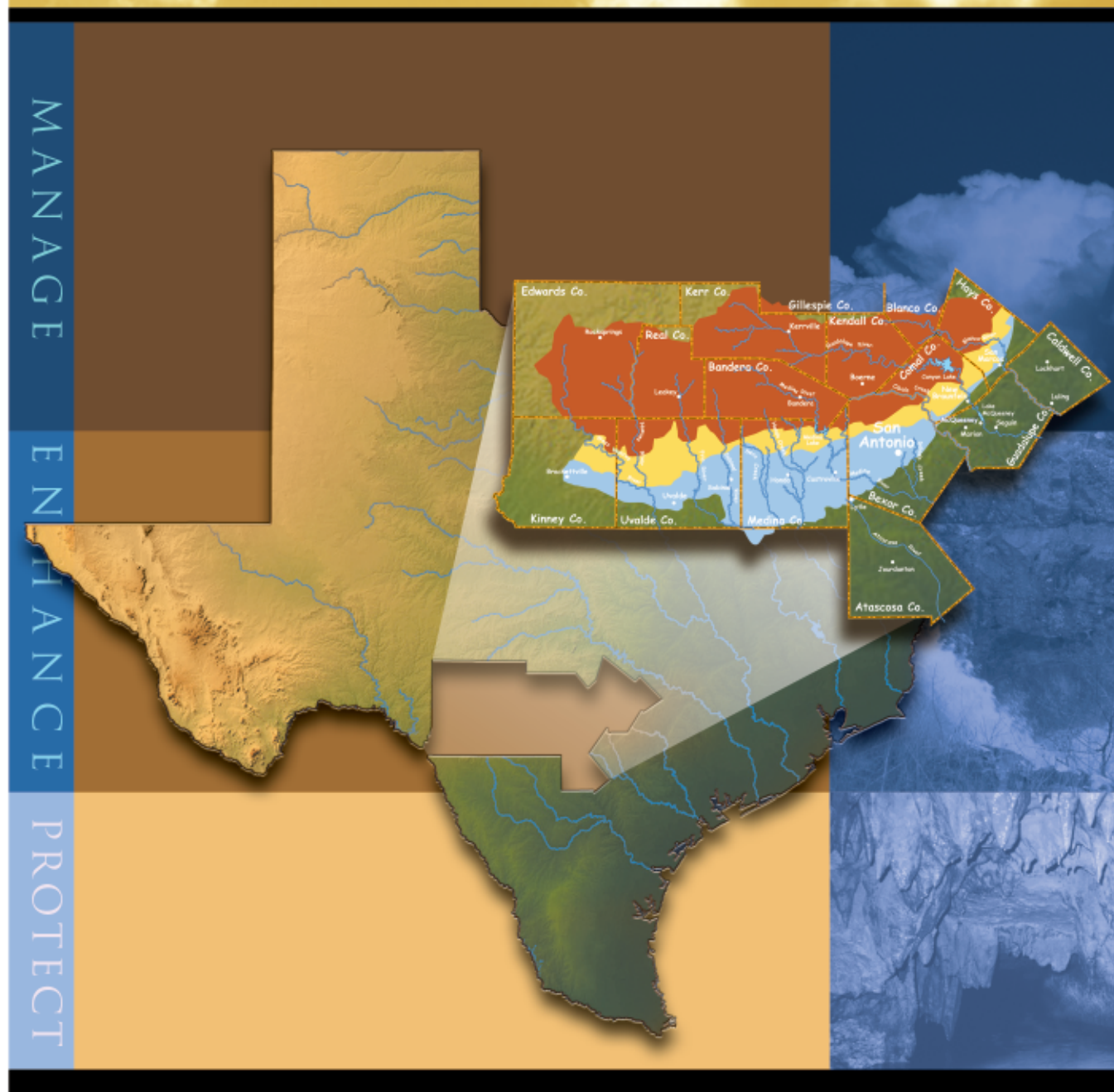


Edwards Aquifer Authority Aquifer Science Research Program Plan 2012–2015





EDWARDS AQUIFER AUTHORITY

AQUIFER SCIENCE RESEARCH PROGRAM PLAN

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2012–2015

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INTRODUCTION

The Edwards Aquifer Authority (EAA) was created by the Texas Legislature in 1993 to replace the Edwards Underground Water District (EUWD) as a special regional water management district in charge of the San Antonio segment of the aquifer. The Legislature authorized the EAA take all reasonable measures to effectively manage the resource to ensure domestic and municipal water supplies, to promote the operation of existing agriculture and industry, to protect terrestrial and aquatic habitat, and to sustain the economic development of the region. To accomplish these goals, the EAA is vested with all of the “powers, rights, and privileges necessary to manage, conserve, preserve, and protect the aquifer, and to increase the recharge of, and prevent the waste or pollution of water in, the aquifer.” (From the Edwards Aquifer Authority Act, as amended.)

Purpose of the Aquifer Science Research Program Plan

The purpose of this Aquifer Science Research Program Plan (ASRPP) is to provide a strategic planning document to direct EAA aquifer research. The ASRPP is developed and implemented by the Aquifer Science Program staff to gain a better understanding of the properties of the Edwards Aquifer. The ASRPP is updated every two to three years and relies on input from EAA staff, the Aquifer Science Advisory Panel (ASAP), and the Technical Advisory Group (TAG), with final approval of all projects provided by the EAA Board of Directors. The ASAP is an outside panel of experts with extensive credentials in the groundwater sciences. The TAG is composed of representatives for local and regional private and public entities with an interest in the Edwards Aquifer.

Goals and Objectives of the ASRPP

This document is intended to serve as guidance to the EAA for aquifer research.

The goal of the ASRPP is to outline the research needed to provide the best available technical information to policy decision makers as efficiently as possible. Although a substantial body of knowledge exists regarding the hydrogeology of the Edwards Aquifer, many unknowns remain with respect to the aquifer's properties and characteristics. Continued data collection and research must concentrate on supplementing, refining, and improving aquifer knowledge to provide policy makers with adequate information to make decisions that assist in implementation of the EAA Act.

Using the current knowledge base derived from existing research and data, the EAA is poised to make further advances in groundwater and surface water modeling, flowpath understanding, recharge methodology, water quality vulnerability, and data collection.

RESEARCH INITIATIVES

Since beginning operations in 1996, the EAA has expanded its data collection and research programs to facilitate a growing body of knowledge of the Edwards Aquifer. The growth in expertise of Aquifer Science staff has allowed the EAA to internalize many of its research initiatives to provide cost savings and greater control over research projects. These projects have included tracer testing, water quality sampling, borehole geophysical logging, passive water quality sampling, and groundwater modeling. In addition, the EAA continues to develop partnerships with numerous public agencies and private entities to further the research capacity of the organization.

Research recommendations have been developed through consultation with EAA staff, the EAA Board of Directors, the ASAP, and the TAG. Proposed projects for 2012 through 2015 (Table 1) are intended to address recommendations from completed studies, continue existing studies (i.e., support projects), or

provide information aimed at addressing basic research needs (**see Appendix A for detailed descriptions of proposed active projects**). Table 1 also provides a rough order of magnitude (ROM) cost for each proposed project. ROM costs—estimates in current dollars—represent approximate costs. The project listing is subject to modification annually, depending on budgetary limitations, time constraints, or development of new directives (Table 2). Although calendar year 2012 projects were programmed into the EAA annual budget, EAA staff will continue to seek joint funding opportunities for these and other projects. Studies proposed for initiation in calendar years 2013, 2014, and 2015, but not yet under way, are summarized in Table 1, along with a list of the currently anticipated project needs for calendar years 2013 through 2015. As further research and planning takes place, studies will be added and amended for years beyond 2015 so as to accommodate “unknowns” or new developments at the EAA, as well as improvements in technology.

Table 1. Summary of Proposed ASRPP Studies, Calendar Years 2012–2015

| Study Number | ASRPP Category | Estimated Initiation-Completion Year | Basic Research Need | Rough Order of Magnitude Costs | Study Title |
|--------------|----------------------|--------------------------------------|---|---|---|
| 1 | Modeling | 2012–2015 | Finite Element Model | \$1,090,852 | Finite element model development |
| 2 | | 2012–2013 | MODFLOW refinement | \$20,000 | MODFLOW Model management model refinement |
| 3 | | 2013–2015 | MODFLOW refinement | \$35,000 | Development of MODFLOW-Dual Conductivity Model 3-Dimensional code (DCM 3-D) |
| 4 | | 2012–2013 | MODFLOW refinement | Funding by U.S. Army Corps of Engineers (COE) | FORTAN Code Development for HSPF to couple MODFLOW Model |
| 5 | Flowpath | 2012–2013 | Knippa Gap Flowpath Evaluation | Non-contract study | Hydrogeologic evaluation of the Knippa Gap area/tracer test study |
| 6 | | 2013–2014 | Nueces River Hydrology | \$75,000 | Nueces River Recharge and Hyporheic Zone Characterization |
| 7 | | 2012–2014 | Interformational Flow Study | \$50,000 | Evaluate interformational flow between the Edwards Aquifer and Trinity, Buda, and Austin Chalk aquifers. |
| 8 | | 2013–2014 | Borehole Hydrophysics Correlation | \$15,000 | Borehole Hydrophysics Correlation of existing data to determine formation properties |
| 9 | Recharge Methodology | 2013–2015 | Remote Sensing Evapotranspiration (ET) Data Estimation for Hydrological Simulation Program - Fortran (HSPF) | \$115,000 | Develop remote sensing ET Data Estimation Program |
| 10 | | 2013–2014 | Upland Recharge Quantification | \$75,000 | Pilot study to develop methodology to quantify regional upland (interstream) recharge: feasibility study for aquifer wide aerial electromagnetic geophysical surveys and analyses |

TBD = To be determined

Projects that are currently active are listed in Table 2, whereas projects completed under the ASRPP since its inception in calendar year 2006 are listed in Table 3. Ongoing or active studies are detailed in Appendix B. Completed studies are detailed in

Appendix C. With the completion of each project, overall understanding of the system as a whole improves. This improved understanding provides one of the basic tools needed to direct development of future projects.

Table 2. Active ASRPP Studies, 2012

| Study Number | ASRPP Study Category | Status | Study Title |
|--------------|----------------------|------------------------|---|
| 11 | Modeling | Ongoing | MODFLOW model—data set development, model verification, post audit, recalibration |
| 12 | | Ongoing | HSPF model data set improvement (in cooperation with COE) |
| 13 | Flowpath Studies | Ongoing | Aquifer Biota study, phase II |
| 14 | | Ongoing | Interstream recharge and vegetative cover study (Camp Bullis) |
| 15 | | Ongoing | Tracer testing (Comal and San Marcos springs, northern Bexar County, Uvalde/Medina counties, and Kinney County) |
| 16 | | Ongoing | Hydrogeology of North Medina County |
| 17 | | Ongoing | Well Hydrophysics Program |
| 18 | Recharge Methodology | Ongoing | Aquifer level retention study |
| 19 | Support Studies | Ongoing | Pilot study to improve analytical water quality data through use of passive sampling techniques |
| 20 | | Ongoing | Synoptic Water Level Program |
| 21 | | Ongoing | Bacterial, pharmaceuticals and personal care product sampling |
| 22 | | Substantially Complete | Guadalupe River gain/loss study |

Table 3. Completed ASRPP Studies, 2012

| Number | Category | Status | Study Title |
|--------|------------------|------------------------|---|
| 23 | Modeling Studies | Complete | Finite element model scope of work |
| 24 | | Complete | Edwards Aquifer computer model (MODFLOW model) |
| 25 | | Complete | Water resources management module for the existing Edwards Aquifer MODFLOW model |
| 26 | | Complete | Enhanced characterization and representation of flow through karst aquifers |
| 27 | | Complete | Hydrologic simulation program Fortran (HSPF) model refinement |
| 28 | | Complete | MODFLOW model—improved storativity estimates |
| 29 | | Complete | Estimation of hydraulic parameters for the Edwards Aquifer management model |
| 30 | | Complete | Development of water resources module for MODFLOW model |
| 31 | | Complete | Conversion of the water resources management module for MODFLOW 2000 |
| 32 | | Complete | Karst aquifer modeling research (phase I) |
| 33 | | Complete | Recharge methodology |
| 34 | | Complete | Recharge methodology (pilot study) |
| 35 | | Complete | Statistical analysis of hydrologic data |
| 36 | | Complete | Well-plugging study |
| 37 | | Complete | Definition and delineation of San Marcos pool |
| 38 | | Complete | Augmentation study (in situ refugia) |
| 39 | | Complete | Hydrologic assessment of flowpaths—north Medina County |
| 40 | | Complete | Noble and active gas sampling in the Knippa Gap region |
| 41 | | Complete | Investigation of groundwater systems in Uvalde County |
| 42 | | Complete | Hydrologic budget analysis of Medina and Diversion lakes |
| 43 | Flowpath Studies | Complete | North Medina County flowpath—helicopter electromagnetic survey in the vicinity of Seco Creek sinkhole |
| 44 | | Complete | Leona Formation geophysical survey |
| 45 | | Complete | Analysis of structural controls on the Edwards Aquifer/Trinity Aquifer in north Bexar County—Camp Bullis quadrangle |
| 46 | | Complete | Analysis of structural controls on the Edwards Aquifer/Trinity Aquifer in north Bexar County—Helotes quadrangle |
| 47 | | Complete | Saline water study |
| 48 | | Complete | Fracture/conduit study |
| 49 | | Complete | Helicopter electromagnetic survey of northern Bexar County |
| 50 | | Complete | Phase II of the Uvalde County study (geophysical study of gravel aquifers to improve water balance) |
| 51 | Support Studies | Complete | Improved gauging at Comal and San Marcos springs |
| 52 | Support Studies | Substantially Complete | Edwards Aquifer well survey project (new wells will be surveyed as they are added to the monitoring program) |

AQUIFER SCIENCE ADVISORY PANEL

In accordance with the EAA Strategic Plan, an ASAP was formed to advise the Aquifer Science Program staff and technically support the ASRPP. The panel is composed of experts in the fields of karst hydrology, geochemistry, geology, computer modeling, structural geology, and hydrology. Panel members are selected on the basis of their expertise and experience from within and outside the region, and they are not compensated for their participation, with the exception of reimbursement of members' expenses directly related to meeting attendance (Table 5). Projects initiated under the ASRPP process are presented to the EAA Research and Technology Committee and subsequently

to the board of directors for approval prior to initiation. In addition, the following people have also attended ASAP meetings as invited guests and have helped to formulate the ASRPP: Dr. Bruce Cutright, Texas Bureau of Economic Geology; Dr. Nathan Sheffer, Texas Bureau of Economic Geology; Dr. Brian Smith, Barton Springs-Edwards Aquifer Groundwater Conservation District; and Dr. Marcus Gary, Zara Environmental, LLC. The ASAP was supported by and the ASRPP was prepared by EAA staff: Geary Schindel, Mark Hamilton, Steve Johnson, Jim Winterle, Al Liu, Ned Troshanov, Marcus Gary, and Rob Esquilin.

Table 4. Aquifer Science Advisory Panel Members for Calendar Year 2012-2013

| Member Name | Background |
|--|--|
| Dr. E. Calvin Alexander, Jr. Minneapolis, Minnesota | Professor of Hydrogeology and Geochemistry, University of Minnesota |
| Mr. Andrew Donnelly Austin, Texas | J. E. Stephens and Associates |
| Dr. Alan Dutton San Antonio, Texas | Professor of Hydrogeology, The University of Texas at San Antonio |
| Dr. Ronald Green San Antonio, Texas | Research Scientist, Southwest Research Institute |
| Dr. Sue Hovorka Austin, Texas | Research Scientist, The University of Texas at Austin, Bureau of Economic Geology |
| Dr. Charles Kreidler Austin, Texas | Vice President, LBG-Guyton Associates |
| Dr. Robert Mace Austin, Texas | Director, Groundwater Resources Division, Texas Water Development Board |
| Dr. Benjamin Schwartz San Marcos, Texas | Professor, Texas State University |
| Dr. Alan Shapiro Washington, D.C. | Research Scientist, USGS |
| Dr. John (Jack) Sharp Austin, Texas | Professor of Geosciences, The University of Texas at Austin |
| Dr. John Van Brahana Fayetteville, Arkansas | Professor of Hydrogeology, University of Arkansas |
| Dr. George Veni Carlsbad, New Mexico | Executive Director, National Cave and Karst Research Institute |
| Member Name | Background |
| Dr. Brad Wilcox College Station, Texas | Professor of Rangeland Hydrology, Texas A&M University |
| Dr. Stephen Worthington Hamilton, Ontario, Canada | President, Worthington Groundwater |

The ASAP will convene as needed to discuss the state of the aquifer, review current research, and make recommendations for future studies.

AQUIFER SCIENCE RESEARCH PLAN REVIEW AND UPDATE

This document will be reviewed annually and updated approximately every two to three years as new research needs are identified. Changes in membership in the ASAP will be reflected in future updates, along with changes

to ASRPP studies or initiation of new studies. This document will serve as the mechanism for summarizing the EAA's research program.

APPENDIX A. Detailed Descriptions of Proposed ASRPP Projects

Proposed ASRPP Projects

ASRPP Category: Modeling

1. Project Title:

Finite Element Model Development

1. Purpose:

To create a finite element groundwater model of the Edwards Aquifer.

2. Background:

This project represents development of a finite element model of the Edwards Aquifer that will complement the existing MODFLOW finite difference model.

3. Aquifer Management Issue to be Addressed:

To improve resolution and decrease the level of uncertainty by having a second model that will be run concurrently with the existing MODFLOW model.

4. Estimated Costs:

\$1,090,852.

5. Time Line:

Project was initiated in March 2012 with an expected completion date of March 2015. The EAA should receive draft coverages and a draft working model in late 2013.

6. Status Report:

Project is proceeding; Southwest Research Institute (SWRI®) was selected as the contractor, and a Groundwater Model Review Panel was formed with a projected first meeting in September 2012.

ASRPP Category: Modeling

2. Proposed Project Title:

MODFLOW Model Management Module Refinement

1. Purpose:

To upgrade the MODFLOW management module to interface with the new data sets being developed as part of the model verification and postaudit process.

2. Background:

The management module allows manipulation of data model data sets such as aquifer pumping or recharge for testing of various management strategies.

3. Aquifer Management Issue to be Addressed:

Improvement of function and performance of the MODFLOW groundwater model.

4. Estimated Costs:

\$20,000.

5. Time Line:

Project will require approximately 6 months.

6. Status Report:

Project will begin after completion of post audit modeling process in 2012.

ASRPP Category: Modeling

3. Proposed Project Title:

Develop MODFLOW-Dual Conductivity Model 3-Dimensional Code (DCM 3-D)

1. Purpose:

MODFLOW-DCM software was developed as a two-dimensional (2-D) program but will need to be modified to allow it to incorporate conduits in 3-D for future model refinements. Doing so may improve model results.

2. Background:

The current MODFLOW model utilizes model cells to approximate conduit flow conditions in the aquifer. Groundwater Vistas, the software package utilized by the EAA, has incorporated MODFLOW-DCM into its software package. However, the DCM model package includes only 2-D modeling capabilities. EAA will contract with the DCM model developer to modify the software for use with the EAA MODFLOW model and incorporate it into future model revisions.

3. Aquifer Management Issue to be Addressed:

Improvement of resolution and functionality of the EAA groundwater models.

4. Estimated Costs:

\$35,000.

5. Time Line:

Project will be initiated in 2012 or 2013, with an expected completion date of 2013–2014.

6. Status Report:

Project is pending budget and manpower availability.

ASRPP Category: Modeling

4. Proposed Project Title:

FORTTRAN Code Development for HSPF to MODFLOW Model Coupling

1. Purpose:

To develop FORTRAN code for converting HSPF output to MODFLOW RCH files efficiently (both modeling platforms are based on FORTRAN code).

2. Background:

The goal of this research is to facilitate the interface between MODFLOW and HSPF, such that recharge data can ultimately be imported directly into MODFLOW from the HSPF model. U.S. Army Corp of Engineers has contracted for completion of this work.

3. Aquifer Management Issue to be Addressed:

Refinement of the accuracy of the EAA groundwater model.

4. Estimated Costs:

This project is being funded by the U.S. Army Corps of Engineers (COE).

5. Time Line:

Research is scheduled to be completed in 2012.

6. Status Report:

Work is ongoing.

ASRPP Category: Flowpath Studies

5. Proposed Project Title: ***Evaluation of Knippa Gap Flowpaths***

1. Purpose:

To better understand the hydrogeology of the Knippa Gap area.

2. Background:

The “Knippa Gap” appears to restrict flow between the Uvalde Pool and the San Antonio Pool near the town of Knippa. This study is intended to define geological controls in the Knippa Gap and to refine the estimated volume of water flowing between the Uvalde and San Antonio pools.

3. Aquifer Management Issue to be Addressed:

Refinement of the accuracy of the EAA groundwater model.

4. Estimated Costs:

Total estimated cost is to be determined.

5. Time Line:

Research began in June 2012 and is expected to continue through 2014.

6. Status Report:

Research was initiated by an EAA Intern/University of Arkansas Graduate Study, in cooperation with SWRI® and the Uvalde County Groundwater Conservation District. Wells have been identified and surveyed, and some sampling has occurred. A tracer test is being proposed for fall 2012.

ASRPP Category: Flowpath Studies

6. Proposed Project Title: ***Nueces River Hydrology***

1. Purpose:

To better understand the hydrogeology of the Nueces River Basin in the Edwards Aquifer region.

2. Background:

The Nueces River, the largest surface water basin in the EAA region, accounts for a significant amount of recharge to the aquifer. Recharge has been loosely quantified and conceptualized. This study is intended to evaluate and quantify the sources of flow gain and loss, both to the Edwards Aquifer and to hyporheic exchange over the roughly 40-mile reach of the river.

3. Aquifer Management Issue to be Addressed:

Refinement of the accuracy of the EAA groundwater model and water balance estimates.

4. Estimated Costs:

\$75,000 per year for three years.

5. Time Line:

Research began in June 2012 and is expected to continue through 2014.

6. Status Report:

Research has been initiated through a gains and losses study of the basin.

ASRPP Category: Flowpath

7. Proposed Project Title: ***Interinformational Flow Study between the Edwards Aquifer and the Trinity, Buda, and Austin Chalk Aquifers.***

1. Purpose:

To evaluate an interinformational flow estimate between the Edwards Aquifer and the Trinity, Buda, and Austin Chalk aquifers.

2. Background:

Interinformational flow occurs between the Edwards Aquifer and the Trinity, Buda, and Austin Chalk aquifers. The volume of water appears to be a significant amount of recharge and discharge and is crucial to an understanding of the water balance of the aquifer and an important component in refining groundwater models.

3. Aquifer Management Issue to be Addressed:

Refinement of the accuracy of the EAA groundwater model.

4. Estimated Costs:

Total estimated cost is to be determined. EAA staff will initiate this project and determine the scope of work in 2012.

5. Time Line:

Research is scheduled to begin in 2012 and is expected to continue through 2014.

6. Status Report:

Research is currently in the proposal stage.

ASRPP Category: Flowpath Studies

8. Proposed Project Title: ***Borehole Hydrophysics Correlation.***

1. Purpose:

The EAA is currently performing borehole hydrophysical logging throughout the Edwards Limestone. Once sufficient logging has been performed on the San Marcos Platform, Devils River Trend, and Maverick Basin, this study will compare hydrophysical logs to determine regional hydrostratigraphic properties.

2. Background:

The EAA has generated hydrophysical logs of wells in the Edwards Limestone, with logging occurring in the San Marcos Platform and the Devils River Trend. This study will evaluate borehole hydrophysical data to determine hydrostratigraphic properties of the formations that make up the Edwards Aquifer.

3. Aquifer Management Issue to be Addressed:

Data will be used to support development of a groundwater monitoring network and be considered in development on multilayer groundwater models.

4. Estimated Costs:

Total estimated cost is \$15,000.

5. Time Line:

Research is scheduled to begin in 2013 and will continue through 2014.

6. Status Report:

Research is currently in the proposal stage.

ASRPP Category: Recharge Methodology

9. Proposed Project Title: *Remote Sensing Evapotranspiration Data Estimation*

1. Purpose:

To develop remote sensing of evapotranspiration data for the recharge and contributing zone.

2. Background:

Evapotranspiration data are an important component of HSPF model construction. Constraining these data by using evapotranspiration (ET) data in the recharge and contributing zones of the Edward Aquifer will improve recharge estimates generated by the HSPF model.

3. Aquifer Management Issue to be Addressed:

Refinement of the accuracy of the EAA HSPF surface water model.

4. Estimated Costs:

The total estimated cost is \$115,000 over a two-year period for the pilot project. The EAA will initiate the study by installing ET stations and contract for ET analysis in 2013. Remote sensing data will be acquired, and the ET stations will be used to calibrate remote sensing data.

5. Time Line:

Instrumentation will be installed in 2013 and will continue through 2014.

6. Status Report:

Instruments for purchase have been identified.

ASRPP Category: Recharge Methodology

10. Proposed Project Title: *Upland Recharge Quantification*

1. Purpose:

To develop methodology to quantify the amount of recharge occurring in upland (interstream) areas. This is a feasibility study for aquiferwide aerial electromagnetic geophysical survey and analysis.

2. Background:

HSPF models estimate amount of recharge occurring in interstream areas. However, these estimates can possibly be refined using aerial geophysical surveys.

3. Aquifer Management Issue to be Addressed:

Refinement of the accuracy of the EAA interstream recharge estimates.

4. Estimated Costs:

The total estimate cost is \$75,000. The EAA proposes to initiate the study in 2014.

5. Time Line:

Study would be initiated and completed in 2014.

6. Status Report:

Pending budget approval.

APPENDIX B. Detailed Descriptions of Active ASRPP Projects (2012)

ASRPP Category: Modeling

11. Active Project Title:

MODFLOW Model— Data Set Development, Verification, Post audit, and Recalibration of MODFLOW Model

1. Purpose:

To perform verification, post audit, and recalibration of the EAA MODFLOW Model.

2. Background:

When the USGS completed the MODFLOW model in 2004, tentative plans were in place to recalibrate the model in five years. Recent studies and data from subsequent years indicate that the model can be verified and improved by incorporating more recent data and new conceptual insights.

Results of the verification process will be used to perform a post audit process to recalibrate the model, including updates such as new or revised barrier fault locations, Trinity Aquifer inflows, and outflows through river floodplain deposits.

3. Aquifer Management Issue to be Addressed:

Refinement in accuracy of the EAA groundwater model in matching observed water levels and spring flows.

4. Estimated Costs:

Estimated cost of model recalibration is \$30,000 over three years.

5. Time Line:

The task was initiated in late 2010 and will extend through 2013.

6. Status Report:

Project is under way.

ASRPP Category: Modeling

12. Active Project Title:

HSPF Model Data Set Improvements

1. Purpose:

To improve HSPF surface water model data sets.

2. Background:

An HSPF surface water model was created by the EAA to calculate recharge to the Edwards Aquifer. The model included stream flow estimates for the contributing zone, as well as estimates of recharge to the aquifer. The U.S. Army Corps of Engineers (COE) expanded the EAA HSPF model to include the entire watershed for all of the Edwards Aquifer surface water basins and is in the process of updating and calibrating the model using data sets through 2007. Once calibrated, the model can be used to obtain recharge estimates through 2011 and later, so long as precipitation and evapotranspiration data are available. Results from the HSPF model will be incorporated into the EAA groundwater models, as well as its being used to calculate yearly recharge to the aquifer.

3. Aquifer Management Issue to be Addressed:

Refinement in accuracy of the EAA groundwater model and improvement in yearly recharge estimates to the aquifer

4. Estimated Costs:

\$0. The COE is funding the cost of this work.

5. Time Line:

The task was initiated in 2010 and will be completed in March 2013.

6. Status Report:

Project is under way.

ASRPP Category: Flowpath Study

13. Active Project Title: ***Phase II Aquifer Biota Study***

1. Purpose:

To identify and determine the range and extent of biota within the Edwards Aquifer.

2. Background:

The Aquifer Biota Study is a comprehensive well-sampling program to expand and update information regarding subterranean aquifer-dwelling organisms. Work was performed by Zara Environmental, and results were published in a phase I report completed in November 2010. This study will continue monitoring for aquifer biota from 2011 through 2014.

3. Aquifer Management Issue to be Addressed:

Collection of information to better document the occurrence and distribution of various aquifer biota.

4. Estimated Costs:

\$70,000 is included in the 2011 and 2012 budgets.

5. Time Line:

The study was initiated in 2011 and will extend to 2014.

6. Status Report:

Currently ongoing.

ASRPP Category: Flowpath Studies

14. Active Project Title: ***Interstream Area Recharge / Vegetative Cover Study (Camp Bullis)***

1. Purpose:

To have a better understanding of interstream recharge and changes in vegetation to groundwater recharge.

2. Background:

The EAA funded a multiyear study on changes in vegetative cover in the recharge area of the Edwards Aquifer on Camp Bullis. The study was done in cooperation with Texas A&M and the U.S. Army. A cave located beneath an area with thick covers of Ashe juniper trees was instrumented and monitored for successive years. The cedar was removed, and grass vegetation was established. This project will examine the long-term recovery of grass vegetation and its influence on recharge to the aquifer.

3. Aquifer Management Issue to be Addressed:

Removal of woody, invasive species such as Ashe juniper is an expensive management tool to improve pastures. Removal of woody, invasive species has been claimed also to increase recharge to groundwater. Data are still being collected to monitor recharge at these sites.

4. Estimated Costs:

Total estimated cost is \$30,000, which was included in the 2012 budget.

5. Time Line:

Research began in 2012 and will continue for two to three years.

6. Status Report:

Research is currently in progress.

ASRPP Category: Flowpath

15. Active Project Title:

Tracer Testing of Aquifer Flowpaths— Comal Springs, San Marcos Springs, Northern Bexar County, Uvalde/Medina Counties, and Kinney County

1. Purpose:

To define aquifer flowpaths and groundwater velocities and to test structural controls, interformational flow between aquifers, and groundwater boundaries.

2. Background:

The EAA conducted its first tracer test at Comal Springs in March and April of 2002 with the help of staff, cooperating agencies, and volunteers. In July 2003, the board approved a contract with George Veni and Associates (GVA) for tracer testing, stormwater monitoring, and water sampling at several sites, including Comal Springs, San Marcos Springs, and northern Bexar County.

Comal Springs Tracer Testing

EAA staff, cooperating agencies, and volunteers completed a tracer test in the Comal Springs area between March 22 and April 12, 2002. The test was directed by the EAA with assistance from New Braunfels Utilities, City of New Braunfels—Parks and Recreation Department, USGS, University of Minnesota, The University of Texas at Austin, The University of Texas at San Antonio (UTSA), Texas A&M University—College Station (TAMU), and others. The test showed that discrete groundwater flowpaths to each of the major springs are in the Landa Park area. Dye injected into the Panther Canyon well appeared in Spring Run 3, rather than in Spring Runs 1 or 2, which are closer to the well. Dye injected in the LCRA well appeared in Spring 7, springs beneath the lake, and springs on Spring Island. The EAA has performed additional tracer tests at the Panther Canyon well under varying aquifer conditions.

Status Report—Comal Springs

Field studies for the initial phase of this work has been completed, and a report will be prepared detailing findings. Additional tracer tests will be performed in the

Cibolo Creek/Hueco Springs/Comal Springs area as conditions and available staff permit.

San Marcos Springs Tracer Testing

Since 2002, EAA staff has performed numerous tracer tests in the Blanco River, San Marcos Springs, and Barton Springs area. Tests have been performed in cooperation with Barton Springs Edwards Aquifer Groundwater Conservation District, as well as the City of San Marcos and the City of Austin. Results of the tracer tests indicate that the groundwater divide between San Antonio and Barton Springs segments of the Edwards Aquifer moves between the Blanco River and Onion Creek, depending on hydrologic conditions. Groundwater velocities range from hundreds to thousands of feet per day, indicating the relative vulnerability of the aquifer to surface activities.

Status Report

The San Marcos study report was completed in September 2012.

Northern Bexar County Tracer Testing

EAA staff completed a study of northern Bexar County concentrated in the Panther Springs drainage basin and published results in 2010. Additional research is being performed in the Cibolo Creek basin to help define the extent of the recharge zone along Cibolo Creek.

The USGS developed an HSPF model for quantifying recharge in the Cibolo Creek channel. The model shows that during 1992–2004, average groundwater recharge in the watershed was 79,800 acre-feet per year, amounting to more than 10 percent of total median aquifer recharge. Recharge was distributed between stream channel infiltration (74 percent) and upland areas (26 percent). Principal recharge areas were

- Trinity Aquifer outcrop: 77 percent,
- Area of transition from the Trinity aquifer outcrop to the Edwards aquifer outcrop: 13 percent,
- Edwards Aquifer recharge zone: 6.4 percent, and
- Area of transition from the Edwards Aquifer recharge zone (outcrop) to the Edwards Aquifer upper confining unit: 3.6 percent.

The Cibolo Creek study will utilize tracer tests, aquifer tests, water quality sampling, and other techniques to verify findings of the HSPF model.

Status Report—Northern Bexar County

The EAA published results of the northern Bexar County tracer tests in 2010. Research in the Cibolo Creek area is progressing and will extend into 2014.

Uvalde and Kinney County Tracer Testing

The purpose of this project is to identify groundwater flowpaths and velocities near Pinto, Las Moras, and Leona springs. In addition, the EAA is testing the conclusions presented by SwRI® in its recent report on groundwater conditions in Kinney and Uvalde counties. Dye has been injected into karst features and wells upgradient of the springs, and groundwater samples are being collected. The EAA is working with the Kinney County Groundwater Conservation District and the Uvalde Underground Water Conservation District on the project.

Status Report—Uvalde and Kinney County

The study is in progress. EAA staff members are planning the next phase of tracer tests in Kinney County under terms of the memorandum of understanding (MOU) with the Kinney County Groundwater Conservation District.

3. Aquifer Management Issue to be Addressed:

Tracer testing is used to determine flowpaths and groundwater velocities and can be used to determine physical properties of the aquifer.

4. Estimated Costs:

Costs are included as part of the Aquifer Management Team budget. No contractor costs are associated with tracer testing.

5. Time Line:

Tracer testing is an ongoing task of the Aquifer Management Team.

6. Status Report:

Research is currently in progress.

ASRPP Category: Flowpath

16. Active Project Title:

Hydrogeology of North Medina County

1. Purpose:

To define hydrogeology of the Edward Aquifer in Medina County.

2. Background:

The USGS has developed a conceptual model for groundwater flow in northern Medina County and northwestern Bexar County. This model assumes that a series of large displacement faults, striking northeast-southwest and acting as barriers to groundwater flow, result in groundwater in this area flowing northeast-southwest. This flowpath merges with the regional flowpath from Uvalde County in central and southern Medina County and ultimately discharges at Comal and San Marcos springs. This conceptual model was incorporated into the EAA groundwater flow model.

The purpose of this project is to investigate groundwater flowpaths in north Medina County using tracer tests, synoptic water level measurements, continuous water level measurements, groundwater analyses, and other techniques. EAA staff and contractors will conduct tracer tests, potentiometric surface mapping, and aquifer tests to assess whether large-scale faults act as barriers to groundwater flow. This project will contribute to conceptual understanding of groundwater flow in northern Medina County and northwestern Bexar County to improve groundwater management strategies, as well as the EAA groundwater model.

3. Aquifer Management Issue to be Addressed:

Results of the study will be used to address water balance issues in the Edwards Aquifer. Data will be incorporated into future groundwater models.

4. Estimated Costs:

Estimated costs to be determined as the scope of the study is developed.

5. Time Line:

Research has been initiated and is expected to continue through 2014.

6. Status Report:

Study is in progress.

ASRPP Category: Flowpath Studies

17. Active Project Title:

Well Hydrophysics Study

1. Purpose:

To define the range of well hydrologic properties in the karstified Edwards Aquifer.

2. Background:

Water wells in karst aquifers are noted for intersecting preferential flow features such as fractures, faults, and conduits. These flow features can affect the quantity and quality of water entering the borehole, thereby having a significant impact on design and interpretation of water quality monitoring system data, preparation and interpretation of potentiometric surface maps, and our understanding of hydrologic properties of various geologic units. A pilot hydrophysics study was performed for the EAA by RAS Consultants in 2005, which indicated that discrete conduits within a monitoring well bore account for most water entering the well bore. In addition, even under “static” conditions, more than 300 gallons a minute of water passed vertically down the borehole, creating a depression in the potentiometric surface of more than 20 feet.

3. Aquifer Management Issue to be Addressed:

An improved understanding of local groundwater flow dynamics on a well bore scale.

4. Estimated Costs:

EAA staff estimates that this study will cost approximately \$90,000 per year for calendar years 2012–2014.

5. Time line:

Project was implemented in 2010 and will run through 2014.

6. Status Report:

Project is currently in progress.

ASRPP Category: Ongoing Studies

18. Active Project Title:

Aquifer Level Retention Study

1. Purpose:

To evaluate the temporal retention of water in specific areas of the aquifer after significant recharge events.

2. Background:

Large recharge events offer an opportunity to measure aquifer stresses on a local to regional basis and to evaluate aquifer properties related to recharge and retention of hydrostatic pressure, as well as water particles.

3. Aquifer Management Issue to be Addressed:

An improved understanding of local and regional aquifer dynamics.

4. Estimated Costs:

EAA staff estimates that this study will cost approximately \$15,000 and will be completed in the fall of 2012.

5. Time line:

Project was implemented in 2011 and will be completed in the fall 2012.

6. Status Report:

Project is currently in progress.

ASRPP Category: Support

19. Active Project Title:

Pilot Study to Improve Analytical Water Quality Data through Passive Sampling

1. Purpose:

This project is designed to evaluate the use of passive sampling devices in making improvements to the EAA water quality sampling program.

2. Background:

Historically the EAA water quality sampling has been limited to collection of “grab” type samples, from wells, streams, or springs. Because of the karstic nature of the Edwards Aquifer, however, grab samples may not be fully representative of aquifer conditions. After all, grab samples provide only an instantaneous or snapshot representation of water quality at the sample point, rather than a cumulative representation of changes in water quality conditions over time. As such, the EAA is seeking to examine the efficacy of sample collection techniques other than the historical *purge and sample* method. Passive sampling allows for samples to be collected without purging, through the process of diffusion across a membrane or by sorption onto applicable media.

3. Aquifer Management Issue to be Addressed:

An improved understanding of changes in water quality in the aquifer and evaluation of new technologies to improve water quality data collection.

4. Estimated Costs:

Total project budget: \$ 48,500.

5. Time line:

Project was implemented in 2007 and will run through 2012.

6. Status Report:

The study is in progress. Field data are still being collected in a number of wells in the Edwards Aquifer, and results are being evaluated for preparation of a report of the findings.

ASRPP Category: Support

20. Active Project Title:

Synoptic Water Level Program

1. Purpose:

To collect water level data in support of the EAA MODFLOW groundwater model.

2. Background:

The EAA currently coordinates the synoptic water level program in support of the MODFLOW aquifer model. The EAA also coordinates the focused synoptic water level program in support of these modeling efforts and to improve understanding of aquifer flowpaths. In association with these synoptic water level programs, the EAA has completed two water well elevation and location survey projects—the first occurred in December 2003 and the second in August 2007.

Synoptic Water Level Program (SWLP) and Focused Synoptic Water Level Program (FSWLP)

The SWLP has recommended the Technical Advisory Group (TAG) to create potentiometric surface maps to assist in modeling and aquifer flowpath studies. Staff from the EAA, San Antonio Water System (SAWS), USGS, and Barton Springs/Edwards Aquifer Conservation District (BS/EACD) measured aquifer water levels in approximately 220 wells over the Edwards Aquifer region, between one and three times annually within a one-week period. The most recent regional event was performed in July 2012.

Recent efforts to improve overall understanding of groundwater gradients in the aquifer include “focused” synoptic measurements, which are essentially synoptic studies limited to a smaller geographic area, in which detail can be enhanced by increasing the number of data points for a subset of the region.

Synoptic measurements made between 2005 and 2010 have been published in a report titled *Edwards Aquifer Authority Synoptic Water Level Program 2005–2010 Report*. The report is available through the EAA website.

Synoptic measurements made between 2005 and 2010 have been published in report format titled Edwards Aquifer Authority Synoptic Water Level Program 2005–2010 Report. The report is available through the EAA's website.

3. Aquifer Management Issue to be Addressed:

An improved understanding of changes in water quality in the aquifer and evaluation of new technologies to improve water quality data collection.

4. Estimated Costs:

Project work is performed by EAA staff.

5. Time line:

Project was implemented in 1999. Water level measurement events are generally performed once or twice a year.

6. Status Report:

Staff completed a report of the synoptic water level data collected between 2004 and 2010 in August 2012.

ASRPP Category: Support

21. Active Project Title:

Bacterial and Pharmaceutical Study

1. Purpose:

To evaluate the presence of specific bacteria, pharmaceuticals, and personal care products in the Edwards Aquifer.

2. Background:

This study involves two potential contaminants of the Edwards Aquifer—(1) bacteria and (2) pharmaceuticals and personal care products (PPCPs). Bacteria enter the aquifer during stormwater recharge events, and both bacteria and PPCPs are likely to enter the aquifer with septic tank effluent and with fluids from sewer system overflows. Bacteria and PPCPs originate from either human or animal waste. Samples of groundwater

collected after recent sewage spills have revealed bacterial contamination in some areas. Testing of groundwater from the Edwards Aquifer for PPCPs has been limited. Analytical techniques for bacterial analyses are rapidly evolving. EAA staff will continue to collect samples for PPCP analysis and will identify a microbiological laboratory to assist in bacterial analysis.

3. Aquifer Management Issue to be Addressed:

Study will prepare a baseline evaluation of PPCPs and bacteria types and sources in the aquifer.

4. Estimated Costs:

\$20,000 is included in the 2012 budget.

5. Time Line:

Study was initiated in 2011 and will extend through 2014.

6. Status Report:

The study is ongoing.

ASRPP Category: Support

22. Project Title:

Guadalupe River Gain / Loss Study

1. Purpose:

To improve our understanding of the contribution of Comal and San Marcos springs to the total flow of the Guadalupe River.

2. Background:

This study is intended to build on previous work on gains and losses along the Guadalupe River and will incorporate data being generated from existing river and spring gauging systems, as well as perform streamflow measurements where appropriate. The study will help to improve our understanding of the contribution of Comal and San Marcos springs to Guadalupe River flow. The study area extends from Canyon Lake Dam to the Gulf of Mexico.

3. Aquifer Management Issue to be Addressed:

This study will assist in determining the contribution of spring discharge from the Edwards Aquifer to the Guadalupe River and will provide information for local and regional water managers.

4. Estimated Costs:

This work has been a cooperative effort between the USGS, COE, Guadalupe Blanco River Authority, and

the EAA. Total estimated cost from all partners exceeds \$50,000; \$13,750 is included in the EAA 2012 budget.

5. Time Line:

Study was initiated in 2010 and will extend through 2013.

6. Status Report:

The study is ongoing.

Appendix C. Detailed Descriptions of Completed ASRPP Projects

ASRPP Category: Modeling

23. Project Title:

Finite Element Model Scope of Work

Background Information

This project represented the first phase in development of a finite element model of the Edwards Aquifer, to complement the existing MODFLOW finite difference model. The new finite element model should improve resolution and decrease level of uncertainty by including a second model to run concurrently with the existing MODFLOW model.

Status Report

This study was completed in January 2012.

ASRPP Category: Modeling

24. Project Title:

Edwards Aquifer MODFLOW Computer Model

Background Information

In April 2000 the board approved a Joint Funding Agreement (JFA) with the USGS for construction of a new computer model of the Edwards Aquifer. The model was constructed using MODFLOW software. In December 2004, the JFA was amended to extend the project completion date to March 1, 2005. The University of Texas at Austin, Bureau of Economic Geology (BEG), served as a subcontractor to the USGS to prepare input data sets. SwRI® used geostatistical techniques to prepare the hydraulic conductivity data set.

To develop an improved model, the USGS and BEG conducted a study in cooperation with the U.S. Department of Defense (DOD) and the EAA. The objective of the study was to improve understanding of the complex hydrogeologic processes that control water

availability of the Edwards Aquifer in the San Antonio area through development, calibration, and testing of a numerical groundwater-flow model that could be used in decision processes to optimize resource management.

So that this goal could be accomplished, all available and pertinent hydrogeologic data were compiled and organized into a comprehensive, digital-based system of data storage and retrieval. The new Edwards Aquifer numerical groundwater-flow model developed in this study (hereinafter, the Edwards Aquifer model) incorporates improvements over previous models by using (1) a user-friendly interface, (2) updated computer codes (MODFLOW96 and MODFLOW2000), (3) a finer grid resolution, (4) less-restrictive boundary conditions, (5) an improved discretization of hydraulic conductivity, (6) more accurate estimates of pumping stresses, (7) a long transient simulation period (54 years, 1947–2000), and (8) a refined representation of zones of large hydraulic conductivity, or conduits. In addition, the Edwards Aquifer model produces a closer match between simulated and measured hydraulic heads for a larger area of the San Antonio segment of the Edwards Aquifer, and between simulated and measured springflows, than do previous numerical groundwater-flow models.

During the initial phases of project planning and implementation, a Ground-Water-Model Advisory Panel (GWMAP) was formed to provide technical input, primarily for conceptualization, but also for construction and calibration of the Edwards Aquifer model. The GWMAP was a group of individuals with expertise in modeling, karst hydrology, and the Edwards Aquifer, including the Chief Technical Officer/Program Manager of the EAA Aquifer Science Program, USGS, SAWS, TWDB, DOD, and contractors. Three employees of the EAA were included as GWMAP staff. The intent was to deliver an end product (Edwards Aquifer model) that had been critiqued, as it was developed, by the groundwater community concerned with the Edwards Aquifer in the San Antonio region, as represented by the GWMAP. The GWMAP met periodically during development of the model, providing comments, suggestions, and technical direction. The GWMAP's

final meeting was on September 29, 2005, to discuss the future of the model.

The model includes both the San Antonio and Barton Springs segments of the Edwards Aquifer in the San Antonio region, Texas, and was calibrated for steady-state (1939–1946) and transient (1947–2000) conditions, excluding Travis County. Transient simulations were conducted using monthly recharge and pumpage (withdrawal) data. The model incorporates conduits simulated as continuously connected (other than being separated in eastern Uvalde and southwestern Medina counties), one-cell-wide (1,320 feet) zones with large hydraulic-conductivity values (as much as 300,000 feet per day). Locations of the conduits were based on a number of factors, including major potentiometric surface troughs in the aquifer, presence of sinking streams, geochemical information, and geologic structures (for example, faults and grabens).

A series of sensitivity tests was made to ascertain how model results were affected by variations greater and less than the calibrated values of input data. Simulated hydraulic heads in the Edwards Aquifer model were most sensitive to recharge, withdrawals, hydraulic conductivity of conduit segments, and specific yield and were comparatively insensitive to spring-orifice conductance, northern boundary inflow, and specific storage. Simulated springflow in the Edwards Aquifer model was most sensitive to recharge, withdrawals, hydraulic conductivity of conduit segments, specific yield, and increases in northern boundary inflow and was comparatively insensitive to spring-orifice conductance and specific storage.

Status Report

This study has been completed. Final paper copies and a PDF-format copy of the Scientific Investigations Report, *Conceptualization and Simulation of the Edwards Aquifer, San Antonio Region, Texas*, were delivered to the EAA on March 2, 2005.

The model was submitted to the TWDB and has been approved as an official Groundwater Availability Model (GAM) for the San Antonio segment of the Edwards Aquifer.

ASRPP Category: Modeling

25. Project Title:

Water Resources Management Module for the Edwards Aquifer MODFLOW Model

Background Information

Under previous contracts with the EAA, HydroGeoLogic, Inc., developed the Groundwater Management Package to enable MODFLOW in simulating the EAA critical period rules and subsequently modified the modules to be compatible with MODFLOW 2000 (see Section 3). HydroGeoLogic, Inc., was retained in April 2006 to upgrade management modules to simulate junior/senior rights that were being considered by the EAA board.

Status Report

HydroGeoLogic, Inc., submitted the revised code for modeling junior rights. It creates two records in the WEL file for each well—one for the junior right and one for the senior right—that can be controlled independently with rules. Project was completed in August 2006.

ASRPP Category: Modeling

26. Project Title:

Enhanced Characterization and Representation of Flow through Karst Aquifers

Background Information

On June 14, 2005, the board of directors approved the contract with SwRI® for phase II of the project, titled *Enhanced Characterization and Representation of Flow through Karst Aquifers*. The purpose of phase II was to continue testing MODFLOW-DCM (dual conductivity module) to enable MODFLOW in simulating groundwater flow in karst aquifers. The project was jointly funded by the Southwest Florida Water Management District and the EAA.

The project consisted of:

Task 1—Code Refinement

Task 2—Barton Springs Demonstration Simulations

Task 3—Floridan Aquifer Demonstration Simulations

Task 4—Subtask 4.1 (*Option 1*): A Graphical User Interface with Environmental Simulations International; or

Subtask 4.2 (*Option 2*): Evaluation of the Costs and Benefits of Developing a Three-Dimensional MODFLOW-DCM.

Task 5—Technical Exchanges, Reporting, and Meetings

Status Report

This study is complete. SwRI® solved dry cell issues associated with MODFLOW by using a solver based on the Newton-Raphson method instead of the Picard method. The project was completed in March 2007.

ASRPP Category: Modeling

27. Project Title:

Hydrologic Simulation Program Fortran (HSPF) Model Refinement

Background Information

The EAA contracted with Clear Creek Solutions, Inc., in November 2006 to evaluate potential refinements to the current HSPF recharge model and develop a graphical user interface (GUI) to simplify model use. Potential refinements consisted of assessing improvements in model output by using ground-calibrated NEXRAD radar data for each four square kilometers of the entire region. The original model was constructed using a limited series of existing National Weather Service (NWS) rainfall gauges across the region, resulting in limitation on input (rainfall) data sets. Calibrated NEXRAD data are available for calendar years 2003–2006.

Status Report

Conclusions of the final report were somewhat surprising regarding use of NEXRAD data sets for model rainfall input. Although NEXRAD data provide comprehensive coverage of the area, the timestep is daily rather than hourly. As such, use of the limited number of NWS rainfall gauges with hourly data appears to provide a more complete assessment of recharge than do daily NEXRAD data because of the need to have information for rainfall intensity. Rainfall events that result in a high degree of runoff affect modeled recharge output more significantly than rainfall events that do not. Daily rainfall amounts from NEXRAD do not provide this information. Future assessments may include evaluation of hourly NEXRAD data sets or incorporation of the EAA real-time network of rainfall gauges. This project is complete, although, given the results of this study, one more iteration of model refinement is probably needed. The project was completed in September 2007.

ASRPP Category: Modeling

28. Project Title:

MODFLOW Model— Improved Storativity Estimates

Background

The goal of this research was to refine storativity estimates of the Edwards Aquifer using a new method based on seismic efficiency of the aquifer matrix. The approach was validated by comparison with an indirect estimate of storativity using barometric efficiency. The research was conducted by Evelyn Mitchell, a Ph.D. student at The University of Texas at San Antonio, and her advisor, Dr. Alan Dutton.

Storativity is a basic hydrogeologic property of aquifers that describes the volume of water that can be recovered from a unit column of an aquifer, given a unit decline in hydraulic head. The accuracy of numerical models is particularly sensitive to uncertainty in storativity. Direct measurements of storativity from aquifer tests

are preferred, but a few data sets are available for the Edwards Aquifer. Consequently, indirect measurements, such as seismic efficiency, are used to fill data gaps.

Status Report

This research began in October 2006 and was completed in December 2007.

ASRPP Category: Modeling

29. Project Title:

Estimation of Hydraulic Parameters for the Edwards Aquifer Management Model

Background Information

In May 2000 the board approved a two-year JFA with the U.S. Army Corps of Engineers (COE) to statistically model hydraulic conductivity measurements and create an input data set for the MODFLOW model being prepared by the USGS. The COE subcontracted the work to SwRI®. The purpose of the project was to create a hydraulic conductivity data set for the management model of the Edwards Aquifer being built by the USGS for the EAA. SwRI® used geostatistical techniques to upscale specific capacity data and hydraulic conductivities measured in pumping tests to each grid cell in the model. The initial geostatistical model involved a stochastic simulation and co-kriging techniques to upscale and interpolate measured values to grid cells in the model. Results were refined in subsequent models using Bayesian statistics and incorporating groundwater levels, as well as hydraulic conductivities.

Status Report

The study is complete. The final report and final hydraulic conductivity model were delivered to the EAA in May 2002. The USGS is using this data set for calibration work for the aquifer model.

ASRPP Category: Modeling

30. Project Title: *Conversion of the Development of Water Resources Module for MODFLOW Model*

Background Information

In December 2003 the board approved a contract with HydroGeoLogic, Inc., to develop water resource management modules in MODFLOW for the Edwards Aquifer model that was under construction by the USGS. The project was completed on May 31, 2005, after the original contract schedule was extended. The purpose of the modules was to simulate effects of EAA demand management/critical period rules that were enacted in 2002. The new modules enabled MODFLOW to accept trigger levels, a variety of recharge and pumping schedules, and other conditions.

Status Report

The study is complete. HydroGeoLogic, Inc., submitted all deliverables required by the contract, including a users' manual, a reference manual, and software.

ASRPP Category: Modeling

31. Project Title: *Conversion of the Water Resources Management Module for MODFLOW 2000*

Background Information

Under a previous contract with the EAA, HydroGeoLogic, Inc., developed the Groundwater Management Package to enable MODFLOW to simulate EAA critical period rules. According to the scope of work, HydroGeoLogic, Inc., wrote the software to be compatible with the Edwards Aquifer model in MODFLOW 96, which was under construction by the USGS. The USGS subsequently converted the model to MODFLOW 2000. This project required the consultant to modify the Groundwater Management Package to be compatible with MODFLOW 2000. HydroGeoLogic, Inc., modified the existing graphical user interface (GUI) for WPM1

to include the capability to generate the trigger rule and managed pumping well files for the modified MODFLOW 2000 code. HydroGeoLogic, Inc., prepared addenda to the quality plan and reference manual that were prepared for the MODFLOW 96 version.

Status Report

HydroGeoLogic, Inc., submitted management modules for MODFLOW 2000 in December 2005. The modules performed satisfactorily with test cases. EAA staff completed testing of the entire model data set in April 2006.

ASRPP Category: Modeling

32. Project Title: *Karst Aquifer Modeling Research (Phase 1)*

Background Information

In August 2003 the board approved a cooperative funding agreement with the American Water Works Association Research Foundation (AWWARF) to initiate development of modeling software that would accommodate hydraulic characteristics of groundwater in karst aquifers. Karst aquifer modeling requires specific modeling capabilities, such as turbulent flow in discrete conduits, which are not included in widely used groundwater modeling software such as MODFLOW. AWWARF contracted the work to SwRI® in San Antonio, who developed software for MODFLOW to accommodate karst groundwater conditions. Draft code was completed at the conclusion of the first year of the study. SwRI® conducted initial tests on the code by modeling the Barton Springs segment of the Edwards Aquifer. Cooperative funding partners in the project were the EAA, AWWARF, and the Southwest Florida Groundwater Management District. These three agencies provided \$100,000 each in cooperative funding for the project. An additional \$102,000 was provided to the project in in-kind services from

- Miami-Dade Water and Sewer Department
- Oklahoma State University
- Water Resources Authority of Jamaica

- Barton Springs/Edwards Aquifer Conservation District
- University of West Indies
- University of Manitoba
- University of South Florida
- University of Connecticut
- The University of Texas at Austin, Bureau of Economic Geology

Status Report

The study is complete. SwRI® submitted the final report in December 2004. SwRI® developed the scope of work for 2005 activities, although AWWARF was not involved.

ASRPP Category: Modeling

33. Project Title: *Recharge Methodology*

Background Information

In October 2002 the board approved a contract with a team led by LBG-Guyton Associates to develop Hydrologic Simulation Program-Fortran (HSPF) models for seven basins, including areas upstream of the Edwards Aquifer Recharge Zone. In March 2004, the contract was amended to extend the performance period from April 30, 2004, through March 30, 2005. The contract amendment also increased the project work scope to create equivalent models for the Blanco and Nueces river basins. The river basins modeled were

- (1) Frio/Dry Frio River Basin
- (2) Sabinal River Basin
- (3) The area between Sabinal and Medina River Basins
- (4) Medina River Basin
- (5) The area between Medina River and Cibolo/Dry Comal Creek Basins
- (6) Cibolo Creek and Dry Comal Creek Basin
- (7) Guadalupe River Basin

- (8) Blanco River Basin
- (9) Nueces River Basin

The LBG-Guyton team consisted of AQUA TERRA Inc., Espey Consultants, Freese and Nichols, and Dr. Bradford Wilcox (TAMU). Methodology for this project was similar to that of pilot HSPF models prepared for the Nueces and Blanco basins in 2002; however, this project also included the basin area upstream of the recharge zone.

Status Report

The study is complete. HSPF recharge models for the nine basins were constructed and run using input (rainfall) data for the period 1950–2000. Model results indicate slightly higher cumulative recharge for the model period than do historical methods. The project final report was submitted on January 31, 2005. The final deliverable, a set of HSPF output data files formatted for use in the MODFLOW model, was submitted prior to the end of the contract period (March 30, 2005).

ASRPP Category: Modeling

34. Project Title: *Recharge Methodology (Pilot Study)*

Background Information

In April 2001, the board approved a contract between the EAA and HDR Engineering, Inc. (HDR), for development of pilot recharge models for the Nueces and Blanco River basins. Under the contract, HDR provided daily recharge estimates as far back as 1950 for the Nueces basin and 1956 for the Blanco basin. Recharge is currently estimated by two methods that provide annual recharge estimates only. The two existing methods, prepared by the USGS and TWDB, produce different volumes of recharge for some basins, the largest differences between the two methods occurring in the Nueces and Blanco River basins. HDR's work updated recharge estimating methods and generated daily recharge values for a future update of the Edwards Aquifer model prepared by the USGS. The new models eventually will be adopted for estimating recharge to the aquifer annually.

Status Report

The study is complete. Final models were presented to EAA staff in February 2002. HDR delivered its final report to the EAA in June 2002. Because the pilot models generated volumes of recharge more representative than the previous methods, the updated methodology will be applied to remaining drainage basins in the recharge zone.

ASRPP Category: Modeling

35. Project Title: *Statistical Analysis of Hydrologic Data*

Background Information

In June 2000 the board approved a JFA with the COE to perform this study. The COE subcontracted the work to Argonne National Laboratory (ANL). The ANL reviewed the Edwards Aquifer data that were provided by the EAA from the major storm event of October 17–18, 1998. The ANL submitted a Phase I Memorandum in December 2000 that assessed data provided by the EAA and described its approach to the study.

Status Report

The study is complete. The ANL submitted its final report in November 2001, which completed its involvement in the project.

ASRPP Category: Flowpath Studies

36. Project Title: *Well Plugging Study*

Background Information

EAA regulations currently require plugging of abandoned wells, which includes either removal or perforation of any well casing and sealing of the annular space. Before implementation of EAA regulations, wells were commonly abandoned by merely filling the well bore and casing with cement or grout and ignoring the annular space. Poor sealing of the annular space of wells, either during drilling or plugging, may create a number of groundwater contamination problems.

This study evaluated the effectiveness of a well-plugging case by geophysical logging of the well before abandonment, perforation of the well casing using mechanical and chemical methods, sealing of the well bore and annular space, drilling of the annular space, geophysical logging of the well, and final abandonment of the well.

Status Report

The study was completed and a final report was submitted in August 2012.

ASRPP Category: Flowpath Studies

37. Project Title: *Define and Delineate San Marcos Pool*

Background Information

Section § 702.1 of EAA rules currently defines two pools in the Edwards Aquifer, the San Antonio, and the Uvalde. Although San Marcos Springs is currently included within the San Antonio Pool, the habitat provided by spring discharge may not be protected properly by trigger levels utilizing Bexar County Index Well (J-17) or Comal Springs discharge. A high correlation exists between J-17 and Comal Springs; however, correlation is rather poor between J-17 and San Marcos Springs. Consequently, demand management and critical period management rules for the San Antonio Pool may have a limited effect on San Marcos Springs discharge. This project investigated methods and tasks to determine whether creation of a San Marcos Pool is technically justified. In addition, the conceptual model of San Marcos Springs was evaluated and updated.

The study utilized information from a variety of sources, including water levels (focused synoptic water levels), water quality analyses, well logs, geologic data, tracer test results, and other information for making a determination.

Status Report

The study is complete. Although the report was issued in February 2008, some work continues on the basis of recommendations (in the report) to characterize

groundwater flowpaths near the springs. EAA and Zara Environmental staff members are continuing tracer testing in the Blanco River area in Hays County. Thus far, the EAA has injected small quantities of nontoxic dyes into three sinkholes in the Blanco River Basin. No dye was detected in nearby wells. Additional dye was injected June 10–12, 2008, to trace groundwater flowpaths to San Marcos and Barton springs. Zara Environmental staff will monitor many wells and the springs over several weeks to detect arrival of the dyes.

ASRPP Category: Flowpath Studies

38. Project Title: ***Augmentation Study (In Situ Refugia)***

Background Information

In November 2002, the board approved a contract between the EAA and LBG-Guyton Associates, Inc., to perform a study titled *Evaluation of Augmentation Methodologies in Support of In Situ Refugia at Comal and San Marcos Springs, Texas*. The purpose of the project was to assess the feasibility of introducing water directly to critical habitat areas of Comal and San Marcos springs ecosystems to extend the viability of the habitat during low springflow. If augmentation, in conjunction with other water management programs, had been insufficient to maintain critical habitat, then threatened and endangered species would have to be moved to traditional refugia under controlled conditions. This project investigated recommendations presented by The University of Texas at Austin, Center for Research in Water Resources (CRWR), in its report titled *Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase I—Feasibility Study* (Technical Report CRWR 247, February 1995). A project amendment was approved in June 2004 to extend the contract performance period through December 31, 2004, in order to obtain additional support services from the contractor as needed by the EAA.

Status Report

The study is complete. The final report was submitted in June 2004.

ASRPP Category: Flowpath Studies

39. Project Title: ***Hydrologic Assessment of Flowpaths—North Medina County***

Background Information

In December 2000, the SAWS board approved a contract with the USGS to perform data collection and evaluation tasks for the Northern Medina County Flowpath Study. The EAA was not involved as a cooperator in the SAWS/USGS agreement; however, EAA staff provided support as requested. As part of the study, the USGS installed new monitoring wells in Medina County on the recharge zone. The EAA was unaware of budget information for this project.

Status Report

The study is complete. The USGS finalized the report in February 2006.

ASRPP Category: Flowpath Studies

40. Project Title: ***Noble and Active Gas Sampling in the Knippa Gap Region***

Background Information

In March 2005 the board approved a joint funding agreement with the USGS to perform analyses of noble gases, active gases, and groundwater-dating geochemistry to improve understanding of groundwater flow in the Knippa Gap region of the Edwards Aquifer. It was hoped that these techniques would identify multiple water sources, recharge areas, groundwater mixing, and unique elemental and isotopic “signatures” of groundwater sources and groundwater-rock interactions. In addition, it was hoped that these data would help predict hydrologic and geochemical responses in major flowpaths down gradient of the Knippa Gap region.

Status Report

The study is complete. The USGS drafted a report of its findings.

ASRPP Category: Flowpath Studies

41. Project Title:

Investigation of Groundwater Systems in Kinney and Uvalde Counties

Background Information

In July 2004 the board approved a contract with SwRI® to investigate groundwater systems in Kinney and Uvalde counties. The purpose of the project was to further characterize the Edwards Aquifer flow system in Uvalde County and to refine the estimated contribution of the Uvalde Pool to the San Antonio Pool and to the Leona Aquifer. The study was considered a focused flowpath study to improve understanding of the effect of the Knippa Gap on flow within the aquifer.

As more information was collected regarding groundwater systems in Uvalde County, a discrepancy seemed to occur in the estimated water budget for the Edwards Aquifer in Uvalde County. For example, groundwater discharged from the aquifer and recharges the Leona Aquifer at a significant but unknown rate. Also, the amount of recharge from the Nueces River estimated from pilot recharge models was less than the amount calculated by previous methods. Consequently, recent studies have revealed a lack of precision in existing estimates of the water budgets in Uvalde County. Because water resources of Uvalde County are an important part of the Edwards Aquifer, continued study of the sources of error in the water balance is important.

The project consists of the following tasks:

- Task 1—Well Inventory
- Task 2—Focused Synoptic Water Level Survey
- Task 3—Water Chemistry Evaluation
- Task 4—Geologic Structural Analysis
- Task 5—Data Analysis and Reporting

Status Report

The study is complete. SwRI® presented its findings to the Research and Technology Committee on June 28, 2006, and to the Board of Directors on July 11, 2006. The project final report is currently posted on the EAA's website under the reports section at http://www.edwardsaquifer.org/pages/research_optimization.htm.

ASRPP Category: Flowpath Studies

42. Project Title:

Hydrologic Budget Analysis of Medina Lake and Diversion Lake

Background Information

In August 2000 the board approved a three-year, eight-month JFA with the USGS for a hydrologic budget analysis (water balance) of Medina and Diversion lakes. Bexar Metropolitan Water District (Bexar Met) also cooperated with the USGS on the project. The study was a continuation of the water balance study prepared by the USGS in 1996 that was limited to low lake levels. This study was conducted with high lake levels. The USGS monitored lake levels, meteorological conditions, inflows, and outflows from the lakes to calculate groundwater losses.

Status Report

The study is complete. The USGS submitted the final Water Resource Investigations (WRI) Report in December 2004.

ASRPP Category: Flowpath Studies

43. Project Title:

North Medina County Flowpath— Helicopter Electromagnetic Survey In the Vicinity of Seco Creek Sinkhole

Background Information

In April 2002 the board approved a JFA with the USGS for an airborne electromagnetic survey of northern Medina County near Seco Creek Sinkhole. A helicopter electromagnetic (HEM) survey was completed for an 81-square-mile area in northwestern Medina County and northeastern Uvalde County. HEM data were collected by towing an airborne magnetometer over predetermined flight lines, which were flown in a north-south and east-west grid pattern centered on the Seco Creek Sinkhole. Survey data were processed to produce apparent resistivity maps—maps that delineate different geologic materials at various depths. Geologic structure and its effect on groundwater flow can be interpreted from the data.

Status Report

The part of the study funded by the EAA is complete. In July 2003 the USGS finalized *Helicopter Electromagnetic and Magnetic Survey Data and Maps, Seco Creek Area, Medina and Uvalde Counties, Texas, Open-File Report (03-226)*. The report concluded that survey data are effective from near surface down to approximately 100 meters and that the data show more structural detail and precise locations than do previously prepared geologic maps. The USGS may produce a follow-up report in the future that will contain conductivity profiles correlated to stratigraphy and geologic structure using existing well logs.

ASRPP Category: Flowpath Studies

44. Project Title:

Leona Formation Geophysical Survey

Background Information

In February 2003 the EAA and SwRI® signed a letter agreement authorizing SwRI® to perform geophysical investigations to determine the lateral extent of the Leona Formation in the Leona River floodplain south of the City of Uvalde. The purpose of this study was to evaluate the depth and lateral extent of the Leona Formation. These data were combined with previously determined Leona Aquifer parameters to estimate the amount of water that may be flowing from the Edwards Aquifer in the area of Leona Springs. This information has improved overall understanding of Edwards Aquifer hydrologic budgets. The project report concludes that as much as 100,000 acre feet of water may be leaving the Edwards Aquifer near Leona Springs.

Status Report

The study was completed in February 2004.

ASRPP Category: Flowpath Studies

45. Project Title:

Analysis of Structural Controls on the Edwards Aquifer/Trinity Aquifer in North Bexar County—Camp Bullis Quadrangle

Background Information

In March 2002 the board approved a one-year JFA between the COE and the EAA for analysis of structural controls on the Edwards Aquifer/Trinity Aquifer interface in the area of the Camp Bullis Quadrangle map. The COE's Planning Assistance to States program paid 48 percent of the cost of this study, which was initiated in June 2002 and completed in December 2003. The purpose of this project was to generate a three-dimensional computer model and predictions of localized fault-related deformation in the Edwards and Trinity aquifers in the study area. A second major objective of this study was to analyze potential hydraulic communication across the interface between Edwards and Trinity aquifers, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

Status Report

The study is complete. The Center for Nuclear Waste Regulatory Analyses (CNWRA) at SwRI®, the COE's contractor for the project, submitted its final report on December 8, 2003.

ASRPP Category: Flowpath Studies

46. Project Title:

Analysis of Structural Controls on the Edwards Aquifer/Trinity Aquifer in North Bexar County—Helotes Quadrangle.

Background Information

In June 2003 the board approved a one-year JFA between the COE and the EAA for analysis of structural controls on the Edwards Aquifer/Trinity Aquifer interface in the area of the Helotes Quadrangle. The COE Planning Assistance to States Program paid 50 percent of the

cost of this study, and the CNWRA at SwRI® was the contractor. The study began in the fall of 2003 and was completed in February 2005. The purpose of this project was to generate a three-dimensional computer model and predictions of localized fault-related deformation in the Edwards and Trinity aquifers in the study area. A second major objective of this study was to analyze potential hydraulic communication across the interface between the Edwards and Trinity aquifers, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

Status Report

The study is complete. SwRI® submitted the final geologic framework model and report in February 2005.

ASRPP Category: Flowpath Studies

47. Project Title: *Saline Water Study*

Background Information

Between mid-1998 and August 15, 2005, the EAA and SAWS cooperatively funded the construction, operation, and maintenance of Edwards Aquifer freshwater–saline water interface monitoring wells. The purpose of the multiyear study was to conduct a regional investigation and data collection program to assess the likelihood of saline water encroaching across the currently mapped Edwards Aquifer freshwater–saline water interface during periods of extended drought. SAWS is currently installing monitoring well transects. Prior to 1994, the USGS and EUWD installed monitoring well transects for the program. To date, monitoring well transects have been installed in the following 10 areas:

- Area of Artesia Pump Station in San Antonio—completed in 1986
- Area of Comal Springs—New Braunfels—completed in 1989
- Area of San Marcos Springs—San Marcos—completed in 1991
- Southwest Medina County (one exploratory well only)—completed in 1993

- Area of Kyle and IH-35—completed in 1998
- Southeast Uvalde County—completed in 1999
- Area of confluence of Bexar-Comal-Guadalupe county lines—completed in 2000
- Area of San Marcos Federal Fish Hatchery—Hays County—completed in 2001
- Area of Mission Road Pump Station in San Antonio—completed in 2002
- Area of Pitluk Road in San Antonio—completed in 2005

During approval of the EAA's 2005 budget, the board voted not to participate in the study after expiration of the 2004–2005 agreement. The 2004–2005 Interlocal Cooperation Agreement (ICA) between the EAA and SAWS expired August 15, 2005. SAWS plans to continue the project without EAA participation.

Status Report

The study is ongoing without EAA cooperative funding for new monitoring well transects. SAWS continues to monitor water levels and water quality in transect monitoring wells.

ASRPP Category: Flowpath Studies

48. Project Title: *Fracture/Conduit Study*

Background Information

In November 2001 the board approved a JFA between the EAA and BEG to investigate the influence of faults and conduits on groundwater flowpaths in both recharge and artesian zones of the aquifer. Dr. Sue Hovorka led the BEG in testing the following hypotheses:

- Karst conduits are strongly controlled by structures such as fracture zones and fault displacements of the aquifer.
- Conduits are preferentially developed and most active beneath streams.
- Conduits preferentially develop in some stratigraphic horizons within the Edwards Group.

- Hydrogeologic characteristics such as transmissivity, travel times, and others can be estimated for groundwater flow in regions or domains of the aquifer.

Project deliverables included a final report and GIS files of geologic structure, fault locations, water levels, and water chemistry.

Status Report

The study was completed in February 2004.

ASRPP Category: Flowpath Studies

49. Project Title:

Helicopter Electromagnetic Survey of Northern Bexar County

Background Information

An airborne helicopter electromagnetic (HEM) survey, funded by the U.S. Army, was flown over the Camp Stanley Storage Facility (CSSA) and Camp Bullis areas in northern Bexar County. The EAA contributed funding to extend the survey south and west of the Army facilities on undeveloped areas of the recharge zone. The survey area is east of I-10, north of Loop 1604, south of Cibolo Creek, and west of Blanco Road. Geophysical information collected from the survey was used to map geologic and hydrologic features in the subsurface. Information from the airborne survey was useful in a variety of groundwater studies in the Bexar County area. Of particular interest was the contact between the Edwards and Trinity aquifers in that area. A similar survey was completed in 2002 in the Seco Creek area north of Hondo in northwestern Medina County.

Status Report

The study has been completed. The USGS submitted a report and map in June 2005.

ASRPP Category: Flowpath Studies

50. Project Title:

Phase II of the Uvalde County Study (geophysical study of gravel aquifers to improve water balance)

Background Information

SwRI® completed a study in June 2006 that updates the conceptual model of groundwater systems in Uvalde County with existing and recently collected data on hydrology, geochemistry, and structural geology and describes the hydrogeologic relationship between the Uvalde and San Antonio pools of the Edwards Aquifer. The area of investigation consisted of Kinney and Uvalde counties and included the groundwater divide in Kinney County to the west and the Knippa Gap to the east. It included all principal aquifers in Uvalde and Kinney counties. Phase II of this study was initiated to investigate floodplain flows in rivers down gradient of the recharge zone in Uvalde and Medina counties.

Discharge from the Edwards Aquifer via floodplain flow is recognized as potentially significant and needs further evaluation. Integrated investigations using geophysical surveys of the subsurface are well suited to providing key information for evaluating the hydraulic relationship between river floodplain sediments and underlying aquifers. The objective of this study was to measure the hydraulic relationship between floodplain sediments and rivers in Uvalde and Medina counties where they traverse and exit the Edwards Aquifer. Work on the Nueces and Frio Rivers is complete, and findings provide direct evidence of hydraulics and hyporheic exchange of rivers, floodplain sediments, and subsurface flow near the south edge of the Edwards Aquifer. This work was performed by Southwest Research Institute.

Results of the study will be used to address water balance issues in the Edwards Aquifer. Data will be incorporated into future groundwater models.

Status Report

This study was completed in 2012.

ASRPP Category: Support

51. Project Title:

Improved Gauging at Comal Springs and San Marcos Springs

Background

Comal and San Marcos springs, the two largest spring systems in Texas, are critically important resources for a number of reasons. Both springs flow from the Edwards Aquifer, which supplies water to more than 1.7 million people. Also, federally listed endangered species live in the springs and surface streams immediately fed by the springs. Because discharge numbers from Comal and San Marcos springs are incorporated into the EAA Demand Management/Critical Period Management rules, accurate estimation of discharge from both of these spring systems is essential to management of the aquifer to protect the federally endangered, spring-dependant species. In addition, discharge data from Comal and San Marcos springs are important data sets supporting the EAA groundwater model.

The purpose of this study was to evaluate a new gauging system for Comal and San Marcos springs. The springflow quantification pilot project involved selection of a new gauging location, as well as installation of a new generation of gauging equipment, to improve accuracy and precision of discharge measurements from Comal and San Marcos springs. Work on the project was performed through a joint funding agreement between the EAA and the USGS.

Work was performed in three phases:

Phase I—initial equipment installation and operation using up to five acoustic Doppler velocity meters (ADVMS) at different locations in each spring system for a period of six to eight months. At the conclusion of the phase I evaluation period, up to two ADVMS at each spring system were placed permanently at the most favorable locations and connected by telemetry so as to obtain real-time data capabilities.

Phase II—data collection and system validation, which included collection of continuous velocity index data for an entire water year as a velocity–discharge rating curve was developed.

Phase III—study report and recommendations for improving the discharge measurement system at both springs.

Status Report

The USGS completed the study in 2008.

ASRPP Category: Support

52. Project Title:

Edwards Aquifer Well Survey Project

Background Information

In April 2002 the board approved a letter agreement with Ford Engineering, Inc. (FEI), to collect survey-grade GPS data at well sites directed by the EAA. The main goal of the project was to obtain professionally surveyed locations and elevations at Edwards Aquifer wells with historical water level data, as well as to install and survey benchmarks and numerous features near Comal and San Marcos springs. The joint survey work of the EAA and FEI staff was performed from May 1, 2002, through December 31, 2003. The 403 wells surveyed included

- Target wells used in steady-state calibration of the model (SSCW),
- Target wells used in transient calibration of the model (TCW),
- All wells included in the Synoptic Water Level Program (SWLP),
- Other wells with water level information available in EAA archives,
- Wells in Hays County necessary for evaluating the location of the Edwards Aquifer groundwater divide, and

- Eight permanently installed benchmarks and numerous spring-related features near Comal and San Marcos springs.

Status Report

The initial well surveying study is complete. Survey project deliverables received by the EAA included

- Latitude, longitude, and elevation data for each surveyed location and
- Data in decimal degrees in the NAD83 horizontal coordinate system and NAVD88 vertical coordinate system.

All data were presented in hardcopy format sealed by Registered Professional Land Surveyor (RPLS) guaranteeing accuracy, as well as in MS Excel format.

Additional wells requiring precision surveying have been identified during various research projects. These wells have been surveyed and incorporated into the EAA data base.