Monthly Letter Progress Report #11:
Period 5, Fiscal Year 2017
Study of Brackish Aquifers in Texas –
Project No. 4 –Trinity Aquifer
TWDB Contract No. 1600011950

Submitted to

Texas Water Development Board
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Monthly Letter Progress Report #11 January 21, 2017-February 17, 2017 Study of Brackish Aquifers in Texas – Project No. 4 – Trinity Aquifer TWDB Contract No. 1600011950

1.0 Budget and Expenses

This report summarizes the project costs for the billing period from Contract Approval Date (January 6, 2016) through the end of Period 5 of Fiscal Year 2017 (February 17, 2017). The total expenses through this period are $171,056.74. A breakdown of the budget by task is provided in Table 1. A copy of the progress report has been sent to Texas Water Development Board (TWDB) along with the monthly invoice.

2.0 Progress on Tasks

This report summarizes activities on project tasks during Fiscal Year 2017, Period 5 (encompassing January 21, 2017-February 17, 2017) and represents the eleventh progress report on this contract.

Task 1: Project Management

Progress was made on the agreements with the two in-kind teaming partners, Edwards Aquifer Authority (EAA) and Barton Springs Edwards Aquifer Conservation District (BSEACD). All documents necessary for project set-up have been delivered to EAA and BSEACD. SwRI Subcontracts and the Project Manager are working with these organizations to complete the steps necessary to finalize the in-kind agreements.

Based on discussions with our teaming partner INTERA, the Northern Trinity and the Hill Country Trinity Aquifer regions will be divided for the majority of this project. SwRI will be responsible for the Hill Country region and the area between the Hill Country and Northern Trinity Groundwater Availability Models (GAMs). INTERA will be responsible for the Northern Trinity region. At the end of the project, both regions will be combined into one deliverable.

Task 2: Data Acquisition and Method Development

Task 2 has been subdivided into four subtasks. Progress on activities for the subtasks is as follows:

Subtask 2.1 Acquisition and Initial Analysis of Groundwater Samples

Water quality data were gathered from TWDB's groundwater database and reformatted to accommodate future statistical analyses. In addition to the aforementioned water quality database, spatial queries continued on Brackish Resources Aquifer Characterization System (BRACS)/TWDB databases. Other sources of information were evaluated, especially groundwater conservation districts, oil and gas databases, and public water supply wells. The project team is in the process of contacting groundwater conservation districts to inquire about potentially useful data.

Subtask 2.2 Acquisition and Initial Analysis of Geophysical Logs

Development of a database with spatial attributes of all available logs [e.g. BRACS, Information Handling Services Markit (IHS Markit), the Bureau of Economic Geology (BEG)], with care to adhere to BRACS format, continued. A total 2,141 wells evaluated from the IHS database that met the criteria for consideration for stratigraphic interpretation (i.e., had a drilling depth that penetrated part or all of the Trinity Aquifer stratigraphic units). Over this reporting period, that number was reduced to 458 based on the number of wells that had logs that covered the Trinity. For these selected wells, the depth-referenced logs were retrieved from the IHS database for use on this project. Over the next reporting period, these logs will be used to interpret stratigraphic units relevant to the project. Other sources of relevant information including published literature, Groundwater Conservation Districts, Oil and Gas databases, water supply wells, Texas Commission on Environmental Quality (TCEQ) Public Supply, and United States Geological Survey (USGS) Produced Water databases are under consideration for use in the project. A project database of water quality data relevant to the project domain and a preliminary hydrochemical facies analysis for the project domain continues to be developed using TWDB's groundwater database. INTERA has continued their analysis of geophysical logs in the Northern Trinity in support of the calculation of water quality. Initial work centered on looking for geophysical logs that had adequate header information in order to use the mud resistivity and mud temperature gradient to make a resistivity ratio method based water quality calculation.

Subtask 2.3 Develop Technical Approach for Estimating Total Dissolved Solids from Geophysical Logs

Efforts have continued towards developing a method for correlating total dissolved solids (TDS) data and geophysical log attributes. Given its technical complexity, work on this task will continue for most of the duration of the project. Interpretation of logs for stratigraphy has begun, as well as estimation of TDS/Salinity from logs.

Although several methods remain potentially viable, the current approach for correlating TDS to geophysical log attributes requires shallow and deep resistivity curves in the water producing zones of interest as well as data for mud and mud filtrate resistivity. As such, efforts have been made to locate all logs that meet these criteria throughout the framework domain, irrespective of proximity to wells with TDS data available from TWDB's groundwater database. Once all of these wells are identified, efforts will be made to correlate curves to proximal TDS data. Geophysical logs in the IHS database have also been evaluated to identify wells with desired geophysical data. These efforts are necessary to identify key wells throughout the framework domain.

Unfortunately, efforts to date have shown that there is limited availability of geophysical logs with desired attributes (i.e., good quality resistivity data) near or associated with fresh water Trinity Aquifer wells in the Hill Country region. The lack of required log data will likely result in limited capability to correlate geophysical log-derived water resistivity (Rw) values with known water compositions and measured Rw values.

Water chemistry data for the Hill Country and Northern portions of the Trinity Aquifer were analyzed to characterize the spatial and hydrostratigraphic distributions of chemical constituents and TDS.

INTERA used water quality data from the Northern Trinity region to calculate NaCl-equivalent TDS ($NaCl_{TDS}$) values with the conversion scheme provided in Schlumberger's GEN-4 chart. Correlations between measured TDS and calculated $NaCl_{TDS}$ were then used to convert log-derived Rw values to TDS. The log-derived Rw values were determined using resistivity ratios and mud filtrate resistivities and were converted to $NaCl_{TDS}$ with the equation of Bateman and Konen (1977) (found in *Introduction to Wireline Log Analysis*, Western Atlas, 1992).

INTERA's efforts resulted in the calculation of water quality over every sand and limestone unit for the Paluxy, Glen Rose, Hensell, Pearsall, and Hosston formations. These calculated water quality values were averaged by formation and subsequently plotted on maps of the study area along with sampled water quality by formation. All of the data were used to parameterize each unit within the northern portion of the Trinity aquifer into fresh (0-1,000 mg/L), slightly saline (1,000-3,000 mg/L), moderately saline (3,000-10,000 mg/L), and very saline (>10,000 mg/L).

SwRI completed an independent analysis of water chemistry from both the Hill Country and Northern portions of the Trinity Aquifer. As reported in a previous meeting with TWDB staff, Hill Country water quality analyses revealed two separate trends of TDS versus conductivity (one with a slope of ~0.6 and another with a slope >0.8). This behavior is problematic because it means that a unique conversion from derived conductivity (Rw) to TDS may not be available. The analyses also indicated that this two-pronged trend was not isolated to a particular formation or location. Similar trends are observed on a lesser scale for Northern Trinity waters. Additional statistical analyses of the water quality data suggested that the presence of significant concentrations of sulfate was a major factor in generating the separate trends.

The geochemical modeling code WATEQ4f was used to calculate chemical speciation and specific conductivity for all available water quality samples (5000+) for both regions. The recalculated conductivity values corrected several problems with the reported data and facilitated further analyses that identified critical sulfate to chloride ratios and concentrations of sulfate that produced the greater (>0.8) TDS versus conductivity slopes. A spatial analysis indicated that the >0.8 slopes were associated with regions of high sulfate concentrations.

Additional work was conducted to generate revised TDS versus conductivity relationships (conversion factors) for the Paluxy, Glen Rose, Hensell, Pearsall, and Hosston formations of the Northern Trinity. The revised conversion factors eliminate the need to generate $NaCl_{TDS}$ prior to calculation of TDS. Due to the influence of sulfate on conductivity being limited in the majority of Northern Trinity waters, the use of two separate factors for converting between TDS and conductivity (representing high and low slopes) is required only for the Glen Rose. A similar approach will be employed for the Hill Country waters.

Recalculating conductivities provides an explicit accounting for the highly variable water chemistry in the Trinity Aquifer and is based on methods that are well-established in the literature. Similarly, some modification of Rwe to Rw correction factors may also be required to account for the complex influences of bicarbonate and sulfate on resistivity and SP logs. Additional work will be conducted to assess needed factors for both portions of the aquifer.

Subtask 2.4 Use Geophysical Log Interpretation to Analyze Stratigraphy and Map Fresh, Brackish, and Saline Groundwater

Gamma ray logs are being utilized for stratigraphic interpretation. In addition, resistivity and spontaneous potential (SP) logs are being used for strategically located wells that do not have gamma logs. Also, resistivity and SP logs (potential use of SP data is likely limited to sand-dominated units such as the Hosston and Hensell but has been effective for some Cow Creek producing zones) will be utilized for the salinity analysis. Digitized well logs are being evaluated and the development of our interpretation approach is underway. Significant progress on this subtask has already occurred, and work is expected to continue in subsequent reporting periods.

Task 3: Develop a Stratigraphic Framework Model of the Trinity Aquifer and Calculate Brackish Water Volumes

Task 3 has been subdivided into two subtasks. Progress on activities for the subtasks is as follows:

Subtask 3.1 Extend Stratigraphy for the Hill Country Trinity

Information on stratigraphy is being collected and evaluated based on the extent of the data acquisition domain. Literature has been assessed for useful stratigraphic and structural information (e.g., cross-sections, fence diagrams, structure contour maps, well header information, stratigraphic horizon picks from wells, and fault maps), which can be utilized to fill in data gaps as needed throughout the project.

Well logs from the BRACS well database that have stratigraphic information (163 wells in total), including stratigraphic horizon picks and lithologic information, have been evaluated and will be quality controlled and re-interpreted as needed. The data are being evaluated to determine whether stratigraphic picks are consistent with those from other logs in the region, and/or with picks from a known reliable source such as a Key Well[1]. Log information from the IHS database has been evaluated and there are 458 wells that have logs that penetrate the Trinity that will be used for stratigraphic interpretation.

[1] A key well is a well that is tightly constrained in terms of identification, position information, well geometry, pick information in measured depth, wireline log data tied to interval picks in measured depth, and formational water chemistry.

Subtask 3.2 Determine Volumes of Fresh, Brackish, and Saline Groundwater

Evaluation of the relationship between electrical resistivity and fluid salinity has continued during this period. It is recognized that defining this relationship will be challenging due to the confounding influences of electrically conductive clay zones, but this work will be central to delineating the extent of brackish water in the Trinity Aquifer because geophysical logs will be the primary source of information used in this subtask.

Task 4: Delineate Potential Production Areas

Progress on this task is contingent on completion of the previous tasks.

Task 5: Determine the Amount of Brackish Groundwater that can be Produced without Causing Impact on Lateral and Vertical Fresh Water

Progress on this task is contingent on completion of the previous tasks.

Task 6: Stakeholder Communication

Progress on this task is contingent on completion of the previous tasks.

Task 7: Reporting

Task 7 has been subdivided into 2 subtasks. Progress on the subtasks is as follows:

Subtask 7.1 Project Monitoring Procedures

The project timeline has been reviewed frequently. The project budget has been monitored on a weekly basis using the SwRI Project Cost System. Project activity for each period is summarized in status reports for review by TWDB.

Subtask 7.2 Project Deliverables

Progress on this task during this reporting period has included preparing and delivering "Monthly Letter Progress Report #10: Period 4, Fiscal Year 2017." Work on all portions of the Methods Report has been continued. The draft outline and decision trees have been considered while developing the report.

3.0 Planned Activities for the Next Reporting Period (Fiscal Year 2017, Period 6)

Task 1: Project Management

The agreements with the two in-kind teaming partners, EAA and BSEACD, will continue to be a project-management focus during the next reporting period.

Task 2: Data Acquisition and Method Development

Task 2 has been subdivided into four subtasks. Planned activities for the subtasks are as follows:

Subtask 2.1 Acquisition and Initial Analysis of Groundwater Samples

Groundwater data, including groundwater data from within the data acquisition domain, will continue to be gathered, evaluated, and analyzed during the next reporting period. This evaluation will be ongoing for most of the project. Groundwater data provided by groundwater districts will be analyzed.

Subtask 2.2 Acquisition and Initial Analysis of Geophysical Logs

Additional geophysical logs (e.g., spontaneous potential, resistivity), including those from the IHS database, will be evaluated for usefulness in determining an approach for estimating TDS from the logs. Development of a database with spatial attributes of all available logs (e.g., BRACS, IHS, BEG), with care to adhere to BRACS format, will continue. Other sources of relevant information including literature, groundwater conservation districts, oil and gas databases, water supply wells, TCEQ Public Supply, and USGS Produced Water databases will continue to be evaluated as needed throughout the project. A project database of water quality data relevant to the project domain and preliminary hydrochemical facies analysis for the project domain will continue to be developed using TWDB's groundwater database. Staff will continue to utilize the IHS database.

Subtask 2.3 Develop Technical Approach for Estimating Total Dissolved Solids from Geophysical Logs

Efforts towards developing a method for correlating TDS data and geophysical log attributes will continue. Interpretation of geophysical logs for stratigraphy will continue. Some wells that have both shallow and deep resistivity curves will be selected and digitized. These curves will be cross-plotted so that the resistivity of the fluid can be estimated. The project team will continue to find resistivity curves that correspond or are proximal to wells with TDS data extrapolated from TWDB's groundwater database. Geophysical logs in the IHS database will continue to be evaluated to connect chemistry and geophysical data. INTERA will continue the quality assurance/quality control check on the calculated water quality where its classification is in disagreement with sampled water quality.

Subtask 2.4 Use Geophysical Log Interpretation to Analyze Stratigraphy and Map Fresh, Brackish, and Saline Groundwater

Digitized well logs will continue to be evaluated, and the development of an interpretation approach will continue as well. Progress on this subtask is expected to continue during the next several reporting periods. Resistivity and SP curves will be evaluated with regard to potential digitization, to be utilized for salinity analysis during method development.

The project team will continue to develop and revise the decision trees and the Methods Report as the project methods are developed, tested, and evaluated.

Task 3: Develop a Stratigraphic Framework Model of the Trinity Aquifer and Calculate Brackish Water Volumes

Task 3 has been subdivided into two subtasks. Planned activities for the subtasks are as follows:

Subtask 3.1 Extend Stratigraphy for the Hill Country Trinity

Progress on this subtask will continue in the next reporting period with the assessment of relevant well data and subsequent stratigraphic interpretation.

Subtask 3.2 Determine Volumes of Fresh, Brackish, and Saline Groundwater

Evaluation of the relationship between electrical resistivity and fluid salinity will continue during the next period. It is recognized that defining this relationship will be challenging due to the confounding influences of electrically conductive clay zones, but this work will be central to delineating the extent of brackish water in the Trinity Aquifer because geophysical logs will be the primary source of information used in this subtask.

Task 4: Delineate Potential Production Areas

No work is expected to occur in the next reporting period.

Task 5: Determine the Amount of Brackish Groundwater that can be Produced without Causing Impact on Lateral and Vertical Fresh Water

No work is expected to occur in the next reporting period.

Task 6: Stakeholder Communication

No work is expected to occur in the next reporting period.

Task 7: Reporting

Task 7 has been subdivided into 2 subtasks. Planned activities for the subtasks are as follows:

Subtask 7.1 Project Monitoring Procedures

The project timeline will continue to be reviewed frequently. The project budget will continue to be monitored on a weekly basis using the SwRI Project Cost System. Project activity will continue to be summarized in status reports for review by TWDB.

Subtask 7.2 Project Deliverables

The eleventh (current) progress report (covering Period 5, FY 2017) will be submitted to TWDB during Fiscal Year 2017, Period 6. As progress is made toward method development, the Methods Report will continue to be prepared.

4.0 Problems/Issues and Actions Required/Taken

No problems or issues were encountered during this period.

Table 1. Project Budget Versus Expenses

Task	Description	Budget	Invoices			Remaining Budget
			Current	Previous	Total	
1	Project Management	$22,640.00	$212.18	$118.62	$16,872.03	$9,512.96
2	Data Acquisition and Method Development	$134,555.00	$1,236.37	$2,925.55	$94,396.61	$50,158.39
3	Develop a Stratigraphic Framework Model of the Trinity Aquifer and Calculate Brackish Water Volumes	$116,878.00	$18,887.35	$9,728.46	$49,794.03	$77,083.97
4	Delineate Potential Production Areas	$40,001.00	$0.00	$0.00	$600.57	$39,400.43
5	Determine the Amount of Brackish Groundwater that can be Produced without Causing Impact on Lateral and Vertical Fresh Water	$56,740.00	$0.00	$0.00	$0.00	$56,740.00
6	Stakeholder Communication	$35,631.00	$0.00	$0.00	$0.00	$35,631.00
7	Reporting	$13,555.00	$217.27	$596.87	$9,393.50	$416.51
Total		$420,000.00	$20,553.17	$13,369.50	$171,056.74	$268,943.26