United States Department of the Interior

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Consultation No. 21450-2007-F-0056

Mark. A. Pohlmeier, Colonel
Department of the Air Force
HQ AETC/A7C
266 F Street West
Randolph AFB, TX 78150-4319

Dear Colonel Pohlmeier:

This is the U.S. Fish and Wildlife Service's (Service) biological opinion based on our review of the effects of ongoing Edwards aquifer (Balcones Fault Zone) well withdrawals by the Department of Defense (DoD) on listed threatened and endangered species pursuant to the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (Act). The groundwater withdrawals support the existing and future missions at the following Department of Defense (DoD) military installations in Bexar County, Texas: (1) Fort Sam Houston, (2) Lackland Air Force Base (AFB), and (3) Randolph AFB (Figure 1).

Species evaluated for effects are the following: (1) Texas wild-rice (*Zizania texana*), (2) Peck's cave amphipod (*Stygobromus pecki*), (3) Comal Springs dryopid beetle (*Stygoparnus comalensis*), (4) Comal Springs riffle beetle (*Heterelmis comalensis*), (5) San Marcos gambusia (*Gambusia georgei*), (6) fountain darter (*Etheostoma fonticola*), (7) San Marcos salamander (*Eurycea nana*), and (8) Texas blind salamander (*Eurycea rathbuni*). We evaluated effects to designated critical habitat of the following species: Texas wild-rice, fountain darter, San Marcos gambusia, San Marcos salamander, Peck's cave amphipod, Comal Springs dryopid beetle, and Comal Springs riffle beetle.

Brooks City-Base also uses water from the Edwards aquifer. However, DoD did not want to include it in this consultation. Therefore, the incidental take statement below will not cover Brooks City-Base activities.

Camp Stanley and Camp Bullis were not included because they pump water from the Trinity aquifer. Research on the extent of cross-formational flow among aquifers in the San Antonio region, especially between the Trinity and Edwards aquifers, is underway. Should an evaluation of groundwater use at either Camp Stanley or Camp Bullis provide evidence of a discernable effect to the Edwards aquifer and listed species or their critical habitats, further discussion and potentially consultation may be needed.

This biological opinion is based on information provided in your biological assessment provided in November 2005, supplemental information provided by DoD, discussions with involved parties, and other information available to us in our files. A complete administrative record of this consultation is on file in the Austin Ecological Services Field Office.

Consultation History

Since 1996, DoD has been in contact with the Service for assistance in fulfilling their endangered species responsibilities, specifically related to the Edwards aquifer. On November 5, 1999, the Service provided a biological opinion for four military installations' use of the Edwards aquifer (Fort Sam Houston, Lackland AFB, Kelly AFB, and Randolph AFB). Kelly AFB was privatized pursuant to Base Realignment and Closure (BRAC) legislation. The area formerly known as Kelly AFB is now the Port of San Antonio. The biological opinion covering Edwards aquifer withdrawals by DoD has been amended and extended through December 31, 2007 (Service in litt. 2007).

On April 19, 2006, the Service and DoD met at Randolph AFB to discuss information needed to complete the biological assessment and have held several telephone discussions and electronic mail (e-mail) exchanges since then to clarify information on DoD aquifer withdrawals and hydrogeology. The Service provided a draft biological opinion on August 2, 2007. DoD provided comments on the draft biological opinion by letter dated October 1, 2007. The Service and DoD discussed those comments in a telephone conference call on November 5, 2007. The Service provided DoD with a revised draft opinion on December 7, 2007. DoD provided comments on the revised draft on December 19 and 20, 2007, and January 7, 2008.

BIOLOGICAL OPINION

Description of the Proposed Action

The DoD withdraws water from the Edwards aquifer to sustain its military missions at the three bases. Water use varies at each base depending on the activities supported at that time. The current mission and tenant organizations excerpted from the biological assessment (BA) follow.

Host Organizations and Current Missions

The three installations are home to multiple organizations and a variety of unique missions. At Fort Sam Houston, the organization that provides headquarters functions for the post is the U.S. Army Garrison. The host organizations for Randolph AFB and

Lackland AFB are the 12th Flying Training Wing (12 FTW) and the 37th Training Wing (37 TRW), respectively. Current DoD functions and missions are provided in Table 2-1 of the BA.

Since 1998, the missions at Fort Sam Houston have increased dramatically with the arrival of Headquarters Southwest Region Office, the Military Entrance Processing Station, the Navy Recruiting District, the Defense Reutilization and Marketing Office, U.S. Army South, and the United States Army Medical Information Technology Center. The post has traditionally performed, and continues to perform, five basic roles or missions: headquarters functions, logistical base, garrison, mobilization/training base, and medical activity. It continues in these roles today. However, the proportion of installation assets devoted to each mission has changed over time to meet current national security requirements. In addition, the new missions have increased the diversity of the basic functions at Fort Sam Houston. The normal activities associated with the daily functions of Fort Sam Houston and its associated properties are diverse and encompass nearly all of the activities of a small city, but with the addition of military training functions. The broad categories of activities associated with Fort Sam Houston can be broken down into the following nine basic functions: (1) administration and support; (2) construction and demolition; (3) research, development, test, and evaluation; (4) operation and maintenance; (5) light industry; (6) medical services; (7) recreation; (8) recruitment; and (9) training.

Randolph AFB continues to be an aviation training base. The 12 FTW provides pilot instructor and navigator training. The installation also supports instructional systems development training for undergraduate pilots and provides all logistics functions for the training wing and all of the tenant organizations located on the base. Lackland AFB is the "Gateway to the Air Force" with an expansive recruit basic training function. The 37 TRW has four primary training missions that graduate approximately 75,000 students annually. In addition to the training functions, the 37 TRW provides all logistics support activities necessary to operate the installation.

Tenant Organizations

Each of the three installations provides logistics support for multiple DoD tenant organizations. There are 10 major tenant organizations on Fort Sam Houston, 11 on Randolph AFB, and 11 on Lackland AFB. Additionally, there are many minor tenants on each installation.

Water Use

Water withdrawal from the Edwards aquifer under consideration in this consultation is water pumped directly by DoD from the Edwards aquifer. DoD use of purchased Edwards aquifer water will not be addressed under this section 7 consultation.

One objective of this biological opinion is to address water use increases in DoD populations due to BRAC. DoD anticipates that BRAC requirements may increase water use by about 50 percent. The Base Withdrawal Volume (BWV) of 424 acre-feet, identified in the BA, is the amount of water needed in a typical winter month. Since discretionary water use is at a minimum in winter, it represents the non-discretionary monthly water use. The BWV is used to calculate the maximum monthly withdrawal limits.

The main effects considered here are the incremental adverse impacts to the listed Edwards species and their critical habitats due to DoD's aquifer withdrawals and resulting decrease in springflows at Comal, Hueco, and San Marcos springs. Hydrogeologists have not resolved the source(s) that provide springflow to Fern Bank Springs. Our current understanding is that Fern Bank springflow may originate from the Trinity aquifer, water associated from the Blanco River, the Edwards aquifer, or some combination of these sources (George Veni *in litt.* 2006). The effects are expected to be more pronounced when Edwards aquifer levels are low because of drought or near-drought conditions.

The installations are like small municipalities, and as such, use water for varied purposes similar to the uses of other municipalities. Mission(s) may be altered, expanded or decreased and could differ from existing installation(s) activities and require a similar increase or decrease in water than currently used. Some of these uses are discretionary, while others are nondiscretionary. Nondiscretionary water uses are necessary to accomplish the missions and support the health and safety of resident employees and their families living on the military installations that pump water directly from the Edwards aquifer. Discretionary water uses on military installations that pump water directly from the Edwards aquifer include water used for irrigation; watering landscaping around administrative buildings and military housing areas, golf courses, parade grounds and similar areas; ornamental fountains; car washing; and maintaining levels in swimming pools used exclusively for recreation and not training.

Table 1 includes recent and projected water use by the subject installations. The Edwards Aquifer Authority (EAA) estimated total well withdrawal from the Edwards aquifer for calendar year 2005 at 388,500 acre-feet. In aggregate, DoD well withdrawals represent 1.29 percent of the 2005 well discharge from the aquifer.

Table 1. Department of Defense Edwards aquifer use current and projected missions.

Military Installation	2005 Annual Total Edwards Use	Projected Maximum Annual Use for period CY 2006-2011
Fort Sam Houston	1,685.18	2,974.73
Lackland AFB	2,440.69	3,627.90
Randolph AFB	887.29	996.48
Total	**5,013.16**	**7,599.11**

A large variety of DoD water conservation measures are detailed in the BA (section 4.3). Water savings have been realized through implementation of large-scale wastewater reuse systems at Randolph and repairs and modifications to the installations' water distribution systems. Randolph currently uses recycled water for irrigating their golf courses. The other two installations have also significantly decreased their dependence on the Edwards aquifer by using recycled water for golf course irrigation. For three golf courses, this amounts to a reduction of about 819 acre-feet per year. Lackland AFB has replaced about 165 acre-feet per year of Edwards water with recycled water at its Total Energy Plant.

Fort Sam Houston and Lackland have a higher percentage of their discretionary water use coming from the Edwards aquifer, 25 percent and 18.7 percent, respectively. Both Fort Sam Houston and Lackland are planning to further decrease their dependence on the Edwards aquifer by using recycled water for irrigating their golf courses as well as for other uses. Both installations have signed contracts with San Antonio Water System (SAWS) reserving options to buy recycled water.

Table 2, provided by DoD, shows the estimated annual well withdrawals by DoD for the five years covered by this opinion

The total aquifer withdrawal limits follow the annual amounts previously authorized by the enabling legislation for the Edwards Aquifer Authority (The Edwards Aquifer Authority Act, of May 30, 1993, 73rd Legislature, Regular Session, Chapter 626, 1993 Texas General Laws 2353, as amended).

Senate Bill 3 (SB 3) was enacted by the 80th Legislature and was signed into law by the Governor of Texas on June 16, 2007. Article 12 of SB 3, related to the EAA, became effective on June 16, 2007. SB 3 directs the Edwards Aquifer Authority to authorize annual (calendar year) groundwater withdrawal through various types of permits totaling 572,000 acre-feet. The actual amount of water authorized for withdrawal in a given year depends on the EAA's critical period management plan. Critical period management is based in part on subdivision of the Edwards aquifer into two pools, namely, the Uvalde and San Antonio pools. Critical Period Withdrawal Reduction Stages for the San Antonio pool provided in SB 3 (I, II, III, and IV) are triggered by the aquifer level measured at the Bexar County index well (J – 17) and springflow discharge at Comal and San Marcos Springs. Thus, in calendar years that involve implementation of any of the critical period stages, the total annual amount of groundwater withdrawal authorized will be less than 572,000 acre-feet. It is not clear whether this amount includes groundwater withdrawal (exempted from permits) for domestic and stock use, which in 2005 was estimated at 13,800 acre-feet.

Table 2. Estimated Department of Defense Well Withdrawals from the Edwards Aquifer covered under this opinion.

Estimated Annual Pumping from Edwards Aquifer by DoD in Acre-Feet					
2007	**2008**	**2009**	**2010**	**2011**	**2012**
6114	6360	6605	6852	7208	7208

Potential new potable water sources include obtaining surface water from projects being posed by existing surface water purveyors such as the Guadalupe-Blanco River Authority (GBRA) and Bexar Metropolitan Water District (BMWD).

Reclaimed wastewater effluent (reuse water) is another means to reduce Edwards aquifer water withdrawal. The uses of non-potable reclaimed water are broad, with turf irrigation being the primary proposed use at the military facilities. Randolph AFB holds rights to obtain reclaimed water from the Cibolo Creek Municipal Authority (CCMA) equal to 70 percent of the volume of wastewater the base conveys to CCMA. SAWS has constructed two water recycling systems that can serve three military installations considered in this opinion.

Water for both discretionary and nondiscretionary purposes will continue to be used efficiently and conservation efforts will be increased. Conservation measures are grouped into two categories: infrastructure components and educational programs. Each installation assesses the feasibility and compatibility of various conservation methods with its missions. A secondary objective for on-installation conservation measures and education programs is for employees to apply these programs at their residences.

Infrastructure conservation includes studies, modifications or improvements to the water distribution systems and water use fixtures. These may include leak detection, repairs, metering, repair and replacement of faulty fixtures and conversion to low or no flow devices. Industrial conservation could include cooling tower recycle studies, kitchen operations, car wash water recycling systems, and aircraft/large vehicle wash water recycling. Other miscellaneous conservation methods could include using pool covers, reusing water for irrigation, xeriscaping, rainwater and gray water collection, and curtailing use of ornamental fountains.

Educational conservation practices that have been and/or could be implemented include such actions as wide-spread distribution of water conservation goals, practices, and achievements in the form of kits, pamphlets, posters, ads, fact sheets, conservation training seminars, and incentive programs to reduce water use.

Proposed Conservation Measures

The DoD installations have identified measures they will actively pursue to further reduce water withdrawals from the Edwards aquifer. These are summarized in the biological assessment's sections 4.3 and 6.3

DoD's Critical Period Management Plan (CPMP)

DoD has a CPMP that is implemented when trigger levels are reached at any of the following locations: (1) aquifer levels as measured at the Bexar County Index Well on Fort Sam Houston (State Well No. AY-68-37-203, commonly referred to as J-17); (2) daily mean springflow discharge as measured at Comal Springs; or (3) daily mean springflow discharge as measured at San Marcos Springs. The trigger conditions are described in Table 3. DoD's CPMP is being implemented pursuant to the current biological opinion. Reduction goals are accomplished by setting time and/or day restrictions on irrigation of lawns, landscapes, or golf courses. The type of irrigation method may also be set. Limits are set on car washing, fire hydrant and sewer line flushing, and water to be served at eating establishments. Ongoing public education campaigns are intensified. Each stage gets progressively more restrictive and prohibitive of some actions. Other reduction methods may include closing pools and gymnasiums or non-essential facilities and prohibiting all water use not necessary for military readiness, safety of personnel and mission of the installation.

The Service has indicated that the probability of species survival and recovery is discernibly and significantly reduced for certain endangered species when flows go below 150 cubic feet per second at Comal Springs and 100 cubic feet per second at San Marcos Springs (Service letters dated April 28, 1993 and June 25, 1993). The existing CPMP allows flows at Comal to go to about 160 cubic feet per second during stage I and down to 60 cubic feet per second before level V (the emergency level) is implemented.

DoD has agreed to the revised drought management plan in Table 3. The last column in Table 3 provides the maximum monthly well withdrawals for the contingency that DoD mission changes resulting from BRAC increase the BWV by a factor of 1.5 times. DoD may increase the BWV annually, based on the previous year's consumption level, up to 636 acre-feet. These changes in water use are considered part of the project description. This flexibility will enable DoD to adjust its water use within a known range. Allowing for BWV adjustments will obviate the need to reinitiate formal consultation for potential new mission-related water needs. DoD will report on changes to the BWV in their annual report to the Service.

All installations that pump directly and considered under this opinion will adopt the same trigger levels and implement them simultaneously. This formal consultation covers DoD well withdrawals. DoD installations that buy Edwards aquifer water are not currently covered for incidental take of listed species. Installations that buy Edwards water follow the CPMP of the water purveyor. In general, the water use restrictions that are either directed or recommended by this biological opinion shall not interfere with the DoD to meet their health and human safety needs. If emergency circumstances and/or national security needs require Edwards aquifer water use to increase, the Service will work with DoD to ensure DoD needs are met.

Water Quality

Monitoring and maintaining good water quality is also important. Faults and wells that penetrate both aquifers are potential routes by which contaminants may flow into the Edwards. The serious potential for contamination of the Edwards aquifer has recently been highlighted in the proposed addition of the Bexar County Bandera Road site to the National Priority List by the U.S. Environmental Protection Agency (71 FR 56433). The risk of ground water contamination in Bexar County has been the subject of research by the U.S. Geological Survey (Clark 2000, Clark 2003) and others. Due to cross-formational flow between the Trinity and Edwards aquifers, the threat of contamination needs to be addressed for both aquifers in Bexar County.

Table 3. Department of Defense Critical Period Management Plan Staged Reductions for Fort Sam Houston, Lackland Air Force Base, and Randolph Air Force Base.

	Implementation Triggers*					
Stage	**Edwards Well J-17**	**Comal Springs Springflow**	**San Marcos Springs Springflow**	**Multiplier ****	**DoD Monthly Maximum Withdrawal Limit *** (Acre-Feet)**	**BRAC Contingency Monthly Maximum Withdrawal Limit ‡ (Acre-Feet)**
I	5 days where level ≤ 657.5 feet	5 days at or below 250 cfs	3 days at or below 80 cfs	1.700	721	1081
II	5 days where level ≤ 647.0 feet	5 days at or below 200 cfs	Any Stage I trigger, plus 3 days at or below 80 cfs	1.600	678	1018
III	5 days where level ≤ 642 feet	5 days at or below 180 cfs	Any Stage II trigger, plus 3 days at or below 80 cfs	1.400	594	890
IV	5 days where level ≤ 640.5 feet	5 days at or below 160 cfs	Any Stage III trigger, plus 3 days at or below 80 cfs	1.300	551	827
V	3 days where level ≤ 637.0 feet	3 days at or below 100 cfs	Any Stage IV trigger, plus 3 days at or below 80 cfs	1.185	502	754

cfs cubic feet per second
Source: Department of Defense 1998
* As estimated by U.S. Geological Survey; Only one trigger required to implement savings measures
** As calculated in the 1999 Biological Opinion
*** Based on a Base Monthly Withdrawal Volume (BWV) of 424 Acre-Feet
‡ Based on a BWV of 636 Acre-Feet, which is an increase of 50 percent to the BWV (424 Acre-Feet), and ongoing efforts to reduce Edwards aquifer use.

<u>Status of the Species and Critical Habitat</u>

Texas wild-rice

Texas wild-rice was listed as endangered on April 26, 1978, and its critical habitat was designated on July 14, 1980. Critical habitat includes Spring Lake and its outflow, and the San Marcos River, downstream to the confluence with the Blanco River.

The first collection of Texas wild-rice was by G.C. Neally in 1892 (Service 1996). The plant was formally described and named by Hitchcock in 1933 (taken from Terrell *et al*. 1978). Texas wild-rice is an aquatic, monoecious (pistillate and staminate flowers are on the same plant), perennial grass, which is generally 1-2 meters long and usually immersed and prostrate in the swift-flowing water of the San Marcos River. The inflorescence and the upper culms and leaves become emergent as flowering commences. Flowering and seed set occur primarily from late spring through fall but may occur sporadically at other times in warm years (Service 1996). In slow moving waters, Texas wild-rice plants function as annuals, exhibiting less robust vegetative growth, then flowering, setting seed, and dying within a single season.

Texas wild-rice occurs only in Spring Lake and the upper San Marcos River, above the confluence with the Blanco River. Plants form extensive stands in substrates of fine gravels, small gravels, sand, medium gravels, and silt (Saunders *et al.* 2001). Other native species that occur in the same general area of the river inhabited by Texas wild-rice include pondweed (*Potamogeton illinoensis*), watercelery (*Vallisneria* sp.), arrowhead (*Sagittaria platyphylla*), hornwort (*Ceratophyllum demersum*), and water primrose (*Ludwigia repens*). Non-native species now commonly present include hydrilla (*Hydrilla verticillata*), hygro (*Hygrophila polysperma*), and elodea (*Egeria densa*).

Distribution and Status - When described in 1933, Texas wild-rice was indicated to be abundant in the San Marcos River, including Spring Lake and its irrigation waterways (Silveus l933, Terrell *et al.* l978). In the 1960s and 1970s, investigators found very little Texas wild-rice remaining. Estimated coverage of wild-rice in 1976 was 1,131 m^2 (Emery 1977). Vaughan (1986) reported annual wild-rice coverage from 1983 through 1986 to be 541, 462, 489, and 454 m^2, respectively. Texas Parks and Wildlife Department (TPWD 1989) has been monitoring Texas wild-rice annually since 1989 (Table 4). TPWD's efforts have documented that Texas wild-rice is growing in a slightly greater geographic area than during its most sparse period of record in the 1970s, though not all of these recorded stands have persisted (Poole and Bowles, l996). Records of wild-rice plants below the outfall of the City of San Marcos wastewater treatment plant outfall are limited to two. Both of those stands are presumed lost.

TPWD (2006) and BIO-WEST (2006) provided recent updates to Texas wild-rice areal coverage. Figure 2 shows the boundaries of segments used by TPWD in their annual surveys.

Several changes in the Texas wild-rice coverage are noteworthy. A large flood occurred in October 1998 between the 1998 and 1999 surveys, which are typically in July or August. Texas wild-rice stands downstream of Interstate Highway 35 suffered significant losses. In August 2006, five wild-rice plants were lost in Segment E in the area between Rio Vista Dam and Cheatham Street Bridge. Recently, researchers from BIO-WEST and TPWD noticed a significant loss of wild-rice in Segment A. It appears that sometime between August and late September of 2006, people destroyed about 237 meters^2 of the wild-rice in Segment A. Over 56 percent of Texas wild-rice occurs in Segment B and in August 2006, over 83 percent of it occurred in Segments A, B, and C (TPWD 2006). Texas wild-rice recovery recommendations advocate increased areal coverage range wide (Table 5).

Habitat and Life History - Saunders *et al.* (2001), citing Watkins (1930) and Devall (1940), reported that Texas wild-rice was a dominant species in Spring Lake in the period 1930–1940. Emery (1967), Emery and Guy (1979), Poole and Bowles (1996), and Poole (2006) have documented the decline in areal coverage in Spring Lake and the upper San Marcos River.

Velocity and Depth Suitability: Optimum habitat for Texas wild-rice consists of relatively clear waters with high to moderate current velocities 1.0-2.0 feet per second and depths between 1.6-3.3 feet (Poole and Bowles, l996).

Saunders *et al*. (2001) developed Texas wild-rice habitat suitability curves for velocity (mean column), depth, and substrate (Figure 3). Power (1996) reported that wild-rice stem density in raceway culture was greater in higher velocity regime 1.3-1.6 feet per second relative to moderate velocities 0.4-0.8 feet per second and slow flowing water 0.16 to 0.4 feet per second.

Wild-rice has been observed in sites deeper than 4.9 feet, but stands do not do well. Minimum depths tolerable for Texas wild-rice are believed to be in the 0.66-0.98 feet range. Texas wild-rice stands in less than one foot are more vulnerable (than stands in deeper water) to desiccation, exposure, and recreation impacts.

Wild-rice appears to grow best in areas with a mean column velocity of 0.3 to 2.0 feet per second (Saunders *et al.* 2001). One concern has been high velocities near the root mass may damage plants by eroding substrates around the plant (Seal and Ellis l997). However, for median and lower river discharges, velocities exceeding one foot per second are rare in the upper San Marcos River (see Saunders *et al.* 2001 and Institute for Natural Systems Engineering 2004). These higher velocity areas are generally restricted to short segments below small dams.

Spring flow and San Marcos River discharge are critically important for growth and survival of Texas wild-rice (Saunders *et al.* 2001). Texas wild-rice requires carbon dioxide as its inorganic carbon source for photosynthesis rather than bicarbonate, which other aquatic plants commonly use (TPWD 1994; Seal and Ellis 1997). While bicarbonate is commonly available in solution in aquatic systems, carbon dioxide diffuses very slowly in water and is readily available only in relatively fast-moving waters and near spring openings. Obligate carbon dioxide-using species may be carbon limited in low flow situations. Velocity has been shown to influence photosynthesis of submerged vegetation (Madsen and Sondergaard 1983; Prins and Elzenga 1989).

Substrate suitability: Experimental work by Power (1990) and Power and Fontyn (1995) concluded that seed germination was triggered by low oxygen in anaerobic sediments, and that seedlings grow well in fine textured sediments. Power has continued to grow plants from seed successfully in fine sediments for cultivated collections and subsequent experimental work. Poole and Bowles (1996) challenge that finding and state, based on transect studies of Texas wild-rice in its natural habitat in l994 and l995, that Texas wild-rice grows preferentially in coarse to sandy substrate. However, it should be noted that Poole and Bowles took substrate samples on the edges of the wild-rice stands to avoid root impacts. Substrate characteristics there may be influenced in part by the impact of the stand itself on flow dynamics around the stand, and may be slightly different than those on the interior of stands. Later (1996) collection of wild-rice specimens for the captive conservation collection involved collecting plants from over 80 sites in the river and observations about substrate texture were made at the time of collection. These collections were taken for the most part more in the interior, receding half of stands.

Observations of these collections include many sands and fine sands, frequently with silty components. Additional work is probably needed to clarify the sediment texture tolerances and requirements of Texas wild-rice.

Reproduction of *Z. texana* occurs either sexually via seeds or asexually (clonally) through stolons. Sexual reproduction occurs through formation of seed produced from wind pollinated florets. Texas wild-rice seed is not long-lived, and no appreciable seed bank would be expected. Viability begins to drop markedly within one year of seed production. Asexual reproduction occurs where shoots arise as clones at the ends of rooting stolons (Emery and Guy 1979).

The genetic variability and structure in the wild population of Texas wild-rice was studied by Richards *et al.* (in manuscript 2007). They genotyped 471 individuals from segments A through K and found relatively high heterozygosity and allelic diversity. Their paper will be useful in informing *ex situ* and *in situ* conservation of wild-rice. For example, if there is no longitudinal structure, recovery efforts can use tillers and seeds from segment B to restore wild-rice in any of the other segments.

Most areas where Texas wild-rice still occurs are within areas recorded as having plants mapped by Emery in the late 1970s and earlier. TPWD monitoring since 1989 has demonstrated stands are capable of relatively long-term persistence and expansion over large areas of substrate. Based on these observations of persistence and its perennial nature, Texas wild-rice does not appear to be a purely successional species with a dynamic, cyclic life history strategy. Successional species adapted for rapid colonization of highly disturbed environments generally rely on frequent dispersal of large numbers of

Table 4. Annual Texas wild-rice areal coverage in meters^2 estimated by Texas Parks and Wildlife Department

SEGMENT	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
A	38.7	34.4	35.9	31.7	49.0	57.4	75.8	77.6	104.4	141.6	256.4	285.6	325.7	410.5	361.2
B	267.4	417.2	513.1	555.1	519.7	766.5	661.8	745.1	991.2	1035.0	1312.0	1799.6	2299.5	2332.1	2529.3
C	540.7	442.6	514.3	460.0	416.1	422.6	493.1	553.3	399.2	425.7	716.9	655.6	830.9	735.0	726.6
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	7.2	12.2	8.4	8.7
E	77.1	62.9	81.2	72.8	76.3	67.8	38.7	24.3	20.0	11.8	19.7	21.2	6.1	5.1	6.1
F	429.4	270.5	276.3	276.0	335.4	327.6	339.5	350.5	359.4	298.4	429.1	460.2	426.1	551.0	539.4
G	20.3	17.6	14.7	10.6	12.0	20.8	23.3	20.9	4.8	6.7	9.7	12.1	16.8	18.2	17.0
H	1.3	3.7	5.0	4.4	2.4	2.8	2.9	3.7	1.0	0.9	12.6	20.4	25.5	15.9	20.2
I	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J	96.6	76.2	46.6	37.0	37.0	48.8	7.3	6.2	6.7	3.0	5.4	0.0	7.3	6.4	5.9
K	136.2	129.5	136.2	202.6	134.4	234.9	2.6	9.6	9.0	5.1	9.8	127.9	37.4	71.9	57.4
L	0.5	1.5	0.5	2.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	6.7	5.8
M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	1608.4	1456.3	1624.0	1652.1	1584.2	1949.3	1644.9	1791.1	1895.6	1916.3	2776.0	3389.6	3992.7	4161.1	4277.5

Table 5. Texas Wild-Rice Recovery Criterion: Areal Coverage Minima in Meters^2

Segment	meters² of Zizania
Spring Lake	1,500
A	1,400
B	5,000
C	1,000
D	100
E	500
F	900
G	100
X	50
H	30
I	50
J	400
K	700
L	100
M	100
Total	11,930

propagules to colonize open sites. Successional stands that become established are usually relatively short-lived, declining and becoming displaced as the site is stabilized and occupied.

Texas wild-rice tillers have been observed floating downstream. Some of these tillers may become established plants if lodged in suitable substrate and physical habitat. Clonal reproduction appears to be the primary mechanism for expansion of an established stand, but it does not appear to be an efficient mechanism for dispersal and colonization of new areas. A life-history strategy using sexual reproduction for dispersal and asexual reproduction within the parental habitat is common in both plants and animals (Sebens and Thorne l985). Seed production may be essential for dispersal and establishment of new stands in Texas wild-rice.

Abundance and trends - The annual Texas wild-rice reports by TPWD include total cover in the river in meters^2, total cover designated within lettered (A, B, C, etc.) river segments, and individual stand-by-stand history. Recent work includes converting the survey data for wild-rice (distance and azimuth from Texas wild-rice survey monuments) to ArcView GIS shapefiles. Total areal coverage in the last few years has increased (Table 4). However, the increase has been concentrated in a few upper segments resulting in a distribution presumably more vulnerable than one of similar total coverage spread proportionally among the segments. As discussed above and below, some situations (such as low flow or seasonal events) may result in losses and impacts that are difficult to discern in an annual survey. The Edwards Aquifer Authority has contracted with BIO-WEST, Inc. to regularly monitor the Comal and upper San Marcos rivers, including surveys of Texas wild-rice and special efforts during lower springflows.

Only a few of 14 river segments has wild-rice seen significant, persistent expansion (segments A and B). Many stands have fluctuated in size from year to year, with frequent significant drops in cover. This raises concern about the likelihood of wild-rice persisting in those segments. Within almost every segment, several stands have disappeared altogether, which also represents a loss of potentially important adaptive genetic material. Many stands and several entire segments (H, I, and J) show an overall decline, relative to the early years of monitoring. These losses are of concern since sexual reproduction (in general) and recruitment of significant numbers of new plants or stands (in these segments) are not occurring. Upon close examination, some records of new stands may be due to the fragmentation and thinning of existing stands rather than to expansion. These fluctuations need to be carefully analyzed in the context of their location and local and system-wide threats to identify and manage problems that may be causing losses or declines (Service 1996).

It appears that plants have not successfully produced significant quantities of seed in the San Marcos River for many years (Emery 1977; Vaughan 1986; Service 1996). However, Richards *et al*. (2007) inferred that sexual reproduction occurs more often than presumed based on observed high heterozygosity. Photos taken near the A.E. Wood Fish Hatchery (historically one of the most robust areas for Texas wild-rice) in the 1980s show a stand blooming well (Paula Power, research photos). Since TPWD's annual monitoring began in l989 however, little inflorescence formation has been noted, and only on one or two occasions have any inflorescences been observed to have set seed in the wild (Jackie Poole, TPWD, and Paula Power, SMNFH, pers. comm. 1995). Plants grown in raceways in cultivation under protected conditions bloom well and produce seed in quantity (Rose and Power 1992). The failure of river grown wild-rice to produce seed in the wild is not thought to be a result of genetic, cytological, or embryological problems, but rather to some extrinsic factor or factors (Emery and Guy 1979). Triggers for flowering are not well understood. Herbivory, particularly by waterfowl, is believed to contribute to inflorescence losses. Impacts by recreational users of the river has also been postulated to interfere with flowering and seed set.

Low flow incidents are of particular concern because of the potentially catastrophic impact such events can have on Texas wild-rice. During the low flow years l990 and l996, significant numbers of Texas wild-rice stands were recorded in depths less than optimum depth. Six out of 11 segments identified (that currently have stands of wild-rice) had more than 30 percent of their stands in depths considered too shallow to be fully suitable. Four out of 11 segments had more than one-third of stands at depths below the minimum needed for survival.

The drought conditions in 1996 resulted in direct and indirect adverse impacts to the existing Texas wild-rice plants. In May 1996, low springflows resulted in the dewatering of significant portions of large stands in TPWD monitoring segments, particularly segments A, E, and F. These three segments together comprise about 25 percent of the proposed recovery area needed for downlisting of the species. The 2007 wild-rice survey will aid in understanding the impacts of lower than average flows in 2006.

In some deep water areas, (particularly in segments B, G, J, and K) root balls of large established plants were also observed to be eroding and exposed, apparently because changes in flow characteristics changed the velocities through these areas (Kathryn Kennedy, Service, pers comm, l996).

Low flows also resulted in floating mats of vegetation fragments (which normally move slowly downriver) becoming hung up in wild-rice leaves that were near the surface, increasing in size and shading out wild-rice as well as mechanically damaging plants (Power 2002 page 579, Poole 2006). Recreational users are also thought to cause damage to wild-rice during low flows because leaves are closer to the surface and more extensive shallow areas result in wading and play areas where, under more normal flows, greater depths would have afforded plants more protection.

Recovery needs - The recovery plan calls for establishing healthy, self-sustaining, and reproductive populations throughout the historic range before the species can be considered for downlisting. Recovery criteria call for 75 percent cover in prescribed areas of potential habitat for wild-rice, which is the percent cover typical of that found in healthy, vigorous stands (Table 5, Service 1996). BIO-WEST (2007) estimated that as of October 3, 2006 there were 3,000.4 meters^2 of wild-rice, which is about 25 percent of the target coverage to meet, in part, the Texas wild-rice recovery criteria.

Threats - The Recovery Plan identifies the potential loss of springflows needed to support riverine habitats as a primary threat for Texas wild-rice. Current water use trends indicate that without conservation action and reduction in demands for Edwards aquifer water, low flow periods of increasing frequency and duration can be expected, with associated significant impacts to Texas wild-rice.

San Marcos springflows for most of 2006 have been well below the long-term average discharge. Regional precipitation and recharge in the first half of 2007 have led to higher than average aquifer levels and springflows. South central Texas in early 2008 is expected to have lower than normal precipitation and higher than normal temperatures due in part to a strengthening of La Niña conditions (El Niño / Southern Oscillation (ENSO) Discussion paper from Climate Prediction Center, National Weather Service 2007).

On June 14, 1992, the Edwards aquifer levels reached a historic level of 703.3 feet (NGVD 1929) at the Bexar Index Well (J-17). Above average conditions for Edwards aquifer continued into 1993. On August 25, 2007, the Bexar Index Well approached this record high with a reading of 700.2 feet. While current aquifer levels are significantly higher than average, the aquifer can decline from record highs to levels where springflows are significantly lower than average in as little as three years. In the summer of 1996, springflows at both Comal and San Marcos springs were inadequate to maintain average habitat conditions. Texas wild-rice areal coverage remained effectively the same in 1996 as 1995, in contrast to more recent years when coverage grew.

Rose and Power (1992) noted that non-point source pollution, floating mats of vegetation, recreational users of the river, and herbivorous waterfowl most likely have a negative impact on wild-rice, as well as changes in the composition of sediments, depletion of the soil seed bank, and plant competition particularly from the exotic hydrilla (*Hydrilla verticillata*), which has been observed surrounding stands of Texas wild-rice.

Various threats to the wild-rice documented by Emery in 1967 included floating debris, bottom plowing, plant collection, and pollution. Poole (2006) reported on the extensive efforts to remove floating mats of vegetation that lodged on Texas wild-rice. Texas wild-rice is threatened by these mats, which virtually block all sunlight resulting in chlorotic wild-rice stands, i.e., many, if not most, of the leaves turn light green and then yellow. Four mat removal efforts were made in 2006 in Segment B (Sewell Park) with a total 17.2 meter^3 of floating vegetation fragments removed to protected compost sites. Coontail (*Ceratophyllum demersum*) accounted for about half of the vegetation removed.

Beaty (1975) noted that the location of the habitat for the wild-rice was in a densely populated and high use area, which subjected these waters to pollution by inflows of the city storm drainage system, occasional raw sewage leaks, and normal stormwater runoff from streets, railroads, and recreational areas. Competition by introduced and native species of plants (Vaughan 1986), predation by animals (waterfowl, nutria, and giant rams-horn snail [*Marisa cornuarietis*]), recreational use of the river, and dams are factors that are known to (or may) negatively impact wild-rice.

Texas wild-rice is anticipated to be more susceptible to damage from recreational activities and/or herbivores such as nutria, during times of decreased flow (Saunders *et al.* 2001). The last several years have seen an increase in kayak and canoe use in Segments D, E, F, G, and H.

Rio Vista Dam has been modified into a series of three chutes specifically designed to attract water recreationists. In Segment E, a 2,187 meter^2 section of the San Marcos River has been rendered unsuitable for wild-rice and other macrophytes. The 2006 construction of Rio Vista Falls involved deposition of rubble substrate (32 to 64 millimeters) throughout the river bed. This substrate generally precludes colonization by aquatic macrophytes. It appears that some of the various sized substrates (including large gravels, cobble, and rubble) dumped in this section are moving downstream to lower reaches of Segment E and degrading macrophyte habitat suitability.

Status of Critical Habitat - Texas wild-rice critical habitat includes Spring Lake and extends downstream to the confluence of the Blanco River. The Texas wild-rice critical habitat designation (Service 1980) emphasizes the importance of the following factors: (1)

flow in the San Marcos River, (2) water quality, (3) substrates, and (4) disturbance to Texas wild-rice stands. Wild-rice critical habitat encompasses 24.8 hectares of the uppermost reach of the San Marcos River.

Pursuant to Federal Judge Lucius Bunton's order, the Service provided determinations of springflows that would result in damage to wild-rice and adverse modification of its critical habitat (Service in litt. 1993). The Service determined that damage to wild-rice and adverse modification of critical habitat occurred when springflows decreased to and below 100 cubic feet per second, given conditions at that time. San Marcos springflows currently (December 2007) are above the long-term mean (average) discharge. However from August through December 2006, San Marcos springflows have been near or below 100 cubic feet per second.

TPWD (Saunders *et al*. 2001) provides a summary of expected effects for a range of discharges in the upper San Marcos River on aquatic plants, including Texas wild-rice (Figure 3). During what they label dry conditions (flows up to 125 CFS of sufficient duration), habitat conditions for many of their target species were below average for all three study segments.

Annual Texas wild-rice surveys provide estimates of areal coverage of each stand. However, we are usually unable to determine the factors that result in losses of stands or decrease in their biomass. Adverse impacts from water recreationists, vandalism, floating vegetation mats, substrate disturbance, shading, herbicides in runoff, depredation by waterfowl and invertebrates, and suboptimal (or unsuitable) water depths and velocities are all considered factors affecting Texas wild-rice critical habitat.

Comal Springs Invertebrates

The Service listed three aquatic invertebrate species known only from Comal and Hays counties, Texas, as endangered under the ESA on December 18, 1997 (62 Federal Register [FR] 66295). These species are dependent on the Edwards aquifer. The primary threat to these species is a decrease in water quantity and quality as a result of water withdrawal and other activities by humans throughout the San Antonio Segment of the Edwards aquifer. Critical habitat has been designated for these species (July 17, 2007; 72 FR 39248). The status of Peck's cave amphipod, Comal Springs riffle beetle, and Comal Springs dryopid beetle follows.

Peck's Cave amphipod

Peck's cave amphipod is a subterranean, aquatic crustacean that is eyeless and unpigmented. This amphipod is an obligate aquatic stygobiontic species, an aquatic species ecologically restricted to caves and subterranean groundwaters, found around spring openings of the Edwards aquifer. Limiting conditions for the amphipod may include decreased spring flow, stagnation of water, and decreased water quality (Service 2007).

Distribution and Status - The first recorded specimen of Peck's cave amphipod was collected at Comal Springs in June 1964. Since then over 300 specimens have been collected, most from crevices in rock and gravel near the orifices of the three largest Comal Springs on the west side of Landa Park. The species has also been collected from a fourth Comal spring run adjacent to Landa Park and one specimen has been collected from Hueco Springs, about 7 km north of Comal Springs (Barr 1993). Randy Gibson of the San Marcos National Fish Hatchery and Technology Center has recently (Gibson *et al.* 2006) collected Peck's cave amphipod at several springs in Landa Park / Landa Lake as well as Hueco Springs. The subterranean distribution of Peck's cave amphipod (66 feet or 20 meters below land surface) was documented by Krejca (2005), when one specimen was collected from Panther Canyon well (also known as Landa Park well and well no. DX-68-23-302).

Habitat and Life History - Peck's cave amphipod habitat is primarily subsurface water-filled conduits and crevices of the Edwards aquifer (Balcones fault zone) in Comal County. Amphipods generally are omnivorous and confined to substrates (Pennak 1989). Pennak noted amphipods are often seen browsing on film of "microscopic plants, animal, and organic debris covering leaves, stems and other substrates" (biofilm). Pennak (1989) stated that subterranean amphipod food may consist of dead vegetation that enters caves and thin bacterial scum covering submerged surfaces. Krejca (2005) found Peck's cave amphipod in baited traps set at 20 meters below land surface. The water level was about 7 meters below land surface. Peck's cave amphipod critical habitat includes an area encompassed by a 15.2 meter buffer around: (1) Hueco Springs; and, (2) Comal Springs and spring-dominated reaches of Landa Lake. This was done to include amphipod food sources in root/water interfaces. Tree roots may extend a similar distance and penetrate the aquifer in these areas, providing a source of living and decaying matter for the trophic levels supporting amphipods.

Abundance and Trends - Little is known about population size of the two known localities. The most recent survey data (2006) is reported by Gibson *et al.* (2007) and BIO-WEST (2006, 2007). Gibson used drift nets deployed for about 24 hours and reported drift rate (number of individuals collected per day). The drift rate for Peck's cave amphipod at Comal Springs was 9.2 individuals per day, which was significantly higher than the drift rate at Hueco Springs (1.2 individuals per day). Future collections with the same technique will enable a comparison to these values. Additional factors to be considered are the springflow discharge for the sample period and seasonal variation.

The Comal Springs drift rate found by Gibson was similar to Barr (1993), who found 9.6 individuals per day. Barr only found one specimen in a drift net sample set for 96 hours at Hueco Springs yielding a drift rate of 0.25 individuals per day.

Recovery Needs - The San Marcos and Comal Springs and Associated Aquatic Ecosystems (Revised) Recovery Plan (Plan) (Service 1996) describes the needed actions to conserve the ecosystems associated with Edwards aquifer species listed in 1996. The Comal invertebrates were not listed at that time. However, the general strategy for recovery is expected to be similar to that in the Plan. Recovery of the Edwards species will depend on efforts that address: (1) regional water use and landscape level management to protect these systems; (2) local actions taken by landowners and local governmental entities; and (3) site specific and species specific conservation actions.

The two known localities for collecting Peck's cave amphipod are Comal and Hueco springs, both associated with the Edwards aquifer. While many research efforts have focused on the Edwards aquifer (Balcones fault zone) over the past three decades, few have dealt with the specific delineation of: (1) flowpaths to Hueco Springs; (2) recharge zones affecting Hueco Springs; (3) discharge features (wells and other springs) affecting Hueco Springs; and (4) vulnerability of the Edwards aquifer near Hueco Springs to contamination. Guyton and Associates (1979) considered the Hueco Springs recharge area to include a local contribution, the Dry Comal Creek basin north of the Hueco Springs fault, the Guadalupe River basin recharge area west of the river, and possibly the upper part of the Cibolo Creek basin recharge area. Guyton and Associates also opined that no recharge for Hueco springs occurs from an area east of the Guadalupe River. The Edwards Aquifer Authority is considering a system of new dams to enhance recharge.

Threats - Threats include: (1) the reduction or loss of physical habitat in the water filled cavities, due primarily to human withdrawal of water from the Edwards (Balcones Fault Zone) aquifer; (2) the degradation of water quality through pollution (potentially involving insecticides, herbicides, fertilizers, hydrocarbons, metals, and detergents) of the Edwards aquifer; (3) the introduction of a novel predator (e.g., fish) or disease into Peck's cave amphipod habitat; and, (4) mortality due to well entrainment. Threats that are unique to Peck's cave amphipod, relative to other species in this consultation, include activities that would impair the flow of ground water near Hueco Springs or otherwise degrade its water quality.

Status of Critical Habitat - Critical habitat for the Peck's cave amphipod has been designated for two localities (units) (Service 2006; Figures 4 and 5). The largest unit is Comal Springs and that part of Landa Lake associated with the springs. The other is the Hueco Spring unit, which encompasses the main and satellite springs.

The primary constituent elements (PCE) of critical habitat for the Peck's cave amphipod include: (1) unpolluted high-quality water, (2) aquifer water temperatures that range from approximately 68 to 75 °F (20 to 24 °C) and turbidity less than 5 nephelometric turbidity units (NTUs), (3) a hydrologic regime that provides adequate levels of dissolved oxygen, (4) food supply that includes, but is not limited to, detritus, leaf litter, and decaying roots, and (5) substrates ranging in size from 0.3 to 5.0 inches (8 to 128 mm). Pollutants of concern include any wetting agents such as soaps or detergents, metals, pesticides, fertilizer, and volatile organic compounds.

Currently, the estimated daily mean spring discharge from Comal Springs is above 400 cubic feet per second (CFS). The average discharge for the period of record (November 12, 1932 through September 30, 2006) is about 290 CFS (U.S. Geological Survey 2006). The spring discharge data for Hueco Springs are less complete. The U.S. Geological Survey (USGS) reported the annual discharge of Hueco Springs (in acre-feet rounded to the nearest thousand acre-feet) was 1000 for 1954, 1000 for 1955, and zero for 1956. The USGS established a discharge gaging station at Hueco Springs in November 2002. Hueco Springs monthly mean discharge in the period of record (December 2002 through September 2005) ranged from 21.8 CFS in January 2002 to 116.6 CFS in January 2003. Hueco Springs discharge provisional data from USGS for December 8, 2006 indicate Hueco Springs daily mean discharge fell to 3.1 CFS. However, recent rains have resulted in Hueco Springs discharge exceeding 90 CFS.

The USGS, EAA, and BIO-WEST are engaged in various water quality monitoring efforts at Comal Springs and to a lesser extent at Hueco Springs. The most current published assessment of water quality in the Edward aquifer (EAA 2006) reported a Bexar County water well (AY-68-36-1DR) had the compound tetrachloroethene (PCE) at 30.5 µg/L. The maximum contaminant level for PCE is 5.0 µg/L. The Texas Commission on Environmental Quality (TCEQ), EAA, U.S Environmental Protection Agency, USGS, and SAWS are investigating the source of this pollution.

Comal Springs riffle beetle

Comal Springs riffle beetles (family Elmidae), are aquatic beetles and adults are about 2 mm long. The beetle is found in gravel substrate and shallow riffles in spring runs at depths of 2 to 10 cm, sometimes deeper.

Distribution and Status - The Comal Springs riffle beetle is known from two localities**:** Comal Springs and nearby habitats in Landa Lake including the spring runs, and San Marcos springs and associated habitats in Spring Lake. Other riffle beetles occur in the spillways below Spring Lake Dam though none have been identified as *Heterelmis comalensis*.

Comal Springs riffle beetles have been collected from spring runs 1, 2, 3, at Comal Springs in Landa Park and various springs in Landa Lake. Multiple specimens have been collected from San Marcos Springs in Spring Lake 32 km (20 miles) to the northeast. The distribution in Spring Lake has not been fully resolved; however all of the collection sites are associated with springs in the upper part of the lake by the Texas Rivers Center (formerly Aquarena Inn).

Habitat and Life History - Observations on habitats are provided in Barr (1993), Norris (2002), Bowles *et al.* (2003), BIO-WEST (2006, 2007), and Gibson *et al.* (2007). These include sampling the substrates, leaf-wood debris, the water column, and most recently, with cotton cloth lures. Comal Springs riffle beetles are found among gravel and larger substrates near spring orifices – upwellings. What little is known of their life history and habitat preferences is summarized in Bowles *et al.* (2003). BIO-WEST (2006) reported that riffle beetles may take 6 months to three years to complete their life cycle from egg, larvae, to adult. Bowles *et al.* (2003) indicated that Comal Springs riffle beetles appear to have overlapping and asynchronous generations in Comal Springs and may be associated with aquatic vegetation.

Abundance and Trends - BIO-WEST (2006, 2007) and Gibson *et al.* (2007) documented the continued presence of Comal Springs riffle beetles in Comal Springs. An assessment of population size is not available. However, BIO-WEST (2007) reported a collection of 1,013 Comal Springs riffle beetles in 2006. Bosse *et al.* (1988) reported populations may be at their highest from February to April although no data were presented. Bosse (1979) presented data on a limited number (n = 38) collected from February 1976 through March 1977. Bowles *et al*. (2003) found that their surveys indicated the emergence pattern for Comal Springs riffle beetle is non-seasonal, which is generally consistent with other spring-dependent elmids.

Surveys in 2006 by BIO-WEST and staff from the San Marcos National Fish Hatchery and Technology Center established that Comal Springs riffle beetles continue to inhabit San Marcos Springs in the upper portion of Spring Lake (BIO-WEST 2007) and possibly spring-like and riffle habitats around Spring Lake Dam (Randy Gibson, Service, pers. comm., 2007).

Nice and Gonzales (2007) have recently examined the genetic variation and structure in the Comal Springs riffle beetle and related species. Their work will be helpful in determining the degree to which Comal Springs populations are isolated from each other.

Recovery Needs - Recovery needs for the Comal Springs riffle beetle are similar to those described for Peck's cave amphipod. The conservation of existing (and any newly discovered) populations will depend on: (1) the maintenance of physical habitat including an adequate springflow regime, (2) supportive aquifer and spring water quality, (3) the biological integrity of Comal Springs riffle beetle habitats, and (4) abatement of threats.

Threats - Threats to Comal Springs riffle beetles are described in the final rule for its listing (62 FR 66295) and the designation of critical habitat (71 FR 40588). The primary threat to this species is a decrease in water quantity and quality as a result of water withdrawal and other human activities throughout the San Antonio segment (Balcones fault zone) of the Edwards aquifer.

Natural water flow is important for the respiration and survival of the riffle beetle, which has a mass of tiny, hydrophobic (unwettable) hairs on its underside to maintain a bubble of air for gas exchange (Chapman 1982). Stagnation of water and/or drying within the spring runs and the photic (lighted) zone of the spring orifices would probably be limiting for the riffle beetle, which depends on natural spring flows for respiration and survival (Chapman 1982).

In 1984 and 1990, some of the higher elevation Comal Springs ceased flowing and water levels in the Bexar County Index Well (J-17) on Fort Sam Houston, San Antonio dropped to within twelve feet of the historic low of 612.5 feet that occurred in 1956 (Wanakule 1990). Flows also ceased in the upper spring run (Spring Run 1) in 1991 and 1996.

One concern is that an inadequate flow regime may lead to loss of a population. Re-establishment of the population would be difficult since captive breeding techniques for this species have not yet been developed. In addition, the probability of natural colonization of more isolated sites may be small.

The Spring Lake population currently is known only from the springs associated with a limestone bench adjacent to the Aquarena Springs Inn. If groundwater flowpaths to these springs were impaired, the San Marcos population of Comal Springs riffle beetles may be at risk. Groundwater management of the San Marcos pool (subset) of the Edwards aquifer will be crucial to the viability of this population.

Status of Critical Habitat - Critical habitat for the Comal Springs riffle beetle has been designated for both known localities (units) (Service 2007; Figures 6 and 7). The largest unit is Comal Springs and that part of Landa Lake associated with the springs. The other is the San Marcos Springs unit, which encompasses the spring dominated portion of Spring Lake.

The primary constituent elements (PCE) of critical habitat for the Comal Springs riffle beetle include: (1) unpolluted high-quality water, (2) aquifer water temperatures that range from about 20 to 24°C and turbidity less than 5 nephelometric turbidity units (NTUs), (3) a hydrologic regime that provides adequate levels of dissolved oxygen, (4) food supply that includes, but is not limited to, detritus, leaf litter, and decaying roots, and (5) substrates ranging in size from 8 to 128 mm. Pollutants of concern include any wetting agents such as soaps or detergents, metals, pesticides, fertilizer, and volatile organic compounds.

Discharge from Comal Springs in 2006 was discussed above in the Peck's cave amphipod section. Discharge from San Marcos Springs for calendar year 2006 (including provisional USGS data) was 111.7 CFS. The long-term average for San Marcos Springs discharge (period of record May 26, 1956 through September 30, 2006) is 173.8 CFS.

Comal Springs dryopid beetle

Comal Springs dryopid beetles are small (adults are about 3 mm long) and reddish brown with vestigial eyes. Larvae are cylindrical, light yellow brown, and about 7 mm long.

Distribution and Status - The Comal Springs dryopid beetle is known from two localities**:** Comal Springs and Fern Bank Springs, which is about 31 km north northeast of Comal Springs. In 2006, Comal Springs dryopid beetles were collected from Comal Springs (and spring runs) in New Braunfels (BIO-WEST 2007) and from Fern Bank Springs (Gibson *et al*. 2007). BIO-WEST (2007) reported the numbers collected at Comal Springs (spring runs 1 and 3) in 2006 were lower than previous years.

Habitat and Life History - Little is known of the habitat, habits, and life stages of Comal Springs dryopid beetles. Barr and Spangler (1992) presumed the microhabitat of larvae to be the ceilings of spring orifices. Research is needed to resolve the troglobitic and epigean habitats used by larvae and adults. While the subterranean extent of its distribution is not known, its presence has been documented in Comal Spring runs 1, 2, 3, 4, and 5, as well as nearby springs just upstream of Spring Island in Landa Lake. Vestigial eyes indicate a subterranean adaptation but the subterranean extent may be limited due to: (1) requirements of immature stages; (2) a trophic association with roots or biofilms (Gibson *et al*. 2007); and/or (3) a need for an air-filled cavern (Barr and Spangler 1992). This species does not swim and may be limited regarding the extent of the subterranean habitats it can colonize.

Abundance and Trends - BIO-WEST (2007) reported the number of larvae collected in drift nets at Comal Springs (spring runs 1 and 3) in 2006 (n=2) was lower than previous years (n=8 for 2005). BIO-WEST did not survey Fern Bank Springs. Gibson *et al*. (2007) found one larval Comal Springs dryopid beetle in their Fern Bank Springs survey, May through August 2003.

Recovery Needs - The conservation of existing (and any newly discovered) populations will depend on: (1) the maintenance of physical habitat including an adequate springflow regime, (2) supportive aquifer and spring water quality, (3) the biological integrity of Comal Springs dryopid beetle habitats, and (4) abatement of threats. One recovery need unique to Comal Springs dryopid beetle is the conservation of Fern Bank Springs, its springflow, and spring associated habitats. The source of Fern Bank Springs may include one or more of the following sources: (1) upper member of the Glen Rose formation (upper Trinity aquifer, Hill Country area, Mace *et al*. 2000), (2) Edwards aquifer, and (3) waters pirated or otherwise associated with the Blanco River (George Veni, pers. comm. 2006).

Threats - The Comal Springs dryopid beetle has been collected from five spring runs at Comal Springs and from Fern Bank Springs about 32 km to the northeast in Hays County. *Stygoparnus comalensis* is the only known subterranean member of the family Dryopidae. Adult beetles are about 3.0-3.7 mm long with vestigial (non-functional) eyes and weakly pigmented, translucent thin cuticle (Barr and Spangler 1992). This beetle does not swim and, since all known dryopid beetle larvae are terrestrial, the species may be associated with air-filled voids inside spring openings. Water flow is important for this species, which uses tiny, hydrophobic hairs on its underside to maintain a bubble of air for gas exchange (Chapman 1982). Decreased water flow and stagnation of water would be limiting factors for the beetle. The population at Fern Bank Springs may be at risk due to groundwater development in the Trinity aquifer Hill Country Area (Mace *et al*. 2000). Mace *et al.* (2000) provided simulated ground water levels over the next four decades and the model indicated the aquifer levels in the area near Fern Bank Springs would decline even under average recharge conditions.

Status of Critical Habitat - Critical habitat for the Comal Springs dryopid beetle has been designated for two localities (units) (Service 2007; Figures 8 and 9). The largest unit is Comal Springs and that part of Landa Lake associated with the springs. The other is the Fern Bank Spring unit, which encompasses the main springs.

The primary constituent elements of critical habitat for Comal Springs dryopid beetle are habitat components that provide:

(i) high-quality water with pollutant levels of soaps, detergents, heavy metals, pesticides, fertilizer nutrients, petroleum hydrocarbons, and semivolatile compounds such as industrial cleaning agents no greater than those documented to currently exist and including: (A) low salinity with total dissolved solids that generally range from 307 to 368 mg/L; and (B) low turbidity that generally is less than 5 nephelometric turbidity units (NTUs); (C) aquifer water temperatures that range from about 20 to 24°C; and (ii) food supply for the Comal Springs dryopid beetle that includes, but is not limited to, detritus (decomposed materials), leaf litter, and decaying roots.

Comal River discharge was discussed in previous sections. Fern Bank Springs discharge is not gaged and is only intermittently estimated. Brune (1981) reported Fern Bank springflow discharge of 4.9 CFS on May 31, 1975, and 0.3 CFS on May 1, 1978. The threat of groundwater level decline in the upper Trinity aquifer in Hays County was previously discussed. Groundwater availability models estimate groundwater levels in the 1-mile square cell (element) that includes Fern Bank will drop 13.0 meters with average recharge through 2043 and drought-of-record conditions from 2044 to 2050 (Mace *et al*. 2000). The designated critical habitat unit at Comal Springs for the Comal Springs dryopid beetle is in the action area. However, based on available information, the Comal Springs dryopid beetle critical habitat unit at Fern Bank is not in the action area because pumping in the southern Edwards aquifer is not thought to affect the discharge from Fern Bank Springs.

San Marcos gambusia

Distribution and Status - The San Marcos gambusia was known from the upper San Marcos River. The earliest (Jordan and Gilbert 1884) collection site is not known with certainty as the locality was referred to simply as San Marcos Springs. The historical distribution likely included the San Marcos River headwaters (impounded as Spring Lake in 1849) downstream to a point upstream of the confluence with the Blanco River. This species has not been collected since 1983 despite extensive sampling efforts in 1990, 1994, 1995, and 1996. This species was declared extinct by Miller *et al*. (1989).

Habitat and Life History - Preferred habitat of this species includes thermally constant quiet waters adjacent to moving water. Historically, it was found mostly over muddy river beds with shade from overhanging vegetation or artificial structures (e.g., bridges). Likely food habits include typical prey of gambusia such as insect larvae and microcrustaceans. Though little is known about San Marcos gambusia reproduction, it is presumed to be similar to other congeners such as *Gambusia affinis*, *Gambusia heterochir*, and *Gambusia holbrooki* in terms of litter size and the ability to simultaneously carry more than one brood (Reznick and Miles 1989).

Abundance and Trends - Edwards *et al*. (1980) and Edwards (1999) summarize the historical abundance data based on collection efforts spanning about 100 years. Hubbs and Peden (1969) estimated that there were fewer than 1,000 individuals in the upper San Marcos River. This species was never very common and the last time it was collected was 1983. All available information indicates that this species is no longer present in the wild. No captive populations exist that would enable repatriation.

Recovery Needs - The primary need is the establishment of an *ex situ* population that is maintained in a such a way that the genetic integrity is assured and suitable stock is available for reintroduction. It also has recovery needs that are similar to the fountain darter as discussed below.

Threats - The San Marcos gambusia was listed as endangered in 1980. Intensive searches for *G. georgei* in May, July, and September of 1990 did not yield any pure San Marcos gambusia. Past attempts to establish a captive population were unsuccessful and no pure *G. georgei* have been found to try captive propagation again. The San Marcos gambusia, one of three Gambusia species native to the San Marcos River system, was first described in 1969. The San Marcos gambusia has strong crosshatchings and a prominent dark pigment stripe across the distal edges of its dorsal fin. A mid-lateral stripe may be present from the base of the pectoral fin to the caudal peduncle. *Gambusia georgei* has a dark subocular bar and fewer spots than *G. affinis*. The median fins tend to be lemon yellow in wild-caught specimens, with dominant males exhibiting a bright yellowish-orange color. *Gambusia georgei* has more than five segments in ray 4a and a compound claw on the end of ray 4p (Hubbs and Peden 1969). According to the recovery plan (Service 1996), the habitat requirements of the San Marcos gambusia include: thermally constant water; quiet, shallow, open water adjacent to sections of moving water; muddy substrates without appreciable quantities of silt; partial shading; clean and clear water; and a food supply of living organisms. Food habits of *G. georgei* are unknown but are presumed to include insect larvae and other invertebrates. Hybridization between *G. georgei* and *affinis* was first noted by Hubbs and Peden in 1969. Any hybrid individuals that persist would be competing with the dominant poeciliid in the upper San Marcos River, namely, the largespring gambusia (*G. geiseri*).

Status of Critical Habitat - Critical habitat includes the San Marcos River, from the Highway 12 Bridge (Hopkins) downstream to about 0.5 miles below the Interstate Highway 35 bridge (45 FR 47355; Figure 10). Currently, San Marcos Springs discharge exceeds 200 cubic feet per second (U.S. Geological Survey provisional data). This discharge exceeds the Service’s springflow determinations provided in 1993 addressing take, jeopardy, and adverse modification of critical habitat for the San Marcos gambusia.

Fountain darter

Distribution and Status - The current range of the fountain darter is restricted to the Comal and upper San Marcos rivers. Historic and present distributions of the fountain darter are presented in the *San Marcos & Comal Springs and Associated Aquatic Ecosystems (Revised) Recovery Plan* (Recovery Plan) (Service 1996).

The current and historic distribution of the fountain darter in the Comal River includes all of the spring runs, Landa Lake, the old and new channels of the Comal River, and the Comal River (proper) downstream to its confluence with the Guadalupe River (Figure 11).

Historically within the San Marcos River, the fountain darter is known from the headwaters (Spring Lake) down to the vicinity of Martindale in Caldwell County (Service 1996). The current San Marcos fountain darter distribution extends from Spring Lake to a point between the San Marcos Waste Water Treatment Plant (WWTP) outfall and the confluence with the Blanco River (Figure 12).

The fountain darter was listed as endangered on October 13, 1970. Critical habitat was designated on July 14, 1980 for the upper San Marcos River, in Hays County and includes Spring Lake and its outflow, the San Marcos River, downstream to about 0.5 mile (805 meters) below the Interstate Highway 35 bridge (Figure 12). There is no critical habitat designated for this species in the Comal Springs system.

Habitat and Life History - The fountain darter is a small, reddish brown fish, averaging about 29 mm total length. Habitat requirements described in the Recovery Plan (Service 1996) include: undisturbed stream floor habitats; a mix of submergent plants (algae, mosses, and vascular plants), in part for cover; clear and clean water; food supply of living organisms; constant water temperatures within the natural and normal river gradients; and adequate springflows.

Fountain darters feed primarily during daylight in response to visual cues (Schenck and Whiteside 1977*a*). Bergin (1996) investigated the fountain darter's diet in detail. The food items selected depended on the size of the individual, but primarily included copepods, dipteran (fly) larvae, and emphemeropteran (mayfly) larvae (Bergin 1996).

Fountain darters use and prefer a mix of submergent vegetation including algae, mosses (e.g., *Riccia* sp.), and vascular (higher) plants such as Texas wild-rice (*Zizania texana*) (Schenck and Whiteside 1976, Linam *et al*. 1993, Linam 1993, Service Austin Field Office unpublished data). Schenck and Whiteside (1976) found that young fish prefer vegetated habitats in areas with little water velocity.

Although natural populations of fountain darters spawn year-round (Schenck and Whiteside 1977*b*), they appear to have two peak spawning periods, in August and late winter to early spring (Schenck and Whiteside 1977*b*). Bonner *et al*. (1998) described the effects of temperature on egg production and early stages of the fountain darter.

Abundance and Trends - The original population of fountain darters in the Comal River was extirpated (Schenk and Whiteside 1976). The primary cause of extirpation is thought to be the 1956 drought, when springflow ceased for 144 days. Cessation of flow probably caused large temperature fluctuations in residual downstream pools. In 1954, rotenone was applied to remove non-native and exotic fish. Although fountain darters were seined and held during rotenone application, the total number of fountain darters probably was reduced since all darters were not caught (Ball *et al*. 1952; Service 1996). The Comal population was re-established by Dr. Bobby Whiteside of Texas State University – San Marcos (with about 500 individuals from the San Marcos River) in 1975 and 1976, and the species now occupies Landa Lake downstream to the vicinity of the confluence of the Comal and Guadalupe rivers. Linam *et al*. (1993) estimated that the Comal River population was about 168,078 individuals above Clemens Dam based on their 1990 survey.

The population of fountain darters in the San Marcos River was estimated to be about 103,000 by Schenck and Whiteside (1976) and 45,900 (downstream of, and excluding, Spring Lake) by Linam (1993). Darter densities appear to be highest in the upper segments of the river and decrease markedly in an area below Cape's Dam (Linam 1993, Whiteside *et al*. 1994). The most recent surveys in the upper San Marcos are by BIO-WEST (2007*a* and 2007*b*).

Recovery Needs - The Executive Summary in the Revised San Marcos and Comal Recovery Plan (Service 1996) lists the actions needed for recovery of subject species, including the fountain darter:

(1) Assure sufficient water levels in the Edwards aquifer and flows in Comal and San Marcos Springs to maintain habitat for all life stages of the five listed species and integrity of the ecosystem upon which they depend.
(2) Protect water quality.
(3) Establish and maintain populations for all five listed species in their historic habitats.
(4) Conduct biological studies necessary for successful monitoring, management, and restoration.
(5) Encourage partnerships with landowners and agencies to develop and implement conservation strategies.
(6) Develop and implement a regional Aquifer Management Plan.
(7) Develop and implement local management and restoration plans to address multiple threats.
(8) Promote public information and education.

On a regional scale, management of the Edwards aquifer is the responsibility of the EAA and TCEQ. The EAA is currently (July 2007) assessing actions it needs to take for critical period management and the reductions required for each drought stage pursuant to SB 3.

The cities of New Braunfels and San Marcos could develop and implement a Comal River Management Plan and a San Marcos River Management Plan respectively to address local threats. Other actions needed include control of certain limiting factors such as non-native species. Significant control of non-native species would help minimize and/or eliminate threats from these species, such as loss or alteration of essential habitat, increased predation, disruption of normal behaviors, or hybridization.

Threats - The Revised San Marcos and Comal Recovery Plan (Service 1996) identifies several local and regional threats to the aquifer and spring systems, and to the threatened and endangered species dependent on these ecosystems, including the fountain darter. The main regional threats are related to the quality and quantity of aquifer and spring water. Decreased and potential cessation of springflows threaten the survival of the aquatic species. Activities that may pollute the Edwards aquifer and its springs and streamflows may also threaten or harm the species.

Significant additional threats also occur on the more local scale level and include effects from increased urbanization near the rivers, recreational activities (Breslin 1997), alteration of the rivers, habitat modification (for example, dams, bank stabilization, flood control), predation, competition, introduced parasites, and habitat alteration by exotic / non-native species. Exotic species of concern include: elephant ears (*Colocasia* spp.), giant ramshorn snails (*Marisa cornuarietis*), Asian clams (*Corbicula fluminea*), red-rimmed melania (*Melanoides tuberculatus*), nutria (*Myocastor coypus*), tilapia (*Oreochromis spp.*), and loricarids (suckermouth catfish) (*Hypostomus plecostomus*). It appears that since 2004, the density of giant ramshorn snails in the Comal and San Marcos systems has decreased significantly (BIO-WEST 2007*b*, 2007*c*). However, the numbers and biomass of loricarids in the both the Comal and upper San Marcos River have grown significantly. These loricarids are known to alter habitat (burrowing, algal grazing, and destruction of aquatic plants) and disrupt the aquatic food web (Hoover *et al.* 2004). Gido and Franssen (2007) stated fish in low trophic positions (herbivores, detritovores, and omnivores) are predicted to do well in colonization because food resources are not expected to be limiting.

The implementation of an aquifer management plan that significantly influences the magnitude and duration of springflows of Comal and San Marcos springs is considered to be among the most important actions needed.

USGS data have indicated high water quality for the springflows and aquifer in general. However, there are increasing risks of aquifer, springflow, and streamflow contamination. Pollution threats include:

(1) groundwater pollution of the Edwards aquifer from land-based hazardous material spills, leaking underground storage tanks, and firefighting on, or near, the recharge zone;

(2) cumulative effect of urbanization (road runoff, leaking sewer lines, residential pesticide and fertilizer use, etc.);

(3) increased effect of contaminants due to decreased dilution from smaller volumes of water in the aquifer and springflows; and,

(4) surface, stormwater, and point and nonpoint source discharges into the streamflows.

Part of the Edwards aquifer has recently been designated by the U.S. Environmental Protection Agency for the National Priority List (Superfund). An investigation, led by TCEQ, identified the presence of tetrachloroethene (PCE) and trichloroethene (TCE) in concentrations above the Safe Drinking Water Maximum Contamination Level (MCL) of 5.0 parts per billion (ppb) within the Edwards aquifer.

Although the aquifer is generally not contaminated to the point of exceeding Federal drinking water standards, certain contaminants have been found with greater frequency in the aquifer in recent years. Many of the threats by urbanization to aquifer water quality also threaten spring-based streamflows. Runoff from streets, highways, and commercial and residential landscapes, and potential spills of hazardous materials (above and below ground) pose the greatest risks to streamflow quality. Ockerman *et al*. (1999) characterized stormwater runoff in the Edwards aquifer recharge zone in Bexar County. Ogden *et al*. (1986) investigated stormwater runoff water quality including nutrients and fecal coliform bacteria.

A serious parasite threat to the fountain darter has been documented by Salmon (2000), Mitchell *et al*. (2000), Cantu (2003), Mitchell *et al*. 2005, and McDonald *et al*. (2006). Their research documents a trematode that attacks fountain darter gills in the Comal and San Marcos river systems. Since 1996, virtually every fountain darter collected in the Comal system has been parasitized. To date, the San Marcos system has not seen the same widespread presence of this trematode with less than 5 percent parasitism rate among fountain darters examined. The risks posed by these parasites will likely increase during stressful periods of low spring discharge (Cantu 2003) and the parasite's adverse effects may be greater to younger fountain darter life-stages (McDonald *et al*. 2006).

Status of Critical Habitat - Critical habitat includes the San Marcos River, including Spring Lake downstream to approximately 0.5 miles below the Interstate Highway 35 bridge (45 FR 47355). Currently, San Marcos Springs discharge exceeds 300 cubic feet per second (U.S. Geological Survey provisional data). This discharge exceeds the Service's springflow determinations provided in 1993 addressing take, jeopardy, and adverse modification of critical habitat for the fountain darter.

San Marcos Salamander

Distribution and Status - The distribution of San Marcos salamanders has not changed significantly since its description (Bishop 1941). It inhabits the springs and spring-like habitats of Spring Lake and the areas associated with both of Spring Lake's spillways. BIO-WEST (2006, 2007*a*, 2007*c*) reported surveys from two sites in Spring Lake and one site from the eastern spillway. The San Marcos salamander was listed as threatened with a special rule on July 14, 1980 (45 FR 47355 – 47364).

Habitat and Life History - San Marcos salamander habitats are strongly associated with San Marcos Springs in the western half of Spring Lake and in the spillway areas below Spring Lake Dam. They are abundant in areas supporting filamentous algae, aquatic mosses (*Leptodictyium riparium* and *Riccia fluitans*), and rooted macrophytes such as delta arrowhead (*Sagittaria platyphylla*), wildcelery (*Vallisneria* sp.), water primrose (*Ludwigia repens*), Carolina fanwort (*Cabomba caroliniana*), hydrilla, and parrot's feather (*Myriophyllum brasiliense*). Suitable substrates include limestone and cherty cobble/rubble, large and small gravels, and sand. San Marcos salamander reproductive biology is described by Bogart (1967), Tupa and Davis (1976).

The San Marcos salamander is a neotenic form and retains its external gills throughout life. The salamander becomes sexually mature and breeds in the water. This small, slender salamander has moderately large eyes with a dark ring around the lens, well developed and highly pigmented gills, relatively short, slender limbs with four toes on the forefeet and five on the hindfeet, and a slender tail with well developed dorsal fin. Habitat requirements described in the recovery plan (Service 1996) include: thermally constant waters; flowing water; clean and clear water; sand, gravel, and rock substrates with little mud or detritus; vegetation for cover; and an adequate food supply. Captive salamanders do not actively pursue prey, but stay stationary until prey items are close enough to engulf. The San Marcos salamander's diet consists of amphipods, tendipedid (midge fly) larvae and pupae, other small insect pupae and naiads, and small aquatic snails. Most evidence suggests reproduction occurs throughout the year with a possible peak about May and June (Service 1996).

Abundance and Trends - Tupa and Davis (1976) and Nelson (1993) estimated the numbers of San Marcos salamanders in and near Spring Lake. One difficulty in making the estimate is the small size of the younger salamanders and their ability to move undetected into spaces among the substrate.

Surveys for San Marcos salamanders found it distributed throughout Spring Lake among rocks near spring openings, in algal mats, mosses, and other plants, and in rocky areas just downstream from the dams (Nelson 1993, BIO-WEST 2006, 2007*a*, 2007*c*). The species occurs near all the major spring openings scattered throughout Spring Lake and is quite abundant at some of these springs (Nelson 1993). Nelson (1993) estimated a total population of 53,200 salamanders in and just below Spring Lake, including 23,000 associated with algal mats, 25,000 among rocky substrates around spring openings, and 5,200 in rocky substrates below Spring Lake.

The most recent surveys were conducted at three sites by BIO-WEST (2007*a*, 2007*c*), which has estimated San Marcos salamander densities on 21 sampling rounds since the Fall of 2000. The current salamander population size appears to be thriving and generally similar to observations made over the previous five years of sampling. For estimated San Marcos salamander densities, please see Table 15 in BIO-WEST (2007*c*).

Recovery Needs - The San Marcos salamander recovery needs overlap with other Edwards aquifer dependent species. These are discussed above in the fountain darter section. One unique recovery need is the maintenance of habitat features of aquatic vegetation and substrates near the springs in Spring Lake and in its spillways. The fountain darter, while often syntopic with the salamander, tolerates silty and unconsolidated substrates better than the San Marcos salamander.

Threats - In general, threats to this and other Edwards aquifer dependent species is discussed previously in the fountain darter threats section. Threats to the San Marcos salamander include loss of protective cover, lack of flowing water, water temperature elevated above ambient spring conditions, contaminants, siltation, and predators. San Marcos salamanders appear to require upwelling and flowing water, as no specimens were found in still waters of the lake or river.

Habitat availability for the San Marcos salamander is adversely affected when springflows decline. The contingency plan for the salamanders is being implemented and salamanders are being collected for captive propagation/maintenance mainly at the San Marcos National Fish Hatchery and Technology Center. Techniques for breeding this species and maintaining its genetic diversity have been improved over the past several years. However, the ability to maintain this species in captivity (without supplemental wild-caught individuals) over the long term is uncertain (Fries 2002). Reintroduction techniques have also not been developed.

Status of Critical Habitat - San Marcos salamander critical habitat was designated July 14, 1980. Critical habitat includes Spring Lake and its outflow, the San Marcos River, downstream about 50 m from the Spring Lake Dam (Figure 13). Currently, San Marcos salamander habitats in Spring Lake appear to have adequate physical habitat as total San Marcos Springs discharge is above the historical average.

Texas blind salamander

The Texas blind salamander was listed as endangered on March 11, 1967 (32 FR 4001). *Eurycea rathbuni* (= *Typhlomolge rathbuni*) is a smooth, unpigmented troglobitic (cave-adapted) species. Adult salamanders attain an average length of about 12 cm with a large, broad head and reduced eyes. The limbs are slender and long with four toes on the fore legs and five toes on the hind legs.

Distribution and Status - The distribution of the Texas blind salamander is thought to be limited to a discrete subset of the Edwards aquifer in the San Marcos area (Figure 14). Its distribution is inferred from individuals seen at springs in Spring Lake, Rattlesnake Cave, Ezells Cave, Primer's Fissure (well), and the Texas State University – San Marcos well adjacent to the Aquatic Biology (Freeman) Building.

Habitat and Life History - The salamander is neotenic and remains aquatic throughout its life in water-filled, cavernous areas in the San Marcos area of the Edwards aquifer. *Eurycea rathbuni* is believed to be adapted to the relatively constant 21° C temperature of the subterranean waters in the Edwards aquifer (Longley 1978). The diet of the salamander includes amphipods, blind shrimp (*Palaemonetes antrorum*), daphnia, small snails, and other invertebrates. Cannibalism has also been documented (Longley, *in litt*., 1994). The salamander appears to be sexually active throughout the year, which is expected since there is little seasonal change in the aquifer (Longley 1978).

Abundance and Trends - Little is known about the population size or trends in population size for this species. A project is underway to capture, mark, and recapture Texas blind salamanders in accessible cave habitats.

The total distribution of this species may be as small as 10 km^2 in a portion of the Edwards aquifer beneath and near the city of San Marcos. All collections or sightings of the Texas blind salamander have occurred in Hays County, Texas. After its first collection at the former Federal fish hatchery site, the salamander has been found at Ezell's Cave, San Marcos Springs, Rattlesnake Cave, Primer's Fissure, Texas State University – San Marcos' well, and Frank Johnson's well (Russell 1976, Longley 1978). The species was previously known to occur in Wonder Cave but searches in 1977 did not locate any specimens (Longley 1978).

Recovery Needs - The Texas blind salamander recovery needs overlap with other Edwards aquifer dependent species. These are discussed previously in the fountain darter section. One unique recovery need is the maintenance of aquifer related habitats in the San Marcos area especially Ezells and Rattlesnake Cave. In the Summer of 2005, with funding and support of the San Antonio Water System and in cooperation with Texas State University – San Marcos, a new pipe was installed over Diversion Springs in Spring Lake. The Diversion Springs pipe represents the best means to collect live Texas blind salamanders for *ex situ* conservation. It also represents a way of inferring the relative abundance of Texas blind salamanders by tracking the number of individuals recovered from Diversion Springs. The number of individuals collected can be compared to the amount of time the net was set and the estimated discharge rate specific to Diversion Springs and to the total San Marcos Springs discharge. The base of the pipe needs to have the seal with the lake bed improved to preclude entrainment of surface – Spring Lake biota (including predatory crayfish) into capture nets.

Threats - In general, threats to this and other Edwards aquifer dependent species is discussed above in the fountain darter threats section. Threats to the Texas blind salamander include: (1) loss of suitable habitat due to decrease in aquifer level; (2) decrease in water quality; (3) encroachment of the saline interface into historical and currently occupied parts of the Edwards aquifer and resulting in unsuitable water quality; and (4) attrition and death due to entrainment into water wells in the San Marcos area.

Attempts are being made to collect Texas blind salamanders as part of the contingency plan implementation. However, very few specimens have been found at collection sites (Krejca and Gluesenkamp 2007) and these low numbers in captivity are likely inadequate to maintain good genetic representation. There are also no techniques developed to reintroduce this species back into artesian zone of the aquifer.

<u>Other Species of Concern</u>

In addition to the listed species, a great diversity of other unique species occur in these aquatic ecosystems. Some may be threatened with extinction, but insufficient information is available to fully assess their status. Some of the species associated with the Edwards aquifer include the Texas cave diving beetle (*Haideoporus texanus*), San Marcos saddlecase caddisfly (*Protoptila arca*), Ezell's cave amphipod (*Stygobromus flagellatus*), Texas salamander (*Eurycea neotenes*), Comal blind salamander (*Eurycea tridentifera*), Blanco blind salamander (*Typhlomolge robusta*), Comal salamander (*Eurycea* sp.), a new species of troglobitic salamander from Comal County, widemouth blindcat (*Satan eurystomus*), and toothless blindcat (*Trogloglanis pattersoni*). While these species of concern have no legal protection, efforts to reduce adverse effects and/or further studies at this stage would benefit the health of the ecosystem and may help prevent future listing. Positive efforts could include such things as researching the extent and effect of water well entrainment of blindcats; developing or improving captive breeding techniques; or assessing habitat and flow requirements of these species of concern.

Environmental Baseline

When referring to the Edwards aquifer in this document, we mean the San Antonio segment of the Edwards (Balcones Fault Zone) aquifer, which extends from Brackettville (Kinney County) to a groundwater divide near Kyle (Hays County).

For the purposes of this consultation the action area includes the Edwards aquifer, the San Marcos, Comal, and Hueco springs, and their associated aquatic systems (including respective springs, lakes and rivers), and caves associated with the aquifer that are connected to, dependent on and an integral part of the larger Edwards aquifer ecosystem. Fern Bank Springs lies on the edge of the Trinity aquifer and near the edge of the Edwards aquifer. The U.S. Geological Survey (Heitmuller and Reece 2006) assigned Fern Bank Springs to the upper zone of the Trinity Aquifer. While we do not know with certainty whether any water issuing from Fern Bank comes from the Edwards aquifer, Fern Bank Springs discharges to the Blanco River just upstream of the Edwards aquifer recharge zone. Thus, Fern Bank Springs may provide some small contribution to Edwards aquifer recharge. Fern Bank Springs are not in the action area (described below) of this consultation.

The revised San Marcos and Comal Recovery Plan (Service 1996) identifies a number of regional and local threats to the aquifer and spring systems, and to the threatened and endangered species dependent on these ecosystems. The main regional threats are related to the quality and quantity of aquifer and spring water. Decreased springflows and potentially cessation of springflows threaten the survival of the listed threatened and endangered Edwards aquifer dependent species. Activities that may pollute the Edwards aquifer and its springs and streamflows may also threaten or harm the species. Additional threats were discussed above in the species background sections.

Springflows at Comal and San Marcos springs are inseparably tied to water usage from the entire San Antonio Segment of the Edwards aquifer. The source of Hueco Springs is considered Edwards aquifer, although the subset of the aquifer supplying Hueco Springs is thought to be smaller than that supplying Comal and San Marcos springs (Guyton and Associates 1979). Lindgren *et al*. (2004) expressed uncertainty about the source of Hueco Springs. However, EAA uses Hueco Springs discharge as part its annual water budget for the Edwards aquifer.

The discharge of groundwater from wells in the aquifer decreases the flow of water from the springs. Total withdrawal from the aquifer has been increasing since at least 1934, when total well discharge was 101,900 acre-feet, and it reached a maximum of about

542,000 acre-feet in 1989. The increasing volume of withdrawals is approaching the aquifer's 1934-1995 average recharge volume of 674,200 acre-feet/year (Brown and Patton 1996). To illustrate the impact of groundwater withdrawals on springflows, we provide the following figures.

Figure 15 shows the estimated annual recharge and pumping amounts from the southern Edwards aquifer for the period of record.

Figure 16 shows the mean monthly discharge estimated by U.S. Geological Survey for Comal Springs for the period of record.

Figure 17 shows the monthly and annual variation in daily discharge from Comal Springs. Notice the lack of monthly variation in early years (lower part of figure) of the period of record compared to years after the drought of record (black line circa 1956 – 1957).

Figure 18 shows the mean monthly discharge estimated by the U.S. Geological Survey and Guyton and Associates (1979) for San Marcos Springs for the period of record.

Figure 19 shows the discharge hydrograph for Hueco Springs (Guyton and Associates 1979).

The hydrograph for the springs can be divided into three periods: before, during, and after the drought of the early 1950s. This combination of this drought and well withdrawals resulted in the drying of the Comal Springs in 1956. It also resulted in the lowest discharge recorded for San Marcos Springs. During the first period, pumping and recharge were both significantly lower than during the second period, and discharge levels had relatively small fluctuations. Following the 1956 drought, recharge increased, but not enough to offset the greater increase in pumping. As a result, the frequency and magnitude of fluctuations in Comal Springs' discharge increased substantially, and several declines in discharge extended below the take/jeopardy levels, as described in the Recovery Plan (Service 1996) and indicated on Figure 2 by the horizontal lines. Overall, the average discharge from the Comal Springs decreased from 330 cubic feet per second for 1934-1949, prior to the drought of record, to 286 cubic feet per second for 1957-1996 after the drought when pumping increased.

Because of the anticipated continued population growth in the Edwards aquifer region, and an associated increase in water use, the trend of declining spring discharge will continue if those water needs are met from the Edwards aquifer. Several estimates have been made that project the increase in regional water demand, and the influence of increased pumping on flows from San Marcos and Comal Springs:

The first detailed computer simulation of flow in the Edwards aquifer (Klemt *et al.* 1979), with assumptions of full continued development and average hydrologic conditions, projected that continuous flow from the San Marcos Springs would cease around the year 2010. A number of studies have modeled springflow at Comal and San Marcos Springs (Texas Water Development Board (TWDB) 1992; McKinney and Watkins 1993) and found that regulation of groundwater withdrawal will be necessary to maintain their continuous flow.

The most recent aquifer simulations (runs) involve the TWDB's GWSIM IV (Mace *et al*. 2007), the USGS's MODFLOW (Lindgren *et al*. 2004), and EAA's Aquifer Management (MODFLOW) Model (G. Schindel, EAA, pers. comm., 2007). MODFLOW is a FORTRAN based simulation that uses a form of numerical processing call finite-difference approximation to solve partial differential equations of groundwater flow. MODFLOW simulates the response of aquifer head and flow to specified aquifer recharge and discharge. The MODFLOW simulation developed by Lindgren *et al.* (2004) has been adapted by the EAA to include critical period management as described in SB 3.

Population and water use projections developed by the TWDB, Texas Natural Resource Conservation Commission, and the TPWD (1996) show an increase in water demand in the Edwards region that by 2050 will exceed current 1934-1995 mean recharge rates by 43-57 percent. These figures include consideration for expected water conservation measures.

A special underground water authority (EAA) was created, under The Edwards Aquifer Authority Act (EAA Act) (Chapter 626, Laws of the 73rd Texas Legislature, 1993, as amended by Chapter 621, Laws of the 74th Texas legislature, 1995), to manage and issue permits for the withdrawal of groundwater from the Edwards aquifer for the purposes of water conservation and drought management and to make and enforce rules. The Edwards aquifer was found to be a unique aquifer and a distinctive natural resource of this State. It is a complex hydrological system and the sole source of water for a diverse group of social and economic interests. The EAA was designated a special regional management district to protect terrestrial and aquatic life, domestic and municipal water supplies, the operation of existing industries, and the economic development of the state. All reasonable measures are to be taken to conserve water; protect water quality in the aquifer; protect water quality of surface streams provided with springflows from the aquifer; maximize the beneficial use of water available to be drawn from the aquifer; protect aquatic and wildlife habitat; protect threatened and endangered species under Federal or State law; and provide for instream uses, bays and estuaries. Prior to SB 3, the EAA was directed to issue permits for water withdrawals from the aquifer not exceed 450,000 acre-feet of water for each calendar year for the period ending December 31, 2007. At the beginning of January 1, 2008, the amount of permitted withdrawals from the aquifer was not to exceed 400,000 acre-feet of water for each calendar year, and not later than December 31, 2012, continuous minimum springflows of the Comal and San Marcos springs are to be maintained to protect endangered and threatened species to the extent required by Federal law. The 80th Session of the Texas Legislature enacted SB 3, which changes the maximum annual permitted withdrawals to 572,000 acre-feet and provides for more aggressive critical period (drought) management. SB 3 requires EAA, TPWD, and TWDB to participate in the development of a cooperative agreement pursuant to the Edwards Aquifer Recovery Implementation Program.

Another effort underway is the Edwards Aquifer Recovery Implementation Program, initiated in 2007. Recovery Implementation Programs are voluntary, multi-stakeholder initiatives that seek to balance water use and development with the recovery of species on the Federal threatened and endangered species list.

As part of a February 1, 1993, Judgement (as amended on May 26, 1993) in the case of Sierra Club vs. Secretary of the Interior (No. MO-91–CA-069, U.S. Dist. Ct., W.D. Texas), the Service used its best professional judgment and available information to determine minimum springflows needed to prevent take, jeopardy, or adverse modification to critical habitat of listed species. Determination of take and jeopardy vary from species to species depending on each species' unique requirements, ecology, and life history. In addition, factors associated with the specific action such as magnitude, timing, duration, frequency, and extent also affect a specific take or jeopardy determination.

Table 6 contains the Service's determination of minimum springflows necessary to prevent take, jeopardy, or adverse modification of critical habitat for the Edwards aquifer dependent endangered and threatened species (see also Service letters dated April 28, 1993 and June 25, 1993).

Table 6. U.S. Fish and Wildlife Service determination of minimum springflows needed to prevent take, jeopardy, or adverse modification of critical habitat. All flows rates are given in cubic feet per second (cfs).

Species (Case)	Take of Species (Animals)	Jeopardy to Species	Adverse Modification of Critical Habitat
Fountain darter in Comal	200	150	---
Fountain darter in San Marcos	100	100	100
San Marcos gambusia	100	100	100
San Marcos salamander	60	60	60
Texas blind salamander	50*	50	---
	Damage & Destruction (Plants)	Jeopardy to Species	Adverse Modification of Critical Habitat
Texas wild-rice	100	100	100

* refers to San Marcos Springs discharge
--- means not applicable, no critical habitat designated for species in that case

The Service's views on the springflow regime needed to support listed species would be influenced by the implementation of an effective aquifer management plan that provides for continuous of springflows of adequate magnitude at Comal, San Marcos, and Hueco springs. This opinion is based on the assumption of maximum total annual well withdrawals of 450,000 acre-feet in 2007 and 400,000 acre-feet from 2008 through 2012.

Another consideration would be efforts to manage and control certain limiting factors such as non-native (exotic) species. Significant control of the following species is needed to help eliminate or minimize threats to listed species: (1) the parasitic trematode *Centrocestus formosanus*; (2) hosts of this trematode (especially *Melanoides tuberculata*); (3) *Marisa cornuarietis*; (4) sailfin catfish and suckermouth catfish (Loricariidae); (5) elephant ears (*Colocasia esculenta*); and (6) tilapia (Cichlidae).

Data gathered by the U.S. Geological Survey show that Comal and San Marcos Springs have little natural variation in water quality (Fahlquist and Slattery 1997, Slattery and Fahlquist 1997). A review of the numbers shows that parameters like temperature, pH, conductivity, total dissolved solids, and major ions generally vary less than 10 percent and usually less than 5 percent from the mean. For example, temperature in the San Marcos Springs typically varies less than 0.5°C (0.9ºF) in the headwaters and only slightly more at the lower end of the spring run habitat (Guyton & Associates 1979). Vaughan (1986) reported a constant temperature of 21.5°C (70.7° F), with ranges in the streamflow from 25.5°C (77.9° F) in August to 20.4°C (68.7° F) in February at the lower end of the wild-rice zone. Oxygen content reported by Vaughan (1986) was between 5-6 ppm. Springflows tend to be alkaline or neutral, which is typical of limestone aquifers (Service 1996). The pH range of the San Marcos Springs was reported as 6.9-7.9 (TWDB 1968; Vaughan 1986). Whiteside *et al.* (1994) reported the lowest pH levels at 6.3 in the upper portions of the river and up to 7.9 in the lower.

The U.S. Geological Survey data also show a high drinking water quality for the springflows and aquifer in general. However, due to land use changes, there are increasing risks of aquifer, springflow, and streamflow contamination. Pollution threats include:

(1) groundwater pollution of the Edwards Aquifer from land-based hazardous material spills and leaking underground storage tanks;

(2) cumulative impact of urbanization (road runoff, leaking sewer lines, residential pesticide and fertilizer use, etc.);

(3) increased impact of contaminants due to decreased dilution from smaller volumes of water in the aquifer and springflows; and,

(4) surface, stormwater, and point and nonpoint source discharges into the streamflows.

Although the aquifer is generally not contaminated to the extent water quality exceeds Federal drinking water standards, contaminants have been found with greater frequency in the aquifer by the following U.S. Geological Survey reports, and include some wells with pollutant levels that exceed the standards. Reeves (1976) noted the occurrence of fecal coliform and fecal strep bacteria, and elevated nitrate and phosphate levels in some wells on the recharge zone. Most of these sites were near suburban developments. Buszka (1987) found elevated levels of nitrates, bacteria, volatile and nonvolatile organic compounds, and pesticides throughout much of the aquifer, but concentrated near Uvalde and San Antonio. Some of these sites were from a leaking landfill in San Antonio and from another point source contamination site in Uvalde, but many are too far removed to be firmly attributed to those sources and likely reflect other contaminant sources. Roddy (1992) reported similar results and additional contaminant localities. Rice (1994) found that 54 wells in Bexar County have reported mercury and chlorinated solvents. While only a few wells had contaminant levels above those permitted by drinking water standards, the presence of any compounds found in Edwards wells demonstrates the potential for aquifer contamination. As a result of these and other related factors that threaten aquifer water quality, the Edwards Underground Water District concluded (Kipp *et al.* 1993):

"The lack of adequate comprehensive standards and regulatory controls to protect the aquifer against water quality degradation, coupled with the rapid pace of development over the ERZ [Edwards aquifer recharge zone] *at this time, and presumably for some time to come, suggests that degradation of water in the Edwards aquifer is imminent."*

Many of the threats by urbanization to aquifer water quality also threaten spring-based streamflows. Runoff from streets, highways, and commercial and residential landscapes, and potential spills of hazardous materials pose the greatest risks to streamflow quality.

The Service has developed a set of water quality recommendations to help protect federally listed aquatic species in Texas including the species covered in this biological opinion (White *et al*. 2006). The objectives of this technical report are to: (1) evaluate water quality conditions and known effects for aquatic and aquatic-dependent species and critical habitat in Texas, and (2) recommend measures to benefit these species and their habitats.

Effects of the Action

One of the major threats to the fountain darter, Texas wild-rice, San Marcos gambusia, San Marcos salamander, Texas blind salamander, Comal springs riffle beetle, Comal springs dryopid beetle, and Peck's cave amphipod is loss of springflows and reductions in aquifer levels. Loss of springflows also results in impacts to critical habitat for the seven species that have designated critical habitat.

Flows at San Marcos and Comal Springs are tied directly to water usage from the Edwards aquifer. Flows at Hueco Springs are attributed to the Edwards aquifer (Guyton and Associates 1979) and estimates of Hueco Springs discharge are used annually as part of the water balance equations for the Edwards aquifer. Use of groundwater in the region decreases flow of water from the springs. The TWDB used their Edwards Balcones Fault Zone flow model to simulate aquifer response to several constant withdrawal pumpage scenarios under various recharge conditions. The model was to examine springflows expected at the San Marcos and Comal Springs under various pumping scenarios. The model's ability to predict springflows on a monthly average at Comal Springs is generally accepted. The model is less accurate in predicting conditions in the San Marcos Springs. The TWDB model shows that at both 450,000 and a 400,000 acre-feet/year constant pumpage scenarios, in a repeat of the historic recharge record, a high probability of springflow decline resulting in jeopardy to the species remains. The longer the timeframe considered, the higher the probability that springflows could cease in the Comal Springs for a period of years. A recent set of groundwater availability model runs by TWDB (Mace *et al*. 2007) for the TCEQ used an empirical estimation (based on the Bexar Index well known as J-17) of Hueco Springs discharge for three Edwards aquifer pumping scenarios.

The greatest threats to water quality are non-point source contamination from spills, urban runoff, construction activities and impurities associated with human activities, particularly in (or just upstream from) the recharge zone (Seal 1996, Clark 2000, Ockerman 2002, Clark 2003, Fahlquist and Ardis 2004). As flows and water quantity decrease the spatial distribution of water quality parameters (temperature, pH, turbidity, conductivity, dissolved gases) increase in magnitude in a manner that may have a negative impact on the listed species (Saunders *et al*. 2001). The Balcones fault zone - San Antonio region is bounded on the south and east by a saline water interface known as the “bad water” line. Groundwater goes from fresh to saline to brackish. Lowered water levels due to cumulative groundwater pumpage or decreased recharge may result in movement of the saline water line into fresh water sections increasing the potential for impacts to species dependent on freshwater. Lower aquifer levels and springflows may also result in increased concentration of contaminants because less water would decrease the potential for dilution.

In the previous consultation, the USAF identified 52 Installation Restoration Program (IRP) sites and 3 Areas of Concern (AOC)s on Kelly AFB. Other installations have similar programs looking at contaminant issues and their effect on water quality. Some proposed actions at the installations would also result in impacts to soils, geology, water and biological resources from ground disturbance associated with construction or redevelopment. Airfield-related activities would continue to require the use of aboveground and underground storage tanks for fuels and other hazardous materials.

If contaminants and potential pathways (for example, wells, and faults) are not controlled, remediated properly, or monitored regularly contamination may increase and threaten plant and animal species as well as humans. To reduce the impacts of hazardous waste and contamination that may reduce water quality, DoD is committed to continue remediation of all sites by retaining the necessary interests (for example, easements), in order to operate and maintain all remediation and monitoring systems; ensuring that any site-specific land-use limitations are identified and enforced, coordinating IRP activities with the environmental regulators; keeping the community abreast of the IRP activities; and, continuing well maintenance program and implementing remediation.

Kelly AFB water quality impacts have been addressed in the previous consultation (2-15-1997-F-039). This biological opinion does not address any water contamination impacts directly to the aquifer from DoD, other than those in the Kelly biological opinion. If any aquifer contamination issues are later identified or expected, DoD will need to consult with the Service further.

The three DoD installations currently rely on the Edwards aquifer as the source of their water. Existing water use levels will be reduced from historic use by transferring a portion of the current Edwards water to reuse water and through conservation practices. The proposed projects include measures to conserve water, implement reuse measures, analyze the feasibility of expanding reuse lines to other areas of the bases, and reduce reliance on groundwater.

The effects of the action on listed threatened and endangered species and designated critical habitat are summarized in Table 7. The biological assessment provides the results of multiple Edwards aquifer model runs. These are summarized in the biological assessment's section 6.2.7.

The San Antonio-area DoD Edwards aquifer well withdrawal represents about 2.1 percent of total permitted withdrawals. The distinction in Table 7 between reduced and slightly reduced is based on the modeling results presented in the BA, and a review of Edwards aquifer research that clearly places San Marcos Springs as part of the regional flow system with its springflows affected by subregional recharge and unique conduits / flowpaths.

Cumulative Effects

Cumulative effects include the effects of future State, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Table 7. Summary of expected effects of the action on listed species and their habitat.

Species & Critical Habitat	Expected Effects of DoD Edwards Aquifer Wells
Texas Wild-Rice and Designated Critical Habitat	Slightly reduced springflow discharge at San Marcos Springs
Peck's Cave Amphipod and Proposed Critical Habitat	Reduced springflow at Comal Springs and slightly reduced springflow at Hueco Springs
Comal Springs Dryopid Beetle and Proposed Critical Habitat	Reduced springflow at Comal Springs and no effect at Fern Bank Springs

Species & Critical Habitat	Expected Effects of DoD Edwards Aquifer Wells
Comal Springs Riffle Beetle and Proposed Critical Habitat	Reduced springflow at Comal Springs and slightly reduced springflow at San Marcos Springs
San Marcos Gambusia and Designated Critical Habitat	No expected effects to San Marcos gambusia, which is presumed extinct; slightly reduced springflow at San Marcos Springs
Fountain Darter and Designated Critical Habitat	Reduced springflow at Comal Springs and slightly reduced springflow at San Marcos Springs
San Marcos Salamander and Designated Critical Habitat	Slightly reduced springflow at San Marcos Springs
Texas Blind Salamander	Slightly reduced springflow at San Marcos Springs and slightly reduced flow through the Edwards aquifer in the vicinity of San Marcos

The most important cumulative effect is the continued level of well withdrawal from the Edwards aquifer by all non-Federal users. As the San Antonio region population grows, there will be increased water demands. As the limits of surface water and alternative groundwater supplies (e.g., from the Trinity aquifer) are reached, well demand from the Edwards aquifer may once again exceed 500,000 acre-feet per year. One effect of this level of use is a greater reliance on critical period (demand management) to abate the decline in springflows. Currently, none of the critical period management plans reduce total annual Edwards aquifer use below 320,000 acre-feet. In comparison, average annual Edwards aquifer well withdrawal for the calendar years 1950 through 1956 inclusive was 239,600 acre-feet.

Recent GWSIM-IV model runs by the Texas Water Development Board found that in a repeat of a drought with the magnitude and duration of the early 1950s, all three scenarios predict that Comal Springs may go dry for at least 25 months (Mace *et al.* 2007).

The BA and recovery plan state a number of biological factors that contribute to the continued risks to the species, including competition between non-native and native plants, introduced species, parasites, recreation, human population growth and development, and runoff. The most significant issue in cumulative impacts is that of groundwater withdrawal from the Edwards aquifer. Groundwater withdrawal has historically been based on a "right of capture." In 1993, the Texas legislature passed the EAA Act creating the Edwards Aquifer Authority with the authority to regulate groundwater withdrawal. Section 1.14 of the EAA Act indicates that authorizations to withdraw water from the aquifer shall be limited in accordance with that section to "protect species that are designated as threatened or endangered under applicable Federal or State law" among other purposes. Except as provided in certain exceptions, the amount of withdrawals permitted may not exceed 450,000 acre-feet for each calendar year through December 31, 2007. For the period beginning January 1, 2008, the amount of permitted withdrawals may not exceed 400,000 acre-feet/year. In addition, the Authority "shall implement and enforce water management practices, procedures, and methods to ensure that, not later than December 31, 2012, the continuous minimum springflows of the Comal Springs and the San Marcos Springs are maintained to protect endangered and threatened species to the extent required by Federal law". The EAA has been challenged by legal actions questioning its authority, structure, rules, and permits. The EAA dismissed water withdrawal permit applications for all Federal facilities on December 14, 2004, in effect exempting wells located on Federal facilities from the EAA's rules.

The EAA established their "final groundwater withdrawal permits" in November, 2005 (EAA 2005). In January, 2006, EAA (2006) released a fact sheet describing uninterruptible ("Senior") and interruptible ("Junior") groundwater withdrawal amounts pursuant to temporary rules and set to expire on December 31, 2007. Junior rights were described as water that may be used generally when the Bexar Index well (J-17) aquifer level is above 665 feet. The Attorney General of Texas issued an opinion on January 9, 2007, indicating that EAA was not authorized by the Texas Legislature to reduce the permitted withdrawal rights using an interruptible junior rights permit system.

Drought and management of the Edwards aquifer in 2006 resulted in San Marcos springflow discharge dropping below 100 cubic feet per second for the period July 1 through December 31. McKinney and Sharp's (1995, page 2.18) classification of historical daily flow at San Marcos Springs (1956 – 1992) has a threshold of "below 115 cfs for the very low flow class". The very low class has an exceedance frequency of 85 to 100 percent.

On June 14, 1992, the Edwards aquifer levels reached a historic high level of 703.3 feet (NGVD 1929) at the Bexar Index Well (J-17). However, in less than four years (mid-1996), springflows declined into the mid-80 cubic feet per second range in the Comal system and mid-70 cubic feet per second range in the San Marcos system. This illustrates that the aquifer can effectively be full and springflow discharge rates may significantly decline in a matter of four years, even when annual mean recharge (1993 – 1996) is 460,350 acre-feet.

Additionally other local threats are likely to continue to occur, some of which will be exacerbated by low flows, further reducing the chances of conservation and recovery of the species.

Jeopardy and Adverse Modification Guidance

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the Act to complete the following analysis with respect to critical habitat.

The Texas wild-rice, San Marcos gambusia, fountain darter, and San Marcos salamander critical habitat designations pre-date the requirement for identification of primary constituent elements that are essential for the conservation of the listed species. Pursuant to the Director's December 4, 2004, memorandum (Jones, in litt, 2004), the best available scientific and commercial data will be used to determine and document these elements or habitat qualities. The analytical framework described in that memorandum has been used to complete section 7(a)(2) analyses for Federal actions affecting critical habitat for the Peck's cave amphipod, Comal Springs dryopid beetle, and Comal Springs riffle beetle. The key factor related to the adverse modification determination is whether, with implementation of the proposed Federal action, the affected critical habitat would remain functional (or retain the current ability for the PCEs to be functionally established) to serve the intended conservation role for the species. Generally, the conservation role of critical habitat units for the Peck's cave amphipod, Comal Springs dryopid beetle, and Comal Springs riffle beetle is to have each unit support viable populations.

Activities that may destroy or adversely modify critical habitat are those that alter the PCEs to an extent that the conservation value of critical habitat for Peck's cave amphipod, Comal Springs dryopid beetle, and Comal Springs riffle beetle is appreciably reduced. Activities that, when carried out, funded, or authorized by a Federal agency, may affect critical habitat and therefore result in consultation for these listed species include, but are not limited to: (1) actions that can negatively affect the PCEs of the Peck's cave amphipod, Comal Springs dryopid beetle, or Comal Springs riffle beetle; (2) activities that would significantly and detrimentally alter the water quality in any of the spring systems listed above and would thereby destroy or adversely modify the critical habitat for any of theses species. These activities include, but are not limited to, sedimentation from construction or release of chemical or biological pollutants into the surface water or connected groundwater at a point source or by dispersed release (non-point source); such activities could also alter water conditions to a point that negatively affects these invertebrate species; (3) actions that change the existing and historic flow regimes and would thereby significantly and detrimentally alter the PCEs necessary for conservation of these species. Such activities could include, but are not limited to, water withdrawal, impoundment, and water diversions. These activities could eliminate or reduce the habitat necessary for the growth, reproduction, or survival of these invertebrate species; and (4) actions that remove hydraulic connectivity of the aquifer and the spring areas where it exists and would thereby negatively affect the PCEs of the critical habitat of these species and the population dynamics of the species. Alteration of subsurface water flows through destruction of geologic features (for example, excavation) or creation of impediments to flow (for example, concrete filling), especially in proximity to spring outlets, could negatively alter the hydraulic connectivity necessary to sustain these species. It is necessary for subsurface habitat to remain intact with sufficient hydraulic connectivity of flow paths and conduits to ensure that PCEs (water quality, water quantity, and food supply) for the designated critical habitat units remain adequate for all three listed invertebrates (72 FR 39248-39283).

Conclusion

After reviewing the current status of the fountain darter, Texas wild-rice, San Marcos gambusia, San Marcos salamander, Texas blind salamander, Comal springs riffle beetle, Comal springs dryopid beetle, and Peck's cave amphipod; the environmental baseline for the action area; the effects of ongoing and proposed actions of the three DoD installations (Fort Sam Houston, Lackland AFB, and Randolph AFB) and the cumulative effects; it is the Service's biological opinion that as proposed, this action is not likely to jeopardize the continued existence of these species. It is also our biological opinion that DoD's Edwards well withdrawals are not likely to adversely modify designated critical habitat. This is based on the assumption that, over the next five years, there will be a successful regional effort resulting in an incidental take permit for all non-Federal groundwater use that addresses listed threatened and endangered Edwards aquifer dependent species. We believe that the Edwards Aquifer Recovery Implementation Program will help foster that success.

The actions proposed by DoD to: (1) reduce reliance on groundwater withdrawal from the Edwards aquifer, (2) implement stringent drought management plans, (3) protect water quality, and (4) fund conservation actions (to the extent that funds are available) will reduce the impacts by DoD installations on the listed species and their critical habitat. The Service believes these actions are consistent with the three DoD installations' overall average historic water use and represent their fair share of reducing those overall impacts over the time covered by this consultation (January 1, 2008 through December 31, 2012). The Service believes the conservative use of Edwards aquifer water by DoD, identified in this biological opinion, represents a reasonable goal for the time frame covered by this consultation. However, as evidenced by the figures presented, further water withdrawal reductions may be needed beyond 2012 to reduce the probability of the species extinctions due to low spring flows.

It is possible that during the period covered by this biological opinion (the next five years), the EAA may have completed a comprehensive aquifer management plan and habitat conservation plan that can form the basis for a region wide ESA incidental take permit application that will cover EAA permitted water use by the entire region. Federal agencies such as the Service and DoD must still comply with section 7(a)(2) consultation requirements of the ESA.

This non-jeopardy conclusion is based in large part on the DoD's ongoing commitment to reduce their reliance on withdrawals from the Edwards aquifer for calendar year 2008 and each year beyond until December 31, 2012, the period covered by this consultation.

These actions will increase the species' chances of making it through a repeat episode of temporary low spring flows in the interim before a region wide management plan is implemented that helps ensures the covered species are not jeopardized and that critical habitat is not adversely modified.

INCIDENTAL TAKE

Section 9 of the ESA, and Federal regulation pursuant to section 4(d) of the ESA as amended, prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering. Incidental take is any take of listed animal species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or the applicant. Under the terms of sections 7(b)(4) and 7(o)(2) of the ESA, taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with an incidental take statement.

The measures described below as reasonable and prudent measures and terms and conditions in this biological opinion are non-discretionary and must be undertaken by DoD so that they become binding conditions of any condition of any grant or permit issued to DoD, as appropriate, in order for the exemption in section 7(o)(2) to apply DoD and subject installations (Fort Sam Houston, Lackland AFB, and Randolph AFB) have a continuing duty to regulate the activity covered by this incidental take statement. If DoD and the three installations (1) fail to assume, implement, or adhere to the terms and conditions of the incidental take statement, and/or (2) fail to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, DoD and the three installations must report the progress of the action and its impacts on the species to the Service as specified in the incidental take statement. [50 Code of Federal Regulations (CFR) §402.14(i)(3)].

Even though the Service expects that groundwater withdrawals that are facilitated by the ongoing and proposed actions of DoD's three installations will contribute to incidental take of fountain darters, San Marcos gambusia, and Comal Springs riffle beetle, and possibly Texas blind salamander, San Marcos salamander, Comal Springs dryopid beetle, and Peck's cave amphipod, the best scientific and commercial data available are not sufficient to enable an estimate of a specific amount of incidental take to the species. In instances such as these, the Service has designated the expected level of take as unquantifiable. The Service is providing DoD with an incidental take statement for: (1) Peck's cave amphipod, (2) Comal Springs dryopid beetle, (3) Comal Springs riffle beetle, (4) fountain darter, (5) San Marcos salamander, and (6) Texas blind salamander.

The Service recognizes that: (1) DoD does not control pumping over the entire aquifer region, (2) for the period covered under this consultation, DoD withdrawal from the Edwards aquifer will generally be about 2.1 percent of total withdrawals, and (3) DoD conservation actions described in this BO demonstrates leadership in addressing their fair share of the overall picture needed to minimize take and avoid jeopardy and reduce the risk of species extinction. Equivalent efforts to reduce withdrawals, and provide springflows for the listed species, and minimize and mitigate any take, and reduce the risk of jeopardizing the species or adversely modifying their critical habitats to low levels is the responsibility of all Edwards aquifer users.

Sections 7(b)(4) and 7(o)(2) of the ESA generally do not apply to the incidental take of listed plant species like Texas wild-rice. However, protection of listed plants is provided to the extent that ESA prohibits the removal, reduction to, and possession of federally listed endangered plants or the malicious damage of such plants on areas under Federal jurisdiction, or the destruction of endangered plants on non-Federal areas in violation of State law or regulation or in the course of any violation of a State criminal trespass law.

This biological opinion does not authorize any form of take that is not incidental to the withdrawal of Edwards aquifer groundwater by the three DoD installations, in the authorized water withdrawal amounts specified and in conjunction with other take minimizing measures described in this biological opinion.

Effect of Take

In this biological opinion, the Service determined that this unquantifiable level of anticipated take from DoD's actions is not likely to result in jeopardy to the fountain darter, Texas wild-rice, San Marcos gambusia, San Marcos salamander, Texas blind salamander, Comal springs riffle beetle, Comal springs dryopid beetle, and Peck's cave amphipod or the destruction or adverse modification of critical habitat for these species.

Reasonable and Prudent Measures

The Service believes that the reasonable and prudent measures presented below are necessary and appropriate to minimize the incidental taking authorized by this biological opinion.

1. The DoD shall, to the maximum practicable extent, avoid and minimize adverse effects to the Peck's cave amphipod, Comal Springs dryopid beetle, Comal Springs riffle beetle, fountain darter, San Marcos salamander, and Texas blind salamander.

2. Progressively reduce DoD's installations dependence on Edwards aquifer groundwater within the time frame covered by this consultation (June 2007 to December 2012); implement water conservation measures and other alternative water sources to reduce Edwards aquifer water withdrawals.

   DoD will evaluate their performance in achieving the necessary cutbacks in Edwards aquifer use and make the necessary adjustments to meet those levels, and manage and accommodate growth and increased water needs without surpassing these permitted levels.

3. DoD shall evaluate the effects on the Edwards aquifer of off-base activities in the San Antonio area. The presence of three DoD installations in this consultation has various effects outside the boundaries of the bases. The population of contractors, employees, military retirees, and their dependents associated with DoD should be quantified and their use of Edwards water estimated.

4. Actively promote public information and education on water use, quantity, quality, and conservation efforts on and off-base. Monitor and include in annual report the progress and effectiveness of such programs implemented.

5. Encourage partnerships among the installations and other Edwards aquifer users, such as local, regional, state, and Federal agencies and other private or public entities for cooperative efforts to manage the Edwards aquifer waters in a way that provides for continuous spring flows needed by the endangered and threatened species.

6. Investigate alternative sources of water, particularly for longer-term additional reductions beyond the time frame of this biological opinion.

7. All Reasonable and Prudent Measures from previous biological opinions are superceded.

8. Submit all annual reports to U.S. Fish and Wildlife Service, 10711 Burnet Rd., Suite 200, Austin, TX 78758. Annual reports are due on March 1st of each year covered by this biological opinion. The first report for CY 2007 will be due March 1, 2008, and the last report will be due March 1, 2013, for calendar year 2012.

Terms and Conditions

To be exempt from the prohibitions of section 9 of the ESA, DoD and the three installations are responsible for compliance with the following terms and conditions, which implement the reasonable and prudent measures described above.

1. DoD shall implement the conservation measures described on pages 6, 7, and 8 of this biological opinion.

2. DoD shall investigate the availability of other alternative water sources to further reduce Edwards water use at DoD installations (Fort Sam Houston, Lackland AFB, and Randolph AFB).

   Edwards aquifer water withdrawals, within the time frame covered by this consultation (January 1, 2008 through December 31, 2012). Withdrawals of all bases combined are not to exceed 12,012 acre-feet per year for any given calendar year from 2008 through 2012 inclusive.

   DoD and the subject installations will evaluate their performance in achieving the necessary cutbacks in Edwards aquifer use and make the necessary adjustments to meet those levels. Management must accommodate for growth and increased water needs without surpassing these permitted levels. Future needs for additional water may be accommodated through such mechanisms as purchasing or leasing water rights from others, using reuse water, and seeking alternative water sources. Construction, intra- or inter-water basin water transfers or other activities associated with potential future mechanisms for decreasing Edwards aquifer withdrawals may result in impacts to endangered species. Therefore, each project will need to be evaluated separately for impacts to federally listed species and determinations made whether these mechanisms and/or projects are in compliance with the ESA and if re-initiation of consultation would be necessary. If DoD or the three installations covered by this consultation fail to demonstrate satisfactory progress (as determined by the Service and/or not meeting these targets) toward reducing pumping demands on the Edwards aquifer, DoD will reinitiate formal consultation with the Service.

3. Monitor the effectiveness of the critical period (drought) management plan and include in the annual report to the Service.

4. Design and implement a voluntary program or partner with EAA, SAWS, and/or other organizations to educate and assist employees in achieving water conservation on base and off base at personal residences. Such program activities could include information on such things as retrofitting with low flow toilets and shower heads or xeriscaping.

5. Investigate and partner with appropriate parties to find alternative sources of water that will yield longer-term, additional reductions of water beyond the life of this biological opinion.

6. DoD will submit annual reports informing the Service of progress made to meet the Reasonable and Prudent Measures and Terms and Conditions set forth in this biological opinion and the effectiveness of those activities for the length of the permit. The reports should include total annual (calendar year) water withdrawal for each of the three installations, broken down on a monthly basis. Annual reports should be sent to the U.S. Fish and Wildlife Service, 10711 Burnet Rd., Suite 200, Austin, TX 78758 and due March 1st of each year (for the previous calendar year) covered by this biological opinion. A report providing information on the indirect effects on the Edwards aquifer by off-base DoD personnel, retirees, and contractors shall be included in the CY 2010 report due March, 2011.

7. DoD will maintain responsibility for assuring these terms and conditions and measures are accomplished during the time frame covered by this consultation. If EAA completes a comprehensive aquifer management plan and habitat conservation plan that can form the basis for a region-wide ESA incidental take permit application that will cover water use by the entire region, the Service will determine whether DoD is in compliance with the regional permit. If it is determined that DoD is not covered under the region-wide habitat conservation plan and incidental take permit, an individual section 7 consultation will be necessary regarding impacts to the listed species and their critical habitats from any continued DoD Edwards aquifer water use beyond the time frame covered by this consultation.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. The term conservation recommendations has been defined as Service suggestions regarding discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or develop information.

The Service recognizes the Department of Defense's leadership role in modeling and protecting the Edwards aquifer over the past ten years. A new and improved MODFLOW model of the Edwards aquifer is now available, largely through DoD support.

The Service has examined the biological and logistical issues involved in water use reduction. We have determined that steady reductions in aquifer withdrawals over time could meet the needs of planners trying to implement comprehensive solutions to meet reduction goals that can ensure the survival of the species and their critical habitat.

In addition, the Service believes that in the foreseeable future as measures are implemented to reach these reduction goals, the risk to species survival is still high and can be reduced by implementing a significant drought management plan for further cut-backs. These actions may include such things as:

- improving the condition of species and habitat in the wild so that they are in better condition going into the low flows and so that the relative portion of the population impacted will be less;

- answering information needs to better manage the aquifer for conservation of listed species, and;
- maintaining captive populations to act as a backup for wild populations and enhance the chances of restoration.

In the previous consultation, we developed a list of possible projects that could serve one or more of these efforts. We are available to discuss projects and actions that would contribute to recovery of listed Edwards aquifer species.

The Service makes these conservation recommendations:

1. Further reduce water dependency beyond the levels set in this biological opinion. (Task 2.31 of Recovery Plan).

2. Provide for additional conservation measures for aquifer-dependent species either by contributing directly, indirectly, or in-kind to Edwards aquifer projects consistent with recovery planning of the Service, Texas Parks and Wildlife Department, and the subject recovery plan.

3. Assist in identifying and sampling Edwards wells for toothless blindcats and widemouth blindcats (two unlisted species endemic to the Edwards aquifer in Bexar County) and help develop conservation measures for these species.

4. Support improvements to the Edwards aquifer model including Hueco springs and relationship to other aquifers.

5. Assist with habitat and flow requirement studies of the listed species as needed

6. Contribute to captive propagation efforts for listed threatened and endangered species.

7. Contribute to the assessment and potential modification of dams and weirs in Comal and Hays counties for the benefit of listed species.

8. Participate in the Edwards Aquifer Recovery Implementation Program. DoD and the subject installations could work with other aquifer users and participate in regional aquifer management planning to develop a comprehensive approach to aquifer management that avoids jeopardizing the species and avoids adversely modifying their critical habitat and minimizes and mitigates negative impacts to the species and their ecosystems as much as possible.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION

This concludes formal consultation on the ongoing and proposed actions at three DoD installations. Reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained and if: (1) DoD Edwards aquifer water withdrawals exceed those outlined in the reasonable and prudent measures; (2) information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this biological opinion, (3) Department of Defense actions are subsequently modified in a manner that causes an effect to a listed species or critical habitat that was not considered in this biological opinion; or (5) a new species is listed or critical habitat designated that may be affected by this action (50 CFR 402.16). This opinion is based on an expectation of that over the next five years, the Edwards aquifer will be effectively managed to maintain adequate springflows should a drought occur.

We appreciate the Department of Defense's continued commitment to conserving our nation's trust resources. In future communications on this project, please refer to consultation number 21450-2007-F-0056. If we may be of further assistance, please contact me at (512) 490-0057 extension 248.

Sincerely,

/s/

Adam Zerrenner
Field Supervisor

cc: State Administrator, Service, Austin, Texas
Regional Director, Service, Albuquerque, New Mexico
Allen Richmond, Randolph AFB, San Antonio, Texas

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LIST OF TABLES

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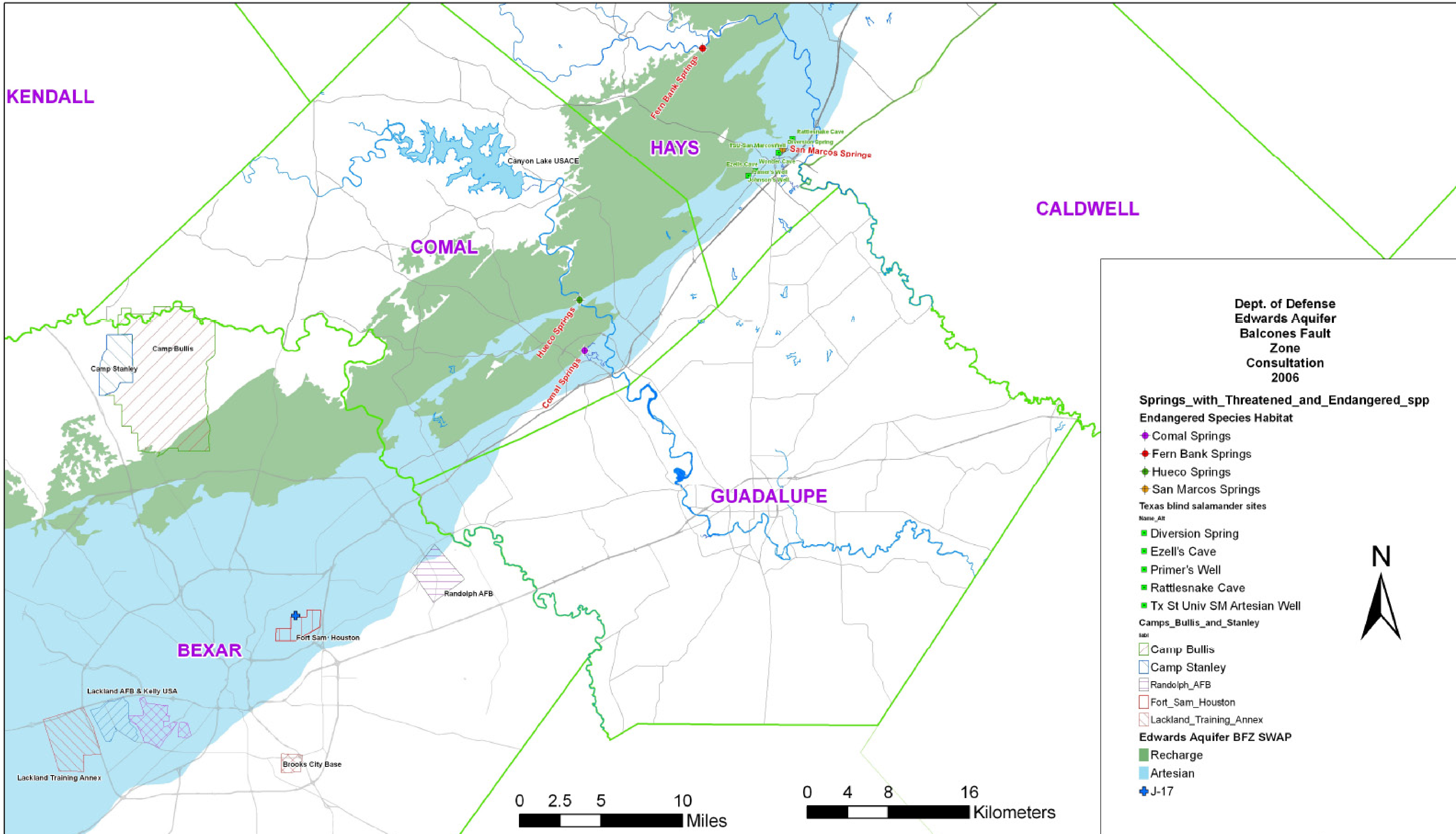

KENDALL
HAYS
CALDWELL
COMAL
GUADALUPE
BEXAR
Canyon Lake USACE
Fern Bank Springs
San Marcos Springs
Hueco Springs
Comal Springs
Camp Bullis
Camp Stanley
Randolph AFB
Fort Sam Houston
Lackland AFB & Kelly USA
Lackland Training Annex
Brooks City Base
Dept. of Defense
Edwards Aquifer
Balcones Fault
Zone
Consultation
2006
Springs_with_Threatened_and_Endangered_spp
Endangered Species Habitat
Comal Springs
Fern Bank Springs
Hueco Springs
San Marcos Springs
Texas blind salamander sites
Diversion Spring
Ezell's Cave
Primer's Well
Rattlesnake Cave
Tx St Univ SM Artesian Well
Camps_Bullis_and_Stanley
Camp Bullis
Camp Stanley
Randolph_AFB
Fort_Sam_Houston
Lackland_Training_Annex
Edwards Aquifer BFZ SWAP
Recharge
Artesian
J-17
N
0 2.5 5 10
Miles
0 4 8 16
Kilometers

Figure 1.

Figure 2.

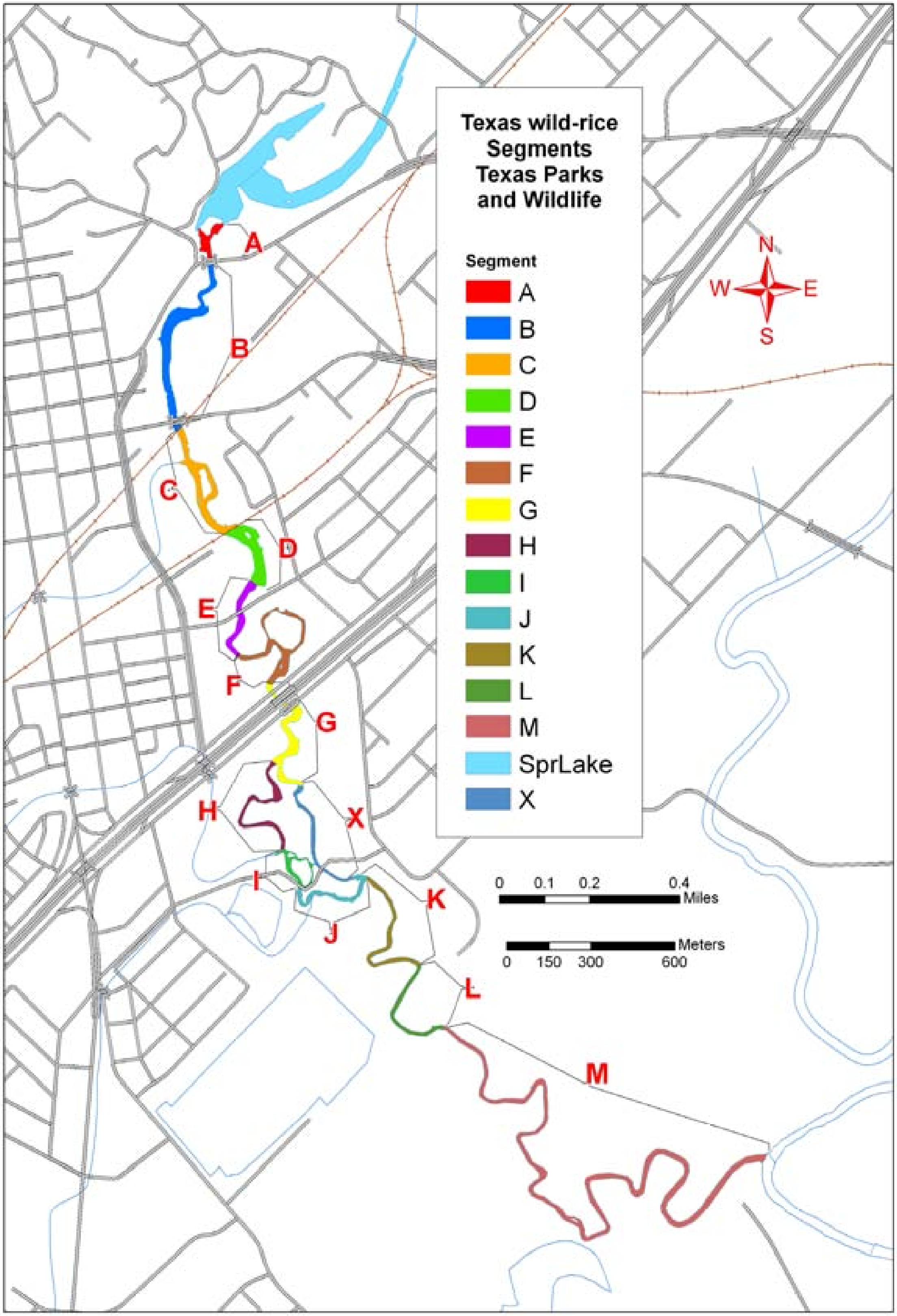
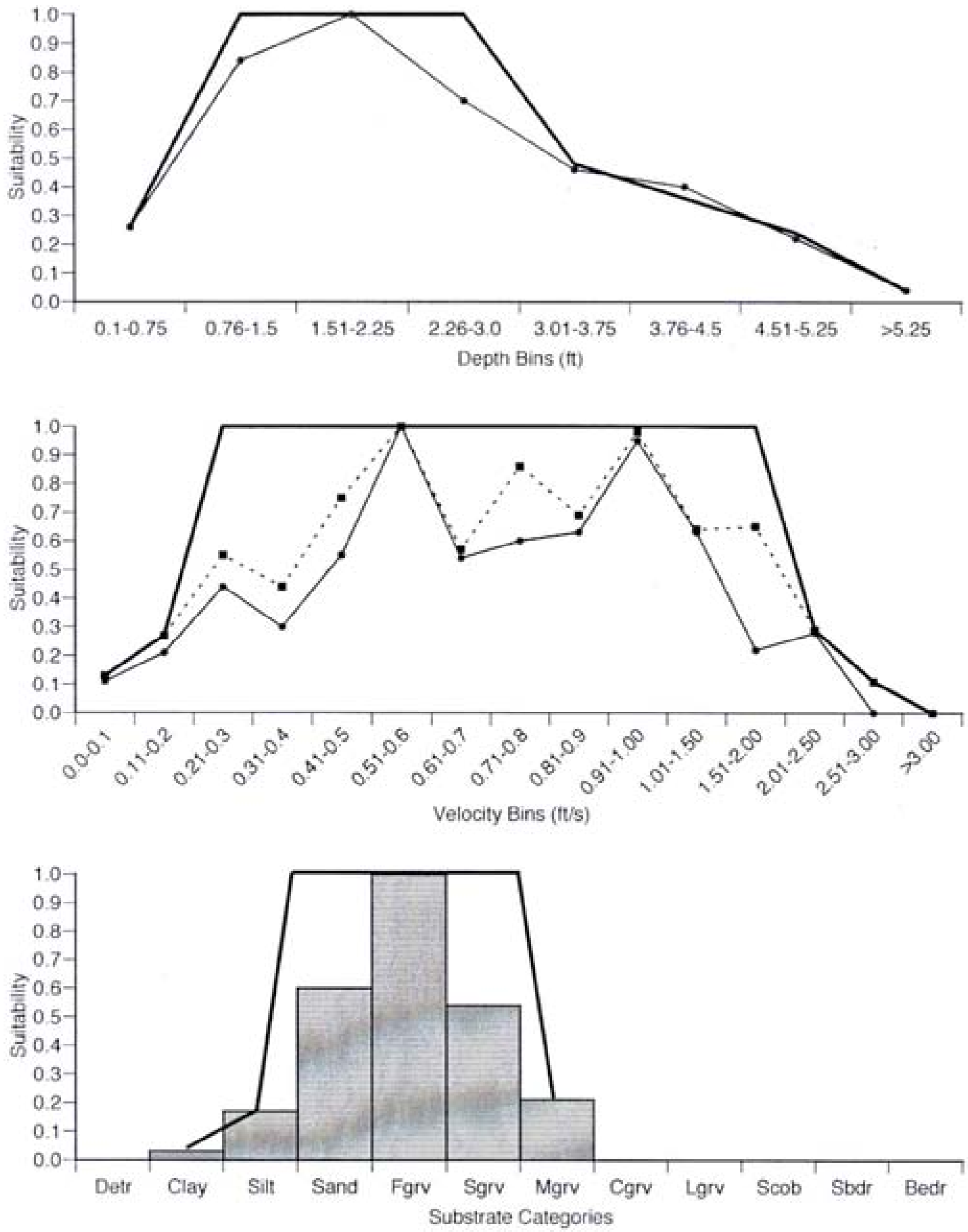
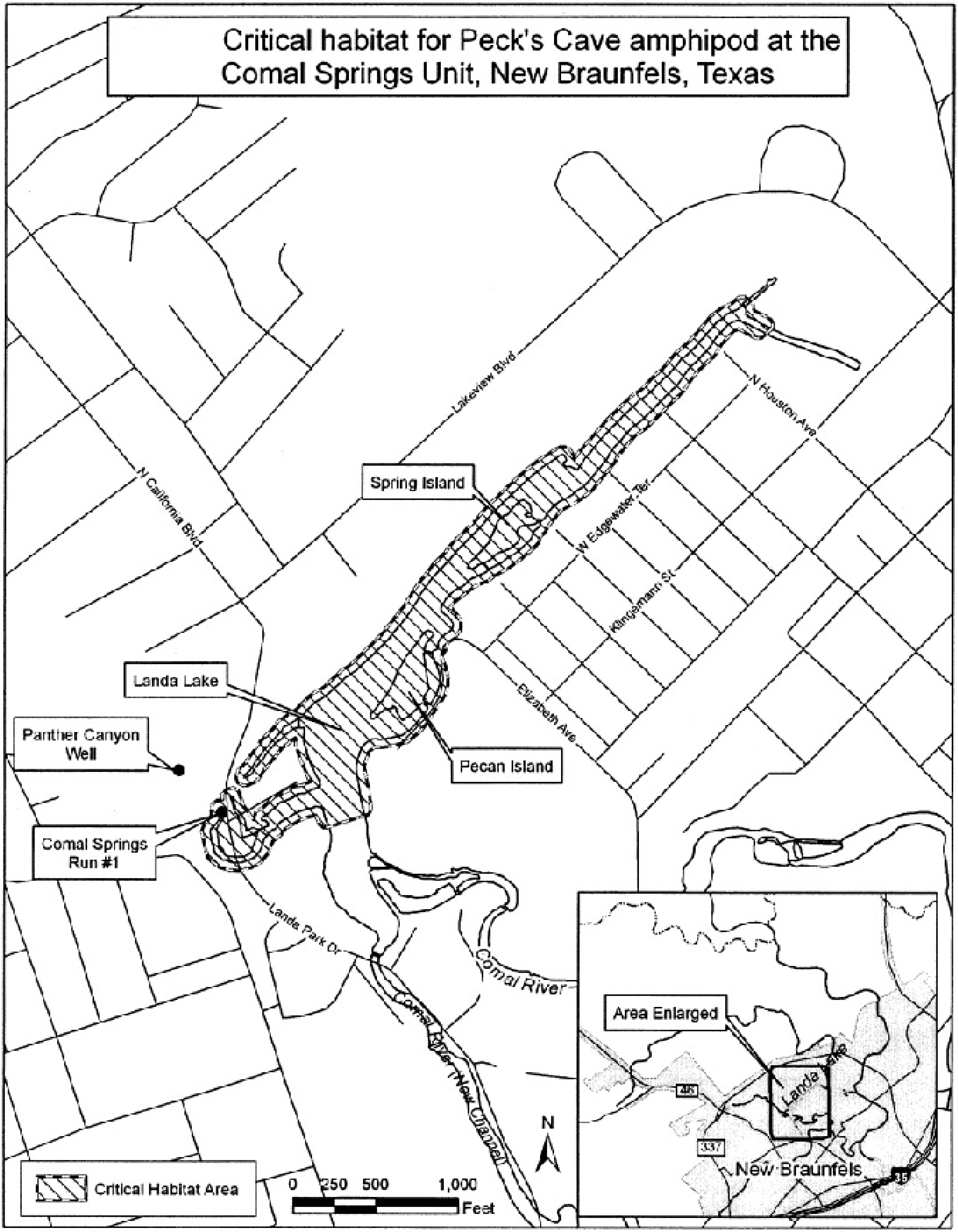

Texas wild-rice
Segments
Texas Parks
and Wildlife
Segment
A
B
C
D
E
F
G
H
I
J
K
L
M
SprLake
X
N
W
E
S
0 0.1 0.2 0.4
Miles
Meters
0 150 300 600

Figure 3



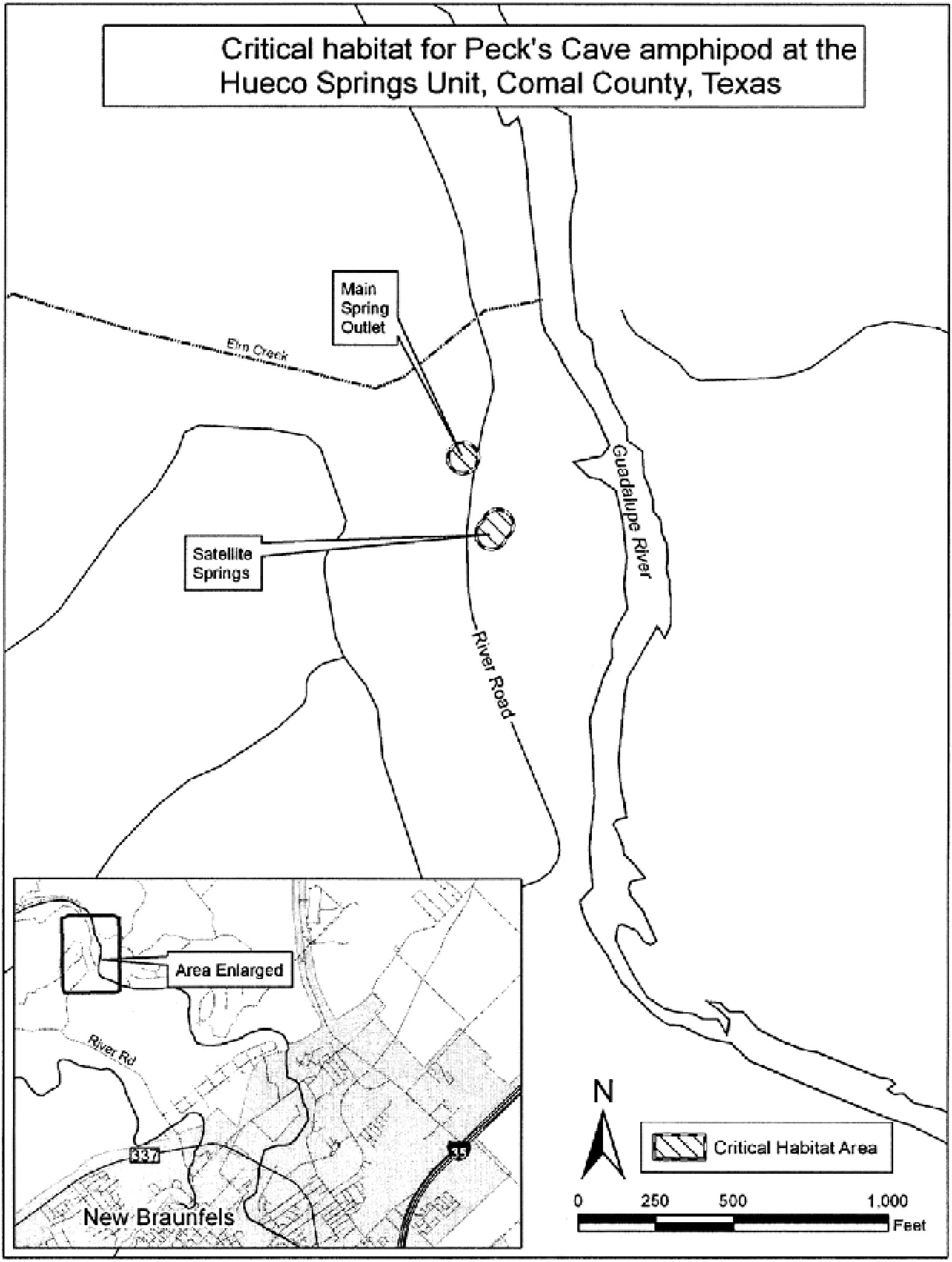
APPENDIX III: FIGURE 2.—Suitability criteria for *Zizania texana* for depth, current velocity, and substrate in the upper San Marcos River. Preference indices are indicated by solid lines or bars (substrate) and supplemental velocity curves are represented by dashed lines. Idealized habitat utilization curves are represented by heavy lines. Refer to Table 2 for substrate classifications used in this study.

Figure 4



Critical habitat for Peck's Cave amphipod at the Comal Springs Unit, New Braunfels, Texas
Lakeview Blvd
N Houston Ave
Spring Island
N Edgewater Ter
N California Blvd
Klingemann St
Elizabeth Ave
Landa Lake
Panther Canyon Well
Pecan Island
Comal Springs Run #1
Landa Park Dr
Comal River
Comal River (New Channel)
Area Enlarged
46
337
Landa Lake
New Braunfels
35
N
Critical Habitat Area
0
250
500
1,000
Feet

Figure 5



Critical habitat for Peck's Cave amphipod at the Hueco Springs Unit, Comal County, Texas
Main Spring Outlet
Elm Creek
Guadalupe River
Satellite Springs
River Road
Area Enlarged
River Rd
337
35
New Braunfels
N
Critical Habitat Area
0
250
500
1,000
Feet

Figure 6

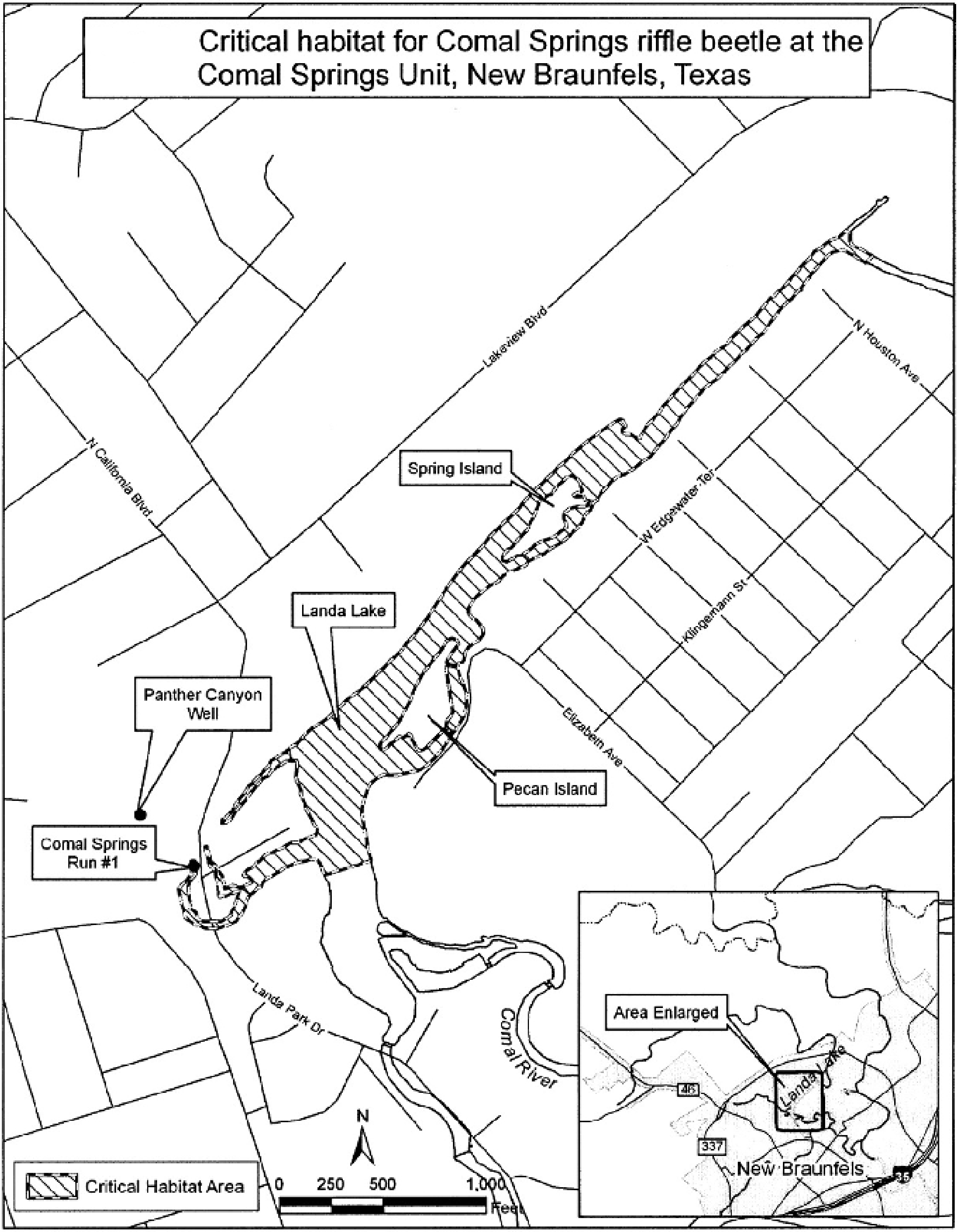
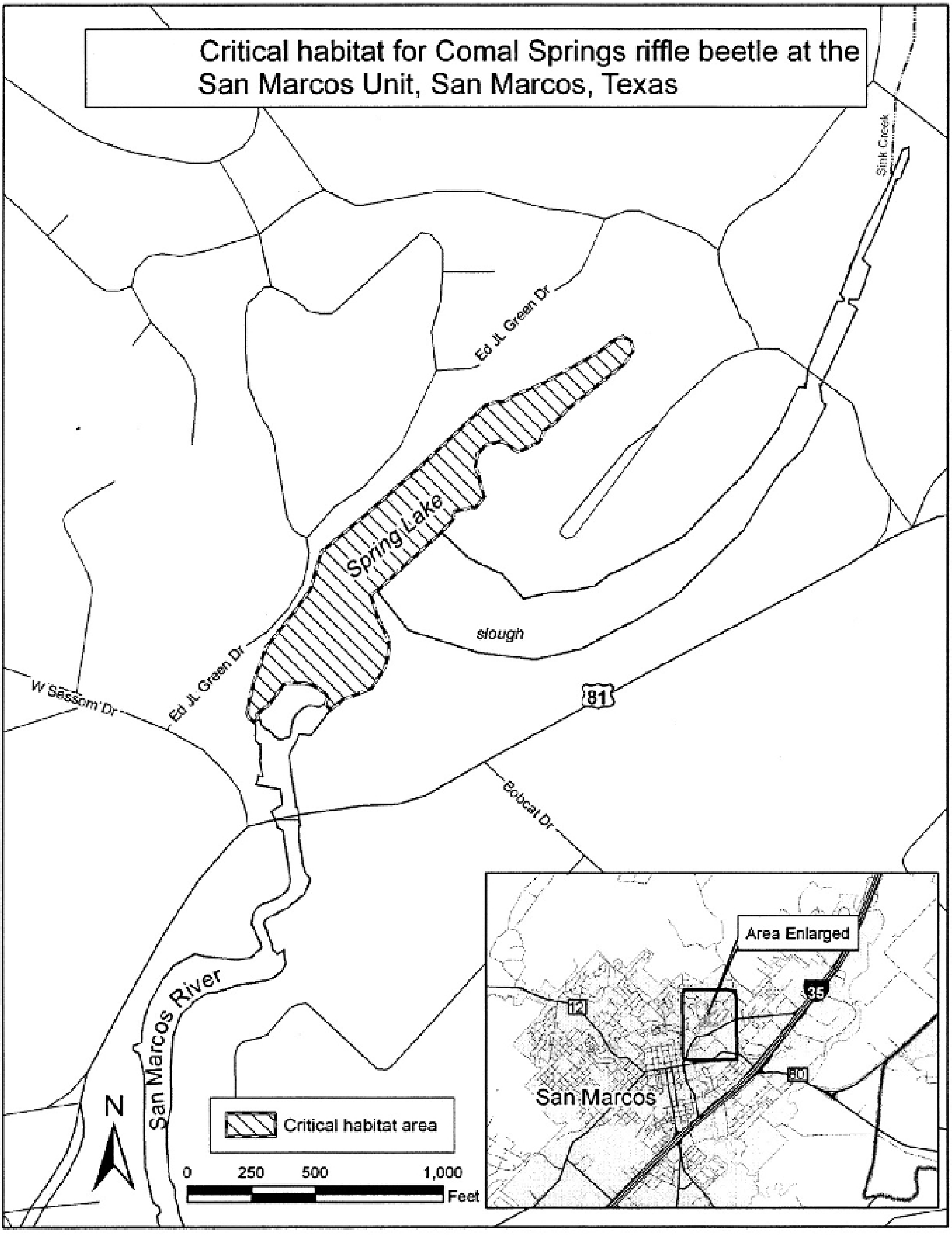
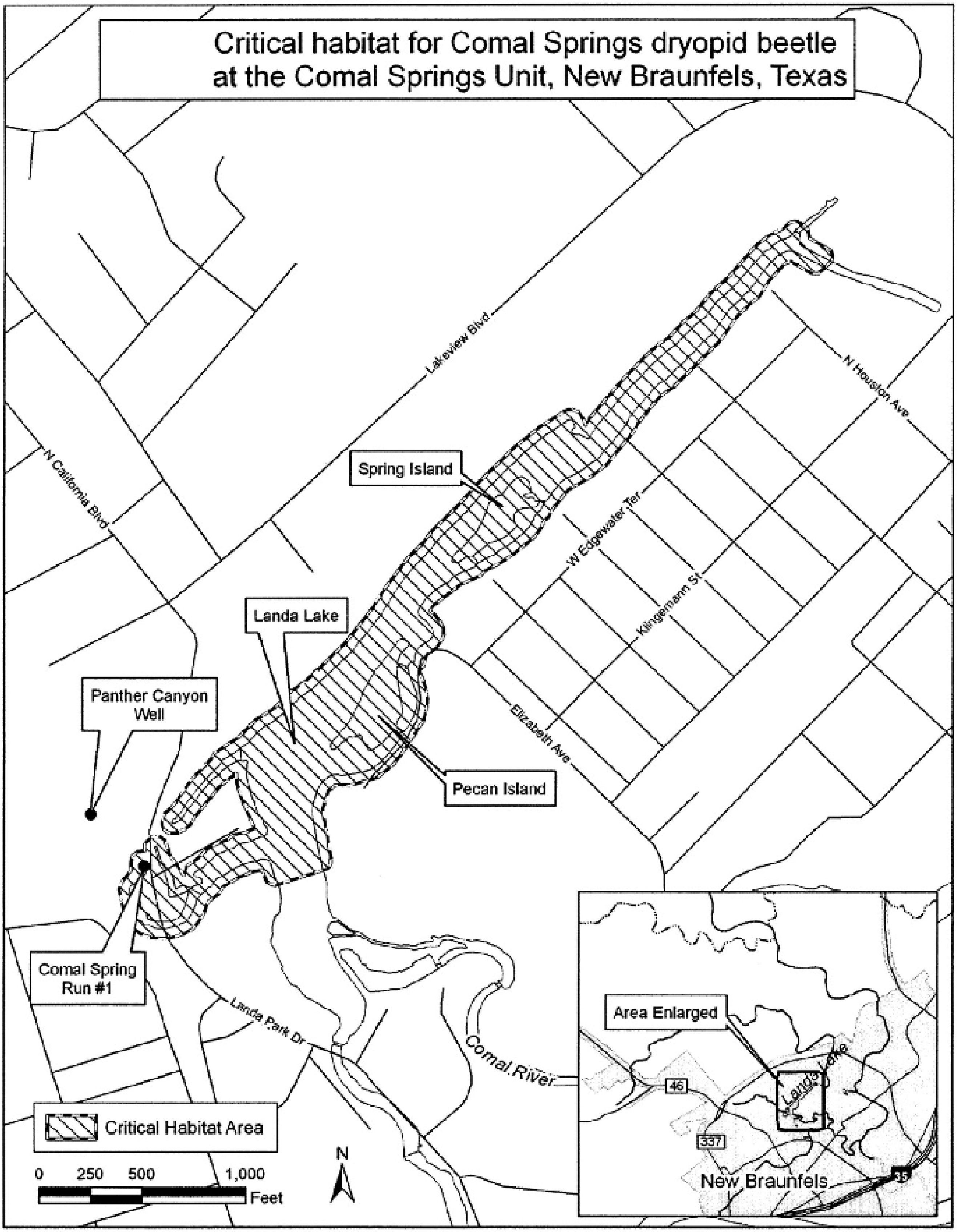

Critical habitat for Comal Springs riffle beetle at the Comal Springs Unit, New Braunfels, Texas
Lakeview Blvd
N Houston Ave
N California Blvd
Spring Island
W Edgewater Ter
Klingemann St
Landa Lake
Elizabeth Ave
Panther Canyon Well
Pecan Island
Comal Springs Run #1
Landa Park Dr
Comal River
Area Enlarged
Landa Lake
46
337
New Braunfels
35
N
Critical Habitat Area
0
250
500
1,000
Feet

Figure 7



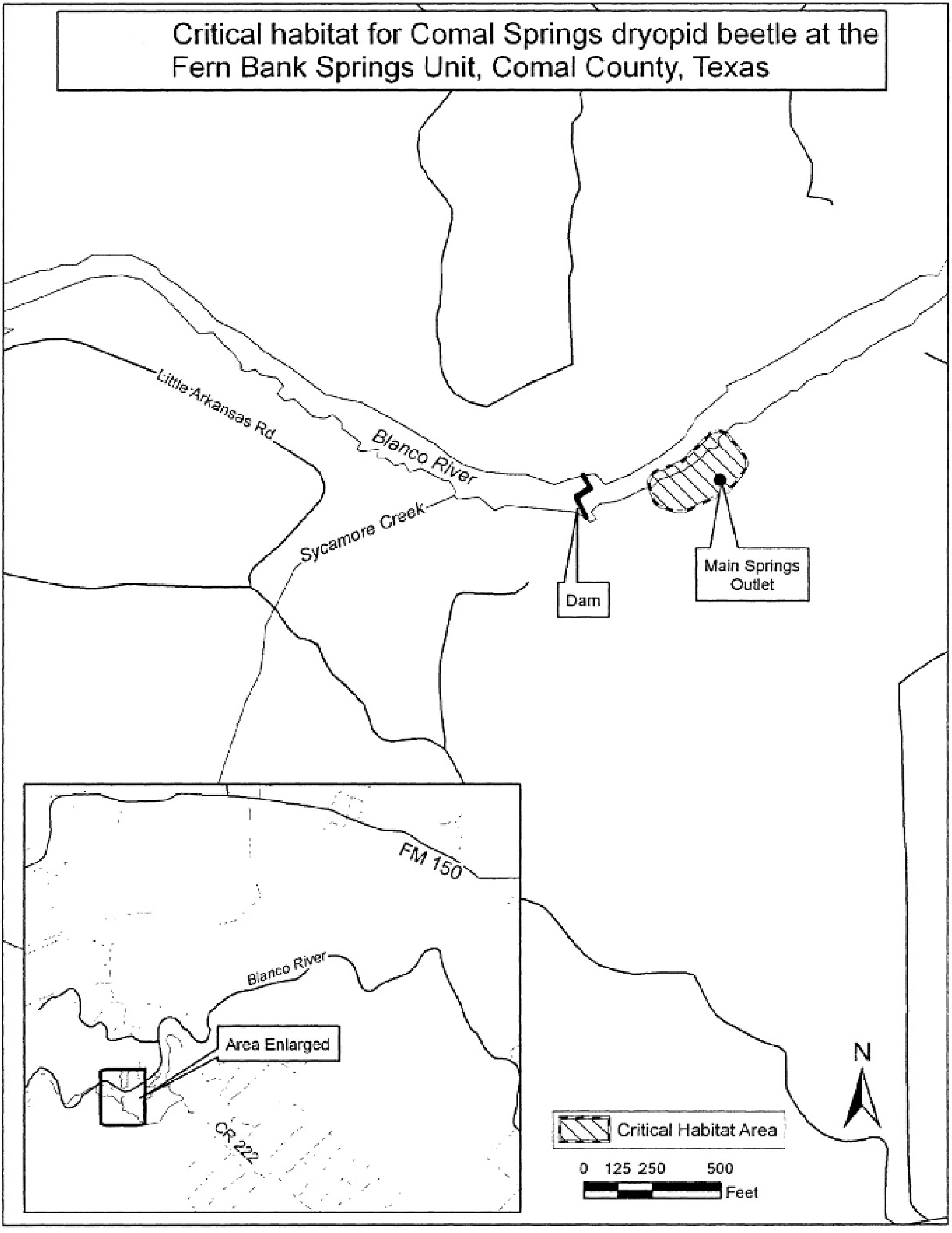
Critical habitat for Comal Springs riffle beetle at the San Marcos Unit, San Marcos, Texas
Sink Creek
Ed JL Green Dr
Spring Lake
slough
Ed JL Green Dr
W Sessom Dr
81
Bobcat Dr
San Marcos River
N
Critical habitat area
0
250
500
1,000
Feet
Area Enlarged
35
12
80
San Marcos

Figure 8



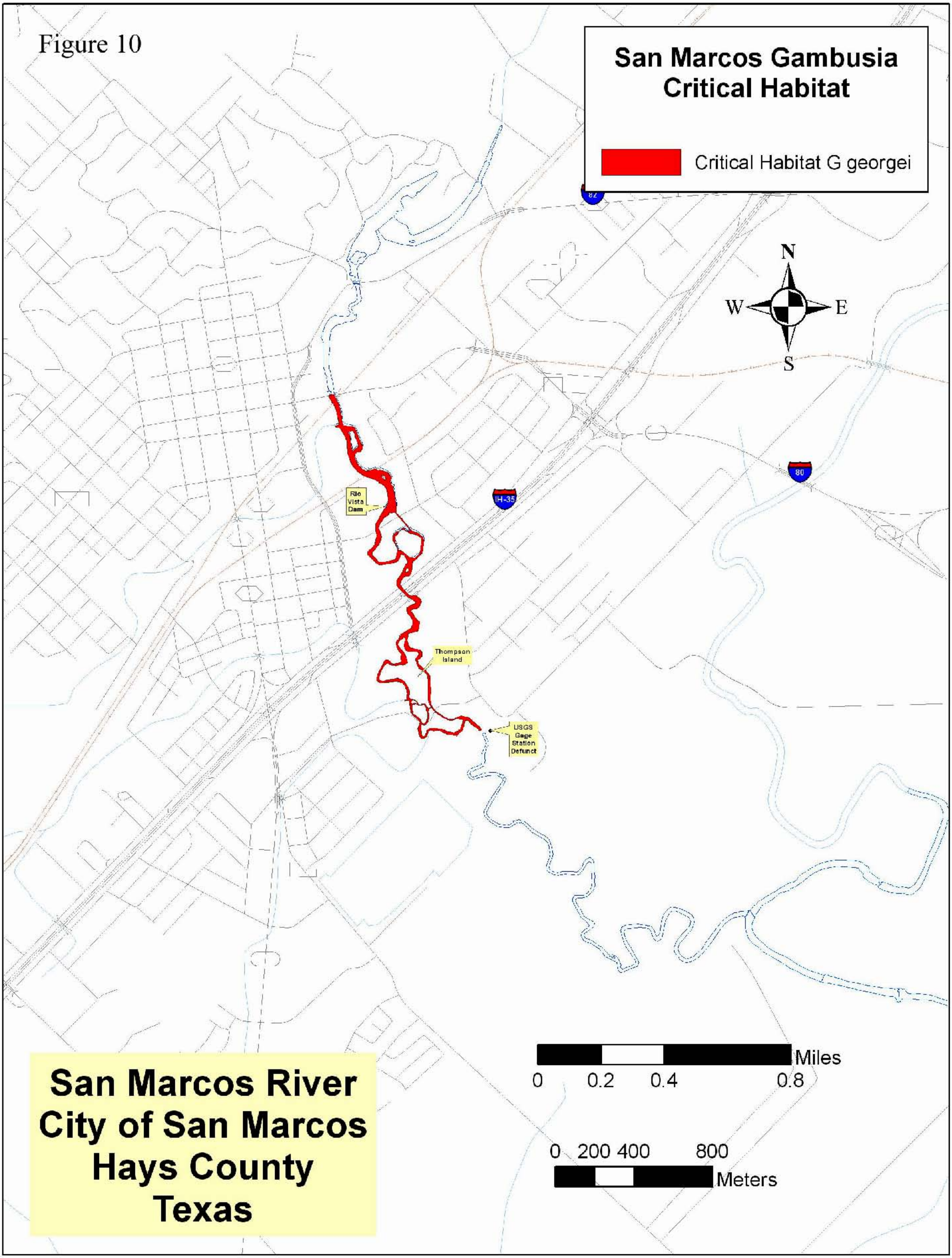
Critical habitat for Comal Springs dryopid beetle at the Comal Springs Unit, New Braunfels, Texas
Lakeview Blvd
N Houston Ave
N California Blvd
Spring Island
W Edgewater Ter
Klingemann St
Landa Lake
Panther Canyon Well
Elizabeth Ave
Pecan Island
Comal Spring Run #1
Landa Park Dr
Comal River
Area Enlarged
46
Landa Lake
337
New Braunfels
35
Critical Habitat Area
0
250
500
1,000
Feet
N

Figure 9



Critical habitat for Comal Springs dryopid beetle at the Fern Bank Springs Unit, Comal County, Texas
Little Arkansas Rd
Blanco River
Sycamore Creek
Dam
Main Springs Outlet
FM 150
Blanco River
Area Enlarged
CR 222
N
Critical Habitat Area
0 125 250 500
Feet

Figure 10


San Marcos Gambusia
Critical Habitat
Critical Habitat G georgei
N
W
E
S
82
Rio Vista Dam
IH-35
80
Thompson Island
USGS Gage Station Defunct
Miles
0 0.2 0.4 0.8
0 200 400 800
Meters
San Marcos River
City of San Marcos
Hays County
Texas

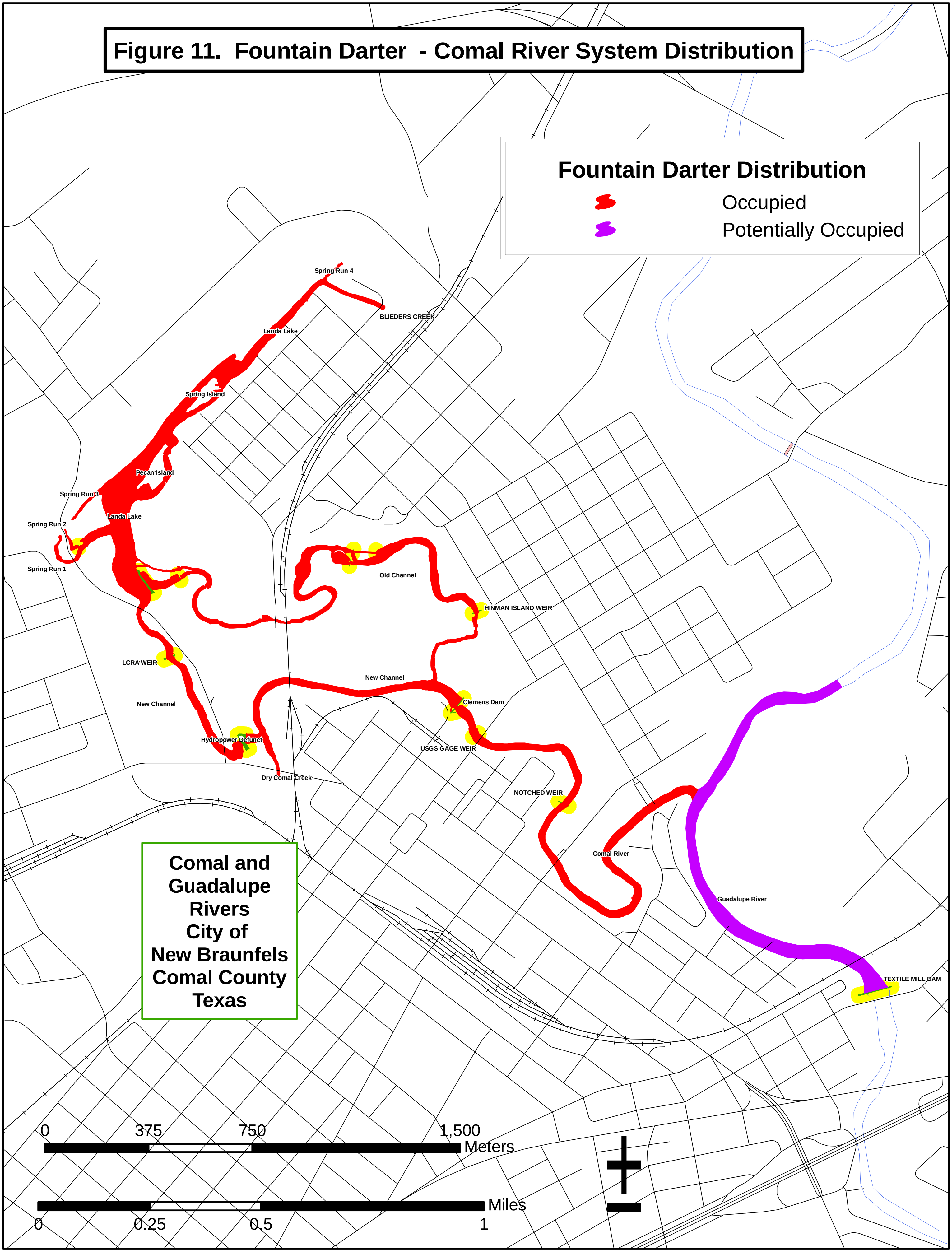
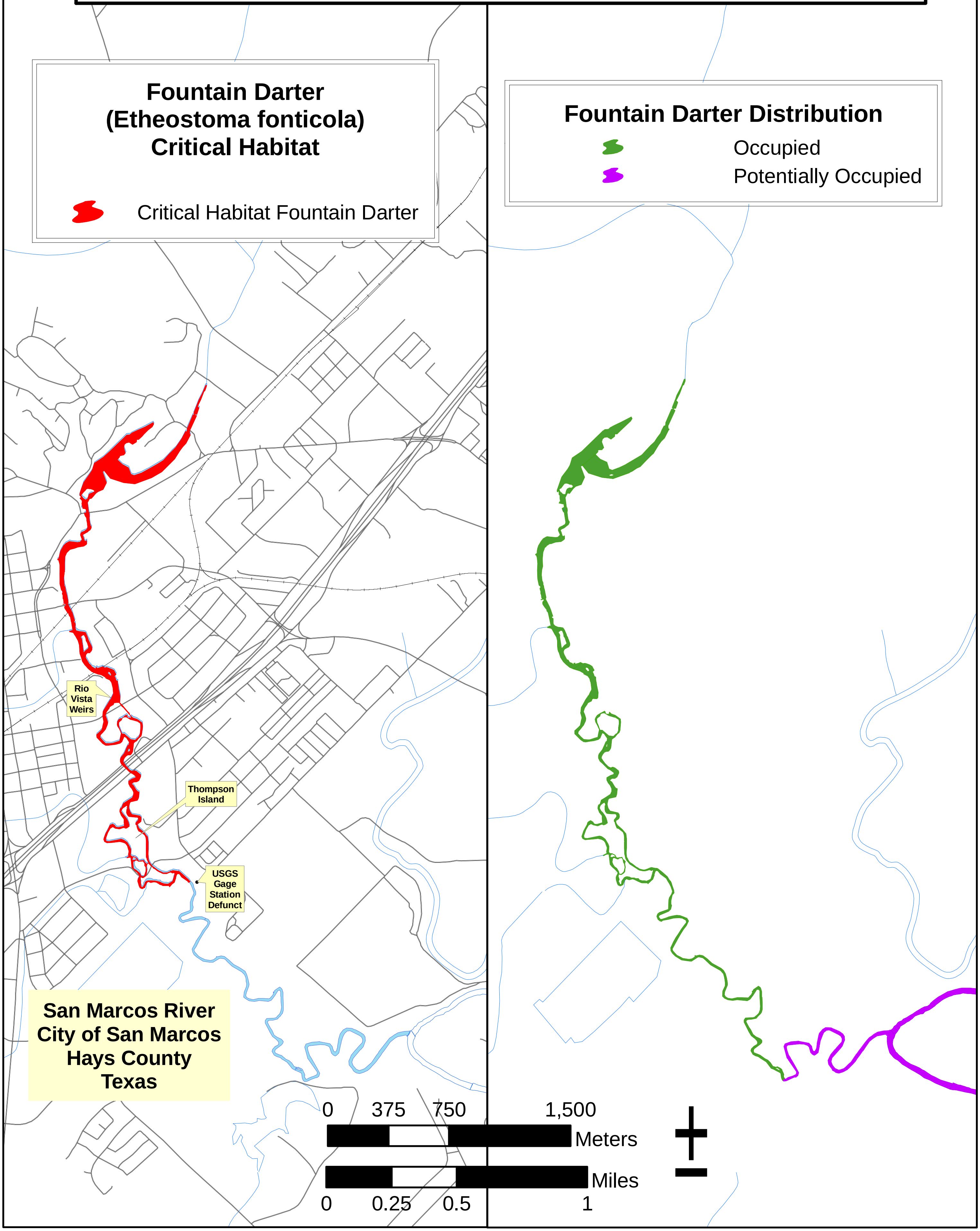


Figure 11. Fountain Darter - Comal River System Distribution

Figure 12. Fountain Darter - San Marcos Critical Habitat and Distribution



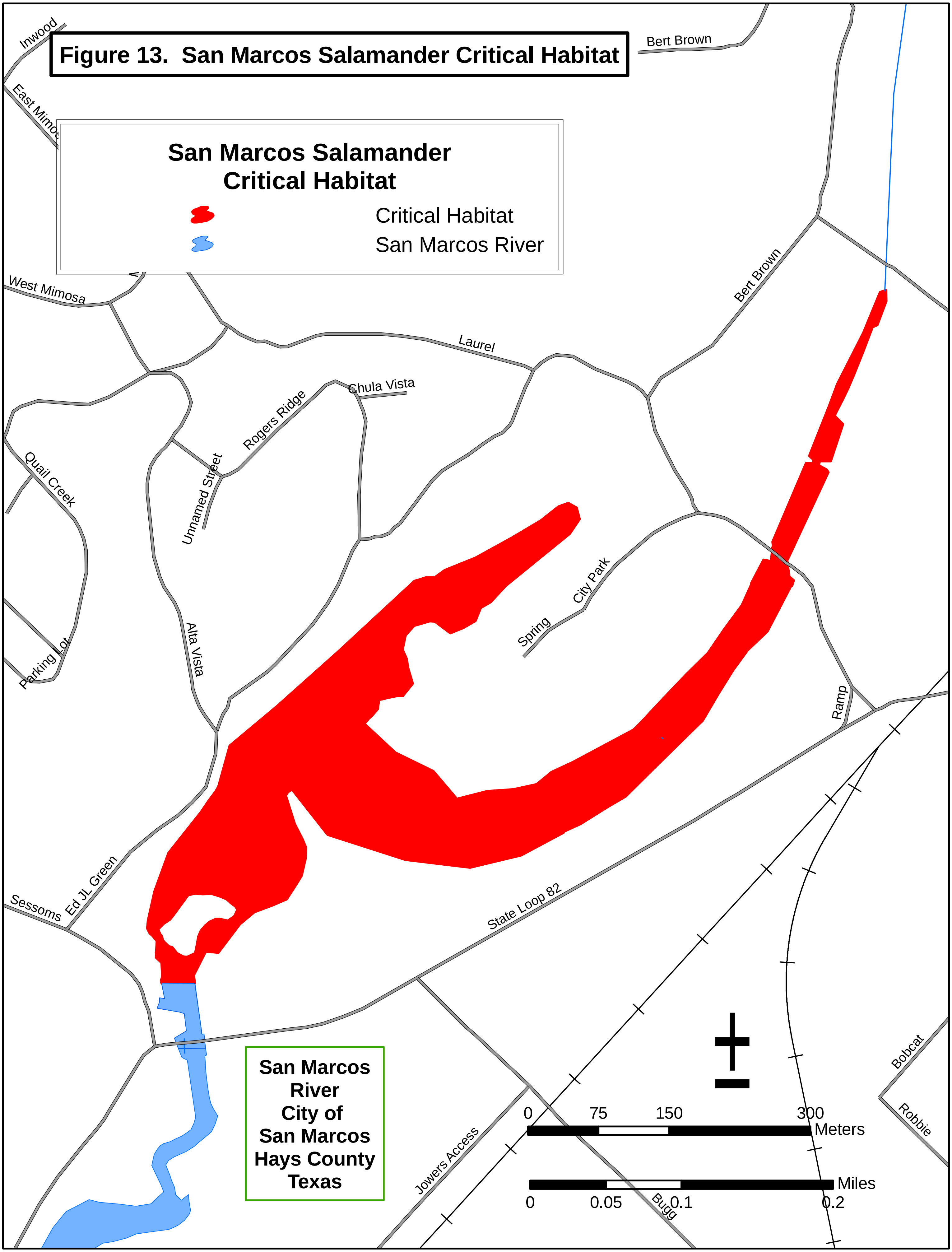


Figure 13. San Marcos Salamander Critical Habitat
San Marcos Salamander
Critical Habitat
Critical Habitat
San Marcos River
Inwood
East Mimosa
Bert Brown
West Mimosa
Laurel
Chula Vista
Rogers Ridge
Unnamed Street
Quail Creek
City Park
Spring
Alta Vista
Parking Lot
Ramp
Ed JL Green
Sessoms
State Loop 82
Bobcat
Robbie
Jowers Access
Bugg
0
75
150
300
Meters
0
0.05
0.1
0.2
Miles
San Marcos
River
City of
San Marcos
Hays County
Texas

Figure 14. Texas Blind Salamander Historic and Known Localities

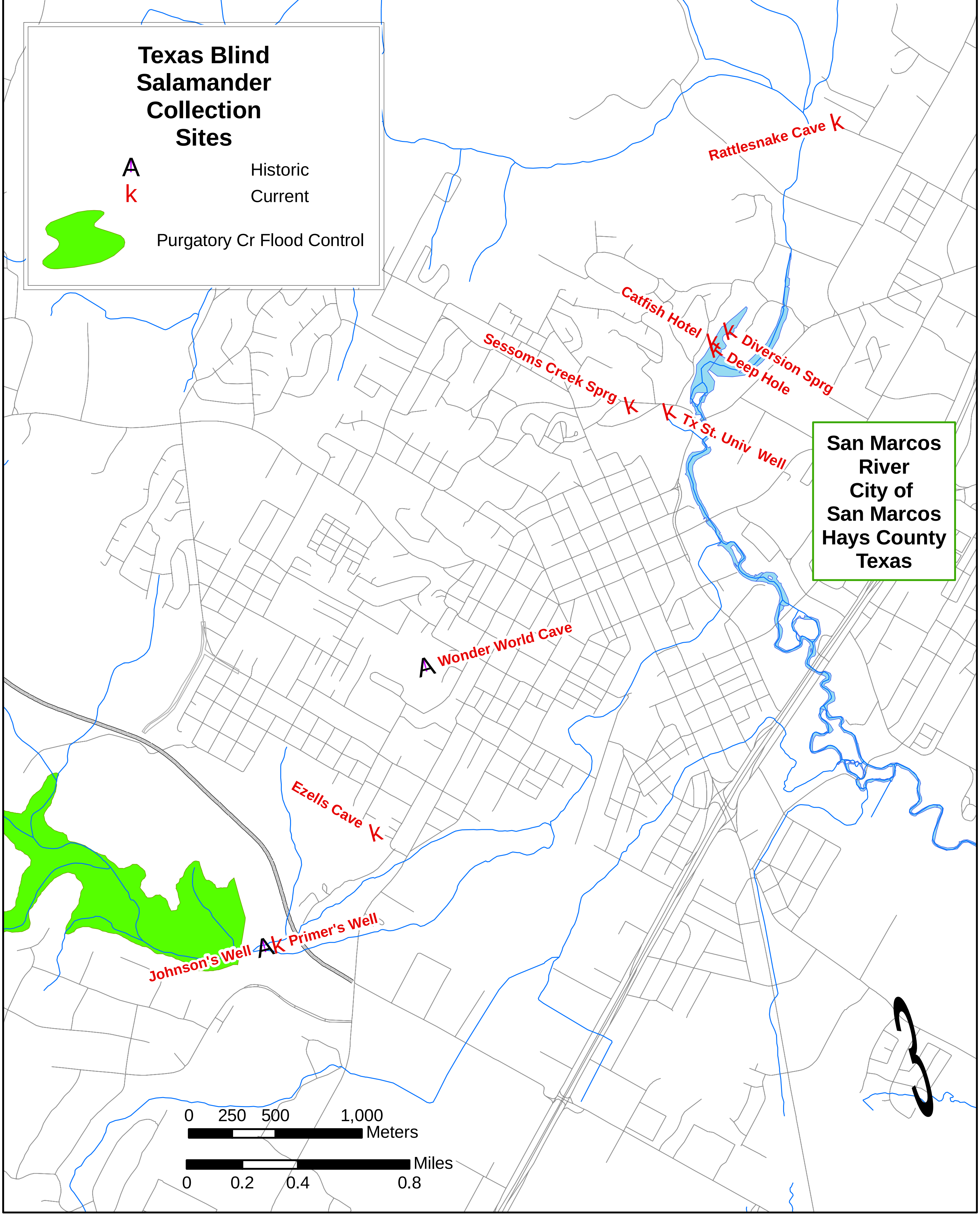
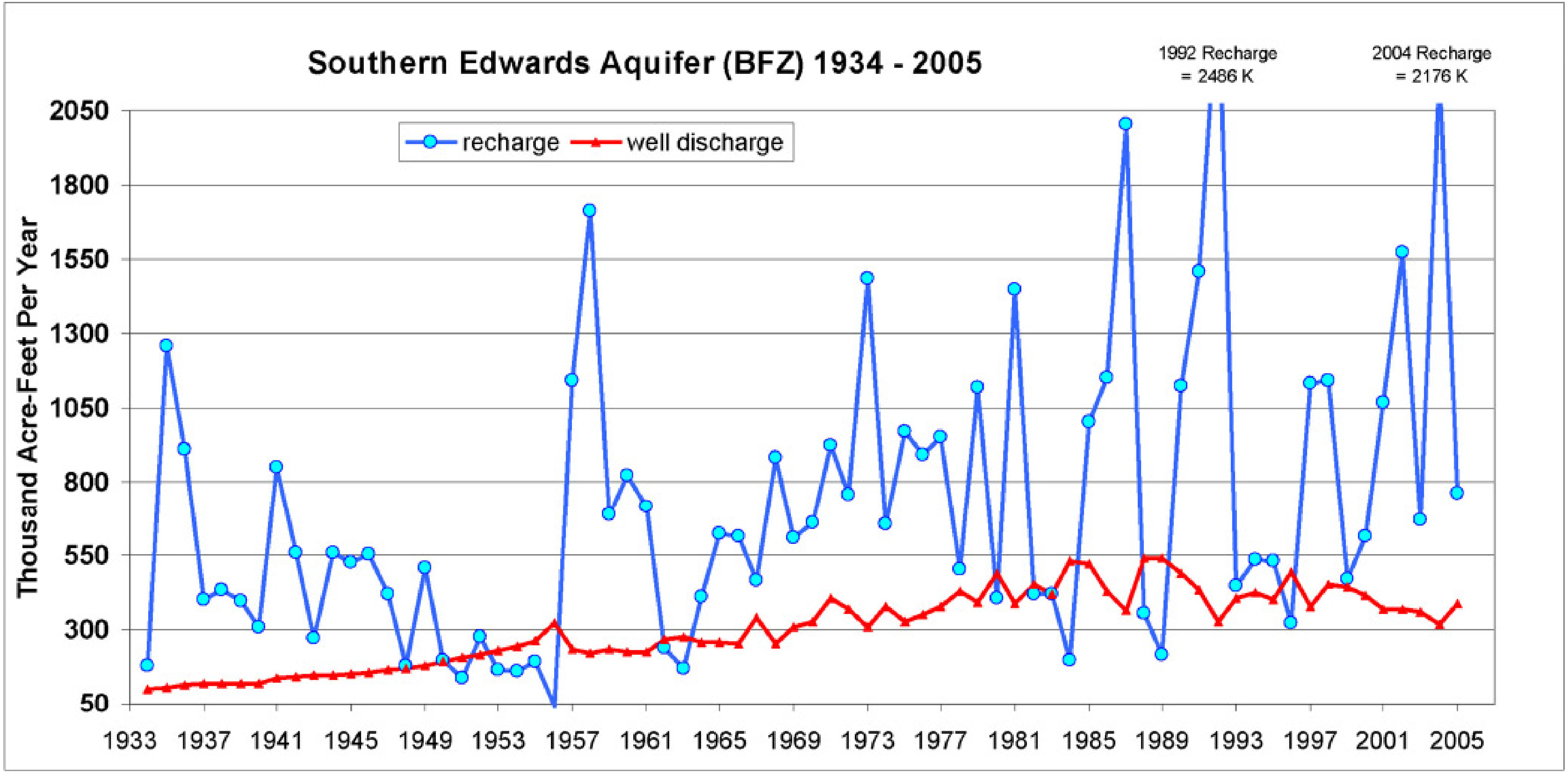


Figure 15



Southern Edwards Aquifer (BFZ) 1934 - 2005
1992 Recharge = 2486 K
2004 Recharge = 2176 K
recharge
well discharge
Thousand Acre-Feet Per Year
2050
1800
1550
1300
1050
800
550
300
50
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005

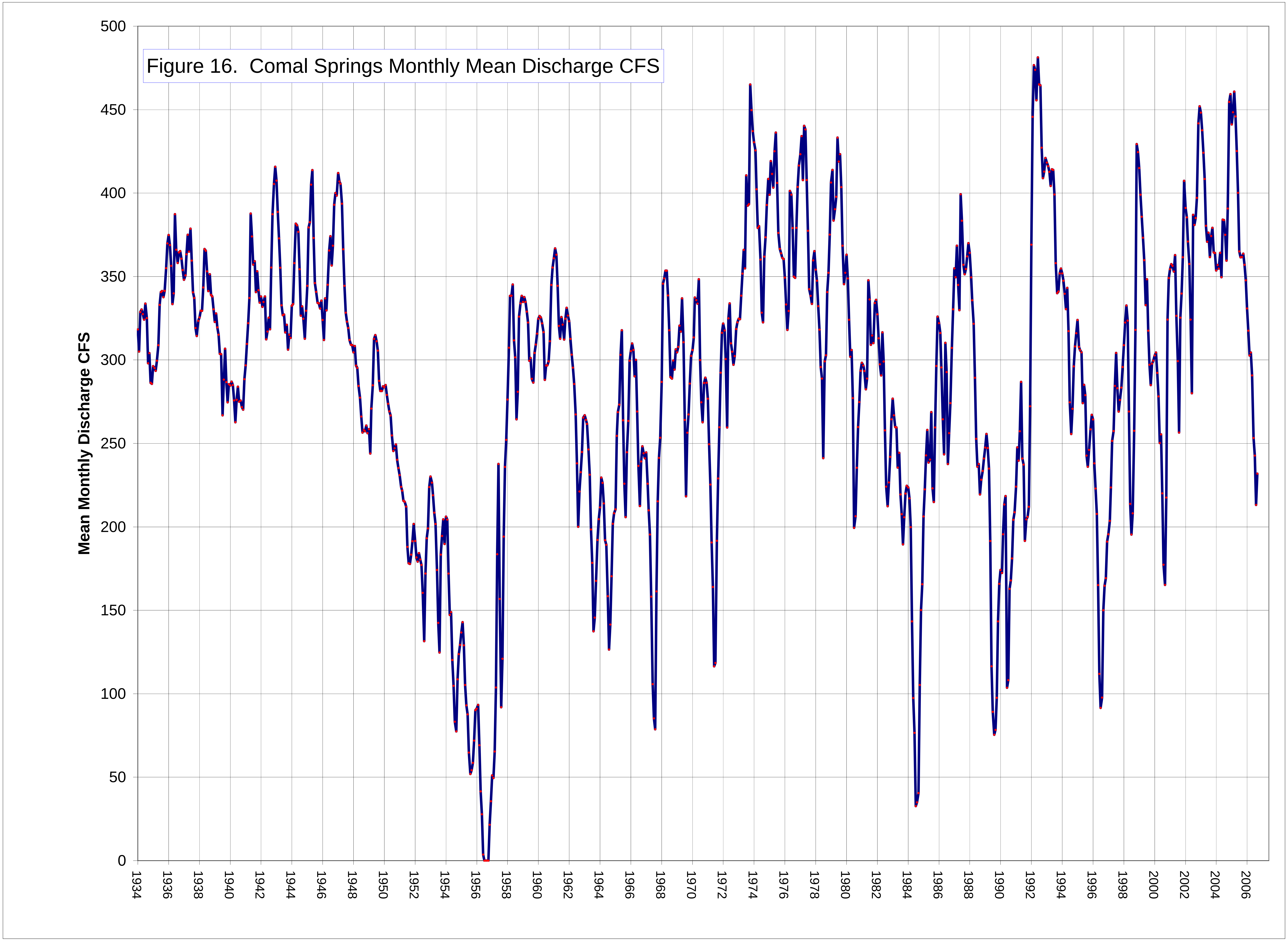
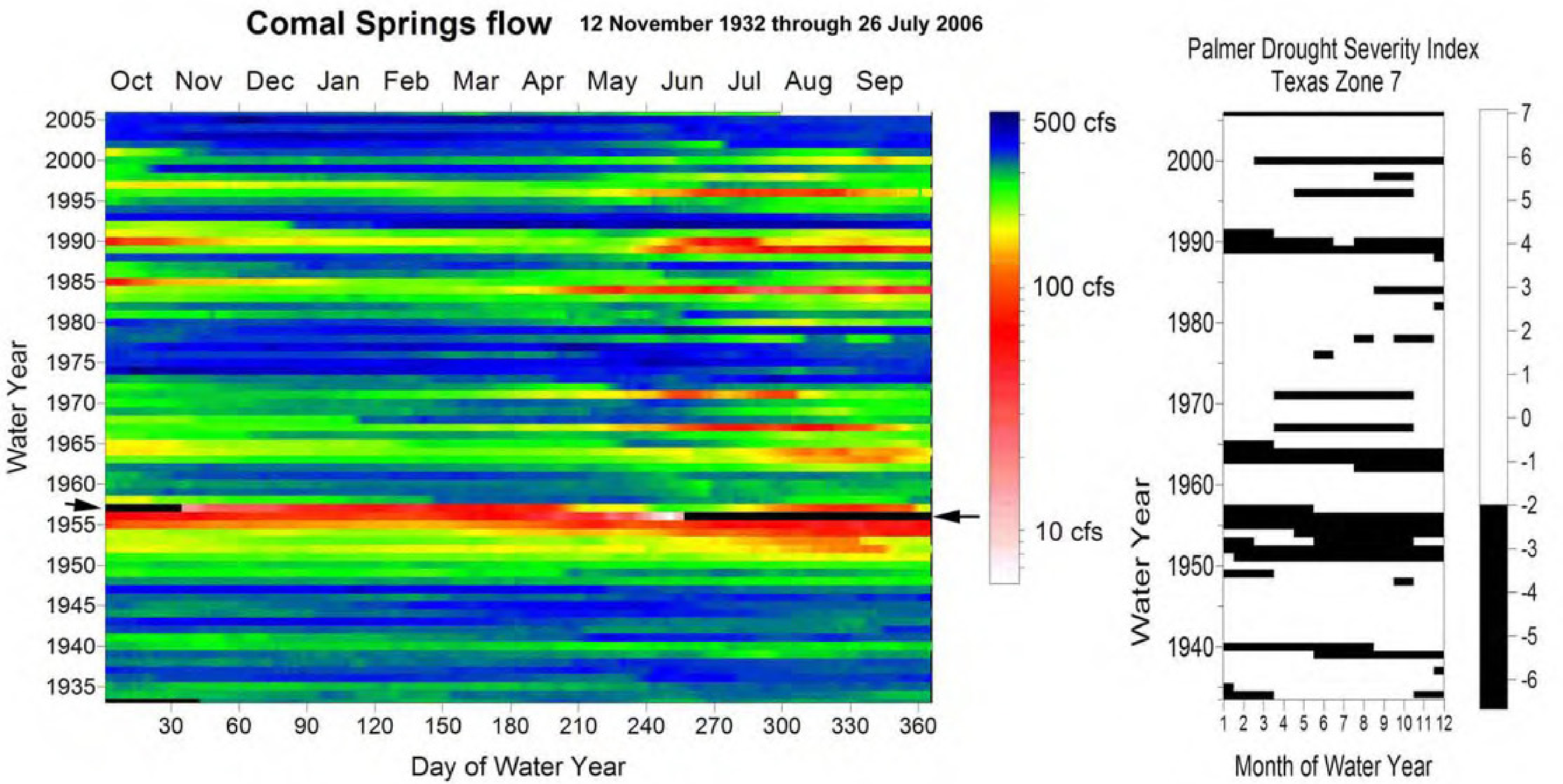


Figure 16. Comal Springs Monthly Mean Discharge CFS
Mean Monthly Discharge CFS
500
450
400
350
300
250
200
150
100
50
0
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006

Figure 17



Comal Springs flow
12 November 1932 through 26 July 2006
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Water Year
2005 2000 1995 1990 1985 1980 1975 1970 1965 1960 1955 1950 1945 1940 1935
30 60 90 120 150 180 210 240 270 300 330 360
Day of Water Year
500 cfs
100 cfs
10 cfs
Palmer Drought Severity Index
Texas Zone 7
2000 1990 1980 1970 1960 1950 1940
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6
1 2 3 4 5 6 7 8 9 10 11 12
Month of Water Year

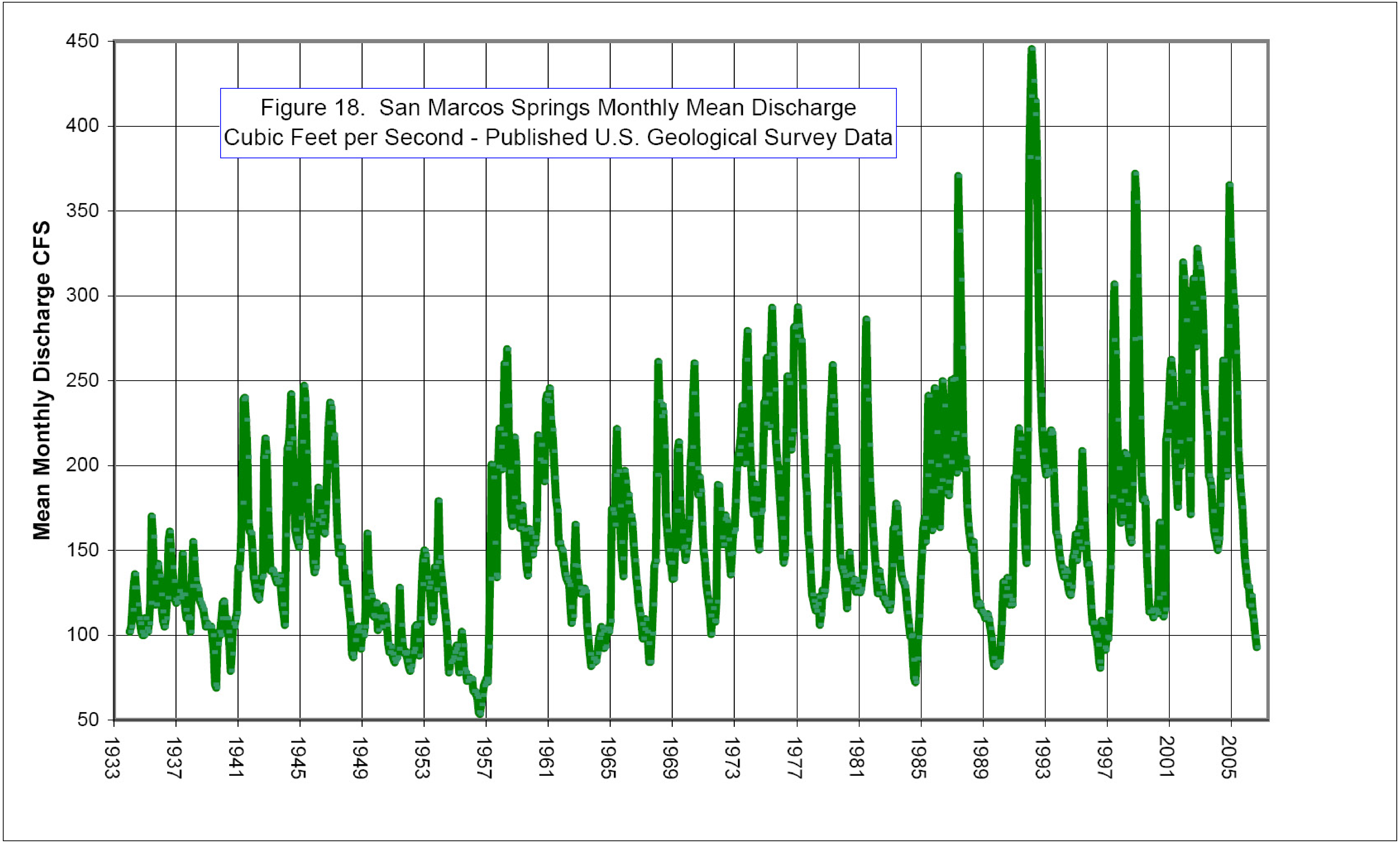
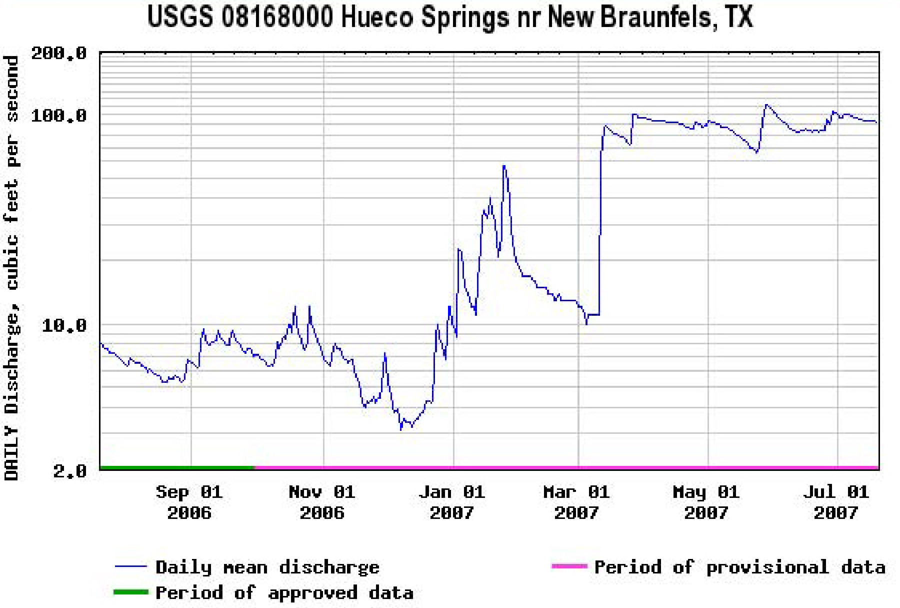


Figure 18. San Marcos Springs Monthly Mean Discharge
Cubic Feet per Second - Published U.S. Geological Survey Data
Mean Monthly Discharge CFS
450
400
350
300
250
200
150
100
50
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005

Figure 19


USGS 08168000 Hueco Springs nr New Braunfels, TX
DAILY Discharge, cubic feet per second
200.0
100.0
10.0
2.0
Sep 01 2006
Nov 01 2006
Jan 01 2007
Mar 01 2007
May 01 2007
Jul 01 2007
Daily mean discharge
Period of approved data
Period of provisional data