



April 7, 2021

Mr. Harry Hardman, Board President
Lone Star Groundwater Conservation District
655 Conroe Park North Drive
Conroe, Texas 77303

RE: Proposed Scope of Work, Schedule, and Cost Estimate –
Phase II Subsidence Investigations
Montgomery County, Texas

Dear Mr. Hardman,

We are providing herein on behalf of the Lone Star Groundwater Conservation District (LSGCD) Technical Consulting Team of LRE Water, LLC (LRE), Thornhill Group, Inc. (TGI) and Advanced Groundwater Solutions, LLC (AGS) a proposed scope of work, schedule, and cost estimate for conducting Phase II Subsidence Investigations. TGI designed Phase I of the subsidence investigations to compile as much data and information as possible, to provide a functional and working knowledge of the existing studies, information, and data, and to provide summaries of historical and on-going subsidence investigations. Additionally, TGI's initial proposal generally identified potential work for subsequent phases of the project. TGI and LRE provided LSGCD a revised Proposal for Phase I Subsidence Investigations and worked collaboratively to complete the Phase I project. During Phase I of the subsidence investigation, TGI and LRE worked to:

1. Compile a comprehensive library and database of past and current subsidence studies with associated monitoring data;
2. Develop a working understanding of historical information, reports, and datasets pertaining to past subsidence;
3. Assess historical and predicted future distributions of modeled subsidence utilizing the current groundwater availability model (GAM) approved by the Texas Water Development Board (TWDB), which is commonly called the Houston Area Groundwater Model (HAGM), particularly related to the current joint-planning efforts of LSGCD and Groundwater Management Area 14 (GMA 14); and,
4. Identify and prioritize additional work efforts and phases of the project to best consider, evaluate, and assess subsidence particularly related to LSGCD groundwater management.

For Phase II, the LSGCD Technical Consulting Team collaborated to develop a Scope of Services to address some items briefly outlined as subsequent phases in the Phase I proposal and identified as potential recommended work in the Phase 1 report. The objective of the proposed Phase II Scope of Services is to build upon summaries and data collection efforts in Phase I to focus on the potential for future land-surface deformation within Montgomery County and adjacent areas along with recommendations for effective monitoring of subsidence within Montgomery County. Specific goals of Phase II are to:

- Build upon Phase I summaries with detailed evaluations, assessments, and critiques of selected previous data and studies with specific implications to Montgomery County;
- Assess the structural and geotechnical parameters controlling the occurrence, distribution, timing and amount of compaction of the subsurface geologic layers through correlation of measured and reported historical pumping, water levels, land-surface deformation, and sub-surface compaction;
- Develop a long-term plan for data collection and evaluation to contribute to the empirical understanding of the effects of groundwater pumping on sub-surface compaction and land-surface deformation within Montgomery County; and,
- Prepare interim deliverables and a project report describing and illustrating the work conducted with key findings and conclusions. Additionally, the work will include preparing one or more presentations to the Board and stakeholders.

Scope of Services

The proposed Scope of Services is designed to address the objective and goals of the project. Licensed professional geoscientists and/or licensed professional engineers from LRE, TGI, and AGS will be responsible for the work and conclusions developed during the project. Collectively LRE, TGI, and AGS will be referred to as the “LSGCD Consulting Team.” The LSGCD Consulting Team will work closely with the LSGCD General Manager, Samantha Reiter, throughout the project. For the project, the overall role for each LSGCD Consulting Team Member is as follows:

- Michael R. Keester, PG with LRE will be the primary point of contact for the project and will be responsible for providing project updates, coordinating work amongst the LSGCD Consulting Team, and adhering to the schedule for deliverables.
- Michael R. Thornhill, PG with TGI will lead QA/QC efforts drawing upon his experience in the area, his knowledge of previous research, and, as the initiator of these subsidence investigations for LSGCD, he will continue to provide overall project guidance and oversight.
- James A. Beach, PG with AGS will guide the practical application of the investigations within the management framework of the District, in addition to providing technical expertise on specific tasks. James will draw on his years of experience working with Districts across Texas to incorporate scientific investigations into policy decisions.

The LSGCD Consulting Team worked collaboratively and iteratively amongst ourselves and with the LSGCD general manager to develop this proposed Scope of Services. The division of responsibilities, including the selection of LRE as the primary point of contact for the project, is proposed by agreement amongst the Team. We anticipate continuous collaboration amongst the LSGCD Consulting Team to complete the proposed Scope of Services. While this collaboration of Team Members is vital to completing a robust, practical, and defensible study, for each task listed below we identify the primary Team Member responsible for work to be conducted under each task. However, for each task we anticipate all Team Members will have specific work tasks to support the Team Member with primary responsibility. LRE will have final responsibility for all project deliverables to LSGCD.

Task 1 –Technical Evaluations of Existing Data and Recent Study

Task 1 will involve detailed technical analyses of the previously identified subsidence study: *Subsidence Risk Assessment and Regulatory Considerations for the Brackish Jasper Aquifer* (Kelley and others, 2018). This study was discussed and summarized as part of the Phase I study. However, information from this study has direct relevance to LSGCD's current and future management of groundwater resources and a more detailed evaluation, including review of the related study data, is warranted. Work under this task will necessarily require review of historical studies and data that are referenced by Kelley and others (2018) as some previous works form the foundation for the assumptions, calculations, and modeling presented. While we will review previous works and information sufficiently to be thorough in our work, we will also focus these reviews to avoid "reinventing the wheel" as we develop the necessary understanding relative to the issues in Montgomery County.

On behalf of the Harris-Galveston and Fort Bend subsidence districts, Kelley and others (2018) created a model to simulate compaction and resulting subsidence due to artesian-head reductions in the Jasper Aquifer. As discussed in the Phase I report, Kelley and others (2018) adjusted geotechnical values for parameters controlling compaction. These parameters were originally derived using core samples collected during the 1970s from the lithologic layers of the Chicot and upper half of the Evangeline aquifers at four study sites in southern Harris and Galveston counties where subsidence had occurred. The methodology applied by Kelley and others (2018) to adjust the geotechnical values is reportedly now being applied to the development of the Gulf Coast Land Subsidence and Groundwater-Flow Model (GULF 2023).

The purpose of our evaluation of the work conducted by Kelley and others (2018) is primarily to assess whether the methodology based on measurements from the Chicot and upper Evangeline aquifers outside of Montgomery County should be applicable to assessing subsidence from the underlying Jasper Aquifer within Montgomery County. In particular, we will investigate the uncertainty associated with the subsidence values obtained through application of the methodology. Since the methodology is reportedly being applied as part of the GULF 2023 model development, LSGCD will benefit from this evaluation by better

understanding how application of the methodology will influence model simulation results of predicted compaction and subsidence within Montgomery County. Anticipated work associated with this task includes:

- Review of references and applicable data used by Kelley and others (2018) to support methodology application;
- Evaluation of the statistical relationships presented within the Kelley and others (2018) report;
- Consideration of other variables (for example, geologic age and mineralogical characteristics) that could influence parameter estimates;
- Assessment of methodology application to the Jasper Aquifer within Montgomery County; and,
- Preparation of a technical memorandum discussing our evaluation.

The work conducted under Task 1.1 may be used by the LSGCD Consulting Team to aid in review of the GULF 2023 model, but is not necessarily connected to any work associated with the model development by the U.S. Geological Survey. The following provides our proposed schedule and cost estimate for Task 1:

- Primary Responsible LSGCD Consulting Team Member: LRE
- Anticipated Start: Upon Notice to Proceed (NTP)
- Draft Deliverable(s) Due: 26 Weeks from NTP
- Stakeholder Meeting: Within 26-30 weeks after NTP
- Comments Due: Within 32 Weeks after NTP
- Final Deliverable(s) Due: Within 38 Weeks after NTP
- Deliverable(s): Technical memorandum (Draft as PDF; Final as PDF and 8 bound hard copies)
- Cost Estimate: \$41,100

Task 2 – Geologic Structure

In a report to the TWDB, LRE stated that “...the three primary variables that determine the magnitude, location, and timing of subsidence related to groundwater pumping...” are: 1) the distribution, thickness and compressibility of clay layers; 2) the amount and timing of water-level changes; and, 3) the lowest historical water level (Furnans and others, 2018). Work during Task 2 will focus on assessing the distribution and thickness of the clay layers within Montgomery County. As discussed in the Phase I report, we identified some irregularities in the existing datasets depicting the geologic formation surfaces within Montgomery County.

The purpose of this task is to improve the mapping of the elevation of the top and bottom of the sub-surface formations along with the thickness of sand and clay intervals within the formations. The benefit of this work to LSGCD’s management of the groundwater resources within Montgomery County is an improved understanding of where the sand and clay (that is, lithologic) layers are within the larger aquifers (namely,

the Chicot, Evangeline, and Jasper). Additionally, the Team can assess the general character of the fine-grained or clay intervals to identify spatial variations across Montgomery County.

Groundwater models, existing and in-development, simulate flow and water-level changes through the full aquifer thickness. However, in some cases deep wells only penetrate the upper portion of an aquifer and water-level declines simulated by a model for the full aquifer thickness may not accurately reflect water-level changes that are primarily occurring in the upper portions of the aquifer. The limited location of water-level changes could in turn affect the estimation of compaction within the clay layers of the aquifer as the overall clay thickness associated with the water-level changes would be less than the total clay thickness of the aquifer. For example, if a deep Jasper Aquifer well is only completed in the upper part of the aquifer, the clay units within and near the completion interval would be the most likely to compact; however, the current and in-development models consider all the clays, including those several hundred feet below the completion interval, when simulating compaction. Understanding the local stratigraphy and where the clay units are located relative to the well completion intervals will aid LSGCD in considering subsidence as part of their groundwater management efforts. Anticipated work associated with this task includes:

- Building upon geophysical log evaluations by others (as discussed in the Phase I report) to refine the geologic surfaces beneath Montgomery County;
- Evaluating geophysical logs to select the top, bottom, sand, and clay elevations and recording data within the project geodatabase;
- Evaluating selected State Well Reports to determine the formation and lithology intervals to supplement data obtained from geophysical logs;
- Interpolating surfaces of the geologic formations and lithologic units; and,
- Preparation of a technical memorandum discussing our evaluation.

For Task 2 work we will evaluate logs up to 10 miles beyond the Montgomery County boundary to aid in constraining the interpolation of surfaces within LSGCD. We will review publicly accessible geophysical logs from the LSGCD, TWDB, and USGS along with logs from private libraries that can be made public. Lithology logs from State Well Reports will be used to fill in gaps in the spatial distribution of geophysical log data. The following provides our proposed schedule and cost estimate for Task 2:

- Primary Responsible LSGCD Consulting Team Member: AGS
- Anticipated Start: Upon Notice to Proceed (NTP)
- Draft Deliverable(s) Due: Within 30 Weeks from NTP
- Stakeholder Meeting: Within 33 Weeks from NTP
- Comments Due: Within 41 Weeks from NTP
- Final Deliverable(s) Due: Within 47 Weeks from NTP
- Deliverable(s): Technical memorandum (Draft as PDF; Final as PDF and 8 bound hard copies)
- Cost Estimate: \$47,700

Task 3 – Reporting, Recommendations, and Presentations

This task will involve providing a written comprehensive Phase II final report to the LSGCD Board of Directors. We will also present the final report to the LSGCD Board and Public at a regular board meeting. The Phase II final report will primarily involve combining the interim deliverables from individual tasks into a single volume with an executive summary. The Phase II final report will, however, contain a new section detailing recommendations, conceptual plans, and budgetary cost estimates for proposed subsequent project phases designed as a long-term plan for collaboratively furthering the scientific understanding of the factors associated with land-surface deformation within Montgomery County. Potential additional phases which may be considered as part of the long-term plan for collaborative scientific investigations are presented below as Phase 3 and Phase 4. The following provides our proposed schedule and cost estimate for Task 3:

- Primary Responsible LSGCD Consulting Team Member: LRE
- Anticipated Start: Upon Notice to Proceed (NTP)
- Draft Deliverable(s) Due: Within 47 Weeks from NTP
- Stakeholder Meeting: Within 51 Weeks from NTP
- Comments Due: Within 56 Weeks from NTP
- Final Deliverable(s) Due: Within 60 Weeks from NTP
- Deliverable(s):
 - Final draft report for review and comment in PDF format
 - Final report – 8 hard copies with PDF
 - Geodatabase
- Cost Estimate: \$33,900

Potential Phase III – Site-Specific Geotechnical Investigations

Some of the most relied upon data for understanding the geotechnical properties of the clay layers are from core samples collected in the Houston area in the 1970s. We anticipate work under Phase 3 would involve utilizing the data and evaluations from Phase II to identify locations where site-specific geotechnical data would be most beneficial to improving the empirical understanding of the compressibility of the sub-surface formations underneath Montgomery County. LSGCD could then work with collaborators for a study that would include collecting core samples for geologic and geotechnical analyses. The field work and analyses would provide direct measurement of the compressibility and vertical hydraulic conductivity coefficients that are key parameters in the prediction of subsidence due to depressurization.

Potential Phase IV – Land-Surface and Geologic Formation Deformation Monitoring

There are currently no extensometers that measure compaction of the clay layers in the formations that make up the Jasper Aquifer. Existing extensometers are anchored in shallower formations and are paired with GPS sites. These existing extensometers measure compaction in the formations making up the Chicot and Evangeline aquifers while the GPS data reflect the total deformation at land surface. The difference between the GPS and extensometer data reflects compaction of units below the anchor point of the extensometer. With the significance of the Jasper Aquifer to District constituents, it would be important to measure the compaction of the Jasper due to depressurization.

We anticipate work under Phase 4 would involve a collaborative project with LSGCD stakeholders interested in the advancement of the scientific understanding of the compaction of formations making up the Jasper Aquifer. Phase 4 work would utilize information developed during previous phases to identify a location for an extensometer anchored within the Jasper Aquifer (likely the upper portion of the aquifer). It is possible that the proposed site would be selected for completion of two extensometers with one anchored in the Jasper and a partner extensometer anchored in the Evangeline; this setup would isolate the measured compaction in the upper portions of the Gulf Coast Aquifer System from the measured compaction amount in the deeper portions of the Gulf Coast Aquifer System. In addition, we anticipate the site would include GPS monitoring to aid in assessing compaction below the anchor point in the Jasper.

Project Budget and Schedule

The total Phase II project cost estimate is \$122,700. Cost estimates are based on anticipated time and materials associated with each task, including routine meetings, workshops, and public hearings with LSGCD. If additional work is requested or protracted LSGCD meetings are needed in association with a particular task, we will discuss the anticipated additional cost with LSGCD prior to commencing with the work. Additional work associated with a particular task may be authorized by LSGCD via email.

We will begin work immediately upon authorization and will provide the final Phase II draft report within 47 weeks following the notice to proceed. Following a Stakeholder meeting and comment period, we will address the comments and submit the final report and deliverables. Interim reports will be provided throughout the project summarizing the results of each task per the schedules identified herein. Each of these interim reports will be provided in draft form to allow for a stakeholder meeting, comment period, and time to address comments prior to finalizing the report. A specific schedule with the deadline dates will be developed within one week following notice to proceed.

Authorization

This letter is intended only as a consolidated description of the proposed scope of work, schedule, and cost estimate. Each LSGCD Consulting Team Member will provide contracting documents to LSGCD separate from this letter for work authorization within two weeks following notice to proceed. Each LSGCD Consulting Team Member acknowledges that time is of the essence in performance of all services in accordance with the identified deadlines and will provide contracting documents to LSGCD that include such provisions.

The LSGCD Consulting Team appreciates the opportunity to serve the District and to provide you with this proposed scope of work to further LSGCD's understanding of subsidence within Montgomery County. We look forward to discussing the proposed work with you, the Board, and District staff.

Sincerely,

LRE WATER



Michael R. Keester, PG
Senior Project Manager | Hydrogeologist

Cc: Mr. Michael R. Thornhill, PG – Thornhill Group, Inc.
Mr. James A. Beach, PG – Advanced Groundwater Solutions, LLC.