Year 2 Predictive Ecological Modeling Scope and Budget Estimate (March 2014)

Submitted by:

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1. Overview

The first year of effort on the development of ecological models for Comal and San Marcos Rivers resulted in the identification of two critical-path elements upon which the overall success of the modeling enterprise is considered by the ecomodeling team to rest: (1) a functioning fountain darter model including response of the darter to distributions of aquatic vegetation, and (2) a functioning aquatic vegetation model that includes both physiological processes and responses of the spatial distribution of vegetation to physical (mainly hydraulic) and biological factors. The second year of effort will continue the focus on these two elements, supported as necessary by literature reviews, data acquisition, and data analysis. A major strength of the ecomodeling team assembled for this work is the mix of scientists, represented by a range of disciplines and a range of specialties from field observation to theoretical modeling. Thus, going forward, there is a need for both formulation and testing of models, as well as objective-specific study of field data and its implications for model capabilities.

The goal of this second year of work is to achieve operating models of both fountain darter populations and aquatic vegetation coverage for two test reaches in the study area, tentatively selected to be the Old Channel study reach of the Comal River, and City Park study reach of the San Marcos River. Recognizing that the underlying formulation of these models will not yet be complete, we will provide calibration during year 2 for the processes that are depicted.

It is important that progress on the modeling be communicated to the Edwards Aquifer Authority (Authority) on a regular basis. Moreover, during the prosecution of this work, two entities will be providing technical and scientific oversight: the HCP Science Committee and the National Academies/National Research Council (NRC) Review Committee. Of necessity, these will require greater detail in reporting and access to the individual scientists on the ecomodeling team. The project team welcomes the input from both of these committees, and the cost estimates below include time devoted to communication with these committees.

The work breakdown structure and scope of work are presented in Section 2, with a proposed schedule and cost estimate included in sections 3 and 4, respectively.

2. Statement of Work

The major work elements (Tasks) proposed are presented in Table 1.

TABLE 1	WORK BREAKDOWN STRUCTURE
Task 1	PROJECT MANAGEMENT / MEETINGS
Task 2	LITERATURE REVIEW
Task 3	FOUNTAIN DARTER MODELING
Task 4	AQUATIC VEGETATION MODELING
Task 5	DRAFT / FINAL REPORTING

Task 1: Project Management / Meetings

Description of Work: Project management, contracting, task coordination, and internal and external communication are included in this category. Internal meetings will consist of monthly face-to-face project team meetings or conference calls and up to 4 meetings directly with the Authority should they be needed. It is possible that meetings with the Authority will be combined into the project team monthly events. External communication of progress with the science review committees and stakeholders is also extremely important. It is anticipated that several meetings will be necessary from June 2014 through May 2015 with the HCP Science Committee, HCP Implementing Committee, and NRC Science Committee to discuss and present HCP ecological modeling status updates and modeling progress.

Key Assumptions: For costing purposes, the following assumptions are included:

- Monthly (12) internal project team meetings
- Up to 4 meetings with Authority Staff and Management
- Up to 2 meetings with the HCP Science Committee
- Up to 2 meetings with the HCP Implementing Committee
- Up to 2 meetings with the NRC Science Committee, plus up to 4 hours of each key project team member's time to address questions specific to their role.

Deliverables: Monthly Progress Letter Reports with invoices

Task 2 – Literature Review

Description of Work: The literature review to be conducted in 2014 will focus on two key areas: (1) available fountain darter food (macroinvertebrates) and (2) aquatic vegetation scour. For the food source assessment, the project team 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. Based on the literature, the project team will also evaluate the feeding rate of fountain darters to assess if the amount of available food will be sufficient to support fountain darters during periods of low-flow. 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 needs to be formally incorporated into the HCP ecological model in 2015.

The second literature review component will be to investigate the mechanisms necessary to create aquatic vegetation scour in the Comal and San Marcos systems. While shear velocities are well-documented for numerous sediment types, the hydrodynamic effects of the stem and root structure of aquatic vegetation, and specific conditions in the Comal and San Marcos Rivers, most notably in areas occupied by aquatic vegetation, make ecosystem modeling efforts more challenging. The diversity of sediments and aquatic vegetation species (or species assemblages) occurring in these rivers makes it necessary to evaluate the critical bed stress of rooted plants and therefore the threshold of current speed 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. This empirical data will be evaluated for what types of aquatic vegetation, how much, where spatially, and what type of discharge caused the removal of aquatic vegetation in the wild following known pulse events. Once determined, the project team will evaluate hydraulic model results to determine what type of velocities and critical stress were likely involved during those events. Following this literature review and existing data analysis, the project team would look to the results of the aquatic vegetation shear stress studies being proposed for 2015 Applied Research to validate or further inform model parameters.

Key Assumption: Only qualitative assessments will be conducted in 2014 via desktop exercises and literature reviews.

Internal Deliverable: Literature review and data analysis to be incorporated into the draft/final Project Report.

Task 3 – Fountain Darter Modeling

Description of Work: Development of the fountain darter model is being led by Texas A&M Agrilife Research (Dr. William Grant, PI), and is an outgrowth of earlier modeling of the fountain darter in the San Marcos River based upon a linear-systems formulation of vital processes of the fish. The earlier linear-systems model was determined to be unsuitable for the needs of the Habitat Conservation Plan (HCP), and instead a spatially-explicit, individual-based modeling format was adopted. In 2014, it will be necessary to 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 1, further 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. This will involve the replacement of the present, rather preliminary representations of the spatial-temporal dynamics of fountain darter habitat characteristics (water depth, water velocity, water temperature, and aquatic vegetation) with more appropriate representations, including functional relationships among these characteristics. This will establish more appropriate functional relationships between habitat characteristics and the life processes of the fountain darter, including recruitment, mortality, and movement rates. For this activity, mathematical representations of the effects of additional external variables on the spatial-

temporal dynamics of aquatic vegetation will be explored for incorporation into the darter model, notably 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 model will be applied to both the Old Channel study reach of the Comal River and the City Park study reach of the San Marcos River. Considerable data conversion, incorporation, and spatial interpretation for the Old Channel study reach were accomplished in 2013. This work will need to be completed in 2014 for the City Park study reach of the San Marcos River. This will include using the hydraulic data at 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.

To allow predictive capabilities during low flow, integration of the existing hourly water temperature models for the Old Channel and City Park study reaches within the NetLogo framework will be conducted in 2014. 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. The strategic goal of linking these models is to ensure that arbitrary flow and meteorological data defined in alternative simulations can be dynamically incorporated into the NetLogo model rather than only having access to historical measured data.

Near completion of 2014 activities, the project team 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. Finally, a series of sensitivity and robustness analysis will be performed 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).

Key Assumption: The Old Channel (Comal River) and City Park (San Marcos River) study reaches will be the two spatial extents used for fountain darter model development in 2014.

Deliverables:

- 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.

Task 4 – Aquatic Vegetation Modeling

Description of Work: Development of the aquatic vegetation model is being led by the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) Environmental Laboratory (EL) (Dr. Todd Swannack, PI). In order to assess the dynamics of vegetation across the landscape, as well as to determine the interactions among vegetative communities and fountain darters, aquatic vegetation must be modeled in a computationally-tractable, and spatially explicit manner. However, the results of the first year analysis of the ERDC aquatic vegetation models were not 100% compatible with a spatially-explicit framework, nor would the models be computationally-tractable if they were implemented in the spatial and temporal scales on which the hydrodynamic and fountain darter models operate. Fortunately, each ERDC model does contain mathematical functions (and associated parameter values) that can be incorporated into a spatially-explicit framework. Further, time series of spatial coverage of aquatic vegetation, as well as environmental parameters, are available for sections of each river system. 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. Rather than simulate individual species growth and dispersal, aquatic vegetation will be divided 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). As for the fountain darter model, the Old Channel study reach of the Comal River and City Park study reach of the San Marcos River will serve as the spatial extent of modeling activities in 2014.

To expand on the modeling activities conducted in year 1, further model development 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 recolonization functions for each structural group. To accomplish these objectives, the project team will first describe and define which species are structurally similar with regards to how fountain darters and other species interact with vegetation and then recategorize 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 recolonization functions for aquatic vegetation, the project team will first 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 project team 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 project team will subsequently quantify and spatially represent vegetative recolonization from stochastic events, like floods (or other scour events).

Growth, dispersal, and recolonization functions will also be assessed based on empirical time-series aquatic vegetation data. However, the present ERDC vegetation growth models which are being adapted for use on the Comal and San Marcos Rivers have vegetation biomass as the primary

response variable. Unfortunately, there is virtually no biomass data for the plant species in these rivers. Instead, over 13 years of data for percent cover is available. As such, the project team will implement a study during the summer of 2014 to develop an empirical relationship between vegetation percent cover and biomass. The study will involve the original surveyors of the percent cover vegetation maps (currently still employed at BIO-WEST or at Baylor) so that a robust relationship can be developed. Quantitative above and below ground biomass samples will be collected on an appropriate aerial basis (likely 0.25 m^2 quadrats). Samples will be separated by species and then above sediment (shoots and leaves) tissues will be separated from below sediment tissues (roots and rhizomes). 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 project team will calibrate growth, dispersal and recolonization 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 recolonization).

Key Assumption: The Old Channel (Comal River) and City Park (San Marcos River) study reaches are the two spatial extents used for aquatic vegetation model development in 2014. However, empirical data review will be conducted on aquatic vegetation data available for the whole system and the percent cover to biomass study will not be confined to these project boundaries.

Deliverables:

- Internal team memorandums summarizing progress to date on 1 August 2014, 1 November 2014, and 1 February 2015.
- Separate report on relationship between plant percent cover and biomass for the key species on the Comal and San Marcos Rivers submitted to the Authority by 1 November 2014.
- Aquatic vegetation modeling portion of the draft interim status report on 1 May 2015.
- Complete documentation for the calibrated aquatic vegetation model(s) on 1 May 2015.

Task 5 – Draft / Final Interim Status Report

Description of Work: Upon completion of data analyses, the project team will prepare a Draft and 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.

Deliverable: Draft interim status report submitted 15 May 2015. Final interim status report submitted within two weeks following comments by the Authority.

3. Schedule

The proposed schedule for the Year 2 Predictive Ecological Modeling is presented below. The schedule assumes a June 1, 2014 start date and completion of Year 2 by May 31, 2015.

SCHEDULE		MILESTONE DATES
Task 1	Project Management / Meetings	
	Project team meetings	Monthly
	HCP Science, IC, and NRC meetings	To be determined
Task 2	Literature Review	1 November 2014
Task 3	Fountain Darter Modeling	
	Internal team progress memorandums	Aug and Nov 2014, Feb 2015
Task 4	Aquatic Vegetation Modeling	
	Internal team progress memorandums	Aug and Nov 2014, Feb 2015
	Percent cover to biomass report	1 November 2014
Task 5	Draft/Final Interim Status Report / Deliverables	
	Draft Interim Status Report	15 May 2015
	Calibrated models and documentation	15 May 2015
	Final Report	Within two weeks following comments from Authority

4. Fee Estimate

A cost estimate by task is presented below. The estimated total fee for Year 2 based on the work outlined in this scope of work and assumptions presented herein is $405,350.

TASK		ESTIMATED COST
Task 1	Project Management / 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/Final Report / Deliverables	$57,730
TOTAL PROJECT COSTS		$405,350