Chapter 7 Biological Goals and Adaptive Management Program

7.1 Biological Goals

Based on the available information and data collected and analyzed during Phase 1, the long-term biological goals and objectives for Phase 2 of the HCP will be refined. These goals will in turn dictate the EARIP approaches, HCP measures, and timeline for implementation that will need to be updated for the continued success of the HCP.

The Phase 1 short-term biological goals for the HCP are to 1) secure the survival of the threatened and endangered species in the Comal and San Marcos Springs/River ecosystems during the interim Phase 1 period, and 2) to maintain or enhance the essential habitat function of both the Comal and San Marcos Springs/River ecosystems.

7.1.1 Comal Springs/River Ecosystem

7.1.1.1 Fountain Darter

The long-term biological goal for the fountain darter at Comal Springs are quantified as areal coverage of aquatic vegetation (habitat) within four representative reaches of the Comal system. The habitat-based goals are presented in the Table 7-1.

The long-term biological goal is accompanied by two key objectives that will need to be achieved as follows (in no particular order).

- Water temperatures <25°C will be maintained throughout the Comal system as to not inhibit fountain darter reproduction and recruitment over time. This excludes infrequent (e.g., once per 10 years) extreme drought conditions.
- Active native vegetation restoration and protection will be implemented in Landa Lake and the Old Channel. Restoration activities will extend beyond the study reaches in proportion to level of effort expended and size of the study area in relation to the total area of Landa Lake or Old Channel.

The current level of uncertainty associated with the long-term habitat-based biological goals and water quality and restoration objectives led to the flow-related objective in Table 7-2 also being proposed at this time.

Table 7-1. Fountain darter habitat (aquatic vegetation) in meters squared (m^2)

Study Reach	Bryophytes	Hygrophila	Ludwigia	Cabomba	Fil. Algae	Sagittaria	Vallisneria
Upper Spring Run Reach	1,850	650	150			600	
Landa Lake	4,000	250	900	500		1,250	13,500
Old Channel	150	200	1500		300		
New Channel	150	1,350		350			
TOTAL	6,150	2,450	2,550	850	300	1,850	13,500

Table 7-2. Long-term average and minimum total Comal discharge conditions

Description	Total Comal Discharge (cfs)[a]	Time-step
Long-term average	225	Daily average
Minimum	30 [b]	Daily average

[a] Assumes a 50-year modeling period
[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for three months.

All long-term biological goals and accompanying objectives are subject to change during the first and/or second phase of the HCP should additional information be obtained and changes agreed upon by the EARIP.

Historical and Present Day Perspective:

Aquatic vegetation and fountain darters have been routinely monitored within these four representative study reaches since fall 2000. The aquatic vegetation and subsequent fountain darter densities have varied over that period (BIO-WEST 2002a-2011a). An example of bryophytes areal coverage in the Upper Spring Run Reach and Landa Lake, and *Hygrophila* areal coverage in the Old and New channels over time is presented below in Table 7-3.

Table 7-3. Example of bryophytes areal coverage in the Upper Spring Run Reach and Landa Lake, and Hygrophila areal coverage in the Old and New channels over time

	Bryophytes (m^2)		Hygrophila (m^2)	
Sampling Period	Upper Spring Run Reach	Landa Lake	Old Channel	New Channel
Spring 2002	457	3,985	3	3,158
Fall 2002	1,156	3,964	2	2,310
Spring 2003	2,476	4,190	21	3,011
Fall 2003	2,021	3,305	133	3,291
Spring 2004	1,859	1,971	493	3,300
Fall 2004	712	735	648	620
Spring 2005	1,386	2,801	953	18
Fall 2005	1,915	1,055	1,326	220
Spring 2006	1,850	2,114	1,444	310
Fall 2006	1,251	929	1,292	715
Spring 2007	2,358	2,779	1,373	1,108
Fall 2007	2,407	2,601	1,519	1,300
Spring 2008	2,760	3,364	1,349	1,340
Fall 2008	1,057	176	1,350	2,131
Spring 2009	1,068	2,789	1,526	1,991
Fall 2009	853	386	1,569	100
Spring 2010	1,872	2,587	1,587	113
Fall 2010	16	412	1,338	181
Long-term Average	1,526	2,230	996	1,401

Table 7-4 breaks out the "current" (spring and fall 2010) areal coverage of aquatic vegetation within each proposed reach (BIO-WEST 2011a).

From review of the above tables, it is evident that the aquatic vegetation in the Comal system can vary considerably (most notable in Upper Spring Run Reach and New Channel) within any given year. In 2010, the considerable reduction in aquatic vegetation in the Upper Spring Run Reach and New Channel, as well as for bryophytes in Landa Lake was due to the intense flooding event experienced in June. As such there are inherent complexities with using habitat measures as long-term goals and thus, they cannot be used independent of long-term monitoring to evaluate these cause-and-effect relationships. For a more comprehensive description of aquatic vegetation in the Comal study reaches over the past decade, please see SSC (2009) or BIO-WEST (2002a-2011a).

Methods and Discussion:

Data collected over the past 10 years for the EAA Variable Flow study was used for this analysis. For this approach, the maximum amount of each aquatic vegetation type per study reach was selected independent of year and vegetation type. For instance 2003 had the highest areal coverage of bryophytes in Landa Lake, but 2009 had the highest amount of *Sagittaria*. As a starting point, both maximums were used even though they did not occur concurrently. Table 7-5 shows the maximum areal coverage per vegetation type within each study reach over the ten-year study period.

An exercise was then conducted to evaluate the total area of each of these study reaches and whether or not these maximum (but not concurrent) values could be supported within a given reach (or if their simply was not enough wetted area). This resulted in adjustments to the proposed biological goals. Additionally, restoration efforts were considered for Landa Lake and the Old Channel to replace the majority of *Hygrophila* with *Ludwigia*. For a recovery program, it does not seem appropriate to base long-term biological goals in key areas (Landa Lake and Old Channel) on non-native vegetation maximums. Some non-native *Hygrophila* was left in each area as realistically, it is likely not possible to remove all of it and it does provide a measure of habitat. To a much lesser degree, expansion of *Cabomba* in Landa Lake was incorporated beyond the maximum as was some restoration of *Ludwigia* at the Upper Spring Run Reach. The latter *Ludwigia* restoration needs to done carefully (i.e. planting in areas protected by *Sagittaria*) or otherwise the routine flushing of this area will limit the effectiveness of that activity.

In summary, the Table 7-5 (immediately above) was transformed into the proposed goals below in Table 7-6 based on these two assessments which involved professional judgment.

Table 7-4. Fountain darter habitat (aquatic vegetation) (m^2)

Study Reach	*Bryophytes*	*Hygrophila*	*Ludwigia*	*Cabomba*	*Fil. Algae*	*Sagittaria*	*Vallisneria*
SPRING 2010							
Upper Spring Run Reach	1,872	297	8			740	
Landa Lake	2,587	512	29	229		1,458	13,671
Old Channel	18	1,587	9		1		
New Channel	96	113	8	109			
TOTAL	4,573	2,509	54	338	1	2,198	13,671
FALL 2010							
Upper Spring Run Reach	16	14				518	
Landa Lake	412	412	28	239		1,484	12,923
Old Channel	0	1,338	22		7		
New Channel	0	181		52			
TOTAL	427	1,945	50	290	7	2,001	12,923

Table 7-5. MAXIMUM - Fountain darter habitat (aquatic vegetation) m^2

Study Reach	*Bryophytes*	*Hygrophila*	*Ludwigia*	*Cabomba*	*Fil. Algae*	*Sagittaria*	*Vallisneria*
Upper Spring Run Reach	2,760	992	42			748	
Landa Lake	4,190	904	259	349		1,552	13,931
Old Channel	99	1,587	209		274		
New Channel	353	3,300	23	751			
TOTAL	7,402	6,784	533	1,100	274	2,300	13,931

Table 7-6. PROPOSED GOALS - Fountain darter habitat (aquatic vegetation) m^2

Study Reach	*Bryophytes*	*Hygrophila*	*Ludwigia*	*Cabomba*	*Fil. Algae*	*Sagittaria*	*Vallisneria*
Upper Spring Run Reach	1,850	650	***150***			600	
Landa Lake	4,000	***250***	***900***	***500***		1,250	13,500
Old Channel	150	***200***	***1500***		300		
New Channel	150	1,350		350			
TOTAL	6,150	2,450	2,550	850	300	1,850	13,500

****Bold/italics*** indicate a restoration activity that deviates from the Maximum observed.

Finally, a review of the Hardy (2011) fountain darter modeling shows that there would be sufficient quality and quantity of habitat in all four reaches at long-term average flows (225 cfs, in this example) to support the proposed biological goals for the fountain darter in the Comal system.

As part of the HCP proposed long-term monitoring program, these reaches would continue to be monitored semi-annually over time. Additionally, to ensure the representative nature of each study reach to the Comal system, aquatic vegetation mapping of the entire system is proposed every five years.

7.1.1.2 Comal Springs Riffle Beetle

The long-term biological goal for the Comal Springs riffle beetle involves a qualitative habitat component and quantitative population measurement. As with the fountain darter, a representative reach approach was employed. From a habitat perspective, the goal is to maintain silt-free habitat conditions throughout each of the three sample reaches (Spring Run 3, Western shoreline, and Spring Island area). Additionally, the population measurement goal is to maintain greater than or equal to the median densities observed over the past six years of EAA Variable Flow study monitoring.

Table 7-7 summarizes the two components of the proposed goal.

The long-term biological goal is accompanied by two key objectives that will need to be achieved as follows (in no particular order).

- Aquifer water quality should not to exceed a 10 percent deviation from historically recorded water quality conditions within the Edwards Aquifer as measured issuing from the spring openings at Comal Springs. This includes all water quality constituents proposed for monitoring. This objective assumes that a 10 percent deviation would be acceptable, however, more extensive work to evaluate and assess water quality tolerances of the Comal Springs riffle beetle is recommended.

- Active restoration of riparian habitat adjacent to spring openings (Spring Run 3 and Western Shoreline) will be implemented to limit the sedimentation that is experienced following rainfall events.

The current level of uncertainty associated with the proposed long-term biological goals and water quality and restoration objectives led to the following flow-related objective also being proposed at this time, presented in Table 7-8.

Table 7-7. Comal Springs riffle beetle long-term biological goals

	Spring Run 3	Western Shoreline	Spring Island Area
Habitat	Silt-free gravel and cobble substrate within 2 meters of spring openings and upwellings		
Density (# of CSRB/Lure)	≥20	≥15	≥15

Table 7-8. Long-term average and minimum total Comal discharge conditions

Description	Total Comal Discharge (cfs)[a]	Time-step
Long-term average	225	Daily average
Minimum	30 [b]	Daily average

[a] Assumes a 50-year modeling period
[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for three months.

Historical and Present Day Perspective

As part of the EAA Variable Flow study, the Comal Springs riffle beetle population is monitored at three spring upwelling reaches in and around Landa Lake. Riffle beetle monitoring occurs in spring seeps within Spring Run 3, in several springs along the western shoreline of Landa Lake, and near springs upstream of Spring Island. Table 7-9 below shows the total number of Comal Springs riffle beetles captured per cotton lure during each sampling event from 2004 through 2010 (BIO-WEST 2005a–2011a). Similar to fountain darter abundance data, this data is variable across sampling events. However, the riffle beetle data also suggests a relatively stable long-term trend in abundance (BIO-WEST 2011c [= ERPA report reference]).

Table 7-9. Number of Comal Springs riffle beetles captured per cotton lure during each sampling event from 2004 through 2010

Sample Period	Spring Run 3	Western Shore	Spring Island	TOTAL
May–June 2004	88	83	122	293
August 2004	169	143	90	402
Nov–Dec 2004	170	175	146	491
April 2005	119	121	121	361
Nov–Dec 2005	262	201	185	648
May–June 2006	256	195	160	611
Nov–Dec 2006	185	92	125	402
May–June 2007	59	161	119	339
Nov–Dec 2007	204	83	132	419
May–June 2008	155	139	156	450
Nov–Dec 2008	144	133	227	504
May–June 2009	136	226	74	436
Nov–Dec 2009	72	56	198	326
May–June 2010	53	110	20	183
Nov–Dec 2010	298	264	104	666
TOTAL	2,370	2,182	1,979	6,531
Average	158.0	145.5	131.9	458.3

Methods and Discussion

Unlike for the fountain darter with aquatic vegetation, it is more complex to quantify the amount (or areal coverage) of high quality habitat for the riffle beetle. A major unknown is the beetle's use of subsurface habitat. As such, the habitat-based component of this goal involves maintaining silt-free substrates (gravels and cobbles) throughout the representative sample reaches.

For the population measurement, data collected over the past 6 years for the EAA Variable Flow study was used for this analysis. The approach involved calculating the minimum, 25th, median, 75th, and maximum densities of Comal Springs riffle beetles collected per lure within the three representative sample reaches. The results are shown in Table 7-10.

Table 7-10. Comal Springs riffle beetle density (#/lure)

	Spring Run 3	Western Shoreline	Spring Island Area
Minimum	7	9	7
25th	12	13	11
Median	17	14	13
75th	21	20	16
Maximum	32	26	23

As the recent six-year trend suggests a stable population of Comal Spring riffle beetles within the sample reaches, it was decided that the median density over the past six years would serve as starting point for a long-term biological goal.

As with the other species, these biological goals require an accompanying set of long-term monitoring and adaptive management flexibility. As such, continued semi-annual monitoring is proposed at each of the three representative study reaches as part of the HCP.

7.1.1.3 Comal Springs Dryopid Beetle and Peck's Cave Amphipod

The Comal Springs dryopid beetle and Peck's Cave amphipod are subterranean species inhabiting the Comal system. SSC (2009) reports that the subterranean nature and restricted range of the Comal Springs dryopid beetle (to the headwaters of the springs and spring upwelling areas) suggests that it does not require substantial surface discharge from springs to survive and presumes that springflow (of sufficient water quality) that continually covers the spring orifice should prevent harm to the population. Similarly, SSC (2009) concludes that the Peck's Cave amphipod requirements include sufficient springflow covering the spring orifices and adequate water quality would prevent harm to the species.

As such, the long-term biological goal for these subterranean species focuses on aquifer water quality. The water quality goal is:

- to not exceed a 10% deviation from historically recorded water quality conditions within the Edwards Aquifer as measured issuing from the spring openings at Comal Springs.

This includes all water quality constituents proposed for monitoring. 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 is recommended. As there is uncertainty embedded in the assumptions underlying the water quality goal, a flow-related goal is also recommended for these species. The goal is the same as for the other Comal species as indicated in Table 7-11.

Table 7-11. Long-term average and minimum total Comal discharge conditions

Description	Total Comal Discharge (cfs)[a]	Time-step
Long-term average	225	Daily average
Minimum	30 [b]	Daily average

[a] Assumes a 50-year modeling period
[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for three months.

Coupled with the water quality goal, these flow conditions should provide habitat conditions and food supplies supportive of the aquifer species.

7.1.2 San Marcos Springs

7.1.2.1 Texas wild-rice

At this time, a long-term biological goal for Texas wild-rice has not been formally selected. Presented herein are three different methodologies for establishing said goal, with each receiving continued evaluation.

1. Maximum Occupied Area over Time

The first approach involves an evaluation of the maximum occupied area of Texas wild-rice that has been present in the San Marcos system over time, coupled with a buffer, as well as additional biological objectives.

The proposed Long-term biological goal using this approach is presented in Table 7-12 and subsequent discussion.

Table 7-12. Proposed long-term biological goal for Texas wild-rice using maximum occupied area over time approach

River Segment	Areal coverage (m^2)	Reach percentage of Total areal coverage
Spring Lake Dam to Rio Vista Dam	5,810	83
Rio Vista Dam to I35	910	13
Downstream of I35	280	4
TOTAL	7,000	100

This long-term goal is accompanied by three key objectives presented below that will need to be achieved as follows (in no particular order).

- Minimum Texas wild-rice areal coverage per segment during drought of record like conditions (Table 7-13).
- Recreation awareness throughout the whole river at all flows with designated control (to be determined) in the following high quality habitat areas below 100 cfs total San Marcos discharge (Table 7-14).
- Active restoration and Texas wild-rice expansion efforts and long-term monitoring focused on high quality habitat areas.

These objectives are subject to change during the first phase of the HCP should additional information be obtained and changes agreed upon by the EARIP.

Table 7-13. Minimum Texas wild-rice areal coverage per segment during DOR- like conditions

River Segment	Areal coverage (m^2)	Reach percentage of Total areal coverage
Spring Lake Dam to Rio Vista Dam	2,490	83
Rio Vista Dam to I35	390	13
Downstream of I35	120	4
TOTAL	3,000	100

Table 7-14. Recreation awareness throughout the whole river at all flows with designated control (to be determined) in the following high quality habitat areas below 100 cfs total San Marcos discharge

Combined River Segment	TPWD Individual Segments
Spring Lake Dam to Rio Vista Dam	B, C
Rio Vista Dam to I35	F
Downstream of I35	K

The long-term biological goals for Texas wild-rice are defined as areal coverage over a spatial extent of the San Marcos River. However, at this time, because of the uncertainty of the goals and the above mentioned objectives, the flow-related objectives in Table 7-15 are proposed.

Table 7-15. Long-term average and minimum total San Marcos discharge conditions

Description	Total San Marcos Discharge (cfs)[a]	Time-step
Long-term average	140	Daily average
Minimum	45[b]	Daily average

[a] Assumes a 50-year modeling period
[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for 3 months.

The long-term biological goals and accompanying objectives are subject to change during the first and/or second phase of the HCP should additional information be obtained and changes agreed upon by the EARIP.

Historical and Present Day Perspective

Whole system monitoring for Texas wild-rice in the San Marcos River was initiated in 1976 and TPWD has conducted annual monitoring since 1989 (SSC 2009). The TPWD 1976 to 2009 data set (SSC 2009) was used for this analysis. During this time period the largest amount of Texas wild-rice in the San Marcos River has been 4,277.5 m^2 measured in 2007. The areal coverage and percentage breakdown per combined river segment for the 2009 TPWD data is presented in Table 7-16.

Table 7-16. Texas wild rice areal coverage and percentage of breakdown per combined river segment for the 2009 TPWD data

River Segment	2009 Areal coverage (m^2)	Reach % of Total areal coverage
Spring Lake Dam to Rio Vista Dam	3,345	87
Rio Vista Dam to I35	402	11
Downstream of I35	81	2
TOTAL	3,828	100

For a complete description of Texas wild-rice historical and present day conditions, please see SSC (2009) or BIO-WEST (2011b).

Methods and Discussion

As mentioned, the 1976 to 2009 data set (SSC 2009) was used for this analysis. TPWD has divided the San Marcos River into 14 segments for their annual monitoring. To evaluate the potential for Texas wild-rice over time in each of these segments, we used the data set to select the largest total of Texas wild-rice in any segment regardless of year. Those totals and associated dates are presented in Table 7-17 below.

Table 7-17. Full TPWD dataset: 1976–2009

TPWD River Segment	Areal Coverage (m^2)	Year Experienced	Combined River Segment	Reach % of Total areal coverage
A	410.47	2006	Spring Lake Dam to Rio Vista Dam (A-D) – 3,785.62 m^2	76.95
B	2529.3	2007		
C	830.9	2005		
D	14.95	2008		
E	109.81	1991	Rio Vista Dam to I35 (E-G) – 728.8 m^2	14.81
F	550.99	2006		
G	68	1976		
H	28.67	2009	Downstream of I35 (H-M) – 405.23 m^2	8.24
I	12.86	1989		
X	1.04	1989		
J	120.46	1990		
K	234.94	1998		
L	6.74	2006		
M	0.52	1989		

Using this approach, the hypothetical total Texas wild-rice areal coverage for the river would have been 4,919.65 m^2. Considering the EARIP is a “recovery” implementation program, a level of conservatism (buffer) was added to this hypothetical total. The level arbitrarily selected was to multiply 4,919.65 by 1.5 for a new total of 7,379.48 m2. This total was then rounded up to 7,500 m^2 and divided by the combined river segment percentages (table above) to come up with the following goals for consideration (Table 7-18.

Table 7-18. “Recovery” 1.5 multiplier goals.

River Segment	Areal coverage (m^2)	Reach percentage of Total areal coverage
Spring Lake Dam to Rio Vista Dam	5,771	76.95
Rio Vista Dam to I35	1,111	14.81
Downstream of I35	618	8.24
TOTAL	7,500	100

Upon initial evaluation of these goals, it was apparent that the 618 m^2 goal for the lower segment was likely unrealistic considering the affect that the 1998 flood has had on Texas wild-rice’s potential for establishment in the lower segment. The greatest amount of Texas wild-rice in this segment (combined) using all data (regardless of year) was 405.23 m^2. The greatest amount observed since the 1998 flood is 170.59 m^2. Since that 1998 flood event, this lower section has had 12 plus years to establish Texas wild-rice including several transplant efforts (under a variety of high, average, and low flow conditions) and yet it has not been able to sustain 200 m^2, and in 2009 only sustained 81.47 m^2. Therefore, for this Method 1 assessment, it was felt that a goal of 616 m^2 for this lower segment would likely not be obtainable without significant channel modification, which likely still left the reach exposed to future flooding impacts.

As such, a subsequent analysis was conducted using the same methodology but only considering the post-1998 data which resulted in the data presented in Table 7-19:

Table 7-19. Post – 1998 flood data*

TPWD River Segment	Areal Coverage (m^2)	Year Experienced	Combined River Segment	Reach % of Total areal coverage
A	410.47	2006	Spring Lake Dam to Rio Vista Dam (A-D) – 3,785.62 m^2	***82.83***
B	2529.3	2007		
C	830.9	2005		
D	14.95	2008		
E	***38.67***	***1999***	Rio Vista Dam to I35 (E-G) – ***613.96*** m^2	***13.43***
F	550.99	2006		
G	***24.3***	***2008***		
H	28.67	2009	Downstream of I35 (H-M) – ***170.59*** m^2	***3.73***
I	***0***	***Post-1998***		
X	***0***	***Post-1998***		
J	***7.33***	1999		
K	***127.85***	***2004***		
L	6.74	2006		
M	***0***	***Post-1998***		

****Bold/italics*** indicates a change from the full data set to the post-1998 data set.

Using the Post -1998 TPWD data and the same approach, the hypothetical total Texas wild-rice areal coverage for the river would have been 4,570.17 m^2. Taking that number times 1.5 results in 6855.26 m^2. That number was then rounded to 7,000 m^2 and used with the percentages to calculate the proposed goals at the beginning of this section. The follow table shows the comparison in total areal coverage per combined segment for the two respective data sets.

Table 7-20. "Recovery" 1.5 multiplier goals – post 1998 data

River Segment	Post -1998 flood Areal Coverage (m^2)	Full Data Set Areal Coverage (m^2)	Difference (m^2)
Spring Lake Dam to Rio Vista Dam	5,810	5,771	+39
Rio Vista Dam to I35	910	1,111	-201
Downstream of I35	280	618	-338
Total	7,000	7,500	-500

The inability of Texas wild-rice to re-establish in the lower reaches to the amounts recorded prior to that event under a full range of flow conditions, led the project team to select the Post-1998 data set for this method. Even such, the 280 m^2 may be difficult to establish in the lower reach into the future as it is a 345% increase from 2009 conditions.

Finally, a review of the Hardy (2011) Texas wild-rice modeling shows that there is enough quality (> 0.75 suitable) Texas wild-rice potential habitat in each combined river segment to meet the proposed long-term biological goals at the flow ranges discussed (45 cfs and above). It needs to be emphasized that this is modeled suitable habitat and not occupied Texas wild-rice area. The current amounts of occupied Texas wild-rice areas within this modeled quality (> 0.75 suitable) Texas wild-rice habitat is lower than the proposed long-term biological goals at all flow ranges discussed (45 cfs and above).

2. USFWS (1996) Recovery Plan Recommendations

Texas Parks and Wildlife Department has suggested consideration of the USFWS (1996) Recovery Plan areal coverage for Texas wild-rice as an alternative to the calculations presented above. Table 7-21 shows the comparison of Post- 1998 data (maximum amount of Texas wild-rice areal coverage observed in each segment) and the USFWS (1996) recommendations.

Table 7-21. USFWS Texas wild rice Recovery Plan recommendations

TPWD River Segment	Post-1998 Maximum Observed Areal Coverage (m^2)	1996 Recovery Plan Recommended Areal Coverage (m^2)*	Percent Difference
Spring Lake	Not measured	1,500	N/A
A	410.47	1,400	341
B	2,529.3	5,000	198
C	830.9	1,000	120
D	14.95	100	669
E	38.67	500	1,293
F	550.99	900	163
G	24.3	100	412
H	28.67	50	174
I	0	30	N/A
X	0	50	N/A
J	7.33	400	5,457
K	127.85	700	548
L	6.74	100	1,484
M	0	100	N/A

***** "Wild-rice plants should be present with at least the following areal coverage and distribution." (USFWS 1996)

USFWS (1996) states the areal coverage per segment was "calculated to achieve an average cover of 75 percent of the potential wild-rice habitat believed to be present in each segment. This percent cover is typical of that found in healthy, vigorous stands of rice monitored over the last several years."

To compare the areal coverage recommended by methodology 1 and 2 (as described in this section) the USFWS (1996) individual segment areas were summed into the three described river segments as used in Method 1. Table 7-22 presents the comparison.

Although no minimum goal is specified in the USFWS (1996) recovery plan, it could easily be calculated based on the reach percentages shown above. Additionally, the key objectives for Method 1 could easily be applied to Method 2, should the EARIP deem appropriate.

Hardy (2010) Texas wild-rice modeling

The third method is to use the 2-D hydrodynamic model results described in Hardy (2011) to determine Texas wild-rice areal coverage goals for each segment. It is envisioned that this exercise will involve an examination of potential high quality Texas wild-rice habitat within each segment. This analysis is currently being conducted by TPWD, but was not available for this draft report.

7.1.2.2 Fountain Darter

The long-term biological goal for the fountain darter is quantified as areal coverage of habitat within three representative river reaches of the San Marcos system. The habitat-based goals are presented in the Table 7-23.

The long-term biological goal is accompanied by two key objectives that will need to be achieved as follows (in no particular order).

- Water temperatures < 25 °C will be maintained throughout the fountain darters range in the San Marcos system as to not inhibit fountain darter reproduction and recruitment over time. This excludes infrequent (e.g., once per 10 years) extreme drought conditions.
- Active native vegetation restoration and protection will be implemented in all three representative study reaches. Restoration activities will extend beyond the study reaches in proportion to level of effort expended and size of the study reach in relation to the total river segment.
- The current level of uncertainty associated with the long-term habitat-based biological goals and water quality and restoration objectives led to the flow-related objectives in Table 7-24 also being proposed.

Table 7-22. Comparison of biological goals using different methodologies

	Proposed Goals (Method 1)				USFWS (1996) Recommended Areal Coverage (no minimum goal specified)	
	Long-term Goal		Minimum Goal		Long-term Goal*	
River Segment*	Areal coverage (m^2)	Reach % of Total areal coverage	Areal Coverage (m^2)	Reach % of Total areal coverage	Areal coverage (m^2)	Reach % of Total areal coverage
Spring Lake Dam to Rio Vista Dam	5,810	83	2,490	83%	7,500	72
Rio Vista Dam to I35	910	13	390	13%	1,500	14
Downstream of I35	280	4	120	4%	1,430	14
Total	7,000	100	3,000	100%	10,430*	100

*USFWS (1996) also recommended 1,500 m^2 for Spring Lake bringing the overall total to 11,930 m^2.

Table 7-23. Fountain darter habitat (aquatic vegetation) (m^2)

Study Reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring Lake Dam	50	200	25	100	1,000	100	125
City Park	200	1,000	50	500	2000	300	50
I35	50	200	300	100	300	100	25
TOTAL	300	1,400	375	700	3,300	500	200

Table 7-24. Long-term average and minimum total San Marcos discharge conditions

Description	Total San Marcos Discharge (cfs)[a]	Time-step
Long-term average	140	Daily average
Minimum	45[b]	Daily average

[a] Assumes a 50-year modeling period
[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for 3 months.

The long-term biological goals and accompanying objectives are subject to change during the first and/or second phase of the HCP should additional information be obtained and changes agreed upon by the EARIP.

Historical and Present Day Perspective

Aquatic vegetation and fountain darters have been routinely monitored within these representative study reaches since fall 2000. The aquatic vegetation and subsequent fountain darter densities have varied over that period (BIO-WEST 2002b-2011b). Table 7-25 breaks out the "current" (spring and fall 2010) areal coverage of aquatic vegetation within each proposed reach (BIO-WEST 2011b).

From review of BIO-WEST (2002b-2011b), it is evident that the aquatic vegetation in the San Marcos system can vary considerably within any given year. As such there are inherent complexities with using habitat measures as long-term goals and thus, they cannot be used independent of long-term monitoring to evaluate these cause-and-effect relationships. For a more comprehensive description of aquatic vegetation in the San Marcos study reaches over the past decade, please see SSC (2009) or BIO-WEST (2002b-2011b).

Methods and Discussion

Data collected over the past 10 years for the EAA Variable Flow study was used for this analysis (BIO-WEST 2002b-2011b). Similar to the Texas wild-rice approach proposed, the maximum amount of each aquatic vegetation type per study reach was selected independent of sample event and vegetation type. For instance, the highest areal coverage of *Cabomba* in the I35 reach was Fall 2006, while Spring 2007 had the highest amount of *Sagittaria* in that same reach. As a starting point, both maximums were used even though they did not occur concurrently. Table 7-26 shows the maximum areal coverage per vegetation type within each study reach over the ten-year study period.

Table 7-25. Areal coverage of aquatic vegetation by reach - fountain darter habitat (aquatic vegetation) (m^2)

Study Reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
SPRING 2010							
Spring Lake Dam	1	0	0	344	400	12	50
City Park	1,099	0	0	2,558	503	106	2
I35	115	8	148	169	0	37	0
TOTAL	1,214	8	148	3,071	903	155	52
FALL 2010							
Spring Lake Dam	65	4	5	201	272	6	32
City Park	1,095	0	0	1,758	562	114	
I35	126	14	142	185	0	19	0
TOTAL	1,286	18	147	2,145	834	138	32

Table 7-26. MAXIMUM (m^2) - fountain darter habitat (aquatic vegetation)

Study Reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring Lake Dam	154	35	7	547	782	77	107
City Park	1,235	0	35	3,021	1,691	253	14
I35	162	22	253	382	0	72	0
TOTAL	1,552	57	295	3,950	2,473	401	121

An exercise was then conducted to evaluate the total area of each of these study reaches and whether or not these maximum (but not concurrent) values could be supported within a given reach (or if their simply was not enough wetted area). Additionally, the long-term biological goals (areal coverage) for Texas wild-rice were incorporated into this evaluation and subtracted from the total available wetted area. This resulted in adjustments to the proposed fountain darter biological goals for aquatic vegetation. Additionally, aquatic vegetation restoration efforts were considered for each of the three reaches. For a recovery program, it did not seem appropriate to base long-term biological goals on non-native vegetation maximums. Some non-native *Hygrophila* and *Hydrilla* was left in each area as realistically, it is likely not possible to remove all of it and it does provide a measure of fountain darter habitat.

In summary, the Maximum table (immediately above) was transformed into the proposed goals (below in Table 7-27) based on these additional assessments which involved professional judgment.

Finally, a review of the Hardy (2011) fountain darter modeling shows that there would be sufficient quality and quantity of habitat in these reaches at long-term average flows (140 cfs, in this example) to support the proposed biological goals for the fountain darter in the San Marcos system.

As part of the HCP proposed long-term monitoring program, these reaches would continue to be monitored semi-annually over time. Additionally, to ensure the representative nature of each study reach to the San Marcos system, aquatic vegetation mapping of the entire system is proposed every five years.

7.1.2.3 San Marcos Salamander

The long-term biological goal for the San Marcos salamander involves a qualitative habitat component and quantitative population measurement. As with the fountain darter and riffle beetle, a representative reach approach was employed. From a habitat perspective, the goal is to maintain silt-free habitat conditions throughout each of the three representative reaches (Hotel area, Riverbed area, and eastern spillway below Spring Lake Dam). Additionally, the population measurement goal is to maintain greater than or equal to the median densities observed over the past ten years of monitoring.

Table 7-28 summarizes the two components of the proposed goal.

Table 7-27. Proposed goals (m^2) for fountain darter habitat (aquatic vegetation)

Study Reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring Lake Dam	50	***200***	***25***	100	1,000	100	125
City Park	200	***1,000***	***50***	500	2000	300	***50***
I35	50	***200***	300	100	***300***	100	***25***
TOTAL	300	1,400	375	700	3,300	500	200

****Bold/italics*** indicates a restoration activity that deviates from the maximum observed.

Table 7-28. Comal Springs riffle beetle Long-term biological Goals

	Hotel Area (Spring Lake)	Riverbed Area (Spring Lake)	Eastern Spillway below Spring Lake Dam
Habitat	Silt-free gravel and cobble substrate ≥ 90% of each study area		
Density (# of salamanders/m^2)	≥15	≥15	≥5

The long-term biological goal is accompanied by two key objectives that will need to be achieved as follows (in no particular order).

- Aquatic gardening at similar capacity to what has occurred over the last 10 years in Spring Lake is continued for the Riverbed Area. This is currently being coordinated and performed by Aquarena Springs personnel.

- Recreation control is implemented in the eastern spillway below Spring Lake Dam, particularly at total San Marcos discharge of < 100cfs.

The current level of uncertainty associated with the proposed long-term biological goals and management and recreation objectives led to the following flow-related objectives in Table 7-29 also being proposed.

Table 7-29. Long-term average and minimum total San Marcos discharge conditions

Description	Total San Marcos Discharge (cfs)[a]	Time-step
Long-term average	140	Daily average
Minimum	45[b]	Daily average

[a] Assumes a 50-year modeling period
[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for 3 months.

Historical and Present Day Perspective:

As part of the EAA Variable Flow study, San Marcos salamander is monitored at two locations within Spring Lake and just below Spring Lake dam. The monitoring occurs near the Hotel, within the Riverbed, and in the eastern spillway below Spring Lake Dam. Table 7-30 shows the total number of San Marcos salamanders observed at each representative study reach from 2000-2010. Similar to other species discussed, this data is quite variable across sampling events.

Table 7-30. San Marcos salamander density (#/m^2) 2000–2010

Sampling Period	Hotel Area	Riverbed	Eastern Spillway
Fall 2000	19.4	3.4	5.2
Spring 2001	9.4	13.9	0.4
Fall 2001	10.0	6.7	3.2
Spring 2002	20.2	8.5	0.6
Fall 2002	16.8	8.7	3.0
Spring 2003	7.9	11.9	1.0
Fall 2003	11.3	9.5	2.7
Spring 2004	14.6	9.9	7.1
Fall 2004	11.7	13.7	4.5
Spring 2005	18.2	7.8	3.5
Fall 2005	11.6	12.6	12.1
Spring 2006	15.5	7.7	7.1
Spring 2007	9.0	13.7	2.8
Fall 2007	9.2	8.1	9.1
Spring 2008	16.8	12.3	6.0
Fall 2008	15.1	11.7	8.6
Spring 2009	13.7	12.1	7.4
Fall 2009	15.3	15.9	4.8
Spring 2010	17.6	23.5	5.8
Fall 2010	8.7	14.1	2.4
Average	13.6	11.3	4.9

Methods and Discussion

Unlike for the fountain darter with aquatic vegetation, it is more complex to quantify the amount (or areal coverage) of high quality habitat for the San Marcos salamander. High quality habitat consists of a synergy of clean substrates, rock sizes, aquatic vegetation, filamentous algae, with the additional complexity of the salamander's use of subsurface habitat. Because of endless combinations of those parameters and embedded complexity, we have simplified the habitat-based goals to the predominant factors of silt-free substrates, with large gravel and cobble substrates present. The habitat-based component of this goal involves maintaining silt-free substrates (gravels and cobbles) over greater than or equal to 90% of the fixed sampling reaches. Unlike the riffle beetle sample areas, the salamander sample reaches have predominantly fixed areas as follows:

- Hotel Area 31 m^2
- Riverbed Area 62 m^2
- Eastern Spillway 20 m^2

This fixed sample area with a known size allows one to assess the amount of total area that is sustaining high quality habitat conditions as specified in the goal.

For the population measurement, data collected over the past decade for the EAA Variable Flow study was used for this analysis (BIO-WEST 2002b-2011b). The approach involved calculating the minimum, 25th, median, 75th, and maximum densities of San Marcos salamanders within the three study sites. The results are shown in Table 7-31.

Table 7-31. Proportional distribution San Marcos salamander densities (#/m^2) 2000–2010

	Hotel Area	Riverbed	Eastern Spillway
Minimum	7.9	3.4	0.4
25th	9.9	8.4	2.8
Median	14.2	11.8	4.7
75th	16.8	13.7	7.1
Maximum	20.2	23.5	12.1

Professional judgment was employed to determine that the median density would serve as starting point for a long-term biological goal. It must be emphasized that the habitat and population goals need to be met concurrently to be deemed successful. For instance, should habitat quality degrade surrounding the study area, it is possible that clumping of salamanders into the study reach would occur inflating the densities. However, if habitat was degrading outside of the study area, and the reaches are representative, soon thereafter it would also start to degrade within the representative study area. In this example, for some period of time the density goal could be met while habitat-based requirement of silt-free substrate would have failed. Another example in the other direction is the habitat goal could be met with silt-free substrates, but because of recreational influences (dam and structure building using rocks suitable for salamander habitat), the densities of salamanders might not be obtainable.

As with the other species, these biological goals require an accompanying set of long-term monitoring and adaptive management flexibility. As such, continued semi-annual monitoring is proposed at each of the three study sites as part of the HCP.

7.1.2.4 Texas Blind Salamander

Similar to the Comal Springs dryopid beetle and Peck's Cave amphipod, the Texas blind salamander is a subterranean species. An assumption of the EARIP HCP is that as subterranean species, mechanisms exist for these species to retreat into the Edwards Aquifer should springflows cease at the spring outlets at San Marcos Springs. As such, the focus of the long-term biological goals for these subterranean species relates to aquifer water quality. The water quality goal for the Texas blind salamander is:

- to not exceed a 10% deviation from historically recorded water quality conditions within the Edwards Aquifer as measured issuing from the spring openings in Spring Lake.

This includes all water quality constituents proposed for monitoring. The long-term goal assumes that a 10% deviation would be acceptable, however, more extensive work to evaluate and assess water quality tolerances of the Texas blind salamander is recommended. As there is uncertainty embedded in the assumptions underlying the water quality goal, a flow-related goal is also recommended for the Texas blind salamander. The goals in Talbe 7-32 are the same as for the other San Marcos species.

Table 7-32. Long-term average and minimum total San Marcos discharge conditions

Description	Total San Marcos Discharge (cfs)[a]	Time-step
Long-term average	140	Daily average
Minimum	45[b]	Daily average

[a] Assumes a 50-year modeling period
[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for three months.

Coupled with the water quality goal, these flow conditions should provide habitat conditions and food supplies supportive of this aquifer species.

7.1.2.5 Comal Springs Riffle Beetle

Due to the paucity of data for this species in the San Marcos system, it is not possible to establish specific long-term habitat-based biological goals. As such, the EARIP HCP assumes that the flow-related goals proposed for the San Marcos system would be protective of this species, until such time that additional information is available.

7.2 Ecological Modeling

To address the objectives listed above and establish the long-term biological goals and objectives for Phase 2 of the HCP, ecological modeling is recommended. Ecological models are numeric or computer-based abstractions of ecological systems, and as such, they are simplifications of real-world processes and interactions. The complexity of ecological models varies from the relatively simple, such as some numeric models, to extremely complex, such as dynamic simulation models. Ecological models are used for a wide variety of purposes, including 1) to better understand ecological relationships, processes, and interactions of the systems being studied, 2) project ecological responses over time, and 3) predict ecological responses to changes in environmental conditions. A predictive ecological model is recommended to be used to evaluate potential adverse ecological effects from EARIP adopted approaches and HCP measures and if such effects are determined to occur, to quantify their magnitude and help develop alternative EARIP approaches, or possible mitigation, strategies. A predictive ecological model can project ecological responses to levels of environmental stressors beyond what are likely to be encountered during the limited time associated with the first phase of the HCP. Therefore, the model would provide the EARIP

[***PROJECT SPONSORS – TBD***] with the ability to investigate potential impacts to these ecosystems from extreme short-term and sustained long-term impacts from natural and anthropogenic factors, including groundwater withdrawal. The project team recognizes two primary purposes for including a predictive ecological model in the HCP: 1) to identify and describe ecological responses and 2) to quantify, predict, and project impacts. Three objectives are associated with each of the two purposes.

Identify and describe specific ecological responses:

- to predict specific ecological responses of the Comal and San Marcos Springs/River ecosystems and associated threatened and endangered species to various environmental factors, both natural and anthropogenic;
- to assist in establishing potential threshold levels for the these ecosystems and associated species relative to potential environmental stressors; and
- to assist the overall scientific effort to better understand the interrelationships among the various ecological factors affecting the dynamics of these ecosystems and associated species.

Quantify, predict, and project impacts:

- to assist in identifying and quantifying the effects of various environmental factors, including groundwater withdrawal, recreation, parasitism, restoration, etc. on ecological changes in these ecosystems and associated species;
- to project long-term effects of the EARIP adopted approaches and HCP measures on these ecosystems and associated species to facilitate designation of HCP phase 2 biological goals and strategies for achievement ; and
- to assist in mitigation design, implementation, and monitoring, where applicable.

There are three broad categories of predictive ecological models, with numerous variations of each. These three categories are: 1) statistical models, 2) state-and-transition models, and 3) mechanistic simulation models. Each category has advantages and disadvantages associated with their use. For the EARIP HCP, we recommend a mechanistic simulation model as it simulates how the ecological systems actually function (examples include Daly et al. 2000, Childress et al. 2002, Mata-Gonzalez et al. 2008). Most mechanistic simulation models are at least moderately-complex models, and some are extremely complex. The most sophisticated of the mechanistic simulation ecosystem models simulate a wide variety of ecological processes including hydrology, aquatic plant growth, aquatic species population dynamics, sedimentation, recreation, and climatic fluctuations, along with their interactions, at spatial scales ranging from small (less than 1 m^2) to entire landscapes. For the EARIP HCP, dynamics would be