Edwards Aquifer Authority 2015
Ecological Modeling Work Plan

The development of a mechanistic Ecological Model is assigned to the Edwards Aquifer Authority (EAA) per section 6.3.3 of the Edwards Aquifer Habitat Conservation Plan (EAHCP). The purpose of the ecological model is to evaluate potential adverse effects to Covered Species and their critical habitat, and to the extent such effects are determined to occur, quantify their magnitude and develop alternate strategies. ~~The fiscal year 2014-2015 (FY 2014-2015) Scope of Work (SOW) is based on the progress made in implementing fiscal year June 2013 – May 2014 (FY 2013-2014) "Predictive Ecological Model(s) for the Comal & San Marcos Ecosystems.~~"

Long Term Objective: Development of a comprehensive mechanistic ecological. ~~This~~ The objective of the predictive ecological model for the Comal and San Marcos ecosystem project is to adapt existing models for aquatic vegetation and fountain darters and begin the development of models for Texas wild-rice and gill parasites impact.

YEAR 1 (June 1, 2013 – May 31, 2014)

Task 1. Literature Review

The Consultant shall gather and review pertinent scientific literature with respect to two issues: (1) identifying a modeling approach for predicting aquatic macroinvertebrate responses to changing physical, chemical, and biotic (*i.e.*, aquatic vegetation dynamics). This review will focus on potential modeling approaches and life history parameters that may have potential for adaptation to specific applications, including general life histories of communities or individual macroinvertebrate species; and (2) existing modeling approaches that may have potential for modification to address the EAHCP specific applications regarding the Comal Springs riffle beetle response/dynamic, even if the literature does not specifically address the Comal Springs riffle beetle.

Task 2. Data Acquisition

The EAA will provide any pertinent data to the Consultant, as available. However, the Consultant shall be responsible for the acquisition of, and for obtaining permission to use any additional data necessary to complete the requirements of this Contract.

Task 3. Modeling

The Consultant shall undertake four separate modeling efforts, identified as subtasks, each designed to address a specific area of concern. All models developed or modified during this task should have the capacity to be linked to the other models developed in this task, using a larger modeling platform.

Subtask 3.1 U.S. Army Corps of Engineers Model Modification

The Consultant shall modify and/or adapt specific models developed by U.S. Army Corps of Engineers' Aquatic Plant Control Research Program for application to the Comal and San Marcos springs ecosystem. The Consultant shall take the four existing monotypic and one competition model and refine them to be specific to the aquatic vegetation of Comal and San Marcos springs. In particular, monotypic models for *Ludwigia*, *Hygrophila*, *Cabomba*, *Vallesneria*, and bryophytes will be explored. Additionally, model parameters including physical/mechanical impacts, carbon dioxide, and substrate will be evaluated for inclusion. Parameters such as water temperature and flow velocity which are already incorporated in the existing models will be evaluated to determine if modifications are needed to apply directly to the Comal and San Marcos system. From these preliminary evaluations it will be determined which system-specific monotypic models are most appropriate for initial development. For 2013, up to 3 monotypic models will be developed that incorporate the response/dynamics of vegetation specific to the Comal and San Marcos system. Calibration techniques for these models will be vetted with the Science Committee and presented at an open meeting of the Implementing Committee early in the process. No data from areas affected by recreation or flooding will be used in model calibration. Upon completion of the monotypic models, the Consultant will make recommendations on linking these models to the spatial and temporal components for both the Comal and San Marcos ecosystems, specifically considering existing aquatic vegetation data that has been shaped by flows, recreation, and flood events. In particular, specific recommendations will be provided on how such physical impacts should be incorporated in future assessments via linked models.

Subtask 3.2 Fountain Darter Response/Dynamics Model

The Consultant shall review and assess available fountain darter, aquatic vegetation, and water quality data for the potential of "data mining" to see if any of the model parameters can be updated. This task shall include but not be limited to the "data mining" efforts of Dr. Mac McKee, Director, Utah Water Research Laboratory at Utah State University, who conducted a preliminary data mining effort in 2012 and early 2013 of the datasets developed during the Edwards Aquifer Recovery Implementation Program. The Consultant shall obtain the results of and review the data mining conducted by Dr. McKee, and based of the assessment, the Consultant shall refine/modify the population dynamics equations to the degree practicable. A final determination on exact modeling framework will be made at the conclusion of the data mining activities and presented to the EAHCP Implementing Committee or their designee. Updates and linkages to the fountain darter model will be explored in 2013 relative to spatial and temporal constraints, aquatic vegetation mapping data and models, and existing water temperature model outputs.

Subtask 3.3 Texas Wild Rice Parameters

Utilizing the modified models identified during subtask 3.1, the Consultant shall simulate the characteristics of Texas wild-rice and identify potential research necessary to parameterize Texas wild-rice dynamics.

Subtask 3.4 Gill Parasite and Non-Native Snails Response/Dynamics Model

The Consultant shall develop the model structure and associated model parameters that will allow an evaluation of the response/dynamics of gill parasites and non-native host snails to projected flow conditions anticipated under the EAHCP.

Task 4. Recommendations and Future Work

The Consultant shall provide recommendations developed during the course of this project regarding the development of the modules and completed ecological model. Specifically, the Consultant shall also provide recommendations for work that should be completed by the EAA or its Consultants in 2014 to continue or enhance the modeling efforts completed during this project. These recommendations should include a timeline that results in the completion of a functional Ecological Model by the end of 2015.

Task 5. Draft and Final Reports

The Consultant shall submit to the EAA two (2) copies of the Literature Review no later than 120 days of the execution of the Contract.

The Consultant shall submit to the EAA two (2) copies of the draft project report no later than 300 days from the execution of the Contract. The report shall discuss any changes to existing models, all modeling results, all data used in calibrating and validating the models, and all assumptions used in the development or adaptation of the models including report describing the modification to the United States Army Corps of Engineers (USACE) model(s) necessary to simulate the characteristics of Texas wild-rice and identify potential research necessary to parameterize Texas wild-rice dynamics.

After receipt and incorporation of EAA's review comments, the Consultant will submit the final report to the EAA on or before 365 days from the execution of this Contract.

Task 6. Meetings and Presentations

The Consultant shall attend a minimum of two (2) meetings to provide information to the Science Committee, Implementing Committee, and Stakeholder group when requested by the EAHCP Director.

Task 7. Deliverables

To the extent possible, the Consultant shall identify a preliminary listing of any needed additional applied research projects as soon as possible, so that the projects may be included in the 2015

Applied Research work plan or executed sooner through some other process. The needed additional Applied Research related to Texas wild-rice and Task 3.3 shall be identified in writing to EAA staff no later than December 31, 2013.

The Consultant shall deliver preliminary models (as described in the tasks above) that can assess:

a) the response/dynamics of native and key nonnative aquatic vegetation during extended periods of low flow;
b) the response/dynamics of fountain darter populations relating to growth and survival during projected flow conditions;
c) identify potential research necessary to parameterize Texas wild-rice dynamics; and
d) identify the model structure and associated model parameters to assess gill parasites and non-native host snails relative to projected flow conditions anticipated under the EAHCP.

(1) All computer models and spreadsheets developed as a part of this project, shall be submitted to the EAA. *User manuals shall be submitted by the Consultant to EAA providing complete documentation of computer models developed under this project. The user manuals shall also contain the source code language and the type of computer equipment necessary to operate the model(s).*

(2) All data collected and/or generated during this study shall be submitted to the EAA in electronic format compatible with its associated software. (*i.e.*, spreadsheets will be in MS Excel format, etc.). Data shall be delivered via pre-approved digital media and shall be labeled to provide sufficient detail to access the information.

(3) All computer models, databases, and spreadsheets developed herein (written and digital formats) are due on the same date as the final report.

(4) To facilitate the EAA's accurate evaluation of the Consultant's work product, computations, conclusions and recommendations, the Consultant shall:

- Include in the final report a section describing the assumptions and methodology used by the Consultant in generating the data and conclusions contained in that chapter.
- Prepare a project notebook containing a description of the assumptions and methodologies used in the study analysis. The notebook shall be organized in such a way as to allow replication of the steps, calculations, and procedures used by the Consultant to reach conclusions, described in the draft final report. The project notebook shall be submitted with the draft final report.

All models developed and/or modified under the tasks described herein, must be provided to the EAA as executable "turn-key" files with all associated datasets fully populated.

No later than June 15th and each month thereafter, the Consultant shall submit a monthly "invoice packet" to the EAA for each previous month's activities. Each invoice packet shall contain, at a minimum:

(1) A progress report containing:
- a description of the work completed in each Task during the billing cycle;
- a monthly update of the work schedule as it relates to achievement of the deliverables;
- an estimate of the percent completion of each Task; and
- a discussion of any issues or problems that may result in a change in the deliverable due date;

(2) Documentation of all costs and expenses incurred during the billing cycle, including supporting documentation; and

(3) A certified invoice summary sheet

The monthly invoice packet will be submitted electronically in Adobe Acrobat (pdf) format via email to the EAA Senior EAHCP Coordinator.

YEAR 2 (June 1, 2014 – May 31, 2015)

Task 1: Project Management and Meetings

The Contractor will provide project management and administration for this project. The Contractor will conduct monthly internal team meetings or conference calls and up to four (4) meetings directly with the EAA, should they be needed. When necessary, meetings with the EAA will be combined into the internal team monthly meetings. The Contractor will attend and provide project information to the EAHCP Science Committee, EAHCP Implementing Committee, and National Research Council (NRC) Committee as requested by the EAHCP Program Manager.

Task 2: Literature Review

The Contractor will conduct a literature review focusing on two key areas: (1) available fountain darter food (macroinvertebrates) and (2) aquatic vegetation scour. Regarding food source assessment, the Contractor will use existing information/literature to evaluate the amount of available food present for the fountain darter in both the Comal and San Marcos systems. If the information is available, the Contractor will also evaluate the feeding rate of fountain darters to assess if the amount of food necessary to support fountain darters during periods of low-flow is predicted to be available in the Comal and San Marcos systems. A qualitative assessment of additional fish species present in the Comal and San Marcos systems and their respective food source utilization will also be conducted. The objective of this literature search and analysis is to determine if a food source component should be formally incorporated into the EAHCP ecological model in 2015.

The second literature review component will investigate the mechanisms necessary to create aquatic vegetation scour in the Comal and San Marcos systems. The diversity of sediments and aquatic vegetation species (or species assemblages) occurring in these systems makes it necessary to evaluate the critical bed stress of rooted plants and therefore the threshold of flow velocities at which the vegetation is scoured. As such, the aquatic vegetation data collected during normal periods and following high flow events over the course of biological monitoring will be reviewed in detail. These empirical data will be evaluated for type of aquatic vegetation, quantity, spatial location, and what type of discharge caused the removal of aquatic vegetation in the wild following known pulse events. Once determined, the Contractor will evaluate hydraulic model results to determine types of velocities and critical stress that were likely involved during those events. Following this literature review and existing data analysis, the Contractor will incorporate the results into the aquatic vegetation model as appropriate and subsequently provide applicable results to the contractor selected to perform the 2015 Applied Research study on aquatic vegetation shear stress.

Task 3: Fountain Darter Modeling

In order to better address the specific needs of the EAHCP, the Contractor will replace current preliminary representations of the relationships among physical and biological habitat characteristics and fountain darter vital rates with more appropriate functional relationships, to extend the underlying mathematical formulation to include spatial and temporal dynamics.

Within the spatially-explicit individual-based modeling format developed in year one, additional model development will concentrate on: (1) improving specification of habitat characteristics, (2) delineating dependency of fountain darter vital processes upon habitat variables, and (3) depicting effects of additional external forcing variables. The Contractor will modify or replace the preliminary representations of the spatial-temporal dynamics of fountain darter habitat characteristics (water depth, water velocity, water temperature, and aquatic vegetation) with more refined representations, including functional relationships among these characteristics. The Contractor will establish appropriate functional relationships between habitat characteristics and the life processes of the fountain darter, including recruitment, mortality, and movement rates. For this activity, the Contractor will explore mathematical representations of the effects of additional external variables on the spatial-temporal dynamics of aquatic vegetation for incorporation into the darter model, more specifically the effects of recreational use and scouring processes of high flows on aquatic vegetation, and the associated darter responses.

Once the foundational components and functional relationships are established, the Contractor will apply the model to both the Old Channel study reach of the Comal River and the City Park study reach of the San Marcos River. The Contractor will use existing model framework established in 2013 for the Old Channel study reach and will complete the necessary application for the City Park study reach to interpolate hydraulic grids for use in the existing NetLogo modeling framework. Interpolation of modeled flows will follow the same procedure used to generate the flows in the Old Channel at the Comal River. In addition, this will include the spatial overlay of existing vegetation mapping results for the simulation period to the interpolated grid coordinate system using the same protocols as used in the Old Channel of the Comal River. The associated daily flow rates for the San Marcos River for the simulation period will be extracted for existing USGS

gage records in the San Marcos River. Finally, the hourly water temperature data for the City Park study reach will be extracted from existing data and incorporated into the model grid format.

The Contractor will integrate the existing hourly water temperature models for the Old Channel and City Park study reaches within the NetLogo framework. The appropriate calibrated QUAL2E model input data file(s) for each segment will be utilized. The QUAL2E model will be modified to run given an input flow rate for the day and associated meteorological data. The program will be modified to allow it to be called from NetLogo and return the hourly temperature data for the day for use in the fountain darter model.

Near completion of 2014 activities, the Contractor will calibrate the Year 2 processes that will have been developed for the fountain darter using existing size-class distribution and abundance data for the Old Channel and City Park study reaches. The Contractor will perform a series of sensitivity and robustness analyses on the working version of the fountain darter model(s), including preliminary quantification of sources and magnitudes of uncertainty. As part of that assessment, the sensitivities and elasticities of the various fountain darter demographic parameters will be calculated (i.e., their relative contributions to population growth).

Task 4: Aquatic Vegetation Modeling

In order to assess the dynamics of vegetation across the landscape, as well as to determine the interactions among vegetative communities and fountain darters, the Contractor will model aquatic vegetation in a computationally-tractable, and spatially explicit manner. Aquatic vegetation modeling will proceed in 2014 by utilizing a hybrid modeling approach, which will incorporate functions from the ERDC models as well as vegetative dispersal modeling in order to be able to capture a wider breadth of vegetative dynamics and vegetation-organism interactions. The Contractor will divide aquatic vegetation into structural categories and growth/dispersal will be simulated for each category. The new, hybrid vegetation model will be a grid-based spatially explicit simulation with two main functions per structural grouping: growth (intracell) and dispersal (intercell). The Contractor will use the fountain darter model, the Old Channel study reach of the Comal River and City Park study reach of the San Marcos River to serve as the spatial extent of modeling activities in 2014.

To expand on the modeling activities conducted in Year 1, further model development the Contractor will concentrate on: (1) defining structural groupings of aquatic vegetation, (2) developing spatial interpolations of critical environmental and physical variables required to parameterize growth and dispersal of aquatic vegetation, (3) developing growth function for each structural group, (4) developing dispersal functions for each structural group, and (5) developing re-colonization functions for each structural group. To accomplish these objectives, the Contractor will first describe and define which species are structurally similar with regards to how fountain darters and other species interact with vegetation and then re-categorize existing vegetation coverage in the model into structural groupings. Year 1 model activities and literature reviews indicated that critical environmental parameters included temperature, carbon dioxide, light (for which turbidity might be used as a proxy), depth, velocity, and substrate.

To develop growth functions, dispersal rates, and re-colonization functions for aquatic vegetation, the Contractor will define the appropriate time step for incorporation into the model. The time

step will be selected to be compatible with the fountain darter model. The Contractor will also quantify average and extreme conditions to identify thresholds for aquatic vegetation responses. Based on the literature review and data analysis described in Task 2, the Contractor will subsequently quantify and spatially represent vegetative re-colonization from stochastic events, like floods (or other scour events).

Growth, dispersal, and re-colonization functions will also be assessed based on empirical time-series aquatic vegetation data. The Contractor will implement a study during the summer of 2014 to develop an empirical relationship between vegetation percent cover and biomass. Quantitative above and below ground biomass samples will be collected on an appropriate aerial basis. Samples will be separated by species and then above sediment tissues will be separated from below sediment. All samples will be washed to remove dirt and detritus and dried to constant weight at 60 °C.

Upon completion of the percent cover to biomass study and previously described Year 2 aquatic vegetation modeling activities, the Contractor will calibrate growth, dispersal and re-colonization functions based on data from time-series of aquatic vegetation. Additionally, a series of sensitivity and robustness analyses will be performed on the working version of the aquatic vegetation model(s), in part to quantify sources and magnitudes of uncertainty. As part of that assessment the sensitivities and elasticities of the various aquatic vegetation parameters will be calculated (i.e., their relative contributions to aquatic vegetation growth, dispersal, and re-colonization).

Task 5: Draft and Final Interim Status Reports

Upon completion of data analyses, the Contractor will prepare a Draft and a Final Interim Status Report. Included in the Interim Status Report will be a summary of all meetings/notes from the project year, the literature review and data analysis conducted in Task 2, the methodologies employed and data analysis and results from Tasks 3 and 4, and a section on future recommendations for 2015.

Task 6: Recommendations and Future Work

By March 1, 2015, the Contractor will prepare a detailed Year 3 scope of work outlining activities for the remainder of 2015 and 2016 and will present this scope of work first to the Science Committee and, then to the Implementing Committee for review, comment, and approval. It is anticipated that in 2015, the scope or work will involve 1) the refinement of the fountain darter and aquatic vegetation models with 2014 applied research results, and 2) an expansion of the spatial domain of the models to include additional representative reaches in both systems. It is anticipated that in 2016, the scope of work will involve model refinement based on 2015 applied research results and extensive model calibration, validation and documentation.

Task 7: Deliverables

In Year 2, besides the submittal of monthly progress reports (as described in Task 7, Year 1), the Contractor will submit a Draft and a Final Status Report (as stated above) for Year 2 of model development. The Final Status Report for Year 2 will be submitted by December 31, 2015.

The Contractor will also submit a detailed Year 3 scope of work by March 1, 2015.

YEAR 3 (June 1, 2015 – December 31, 2016)

Task 1. EAHCP Ecological Model Development, Calibration, and Validation

Following completion of Year 2 activities, the Contractor will carry out its detailed Year 3 scope of work as approved by the Science and Implementing Committees.

Task 2. EAHCP Ecological Model Training and User Guide

Concurrent with the conclusion of model validation, the Contractor will provide on-site training to EAA in the use of the NetLogo software as it pertains to the user interface developed specific to EAHCP Ecological model utilization. In addition to on-site training, the Contractor will develop a "User Guide" to assist EAA staff in becoming familiar with the NetLogo user interface and to serve as a reference in developing model runs. It is anticipated that this training and user guide development would occur in the latter part of 2016.

Task 3: Deliverables

In Year 3, besides the submittal of monthly progress reports (as described in Task 7, Year 1), the Contractor will submit a Draft and a Final Report (as stated above) for Year 3 of model development. The Final Report for Year 3 will be submitted by December 31, 2016.

EXHIBIT B
PROJECT BUDGET

YEAR 1

TASK		ESTIMATED COST
Task 1.	Literature Review	$ 12,500.
Task 2.	Data Acquisition	$ 3,500.
Task 3.1	U.S. Army Corps of Engineers Model Modification	$ 55,000.
Task 3.2	Fountain Darter Response/Dynamics Model	$ 47,500.
Task 3.3	Wild Rice Parameters	$ 7,500.
Task 3.4	Gill Parasite and Non-Native Snails Response/Dynamics	$ 4,500.
Task 4.	Recommendations and Future Work	$ 5,000.
Task 5.	Draft and Final Reports	$ 10,500.
Task 6.	Meetings and Presentations	$ 11,500.
Task 7.	Deliverables	$ 12,500.
	YEAR 1 SUBTOTAL	$170,000.

YEAR 2

TASK		ESTIMATED COST
Task 1.	Project Management and Meetings	$ 37,765.
Task 2.	Literature Review	$ 16,580.
Task 3.	Fountain Darter Modeling	$154,755.
Task 4.	Aquatic Vegetation Modeling	$138,520.
Task 5.	Draft and Final Interim Status Reports	$ 57,730
Task 6.	Recommendations and Future Work	No Cost
Task 7.	Deliverables	No Cost
	YEAR 2 SUBTOTAL	$405,350.

YEAR 3

TASK		ESTIMATED COST
Task 1.	EAHCP Ecological Model Development, Calibration, and Validation	$330,000.
Task 2.	EAHCP Ecological Model Training and User Guide	$ 25,000.
Task 3.	Deliverables	No Cost
	YEAR 3 SUBTOTAL	$355,000.

TOTAL PROJECT COSTS	$930,350.

~~information will be critical to the Adaptive Management Process (AMP), especially the strategic AMP.~~

Assumptions: The EAA will execute the first, one-year extension (as amended) of the current Predictive Ecological Model(s) contract based on the FY 14-15 SOW "Year 2 Ecological Modeling Scope and Budget Estimate."

Target Performance Measures for 2015: Execution of the amended extension of the contract to complete recommendations and next steps identified in the FY 2014-2015 SOW (Attachment 1); leading to a fully functional Ecological Model in 2015.

Methodology: The approach for 2015 is utilize the first contract extension to amend and extend the FY 2013-2014 Eco Model contract to reflect the work that has been done, what has been accomplished and what remains to be done in the FY 2014-2015 Eco Model contract. For 2015, the deliverables are:
Internal team memorandums summarizing progress to date on 1 August 2014, 1 November 2014, and 1 February 2015.
Fountain darter modeling portion of the draft interim status report on 1 May 2015.
Complete documentation for the calibrated fountain darter model(s) on 1 May 2015.

BIOWEST will be required to submit a written report within 365 days of the execution of a contract with the EAA. This requires that fulfillment of this contract extend into 2015. Utilizing the provided results and recommendations of the initial contract coupled with the findings of the Technical Memorandum, the EAA will develop a new Scope of Work to be reviewed by the Science Committee and Implementing Committee. The EAA may then either extend the contract already established with BIOWEST, or utilize the EAA competitive procurement process.

Monitoring: All Ecological Modeling contracts will be closely monitored by EAHCP staff. Contractors will be required to submit regular status reports on their activities.

Science Committee Review: The FY 2014-2015 SOW was reviewed by the Science Committee at their April 8, 2014 meeting.

Budget:
Budgeted Amount 7.1: $175,000
Work Plan Budget Amount: $405,350

Budget Justification: The development of the Ecological Model is a priority project that will involve multiple years of work. To continue the expedited development of the Ecological Model, the level of activities have been increased and those listed in the SOW scheduled for FY 2014-2015 require more funding than the amount in Table 7.1 of the EAHCP.

~~**NEEDS 2014-2015 SOW FOR ATTACHMENT 1**~~