Section 5
Georgia Coastal Plain: Regional and Sub-Regional Calibrated Groundwater Flow Models

Where sufficient hydrogeologic data existed, a calibrated three-dimensional groundwater flow model of the aquifer system was developed. A calibrated model increases the confidence level of the sustainable yield estimate. Additionally, transient flow capabilities would allow for the ability to change the magnitude and direction of flow with time. With transient capabilities, the model can be used to assess the timing of withdrawals as well as the spatial distribution of withdrawals. Numerical flow models were developed for the Claiborne, Cretaceous, and Upper Floridan aquifers in the Coastal Plain aquifer system in Georgia.

5.1 Dougherty Plain Modeling Approach

In order to provide a basis for estimating the sustainable yield in Upper Floridan aquifer in the Dougherty Plain area, an existing United States Geological Survey (USGS) Modular Finite Element (MODFE) model of the Upper Floridan aquifer in this area was used with no modifications. The model domain, along with Georgia, Alabama, and Florida counties is shown by the dashed purple area in Figure S-1. The Dougherty Plain area is located at the southwestern corner of Georgia and the model extends slightly into Alabama and Florida. The model covers an area of approximately 4,700 square miles. Two versions of the model were furnished by the USGS: a transient model and a steady state model. The steady state model was chosen for this analysis because it was determined to be sufficient for sustainable yield evaluations.

The model was calibrated to conditions in October 1999, during which time the model area was experiencing a drought. Because it was the month of lowest stream baseflow, it was therefore a month of greatest constraint on the sustainable yield. Groundwater withdrawals during months other than October, particularly those during the agricultural irrigation season, would be higher than the October 1999 baseline and may in fact exceed the sustainable yield during the time of withdrawal.

During a review of the model documentation and the execution of several preliminary test simulations, it was apparent that the critical sustainability metric in the Dougherty Plain area was the potential impact to base flows of the river system. Because there is a significant degree of connection between the Upper Floridan aquifer and the rivers in this part of Georgia, excessive drawdown of the aquifer does not appear to be a major concern because the rivers would recharge the aquifer under increased withdrawal scenarios.

There are a number of river systems within the model domain. **Figure S-6** shows the model domain with the associated tributary basins or hydrologic unit. Each hydrologic unit is identified by a unique hydrologic unit code (HUC).

To assess sustainable yield, drought condition withdrawals were incrementally increased in a specific hydrologic unit while keeping the withdrawals in the remaining hydrologic units at the original rate. The withdrawal rate multiplier was increased until a streamflow reduction metric was triggered. This process was repeated for each hydrologic unit until unique multipliers were determined for each hydrologic unit. Once all of these multipliers were determined, a series of simulations followed in which the groundwater withdrawals were increased in all hydrologic units by their unique multiplier. Due to the cumulative effect of withdrawals on streamflow, it became necessary to lower the withdrawal multipliers until the streamflow reduction metric was no longer violated. This then, represented an estimate of the sustainable yield of the Upper Floridan aquifer in the Dougherty Plain.

5.2 Dougherty Plain Sustainable Yield Ranges

Table S-5 shows the multipliers when the groundwater withdrawal increases are simulated concurrently. There are several river reaches in HUC 03130004, including the Chattahoochee River, Sawhatchee, Kirkland, and Bryans. While it appears to be technically possible to have a significant increase in the groundwater withdrawal from the Chattahoochee River basin, this hydrologic unit straddles both the Alabama and Florida state lines. Significant increases in groundwater withdrawals would cause impacts in these adjacent states. Therefore, Table S-5 shows a sustainable yield range that both includes and does not include additional withdrawals from this hydrologic unit code.

The table lists the October 1999 baseline withdrawals and the revised withdrawals providing a sustainable yield estimate. These cumulative increases in groundwater withdrawals result in an overall increase in the withdrawal of between 80 mgd and 171 mgd over October 1999 baseline for the study area.

There are two hydrologic unit groups (03130009 – Ichawaynochaway Creek, and 03130008 – Lower Flint River, with minor portions of the upper and lower Ochlocknee River) in which approximately 70 percent of the potential increase in groundwater withdrawals originates. Thus, there is a significant amount of water available, but this available water tends to be centrally located in the basin.

As discussed previously, the most significant metric was the reduction in baseflow to the rivers; however, there is also a drawdown effect. To ensure that there were no violations, the drawdown was calculated. Due to the lack of a significant confining unit above the Upper Floridan aquifer, the drawdown due to increased withdrawals is less than 5 feet and does not approach the 30 foot drawdown metric. In this case, streamflow reduction controls the estimate of sustainable yield. **Figure S-7** shows the river reach that violated the baseflow metric used to determine sustainable yield when simulating the increased withdrawals concurrently.

In order to further examine the range of sustainable yield, an additional simulation was performed using March 2001 data. March 2001 was the month that had the highest river stages within the time range of the U.S.G.S transient model. Completing sustainable yield runs using March 2001 data, therefore, allowing a comparison of sustainable yield during times of low and high stream baseflow.

The original steady state model input parameters were replaced with those parameters that represented the March 2001 period in the transient model. Specifically, river stages, groundwater withdrawals, and recharge/leakage values were replaced with March 2001 information. The sustainable yield simulations were then rerun with March 2001 baseline withdrawals. Similar to the original simulation, there were two general scenarios considered, pumping increases allowed in HUC 03130004, which causes some drawdown in Alabama and Florida, and pumping increases not allowed in HUC 03130004. These scenarios resulted in an overall sustainable yield range of 262 to 347 mgd, slightly higher than the October 1999 results of 237 to 328 mgd.

5.3 Coastal Plain Modeling Approach

Sustainable yields were determined for four prioritized Coastal Plain aquifers:

- The Upper Floridan aquifer in south-central Georgia;
- The Upper Floridan aquifer in the eastern Coastal Plain of Georgia;
- The Claiborne aquifer in southwestern Georgia; and
- The Cretaceous aquifer between Macon and Augusta.

The approach used to model the prioritized Coastal Plain aquifers was as follows:

- An existing regional USGS Coastal Plain Clastic aquifer System model was modified and updated by incorporating available data and the existing groundwater models in or adjacent to the project areas to better represent the hydrogeologic conditions within the project area.
- A regional groundwater flow model was developed and calibrated to observed groundwater elevations at monitor well locations. It was also calibrated using available hydrogeologic data, groundwater monitoring well data, and existing models under steady-state conditions to establish boundary conditions (elevations) for the sub-regional models.
- Three sub-regional groundwater flow models for the prioritized aquifers were developed by zooming into portions of the calibrated regional groundwater model.
- Models of the prioritized aquifers were calibrated to observed groundwater elevations at monitor well locations under transient conditions that represented average, high, and low rainfall years. The transient conditions consisted of 36

monthly stress periods (January 2004 through December 2006) to represent an average rainfall year (2004), a high average rainfall year (2005), and a low rainfall year (2006). The benchmark condition was that heads should have achieved at least 90 percent of their pre-drought levels within four years.

- The calibrated model of each prioritized aquifer was used to simulate increased groundwater withdrawals from the aquifer to determine the range of sustainable yield for the individual aquifer.
- The calibrated regional model was used to simulate increased groundwater withdrawals from all prioritized aquifers to determine the total range of sustainable yield for simultaneous increased withdrawals from all of the prioritized aquifers.

The extents of the regional and prioritized aquifer models are shown on **Figure S-8**.

The general sustainable yield metrics presented in Section 2 were further refined to be used for the Georgia Coastal Plain numerical models. To estimate a range of sustainable yields using a calibrated numerical model, withdrawals were increased over baseline withdrawals and the aquifers were allowed to fully adjust to the new groundwater withdrawal regime. In other words, aquifers were allowed to reach a new equilibrium at the higher withdrawals. Equilibrium was seen once the pattern of annual variation in aquifer heads had stabilized. Model results for the time of year when heads were at their lowest (usually in August or September) were compared to the set of selected sustainable yield metrics.

Even if it is assumed that the sustainable yield is properly assessed and that the 30-foot groundwater level drawdown metric at system equilibrium for the driest month is the determining metric, this still does not mean a single sustainable yield number can be calculated. The sustainable rate of aquifer withdrawal is sensitive to the location and density of withdrawals. Withdrawals in a small area may result in a 30-foot drawdown whereas the same withdrawals dispersed over a larger area will have a lesser drawdown result. This means that sustainable yield must be assessed as a range, and that the ultimate sustainable yield within that range will depend on the pattern and density of withdrawals.

In the Coastal Plain, there are multiple aquifers underlying the region. Withdrawals in one aquifer often cause groundwater level drawdown in underlying and overlying aquifers. If withdrawals are allowed to increase in each of the aquifers within the sustainable yield of that individual aquifer, the cumulative effect of simultaneous withdrawals from multiple aquifers could result in drawdowns of more than 30 feet more than 40 percent recharge from streamflow.

The regional model was run simultaneously increasing withdrawals from all prioritized aquifers with withdrawals reduced until the metrics for drawdown and recharge from streamflow were met across the multiple aquifers. This analysis resulted in estimates of sustainable yield for increasing withdrawals in multiple aquifers simultaneously.

5.4 Sustainable Yield of South-Central Georgia and Eastern Coastal Plain Upper Floridan Aquifer, Claiborne Aquifer, and Cretaceous Aquifer

The sustainable yield in the Upper Floridan aquifer in south-central Georgia and the eastern Coastal Plain were evaluated together. First, the sustainable yield of south-central Georgia was evaluated by itself by increasing withdrawals from existing and hypothetical new wells. Withdrawals from the Upper Floridan aquifer in the eastern coastal plain were held at baseline levels. Then, withdrawals were increased in the existing wells in the eastern Coastal Plain along with increasing withdrawals from existing and hypothetical new wells in south-central Georgia. Unlike in south-central Georgia, new wells were not considered in the Upper Floridan aquifer in the eastern Coastal Plain when simulated withdrawals were increased because existing withdrawals are low and there is widespread spatial coverage of existing wells. Two scenarios were evaluated for withdrawal increases: one included all wells increasing uniformly, and the other increased withdrawals only in areas where there are relatively little withdrawals currently.

Table S-6 provides a summary of the results of sustainable yield modeling of the individual prioritized aquifers. The table provides a range of increases in withdrawals over current rates of withdrawals for each individual prioritized aquifer, assuming that the other prioritized aquifers do not increase withdrawals above their current levels. Section 5.5 provides the range of increases in withdrawals over current rates of withdrawals for each individual prioritized aquifer, assuming that all of the other prioritized aquifers simultaneously increase withdrawals above their current levels to their sustainable yield rates.

5.4.1 Upper Floridan Aquifer in South-Central Georgia

As shown in Table S-6, the estimated baseline withdrawal rate from the Upper Floridan aquifer in south-central Georgia was approximately 329 mgd. Uniformly increased withdrawals from the existing wells in the Upper Floridan aquifer in south-central Georgia represented the low end of the range of sustainable yield, whereas non-uniformly increased withdrawals from the existing wells and hypothetical new wells in the south-central Georgia Upper Floridan aquifer represents the high end of the range of sustainable yield.

If withdrawals are uniformly increased from existing wells in the Upper Floridan aquifer in south-central Georgia, the withdrawals can be increased from a baseline of 329 mgd to 622 mgd. This pumping scenario results in localized exceedance of the 30-foot groundwater level drawdown metric and a corresponding baseflow reduction of approximately 23 percent.

If withdrawals are non-uniformly increased (that is, only in areas where there are relatively little withdrawals currently), total withdrawals could be increased further in south-central Georgia toward 836 mgd, an upper bound for the range of sustainable yield. **Figure S-9** presents the range of sustainable yield for the Upper

Floridan aquifer in south-central Georgia. The results presented in this figure assume that withdrawals in the aquifer are increased while holding withdrawals in the other aquifers at existing estimated rates. **Figures S-10a and S-10b** are groundwater level drawdown maps, showing where the drawdown metric of 30 feet was exceeded for the minimum and maximum sustainable yield, respectively.

5.4.2 Upper Floridan Aquifer in South-Central and Eastern Coastal Plain Georgia

Table S-6 provides sustainable yield estimates for withdrawal increases in south-central Georgia and Eastern Coastal Plain Georgia occurring simultaneously. Estimated baselines withdrawals in both areas were approximately 475 mgd. If withdrawals are uniformly increased from existing wells in the Upper Floridan aquifer in south-central Georgia and the eastern Coastal Plain, the withdrawals could be increased from a baseline of 475 mgd to 868 mgd. This withdrawal scenario resulted in a localized exceedance of the 30-foot groundwater level drawdown metric and a corresponding baseflow reduction of approximately 23 percent.

If withdrawals are non-uniformly increased from existing wells in south-central Georgia and the eastern Coastal Plain, total withdrawals could be increased further toward 982 mgd, an upper bound for the range of sustainable yield. Note that there is already a wide distribution of existing pumping wells in this area. Therefore, the addition of new wells within this combined area did not result in the maximum estimate of increased sustainable yield over the estimate of increased sustainable yield for south-central Georgia by itself. **Figure S-11** presents the range of sustainable yields for the Upper Floridan aquifer in south-central Georgia and the eastern Coastal Plain of Georgia. The results presented in this figure assume that withdrawals in the aquifer are increased while holding withdrawals in the other aquifers at existing estimated rates. **Figures S-12a and S-12b** are groundwater level drawdown maps, showing where the drawdown metric of 30 feet was exceeded for the minimum and maximum sustainable yield, respectively.

5.4.3 Claiborne Aquifer

The results of the groundwater modeling for the Claiborne aquifer sustainable yield assessment are also summarized in Table S-6. The estimated baseline withdrawal rate from the Claiborne aquifer in Georgia is approximately 67 mgd. If withdrawals are uniformly increased from the existing wells in the Claiborne aquifer, the withdrawals can be increased from a baseline of 67 mgd to 100 mgd. This pumping scenario results in an exceedance of the 30-foot groundwater level drawdown metric and a corresponding baseflow reduction of approximately 6 percent. If withdrawals are non-uniformly increased from the existing wells, total pumping withdrawals can be increased to 250 mgd. **Figure S-13** presents the range of sustainable yield for the Claiborne aquifer. The results presented in this figure assume that withdrawals in the aquifer are increased while holding withdrawals in the other aquifers at existing estimated rates. **Figures S-14a and S-14b** are groundwater level drawdown maps, showing where the drawdown metric of 30 feet was exceeded for the minimum and maximum sustainable yield, respectively.

5.4.4 Cretaceous Aquifer

The results of the groundwater modeling for the Cretaceous aquifer sustainable yield assessment are presented in Table S-6. As shown in the table, the estimated baseline withdrawal rate from the Cretaceous aquifer is approximately 124 mgd, with 100 mgd pumped from the Providence aquifer and 24 mgd pumped from the Eutaw-Midville aquifer. If withdrawals are uniformly increased from the existing wells in the Cretaceous aquifer, the withdrawals can be increased from a baseline of 124 mgd to 198 mgd. This withdrawal scenario results in exceedance of the 30-foot groundwater level drawdown metric and a corresponding baseflow reduction of 39 percent. If withdrawals are non-uniformly increased from the existing wells, total withdrawals can be increased to 201 mgd. **Figure S-15** presents the range of sustainable yield for the Cretaceous aquifer between Macon and Augusta. The results presented in this figure assume that withdrawals in the aquifer are increased while holding withdrawals in the other aquifers at existing estimated rates. **Figures S-16a and S-16b** are groundwater level drawdown maps for the Providence aquifer, showing where the drawdown metric of 30 feet was exceeded for the minimum and maximum sustainable yield, respectively. **Figures S-17a and S-17b** are groundwater level drawdown maps for the Eutaw-Midville aquifer, showing where the drawdown metric of 30 feet was exceeded for the minimum and maximum sustainable yield, respectively.

5.5 Regional Model Combined Prioritized Aquifer Sustainable Yield Adjustment

Increased withdrawals occur at the same time in more than one Coastal Plain aquifer. Therefore, groundwater modeling simulations that increased withdrawals in all of the prioritized aquifers were completed to assess the potential impact of combined withdrawals on the overall range of sustainable yields.

Following the estimate of sustainable yield of each individual aquifer, the regional groundwater model was used to assess the potential impact of withdrawal increases in all the aquifers simultaneously. **Table S-7** shows the ranges of sustainable yields of individual prioritized aquifers with withdrawals increased in all prioritized aquifers simultaneously. Uniformly increasing withdrawals from the existing wells in all the prioritized aquifer represented the low end of the range of sustainable yields, whereas non-uniformly increasing withdrawals from the existing wells in each prioritized aquifer represents the high end of the range of sustainable yields. **Figure S-18** presents the results if withdrawals are increased in all of these prioritized aquifers. **Figures S-19a through S-19e** are groundwater level drawdown maps for each of the regional model layers, showing where the drawdown metric of 30 feet was exceeded for the minimum sustainable yield. **Figures S-20a through S-20e** provide the same information for the maximum sustainable yield.

Table S-8 presents the total sustainable yield of individual prioritized aquifers with aquifer withdrawals modeled individually and simultaneously. The results of this analysis show that if withdrawals in each prioritized aquifer are increased simultaneously, the total sustainable yield of prioritized Coastal Plain aquifers is lower than individual aquifers. When withdrawals are increased simultaneously in each prioritized aquifer, there is hydraulic interference between well pumping on a larger scale that limits the aquifer yield before exceeding sustainable yield metrics.