March 5, 2007

Robert E. Mace
Director, Groundwater Resources Division
Texas Water Development Board
1700 N. Congress Avenue
Austin, TX 78711

Dear Dr. Mace:

The attached Table 1 provides our responses to comments on a LCRA report that documents the initial model calibration of the LSWP groundwater model. The TWDB comments were submitted to Leah Manning on November 30, 2006.

We appreciate the TWDB's thorough review and we have found the comments helpful. We plan on completing a revised model report in Summer 2007 which will incorporate the disposition of your comments attached.

Please let us know if you have any question regarding our responses or the reports.

Sincerely,

Steven C Young

Steve Young
Study Manager for LSWP
Groundwater Study for Agriculture

C: Leah Manning, Project Manager for LCRA-SAWS Water Project
John Burke, Chair, Region K, Water Planning Group
Haskell Simon, Vice Chair, Region K, Water Planning Group
Neil Hudgins, General Manager, Coast Plains GCD and Coast Bend GCD
James Dwyer, QA/QC Study Lead for LCRA

Table 1: Responses to TWDB Comments on the Report“ Development of a Detailed Groundwater Flow Model for the Chicot and the Evangeline Aquifers in Colorado, Wharton, and Matagorda Counties.”

Comment	Response
General Comment #1 We acknowledge the significant efforts put together by the project team to better understand and model the groundwater flow system in the central parts of the Gulf Coast Aquifer. We particularly appreciate the team’s efforts in the following areas: • thoughtful approaches for designing model calibration, • simulation of groundwater-surface water interactions, • recharge estimation (inclusion of baseflow, irrigation return flow, and topography), • application of PEST to constrain calibration, • use of numerous hydrographs for testing model calibration, and • delineation of downdip extent of the flow boundary.	Response to General Comment #1 No response required.
General Comment #2 In addition, new information was collected on various topics essential for the development of this local scale groundwater model. Some of the information presented in this report is not final, which will be addressed during the final calibration in 2007. For example, there are issues with simulating flow along the eastern boundary of the model. The differences between the simulated and measured water levels in this area are considerably higher than in the rest of the model.	Response to General Comment #2 As recognized by the reviewers, the report is not final. A final report will be issued in Summer 2007. We plan to achieve a better model calibration along the eastern boundary in early 2007. Our efforts will be focused on improved representation of pumping and an improved implementation of the eastern model boundary.
General Comment #3 Compaction of clays in the Gulf Coast Aquifer, which has often been considered as a source of water and a subsequent trigger for land-surface subsidence, has not been incorporated in the current model. Inclusion of this component into the current model would help evaluate whether possible compaction of clays due to increased pumping would affect existing model calibration in addition to possible land surface subsidence. Sensitivity of the various model calibration parameters have not been reported, which to our understanding will be undertaken during final model calibration.	Response to General Comment #3 We agree that compaction of clays as a source of water has not been incorporated into the model. In early 2007, a land subsidence package will be added to the model. An investigation of the sensitivity of various model calibration parameters will be reported in 2007.

<u>General Comment #4</u> Along this line, it could be important to observe whether any changes to groundwater-surface water interaction occur by assigning pumpage in layer 1 of the model. Currently, no pumpage has been assigned to layer 1 of the model presumably due to shallow thickness (up to 150 feet) of the aquifer. However, numerous wells could be completed within the shallower areas of the Gulf Coast Aquifer. Groundwater pumpage distribution in the model area could also be better illustrated on a county and year basis.	<u>Response to General Comment #4</u> We agree. In the revised model, pumping from wells of shallow depth will be represented in Model Layer 1. In the revised report, we will more clearly document the pumping schedule and rates. We envision that pumping will be summarized by county and by year.
<u>General Comment #5</u> The report requires a thorough review to improve the clarity of information presented on various topics. A lot of important graphics were presented in the report but some of these graphics were not adequately described in the text. Detailed description of these important findings, presented in a manner readily understood by the general public, would help in a greater understanding of the Gulf Coast Aquifer in Texas.	<u>Response to General Comment #5</u> We agree that several of the report sections and graphics may not be readily understood by the general public. We plan to address this issue in the revised report. Our plan is to make sections of the report more general and to create Appendices that contain important technical details.
<u>General Comment #6</u> The report does not have a conclusion section. The report needs a conclusion section that would summarize the important findings of this investigation. Many references cited in the text are missing in the reference list. Therefore, some statements that were referred to in the text could not be further verified. Many of the color schemes used in the text and graphics were not readable in black and white print.	<u>Response to General Comment #6</u> The revised report will include a conclusion section. The revised report will provide a complete listing of the references. We acknowledge the concern about the color schemes used in the report. We will investigate the concern.
<u>Specific Technical Comment #1</u> **Table 2-1, page 2-4**, Average Recharge Values: Please consider completing the table with the recharge rate from groundwater availability model of the central part of the Gulf Coast Aquifer (0.17 to 0.48 inches per year).	<u>Response Specific Technical Comment #1</u> We agree. The missing values were an oversight.
<u>Specific Technical Comment #2</u> **Pages 2-2 and 2-3**: It was stated that shallow groundwater in the area flows to depths of 20 to 100 feet with a travel time of a month to a few tens of years and deep groundwater flows to depths of 500 to 2,000 feet with travel times that range between 50 and 10,000 years. Please consider providing supporting information or appropriate reference to support these specified travel times.	<u>Response Specific Technical Comment #2</u> We agree. In the final model report, these estimates will be supported by results of particle tracking.
<u>Specific Technical Comment #3</u> **Page 3-2, Figure 3-3**: Paragraph 2 describes the spatial extent and vertical layering of the model layers. Model layer 1 represents the shallow aquifer system and is up to 150 feet thick. Model layer 2 represents the Beaumont, layer 3 represents the Lissie, layer 4 represents the Willis, layer 5 represents the Upper Goliad, and layer 6 represents the lower Goliad formations. Figure 3-3 demonstrates the extent of the model layers in addition to showing locations of the active, inactive, and active thin	<u>Response Specific Technical Comment #3</u> We acknowledge the concern and we understand the cause for the concern. The revised model will explain the apparent consistency between the two sets of results. The figures shown in Deeds (2006), which we reference as Young and Kelley(2006) in the LCRA reports, are for the five geologic formations that comprise the Chicot and the Evangeline Aquifers. Deeds (2006) does not show the location of these formation boundaries relative to Model Layer 1. The 1-foot layers

cells. Active thin cells are cells that are 1 foot thick that are placed in the outcrop area to allow vertical communication between model layers above and below. However, when areas occupied by active thin cells are compared with thickness maps (Figures 3.18 to 3.21) presented in Deeds and others (2006), we observe that thin cell areas also occupy model areas with aquifer thicknesses that range from 20 to 100 feet. Please consider providing an explanation on why active thin cells include areas with appreciable aquifer thickness.	exist where the depth of Model Layer 1 exceeds the depth of a geologic formation.
Specific Technical Comment #4 **Page 4-1**: The following statements "For any given year, recharge is set at a constant rate and does not vary among the different months. For each calendar year, the average recharge rate varies as a non-linear function of total precipitation" appear contradictory and need further clarification	Response Specific Technical Comment #4 We agree. The revised model will include additional clarification. Basically, we vary the recharge rate at the temporal resolution of the model and our datasets. Our baseflow analyses were performed on a annual basis and our model time step averages four months.
Specific Technical Comment #5 **Page 4-9, Figure 4-4**: This figure shows recharge distribution for the steady-state model. Large areas in Colorado and Austin counties show recharge in excess of 5 inches per year. It is unclear how much greater than 5 inches per year recharge occurs in the area. Please consider providing the range of calibrated recharge values in the legend for this recharge category. Please consider mentioning that such high values of recharge have not been previously used in developing groundwater models of the Gulf Coast Aquifer in Texas.	Response Specific Technical Comment #5 We agree to provide addition detail on the recharge distribution. The upper limit is 6" per year which is the rate determined by field analysis of tritium profiles. Additional work is on-going to revisit the recharge percentage as a function of rainfall. We plan on discussing revisions to the recharge implementation with the TWDB and other stakeholders in 2007. Our analysis shows that recharge does not exceed 15% of rainfall at any stress period of the model calibration. We will mention in the revised report that such high values of recharge have not been previously used in developing groundwater models of the Gulf Coast Aquifer in Texas. However, the draft report does address this issue by providing the recharge rates used in the previous model in Table 2-1 (see Technical Comment #1).
Specific Technical Comment #6 **Page 5-4, Table 5-1**: Please consider providing consistent terminologies for depositional environments. For example, the Lissie, Willis, Upper, and Lower Goliad formations were grouped under "alluvial" and "coastal" depositional environments. Since alluvial environments could equally occur in the uplands and coastal settings, we suggest use of unique terms or that these specific environments are specifically defined to avoid confusion.	Response Specific Technical Comment #6 We acknowledge the reviewer concerns. In Table 5-1, "Alluvial" will be replaced with "Primarily Alluvial" and "Coastal" will be replaced with "Primarily Coastal."
Specific Technical Comment #7 **Page 5-12, Figure 5-3**: Figure 5-3 shows relationship between measured and estimated transmissivity from lithology. However, the data in the plot represent the Chicot and the Evangeline aquifers. Since, the transmissivity estimation was based on lithology, we expected that the data could as well be grouped based on specific formations used to develop the model layers.	Response Specific Technical Comment #7 We agree that the comment has merit and we did consider doing the recommended analysis prior to preparing the report. We decided against performing the work for three reasons. First, nearly all of the field data from Figure 5-3 was comprised from the western region of Harris County where we have poor geological control. Therefore our errors in separating the data into different geologic units may be large. Second, we do not have many data points for division of these relatively few points from two major groups to five minor groups. Third, the primary issues is not correlations involving drillers logs but with geophysical logs so that additional efforts associated with refining the data in Figure 5-3 would not provide any

	additional value to the development of the model. All Figure 5-3 needs to show is that transmissivity values can be reasonable predicted by sand content --- a findings that had not yet been adequately demonstrated by any other regional model in Texas.
Specific Technical Comment #8 **Page 6-6**: It was stated that the conductance between the general head boundary node and the adjacent model cell was set to 1.06E6 ft^2/day. How sensitive are the conductance values to flow across the general head boundary?	Response Specific Technical Comment #8 The model results are relatively insensitive to changes in the 1.06E6 ft^2/day conductance values. We have varied the values by factors of 100 and observed very small changes in the simulated hydrographs located a few grid cells away from the eastern boundary.
Specific Technical Comment #9 **Page 6-10, Figure 6-4**: Minimum river elevation using digital elevation models and Lower Colorado River Authority's HEC RAS model: please consider updating figure to include the elevation used in the final model.	Response Specific Technical Comment #9 We agree to update Figure 6-4 to include elevations used in the final model.
Specific Technical Comment #10 **Page 7-1, paragraph 4**: For model layer 1, no flow conditions were used to simulate the eastern boundary. However, considerable water could potentially flow across the boundary given a layer thickness of up to 150 feet. Therefore, we suggest that the no-flow boundary be replaced with a general head boundary similar to that assigned in the remaining model layers.	Response Specific Technical Comment #10 We disagree with the review comment that there could be enough groundwater flow across the layer 1 boundary. The Layer 1 boundaries roughly represent surface water basin boundaries which should be relevant hydrologic boundaries in the shallow aquifer. No major pumping wells are know to exist in model layer 1 so that there is no reason to expect significant large-scale deviation in flow lines (or fluxes) from those simulated by the no-flow boundaries in layer 1. With areal recharge and a relatively high storage in layer 1, we do not believe that capture lines will propagate laterally over large distances. Inclusion of GHBs in model layer 1 would require a major effort and would be based on the limited data.
Specific Technical Comment #11 **Page 8-1, paragraph 2**: states county other water use consists primarily of unreported domestic water use. Please note that this category of use represents all municipal use outside of designated cities (populations greater than 500 during the last planning cycle) and, therefore, includes both unreported domestic water use and public water supply for rural use.	Response Specific Technical Comment #11 We have noted the comment and will make appropriate changes in the revised model report.
Specific Technical Comment #12 **Page 8-8, paragraph 1**: The report lists two figures for figure 8-7 (one on page 8-15 and another on page 8-16). Please consider relabeling the figure on page 8-16 to Figure 8-8 and update the text accordingly. Also in the figure on page 8-16 it appears pumpage was assigned to cells where there does not appear to be a well in 2006. Please consider expanding the discussion in Section 8.4.4 to clarify how spatial distribution included cells without current wells or adjust the figure on page 8-16 to reflect current well locations more clearly. It is our understanding that the resource used for the spatial location of the irrigation wells was the TWDB groundwater database. This database contains only a fraction of all the irrigation wells in the state of Texas. Even though the data from the local groundwater	Response Specific Technical Comment #12 We plan to respond to the comments in the revised modeling report. We will relabel the figures per the recommendation. We are in the progress of improving the algorithm that locates the pumping wells and a detailed description of this algorithm will be provided in the revised report. Our current database for the irrigation wells includes the wells in the GCD database. Our database also includes municipal wells in the TCEQ database. We have also augmented our database with a detailed search of the well screen information from the TCEQ files. In 2007 we plan to improve our methodology by using the actual location of the pumping irrigation wells in Wharton and Matagorda County. However, this information will not be available until late March 2007.

conservation district's arrived too late to be incorporated into the model, it would possibly strengthen the validity or note the uncertainty of this methodology if the distribution of irrigation wells in the TWDB database was compared to the distribution of permitted irrigation wells by county from the groundwater conservation district data	
<u>Specific Technical Comment #13</u> **Page 8-8, paragraph 1**: states the method used for [spatially] locating wells was based on the known well locations in 2006. Please consider clarifying if this references the method discussed in Section 8.4.4. If this is the case, please consider cross-referencing text in Section 8.7 to Section 8.4.4.	<u>Response Specific Technical Comment #13</u> We agree with the comment.
<u>Specific Technical Comment #14</u> **Page 9-3, Figure 9-3**: It was stated in the text that for model layer 1, vertical hydraulic conductivity was uniform and set to 0.1. However, a distributed vertical hydraulic conductivity that ranges from 0.05 to 0.01 was shown for layer 1 in figure 9-3. Please consider clarifying the inconsistency between the text and the figure.	<u>Response Specific Technical Comment #14</u> The report on Page 9-3 has an error. The K values in Model Layer 1 are uniform and are set to 0.01 ft/day and not 0.1 ft/day.
<u>Specific Technical Comment #15</u> **Page 9-5**: Tables 9-2 and 9-3 reports root mean squared error values by counties using the FWL5 package and the WEL package. However, part of the table is confusing, particularly the last column of values with root mean squared errors greater than 80. Please consider providing some description of these tables so that the values presented in each column are easily understood.	<u>Response Specific Technical Comment #15</u> Agreed. We will provide additional information. We agree the table is confusing. The values in Table 9-3 provide cumulative number of wells for each group. Thus, although Austin has 17 wells with RMS >80 it also has 17 wells with RMS of <70, and <80. In reality, Austin has no wells with RMS >70.
<u>Specific Technical Comment #16</u> **Page 9-6, paragraph 3**: This paragraph discusses problems with hydraulic head data. Please consider clarifying if the data retrieved from the TWDB groundwater database were screened for publishable data and water level measurement comments indicated static water levels (remarks should be null or "1"). We are concerned using measurements from a pumping well as targets that may not reflect ambient water levels.	<u>Response Specific Technical Comment #16</u> We agree with the comment.
<u>Specific Technical Comment #17</u> **Page 9-6**: Figures 9-17 through 9-19 are confusing. Do contours on these maps represent residual values (differences between measured and simulated water levels) as stated in the caption of the figure? If yes, then these residuals are way too high. If they are simulated water levels for 1900–1910, 1910–1920, and 1920–1930, then please correct the caption. Please remove the reference to residuals from the caption if this is not what was presented in the map.	<u>Response Specific Technical Comment #17</u> We will modify the captions to provide additional information. The plotted points are residuals averaged over the periods cited in the figure captions. The contours represent model predictions for the specific year listed in the caption.
<u>Specific Technical Comment #18</u> **Page 9-7**: The report states that there is some spatial and temporal bias in the occurrences of the residuals. The model underpredicts heads in the central portion of the model and overpredicts along the boundaries. In addition, the residuals increase over time. How would this result affect the predictive simulations through	<u>Response Specific Technical Comment #18</u> The cause for the temporal and spatial basis appear to be caused by biases in the spatial distribution in the K function and the temporal and spatial biases in the general head boundaries. We anticipate that these issues will be resolved in the final model.

2060? We suggest that some discussion on this may help provide greater confidence in the model.	
Specific Technical Comment #19 **Page 9-7**: Figure 9-27 shows that during post-1950s, when groundwater pumping was increasing, baseflow discharge tends to show a corresponding decrease. During 1980s to 1990s, a reversal in flow occurs through the general head boundary. These observations of model response provide an illustration on how the aquifer behaves under various pumping conditions; therefore, please consider discussing these observations in the text.	Response Specific Technical Comment #19 We agree that this observation needs further discussion. We hesitated in providing this type of detail in the draft report because additional information was needed to properly discuss this issue. We have collected the additional data and have revised our model algorithms to better include irrigation return flow, which could affect the simulated results.
Specific Technical Comment #20 **Page 9-7, paragraph 4**: Appears to state conflicting conclusions. Please clarify. Report states center of the model under predicts hydraulic head in the center of the model yet calibration is quite good in Colorado, Wharton, and Matagorda counties.	Response Specific Technical Comment #20 We will provide additional details in the revised report. The calibration is good but the bias suggests a slight under prediction in these counties.
Specific Technical Comment #21 **Page 9-7, Paragraph 6**: Please consider noting that no pumping has been assigned in layer 1 of the model. Given that layer 1 occupies up to 150 feet of aquifer thickness and presumably contains numerous shallow wells, assigning no pumpage in this layer may potentially affect the degree of groundwater-surface water interactions and the net water budget in the model.	Response Specific Technical Comment #21 We agree. We have changed our pumping algorithms and the model currently includes pumping from Model Layer 1.
Specific Technical Comment #22 **Page 9-8, Paragraph 2**: Please consider clarifying these sentences "Before 1953, there is a net upward movement of groundwater from layer 2 to layer 1. After 1953, there is a net upward movement of groundwater from layer 1 to layer 2".	Response Specific Technical Comment #22 We agree. This issue has been addressed in response to Specific Technical Comment #19.
Specific Technical Comment #23 **Page 9-14:** Steady-state cross-plot includes all layers; suggest separating out cross-plots for each layer. Also suggest including cross-plots for each layer of the transient run in the final report.	Response Specific Technical Comment #23 We agree with the comment. Figure 9-7 already separates the calibration fits by layer but for brevity we may provide all of the results on a single plot.
Specific Technical Comment #24 **Page 9-17:** Figure 9-13 shows root mean squared error plots for the transient calibration. Numerous wells along the eastern model boundary show root mean squared error values in excess of 60 feet. This suggests that the flow near the general head boundary could be simulated better. As pumping in the central part of the model presumably draws in more water across the general head boundary, how would this simulation affect calibration in other parts of the model area?	Response Specific Technical Comment #24 We agree that that there are numerous wells with RMS errors in excess of 60 feet. Since our initial model calibration we have reduced substantially in the revised model.
Editorial Comment #1 **Page 2-1**: Definitions for Chicot and Evangeline aquifers reference only two aquifers in the Gulf Coast Aquifer, while the definition for the Gulf Coast Aquifer	Response Editorial Comment #1 We agree to include a better definition of the Gulf Coast Aquifer in order to avoid future confusion.

also mentions the Burkeville Confining Unit and the Jasper Aquifer. This appears inconsistent and confusing. Please consider clarifying and adjusting text accordingly. Suggest stating the Chicot and Evangeline aquifers are the two 'main' aquifers that comprise the Gulf Coast Aquifer.	
Editorial Comment #2 **Page 3-2:** Young and others (2004) is not in the reference list.	Response Editorial Comment #2 We will include the citation in the reference list in the revised report.
Editorial Comment #3 **Page 3-4, Figure 3.2**: Vertical Cross-Section: Suggest adding some point of reference for orientation such as Gulf of Mexico or South on the left axis and North or Outcrop on the right axis.	Response Editorial Comment #3 We agree.
Editorial Comment #4 **Page 4-3, reference to Figure 2-5**: Please consider adjusting to reference 4-2 or include corresponding figure in section 2.	Response Editorial Comment #4 We will consider the suggestion.
Editorial Comment #5 **Page 5-1**: Young et al. (2002), Kelly and others (2002), and Deeds and others (2002) are not included in the reference list	Response Editorial Comment #5 We will include the citations in the reference list in the revised report.
Editorial Comment #6 **Page 5-6:** Deeds et al. (2003) and Dutton et al. (2003) are not included in the reference list.	Response Editorial Comment #6 We will include the citations in the reference list in the revised report.
Editorial Comment #7 **Page 5-8**: Kelly and others, 2004 is not included in the reference list.	Response Editorial Comment #7 We will include the citations in the reference list in the revised report
Editorial Comment #8 **Page 5-14, Figure 5-6**: Please consider updating references to 'faction' to 'fraction' in the legends.	Response Editorial Comment #8 We will include the citation in the reference list in the revised report.
Editorial Comment #9 **Page 8-6**: References Figure 8-4 and states '…average pumpage rate of 24 AFY to yield 4 grid cells…', please consider updating text to '25 AFY' to agree with Figure 8-4.	Response Editorial Comment #9 We agree to the suggested change.
Editorial Comment #10 **Page 9-4, paragraph 2**: References TWDB and Harris-Galveston Subsidence District, suggest discarding TWDB data and use Harris-Galveston Subsidence District data since it is more comprehensive	Response Editorial Comment #10 We will provide a more thorough discussion of this issue in the revised report. In general, we agree with the comment and are implementing the suggested action.
Editorial Comment #11 **Page 9-5, paragraph 1**: Last sentence is unclear: "Nonetheless, the well package is often used in modeling because of it is simple to apply and simple to developed…"	Response Editorial Comment #11 We agree to modify the report to address the concern.
Editorial Comment #12 **Page 9-6, paragraph 2**: References "RSM", rest of section references "RMS".	Response Editorial Comment #12 We agree to modify the report to address the concern.
Editorial Comment #13	Response Editorial Comment #13

Page 9-6, paragraph 3: Fifth and sixth sentences are unclear: “A second issue is that after 1980, the many of the hydrographs show that heads are rebounding as a result of decrease pumping. A third issue is the wide-range of in the range of fluctuations caused by irrigation pumping during the summer months.”	We have corrected the grammatical errors.
Editorial Comment #14 **Page 9-6, paragraph 2**: Last sentence is unclear or incomplete: “Another reason is that in Model Layer 1 the groundwater system is an unconfined.”	Response Editorial Comment #14 The sentence should read that Model Layer 1 represents an unconfined aquifer. We agree to make the appropriate revision.
Editorial Comment #15 **Page 9-7, paragraphs 2, 3, 4**: Have numerous grammatical errors. Please review and update as needed	Response Editorial Comment #15 We agree to make appropriate changes.
Editorial Comment #16-#17 These comments were accidentally omitted by the TWDB or the TWDB comments are misnumbered.	Response Editorial Comment #16-#17 No respond required.
Editorial Comment #18 **Page 9-10, Figure 9-2**: In the legend, there is a category of hydraulic conductivity values that range from 61–70 ft/d but no corresponding color zones for this range of values were reported. Therefore, we could not locate where this high hydraulic conductivity areas occur on the map.	Response Editorial Comment #19 We agree to change the color for the range of K values from 61 to 70 ft/day in the revised model report.
Editorial Comment #19 **Pages 9-18 to 9-20**: The hydrographs in Figures 9-14 to 9-16 are too small to read. Suggest expanding to hydrographs per layer or including larger size hydrographs in appendix	Response Editorial Comment #19 We agree to increase the size of the figures in the revised model report.
Editorial Comment #20 **Pages 9-21 to 9-30**: Figures 9-17 to 9-26 appear to have different contour intervals in each inset. Difficult to interpret due to size. Suggest enlarging.	Response Editorial Comment #20 We agree to increase the size of the figures in the revised model report.