Year 3 Predictive Ecological Modeling Scope (March 2015)

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 and biological factors. The second year of effort continued focusing on these two elements, supported by literature reviews, data acquisition, 2014 HCP Applied Research, and comprehensive data analysis. During the second year (May 2014 – May 2015) of work, operating models of both fountain darter populations and aquatic vegetation coverage for two test reaches (one in each system) were completed. The reaches included the Old Channel study reach of the Comal River and City Park study reach of the San Marcos River. It is important that progress on the modeling continue to 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 documentation 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 for Year 3 are presented in Section 2, with a proposed schedule included in Section 3.

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	FOUNTAIN DARTER MODELING
Task 3	AQUATIC VEGETATION MODELING
Task 4	DRAFT / FINAL REPORTING
Task 5	EAHCP ECOLOGICAL MODELING TRAINING AND USER GUIDE

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 2015 through December 2016 with the HCP Science Committee and HCP Implementing Committee to discuss and present HCP ecological modeling status updates, modeling progress and results.

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 8 hours of each key project team member's time to address questions specific to the NRC review.

Deliverables: Monthly Progress Letter Reports with invoices

Task 2 – Fountain Darter Modeling

Description of Work: Development of the fountain darter model continues to be 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 and pursued in 2014. In Year 2, preliminary representations of the relationships among physical and biological habitat characteristics and fountain darter vital rates were updated and replaced (where applicable) with more appropriate functional relationships. Data used for these modifications were gathered from additional literature evaluation, complex statistical analysis of existing data, ongoing HCP biological monitoring, and 2014 HCP Applied Research results. Modification to the fountain darter model in Year 2 has allowed extension of the underlying mathematical formulation to include spatial and temporal dynamics.

Within the spatially-explicit, individual-based modeling format model development concentrated 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 allowed for more appropriate representations the spatial-temporal dynamics of fountain darter habitat characteristics (water depth, water velocity, water temperature, dissolved oxygen, and aquatic vegetation) including functional relationships among these characteristics. These improved representations established more appropriate functional relationships between habitat characteristics and the life processes of the fountain darter, including recruitment, mortality, carrying capacity, habitat quality and movement. Additionally, mathematical representations of the effects of additional external variables on the spatial-temporal dynamics of aquatic vegetation

were explored for and incorporated into the darter model, notably the effects of recreational use and scouring processes of high flows on aquatic vegetation, and the associated darter responses.

Upon completion of the foundational components and modification of functional relationships, the fountain darter model was applied to both the Old Channel study reach of the Comal River and the City Park study reach of the San Marcos River.

In Year 3, the project team will expand the fountain darter model to include two additional reaches on the Comal system (Upper Spring Run reach and Landa Lake) and one on the San Marcos system (I35 reach). This will include using the hydraulic data at each additional study reach to interpolate hydraulic grids for use in the existing NetLogo modeling framework. Interpolation of modeled flows for the Upper Spring Run reach will follow the same procedure used to generate the flows in the Old Channel at the Comal River. The associated daily flow rates for Landa Lake for the simulation period will be extracted for existing USGS gage records in the Comal River. The associated daily flow rates for the I35 study reach for the simulation period will be extracted for existing USGS gage records in the San Marcos River. In addition, this spatial expansion 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 completed study reaches. Finally, the hourly water temperature data for these study reaches 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 and available dissolved oxygen data will be used in the calibrated QUAL2E model input data file(s) for each study site. The QUAL2E model will be run off of a given input flow rate for the day and associated meteorological data for the selected period of record. The program will run as a standalone utility for a given scenario of flow and/or meteorological data for the selected period of simulation and return the required maximum daily temperature and minimum DO data for each day for use in the NetLogo fountain darter and vegetation model. The standalone utility will allow linking of the water temperature/DO model results given flow and meteorological data defined in alternative simulations that can subsequently be incorporated into the NetLogo fountain darter and vegetation model rather than only having access to historical measured data.

Near completion of year 3 activities, the project team will calibrate the final fountain darter models per study reach that will have been developed for the fountain darter using existing size-class distribution and abundance data for each respective study reaches. The project team will calibrate the new version of the model and evaluate its performance via a series of sensitivity analyses, which will quantify the sensitivities of simulated fountain darter population dynamics to uncertainties in the estimates of the various fountain darter demographic parameters.

Key Assumption: The Upper Spring Run and Landa Lake (Comal River) and I35 (San Marcos River) study reaches will be the three spatial extents used for continued fountain darter model development in Year 3.

Internal Team Deliverables:

- Internal team memorandums summarizing progress to date on 1 August 2015, 1 November 2015, and 1 February 2016.
- Fountain darter modeling portion of the Year 3 draft report on 1 August 2016.

- Complete documentation for the calibrated fountain darter model(s) on 1 October 2016.

Task 3 – 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). Aquatic vegetation modeling in Year 2 included the utilization of a hybrid modeling approach, which incorporated functions from the ERDC models as well as vegetative dispersal modeling in order to capture a wider breadth of vegetative dynamics and vegetation-organism interactions. The new, hybrid vegetation model is a grid-based spatially explicit simulation with two main functions: 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 were completed in Year 2.

In Year 2, the project team described and defined which species are structurally similar with regards to how fountain darters and other species interact with vegetation and then recategorized existing vegetation coverage in the model accordingly. Year 2 model activities and literature reviews indicated that critical environmental parameters included temperature, light (for which turbidity might be used as a proxy), depth, velocity, and substrate. In Year 2 the project team determined a daily time-step and quantified average and extreme conditions to identify thresholds for aquatic vegetation responses. Growth, dispersal, and recolonization functions were assessed based on empirical time-series aquatic vegetation data. However, the new hybrid model (similar to historical models) has vegetation biomass as the primary response variable. As noted during Year 2, there was virtually no biomass data for the plant species in these rivers prior to 2014 HCP Applied Research. During Year 2, the project team completed a field study that developed an empirical relationship between vegetation percent cover and biomass.

In Year 3, the project team will expand the aquatic vegetation model to include two additional reaches on the Comal system (Upper Spring Run reach and Landa Lake) and one on the San Marcos system (I35 reach). Time series of hydrodynamic model results, water quality data, and spatial coverages of aquatic vegetation are available for the proposed reaches of each river system. The aquatic vegetation model will be applied to these new reaches by incorporating reach-specific vegetation coverages from the long-term vegetation mapping studies. The existing model structure will be recalibrated and validated for any reach-specific characteristics. Results from the 2015 Applied Research plant competition, algal dynamics, and turbidity studies will be incorporated into the model parameterizations if deemed appropriate. Once the model for each reach has been thoroughly evaluated, it will be linked to reach-specific fountain darter models. Detailed model documentation will be prepared and will describe (1) the equations used in the model, (2) the assumptions used to develop the equations, (3) the procedure used to evaluate the model, (4) the uncertainty associated with model projects, and (5) the conditions under which model equations can be applied.

Specific Year 3 activities include:

- Create time series of vegetation maps and hydrodynamics from existing spatial coverage data for each of the new modeled reaches
- Apply plant growth, dispersal and other model equations to new reaches.
- Evaluate models for each of the three new reaches
  a) Calibrate and validate each modeled reach through rigorous evaluation of growth, dispersal and recolonization functions based on data from time series of vegetation maps
     a. Ensure time step for vegetative growth is compatible with fountain darter model
     b. Evaluate growth functions based on data from time series of vegetation
     c. Evaluate dispersal functions based on data from time series of vegetation
     d. Quantify average and extreme conditions to identify thresholds
     e. Evaluate linkages to fountain darter model
     f. Reparameterize equations as needed

- Incorporate results of 2015 Applied Research Studies
  a) Incorporate results from plant competition study into spatial dispersal functions (if deemed appropriate)
     a. Quantify appropriate time step of competitive interactions
     b. Quantify spatial scale of competitive interactions
  b) Incorporate results from algal dynamics study if determined that algal dynamics impact vegetation growth and/or darter dynamics (if deemed appropriate)
     a. Quantify appropriate time step of competitive interactions
     b. Quantify spatial scale of competitive interactions
  c) Incorporate results from turbidity study if determined that water clarity impact vegetation growth and/or darter dynamics
     a. Quantify appropriate time step of competitive interactions
     b. Quantify spatial scale of competitive interactions
  d) Parameterize new equations
  e) Evaluate new equations

- Task 5: Develop model documentation
  a) Describe the equations used in the model,
  b) Describe the assumptions used to develop the equations,
  c) Describe the procedure used to evaluate the model,
  d) Describe the uncertainty associated with model projects,
  e) Describe the conditions under which model equations can be applied

Key Assumption: The Upper Spring Run and Landa Lake (Comal River) and I35 (San Marcos River) study reaches will be the three spatial extents used for continued fountain darter model development in Year 3.

Internal Team Deliverables:

- Internal team memorandums summarizing progress to date on 1 August 2015, 1 November 2015, and 1 February 2016.

- Aquatic Vegetation modeling portion of the Year 3 draft report on 1 August 2016.
- Complete documentation for the calibrated aquatic vegetation model(s) on 1 October 2016.

Task 4 – Draft / Final Project Report

Description of Work: Upon completion of data analyses, the project team will prepare a Draft and Final Project Report. Included in the Project Report will be a summary of all meetings/notes from the project year, the methodologies employed and data analysis and results from Tasks 2 and 3, and a section on future recommendations for consideration. Additionally, the final report will include documentation of one scenario run describing the HCP flow regime. The structuring of the HCP flow regime scenario will founded upon the HCP and vetted with the HCP Science and Implementing committees prior to performing that model run.

Deliverable: Draft project report submitted 1 December 2016. Final project report submitted within two weeks following comments by the Authority.

Task 5 – Ecological Model Training and User Guide

Description of Work: Concurrent with the conclusion of model validation, the project team will provide on-site training to the Authority in the use of the NetLogo software as it pertains to the user interface developed specific to the EAHCP Ecological Model utilization. In addition to on-site training, the project team will develop a "User Guide" to assist the Authority in becoming familiar with the NetLogo user interface and to serve as a reference in developing model runs. The core intent of the User Guide will be to describe how to use the graphic user interface of the model to develop management scenarios, run the model, and interpret the results. Documentation of the one model run of the HCP flow regime will be used as an example within the User Guide to illustrate operation of various components of the tool.

Key Assumptions:

- Two half day training sessions for Authority staff in San Antonio are included in the cost estimate.
- The "User Guide" is specific to the application of the holistic EAHCP Ecological Model and is anticipated to be between 15 and 30 pages in length.
    - This guide is not intended to be a substitute for existing NetLogo, Qual2E, MegaPlant, Charisma, ERDC vegetation models, or hydraulic model documentation;
    - This guide is not intended to be a comprehensive guide of all modeling components, formulas or calculations performed by the series of models that are incorporated within the holistic EAHCP Ecological Model.

Deliverable: Draft "User Guide" submitted 1 December 2016. Final "User Guide" submitted within two weeks following comments by the Authority.

3. Schedule

The proposed schedule for the Year 3 Predictive Ecological Modeling is presented below. The schedule assumes a June 1, 2015 start date and completion of Year 3 by December 31, 2016.

SCHEDULE		MILESTONE DATES
Task 1	Project Management / Meetings	
	Project team meetings	Monthly
	HCP Science and Implementing Committee meetings	To be determined
Task 2	Fountain Darter Modeling	
	Internal team progress memorandums	Aug and Nov 2015, Feb 2016
Task 3	Aquatic Vegetation Modeling	
	Internal team progress memorandums	Aug and Nov 2015, Feb 2016
Task 4	Draft/Final Report / Deliverables	
	Draft Report	1 December 2016
	Calibrated models and documentation	1 December 2016
	Final Report	Within two weeks following comments from Authority
Task 5	Ecological Model Training and User Guide	
	Draft User Guide	1 November 2016
	Training Sessions	November / December 2016
	Final Report	Within two weeks following comments from Authority