Adaptive Management Studies Referenced in Chapters 4 and 6 of EAHCP

Excerpt from EAHCP referencing issue to be studied.	Page in EAHCP	Status of studies or alternative approach	Scheduled next steps, if any	Work Group recommendation?
Comal Springs				
A. "This objective assumes that a 10 percent deviation in average conditions would be acceptable; however, more extensive work to evaluate and assess water quality tolerances of the fountain darter will be addressed as part of the AMP."	Page 4-5 repeated at page 4-27 Issue CS 1	- Low-flow food source threshold study (BIO-WEST 2013) - Effects of low flow on fountain darter reproductive effort (BIO-WEST 2014) - Effects of predation on fountain darters (Texas State University and BIO-WEST 2014) - Fountain darter movement under low flow conditions in the Comal Springs/River ecosystem (BIO-WEST 2014b) - Hardy T., Oborny E., and others, 2017. Fountain Darter modeling system for the Comal and San Marcos Rivers.		No obvious inconsistency with EAHCP study commitments.

B. "This objective assumes that a 10 percent deviation would be acceptable. More extensive work to evaluate and assess water quality tolerances of the Comal Springs riffle beetle will be addressed as part of the AMP."	Page 4-12 Issue CS 2	- Effect of low-flow on riffle beetle survival in laboratory conditions (BIO-WEST et al. 2014) - Determination of Limitations of Comal Springs Riffle Beetle Plastron Use During Low-Flow Study (Nowlin et al. 2014) - Evaluation of the long-term, elevated temperature and low dissolved oxygen tolerances of the Comal Springs riffle beetle(Nowlin et al., 2017b)		No obvious inconsistency with EAHCP study commitments.
C. Comal Springs Dryopid Beetle and Peck's Cave Amphipod: "This goal assumes that a 10 percent deviation would be acceptable; however, more extensive work to evaluate and assess water quality tolerances of these species will be addressed as part of the AMP."	Page 4-15	None.		Permit extension issue
D. Comal Springs Dryopid Beetle and Peck's Cave Amphipod: "As such, semiannual drift net sampling for both species will be continued in the context of the AMP during Phase I, and this additional data will be evaluated with the intent of establishing population metrics for these species for Phase II of the HCP."	Page 4-15	Semiannual drift net sampling has continued during Phase I for these species. No 'population metrics' have been established.		Permit extension issue

E."At this time, it is uncertain whether 196 cfs as a long-term average would be supportive of the conditions necessary to rejuvenate the system to the degree that would be necessary to prepare the system for repeated low-flow periods or extended low-flow periods. This rejuvenation of habitat is important not only to the fountain darter, but to all Covered Species at Comal Springs. This question will be examined in the AMP."	Page 4-56	-Hardy T., Oborny E., and others, 2017. Fountain Darter modeling system for the Comal and San Marcos Rivers.		Permit extension issue

F. "In addition, the projected extended periods of consecutive days below 150 cfs, 120 cfs, and 80 cfs for the HCP will require additional evaluation during the Phase I AMP. Each of those three flow levels is a take threshold. At 150 cfs, take for the fountain darter starts to occur in the Upper Spring Run reach. At 120 cfs, Spring Runs 1 and 2 start to constrict and go subsurface, and below 80 cfs Spring Run 3 also constricts and goes subsurface." "Relative to the fountain darter, during the drought of record the system was below 150 cfs for 1,063 straight days (nearly 3 years). With the Phase I and Phase II flow-related measures in the HCP, the consecutive period below 150 cfs is projected to be approximately 2,760 days (or over 7.5 years). That is longer than the Phase I period itself, and approximately 3 times the life span of a fountain darter in the wild. With respect to the Comal Springs riffle beetle, during the drought of record, springflow in the Spring Runs 1 and 2 were below 120 cfs for 750 consecutive days (just over 2 years straight) and the riffle beetle as well as the other Covered invertebrate species survived. However, even with the flow-related measures (Phase I and II), flows below 120 cfs are projected for approximately 2,400 consecutive days (over 6.5 years). During Phase I, applied research on the effects of low flows on the species and their habitat will be conducted, mechanistic ecological models with be developed and applied, and the MODFLOW model used to simulate the effects of the Phase I package will be improved. Until the Phase I AMP decision-making process is complete, it will not be known what durations might be acceptable or the amount of additional flows that might be needed."	Page 4-56	- Effect of low-flow on riffle beetle survival in laboratory conditions (BIO-WEST et al. 2014) - Determination of Limitations of Comal Springs Riffle Beetle Plastron Use During Low-Flow Study (Nowlin et al. 2014) - Evaluation of the long-term, elevated temperature and low dissolved oxygen tolerances of the Comal Springs riffle beetle(Nowlin et al., 2017b) -Hardy T., Oborny E., and others, 2017. Fountain Darter modeling system for the Comal and San Marcos Rivers.		Permit extension issue? WG priority subset: Recompute duration statistics with Phase II flow regime and additional flow increments?

G. During Phase I, applied research on the effects of low flows on the species and their habitat will be conducted, mechanistic ecological models with be developed and applied, and the MODFLOW model used to simulate the effects of the Phase I package will be improved. Until the Phase I AMP decision-making process is complete, it will not be known what durations might be acceptable or the amount of additional flows that might be needed.	Page 4-56	-Hardy T., Oborny E., and others, 2017. Fountain Darter modeling system for the Comal and San Marcos Rivers.		No obvious inconsistency with EAHCP study commitments for Fountain Darter; Permit extension issue for other species
H. "A concern noted in Hardy (2011) is that at 30 cfs total Comal springflow, there is the potential for cool water inflows from springs along the western margin of Landa Lake flowing down the New Channel instead of entering the Old Channel. This could affect water quality in the Old Channel and the success of the proposed ERPA, and, thus, this flow pattern is proposed for study during Phase I."	Page 4-74	Phase I SAV AMP defines volumetric flow splits. COSM is tasked with implementation of flow splits		WG priority subset/ Overlap with WQ

I. "Three main concerns noted in Hardy (2011) regarding this flow regime were 1) the potential for aquatic vegetation die-off and subsequent dissolved oxygen (DO) problems in Landa Lake, 2) the reduction in larval production of fountain darters that would likely be experienced, and 3) the potential for cool water inflows from springs along the western margin of Landa Lake flowing down the New Channel instead of entering the Old Channel, which could result in water quality impacts, including higher temperatures, greater than currently predicted in the Old Channel. Regarding the first concern, the aquatic vegetation question remains unanswered and assessing aquatic vegetation dynamics relative to springflow is a critical applied research component in the AMP. … The third concern is directly related to uncertainty associated with the temperature modeling and will require additional hydrodynamic modeling with follow-up water temperature modeling in addition to intensified spatial monitoring during low-flow events, which are proposed HCP research components."	Page 4-88	-Low-flow threshold evaluation of native aquatic vegetation – Pond experiment (BIO-WEST 2013) -Laboratory versus field comparison of flow for aquatic vegetation in the Comal ecosystem (BIO-WEST 2013) -Bicarbonate utilization by SAV (pH Drift Study) (BIO-WEST 2013) -Algae and dissolved oxygen dynamics of Landa Lake and the Upper Spring Run (BIO-WEST 2015) -Ludwigia repens interference plant competition (BIO-WEST and CRASR 2015) -Distributional patterns of aquatic macrophytes in the San Marcos and Comal Rivers from 2000 to 2015 (Hutchinson and Foote 2017) -Phase I SAV AMP defines volumetric flow splits. COSM is tasked with implementation of flow splits		1. and 2. No obvious inconsistency with EAHCP study commitments. 3. WG priority subset/ Overlap with WQ

		-Hardy T., Oborny E., and others, 2017. Fountain Darter modeling system for the Comal and San Marcos Rivers.		
J. "Applied research and modeling conducted during Phase I are anticipated to provide valuable information on the low-flow requirements and subsurface habitat use of the Comal Springs riffle beetle, which will inform any Phase I and Phase II adjustments that may be necessary. (See, e.g., Section 6.3.4.2). From the statistical flow analysis presented in Table 4-30 it is evident that periods of low-flow will be extended for the HCP alternative compared to what was historically observed. As discussed in Section 4.2.1.3.1, this along with the long-term average flow management objective will need to be evaluated during Phase I activities.	Page 4-106	-Effect of low-flow on riffle beetle survival in laboratory conditions (BIO-WEST et al. 2014) -Determination of Limitations of Comal Springs Riffle Beetle Plastron Use During Low-Flow Study (Nowlin et al. 2014) Comal Springs Riffle Beetle Habitat Connectivity Study (BIO-WEST and Texas State 2015) -Comal Springs riffle beetle occupancy modeling and population estimate within the Comal Springs system (ZARA et al. 2015) -Evaluation of the long-term, elevated temperature and low dissolved oxygen tolerances of the Comal Springs riffle beetle(Nowlin et al., 2017b)		No obvious inconsistency with EAHCP study commitments.

		-Evaluation of the trophic level status and functional feeding group categorization of larvae and adult Comal Springs riffle beetle (Nowlin et al., 2017) -Comal Springs Riffle Beetle (Heterelmis comalensis): Life History and Captive Propagation Techniques (BIO-WEST 2018)		

K. Comal Springs Dryopid Beetle and Peck's Cave Amphipod "A concern identified, during these low-flow periods which will require further research includes the impacts to the energy flow regime in the Aquifer and near the springs."	Page 4-108	None.		Permit extension issue

L. "A key unknown is the tolerance of native aquatic vegetation to reduced flow conditions in these systems. The timing and duration of these low-flow events will be studied relative to the native vegetation, starting with the plant species identified in the long-term biological goals for the fountain darter. Decay of the above ground and below ground biomass will be measured over time. Above ground biomass is important for Covered Species habitat while below ground biomass is critical for root establishment and holding the plant in place during any subsequent pulse event. Water quality will be continuously measured to evaluate the before, during, and after effects of vegetation decay on water temperature, dissolved oxygen, carbon dioxide, and pH. Additional water quality parameters such as nutrients may also be studied. In addition to studying the effect of vegetation decline, decay and ultimately death, studies will be designed to evaluate recovery of native vegetation following various stages of aquatic vegetation decline and decay.	Pages 6-8 and 6-9	-Low-flow threshold evaluation of native aquatic vegetation – Pond experiment (BIO-WEST 2013) -Laboratory versus field comparison of flow for aquatic vegetation in the Comal ecosystem (BIO-WEST 2013) -Bicarbonate utilization by SAV (pH Drift Study) (BIO-WEST 2013) -Algae and dissolved oxygen dynamics of Landa Lake and the Upper Spring Run (BIO-WEST 2015) -Ludwigia repens interference plant competition (BIO-WEST and CRASR 2015) -Suspended sediment impacts on Texas wild-rice & other aquatic plant growth characteristics & aquatic macroinvertebrates (Crawford-Reynolds et al. 2017) -Distributional patterns of aquatic macrophytes in the San Marcos and Comal Rivers from 2000		No obvious inconsistency with EAHCP study commitments.

		to 2015 (Hutchinson and Foote 2017) -Landa Lake DO mgt plan -EAA RTWQ network -EAHCP WQ/Biomon monitoring		
M. Another critical component of fountain darter habitat that is presently unknown is the relationship of macroinvertebrates (fountain darter's main food source) to low-flow conditions. Studies will be designed to evaluate the simulated effects of changing water quality conditions and aquatic vegetation composition on the macroinvertebrate (mainly amphipods) community. … Similar to the aquatic vegetation study, not only will simulated impacts be assessed during extended periods of simulated low flow, but recovery following these periods will be studied to learn response time (amphipod recovery) following a severe event.	Page 6-9	-Low-flow food source threshold study (BIO-WEST 2013)		No obvious inconsistency with EAHCP study commitments.

N. The first step will be to assess the survival success of adults. Once an adult population is established, flow manipulations will be performed to study the affinity of riffle beetles to flow and to track movement from surface to subsurface habitats and vice versa. The immediate goal is not to establish a reproducing riffle beetle population but to evaluate movement patterns of riffle beetles during periods of varying springflow.	Page 6-9	-Effect of low-flow on riffle beetle survival in laboratory conditions (BIO-WEST et al. 2014) -Determination of Limitations of Comal Springs Riffle Beetle Plastron Use During Low-Flow Study (Nowlin et al. 2014) -Comal Springs Riffle Beetle Habitat Connectivity Study (BIO-WEST and Texas State 2015) -Comal Springs riffle beetle occupancy modeling and population estimate within the Comal Springs system (ZARA et al. 2015) -Evaluation of the trophic level status and functional feeding group categorization of larvae and adult Comal Springs riffle beetle (Nowlin et al., 2017)		Permit extension issue

O. Once a population is established in the experimental habitat, extended periods of low-flow will be tested to evaluate the effect of these periods on riffle beetle survival and habitat use. Surface habitat will be completely removed for extended periods of time, water quality will be altered to simulate extreme conditions, and other factors adjusted (e.g., reductions in leaf material or detritus, etc.) to simulate conditions that might be experienced in the wild during these conditions. As with other proposed Tier A efforts, recovery following impacts will also be investigated.	Pages 6-9 and 6-10	-Effect of low-flow on riffle beetle survival in laboratory conditions (BIO-WEST et al. 2014) -Determination of Limitations of Comal Springs Riffle Beetle Plastron Use During Low-Flow Study (Nowlin et al. 2014) -Comal Springs Riffle Beetle Habitat Connectivity Study (BIO-WEST and Texas State 2015) -Comal Springs riffle beetle occupancy modeling and population estimate within the Comal Springs system (ZARA et al. 2015) -Evaluation of the trophic level status and functional feeding group categorization of larvae and adult Comal Springs riffle beetle (Nowlin et al., 2017)		Permit extension issue

P … the concept of spring run connectivity will be tested. This will involve simulating subsurface habitat cutoff from surface habitat and riparian detritus, and subsurface habitats that are connected to surface habitats via the trickling of water across the surface habitat. This is a key study to assess the value of this concept as an additional protection measure in Spring Run 3 of the Comal system as discussed in BIO-WEST (2011).	Page 6-10	-Effect of low-flow on riffle beetle survival in laboratory conditions (BIO-WEST et al. 2014) -Determination of Limitations of Comal Springs Riffle Beetle Plastron Use During Low-Flow Study (Nowlin et al. 2014) -Comal Springs Riffle Beetle Habitat Connectivity Study (BIO-WEST and Texas State 2015)		Permit extension issue
Q A series of low-flow experiments with various timing and durations will be evaluated while examining direct impacts to fountain darters. A whole host of questions can be addressed under this topic with just a few examples including: • when and where do darters move as vegetation decays and water quality deteriorates; • when does reproduction stop or does it; • does compensatory reproduction get triggered, and if so, when and what causes it; and • what is the effect of predation on fountain darter population size?	Page 6-10	-Low-flow food source threshold study (BIO-WEST 2013) -Effects of low flow on fountain darter reproductive effort (BIO-WEST 2014) -Effects of predation on fountain darters (Texas State University and BIO-WEST 2014) -Fountain darter movement under low flow conditions in the Comal Springs/River ecosystem (BIO-WEST 2014b)		No obvious inconsistency with EAHCP study commitments.

R A series of low-flow experiments with various timing and durations will be evaluated while examining direct impacts to Comal Springs riffle beetles. A core question is: when are reproduction and survival compromised as physical habitat (surface and subsurface) declines and water quality deteriorates? The reproduction component assumes that a reproducing population can be established in the study habitat during Phase I. If a reproducing population is successfully established, this flow manipulation research could be expanded to include evaluation of desirable and threshold environmental conditions for larval and pupae stages.	Page 6-10	Reproducing populations haven't been established		Permit extension issue for reproduction WG priority subset for survival aspects
S Towards the end of Phase I, specific studies will be designed and conducted to test the validity of ecological model results. This may involve simple or complex parameters and single or multiple low-flow events depending on Phase II questions that may be relevant at that time.	Page 6-11	None.		WG priority subset
T The initial activity will be the evaluation of alternative methods for snail removal so that removal can be accomplished in the most effective, yet least destructive manner. The second activity deals with understanding the magnitude of snail removal necessary to affect downstream cercaria concentrations in the water column. Once the magnitude of snail removal for effective control of water column cercaria is identified, a study is necessary to evaluate the long-term benefits of that removal.	Page 6-13	None.		Permit extension issue
U Should it be determined during applied research conducted at the NFHTC during Phase I that spring run connectivity is effective and that additional protection may be required for the Comal Springs riffle beetle, then	Page 6-18	-Comal Springs Riffle Beetle Habitat Connectivity Study (BIO-WEST and Texas State 2015)		Permit extension issue

some version of that component may be implemented during Phase II.				
V Comal Springs Dryopid Beetle Adaptive Management Objectives • Maintain adequate water quality within aquifer (parameters maintained within historical ranges); • Monitor bad water line; • Determine spatial and temporal distribution in the Aquifer; • Determine life history characteristics (life span, tolerance to water quality changes, reproduction, food sources) and minimize impacts; and • Determine how food sources, particularly those that originate from far away (e.g., organic material washed in from recharge features and chemolithoautotrophic bacteria in deep aquifer) vary naturally and minimize impacts as appropriate.	Page 6-19	Life history of CSDB is currently underway with Refugia program.		Permit extension issue
W Edwards Aquifer Diving Beetle Adaptive Management Objectives • Maintain adequate water quality within aquifer (parameters maintained within historical ranges); • Monitor bad water line; • Determine spatial and temporal distribution in the Aquifer; and • Determine life history characteristics (life span, tolerance to water quality changes, reproduction, food sources) and minimize impacts; and • Determine how food sources, particularly those that originate from far away (e.g., organic material washed in from recharge features and chemolithoautotrophic bacteria in deep aquifer) vary naturally and minimize impacts as appropriate.	Pages 6-19 and 6-20	None.		Permit extension issue

San Marcos Springs				
X "To be conservative, the long-term goal assumes that a 10 percent deviation would be acceptable; however, more extensive work to evaluate and assess the validity of that assumption and the water quality tolerances of the Texas blind salamander will be considered in the AMP."	page 4-35	None		Permit extension issue
Y "Although the projected long-term average flows are not concerns, the extended periods of consecutive daily average flows under 100 cfs and 80 cfs were examined. At 100 cfs, take for the fountain darter and impacts to Texas wild-rice have been documented. At 80 cfs, take is anticipated for the San Marcos salamander. Unfortunately, there is not a duration factor (i.e, memory) incorporated into any of the basic habitat modeling conducted for the incidental take analysis presented below. As such, a future evaluation of these potential impacts will be addressed with Phase I applied research and mechanistic ecological modeling."	page 4-62	-Hardy T., Oborny E., and others, 2017. Fountain Darter modeling system for the Comal and San Marcos Rivers.		Permit extension issue
Z "As discussed for Comal Springs, during Phase I, applied research on the effects of low flows on the Covered Species and their habitat at San Marcos Springs will be conducted, mechanistic ecological models with be developed and applied, and the MODFLOW model used to simulate the effects of the Phase I Package will be improved. Until the Phase I AMP decision-making is complete, it is not known whether additional flow protection measures might be necessary or what duration might be acceptable, or amount of additional flows that might be needed."	page 4-63	-Hardy T., Oborny E., and others, 2017. Fountain Darter modeling system for the Comal and San Marcos Rivers.		Permit extension issue for species other than fountain darter For fountain darter, no obvious inconsistency with EAHCP study commitments.

AA An assumption was made that a minimum number of salamanders would survive in Spring Lake as long as some springflow was provided. Siltation around spring openings will likely be the biggest detriment to the salamander population in Spring Lake at extremely low flows. It has been observed in Landa Lake (Comal system) that as upwelling springs in the Upper Spring Run area cease flowing, siltation ensues and salamanders retreat from those areas. Although observed at Comal Springs, flows have not reached a level over the past decade at San Marcos Springs to cause a similar condition in Spring Lake, and as such this assumption is currently unfounded. Similarly, establishing a cutoff point on habitat suitability within Spring Lake would be equally unfounded at this time. This again highlights the importance of the applied research and mechanistic ecological modeling to be developed for this species as part of the AMP.	Page 4-140.	None		WG priority subset