PROPOSAL
To improve the Groundwater Availability Model for the Carrizo-Wilcox Aquifer in Central Texas to include a robust groundwater-surface water package

by
Environmental Stewardship
and INTERA

SUMMARY

The Texas Water Development Board (TWDB) and Groundwater Management Area 12 (GMA-12) have agreed to update and improve the current GMA-12 Groundwater Availability Model (GAM) and have selected INTERA to conduct the work under contract with the TWDB. The work funded by TWDB is primarily targeted to improve the way the model deals with faults. The GMA-12 Districts have also agreed to fund a refinement of the model that will provide an improved groundwater-surface water interaction capability. Based on discussions with INTERA, Environmental Stewardship believes that additional improvements to the model's capability beyond the work funded by the GCDs is needed to adequately simulate the groundwater-surface water interactions at the level required to understand, forecast and manage the aquifers, especially the Simsboro Aquifer that is the primary aquifer targeted for development in Central Texas. This proposal justifies and seeks funding for the incremental work necessary to provide a robust model. Because of the nature of the work and the review processes required to adopt a newly improved model, this is a unique opportunity to get a serious groundwater-surface water simulation into the current revision.

BACKGROUND

The Central Sparta-Queen City-Carrizo-Wilcox Groundwater Availability Model (GAM) includes the Simsboro aquifer formation in Groundwater Management Area 12 which is projected to become a major water supply aquifer for Central Texas and the I-35 corridor. The GAM simulates the interactions of the Carrizo-Wilcox aquifer with the Queen City and the Sparta aquifers during the period from 1975 to 1999. Among the concerns with the predictive accuracy of the GAM is that limited aquifer test data from all aquifers and very limited water level data from the Simsboro aquifer in Lee and Burleson counties were used to develop the GAM. In addition, the GAM was developed using a simplified approach to simulate the impact of the Mexia-Talco fault on groundwater flow and the interaction between groundwater and surface water flow. Since the GAM was completed in 2003 a considerable amount of hydrogeological testing and data collection has occurred in GMA 12. In addition, significant advancements have been made in improving methods for modeling groundwater-surface water interactions.

Analysis of recently gathered hydrogeological data in GMA 12 suggests that several of the major assumptions used to develop the GAM may not accurately represent the groundwater flow system. The most significant of these assumptions is that many of the geological faults in the model are represented as hydrological barriers to groundwater flow whereas in reality they likely allow considerable amounts of groundwater flow to pass through them. For several years, the GCDs in GMA 12 have expressed an interest to the TWDB to co-fund improvements to the GAM. To help address their concerns, the GCDs committed $200,000 to help co-fund an improved GAM in 2009. As a result of GMA 12's desire to have a revised GAM, the Texas Water Development Board (TWDB) provided $320,000 to match the GCDs' $200,000 in Fall 2014 to fund a project from private contractors. In Winter 2015, the TWDB selected INTERA to update the GAM by performing the following:

- Improve the historical estimate of pumping in GMA 12 from pre-pumping conditions to 2010
- Assemble and analyze the large amount of aquifer pumping test data that has been performed in GMA 12 to determine the hydraulic properties of the aquifer formations and the impacts of

geological faults on groundwater flow conditions

- Assemble and analyze the water level information from 1900 to 2010 with an emphasis on large-scale pumping tests to help evaluate the location and impacts of geological faults on groundwater flow
- Assemble and analyze geophysical well logs to help evaluate the location and impacts of the geological faults and the regions of thick sand units on groundwater flow
- Assemble and analyze well pumping information from GMA 12 from 1900 to 2010
- Develop a steady-state condition for the GAM that represents pre-pumping condition where no pumping occurred from the aquifer and the simulated water levels represents conditions where the amount of natural discharge out of the aquifers into surface water sources and down-dip groundwater flow equals the natural recharge of the aquifer from precipitation
- Recalibrate the GAM by changing the mathematical representations of the geological faults and the aquifer properties as appropriate so that the GAM better reflects groundwater flow
- Expand calibration to include the period from pre-development conditions (around 1900) to 1975 and from 1999 to 2010

Because of limited funding the TWDB did not include improving the GAM's capability to simulate groundwater-surface water interaction despite the fact that the GAM is known to contain potentially significant error in predicting the exchange of water between the major rivers and the underlying aquifers they intersect. As a result of this concern, several GCDs in GMA 12 met with the TWDB in Fall 2014 to discuss options for expanding the TWDB contract to include a provision for expanding the contract scope of work to improve groundwater-surface water interaction. The TWDB provided the GCDs with the option of negotiating with the winner of the bid to expand the TWDB contract to include additional tasks that would be funded by non-TWDB money. In Fall 2014, the GCDs decided to provide the additional resources in Table 1 for the purpose of accomplishing the work in Table 2.

Table 1. Funding Provided by GCDs beyond their Original $250,000 to to Expand the Scope of Work Associated with of the TWDB Contract Awarded to INTERA

Groundwater Conservation District	Resources Committed
POSGCD BVGCD	$100,000 funding
METGCD	$2,500 funding
LGPCD	$50,000 in-kind services from their hydrogeologic consultant

Table 2. Expanded Scope of Work Requested by GCDs with Additional Funding Listed in Table 1

Tasks	
#	**Description**
1	Improve numerical representation of surface water-groundwater interaction
2	Improve historical matches of baseflows associated with the Lower Colorado River and the Brazos River
3	Refine the 1-mile by 1-mile grid spacing near the major rivers to 0.5-mile by 0.5-mile grid spacing
4	Investigations into using MODFLOW-USG unstructured grid to help improve the representation of the faults and groundwater-surface water in the GAM

After being selected by TWDB to improve the GAM, INTERA reviewed the estimated costs for completing the tasks in Table 2 and determined that the most cost effective approach for completing the tasks listed in Table 2 is to convert the existing GAM to a newer version of MODFLOW. The existing GAM is in a version of MODLOW called MODFLOW 96. The newer version of MODFLOW proposed by INTERA is MODFLOW-USG. INTERA has developed a cost estimate for completing the work in Table 2 based on updating the GAM to a MODFLOW-USG model. The MODFLOW-USG model is a recent and very significant advancement in groundwater modeling that permits a very robust and resource effective method for refining grids around wells and rivers by allowing a mix of grid sizes to be used. The principal developer of MODFLOW-USG is on the INTERA team.

The TWDB has not executed a contract with INTERA. As a result, INTERA has not begun negotiating with the TWDB and GCDs regarding an expanded work scope and funding. To help prepare for these negotiations, INTERA has estimated the cost of developing a MODFLOW-USG model to be not less than $150,000. This estimate does not include field work that could provide useful information for the project. In order to fund the $150,000 to develop the MODFLOW-USG model, INTERA asked Lost Pines GCD to convert the commitment from $50,000 in-kind services to $50,000 funding (see Exhibit A). Environmental Stewardship also wrote a letter to Lost Pines GCD in support of INTERA's request (see Exhibit B). The LPGCD discussed INTERA's request during two Board meetings and decided that they needed to stay with their original commitment of in-kind. Currently, the LPGCD is deciding what in-kind services and deliverables it will provide to help accomplish the tasks in Table 2. Of principal concern to INTERA is having the appropriate funding for its modeling team to develop the MODFLOW-USG model.

EXPANDING THE TWDB CONTRACT TO BETTER SIMULATE GROUNDWATER-- -SURFACE WATER INTERACTION

INTERA's approach to accomplishing the tasks in Table 2 will be similar to the approach used to develop the Lower Colorado River Basin (LCRB) model as a part of the LCRA-SAWS Project. One of the principal reasons the LCRB model was developed is because the GMA 15 GAM used by the GCDs to guide the groundwater management does not accurately simulate groundwater-surface water interaction because of improperly sized grid cells in the vicinity of the river cells. Among the known limitations of the GMA 15 GAM and most other GAMs is that they lack the vertical resolution in the model layers to represent a shallow groundwater flow zone. This limitation exists in most GAMs such as the GAMs for GMA 15 and 12 because these GAMs were developed primarily for regional planning and for simulating groundwater flow at a regional scale of several counties. Consequently, these GAMs do not accurately simulate groundwater flow at the scale of a few miles and less, which is required to accurately model groundwater-surface water interactions. To develop a groundwater flow zone in the LCRB model, the modelers added model layers near ground surface to allow the model to simulate shallow groundwater flow near the rivers and decreased the size of the grid cells model to better represent the location of rivers and wells.

A metric for measuring groundwater-surface water interaction is baseflow. Baseflow is the amount of groundwater that flows into a river. Figure 1 shows the results of measured baseflow from two field studies that were performed along a segment of the Colorado River that crosses through Colorado, Wharton, and Matagorda counties. The figures shows that the baseflow was about 115,000 AFY/yr in 1918 and about 95,000 AFY/yr in 2005-2006. The decrease in the baseflow over time is attributed to the declines in the water table in the shallow groundwater zones caused by regional pumping.

Prior to developing the LCRB model, the GAM 15 GAM was demonstrated by the LCRB modeling team and LCRA to be a very poor simulator to rivers baseflow as illustrated by the results in Figure 1. This poor comparison occurs primarily because the GMA 15 GAM model does not have the required model layering and grid cell size to model shallow groundwater flow separately from the deeper groundwater

flow (which is under the influence of heavy irrigation pumping) in the vicinity of the Colorado River. To correct this problem, the LCRB modeling team constructed the LCRB model with much greater grid refinement. As shown in Figure 1, the LCRB provides a significantly better match to the measured baseflows than does the GAM 15 GAM.

The approach used by the LCRB model to improve simulation of groundwater-surface water interaction has been documented in conferences and peer-reviewed articles. The approach requires specialized modeling expertise to execute, but is mathematically sound. INTERA has used the same approach in developing the Yegua-Jackson GAM and the recently developed Northern Trinity Woodbine GAM. Dr. Steve Young with INTERA was the person who first implemented the approach with the LCRB model and he will be leading the effort to improve the GMA 12 GAM capability to simulate groundwater-surface water interaction.

The potential importance of refined grid spacing around a river is dependent on many factors. Among the most important of these factors is the proximity of pumping wells to the rivers and how many model layers separate the wells from the top model layer. The large amount of errors that the GMA 15 GAM has in its simulated baseflow is a result of the large number of irrigation wells located by the river. Because the GMA 12 GAM was constructed using the same model layering and grid spacing guidelines as the GMA 15 GAM, the GMA 12 GAM cannot accurately simulate groundwater-surface water interaction in the vicinity of large pumping occurring near the river where the most shallow grid cells include both pumping wells and rivers.

The amount of grid refinement that will be needed to improve the GMA 12 GAM is unknown at this time. INTERA anticipates that up to two vertical model layers may need to be added to represent the shallow groundwater flow zone and that grid cells will need to be reduced from 1-mile grid cells. For the LCRB model, a grid cell size of 0.25 mile was determined adequate to meet the modeling objectives without exceeding budget constraints. Figure 2 provides a comparison of a 1-mile and a 0.25 mile grid for a portion of the LCRB model study area. In general, smaller grid cell sizes around a river will provide a greater ability to accurately model groundwater-surface water data as long as there is sufficient field data to support grid construction. This is because greater refinement allows for better representation of the river location, topographic gradients, and the base elevation of the river. However, the smaller the grid spacing around the river the more costs associated with developing the model. A principal factor in determining grid cell size around a river is the funding available for developing the model. INTERA estimates that an incremental cost of $35,000 will be needed to adequately develop the 0.25 mile grid spacing necessary to ensure that the model is robust enough to accurately simulate the groundwater-surface water interaction in the GMA-12 model.

Currently, INTERA is developing a GAM for the Brazos River Alluvium as part of another TWDB contract. To develop this GAM, INTERA is using MODFLOW-USG. One reason for using MODFLOW-USG for the Brazos River Alluvium GAM is that it provides the capability to decrease the size of grid cells near the river without having to decrease the grid size away from the river. Figure 3 shows a MODFLOW-USG numerical grid for the Brazos River Alluvium GAM that is currently be used to model groundwater-surface water interaction. This numerical grid uses 0.125-mile grid cells near the river and 1-mile grid cells away from the river. The ability of MODFLOW-USG to allow grid cells to transition from small to large grid cells is one of the features of MODFLOW-USG that makes it the model best suited for improving the simulation of groundwater-surface water interaction in the GMA 12 model. The 0.125-mile grid is a requirement that is a part of the TWDB contract to help the model accurately simulate groundwater-surface water interaction.

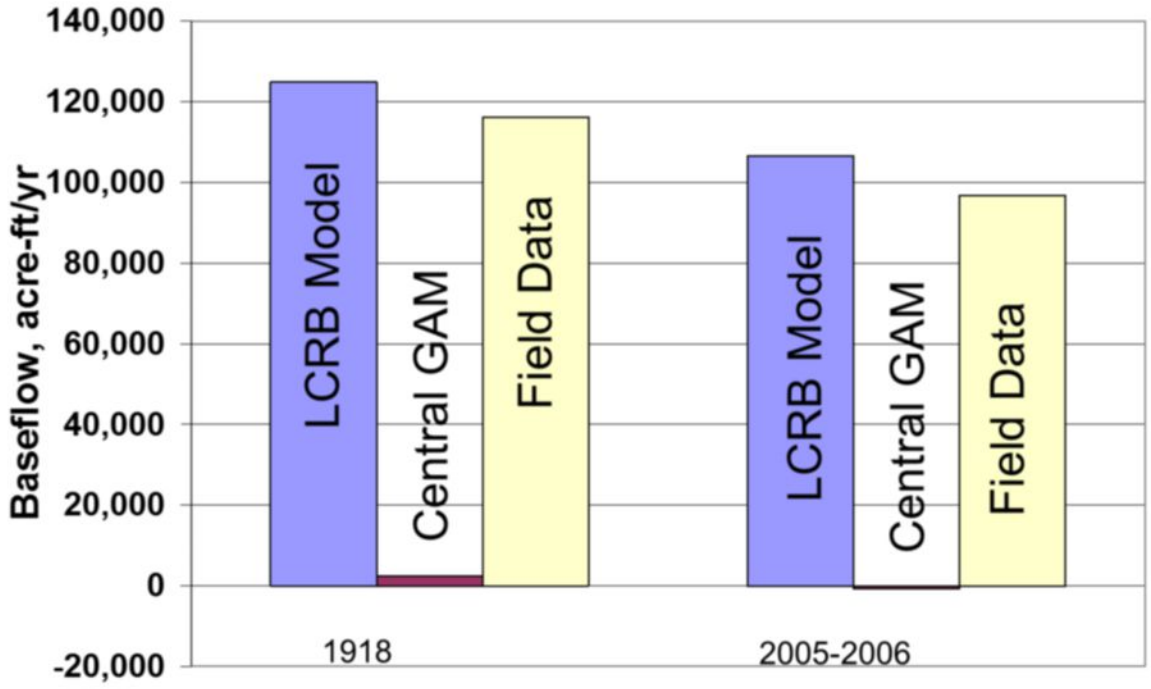

Figure 1. Comparison of measured and simulated groundwater and surface water exchange between the Colorado River and the Gulf Coast Aquifer System along the river reach in Colorado, Wharton, and Matagorda counties for 1918 and 2005-2006

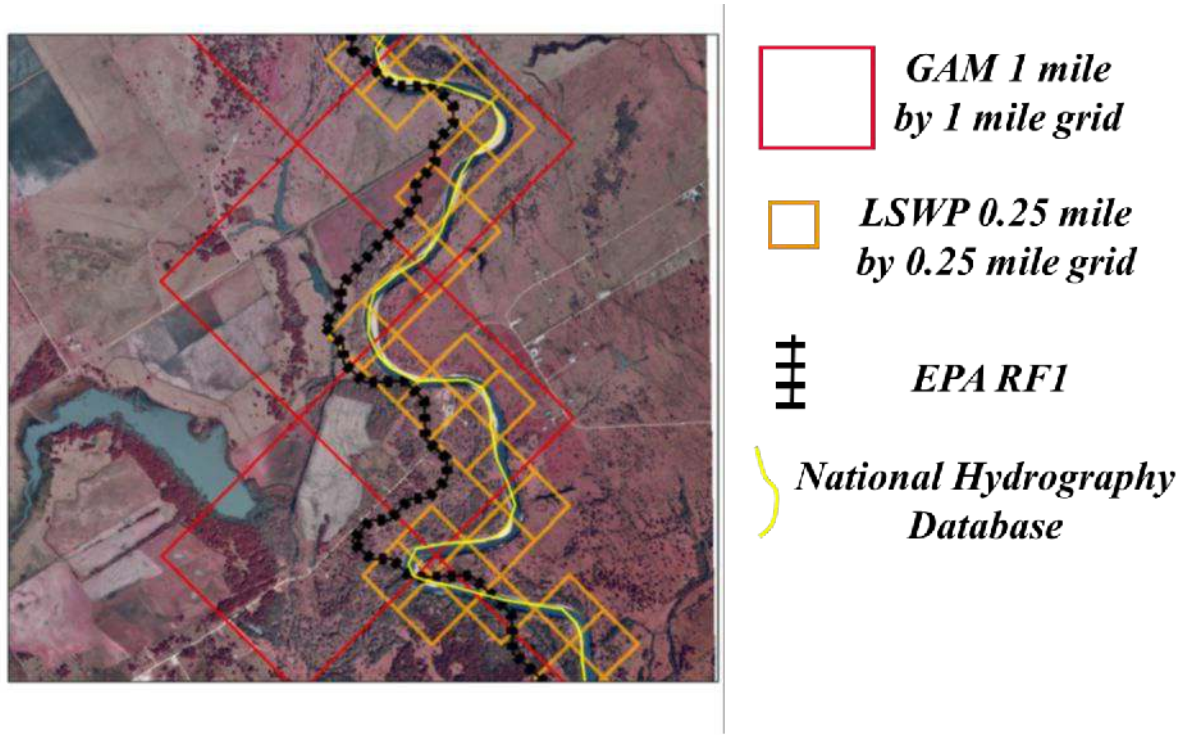

Figure 2. Comparison of the approaches for representing the Colorado River based on EPA RFI dataset and the National Hydrography dataset and based on a 1-mile grid cell and on a 0.25-mile grid cell

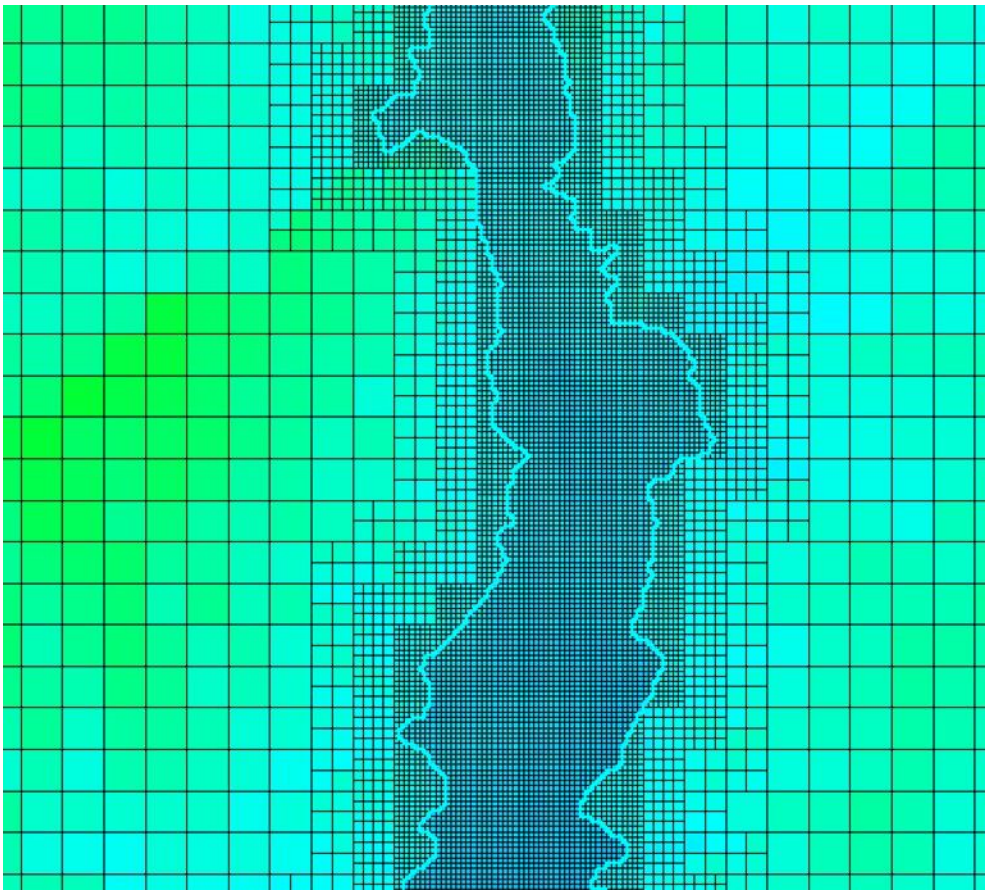

Figure 3. Illustration of the type of refinement in the numerical grid that can be realized by using the quadtree option. The illustration shows a 1/8 mile size grid cells across the extend of the Brazos River Alluvium (the light blue line) that extends outward to a 1-mile grid spacing a few miles away from the Brazos River Alluvium.

FUNDING:

The TWDB has allocated funding to improve the GMA 12 GAM's capability to simulate the impact of faults on groundwater flow, but the TWDB did not have sufficient funding to improve the capability of the GMA 12 GAM to simulate groundwater- surface water interaction. INTERA estimates that no less than $150,000 of funding is needed by their modeling team to develop the GMA 12 GAM into a MODFLOW-USG model that will significantly improve the GAM's ability to simulate groundwater-surface water flow. INTERA currently has $102,000 from GCDs of the required $150,000 to develop a MODFLOW-USG model that has 0.5 mile grid cells by the river. INTERA is actively exploring options to secure an additional $48,000 to develop a MODFLOW-USG model. Among the funding options that may help provide this funding are LCRA and GCDs.

Based on discussions with INTERA, Environmental Stewardship believes that a 0.25 mile grid spacing is needed to ensure that the GMA-12 model has a robust groundwater-surface water interaction capability. INTERA estimates that an incremental cost of $35,000 will be adequate to develop the 0.25 mile grid spacing necessary to ensure the model is robust enough to accurately simulate the groundwater-surface water interaction for the GMA-12 model. The incremental cost will need to be delivered during the term of the project which is likely to extend into 2017 (dates and milestones for payment will be negotiated as needed). Environmental Stewardship is currently able to commit $5,000 toward funding the incremental work. Environmental Stewardship is seeking other funding commitments to raise the full $35,000 prior to a final contract being finalized with TWDB.

Environmental Stewardship also anticipates that there will be a need to develop a groundwater-surface water monitoring plan for implementation by the GMA-12 Districts to provide future data for forecasting and managing the aquifer-surface water interactions. INTERA estimates that such a plan can be developed for $15,000 and would include analysis of existing data, location and specifications for monitoring wells, a proposed monitoring strategy for both surface and groundwater, and a few test model runs to evaluate the utility of the model. Estimate also includes several meetings with ES and others to discuss and present project. This would be a separate contract with ES and would not involve TWDB.

Exhibit A: Letter Sent to LPGCD Requesting Change from $50,000 in-- -kind services to $50,000 funding

INTERA Incorporated
1812 Centre Creek Drive, Suite 300
Austin, Texas, USA 78754
512.425.2000

May 6, 2015

Mr. James Totten, Manager
Lost Pines Groundwater Conservation District
908 Loop 230
Smithville, Texas 78957

Re: TWDB Contract to Revise the Central Queen-City Sparta GAM

Dear Jim:

The purpose of this letter is to request that Lost Pines Groundwater Conservation District (GCD) consider changing their commitment of $50,000 in-kind services to a commitment of $50,000 funding for the revised GMA 12 groundwater availability model (GAM).

The commitment letter included as Attachment A describes the GMA 12 districts' commitment for revising the GMA 12 GAM. These commitments provide for: 1) $200,000 funding to cover the baseline project that focuses on improving the representation of the faults, and, 2) $102,000 funding and $50,000 in-kind services to enhance the baseline project to include the following:

- Improved numerical representation of surface water-groundwater interaction
- Improved historical matches of baseflows associated with the Lower Colorado and Brazos rivers
- Refinement of the 1-mile grid spacing to a 0.5-mile grid spacing near major rivers
- Investigation into using the MODFLOW-USG unstructured grid to help improve the representation of the faults and surface water-groundwater in the GAM

An important consideration regarding the above model enhancements is that grid size refinement of a GAM is a very costly and time consuming process. The only GAM that has been refined from a 1-mile grid spacing to a smaller grid size was performed by INTERA for the Northern Trinity and Woodbine GAM (NTGAM). The funding for this project was about $2MM. Another important consideration regarding the above model enhancements is that improved representation of surface water – groundwater interactions requires refinement in the vertical layering. This process is also costly and time consuming. The type of vertical refinement needed to improve baseflow predictions was pioneered during the LCRA-SAWS project (LSWP), which included development of the Lower Colorado River Basin (LCRB) model, and cost approximately $3MM.

The INTERA modeling team includes six subcontractors, of which four of these firms have extensive experience with developing models in GMA 12 for the Carrizo-Wilcox aquifer. In addition, three of the firms helped develop the LCRB model and two of the firms have extensive experience with modeling using the MODFLOW-USG unstructured grid. INTERA has concluded that the requested enhancements cannot be accomplished for $152,000 using traditional MODFLOW. A possible way to accomplish the requested tasks for $152,000 is to convert the entire GMA 12 model from MODFLOW 96 to a MODFLOW-USG unstructured grid.

Based on our team's modeling experience, the process of refining grid spacing around rivers is best accomplished by a few select modelers who share and co-develop tools for model development, and who have years of experience with this complex process. For this reason, our team includes a group of modelers who have worked extensively on the NTGAM, the LCRB model, and on development of the MODFLOW USG code. Since the majority of the work for the enhancements will focus on developing a refined model grid using MODFLOW USG, there is a need to focus much of the funding resources to our modeling team. We therefore request that Lost Pines GCD consider changing their commitment of $50,000 in-kind services to a commitment of $50,000 in funding. If this is not an option, we would then request that Lost Pines GCD consider a reduction in the degree and type of enhancements for simulating surface water – groundwater interactions.

Sincerely,

Steve C Young

Steve Young, PG, PE. Ph.D
Principal Hydrogeologist

EXHIBIT B Environmental Stewardship letter to Lost Pines GCD Board in support of project.

Environmental Stewardship
A Sustainable Ecosphere

June 15, 2015

Delivered by email

Board of Directors
Lost Pines Groundwater Conservation District
908 Texas 230 Loop
Smithville, TX 78957

Re: Item 6: TWDB update of Queen City – Sparta Groundwater Availability Model

Dear President Talbot and Board Members,

I am writing in support of item 6 requesting that the District participate in funding the TWDB update of the Queen City Sparta Groundwater Availability Model (GAM) used by Groundwater Management Area 12 and the Lost Pines GCD t estimate impacts of groundwater pumping on the Carrizo-Wilcox and other aquifers within the GMA and District. Environmental Stewardship urges the Board to approve this expenditure to improve the groundwater-surface water modeling capabilities of the GAM.

ES has, for many years, advocated to this Board and GMA-12 for the protection of the groundwater-surface water relationship between the Colorado and Brazos rivers and the Simsboro formation of the Carrizo-Wilcox Aquifer Grou We believe that protection of this relationship is the key to protecting and conserving the groundwater and surface water resources of the region while sharing these resources with other parts of Texas. In addition, the the Conservation Amendment of the Texas Constitution and the Texas Water Code make it the duty of the District to protect and conserve these resources by considering the impact of pumping of groundwater on surface waters before adopting desired future conditions (DFC) and before granting groundwater pumping permits.

Of all the duties of groundwater districts prescribed in the water code, this duty is perhaps the least understood on a scientific basis, and yet perhaps the most critical to balancing between conservation and development of the aquifers while protecting the surface water resources. Though the requirement to consider the impact on surface waters for DFCs and permits have been in the code for 3+ and 18 years respectively, the state has not taken the initiative to do the science and develop the models needed to assist districts in fully implement this duty. We now have an opportunity to start developing the information and tools necessary to evaluate and manage the impact of groundwat pumping on aquifers and surface waters.

ES believes that this expenditure by the District, the GMA, and the TWDB is a major step forward in constructing the groundwater availability modeling tool needed to estimate and manage the impacts of groundwater pumping on our water resources. We believe this tool, as it integrates existing empirical information and models the impacts of potential new pumping, will be very valuable in making sound decisions regarding the future management of these aquifers. We encourage the Board to approve this expenditure.

Respectfully submitted,

Steve Box
Executive Director
Environmental Stewardship

Environmental Stewardship is a charitable nonprofit organization whose purposes are to meet current and future needs of the environment and its inhabitants by protecting and enhancing the earth's natural resources; to restore and sustain ecological services using scientific information; and to encourage public stewardship through environmental education and outreach. We are a Texas nonprofit 501(c) (3) charitable organization headquartered in Bastrop, Texas. For more information visit our website at http://www.environstewardship.org/.