NOTE: THIS VERSION INCLUDES TOM BRANDT'S AND JOHN WAUGH'S COMMENTS

October 1, 2010

Dr. Robert Gulley, Program Director
Edwards Aquifer Recovery Implementation Program

Delivered via email

Re: Review of the Thomas Hardy presentation on spring flows for endangered species at Comal and San Marcos springs

Dear Dr. Gulley:

Per your request, attached are comments from members of the Edwards Aquifer Area Expert Science Subcommittee on Thomas Hardy's presentation on spring flows for endangered species at Comal and San Marcos springs. Thomas Hardy gave this presentation to the Edwards Aquifer Recovery Implementation Program group on September 9, 2010:

http://earip.tamu.edu/EARIPMeetings/Sep0910/09-11-10%20Hardy%20Presentation.pdf

The subcommittee met on September 21, 2010, to hear and discuss the presentation. All members were able to attend the meeting except Doyle Mosier, Mary Musick, and John Waugh. I instructed members to email me their comments by the end of the day September 28, 2010, to be included in this review. Because Ed Oborny has been involved with the general development of spring flows for the Edwards Aquifer Recovery Implementation Program, he did not participate as a reviewer of the presentation.

Note that this is a compilation of comments from members and in no way infers subcommittee consensus on the report.

Please let me know if you have any questions on this review.

Sincerely,

Robert E. Mace, Ph.D., P.G.
Chair, Edwards Aquifer Area Expert Science Subcommittee

Comments by members of the Edwards Aquifer Area Expert Science Subcommittee on the presentation by Thom Hardy on Spring Flows for Endangered Species at Comal and San Marcos Springs

Acronyms used in the comments:

cfs = cubic feet per second

CPM = critical period management

EARIP = Edwards Aquifer Recovery Implementation Program

ERPA = environmental restoration and protection area

ESA = endangered species act

ESS and ESSC = Expert Science Subcommittee

GAM = Groundwater Availability Model

RIP = Recovery Implementation Program

RIPSS = Recovery Implementation Program Science Subcommittee

SSC = Expert Science Subcommittee

USFWS = U.S. Fish and Wildlife Service

USGS = U.S. Geological Survey

Note that subcommittee members are listed in alphabetical order.

Rene Barker

From my vantage point as a hydrogeologist, I believe that Thom Hardy's presentation adequately explains the results and caveats of his work to determine minimal springflow conditions on behalf of selected endangered species at San Marcos and Comal springs. Thom takes great care to support his finding with references to relevant literature, as well as qualifying his results with a comprehensive discussion of assumptions and possible pitfalls associated with his analyzes.

My greatest concern regarding Thom's recommendations is that they are based largely on the results of simulations with a computer model that was calibrated on the basis of velocity, temperature, and bathymetric data collected during conditions of much higher flow than those he recommends as "edge-of-the-cliff" determinations. In others words, Thom has extrapolated the limiting conditions of species survival from associations observed during relatively normal hydrologic conditions characteristic of comparatively protective habitats. For this reason, his exhaustive listing of potential ramifications resulting from "reduced flow" conditions should be thoroughly understood and carefully considered before final decisions are cast.

Another aspect of Thom's "break-point" or "low-end" flow rates is the assumption of periodic flow pulses that are considerably higher than flows approaching the absolute minimum rates that he thinks can be tolerated. It must be realized that just because such pulses are thought to have occurred during the brunt of past droughts, there is no guarantee that similar events will occur within appropriate intervals, for sufficient durations, or at high-enough rates during future droughts. Current RIP deliberations are focused on satisfying minimal flow recommendations during conditions anticipated to result from a repeat of the 1947-56 "drought-of-record." However, the next drought to seriously test CPM procedures will likely differ in yet-unappreciated ways from the time and spatial configurations of previously experienced droughts. In other words, our next "big" drought may present challenges much different than those of previous droughts, at least in terms of their timing, duration, and intensity-conditions that will ultimately determine the distributions of species take, jeopardy, and/or survival.

From having attended recent steering committee and stakeholder meetings, it is not difficult to understand the confusion caused by the various minimum-flow recommendations under RIP consideration. Rather than attempting to sort out and reconcile the differences, I can only emphasize that what may appear as "conflicting" information results primarily from almost entirely different sets of criteria. Whereas Thom characterizes his continual flow limits as "absolute minimum, off-the-cliff" numbers (assuming mitigation activity and periodic pulses), the Science Subcommittee's three-tiered matrix of minimum "average" discharges reflects a different approach. It is important to understand that the Subcommittee's recommendations support flow regimes that insure the "protection of all listed species as well as the integrity of each ecosystem," wherein the population trends of threatened and endangered species are maintained or increased without the aid of mitigation measures.

Norman Boyd

On September 21, 2010, Thom Hardy presented recommended minimum springflow numbers to the Science Subcommitee of the EARIP. These minimum flows of 30 cfs for Comal Springs and 45 cfs for San Marcos Springs are intended to be sufficient to ensure that the listed species could survive a repeat of the drought of record with the potential for recovery. These flows are subject to two conditions: (1) that key mitigation measures tentatively adopted by EARIP, including ERPAs and recreation management, would be implemented, and (2) that pulses of 80 cfs for 2 to 3 months would be used to ensure that minimum flows did not extend for longer than 6 months.

It is essential that everybody understands that these low flow numbers are intended to occur only during a repeat of the drought of record. In other words, these flows should result from a natural repeat of the drought of record and not a pumping-induced “drought.”

Dr. Hardy’s recommendations are predicated on the assumption of restoration and mitigation success**.** Exactly what constitutes successful restoration and mitigation is important and needs to be defined. Adequate control of exotics, darter parasites, aquatic recreation, sedimentation, etc. is of extreme importance to the success of any critical period survival of the listed species. Current information is needed on the population size of exotics species and parasites and areas where sedimentation and recreation are an issue need to be delineated to guide restoration and mitigation efforts and aid in defining “success.”

The Hardy model was developed with flows much higher than those recommended and then extrapolated to the lower recommended flows. While it is common for researchers to make predictions outside the values with which their models were calibrated, it does inject an element of uncertainty into the analysis. For this reason adaptive management should be more than just a buzz word—it needs to be a foundation of any plan to conserve these habitats and species.

Keeping in mind that Comal Springs was dry for several months during the drought of the 1950s drought of record (DOR) and that the proposed 30 cfs number is supposed to represent target flow during a recurrence of that event, a minimum flow of 30 cfs seems to provide a better stage for the species to recover than 0 cfs. However, some form of jeopardy and/or take (as defined by the ESA) is likely to occur as the result of altered and/or lost habitat (due to reduced water quality and quantity), increased competition, increased predation, and other unknown or unforeseen factors that will occur at 30 cfs.

The loss or alteration of habitat at 30 cfs will perhaps be most evident in the spring runs. Riffle beetle populations that inhabit the spring runs lack the genetic diversity, including unique haplotypes, of the populations in Landa Lake and western shoreline. This may have happened as a result of past droughts. In Dr. Hardy’s presentation he states that the mechanism of beetle population reestablishment post-DOR is unknown. While it is clear that the riffle beetles in the Comal spring runs survived the DOR, it is not clear that they would survive a similar event. I say this because the pre-DOR population size is unknown. It is possible that the current population is but a small remnant of what existed pre-DOR. If current riffle beetle numbers are much smaller than what existed before the DOR then survival of a similar drought is less certain. And the reduced genetic diversity resulting from the 1950s drought-induced genetic bottleneck would exacerbate the species survival. It is also possible other listed species in the springs and spring runs could be impacted, including Peck’s Cave Amphipod, the Dryopid beetle, and the fountain darter (and the Blind Salamander).

Also, the comment was made that 30 cfs maintains suitable habitat for riffle beetles at the springs along the western shoreline. It does seem as though these springs would remain hydraulically connected to the lake; however, it is unclear that they would still be flowing. If the springs are not flowing, then it is probably not suitable habitat.

As mentioned previously, the minimum flows of 30 cfs for Comal Springs and 45 cfs for San Marcos Springs are intended to be sufficient to ensure that the listed species **could survive a repeat of the drought of record with the potential for recovery.** These numbers were offered as instantaneous flow rates. That is, they represent the minimum flow that should be allowed during a repeat of the drought of record. It is important to note that flows at Comal and San Marcos springs have a diel variation to them and that instantaneous data can be much lower than the daily average and the daily averages are often quite different than monthly averages. To account for these variations and to ensure that flows do not fall below 30 and 45 cfs at Comal and San Marcos springs, respectively, a correction factor should be applied. HDR reported that for flows less than 75 cfs the difference between the daily and monthly averages were 16 and 8 cfs for Comal and San Marcos springs, respectively. This implies a monthly average minimum flow target no lower than 46 for Comal Springs and 53 cfs for San Marcos Springs.

If pulse flows are considered, we need to ask what the goal is. If it is to achieve a flushing in the lakes and river, then we need to define the flows that result in a flushing—likely a very high number (200 to 250 cfs) for Comal Springs given the fact that it is a lake with several dams. If the goal is to reconnect the spring runs, then we need the flows that would get the springs flowing again—also likely to be a high number (100 cfs). And these spring flows would need to last long enough to be biologically meaningful. We don't know how or if it will benefit the darters; more study is needed.

Historically, Comal Spring discharges only infrequently drop below 100 cfs. So comparatively an 80 cfs flow will not likely produce substantial flushing. In terms of the recommended 80 cfs pulse flows, it is not clear what benefit they would provide other than allowing Landa Lake to turn over quicker (every 7 days as opposed to 13 days). This may lead to improved water quality in terms of temperature. Dr. Hardy indicated the pulse flows were intended to allow for darter reproduction, flush organic matter and would also allow spring run 3 to be hydraulically connected to Landa Lake. It isn't clear that a pulse of 80 cfs is sufficient to flush organic matter. In terms of darters, it's unclear that these pulses will cause them to entertain thoughts of reproduction, especially if they are already stressed.

As far as hydraulically connecting spring run 3 to the Lake, the benefit is unclear. Lake water (albeit spring influenced) level rising into the spring run offers little to no benefit for the listed species other than maybe the darter. If the intent is to help the inverts, I don't see the benefit. The beetles and amphipod live in the springs or aquifer and need the springs to be flowing. Water from the lake would likely only fill the hyporheic zone of spring run 3, which is unlikely to be inhabited by anything after 6 months of being dry.

Though the proposed ERPA was offered as "'an insurance policy' to reduce the uncertainties" associated with riffle beetle survival during a severe drought, the ERPAs are an unknown quantity and may prove to be less successful than proposed. While ERPAs are an interesting concept, until they are proven they should not be relied upon to provide an *in situ* refuge or relief from a drought for these listed species.

In the end, it is proposed to allow the San Marcos Springs to drop to 45cfs for a period of 6 months (with pulses) during a repeat of a DOR-type drought. This is lower than has ever been recorded for that spring and for a duration longer than even 60 cfs has ever been recorded. Very little is known about the pre-DOR Texas wild rice and fountain darter populations, and nothing is known of the other listed species during that time. Without such knowledge it is impossible to understand the impact of the DOR on those species, and certainly no way of knowing the impact of the more severe proposed flows.

Tom Brandt:

Dr. Thom Hardy's assessment that fountain darters can survive 6 months in Landa Lake at an average flow near 30 cfs is probably correct. This is assuming that the non-native fishes, snails, and gill parasite are under control. Limiting the effect non-natives will have on fountain darters will be difficult especially at low flows. Fountain darter temperature/survival/reproduction related research I have been involved with has documented that physiologically the fountain darters should be able to survive and reproduce during a 6 month period at 30 cfs in Landa Lake in areas where temperatures remain between 76 and 81ºF. Landa Lake has not experienced 6 months flows near or below 30 cfs since the mid 1950s. Landa Lake during 1984 did experience 1 month with an average flow of 30.4 cfs but the 6 month average during that period was 67.4 cfs and flow returned to 200 cfs by the end of the year. No population data on fountain darters in Landa Lake was collected during that period. The darters did survive the 1984 drought which provides some support for Dr. Hardy's assessment. Since the fountain darter is a short lived animal (life span estimated to be about 18 months in wild) and since reproduction will be occurring at sub-optimal conditions, I expect death rate will exceed recruitment from reproduction during periods when flows are near 30 cfs. Darter population numbers probably will be decreasing.

No one has collected any data on the competition and predation between fountain darters and other native organisms in critical habitat during low flow conditions. There is no physiological reason why fountain darters could not survival downstream of critical habitat for at least a short distance. I assume their range is not greater because they cannot compete successfully with other native organisms. Most fish start their lives consuming the same invertebrates that fountain darters consume during their whole lives. The more young fish of other species, the more competition the fountain darter experiences. I fear that maintaining flows near 30 cfs for extended period of time would allow native species populations to grow and with the growth of these populations, fountain darters would be out competed. The extent to which fountain darters are out competed will determine how fast darter population numbers will drop. The fountain darter may be able to survive a one-time exposure to 6 months of 30 cfs in the Comal River, but I feel a large percentage of the population will be lost. If the fountain darter population is not allowed to fully recover from a 6 month period of 30 cfs, a second period of 30 cfs would pull the population down even further than occurred during the first period. The Science Sub-Committee recommendation that 6 month averages

> 75 cfs and long term averages > 225 cfs for the Comal River would prevent average flows of 30 cfs from occurring too often.

During the 2009 drought, there was much discussion among area biologists about the accuracy of the upper San Marcos River flow measures. People did not believe the flows being reported during 2009 reflected what they remembered during earlier drought. They felt during 2009 that conditions (e.g., water levels) were worse than at the same recorded flows during earlier time. USGS hydrologists told the SSC that as flows lower, their reading become less accurate. The accuracy of flow measurements must increase as spring flow decrease.

Ron Green

I have only a general comment on the Hardy presentation. My concern is when "blunt" models are inappropriately used to make high-resolution predictions (i.e., split hairs). This is particularly true with the Edwards Aquifer GAM and potentially true with Hardy's models. Hardy's analyses do not appear to attempt to make high-resolution predictions. My concern is when those who evaluate the results try to read too much into the predictions. My only recommendation is that very clear, bold caveats be included with the model results and all other model documents so that the users of the results do not mistakenly extend the certainty of the predictions. My sense is that the ESS clearly understands this, but that some on the Steering Committee and some in the general public do not.

Charlie Kreitler

The following are my preliminary comments on Tom Hardy's oral/PowerPoint presentation on minimum spring flow required to maintain endangered species at Comal and San Marcos Springs.

1. Overall a very interesting presentation.

2. Tom's stated purpose of his study is to define minimum flow conditions needed at Comal and San Marcos springs during the drought of record. Don't fall of the cliff.

3. Comal Springs. In the context for Comal Springs, his minimum flow is 30 cfs. It is unclear whether that minimum flow is an instantaneous flow or a minimum flow over 6 months. I believe we heard both answers. In Tom's report he needs to be specific as to what that 30 cfs is related to. This number of 30 cfs differs from the instantaneous number of 5 cfs which was the minimum defined by the biologists in the RIPSS. Ed Oborny indicated that the RIPSS minimum of 5 cfs represented a different minimum than Tom Hardy's minimum. I think several of us at today's meetings left confused as to what the difference was. This difference needs to be clarified.

4. San Marcos Springs. In the context for San Marcos he felt that 45 cfs was his minimal amount of flow. He did not qualify it for a period of time (e.g. 6 months) The question I have is "What is the appropriate amount of wild rice that the biologists like to have for the long-

term". I hear Tom saying that 1,000 m^2 is reasonable. I heard Jackie say 12,000 or more. These are very different numbers. The question is "How much is enough" The report probably needs a discussion of this topic.

Robert Mace

It was helpful for me to hear the presentation a second time and listen to the discussion between Thom and subcommittee. What is clear to me is that Thom's numbers and the Expert Science Subcommittee's numbers are two different animals, his driven by the question "How low can you go?" and ours driven by maintaining and increasing populations.

The modeling component of the study was of some concern to some members of the subcommittee. As a modeler, it's difficult for me to assess if the models are good tools for the tasks they were used for without understanding what governing equations the models use, how they were calibrated, and how well the models reproduce past conditions. While I understand such a discussion may not be appropriate for members of the recovery implementation program, I'm hoping that the final reports discuss these items.

Jackie Poole

Thom's simulated flow studies on the Comal and San Marcos have provided us with many more flows than his previous studies and this allows a better analysis of the data.

I agree with his conclusions that temperature at flows down to 30 cfs for six months do not appear to result in long-term damage to the fountain darter. However, there are several unanswered questions such as the possibility of increased competition and/or predation by other fish in the system. It should be noted that Thom does point out the need for control of non-native fish but for other reasons. While it was assumed that the gill parasite would be controlled, whether this can be accomplished is unknown. Also, the assumption of "control" of various organisms is mentioned throughout the document without definition. "Control" needs to be defined to allow more certainty in determining whether the "control" level will produce an increase in the endangered species population or hold it at status quo.

Thom did a good job in compiling the literature on the impact of velocity on the submerged aquatic vegetation. It is certainly possible that there may be impacts from decaying vegetation that would be detrimental to the fountain darter. Additionally, it should be considered that many of the non-native aquatic plant species at Comal may increase at lower flows. Because Texas wild-rice is a CO_2 obligate species, the issue of increasing boundary layers with decreasing velocities could be a definite problem for wild-rice. While the plants probably assume an annual habit in order to obtain more CO_2, these annual plants will produce seed and die, thus reducing the amount of aerial coverage. Also, at lowered velocities, the other submerged aquatic plants in the San Marcos (all of which are not CO_2 obligates according to Mara Alexander, USFWS) could outcompete Texas wild-rice. It would be interesting in future modeling to add in CO_2 and associated vegetation to see if these two factors would help fine-tune the fit of wild-rice occupied areas to those predicted by the current model.

I am still concerned about the populations of riffle beetles in Spring Runs 1 to 3. Assuming that these populations survived the drought of record, they did go through a genetic bottleneck. How many more times they could go through such drought is not known. It is also unknown if any of the mitigation measures suggested (the “sprinkler”, 80 cfs pulses, etc.) would keep the populations alive and able to recover.

I’m not sure that pulses of 80 cfs will actually be enough to “flush” the system, but I do agree that it might provide some time for fountain darter populations to recover. However, the amount of time of this pulse is probably longer than 1 or 2 months.

While I like the work on the aquatic vegetation and shade, I’m still not sure exactly what “shade” or “not in shade” means. The graph that shows the percent of each species in shade vs. not in shade indicates two character states. Where is the dividing line between these two? Is “not in shade”, full sun all the time at all seasons? And “shade” everything else?

I would like to more carefully examine the maps/models showing suitable habitat for wild-rice. Unlike the BioWest presentation, Thom’s presentation does not show where current wild-rice stands overlap with modeled suitable habitat. Thus I am unsure where the 1000 m^2 occurs. From the presentation maps, there are several areas where there is modeled suitable habitat that does not currently (or in some cases, has ever) contain wild-rice (under the University Drive bridge, below the Salt Grass Restaurant, east channel in upper Sewell Park). It would also be important to analyze the vigor of the stands that are predicted to remain at 45 cfs. Are these stands currently in good condition? How long have they been in existence? Are they more than 1 m^2 in size? The larger the stand, the more likely it is to persist as well as contain more genetic diversity.

Also, the configuration and location of wild-rice stands is extremely important. 1000 m^2 in 1989 might have grown into over 4000 m^2 because somehow, despite all the dredging, there were a few plants at the upstream end of the river that repopulated the blank slate that went from Spring Lake down to Hopkins Street. However, the 1989 scenario vs. an extreme low flow future scenario are far from identical. There is no guarantee that such a reestablishment will occur again. Additionally flowering stems have to be extremely close (less than one foot) for pollination.

While I understand why Thom is using 1000 m^2 as a baseline, I feel that it is somewhat arbitrary and, with some work, a better number could be obtained which would probably result in a different recommended drought of record flow. In 1933 Texas wild-rice was described as “abundant” in the San Marcos River, including Spring Lake and its irrigation waterways. Around the time of listing (1978) 1131 m^2 of wild-rice was recorded. Thus using 1000 m^2 as a baseline takes us back to the amount that led to listing. Currently there is around 4000 m^2. It took almost 20 years to reach this amount. If the “drought of record” will be occurring at a frequency of 15 to 20 years (Ed Oborny stated this at the meeting), then wild-rice will have just barely recovered. It should be noted that Thom did not provide a time period for frequency of drought of record occurrence. Flows in the San Marcos were only at

46 cfs for two days during the drought of record and at or below 52 cfs for a month (with some higher flows during that time). Thom's model shows that at high flows there is as much as 23,687 m^2 of potential high quality habitat for wild-rice (this does not include the 8,954 m^2 of exotic vegetation in potential high quality habitat that could be replaced by wild-rice). If according to the mitigation measures that are supposed to be in place before flows are allowed to go this low, dropping the amount of wild-rice to 1000 m^2 reduces the population by 94%. It is hard to believe that such a reduction would not be considered jeopardy. Even using the potential restorable area for wild-rice as the 12,000 m^2 recommended in the 1996 recovery plan, a reduction to 1000 m^2 would still be an over 90% reduction. The amount of high quality potential habitat that Thom's model predicts at 12,718 m^2 (plus another 3,394 m^2 of exotic species habitat that could be restored to wild-rice) should indicate that at a flow of 45 cfs, with restoration mitigation, shouldn't there be over 16,000 m^2 of wild-rice, rather than a mere 6% of that?

I would also like to see the maps and models for downstream areas. Although Thom felt that it would be best to conserve the upstream-most pockets of wild-rice, this would not conserve genetic diversity throughout the river. While it is logical that the upstream plants would hopefully reestablish a healthy population downstream, this is not currently the case. 25% of the wild-rice population was wiped out by the 1998 flood and has not yet reestablished. Additionally dozens of stands have been lost below Rio Vista Dam. The contraction of the range of this extremely rare species is frightening, but worse is to knowingly cause an even greater contraction of the range. A basic principle of conservation biology is to avoid range contraction.

While Thom ran the model at numerous flows, in Figure 10, only the lower flow data points and one high flow data point are shown. It would be more informative to include the entire range.

I am concerned that there are different interpretations as to what constitutes the drought of record. My interpretation of the drought of record was a severe low flow event in the mid-1950s caused by below average precipitation for several years (1947, 1948, 1950-1951, 1953 to 1956) with only two above average years that probably did little to recharge the aquifer. A drought of this severity has not been repeated in over 60 years. In the Science Subcommittee report, our low flow numbers were not supposed to happen except as a "rare hydrologic event". Thus, one would assume that flows even lower than the Science Subcommittee number would be even rarer. At the meeting on Sep. 21, Ed Oborny said that these events could happen every 15 to 20 years. This is no longer a "rare hydrologic event". Thom provided no time frame as to how often these extremely low flows might occur. The current interpretation seems to be severe low flows similar to those of the drought of record but not necessarily caused by the drought of record. In my opinion the drought of record should be interpreted as a climate-driven event, not a human-induced or accelerated one.

Finally I am extremely concerned about the feasibility of mitigation and management. In order to compare mitigation and management to the engineered solutions, the costs of mitigation and management should be determined. Because there are so many uncertainties with the proposed mitigation and management and because I have worked within the San Marcos system, both natural and political, for over 20 years and have seen little happen along the lines of recreation control, sediment removal, or restoration, it takes much more optimism than I have ever had to be able to envision to assume that all this will come to pass.

Shirley Wade

The presentation was very informative, but it would be helpful to have more explanation on how the minimum 6 month duration flow of 30 cubic feet per second for Comal Springs and 45 cubic feet per second for San Marcos Springs fit in with the Science Subcommittee determination of a minimum 6-month average flow of 75 cubic feet per second for both Comal Springs and San Marco Springs.

John Waugh

My impressions of the Hardy work prior to the meeting were that there seemed to be confusion in the stakeholders' minds in comparing Hardy & Oborny's minimum springflow numbers and those of the ESSC. In particular, the definition of "daily minimum" versus "instantaneous minimum" flows. Also, their description of 30 cfs as "comfortable", while at the same time considering it "at the edge of the cliff". Many stakeholders, and a number of the ESSC biologists, would like to see a buffer built into the minimum numbers, to account for their fear of uncertainty inherent in the modeling analyses.

Notes from attendees that I have examined indicate concerns that competition from native species, as well as doubt whether control of invasive species and recreation is possible. While I agree that these are challenging tasks, we must develop and implement the necessary steps to achieve these important goals to enhance the ability of the habitat to support the various endangered species through the entire flow regime. As Glen Longley stated, another issue that needs to be addressed in the eco-restoration and mitigation program is dealing with pumping from wells nearby the spring areas. I also agree with Dr. Hardy that water quality effects from golf courses directly adjacent to the two lakes, as well as residential lawns on the hillside above Landa Lake, need to be considered in formulating a plan to protect water quality in the two spring areas and adjacent stream reaches.

I personally feel that if Hardy and Oborny are comfortable with the 30 cfs minimum flow, assuming that the eco-restoration and mitigation measures are successfully implemented, and that the "pulses" naturally occur between lower flow periods, then this should be adequate protection for the Comal Springs species. This is assuming that the model does, in fact, accurately predict suitable habitat as a result of analysis of various springflow scenarios.

I agree with Renee Barker and Charlie Kreitler that the Hardy model(s) need better documentation, including a discussion of all assumptions and a description of the uncertainties in the modeling process. This documentation need to be written for the stakeholders, as well as the ESSC and technical community. I believe that through the adaptive management phase of the HCP implementation, new data and refinement of Dr. Hardy's model will contribute to a much better means to analyze the progress of the program, and to help us refine our current plans and future steps.