conducted by SAM
SG-21-83	1791980	54633	-43.5	2	USACE Investigations conducted by SAM
SG-21-83	1791980	54633	-50.5	3	USACE Investigations conducted by SAM
SG-21-83	1791980	54633	-71.5	3	USACE Investigations conducted by SAM
SG-22-83	1791498	53060	-45.5	2	USACE Investigations conducted by SAM
SG-22-83	1791498	53060	-48.5	3	USACE Investigations conducted by SAM
SG-22-83	1791498	53060	-71.5	3	USACE Investigations conducted by SAM
SS-163	1799663	105095	-25.5	2	USACE Investigations conducted by SAM
SS-163	1799663	105095	-45.5	3	USACE Investigations conducted by SAM
SS-163	1799663	105095	-51.5	3	USACE Investigations conducted by SAM
SS-165	1799679	103076	-32.5	2	USACE Investigations conducted by SAM
SS-165	1799679	103076	-46.5	3	USACE Investigations conducted by SAM
SS-165	1799679	103076	-51.5	3	USACE Investigations conducted by SAM
SS-167	1799695	101057	-36.5	2	USACE Investigations conducted by SAM
SS-167	1799695	101057	-50.5	3	USACE Investigations conducted by SAM
SS-167	1799695	101057	-51.5	3	USACE Investigations conducted by SAM
SS-169	1798892	99144	-27.5	2	USACE Investigations conducted by SAM
SS-169	1798892	99144	-43.5	3	USACE Investigations conducted by SAM
SS-169	1798892	99144	-51.5	3	USACE Investigations conducted by SAM
SS-171	1799181	97090	-25.5	2	USACE Investigations conducted by SAM
SS-171	1799181	97090	-48.5	3	USACE Investigations conducted by SAM
SS-171	1799181	97090	-51.5	3	USACE Investigations conducted by SAM
SS-179	1797930	89166	-30.5	2	USACE Investigations conducted by SAM
SS-179	1797930	89166	-47.5	3	USACE Investigations conducted by SAM
SS-179	1797930	89166	-51.5	3	USACE Investigations conducted by SAM
SS-29	1801343	238353	-37.5	2	USACE Investigations conducted by SAM
SS-29	1801343	238353	-43.5	3	USACE Investigations conducted by SAM
SS-29	1801343	238353	-47.5	3	USACE Investigations conducted by SAM
SS-31	1800995	236365	-41.5	2	USACE Investigations conducted by SAM
SS-31	1800995	236365	-47.5	3	USACE Investigations conducted by SAM
SS-31	1800995	236365	-68.5	3	USACE Investigations conducted by SAM
SS-33	1801471	234346	-31.5	2	USACE Investigations conducted by SAM
SS-33	1801471	234346	-41.5	3	USACE Investigations conducted by SAM
SS-33	1801471	234346	-51.5	3	USACE Investigations conducted by SAM
SS-37	1801050	230359	-40.5	2	USACE Investigations conducted by SAM
SS-37	1801050	230359	-42.5	3	USACE Investigations conducted by SAM
SS-37	1801050	230359	-48.5	3	USACE Investigations conducted by SAM
SS-39	1801252	228350	-31.5	2	USACE Investigations conducted by SAM
SS-39	1801252	228350	-42.5	3	USACE Investigations conducted by SAM

Appendix A
Boring Logs used in Model Construction

Well ID	NAD 83 State Plane Alabama West		Contact Elev	Model Layer	Data Source
	Easting	Northing	(ft NAVD 88)		
SS-39	1801252	228350	-50.5	3	USACE Investigations conducted by SAM
SS-41	1800629	226371	-41.5	2	USACE Investigations conducted by SAM
SS-41	1800629	226371	-45.5	3	USACE Investigations conducted by SAM
SS-41	1800629	226371	-49.5	3	USACE Investigations conducted by SAM
SS-43	1801231	224391	-41.5	2	USACE Investigations conducted by SAM
SS-43	1801231	224391	-46.5	3	USACE Investigations conducted by SAM
SS-43	1801231	224391	-49.5	3	USACE Investigations conducted by SAM
SS-45	1801141	222375	-40.5	2	USACE Investigations conducted by SAM
SS-45	1801141	222375	-45.5	3	USACE Investigations conducted by SAM
SS-45	1801141	222375	-50.5	3	USACE Investigations conducted by SAM
SS-47	1801051	220358	-39.5	2	USACE Investigations conducted by SAM
SS-47	1801051	220358	-47.5	3	USACE Investigations conducted by SAM
SS-47	1801051	220358	-49.5	3	USACE Investigations conducted by SAM
SS-49	1801783	218417	-23.5	2	USACE Investigations conducted by SAM
SS-49	1801783	218417	-47.5	3	USACE Investigations conducted by SAM
SS-49	1801783	218417	-51.5	3	USACE Investigations conducted by SAM
SS-51	1801419	216375	-8.5	2	USACE Investigations conducted by SAM
SS-51	1801419	216375	-47.5	3	USACE Investigations conducted by SAM
SS-51	1801419	216375	-48.5	3	USACE Investigations conducted by SAM
SS-53	1801877	214408	-41.5	2	USACE Investigations conducted by SAM
SS-53	1801877	214408	-47.5	3	USACE Investigations conducted by SAM
SS-53	1801877	214408	-50.5	3	USACE Investigations conducted by SAM
SS-85	1804819	182544	-33.5	2	USACE Investigations conducted by SAM
SS-85	1804819	182544	-47.5	3	USACE Investigations conducted by SAM
SS-85	1804819	182544	-48.5	3	USACE Investigations conducted by SAM
VC-10-84	1801777	214854	-42.5	2	USACE Investigations conducted by SAM
VC-10-84	1801777	214854	-51.5	3	USACE Investigations conducted by SAM
VC-10-84	1801777	214854	-66.5	3	USACE Investigations conducted by SAM
VC-11-84	1802068	212328	-42.5	2	USACE Investigations conducted by SAM
VC-11-84	1802068	212328	-47.5	3	USACE Investigations conducted by SAM
VC-11-84	1802068	212328	-62.5	3	USACE Investigations conducted by SAM
VC-12-84	1802317	209667	-42.5	2	USACE Investigations conducted by SAM
VC-12-84	1802317	209667	-44.5	3	USACE Investigations conducted by SAM
VC-12-84	1802317	209667	-69.5	3	USACE Investigations conducted by SAM
VC-16-84	1803348	200185	-36.5	2	USACE Investigations conducted by SAM
VC-16-84	1803348	200185	-43.5	3	USACE Investigations conducted by SAM
VC-16-84	1803348	200185	-65.5	3	USACE Investigations conducted by SAM
VC-17-84	1803402	198503	-41.5	2	USACE Investigations conducted by SAM
VC-17-84	1803402	198503	-47.5	3	USACE Investigations conducted by SAM
VC-17-84	1803402	198503	-69.5	3	USACE Investigations conducted by SAM
VC-18-84	1803444	196773	-43.5	2	USACE Investigations conducted by SAM
VC-18-84	1803444	196773	-46.5	3	USACE Investigations conducted by SAM
VC-18-84	1803444	196773	-72.5	3	USACE Investigations conducted by SAM
VC-19-84	1803771	194553	-41.5	2	USACE Investigations conducted by SAM
VC-19-84	1803771	194553	-48.5	3	USACE Investigations conducted by SAM
VC-19-84	1803771	194553	-58.5	3	USACE Investigations conducted by SAM

Appendix A
Boring Logs used in Model Construction

Well ID	NAD 83 State Plane Alabama West		Contact Elev (ft NAVD 88)	Model Layer	Data Source
	Easting	Northing			
VC-1A-84	1801568	240909	-40.5	2	USACE Investigations conducted by SAM
VC-1A-84	1801568	240909	-46.5	3	USACE Investigations conducted by SAM
VC-1A-84	1801568	240909	-68.5	3	USACE Investigations conducted by SAM
VC-21-84	1804755	183977	-41.5	2	USACE Investigations conducted by SAM
VC-21-84	1804755	183977	-45.5	3	USACE Investigations conducted by SAM
VC-21-84	1804755	183977	-72.5	3	USACE Investigations conducted by SAM
VC-23-84	1805705	173577	-37.5	2	USACE Investigations conducted by SAM
VC-23-84	1805705	173577	-53.5	3	USACE Investigations conducted by SAM
VC-23-84	1805705	173577	-68.5	3	USACE Investigations conducted by SAM
VC-24-84	1806105	169277	-43.5	2	USACE Investigations conducted by SAM
VC-24-84	1806105	169277	-66.5	3	USACE Investigations conducted by SAM
VC-24-84	1806105	169277	-70.5	3	USACE Investigations conducted by SAM
VC-2-84	1801308	235164	-40.5	2	USACE Investigations conducted by SAM
VC-2-84	1801308	235164	-52.5	3	USACE Investigations conducted by SAM
VC-2-84	1801308	235164	-65.5	3	USACE Investigations conducted by SAM
VC-28-84	1806505	155927	-42.5	2	USACE Investigations conducted by SAM
VC-28-84	1806505	155927	-57.5	3	USACE Investigations conducted by SAM
VC-28-84	1806505	155927	-72.5	3	USACE Investigations conducted by SAM
VC-32-84	1805005	143977	-42.5	2	USACE Investigations conducted by SAM
VC-32-84	1805005	143977	-59.5	3	USACE Investigations conducted by SAM
VC-32-84	1805005	143977	-69.5	3	USACE Investigations conducted by SAM
VC-3-84	1801124	233683	-39.5	2	USACE Investigations conducted by SAM
VC-3-84	1801124	233683	-52.5	3	USACE Investigations conducted by SAM
VC-3-84	1801124	233683	-59.5	3	USACE Investigations conducted by SAM
VC-4-84	1801075	231623	-41.5	2	USACE Investigations conducted by SAM
VC-4-84	1801075	231623	-44.5	3	USACE Investigations conducted by SAM
VC-4-84	1801075	231623	-60.5	3	USACE Investigations conducted by SAM
VC-5-84	1801010	229659	-41.5	2	USACE Investigations conducted by SAM
VC-5-84	1801010	229659	-44.5	3	USACE Investigations conducted by SAM
VC-5-84	1801010	229659	-67.5	3	USACE Investigations conducted by SAM
VC-6-84	1800860	227348	-41.5	2	USACE Investigations conducted by SAM
VC-6-84	1800860	227348	-54.5	3	USACE Investigations conducted by SAM
VC-6-84	1800860	227348	-70.5	3	USACE Investigations conducted by SAM
VC-7-84	1801096	224471	-36.5	2	USACE Investigations conducted by SAM
VC-7-84	1801096	224471	-43.5	3	USACE Investigations conducted by SAM
VC-7-84	1801096	224471	-64.5	3	USACE Investigations conducted by SAM
VC-8-84	1801245	220611	-43.5	2	USACE Investigations conducted by SAM
VC-8-84	1801245	220611	-51.5	3	USACE Investigations conducted by SAM
VC-8-84	1801245	220611	-66.5	3	USACE Investigations conducted by SAM
VC-9-84	1801604	218000	-41.5	2	USACE Investigations conducted by SAM
VC-9-84	1801604	218000	-50.5	3	USACE Investigations conducted by SAM
VC-9-84	1801604	218000	-66.5	3	USACE Investigations conducted by SAM
MOBKK-01	1747040	190250	118.5	1	GSA Well Records
MOBKK-01	1747040	190250	47.5	2	GSA Well Records
MOBKK-01	1747040	190250	-39.5	3	GSA Well Records
MOBKK-01	1747040	190250	-142.5	4	GSA Well Records

Appendix A
Boring Logs used in Model Construction

Well ID	NAD 83 State Plane Alabama West		Contact Elev	Model Layer	Data Source
	Easting	Northing	(ft NAVD 88)		
MOBKK-01	1747040	190250	-147.5	4	GSA Well Records
MOBGG-TestHole1	1723251	227372.1	180	1	GSA Well Records
MOBGG-TestHole1	1723251	227372.1	75	2	GSA Well Records
MOBGG-TestHole1	1723251	227372.1	-10	3	GSA Well Records
MOBGG-TestHole1	1723251	227372.1	-50	4	GSA Well Records
MOBGG-TestHole1	1723251	227372.1	-160	5	GSA Well Records
MOBGG-TestHole1	1723251	227372.1	-300	5	GSA Well Records
MOBFF-4	1746080	214540	128	1	GSA Well Records
MOBFF-4	1746080	214540	40	2	GSA Well Records
MOBFF-4	1746080	214540	-8	3	GSA Well Records
MOBFF-4	1746080	214540	-45	4	GSA Well Records
MOBFF-4	1746080	214540	-302	5	GSA Well Records
MOBFF-4	1746080	214540	-366	5	GSA Well Records
MOBFF-04	1753310	214330	150	1	GSA Well Records
MOBFF-04	1753310	214330	44	2	GSA Well Records
MOBFF-04	1753310	214330	-43	3	GSA Well Records
MOBFF-04	1753310	214330	-100	4	GSA Well Records
MOBFF-04	1753310	214330	-313	5	GSA Well Records
MOBFF-04	1753310	214330	-364	5	GSA Well Records
MOBNN-010	1752661	156727.8	33	2	GSA Well Records
MOBNN-010	1752661	156727.8	-36	3	GSA Well Records
MOBNN-010	1752661	156727.8	-67	4	GSA Well Records
MOBNN-010	1752661	156727.8	-354	5	GSA Well Records
MOBNN-010	1752661	156727.8	-437	5	GSA Well Records
MOBNN-02	1742530	160750	94	1	GSA Well Records
MOBNN-02	1742530	160750	40	2	GSA Well Records
MOBNN-02	1742530	160750	-144	3	GSA Well Records
MOBNN-02	1742530	160750	-156	4	GSA Well Records
MOBNN-02	1742530	160750	-331	5	GSA Well Records
MOBNN-02	1742530	160750	-402	5	GSA Well Records
BALUU-22 Approx	1904458	154711	75	2	GSA Well Records
BALUU-22 Approx	1904458	154711	30	3	GSA Well Records
BALUU-22 Approx	1904458	154711	-160	4	GSA Well Records
BALUU-22 Approx	1904458	154711	-225	5	GSA Well Records
BALZZ-044 Approx	1923974	127426	50	1	GSA Well Records
BALZZ-044 Approx	1923974	127426	-30	2	GSA Well Records
BALZZ-044 Approx	1923974	127426	-110	3	GSA Well Records
BALZZ-044 Approx	1923974	127426	-220	4	GSA Well Records
BALZZ-044 Approx	1923974	127426	-270	5	GSA Well Records
BALZZ-044 Approx	1923974	127426	-450	5	GSA Well Records
UU-4	1771336	91155.97	6	1	GSA Well Records
UU-4	1771336	91155.97	-39	2	GSA Well Records
UU-4	1771336	91155.97	-54	3	GSA Well Records
UU-4	1771336	91155.97	-260	4	GSA Well Records
UU-4	1771336	91155.97	-453	5	GSA Well Records
UU-4	1771336	91155.97	-492	5	GSA Well Records

Appendix A
Boring Logs used in Model Construction

Well ID	NAD 83 State Plane Alabama West		Contact Elev	Model	Data Source
	Easting	Northing	(ft NAVD 88)	Layer	
UU-17	1782086	91090	7.9	1	GSA Well Records
UU-17	1782086	91090	-25.1	2	GSA Well Records
UU-17	1782086	91090	-52.1	3	GSA Well Records
UU-17	1782086	91090	-266.1	4	GSA Well Records
UU-17	1782086	91090	-292.1	4	GSA Well Records
Well 4	1774085	96695.87	4.1	1	GSA Well Records
Well 4	1774085	96695.87	-25.9	2	GSA Well Records
Well 4	1774085	96695.87	-61.9	3	GSA Well Records
Well 4	1774085	96695.87	-181.9	4	GSA Well Records
Well 4	1774085	96695.87	-328.9	4	GSA Well Records
Well 2	1771915	92916	5.54	1	GSA Well Records
Well 2	1771915	92916	-51.46	2	GSA Well Records
Well 2	1771915	92916	-57.46	3	GSA Well Records
Well 2	1771915	92916	-147.46	4	GSA Well Records
Well 2	1771915	92916	-294.46	4	GSA Well Records
UU-3	1775115	92650.7	5	1	GSA Well Records
UU-3	1775115	92650.7	-30	2	GSA Well Records
UU-3	1775115	92650.7	-65	3	GSA Well Records
UU-3	1775115	92650.7	-140	4	GSA Well Records
UU-3	1775115	92650.7	-322	5	GSA Well Records
UU-3	1775115	92650.7	-495	5	GSA Well Records
BALOO-02	1868040	177750	105	1	GSA Well Records
BALOO-02	1868040	177750	70	2	GSA Well Records
BALOO-02	1868040	177750	-37	3	GSA Well Records
BALOO-02	1868040	177750	-82	4	GSA Well Records
BALOO-02	1868040	177750	-186	5	GSA Well Records
BALOO-02	1868040	177750	-354	5	GSA Well Records
BALLL-011	1848360	222580	142	1	GSA Well Records
BALLL-011	1848360	222580	66	2	GSA Well Records
BALLL-011	1848360	222580	-1	3	GSA Well Records
BALLL-011	1848360	222580	-51	4	GSA Well Records
BALLL-011	1848360	222580	-182	5	GSA Well Records
BALLL-011	1848360	222580	-324	5	GSA Well Records

ATTACHMENT A – 8

COST ESTIMATE

WALLA WALLA COST ENGINEERING MANDATORY CENTER OF EXPERTISE

COST AGENCY TECHNICAL REVIEW

CERTIFICATION STATEMENT

For Project No. 444633

SAM – Mobile Harbor General Reevaluation Report (GRR)

The Mobile Harbor General Reevaluation Report (GRR), as presented by Mobile District, has undergone a successful Cost Agency Technical Review (Cost ATR), performed by the Walla Walla District Cost Engineering Mandatory Center of Expertise (Cost MCX) team. The Cost ATR included study of the project scope, report, cost estimates, schedules, escalation, and risk-based contingencies. This certification signifies the products meet the quality standards as prescribed in ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering.

As of April 19, 2019, the Cost MCX certifies the estimated total project cost:

FY19 Project First Cost: $338,548,000
Fully Funded Amount: $365,732,000

It remains the responsibility of the District to correctly reflect these cost values within the Final Report and to implement effective project management controls and implementation procedures including risk management through the period of Federal Participation.

®

JACOBS.MICHAEL.PIERRE.1160569537 Digitally signed by JACOBS.MICHAEL.PIERRE.1160569537 Date: 2019.04.19 14:36:33 -07'00'

Michael P. Jacobs, PE, CCE
Chief, Cost Engineering MCX
Walla Walla District

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: Mobile Harbor GRR
PROJECT NO: P2 444633
LOCATION: Mobile, Alabama

DISTRICT: SAM Mobile District
POC: CHIEF, COST ENGINEERING,George Brown
PREPARED: 3/9/2019
UPDATED: APRIL 2019

This Estimate reflects the scope and schedule in report; Mobile Harbor Integrated GRR and Supplemental EIS

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2019 / Effective Price Level Date: 1 OCT 18									
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	TOTAL ($K) J	Spent Thru: ($K)	TOTAL FIRST COST ($K) K	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
12	NAVIGATION PORTS & HARBORS	$259,977	$67,594	26.0%	$327,571	0.0%	$259,977	$67,594	$327,571	$0	$327,571	7.9%	$280,581	$72,951	$353,532
12	LOCAL SERVICE FACILITIES (Berthing)	$9,118	$2,371	26.0%	$11,488	0.0%	$9,118	$2,371	$11,488	$0			excluded from Fully Funded Costs		
12	ASSOCIATED (ATON)	$487	$127	26.0%	$614	0.0%	$487	$127	$614	$0			excluded from Fully Funded Costs		
	CONSTRUCTION ESTIMATE TOTALS:	$269,582	$70,091		$339,673	0.0%	$269,582	$70,091	$339,673	$0	$327,571	4.1%	$280,581	$72,951	$353,532
01	LANDS AND DAMAGES	$55	$4	6.8%	$59	0.0%	$55	$4	$59	$0	$59		excluded from Fully Funded Costs		
30	PLANNING, ENGINEERING & DESIGN	$4,405	$1,145	26.0%	$5,550	0.0%	$4,405	$1,145	$5,550	$0	$5,550	8.4%	$4,777	$1,242	$6,019
31	CONSTRUCTION MANAGEMENT	$4,260	$1,108	26.0%	$5,368	0.0%	$4,260	$1,108	$5,368	$0	$5,368	15.1%	$4,905	$1,275	$6,180
	PROJECT COST TOTALS:	$278,302	$72,348	26.0%	$350,650		$278,302	$72,348	**$350,650**	$0	**$338,548**	4.3%	$290,263	$75,468	$365,732

BROWN.GEORGE.L.1113832319 Digitally signed by BROWN.GEORGE.L.1113832319 Date: 2019.04.25 08:32:50 -05'00'
CHIEF, COST ENGINEERING,George Brown

NEWELL.DAVID.P.1230678312 Digitally signed by NEWELL.DAVID.P.1230678312 Date: 2019.04.25 09:42:13 -05'00'
PROJECT MANAGER, David Newell

KNIGHT.DONOVAN.D.1261247808 Digitally signed by [illegible]
CHIEF, REAL ESTATE, Willie Patterson

FLAKES.CURTIS.M.1230659873 Digitally signed by FLAKES.CURTIS.M.1230659873 Date: [illegible]
CHIEF, PLANNING, Curtis Flakes

Digitally signed by OTTO.DOUGLAS.C.JR.1041723218 Date: 2019.05.01 12:41:54 -05'00'
CHIEF, ENGINEERING,Douglas Otto

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

ESTIMATED FULLY FUNDED TOTAL PROJECT COST: $365,732
GENERAL NAVIGATION FEATURES[1]: *$353,532*

PROJECT FIRST COST: $338,548
LOCAL SERVICE FACILITIES COST[2]: *$11,488*
ASSOCIATED COSTS[3]: *$614*
LERR[4]: *$59*
INCREMENTAL AVERAGE ANNUAL O&M[5]: $2,537

[1]GENERAL NAVIGATION FEATURES ARE COST SHARED 75% FEDERAL-10% GNF OVER 30 YEARS, 25% NON-FED + 10% GNF PAID OVER 30 YEARS
[2]LOCAL SERVICE FACILITIES ARE 100% NON-FEDERAL COSTS
[3]ASSOCIATED COSTS ARE 100% FEDERAL (USCG) COST
[4]LERR IS A CREDITABLE COST, ALSO INCLUDED IN PROJECT FIRST COST
[5]O&M IS BASED ON 50 YEAR ANALYSIS, COST IS NOT INCLUDED IN SUMMARY