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Comal Springs Ecosystem Management Plan

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U.S. Fish and Wildlife Service
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I. BACKGROUND [1]

A. PURPOSE AND INTRODUCTION

The Comal Springs Ecosystem Management Plan (Comal Plan) was developed to help protect and maintain existing populations of endangered and other native species in the Comal aquatic ecosystem. The U.S. Fish and Wildlife Service (USFWS or Service) listed the fountain darter (*Etheostoma fonticola*) as endangered October 13, 1970, (35 FR 16047). The species occurs throughout the Comal Springs and River and in the San Marcos Springs and River. The Comal Springs riffle beetle (*Heterelmis comalensis*), Comal Springs dryopid beetle (*Stygoparnus comalensis*), and Peck's cave amphipod (*Stygobromus pecki*), three aquatic invertebrates, were also listed as endangered December 18, 1997, (50 FR 6629). The Comal Springs riffle beetle is known from specific **habitats** in the Comal spring runs and near spring outlets in Landa Lake, the other two invertebrates are subterranean aquatic species. The Comal Springs dryopid beetle is found in subterranean areas near Comal Springs and Fern Bark Springs in adjacent Hays County. Peck's Cave amphipod is found in subterranean areas near Comal Springs and Hueco Springs, also in Hays County. A number of other unique species also occur in the Comal Springs ecosystem.

The City of New Braunfels has expressed appreciation for this natural treasure and a desire to continue careful stewardship of the ecosystem. They have frequently sought information and advice from various technical experts to assist them in determining the best management practices for protecting the natural resources of Comal Springs. This Plan serves as an aid in managing various public lands consistent with maintaining this unique environment. By using management procedures that are compatible with the long-term survival of the unique species in Comal Springs, the City of New Braunfels will

[1] Appendix B contains a glossary of terms used in this document. Terms defined in the glossary are indicated by **bold** face type in the text wherever they first appear in the document.

help keep the ecosystem healthy and attractive, and help assure its quality for human use into the future. The Comal Plan addresses areas owned or managed by the City of New Braunfels (City), Lower Colorado River Authority (LCRA), and New Braunfels Utilities (NBU).

The Comal Springs system is the largest spring system in Texas. It consists of several major springs and numerous small springs and seeps. The source of its spring flow is the Edwards-Balcones Fault Zone Aquifer (Edwards Aquifer). Two large springs systems (San Marcos and Comal) fed by the Edwards Aquifer support diverse habitats and organisms and are considered biologically unique systems, and many species in the headwaters of these springs are found nowhere else. Several species are found only in the headwaters and first few miles of the Comal and San Marcos rivers. The persistence of these species depends on flows from the Edwards Aquifer.

The San Marcos and Comal Springs & Associated Aquatic Ecosystems (Revised) Recovery Plan (Recovery Plan) (USFWS 1996) is an extensive plan that outlines the goals and actions needed for long-term protection of the threatened and endangered plants and animals in the Edwards Aquifer and the Comal and San Marcos spring systems. The Recovery Plan specifies a number of tasks addressing both regional and local threats to these species. The regional threats include loss of adequate springflow and water quality impacts, while local threats include impacts from **non-native species**, local water quality impacts, habitat alterations, and recreational impacts. One task recommended in the Recovery Plan is the development of local management plans for addressing local threats to the species. This Comal Plan was developed as a response to both the City's active interest in protecting their resource and to Task #2.42 (Develop and implement management plans for the Comal system) identified in the Recovery Plan (USFWS 1996).

Although the objective of the Comal Plan is to maintain the high quality of the Comal ecosystem, it is outside the scope of this plan to address major threats to spring flow, such as groundwater pumping from the Edwards Aquifer, and if the springs cease to flow, the best local management practices will not prevent ecosystem failure. The

Recovery Plan outlines and recommends steps for addressing this regional threat. The Comal Plan concentrates exclusively on local management practices that can minimize local threats to the listed species.

The Comal Plan includes two sections. This section (Section I) provides background information on the Comal Springs ecosystem to assist local managers in making resource-sensitive decisions. It covers the physical environment, biological characteristics, and the influence of human activities on the ecosystem. Private and commercial properties are mentioned in this section to provide historical perspective, but are not considered part of the management plan. Section II is the Management Plan. It contains specific recommendations for management of areas owned or managed by the City, LCRA, and NBU in a manner compatible with endangered species and other unique aquatic resources in the Comal ecosystem.

Once the Comal Plan is finalized, the Service and partners may draft a other documents that describe how management actions would be implemented. The Service may also issue a Biological Opinion and Incidental Take Statement as a part of the Intra-Service Consultation that considers the effects of implementation of the Comal Plan, pursuant to Section 7(a)(2) of the Endangered Species Act of 1973, as amended. Finally, the Service must comply with the National Environmental Policy Act for implementation of the Comal Plan.

B. DESCRIPTION OF THE COMAL SPRINGS ECOSYSTEM

1. PHYSICAL DESCRIPTION. The Comal River is about 3.2 miles (5 km) long. The river has three tributaries, Blieders Creek, Panther Canyon, and Dry Comal Creek (Figure 1). All three tributaries are **intermittent streams**. Hardy et al. (1999) provides a detailed description of Comal Springs.

A number of springs contribute to flow in the Comal system, with most discharging into its impounded headwaters (Landa Lake). Along with numerous small seeps on the banks and bottom of Landa Lake, there are four major **spring runs** flowing directly into

Landa Lake, spring runs 1, 2, 3, and 4 (numbered in descending order of elevation; Figure 1).

Spring run 1 has the second largest discharge of the four major springs. Its orifices are located at the highest elevation (about 600 ft above mean sea level), so this run is the first to stop flowing when total discharge of the springs falls to about 100 **cubic feet / second (cfs)**.

Spring run 2 has numerous **low volume springs**. Spring run 3 has the largest discharge and is composed of many springs ranging from moderately large outlets to small seeps (Barr 1993, Rothermel and Ogden 1987). Spring run 4, located at the northeastern end of Landa Lake, has two main spring heads at either side of the base of a concrete wall at the head of the run. They are both low volume springs.

The depth, width, and flow velocity in the spring runs at any given time is dependent on the amount of total spring discharge at that time. This makes it impractical to present absolute values for these measurements without also presenting total spring or river discharge. Rothermel and Ogden (1987) measured spring discharge in 1982-1983 on a weekly basis yielding values ranging from 6 to 29 cfs for spring run 1; 1 to 2.5 cfs for spring run 2; 15 to 53 cfs for spring run 3; and 0.8 to 0.9 cfs for spring run 4. For the same period, the daily mean Comal springs discharge was 246 cfs as measured downstream in the river at the U.S. Geological Survey (USGS) dam (Figure 1) (USGS Station #08168710). Total river discharge measured at this point can be higher than total spring run discharge due to contributions to river flow from non-spring run sources (for instance, springs located in other areas and/or rainfall run-off into the river).

Additional spring input comes from seeps along the north bank of Landa Lake and numerous small springs that bubble up from the lake and spring run **substrates**. Based on springflow discharge measurements in December 1992 (USFWS) and June 1993 (USGS), Marshall Jennings (USGS, personal communication, 1993) determined that at the time of these measurements 78% of Comal's spring flow came from the many small springs on the bottom and along the shores of Landa Lake.

In the late 1930s, all the spring runs were channeled by rockwork, and a children's pool was built at the lower end of spring run 2 (Gregory and Goff 1993). Spring runs 1 and 3 have a substrate of gravel and cobble with some bedrock, while spring run 2 has pebble and larger cobble. In the lower portion of spring runs 1 and 2 (below their confluence), the substrate is silt. Spring run 4 has a sand/gravel substrate near the spring outlets which changes to a silt/clay mixture (Crowe 1994; Melani Howard, USFWS, personal communication, 1995).

Impoundment has significantly enlarged the headwaters of the Comal River and modified flow velocity in this area. The width, depth, and surface area of Landa Lake depend largely on the total spring discharge at the time of the measurements. Landa Lake's surface area is approximately 910,000 ft^2 (82,000 m^2), but can vary with spring discharge. In October 1995, when spring discharge was 211 cfs (which is lower than the average daily spring discharge for the years 1929 through 1992), the lake's depths ranged from 0.6 ft to 10.8 ft (18 cm to 3.23 m) and its widths ranged from 3 ft to 290 ft (1 m to 88 m) (David Whatley, New Braunfels Parks and Recreation Department, unpublished data, Hardy et. al. 1999).

Substrates vary in Landa Lake. Where vegetation is present, the substrate is usually a silt/clay mix. Exposed substrates are usually gravel ranging from granule-sized to large gravel and cobble (Linam et al. 1993). Some open areas that were previously vegetated, now have a silty substrate.

Outflow from Landa Lake occurs at three points:

1. to the "new channel", which historically serviced a power plant;
2. through the inlet to the spring-fed swimming pool;
3. to three gated culverts by-passing the spring-fed pool (Figure 1).

These latter two points supply water to the "old channel" (the original Comal River bed). The depths and widths of the old and new channel vary with total spring discharge and flow partitioning between the channels.

This needs work

In 1994, the total spring discharge averaged 329 cfs (range __to___?), while the old channel ranged in depth from 1.2 ft to 4.7 ft (0.36 to 1.4 m) and discharge ranged from 10 to 30 cfs (Hardy et al. 1999). The remainder of the flow went down the new channel. The substrate is primarily a thick silt/clay mix covered by vegetation. The old channel joins the new channel just above the tube chute dam (Figure 1).

In 1847, the Comal River was dammed (same location as spring-fed pool dam) and the upper section of the new channel was excavated to provide water to Merriwether's Mill. Since then, the new channel has been widened and dredged to impose a uniform width and straight course. It was last dredged in 1983 (Gregory and Goff 1993). Presently, part of the new channel water section flows through a non-working hydroelectric plant, and the remainder flows through gates that bypass the hydroelectric plant to continue down the lower half of the new channel (Figure 1). The new channel ranges from 3 ft to 6 ft (0.9 to 1.8 m) deep with flow velocity at about 1 to 2 ft/sec *at flow of __ to __ cfs* (McKinney and Sharp 1995; Hardy et al. 1999). Bedrock is the dominant substrate, occasionally interspersed with mid-channel silt/clay mixture and large gravel (Crowe 1994).

Substrate in the lower section of the Comal River (below the confluence of the old and new channels) is primarily bedrock and large gravel (Crowe 1994). Average depth is 8 ft (2.4 m) with flow velocities about 2 ft/sec *at flows of ___ cfs* (Hardy et al. 1999). Toward the confluence with the Guadalupe River, there is a **backwater effect** on the Comal River. The river's velocity drops significantly, while **turbidity** and river depth greatly increase due to Guadalupe River water filling the Comal River channel.

2. HYDROLOGY. Comal Springs flow from the confined freshwater portion of the Edwards Aquifer (Figure 2). The water's journey through the aquifer originates in the recharge area about 62 to 124 mi. (100 to 200 km) west in Kinney, Uvalde and Medina counties (Kuniansky and Holligon 1994). McKinney and Sharp (1995) state that 70% of

Comal Springs' water comes from recharge zones west of Cibolo Creek basin. The remaining 30% is recharged locally by Cibolo Creek and Dry Comal Creek. About __% of the Recharge occurs through rainfall and stream flow entering sinkholes and cavities, especially where faults cross the creeks. The remaining __% is recharged in features outside stream channels.*EAA? USGS?* After entering the Edwards limestone, the water generally travels eastward and northeastward, moving along faults and caverns resulting from solution enlargement of faults (Crowe 1994). According to Pearson et al. (1975), most of the water has been in the aquifer system for over 20 years, and only a small portion is less than 10 years old.

After a rain event in the western recharge area, flows peak in the Comal River 1 or 2 months later. After local rains, however, minimal response is noted in the springs. *USGS Comal hydrogeology*. Rothermel and Ogden (1987) suggested that the faults act as barriers to local groundwater flow, thus preventing recharge waters originating from around New Braunfels from traveling to Comal Springs. Based on USGS annual recharge estimates (1934 to 1992), Cibolo and Dry Comal Creeks contribute 106,700 ac-ft/yr of local recharge, but McKinney and Sharp (1995) suggested that Comal Springs is not receiving a significant portion of this recharge. However, Rothermel and Ogden (1987) found spring run 3 to be strongly influenced by local recharge. They measured spring discharges following local rainfall and found that spring run 3 discharge increased immediately. Dye injected into a well about 500 ft to the west of spring run 3 emerged only at spring run 3 and not at spring run 1, which is closer, indicating that separate flow paths feed the individual spring orifices (Rothermel and Ogden 1987). Several previous studies, however, do not support the role of local recharge (Thompson and Hayes 1979, Pearson et al. 1975, and Ogden et al. 1986).

FIGURE 2

Monthly statistics of the daily river flow below the confluence of the old and new channels (1929- present) are shown in Table 1. Mean flow rates for December through June usually run above the average annual flow rate of 295 cfs * use last Edwards hydrogeo. Report*, while mean flow rates for July through November are usually below the average (USGS records 1933-present). *check figures for accuracy*

The springs were dry from June 13, 1956, to November 3, 1956 *is this date correct?

Why 0 for monthly average?*, when aquifer levels reached a record low after 7 years of drought (Brune 1981) (Figure 3). Some of the springs have also ceased flowing more recently during less severe droughts. During the summers of 1984, 1989, and 1990, several springs ceased flowing for 1 to 3 weeks (Melani Howard, USFWS, personal communication, 1990; David Whatley, New Braunfels Parks and Recreation Parks, personal communication, 1984; and Tom Arsuffi, Southwest Texas State University, personal communication, 1989). Comal Springs dropped below 100 cfs for 99 days in 1989, to a low of 46 cfs. The minimum total discharge from the springs was 26 cfs (August) in 1984, 57 cfs (September) in 1989, and 46 cfs (June 29) in 1990. The all-time maximum recorded discharge of the springs was 666 cfs on December 22, 1991 (USGS records). Hardy et al. (1999) includes a historic overview of the hydrology of the Comal Springs system.

Recent hydrological events demonstrate the range of flows from Comal Springs resulting from precipitation patterns. At the USGS gaging station for the Comal River at New Braunfels, the mean daily discharge was near or below 100 cfs for about 2 months during the summer of 1996. In contrast, a severe thunderstorm in 1998 resulted in heavy precipitation on the New Braunfels area, and the discharge peaked at over 22,000 cfs, primarily from surface runoff, on October 17, 1998, the flood of record (Slade and Persky 1999).

3. GEOLOGY AND SOILS. The Comal Springs issue from the Edwards Aquifer at the base of the Balcones Escarpment where the aquifer has been **down-dropped** by the Comal Springs fault and several adjacent minor faults. The Comal Springs fault, which is the main conduit for flow to the springs, places the Edwards Group (limestone) against the Taylor Group (clayey marl), forming a barrier. The water, under artesian pressure, is forced upward along the fault forming Comal Springs. Solution-enhanced faults in the Edwards Group limestone form interconnected caverns, which can create tremendous underground reservoirs within the aquifer (Guyton and Associates 1979).

The soils immediately surrounding the Comal River are Oakalla soils. Oakalla soils are silty and clayey loams typically found on stream terraces and in flood plains. They are deep, nearly level, alkaline, and calcareous. These soils are typically well-drained and flooded more than once every 2 years for brief periods.

Between 1960 and 1980, five flood control structures were built in the Comal River watershed to control the frequency and intensity of flooding. These structures are at the following locations (Figure 4*no reference to figure 3 yet*): Site 1 - west fork of the Dry Comal Creek; Site 2 - on the Dry Comal Creek; Site 3 - Blieders Creek; Site 4 - Bear Creek (a tributary to Dry Comal); and Site 5 - tributary of the west fork of Dry Comal Creek. The Natural Resources Conservation Service (NRCS - formerly the Soil Conservation Service) stated that decreased flooding has little effect on Oakalla soils and associated vegetation (Michael Raney, NRCS, personal communication, 1995). These soils have a moderate permeability with high water capacity. The potential for soil erosion is slight (Soil Conservation Service 1984). The Oakalla soils are probably a primary constituent of the muddy substrate often found in vegetated areas of the river. Other less dominant soils within 100 m of the river have a slight to moderate erosion potential.

The outcrop along the northern bank of Landa Lake (Eckrant-Rock complex) consists of a mix of extremely stony clay about 10 inches thick with patches of exposed barren limestone. Eckrant soil is well drained. Surface **runoff** is rapid and there is a severe soil erosion potential (Soil Conservation Service 1984).

4. WATER QUALITY. Water quality includes chemical and physical parameters. Some of the chemical parameters are dissolved ions, trace elements, pH, nutrients, dissolved oxygen, and organic contaminants (for example, compounds of petrochemicals or pesticides). Physical parameters include water temperature and turbidity. Water quality in the Edwards Aquifer has been monitored since the 1930s and has been found suitable for all uses, including human consumption (USGS 1987). It is, however, susceptible to groundwater contamination because it has a rapid rate of recharge (*Allen Clark vulnerability study*). Rainfall and streams enter sinkholes and cavities in some places and flow directly into the aquifer. There is minimal layering of soil and rock to filter contaminants from the entering waters. However, the aquifer currently has low contamination levels because a majority of the water in the Edwards Aquifer originates as precipitation on the Edwards plateau, which is mostly undeveloped range land (*Vulnerability Study*). The Texas Commission on Environmental Quality (TCEQ) (formerly the Texas Natural Resource Conservation Commission and the Texas Water Commission) has identified the Edwards Aquifer as one of the most sensitive aquifers in Texas to groundwater pollution (Texas Water Commission 1989).

Water quality data collected from area monitoring wells, Comal Springs discharges, and in the Comal River are displayed in Table 2. The Comal River exhibits generally stable values for most water quality parameters. Comal spring water temperature normally ranges from 74°F to 75°F (23.1°C to 23.9°C), about 3°C higher than the average annual air temperature at New Braunfels. Rothermel and Ogden (1987) suggested the long residence time of the water in the aquifer before discharge at the springs produces a very constant chemical composition. Minor variation in Comal River water quality includes a natural gradient of slightly increasing or decreasing water temperature, depending on air temperature, from the headwaters to the lower reaches as well as fluctuations in dissolved oxygen concentrations due to the presence or absence of aquatic plants and structural and natural stream aeration. However, water quality can be rapidly impacted by such things as decreasing flows, surface runoff, and pollutants. Variations in water quality due to local recharge are minimal and short in duration because local recharge occurs in such relatively small quantities.

Decreased spring discharge could affect water quality in many ways. Lower water levels can lead to elevated or reduced water temperatures, particularly in the areas downstream*cite Comal Report*. Lowered spring flow would also result in less water available to dilute pollutants in the system and higher pollutant concentrations.

5. PLANTS AND ANIMALS. Most available studies on Comal plants and animals have been conducted within the last decade. The following studies have sampled for animals in the Comal River: Hubbs et al. 1953; Espey, Huston and Associates 1975; Whiteside, unpublished data, 1974-90; Barr and Spangler 1992; Linam et al. 1993; Barr 1993; Bowles et al. 1994; Chippendale et al. 1994; Hardy et al. 1999 *Hubbs, BioWest, Arsuffi, Bowles*. Species lists from past surveys of Comal animals are shown in Tables 3 - 6. These tables do not reflect a complete list of all species occurring within the ecosystem as intensive surveys have not been done on amphibians, reptiles, and invertebrates.

The following studies have surveyed vegetation in the Comal River: Espey, Huston, and Associates 1975; Angerstein - unpublished data 1990-1992; Linam et al. 1993; USFWS, unpublished data, 1994; Lemke 1994; Angerstein and Lemke 1994; Crowe 1994; and Hardy et al. 1999 *Oborny?*. Plant species composition appears to change frequently over time in the Comal River (Tom Arsuffi, Southwest Texas State University, and David Whatley, Parks and Recreation Department, personal communications, **need date**), but as yet, no quantitative studies have been conducted to determine the pattern of change. Table 7 is a partial list of native terrestrial *and aquatic* plants of the Comal River.

Many of the plant and animal species found in Comal Springs depend on the pristine conditions of the system. These conditions can be degraded by increased sedimentation, scouring, introduction or proliferation of non-native species, and changes in water quality, which would adversely affect the plants and animals. These changes can be caused by many factors including a decrease in spring flow, stormwater and non-point source runoff, increased flooding (due to urbanization), and erosion. Non-native aquatic species can be introduced by dumping bait buckets and aquaria and by use of boats that have been used in waters containing non natives.

6. ADJACENT LAND USES. Lands along the Comal River are used for residential, public, commercial, and industrial purposes (Figure 5). Public land use includes camping facilities, a golf course, and city parks. Commercial land use includes Schlitterbahn Water Park and resorts. The only industries on the river are Archer Daniels Midland (ADM) (grain supplier) and NBU. The entire Comal River runs through an urban area and intermittent tributaries drain urban, suburban, and agricultural lands.

7. PUBLIC RECREATION. The Comal River is a popular recreation site that provides a variety of activities such as tubing, canoeing, and fishing. In the Landa Park area, swimming is not allowed. Paddle boats and glass-bottomed boat tours are available for rental during the summer season and fishing is allowed year round. Landa Park hosts about 1,200 picnic groups annually (City of New Braunfels Parks and Recreation Dept. 1995). The City's Parks and Recreation Department published a "2000 Program Guide" that provides a comprehensive overview of the recreational opportunities and programs offered by the City. *update this information* The mission statement of the Parks and Recreation Department is:

> *"Within the annual operating budget, it is the mission of the New Braunfels Parks and Recreation Department to fulfill the recreation needs and desires of the citizens of New Braunfels in a comprehensive, efficient, and effective manner."*

Besides Land Park, the City has two additional parks that provide public access to the river - Prince Solms Park and Hinman Island Park (Figure 1). Activities in these two parks include swimming, tubing, canoeing, and fishing. Prince Solms Park and its tube chute have more than 50,000 visitors during its five month operating season. Tubers float to a choice of two public exits located a short distance above the confluence of the Comal and Guadalupe rivers (City of New Braunfels Parks and Recreation Dept. 1995).

add: road crossing, railroad crossing?

8. ARTIFICIAL STRUCTURES. The river course and certain characteristics of flow from Comal Springs are modified by artificial structures in a number of places below the springs. The most prominent modifications are dams. There are eight dams on the Comal River, which typically pool water above, and increase flow velocity immediately below, the dams (Figure 1).

One of the first modifications of the Comal River occurred in 1847 when William Merriwether built a small overflow dam on the original course of the Comal River (about where the spring-fed pool dam is now located) to divert a portion of the river into a mill race. The mill race has been further developed and is now called the new channel (Figure 1). The historic path of the river is the old channel. The dam raised the surface water elevation in the headwater area. As a result, the headwater area was marsh-like and had abundant riparian vegetation (Gregory and Goff 1993). Brune (1981) described an 1868 Map of New Braunfels that showed a large swamp downstream from the Comal Springs.

In 1898 the spring-fed swimming pool was built just below Landa Lake on the old channel (Gregory and Goff 1993) (Figure 1). At the same time, a bypass was built alongside the pool to carry more water from Landa Lake into the old channel.

Areas of Landa Lake were used as landfills in the early 1900's. In fact, the back nine holes of Landa Park golf course, which opened in 1939, was built over a land fill (David Whatley, Parks and Recreation Department, personal communication, 1995).

In 1926, the San Antonio Public Service Company dammed the new channel about 1/2 mile downstream of the Comal Canal dam to create a small "reservoir" for a hydroelectric plant (Figure 1). Both the Comal Canal dam and the "reservoir" dam are owned by the LCRA. Waters in the 150 ac-ft "reservoir" pass through the hydroelectric plant, over and around the dam, and into the Comal River at its confluence with Dry Comal Creek. The hydroelectric plant closed from 1984 to 1987, and again from 1990 to the present for economic reasons. **NBU has a long term goal to automate the entire plant (Roger Biggers, NBU, personal communication, 2003 *). The plant requires a minimum of 100 cfs for operation, and has a maximum capacity of 393 cfs.**

When the plant is closed, most of the river flow passes over the dam. If the plant were to reopen, most of the water would enter the plant. The water would flow through grates (with 3 inch spacing) into the hydroelectric plant, through the hydrogenerator, and back into the Comal River. The grates are 28 feet across and reach the substrate of the river. As water flows through, floating vegetation is caught on the grates.

In 1926, the Comal cogeneration power plant was built on the west bank of the new channel across from the present location of the hydroelectric plant. Water was pumped from the new channel through surface culverts through the cogeneration plant for cooling purposes. As a result of the 1950's drought, which caused the springs to stop flowing for 5 months beginning June of 1956, the Comal Canal Dam (Figure 1) was built in the late 1956 to keep water pumped from the aquifer in the new channel for the power plant. This is why support structures were placed on the upstream side of this dam (Martyn Turner, LCRA, personal communication, 1995) (Figure 1). The power plant closed in 1973 and the Comal Canal dam presently acts to maintain water levels in Landa Lake (David Whatley, personal communication, 1995). In 1991, NBU cut a 4-ft hole in the west side of the dam to relieve the pressure of unusually high flows resulting from flooding. Since that time, the dam has begun to erode and the opposite bank has been undermined. The LCRA filled the opening with boulders in 1994.

The two dams below the spring-fed pool on the old channel are located in the river section covered by the Bad Schloess Inc. (Schlitterbahn) surface water rights permit. They are both low water dams (Figure 1) *designed to _____*. The first dam does not completely cross the river, but directs the water toward the right bank (looking downstream) and forms a small pool of water on the left. The second dam was built by Schlitterbahn in 1984 (David Whatley, New Braunfels Parks and Recreation Department, personal communication, 1995) and is located in a small residential area.

The public tube chute is part of a large dam (tube chute dam) that lies below the confluence of the new and old channels and is owned by the City of New Braunfels (City) (Figure 1). The dam was originally built in 1848 by John Torrey to run a mill. Destroyed by floods several times, the dam (Clemen's dam) was rebuilt in 1882 (Gregory and Goff 1993). Today, it serves only a recreational function as a tube chute. Immediately below this dam is a low water dam built by USGS in 1956 with help from the City and Guadalupe-Blanco River Authority (GBRA) to gage flows (David Whatley, Parks and Recreation Department, personal communication, 1995) (Figure 1).

The final dam is located in the former Camp Warnecke area and is owned by Schlitterbahn (Figure 1). It is also a low water dam, built for recreational purposes and has a notch on the left bank (looking downstream).

9. HISTORY. [2] “Comal” is the Spanish word for basin, probably referring to the bowl-like valley surrounding the springs (Brune 1981). But according to Roemer (1849), “comal” was a term used by the Mexicans to designate the plate on which tortillas are baked. "Why the stream was named thus was not clear to me" (Roemer 1849).

The Comal Springs were an often used camping place of the Tonkawas and their predecessors for many thousands of years. The 1600s and 1700s brought many Spanish expeditions to the area. In 1691, Domingo Teran and Fray Damian Massanet,

[2] Much of the historical information presented here can be found in Gregory and Goff (1993).

Spanish explorers, blazed a trail across the Guadalupe River known as the San Antonio-Nacogdoches Road Crossing. They found a large concentration of Indians at Comal Springs, some from as far away as New Mexico and Parral, Mexico (Grist 1987). During the Texas Revolution, both Mexican and Texan armies used the springs as a stopping place (Gregory and Goff 1993).

In 1845, a group of German immigrants with Prince Carl of Solms-Braunfels traveled the San Antonio-Nacogdoches Road Crossing and settled New Braunfels, calling the springs Las Fontanas. They purchased the 1,297 acres surrounding the springs (the Comal Tract) for $1,111 from Governor Juan Martin de Veramandi. The first winter for the new settlers was difficult, and about 800 became ill and died. Despite the hardships, New Braunfels continued to grow. By 1850, New Braunfels was the fourth largest town in Texas (Brune 1981).

New Braunfels was originally a precinct of Bexar County. Comal County was created by the legislature on March 24, 1846. The charter for the city of New Braunfels was ratified on June 7, 1847. Because of the city's ideal climate and abundant natural resources, agriculture and industry thrived. As early as 1847, industries were being established. William Merriwether, using slave labor, built a dam and dug a channel off the Comal River to power his sawmill. In 1848, John Torrey built a gristmill and dam where the tube chute is presently located. By 1860, seven grist, flour, and sawmills were using the spring waters for power. *did all have dams? What happened to them?* Cotton and woolen factories, a paper mill, an ice plant, and a brewery also used Comal's water (Brune 1981).

John Torrey's dam was destroyed by a flood in 1870, and a second flood in 1872 destroyed both the gristmill and rebuilt dam. Torrey finally gave up and left New Braunfels. Clemen's dam replaced the old Torrey mill dam in 1882.

In 1850, Friedrich Holekamp built a mill on the river, at the foot of Garza Street, that served numerous capacities: a sawmill, gristmill, paper pulp mill, and ice plant. In 1869, a flash flood almost completely destroyed the mill, but it was quickly rebuilt. At one time, Harry Landa used the mill to pump water into his private "trout" pond in Landa Park. (Native largemouth bass were commonly called trout). The remains of the mill were completely washed away in the September 1952 flood. Schlitterbahn later acquired that property to develop a water park (Gregory and Goff 1993).

Landa Park and the springfed swimming pool were opened to the public in 1898. The history of the park is eventful, with both difficulties and successes. William Merriwether owned much of the property along the headwaters of the Comal River. Joseph Landa purchased the land from Merriwether and it became known as "Landa's Estate". When Joseph's son, Harry Landa, took over the property, he built the covered dance hall and gazebo seen in Landa Park today. Steamboat excursions became a common sight on Landa Lake. Harry Landa introduced cabbage palms, banana palms, and elephant ears, as well as built a fenced-off alligator pond, which once discharged its occupants during a flood. Many cedar branch bridges and benches were constructed. When opened to the public, the park flourished (Gregory and Goff 1993).

In 1927, Landa Park was sold to investors. They went bankrupt in 1933 and closed the park to the public, surrounding it with a 12 ft.-tall barbed wire fence. The gates to the springfed pool were shut, leaving only a shallow stream of water flowing through the pool area. The City purchased the park with an $80,000 bond and reopened it in 1936 (Gregory and Goff 1993).

Below the confluence of the old and new channels, another public area was gaining recognition. Camp Warnecke opened in 1918. Otto and Marsha Warnecke bought land along the Comal River and built several cabins. Over several years they built 103 cabins, a recreation hall and a restaurant. It became quite a popular tourist area. In fact, it made the cover of LIFE magazine on August 6, 1951, the ultimate in national recognition at that time. Camp Warnecke is now part of Schlitterbahn, a water park which occupies the former Camp Warnecke and Camp Landa properties (Gregory and Goff 1993).

Among river resorts attracting tourists in the 1940s and 1950s, was Camp Ulbricht near the headwater springs. They pumped water from a well to supplement decreasing spring flow from 1954 to 1956. The resort closed in 1956 when the springs dried up. All water-oriented tourist businesses collapsed until the abundant rains of the following fall and winter raised the water levels in the aquifer enough to return spring discharge to the Comal River (Gregory and Goff 1993).

A few years prior to the 1956 drought, Paul Jahn, chairman of the New Braunfels Chamber of Commerce for Water Conservation, warned that without conservation the springs would not last. He eventually succeeded in having the Edwards Underground Water District formed in 1959 to guard the purity of the area's drinking water and encourage recharge of the Edwards Aquifer (Grist 1987). Tourism began replacing agriculture as the major economic industry for New Braunfels in the 1960s. At the center of this industry is New Braunfels' jewel - the Comal Springs.

10. SURFACE WATER RIGHTS. There are three permit holders for the surface water rights of the Comal River: 1) City of New Braunfels, 2) NBU and, 3) Bad Schloess Inc. (Schlitterbahn). The amounts and purpose of water diverted annually are included in Table 8.

NBU has the only permit for new channel water. It authorizes non-consumptive diversion of 345 cfs (124,870 acre-ft/yr), which is necessary for maximum operation of a **run-of-river hydroelectric plant**, although the plant can handle up to 393 cfs. The plant has not been in operation since 1990.

NBU also has a water rights permit on the new channel for the Comal Canal dam, which was originally designed to keep water in the new channel during the 1956 drought. The dam presently helps to maintain water levels in Landa Lake.

Water entering the old channel can be regulated by the bypass structure installed in ___. Current flows are regulated to a maximum of about 110 cfs around the spring-fed pool plus about 5 cfs from the spring-fed pool overflow. The City consumes 1 cfs (100 ac-ft/yr) of old channel flow for irrigation of the golf course and some residential use.

Bad Schloess Inc. has a non-consumptive permit to divert 111.5 cfs (5000 ac-ft/yr) *is right af or cfs?*. The diverted water is returned to the old channel at several locations above the point it was pumped from the river. However, because of spillover within the park and evaporation, not all water is returned to the Comal River. *does water temperature change?*

Below the confluence of the old and new channels, the City has a permit covering water use of the tube chute dam. Bad Schloess Inc. has a permit for the Camp Warnecke dam and irrigation of 3 acres at a diversion rate of less than 1 cfs *what is water right?*. The previous owner of Camp Warnecke used this permit to run a sprinkler system on the tin roof of their pavilion for cooling. Bad Schloess Inc. does not currently use this permitted water (*reference?*).

C. HABITAT REQUIREMENTS

The organisms inhabiting the Comal Springs system are numerous and diverse. Four species (fountain darter, Comal Springs riffle beetle, Comal Springs dryopid beetle, and Peck's cave amphipod) are federally listed endangered species because of their limited geographic range and threats to their existence, primarily by habitat loss or destruction. Other rare species also occur here and may also be vulnerable to extinction. A new species of stygobiontic dytiscid beetle was discovered and described in the literature as recently as 1995 (Spangler and Barr 1995). To preserve the quality of this spring ecosystem, the natural physical, biological, and chemical parameters required by these species need to remain intact. Full species descriptions, habitat requirements and distributions of listed species except the invertebrates can be found in the San Marcos & Comal Springs and Associated Aquatic Ecosystems (Revised) Recovery Plan (USFWS 1996).

1. HABITAT TYPES. Habitats are the living places of organisms and are characterized by their physical and biological properties. For aquatic communities, they include combinations of such things as vegetation, substrate, water quality, and **flow type**. Linam et al. (1993) described the different types of vegetation, substrate, and flow throughout the Comal River.

2. TARGET ORGANISMS. The following species are highlighted because they are believed to be one or more of the following: (1) intolerant of wide ranges in physical, chemical, and/or biological parameters induced by human actions; (2) relatively rare, unique, and/or limited to very few locations; and (3) particularly sensitive to changes in habitat. Some of the more sensitive organisms may be indicators of water quality and ecosystem health.

Fountain darter (*Etheostoma fonticola*)

The fountain darter is a small fish that was listed as endangered on October 13, 1970, and critical habitat was designated on July 14, 1980. Critical habitat was designated in Hays County and includes Spring Lake and its outflow, the San Marcos River, downstream to about 0.5 mile below the Interstate Highway 35 bridge. There is no critical habitat designated for this species in the Comal Springs system. *explain why Comal not designated as CH*

General habitat: Habitat requirements described in the recovery plan (USFWS 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 use and prefer a mix of submergent vegetation including algae, mosses, and higher plants (Schenck and Whiteside 1976, Linam et al. 1993, Hardy et al. 1999). Schenck and Whiteside (1976) found that young fish prefer vegetated habitats in areas with little water velocity.

Fountain darters feed primarily during daylight in response to visual cues (Schenck and Whiteside 1976). 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 larvae, and ephemeropteran larvae (Bergin 1996).

Although natural populations of fountain darters appear to spawn year-round (Schenck and Whiteside 1976), they appear to have two peak spawning periods, in August and late winter to early spring (Schenck and Whiteside 1976). Bonner et al. (1998) described the effects of temperature on egg production and early stages of the fountain darter.

<u>Distribution and abundance</u>: The fountain darter is found throughout the Comal River. Linam et al. (1993) collected the largest numbers per unit area in the old channel area. Blieders Creek, parts of Landa Lake, portions of the old channel and some of the stream bank areas in the new channel provide good darter habitat. Texas Parks and Wildlife Department (TPWD) sampled seven transects in Landa Lake and the Comal River in 1990 and estimated the fountain darter population above the tube chute dam to be between about 115,000 and 250,000 (Linam et al. 1993).

The fountain darter was most likely eliminated from the Comal River during the 1956 drought. The pools that remained after springs ceased to flow probably underwent drastic temperature fluctuations creating a highly stressful environment for the fountain darter. Unsuitable temperatures and increased predation and competition likely resulted. Schenck and Whiteside (1976) spent 300 hours sampling the Comal River from 1973 to 1975 and did not find any fountain darters. They reestablished the population by releasing 457 adult fountain darters (collected from the San Marcos River) into the headsprings of the Comal River from February 1975 through March 1976 (USFWS 1996).

A significant threat to the health of fountain darters is the damage to gills and gill arches caused by a recently-discovered introduced trematode. The risk posed by these parasites appears to increased during low spring discharge. *cite and elaborate*

Thomas Brandt (in litt. 1997) has summarized the parasite problems faced by the fountain darter. None of the fountain darters collected in the Comal system in June and early July, 1996 were observed to have swollen gills. On July 19, 1996, one of 11 fountain darters collected and released was noted as having swollen gills. This was the first indication of an apparently recently introduced heterophyid trematode parasite attacking fountain darter gills in the Comal system. In October, 1996, heavy parasite loads were documented in Comal fountain darters including the trematode of concern (as well as a myxosporean and an epithelial flagellate). Publication of an article on their research on this trematode and the fountain darter by Dr. Brandt, Melissa Salmon, Drew Mitchell, Dr. David Huffman and A. Goodwin is expected in 2000. *update* Alternate hosts for these gill parasites may include animals found in both Comal and San Marcos systems. Yellow-crowned night herons, one of the trematode's putative hosts, may easily fly from Comal to San Marcos.

<u>Flow requirements</u>: An instream flow study by Hardy et al. (1999) concluded that useable habitat for fountain darters declined with declining total spring flow rates, most notably below 150 cfs. As total flows fall below 150 cfs, declines in hydraulic (velocity-depth relationships) and temperature parameters are evident. Below 100 cfs, temperature *and other parameters, such as water surface elevation*, contribute to the overall decline in useable habitat availability for fountain darters. Flows should be partitioned equally in the old and new channels to provide fountain darter habitat, up to a maximum of 110 cfs flow in the old channel (220 cfs total spring flow). Above that total springflow, all flows in excess of 110 cfs should be routed down the old channel (Hardy et al. 1999). These recommendations are designed to provide optimum habitat for the fountain dater and to prevent flooding in the old channel.

<u>Comal Springs salamander (*Eurycea* sp.):</u>

Genetic studies using **allozyme electrophoresis** and **ribosomal RNA** data determined that the Comal Springs salamander population is not the same species as the San Marcos salamander (*Eurycea nana*) and is molecularly unique in that it shares an **allele** found only in the Texas blind salamander (*Typhlomolge rathbuni*) (Chippindale et al. 1992, 1994). Although Chippindale et al. (1994) believe the Comal Springs salamander is probably a unique species, the taxonomic status of the species warrants further investigation. It appears to be geographically isolated, but additional surveys and genetic work are needed for verification.

General habitat: The habitat requirements of the Comal Springs salamander are not fully known but are probably similar to those of the closely related San Marcos salamander. Both of these species live in the thermally constant, clean and clear waters flowing from the Edwards Aquifer. Nelson (1993) found San Marcos salamanders associated with gravel and rock substrates with little mud or detritus, as well as some vegetated areas. In general, central Texas *Eurycea* salamanders are often closely associated with spring openings and have been found in highest abundances in waters with constant water temperature (Sweet 1984). Some are known to enter spaces within gravel substrates making them difficult to find.

Distribution and abundance: The Comal Springs salamander has been found in spring runs 1, 2, and 3. Two sightings also occurred 10 to 20 ft (3 to 6 m) upstream of "Casey Island" in Landa Lake, possibly near spring openings within the lake (Figure 1) (Casey Berkhouse, USFWS, personal communication, 1995). No population estimates or thorough surveys have been done. *update found in spring on island? *

Flow requirements: Under normal flow conditions no specimens have been found in still water areas, so flowing waters seem to be a prerequisite for suitable habitat. However, the Comal Springs salamander apparently survived the temporary loss of springflow in 1956. Although they appear to be able to retreat into the aquifer and wet gravel for a time, the effect on the population from these conditions and from increased duration or frequency of drought is not known.

Comal Springs riffle beetle (*Heterelmis comalensis*)

The Comal Springs riffle beetle was added to the Federal endangered species list in December 1997 (*FR December 18, 1997 (Volume 62, Number 243*). No critical habitat was designated for the species.

General habitat: **Larvae** and adults have been collected in gravel/cobble substrate in the headwater spring runs of the Comal River. *update w/ Oborny info spring openings in lake?* General habitat preferences for riffle beetles include flowing streams with pebble/cobble-sized rocks.

Distribution and abundance: The beetle has been found in spring runs 1, 2 and 3 (Barr 1993) of the Comal River. It is believed to be in greatest densities from February through April (Bosse et al. 1988). A single specimen was also found along the margin of Spring Lake in the San Marcos River (Barr 1993). No population estimates have been made.

Flow requirements: Flow requirements for survival are not known. They apparently survived the 1950's drought, during which water ceased to flow from the springs for 6 months, probably by retreating into the springheads and/or burrowing into the substrate at their specific habitats. It is not known how much of an impact this drought had on the population or if they could survive a longer or more frequent drought conditions. *check on Bowles' paper*

Aquifer-dwelling invertebrates

Comal Springs dryopid beetle (*Stygoparnus comalensis*), Peck's cave amphipod (*Stygobromus pecki*), subterranean **amphipods** (*Mexiweckelia hardeni* and *Seborgia relicta*), and two predaceous diving dytiscid beetles, *Haideoporus texanus* and *Comaldessus stygius*. The Comal Springs dryopid beetle and the Peck's cave amphipod were added to the Federal endangered species list in December 1997 (get FR citation*). The dryopid beetle is a monotypic genus and is the only subterranean dryopid beetle known *check*. No critical habitat was designated for these species. The other four species have no status under the ESA.

General habitat: These subterranean invertebrates inhabit the aquifer and can also be found close to the spring outlets. Substrate of the spring outlets and runs consists of gravel and cobble. Because all other known dryopid beetle larvae are terrestrial, the Comal Springs dryopid beetle is presumed to be associated with the soil, roots, and debris lining the ceiling of the subterranean orifices (Barr and Spangler 1992).

Distribution and abundance: The Comal Springs dryopid beetle was found at spring runs 2, 3 and 4 in small numbers (*citation*). It has also been found at Fern Bank (Little Arkansas) Springs about 20 mi. (32 km) to the northeast of the Comal River (Barr 1993). Peck's cave amphipod occurs near the heads of all four spring runs (*citation*). It has also been found in Hueco Springs about 4 mi. (7 km) north of the Comal River (Barr 1993). *Haideoporus texanus*, previously known only from San Marcos, was found near the heads of Comal spring runs 2 and 3; and a previously undescribed dytiscid beetle, *name* (*citation*) was found at the heads of spring runs 3 and 4 (Barr 1993). *Mexiweckelia hardeni*, a species formerly only known from Medina County, was found at the head of Comal spring runs 2 and 4 (Barr 1993). *Seborgia relicta* was discovered in spring run 3 and specimens have also been found in Hondo Creek, Hueco Springs, and an artesian well in San Marcos (Barr 1993). These invertebrates were collected by placing drift nets over the spring outlets of low volume springs and seeps as well as high volume springs.

Roundnose minnow (***Dionda episcopa* complex**) *update information*

This fish is part of a large complex of closely related forms and is believed to be one of two unnamed forms. It is believed by some experts to be a possibly unique form.

General habitat: This small fish is primarily found in channels of fast-flowing, spring-fed water over gravel bottoms (Harrell 1978). They have been observed breeding in seep springs (Lee and Gilbert 1980). Many species of *Dionda* exhibit a limited tolerance for a broad spectrum of environmental conditions and are restricted to headwaters and springs (Mayden et al. 1993).

Distribution and abundance: *Dionda episcopa* complex is composed of several species: *D. episcopa, D. serena, D. melanops, D. argentosa, D. diaboli,* and perhaps

D. punctifer, as well as two unnamed forms (one from the Guadalupe and Colorado rivers and one from the upper Rio Conchos, Mexico) (Mayden et al. 1993). David Hillis (University of Texas, personal communication, 1995) believes that the *Dionda* species in the Comal River is one of the two unnamed forms. Hubbs (1956) noted that Dionda in the Comal River were quite distinct from those in other tributaries of the Guadalupe River. Population estimates have not been made.

<u>Big Claw River Shrimp (*Macrobrachium carcinus*)</u>

This is the largest species of river shrimp (sometimes called **prawns**) in the United States. Adult males can approach 12 in. (30 cm) in length and weigh 2.2 lbs (1 kg), while females typically range from 5 to 7 in. (13 to 17 cm).

<u>General Habitat</u>: River shrimp hatch in **estuaries**. The larvae require **brackish** water for development and can survive only 5 to 6 days in freshwater (Hughes and Richard 1973). Juvenile prawns move upstream into freshwater and travel inland several hundred miles, as far as San Marcos and Austin, where they spend their adult lives. Therefore, their main requirements are accessibility to estuaries as well as freshwater ecosystems (David Bowles, TPWD, unpublished).

<u>Distribution and abundance</u>: In the United States, the big claw river shrimp is found in Florida, Mississippi, and Texas. It is also known from the Caribbean Islands, Mexico and southward to Brazil (David Bowles, TPWD, unpublished *update*). In the Comal River, the big claw river shrimp can be found throughout the system. No population estimates have been made.

<u>Cagle's Map Turtle (*Graptemys caglei*)</u>

The Cagle’s map turtle is included as a Federal candidate species for possible future listing as a threatened or endangered species. *(Federal Register: February 28, 1996, Volume 61, Number 40, Page 7595-7613)*

General habitat: Cagle's map turtles prefer short stretches of shallow water with swift to moderate flow and gravel/cobble bottoms (riffles), connected by long stretches of deeper pooled waters with slower flow rates and mud/silt bottoms. Ideally, the banks should support a diverse growth of vegetation. It is also important for the river banks to have fallen trees and logs that can be used as basking sites (Killebrew 1991*additional references*).

Distribution and abundance: Cagle's Map turtle is restricted to segments of the Guadalupe and San Marcos river systems. It has been found in Kerr, Kendall, Comal, Guadalupe, Gonzales, Dewitt, and Victoria counties. The largest continuous population occurs in the Guadalupe River between Cuero and Seguin, Texas (Killebrew and Porter 1991). Cagle's map turtle has not been sighted in the Comal River, however its presence above and below New Braunfels in the Guadalupe River suggests the possibility of occurrence in the Comal River system.

3. PROBLEMATIC ORGANISMS. Non-native species can represent a threat to native species because their populations can rapidly increase in a system that lacks their native predators and competitors. Also, where a habitat has been altered as a result of human activity, the changes may be more favorable toward non-native species than native species. An increase in non-native species can lead to their replacement of native species. Some of the known impacts non-natives can have are removal of vegetation, degradation of water quality, introduction of parasites and diseases, hybridization, competition, and predation.

Non-natives species are introduced in numerous ways. Some examples include, including through aquarium “dumping”, planting exotic plants, releasing baitfish, adhering to hull surfaces on boats used in other water bodies or pumping of bilge water, and intentional stocking. As non-native densities increase, interactions between non-native and native populations may become more frequent. This interaction may directly affect the distribution, density, and survival of native organisms. Native populations may be displaced from preferred feeding, resting, and spawning grounds. Cessation of reproduction in the presence of high densities of non-natives has been repeatedly demonstrated in populations of largemouth bass and other species (Smith 1976, Dean and Bailey 1977).

The following species do not represent all known non-natives in the Comal ecosystem, just those that pose a known threat, or are most likely to pose a threat, to native species.

<u>Rio Grande cichlid (*Cichlasoma cyanoguttatum*)</u>

<u>Native range:</u> This fish is native to the lower Rio Grande drainage in Texas and Mexico. However, a number of populations have been established in large springs and rivers of Central Texas' Edwards Plateau including the Comal, San Marcos, Guadalupe, San Antonio and Colorado rivers.

<u>Impact</u>: Overcrowding by the Rio Grande cichlid can cause negative effects on reproduction as well as displacement of native fish (Chew 1972). They primarily consume aquatic plants, which could increase loss of vegetation and thereby loss of habitat for native species (Birkhead 1980).

<u>Common carp (*Cyprinus carpio*)</u>

<u>Native range</u>: This fish is imported from temperate portions of Eurasia (Banarescu 1964).

<u>Impact</u>: The common carp causes impacts similar to the Rio Grande cichlid, but in addition stirs up the bottom sediments during feeding, which increases siltation and turbidity of the aquatic systems (Allen 1980).

<u>Tilapia (*Oreochromis* species)</u>

<u>Native range:</u> These fishes are imported from Africa and parts of the Middle East. The exact identity of the tilapia in the Comal River system is unclear but probably is the blue tilapia (*Oreochromis aurea*), the Mozambique tilapia (*Oreochromis mossambica*), and/or hybrids between these two species (Hensley and Courtenay 1980).

<u>Impact</u>: Tilapia destroy vegetation through consumption and maintenance of large bareground nests within plant stands. Increases in turbidity have been attributed to digging associated with nest-making. Tilapia have also demonstrated the capacity for rapid expansion and explosive population increases in several states, which could crowd native fauna from their habitat or repress reproduction (Swingle 1960, Courtenay and Stauffer 1984).

Giant ramshorn snail (*Marisa cornuarietis*)

Native range: This snail is imported from southern Central America and northern South America (Horne et al. 1992).

Impact: Giant ramshorn snail populations in Landa Lake have increased dramatically since they were first observed there in 1984. They have spread throughout Landa Lake and into the river and have been implicated in the elimination of several vegetative stands (Horne et al. 1992). Their populations were reduced some during 1991, possibly due to high flows, and have not yet rebounded to previous levels. Populations of this snail are much smaller below Landa Lake, probably due to higher flow velocity. *update with info from Arsuffi report? Oborney results?*

Elephant Ear (*Colocasia esculenta*)

Native range: This large, emergent plant is imported from Asia (Godfrey and Wooten 1979)

Impact: This plant was initially brought into the United States as food for African slaves. It was subsequently cultivated by the Department of Agriculture in the 1900s for its starchy and edible (when well-cooked) tubers. Improperly cooked tubers can be toxic. Elephant ear can spread rapidly and replace native vegetation. This alters the vegetative structure and dynamics of the spring ecosystem. Elephant ear also modifies the stream channel through accumulation of sediment and narrowing of the channel.

Hydrilla (*Hydrilla verticillata*)

Native range: This submergent plant is imported from Europe (Godfrey and Wooten 1979).

Impact: *Hydrilla* is a pest in many aquatic systems including clear water springs. It grows rapidly, choking aquatic systems and displacing native plants.

Nutria (*Myocastor coypus*)

Native range: This aquatic mammal is native to South America.

Impact: Nutria feed on valuable wetland vegetation. Their burrowing activities can severely damage stream banks, levees, dikes, earthen dams, and other structures (USDA 1990).

Exotic gill trematode **(*scientific name*?)**:

Native range: **Asia?** *update*

Impact: The trematode infests gills of fish (heavily in fountain darters) causing physiological stress and possibly death to infected individuals.

intermediate host

II. MANAGEMENT PROCEDURES

This portion of the Comal Plan identifies management practices currently used or, in some cases, proposed to be used on the public portions of the Comal Springs, Landa Lake, and the Comal River that may have an impact on aquatic habitats, individuals, or populations of listed species.

This section is organized by management topics. For each management topic the current management practices are identified and described. Problems and concerns related to each practice are discussed and recommendations are made to avoid significant impacts to fountain darters and riffle beetles. In making these recommendations, we have also considered feasibility of implementation, including costs. The Service has worked with the City, NBU, and LCRA to develop practical management options.

Because this plan is being developed to assist in conservation, we have made recommendations that, in some cases, go beyond just avoiding or minimizing take. In some cases we have made recommendations that would benefit the overall health of the ecosystem upon which the listed species, as well as many other native species, depends. *Additional documents will be developed after this document is finalized. *delete the following? Included in this documentation isA Biological Opinion (BO) for the intra-Service section 7 consultation for the technical guidance and implementation of this plan will be issued once this Plan and a MOA with all of the Plan partners is finalized. The BO will provide a list of recommendations that the Service, City, NBU, and LCRA agree must be taken to avoid and/or minimize take and to satisfy the requirements of the section 7 consultation. Also included in the BO will be a list of conservation recommendations, which are not required but would be beneficial to the overall health of the ecosystem and, therefore, the listed species.*

Because the Service believes that the implementation of these recommendations will have an overall beneficial effect for the conservation of the listed species' and their habitats, the Service intends to seek funding from various sources to assist in the implementation of some of the recommendations.

A. MAINTENANCE OF SPRING-FED SWIMMING POOL

<u>Objective</u>: Maintain spring-fed swimming pool to provide similar recreational opportunities as the Olympic pool, but in a more natural setting.

<u>Current practice</u>: The pool previously held up to 1.5 million gallons, but construction of the shallow children's area in *19__* has reduced this capacity some. Water enters the pool from Landa Lake through a 10-inch (25-cm) diameter pipe located in the shallow section (cement area) of the pool. The intake is covered with a screen that has a 0.00155 (1mm) in. mesh, which is small enough to help prevent adult darters from entering the pool. However, it does not prevent fountain darter eggs and juveniles from entering and residing in the pool. A few (three to five) fountain darters were collected in the gravel and cobble area (deeper end of the pool) in 1993 and 1995 (Casey Berkhouse, USFWS, personal communication, 1995). Debris that collects on the screen is removed every few days by the aquatic staff to prevent the screen from clogging.

During the summer (May through September), the pool is drained and cleaned every Monday and Thursday at 5:00 p.m., after closing. The primary purpose of the cleaning is to remove algae from the bottom and sides of the pool, and to control the growth of aquatic **macrophyte**s and algae in the gravel and cobble section. This is done for both aesthetic and safety reasons.

The outflow gate is raised for about 30 minutes before beginning cleaning operations. The outflow gate drains from the bottom of the pool. It takes about 2 hours to drain the pool. However, pool personnel do not close the inflow gate, so there is always a narrow, shallow stream of water (about 5 cfs) flowing through the pool during the cleaning process. The pool cannot be entirely drained because the bottom of the outflow gate is slightly higher than the bottom of the pool.

Cleaning operations begin in the shallow, concrete section of the pool. A pressure hose supplied with municipal water is used to remove algae. Personnel hose the concrete areas for about 4 hours. After one hour, when the water level has sufficiently dropped, the deeper, gravel and cobble portion of the pool is cleaned. A tractor pulling a 5 ft x 4 ft (1.5 m x 1.2 m) wire brush is driven in circles over the gravel and cobble for about one hour (due to the inability to completely drain the pool, standing water prevents the use of the tractor in some areas of the gravel and cobble portion of the pool). This practice is used to help remove vegetation by fragmenting the plants. Some of the plant fragments float downstream, and some remain in the pool area. The outflow gate is then closed, and the pool refills overnight (about 8 - 10 hours). After September, the outflow gate is left open and no maintenance is done until December. In December, general repairs and overall cleaning begin. In May, the outflow gate is closed, the pool is allowed to fill, and semi-weekly cleanings begin again.

<u>Problems and concerns</u>:

1) Algal growth in the shallow end of the pool - Algal growth on the concrete surfaces in this end of the pool makes surfaces slippery and unsafe for swimmers. The standard method of eliminating algae from a pool area is the use of chlorine. However, chlorine is toxic to aquatic organisms, and EPA toxicity tests have shown aquatic animals to be even more sensitive to chlorine than aquatic plants (EPA 1984). The use of chlorine could severely impact fountain darter populations and other animals and plants immediately downstream of the pool. The City has been using pressure hoses to control algal growth, but because of the amount of time it requires and its effectiveness, the City would like another alternative. Also, pressure hosing uses chlorinated water without a dechlorination procedure, which may have an impact on fountain darters in the pool. An alternative procedure is needed to effectively deal with the problem without impacting plants and animals.

2) Vegetation growth in the deep end of the pool - This plant growth impairs lifeguards' view of the pool bottom and is a safety concern. Also, it is considered unattractive by many of the pool's guests. The practice of dragging a wire brush with a tractor over the cobble could harm or kill any fountain darters in the pool.

3) Sediment plume and water surge during pool cleanings - As a result of opening the outflow gate to drain the pool for cleanings, the rate of flow in the channel below the pool increases from about 0.6 to 2.1 cfs for about 1.5 hours (Melani Howard and Casey Berkhouse, USFWS, personal observation, 1995). Some sediment is released with the outflow, increasing the turbidity of the water temporarily. Increased current velocities are observed down the old channel to at least the Schlitterbahn dam. Schlitterbahn personnel are aware of this procedure and remove boards from their dam on the old channel to moderate the extra surge of water. The increased turbidity potentially disrupts feeding and breeding behaviors of fountain darter populations in a *small portion of *the old channel for *less than 4 Hours?*a short time.

<u>Recommendations</u>:

1) Algal growth in the shallow end of the pool - A mechanical means of algae removal is the most desirable control technique; however, as part of the modifications for the new children's pool area, play equipment was set up at various locations in the shallow end, making it hard to get at certain areas with machinery, such as a tractor pulling a roller brush. Other non-chemical alternatives include shading the concreted area to slow the rate of algal growth and selling or renting "aqua socks" to decrease slipping.

Though the use of chlorine is not usually recommended in sensitive areas, the City and Service have made preliminary investigations of a chemical method of controlling algal growth in the New Braunfels spring-fed pool and the method appears acceptable. This method includes the use of chlorine <u>followed by treatment with</u> sodium thiosulfate (a dechlorinating agent). Sodium thiosulfate neutralizes free chlorine immediately upon application, which should eliminate the negative impacts of chlorine on animals and plants both in the deep end of the pool and downstream. The recommended procedure is as follows (it is also important to follow the manufacturer's safety instructions when using these chemicals):

1. After the pool is drained, the main outflow and inflow gates would be closed.
2. Calcium hypochlorite (no more than 100 lbs [45 kg]) would be applied to algae on the concrete surfaces in the shallow end of the pool and allowed to sit for about 10 minutes (or as long as necessary to kill the algae), then followed with an application of sodium thiosulfate (200 lbs [90 kg]). Sodium thiosulfate and hypochlorite must be used in a 2:1 ratio (2 parts sodium thiosulfate to 1 part calcium hypochlorite). Make sure that all surfaces treated with calcium hypochlorite are treated with sodium thiosulfate. <u>This step is critical to neutralize the toxic effects of chlorine</u>.
3. Neutralization occurs immediately, so the inflow gate could be opened anytime <u>after</u> the application of sodium thiosulfate is complete.
4. Allow the pool to fill completely so that water spills over the dam - leave the outflow gate closed. This is important to get the maximum dilution of any residual chlorine prior to discharging water to the old channel.

This procedure should control the algal growth without harming other aquatic life in the gravel and cobble section of the pool or downstream. Tim Dean (Aquatic Superintendent of the New Braunfels Parks and Recreation Department at the time) applied calcium hypochlorite and sodium thiosulfate to the concrete section of the spring-fed pool in August 1995 as a trial run of this procedure. The Service collected the first 100 ml of water that ran off the concrete area onto the gravel/cobble section after the inflow gate was reopened. The LCRA lab found the sample to have less than 0.01 mg/L residual chlorine. The EPA (1984) recommends that the total residual chlorine concentration in freshwater should not average in excess of 0.019 mg/L for one hour during any 3 year period. The procedure presented above has been in use regularly since 1995 and should be checked to assure that it meets EPA criteria and modified if necessary. The following precautions should be taken when using this procedure:

1. An experienced supervisor should be on hand throughout the procedure.

2. Water samples should be taken as described above for the first month this procedure is used and the first two times this procedure is used each season thereafter to ensure that the chlorine concentration is not exceeding an average of 0.019 mg/L for one hour.
3. The supervisor should experiment with lower concentrations of the calcium hypochlorite to determine the smallest amount needed to control the algae (this will keep the cost and use of chemicals to a minimum).

2) Vegetation growth in the deep end of the pool - Reducing the number of fountain darters in the pool is the first step toward reducing the number harmed during the gravel and cobble cleaning procedures. To help keep fountain darters and other animals out of the pool, the City should continue to maintain the screen over the inflow gate. The screen should be checked daily and cleaned and/or repaired as soon as a problem is noticed. However, even with the screen, some juvenile fountain darters and fountain darter eggs will enter the pool.

We also recommend adding a firm, rubber (or some other suitable material) skirt to the front edge of the wire brush used to fragment vegetation in the deep end of the pool. The skirt should be long enough to create a forward surge of water helping fountain darters avoid the brush. The procedure should be performed in water deep enough (3 to 4 inches) to allow fountain darters avenues of escape. Another technique that could be used in combination with the brush or by itself, is to grade the gravel bed so that gravel is higher on the sides, creating a channel to the outflow gate and increasing the chances for fountain darters to escape as water is drained from the pool. If a method that uses a tractor is chosen, the tractor should be inspected before each use for fuel, antifreeze, hydraulic, and oil leaks. Although harm to fountain darters in the pool may still occur, the above recommendations will reduce the harm.

3) Sediment plume and water surge during pool cleanings - Due to the limited duration and frequency of this event it is likely to have no detectible adverse impacts on fountain darters in the old channel.

B. REOPENING OF THE NEW BRAUNFELS UTILITIES HYDROELECTRIC PLANT

<u>Objective</u>: NBU is considering reopening the hydroelectric plant as both a minor producer of electricity and a historical building.

<u>Current practice</u>: The hydroelectric plant currently is not operating (Section I.B.8 - Artificial Structures), but NBU is considering reopening in the future. Water from the new channel flows into the plant's **forebay**. At this point, the water either enters the plant through a grated entrance or passes through bypass gates and over the 17-ft reservoir dam. When the plant is operating during flows below 300 cfs, the bypass gates are almost entirely closed, so 90% to 100% of the flow entering the forebay passes through the grates, passes through a turbine, exits the plant, and flows into the river. Any remaining portion of the water flows through the bypass gates and over the reservoir dam. The plant cannot handle flows over 300 cfs, so the bypass gates are opened further when flows are over 300 cfs, allowing more water to flow over the dam (Roger Biggers, NBU, personal communication, 1996). While the plant is not in operation, most of the water entering the forebay flows over the dam. For hydroelectric plant operations to remain feasible, at least 100 cfs of flow must be going down the new channel and through the plant (Gene Laponec and Roger Biggers, NBU, personal communication, 1995 and 1996).

The bars of the grate at the plant entrance are about 3 inches apart (Roger Biggers, NBU, personal communication, 1996), which allows the passage of fountain darters into the hydroelectric plant. As water flows through, floating vegetation gets caught on the bars. In the past, vegetation was removed from the grate by hand using rakes down to a point about 4 ft from the bottom because removing the upper vegetation is less likely to affect fountain darters. Vegetation was not removed from this lower portion of the grate. NBU plans to use an automatic grate cleaner to remove vegetation if the plant reopens. Once removed from the grate, the vegetation would be placed in a dump truck and hauled away. NBU stated that the grate cleaner could be set to not remove vegetation from the lower several feet of the grate (Roger Biggers, personal communication, January 1996).

<u>Management Issues</u>:

1) Partitioning of instream flow between the old and new channel - As discussed in Section II.C., it is desirable to maintain about 110 cfs for fountain darter habitat in the old channel. Maintaining certain flows in the new channel for plant operation will influence the amount of flow in the old channel. During periods of low spring discharge, flows could drop dramatically in the old channel. Below 40 cfs would cause a loss of habitat and negative effects to fountain darters.

2) Fish injury - Injury or death to fountain darters could occur in a number of ways as fish pass through the turbines. A study on survival results of fish passing through turbines indicated that about 83% of the fish studied survived turbine **entrainment** (Matousek et al. 1994). One of the turbines in this study is similar to the one in the NBU hydroelectric plant, but the majority of the experimental fish were larger than fountain darters. Matousek et al. (1994) noted that a smaller body size seemed to decrease the chance of a blade strike. Therefore, the percentage of fountain darters surviving passage through the turbine could be higher than 83%. A study by Bell (1972) found two factors dramatically increased mortalities as fish pass through a hydroelectric plant: 1) fish hitting the sides of the conduit during abrupt changes of direction, and 2) **cavitation** resulting from the action of the turbine.

Another impact associated with spillways and hydroelectric plants is the supersaturation of water with atmospheric gases, especially nitrogen. This is a potential issue with all low head dams in the Comal River. Fish exposed to supersaturated water often develop gas bubble disease which is characterized by disorientation, emphysema, gas **emboli**, lesions, exophthalmia ("popeye"), and death (USFWS 1977). Experiments at the San Marcos National Fish Hatchery and Technology Center suggest that in captivity fountain darters begin to die at 105 to 110% supersaturation (Tom Brandt, USFWS, personal communication, 1995).*Check on measurements below structure*

3) Vegetation removal procedures - Fountain darters might be harmed or killed during the collection and removal of vegetation from the grate in front of the hydroelectric plant.

Fountain darters have been found in the vegetation mats that float down the river (Hardy et al. 1999) and eventually collect in the grate.

<u>Recommendations</u>:

The purpose of this plan in relation to the NBU hydroelectric plant is to begin to identify possible impacts to fountain darters from the reopening of the plant. Establishing detailed requirements for the operation of the NBU hydroelectric plant is beyond the scope of this management plan. The details of what would be required to minimize the take of fountain darters should the plant reopen would need to be determined in further consultation with the Service. This consultation may occur as a part of applying for hydropower licensing from the Federal Energy Regulatory Commission or as part of obtaining a permit for take under the Endangered Species Act from the Service. The following general recommendations are made as a preliminary step toward identifying areas of concern.

1) Partitioning of instream flow between the old and new channel - An agreement between NBU and the City (and any other parties deemed necessary) should be developed to assure an adequate flow regime, with a 40 cfs minimum, would be maintained in the old channel as spring discharge decreases. TCEQ should be contacted to assure that the partitioning of flows is consistent with state water rights regulations *has this been written out on 1st use in Part II?*. The ability to control flows would be enhanced by improving the LCRA dam on the new channel (as discussed in Section II.C.).

2 and 3) Fish injury, Vegetation removal procedures - Prior to consultation with the Service concerning the details of what is needed to minimize take should the hydroelectric plant reopen, more information and data need to be collected to better estimate the impact of the plant's operation on fountain darters (see below). The Service is willing to help in the collection and analysis of these data. In particular, the following information is needed:

1. Estimate extent of fountain darter death and injury that would occur as a result of passage through the hydroelectric plant, from the effects of supersaturation, and during vegetation removal needs to be determined.
2. Measure total dissolved gases in the area of the discharge from the plant (and the affected downstream area) through a range of conditions, including various flows.
3. Estimate fountain dater abundance in the vicinity of the grates and in mats of floating vegetation in the forebay to help evaluate the likelihood of fountain darters entering the hydroelectric plant or being injured during vegetation removal.

Once the extent of take is estimated using the collected information, the necessity and methods of minimizing take can be addressed. There are resources and references available to use for deciding on applicable methods. For instance, the Service (USFWS 1977) describes several measures that have successfully minimized and/or offset fish passage through hydroelectric plants. It may be necessary to develop a protocol for cleaning the grate and maintaining the vegetation in parts of the forebay as a way to reduce the probability of fountain darters entering the plant.

C. MANAGEMENT OF FLOWS TO THE OLD AND NEW CHANNELS

<u>Objective</u>: To better manage the flow regime from Landa Lake to the old and new channels to maximize fountain darter habitat availability throughout the system, particularly during low-flow times (when total flow is less than 200 cfs).

<u>Current practice</u>: The flow of water out of Landa Lake into the new channel is restricted by the Comal Canal Dam. This dam is maintained and inspected by the LCRA. The flow from the lake into the old channel is controlled by the spring-fed pool dam and new bypass culvert that was installed in 2000 with funding from FWS. The spring-fed pool dam is maintained by the City. The only maintenance activity for the bypass culvert is the removal of debris that collects on the trash rack in front of the culvert intake.

The new culvert to the old channel allows more ability to regulate flows to the old and new channels. If the water surface elevation in Landa Lake falls to a low level, maintaining flows in the old channel for critical fountain darter habitat should now be possible by adjusting the valve on the gate. The inflow gate at the spring-fed pool dam (see Section II.A. Maintenance of Spring-Fed Swimming Pool) is normally closed only during cleaning and pool maintenance during the summer season. Partially or completely closing this gate could alter the quality of the spring-fed pool as a swimming area and would reduce the amount of water flowing into the old channel. The new bypass culvert allows *up to* more than 100 cfs to be diverted down the old channel. The new bypass culvert was constructed with an intake elevation to allow water into the old channel, even when Landa Lake is at very low levels.

<u>Problems and concerns</u>:

1) Lake levels and stream flows into the old and new channels - Landa Lake and the old channel support large numbers of fountain darters. It is therefore particularly important to maintain spring discharge in Landa Lake as well as sufficient flows through the old channel. While assuring adequate spring flows is beyond the scope of this document (and beyond the ability of the City to do by itself), managing flows to the old and new channels is within the City's purview.

2) Shutting off flow to the spring-fed pool for maintenance and other purposes - The decrease in flow to the old channel may impact fountain darter populations, especially during periods of decreased spring discharge.

<u>Recommendations</u>:

1) Maintenance of adequate flows to old channel - 1a) Hardy et al. (1999) recommends 40 cfs be maintained in the old channel anytime the total spring discharge exceeds 80 cfs. Flows up to 110 cfs provide additional habitat and do not cause downstream flooding. The proposed flow split is to partition flows equally between the two channels at total springflows below 220 cfs. Above that flow, 110 cfs would go down the old channel, and the remainder would be routed down the new channel. This recommendation is based on fountain darter habitat modeling, which indicates the need

to moderate water temperatures downstream in both the new and old channels as well as the Comal River proper below the confluence of the old and new channel.

1b) The trash rack on the new bypass culvert should be inspected at least once per week and cleaned as soon as excessive debris is noticed to prevent impeding flow.

1c) Narrow areas of the old channel are susceptible to restrictions in flow caused by the accumulation of debris or fallen trees and limbs. The portions of the old channel adjacent to city park or golf course land should be inspected at least twice a week by parks and golf course personnel and any obstructions should be removed.

1d) Modifications could be made to the Comal Canal Dam that would give greater control over the amount of water flowing through this structure. The addition of a gate or valve at this dam could help maintain lake levels and old channel flows in times of low spring discharge.

1e) An alternative to these modifications of the Comal Canal Dam is to totally replace the dam. The LCRA has expressed an interest in this idea. The best time to construct such a dam is during a period of low flow when water levels in the new channel would only have to be lowered a little or none at all. Some take of fountain darters may occur during the construction of a new dam (or during modification of the existing dam). If this alternative is pursued and design details and construction schedules are available, the Service will coordinate with the involved parties to make recommendations for avoiding and/or minimizing take. **[UPDATE W/ INFO FROM BO - NEED TO GET FROM PAT]**

Modifications to any of these control structures should be cleared with the TCEQ to ensure that they are in compliance with state water rights regulations. Also, a coordination plan between the Parks and Recreation Department, NBU, and LCRA should be established to outline how the control structures will be managed to maintain an optimum water surface elevation of the lake and/or flow down the old channel, based in part on results from Hardy et al. (1999). The plan should also set a schedule for periodic inspection of the control structures to ensure adequate functioning.

2) Shutting off flow to the spring-fed pool for maintenance and other purposes - Flows through the new bypass culvert should be adjusted upward to account for flows not passing through the spring-fed pool to avoid or minimize any impacts from the loss of spring-fed pool flow.

D. MAINTENANCE OF COMAL RIVER DAMS

Objective: Keep public dams on the Comal River below Landa Lake in good repair for public safety and to maintain flow regimes.

Current practice: There are six dams on the Comal River downstream of the Landa Lake control structures. However, clear public ownership has been established for only two of these dams and only they are considered to be within the scope of this management plan *check on USGS dam - city proposal to repair*. See Section I.B.8. - Artificial Structures, for discussions of all dams; and Figure 1, for the location of the dams.

The reservoir dam is located at the NBU hydroelectric plant on the new channel. This dam serves to pool water in the plant's forebay for plant operations (see Section II. B. Reopening of the NBU Hydroelectric Plant, for more details on this dam). This dam is owned by the LCRA.

The tube chute dam (Clemen's dam) is located on the Comal River below the confluence of the old and new channels. This dam is maintained by the City. The TCEQ has no record of inspection for this dam.

Problems and concerns:
1) The current availability of fountain darter habitat in some areas of the Comal River is shaped in large part by the presence of these dams. Fountain darters have been collected in areas of the river influenced by these dams. Altering the dams may alter

the quantity and quality of fountain darter habitat, though it is unclear if the changes would be positive or negative.

Recommendations:

1) The City and LCRA should schedule periodic inspections (about every 5 years) for their dams and ensure that these dams are repaired as needed. The dam safety unit of the TCEQ can be contacted for information on dam inspection (Appendix C). Each dam could have different influences (back-water effects, width and depth of pool, etc.) on the river. Changes in these dams may not necessarily result in negative impacts. However, any changes should be carefully planned and evaluated for impacts. It is also important to avoid changes in the dimensions of the dams, including the height of a dam, without first evaluating the consequences.

E. FISHING DERBY IN OLYMPIC AND SPRING-FED SWIMMING POOLS

Objective: Provide a fun, safe fishing experience for children.

Current practice: The fishing derby ("Troutfest") is held once a year during the winter in either the Olympic or, primarily, spring-fed swimming pool, and the fishes are in place for about 10 days. The Parks and Recreation Department uses rainbow trout measuring 8 to 10 inches (20 to 25 cm) long, provided by the A.E. Wood State Fish Hatchery (TPWD), and channel catfish weighing 1 to 5 lbs. (0.5 to 2.3 kg) obtained from a private fish farm. About 1000 rainbow trout and 1000 to 1200 lbs. of channel catfish are stocked. Precautions are used in the spring-fed pool to prevent the escape of fishes. A barrier net of galvanized wire is extended across the outflow gate and over the spillway. It is in place before fish are added to the pool and is not removed until the pool is drained and left over fish are removed. Although the Parks and Recreation Department staff keeps a tally sheet for fish removed by guests during the derby, due to predation by birds, this tally probably does not reflect the actual number of fish remaining in the pool. Catfish remaining at the end of the fishing derby are donated to a local food bank.

Both locations, the spring-fed pool and the Olympic pool, have advantages and disadvantages for management of the fishing derby. In the spring-fed pool, cormorants (a fish-eating bird) consume a large number of the trout, and so much natural food is available for catfish that they are not eager to take the bait during the derby. The Olympic pool does not have these problems, but it does not hold as many fish, so fewer people can participate. We will address precautions to be taken for the derby in both locations.

Problems and concerns:

The following are concerns for both the Olympic and spring-fed pools:
1) Fish escapement - Accidental release of trout (which are not native to this area) into the Comal ecosystem is a problem because of potential impacts on native fishes (McDowall 1976) and invertebrates (Fish 1966) (see Section I.C.3. - Problematic Organisms). The introduction of a large number of channel catfish, though probably native to the river, could also impact fountain darters through impacts on habitat and competition for food resources.

2) Disease and parasite concerns - Stocked fish may carry parasites or diseases that are transmittable to other fishes. In the spring-fed pool, any disease carried by the derby fish can spread downstream even if none of the fish escape. In the Olympic pool, water drains into the Comal River, also giving disease a pathway to the river.

Recommendations:
1) Prevent fish escapement - We recommend that when the spring-fed pool is used, the Parks and Recreation Department continue their current practice for preventing escapement of derby fish. (Even with these precautions, derby fish are much more likely to escape into the Comal River from the spring-fed pool than the Olympic pool).

Weather forecasts should be monitored so derby fish can be removed from the spring-fed pool prior to any possible flooding. Otherwise fish could be washed out of the pool into the river. In the Olympic pool, fish should be removed before draining the pool, or nets of a mesh size small enough to contain the derby fish, should be placed over drains, and fish removed after draining the pool.

2) Parasite and disease control - The Parks and Recreations Department should obtain their derby fishes from a reputable supplier with a good reputation for supplying parasite and disease-free fishes. The A.E. Wood State Fish Hatchery (TPWD) supplies trout that have been certified disease-free. However, there is no certification procedure for the suppliers of the catfish. A TPWD biologist may be available to perform a cursory, external examination of a small number (10 to 15) of the catfish prior to stocking them into the derby pool (see Appendix E for information). Such an inspection by TPWD personnel would serve only to provide information, not advice, to the City. The responsibility for deciding to stock or not to stock, and the consequences of that decision, would still belong solely to the City. Before and during the event, the City should work to educate the public to discourage people from releasing any trout caught during the derby into the wild.

F. MAINTENANCE OF THE OLYMPIC SWIMMING POOL

<u>Objective</u>: Provide a fun, safe swimming environment for the public.

<u>Current practice</u>: The Olympic pool is open on weekends beginning in early May and open daily from 11:00 a.m. to 7:00 p.m. from mid-May through the Labor Day weekend. City water is used to fill the pool and more water is added as needed throughout the season. The pool's filter is cleaned by **backwashing** into the old channel about once a week. The end result is about a 10,850 gallon slug of turbid, chlorinated (about 1 ppm) water, heated about 10°F higher than the river, discharged into the old channel. The backwashing process takes about 7 minutes. If the filter is backwashed less often than once a week during the pool season, it may require 15 minutes of backwash to clean the filter, which doubles the discharge (Tim Dean, Parks and Recreation Department, personal communication, 1995).

At the end of the season, the pool is closed and the water is allowed to sit until February. It is then drained into the old channel and the pool is cleaned. It is not a problem to drain the water into the old channel, because by this time the chlorine has dissipated.

Problems and concerns:

1) Filter cleaning - The discharge of the backwash water might have negative impacts on fountain darters in the old channel.

Recommendations:

1) Filter cleaning.

1a) Prior to deciding on a management option, additional information on the significance of the impact should be collected. In particular, the water quality should be checked 1 meter out from the point of discharge and 2 meters downstream, and again 5 meters out and downstream to help determine if any significant changes in water quality occur as result of discharge. Temperature and chlorine residuals are the primary concerns (the temporary increase in turbidity probably poses only minor impacts to fountain darters). The EPA (1984) recommends that residual chlorine levels in freshwater should not exceed an average of 0.019 mg\L for an hour during any 3 year period. Water quality in the area of the effluent should be tested to determine if this criteria is being met. This test should be conducted at low flows as well as normal flows. The short period of discharge, in combination with the diluting factor of the river, at normal and high flows, may reduce the temperature and chlorine concentrations to inconsequential levels. However, the dilution capability of the old channel will be reduced at low flows.

If, after analyzing water samples collected as described above, it is determined that a change in procedure is warranted, there are several options to explore:

1b) A method of delivering a steady supply of a dechlorinating chemical (such as sodium thiosulfate) to a discharge of chlorinated water is being used at some facilities. In the case of the Olympic pool, a portable device could be placed near the cistern when the pool is backwashed and set to deliver a steady supply of a known concentration of dechlorinating agent for the duration of the discharge. The use of this method would necessitate the standardization of the backwash procedure in terms of duration and amount of water discharged so that dechlorination is consistently achieved. Backwashing should be done in the morning when the pool water temperature and river temperature are most similar.

1c) Construction of a small, concrete-lined retention pond located close to the filter area would allow the chlorine to **volatilize** and the sediment to settle before the pool water enters the Comal River. The volume capacity would not need to be larger than about 12,000 gallons if the filter were backwashed on a weekly basis during the pool season. The captured water should be tested daily with a chlorine test kit and released when the chlorine concentration is below 0.019 ppm. The water should be discharged in the early morning when its temperature is most similar to the river temperature. Storm events would cause a diluted overflow that would travel about 40 feet (10 meters) before reaching the river, and should therefore contain very little chlorine. The disadvantages to a retention pond include safety concerns, sediment removal, algal blooms, and mosquito problems. Most of these could be avoided if the pond were fenced and emptied 24 hours after filling. An outflow gate or release valve would need to be included in the design of the pond. See the Urban Drainage and Flood Control District (1992) manual for more information. This may be the method that best addresses chlorine, temperature, and turbidity.

1d) The backwash could be run into the sewer system, so it is transported to the wastewater treatment plant or to the golf course to be used for irrigation.

G. LANDA PARK GOLF COURSE MANAGEMENT PRACTICES

Objective: To maintain a high quality golf course for its users.

Current practice: The Landa Park Golf Course runs along Landa Lake and the old channel (Figure 1). It is open to golfers year round and is a popular course.

Management practices that are pertinent to this plan include: 1) the use of pesticides and fertilizers to maintain the grounds, 2) removal of aquatic vegetation in the waterways to make golf balls more visible and for aesthetics, and 3) retrieval of golf balls from the waterways for resale in the golf shop.

All areas of the course are treated with chemicals, including the **roughs**. Pesticides, colorants, defoamers, and iron supplements are sprayed on the **greens** from about October through February. The entire course is sprayed March through September, with the greens and **fairways** sprayed at least twice a month. Fertilizers are applied about once a month for the entire year to the greens and **tees**.

Aquatic vegetation is removed from the canal that runs between the golf course and Pecan Island (Figure 1) *does figure need work?*. A rake, secured with a rope, is thrown out into the canal, and dragged back to pull up vegetation. In the past, floating vegetation has been chopped with the propeller of a boat and pushed out of the canal to float downstream (Fernando Gutierrez, golf course greenskeeper, personal communication, 1995).

Golf balls are retrieved from the bottom of the canal alongside Pecan Island in Landa Lake and in areas of the old channel that run along the golf course. Golf course employees wade and snorkel through these areas collecting golf balls as often as twice a week during the summer (Fernando Gutierrez, personal communication, 1995).

<u>Problems and concerns</u>:

1) Chemical use - The primary area of concern is the impact of herbicides, fungicides, fertilizers, and insecticides on the Comal ecosystem. These chemicals are useful in controlling pests, but they may also present a hazard to species not considered to be pests in the surrounding environment. For example, runoff of pesticides used on the golf course into Landa Lake may reduce populations of aquatic insects, which are important food sources for many freshwater fish. Runoff of methoxychlor (a pesticide used on the Landa Park Golf Course) into a stream has been shown to greatly reduce stream invertebrate populations (Eisele and Hartung 1976 *not in lit cited*).

Methoxychlor also interferes with fetal development and can cause sterility in mammals. Fish can also be directly affected by pesticides. Dursban *is it still applied?*, another chemical applied on the golf course, has immediate, highly toxic, and long-term effects upon all forms of aquatic life, as well as mammals (Briggs 1992).

Once in the water, pesticide residues can become attached to suspended material, deposited on bottom sediments, and absorbed by organisms. They may be transported through the aquatic system by water currents or in the bodies of aquatic organisms. Impacts that some chemicals have on some forms of aquatic life include behavioral changes (such as swimming and predator avoidance), physiological changes (such as growth and reproduction), biochemical changes (such as blood enzyme and ion levels), and death. These effects can be acute (happening relatively soon after exposure) or chronic (happening some time after a single exposure or after repeated or long-term exposure) (Rand and Petrocelli 1985).

Fertilizers can be a problem because of their nutrient-enrichment effect on receiving aquatic systems. An excess of phosphorus and nitrogen (fertilizer nutrients) will promote algal growth and can lead to "algal blooms" (a rapid increase in the algal population). These "blooms" can cause a depletion of dissolved oxygen in the water, particularly at night. In the Comal River, this could be a problem during very low or no flow times.

2) Vegetation harvesting - The harvesting of aquatic vegetation from the canal along Pecan Island could result in some destruction of fountain darter habitat and direct mortality to fountain darters. Fountain darters have been found in this area and aquatic plants are essential components of their habitat in the Comal River (see Section II.H. Management of Aquatic Vegetation).

3) Golf ball retrieval - Wading and snorkeling to retrieve golf balls can damage the aquatic plants. Fountain darters have been found in the areas from which golf balls are collected.

Recommendations:

1) Chemical usage - A good approach for addressing chemical usage at Landa Park Golf Course is to develop and implement an integrated pest management plan (IPMP), incorporating appropriate information from the Service and other sources, that is specific for the local environment and concerns. IPMPs are being developed and used by many U.S. golf courses to keep management practices as ecologically sound as possible. For example, Barton Creek golf course in Austin, Texas, developed an IPMP plan using information obtained from the LCRA, EPA, City of Austin, Texas Agricultural Extension Service, the Golf Course Superintendent Association of America, and the U.S. Golf Association. As part of the plan, the Barton Creek golf course staff is using no chemicals on the roughs, they are mowed only, and the weeds on the greens are managed strictly by physical/mechanical methods. Also, a greater abundance of insect pests are tolerated on the roughs than on the greens. Practices such as these allow an important reduction in chemical use, while still maintaining an attractive course. Pesticides and fertilizers are expensive, using them as efficiently as possible will also reduce expenditures. Lost Pines golf course in Bastrop also uses IPM and as a result has dramatically reduced their use of chemicals.

Landa Park Golf Course runs along the Comal River with tees on Pecan Island. Because the golf course extends to the river bank, we recommend that golf course personnel explore alternative pesticides to reduce impacts on aquatic life. Because Pecan Island is surrounded by water, it is particularly difficult to prevent runoff of chemicals into the water. It is important that the smallest possible amount of pesticides and fertilizers be applied to the island. The manufacturer's recommendation is not necessarily the minimum. For the rest of the golf course, a 100 feet buffer of untreated land with increased vegetation between the course and the river is recommended. A healthy **riparian** zone would dramatically reduce runoff of chemicals. However, because it is not a large course, it might be more feasible to emphasize the elimination of surface runoff.

The rate, method, and timing of pesticide and fertilizer application are important in minimizing transport by surface runoff, as well as optimizing the intended purpose of pesticides and fertilizers in landscape maintenance. For controlling runoff, irrigation is the most critical, but it is a difficult practice to control. Overwatering can provide the vehicle for transport of chemicals into the river. Limits on irrigation could be set so no part of the course is overwatered. At Barton Creek Golf Course, for example, a watering schedule is used that minimizes percolation below the root zone, which reduces the likelihood of runoff into Barton Creek as well as reduces fungal problems. Also, weather reports should be monitored to avoid irrigating or applying pesticides before a storm, and to change required water amounts in response to changes in humidity, soil moisture, and air temperature. TCEQ can provide information on determining application rates for irrigation (Appendix C).

The Audubon Cooperative Sanctuary System, is a program for golf courses designed to promote protection of wildlife and other natural resources. Monitoring wildlife on and around golf courses, setting up nest boxes and feeders, protecting endangered species, and creating natural buffer zones along stream edges are just a few of their recommended activities. They want to encourage golf courses to take a leadership role in conservation projects. They will provide information to assist the golf course superintendent and course officials through publications, telephone consultations, and specially arranged on-site visits. Further information on this program can be obtained from the Audubon Society (Appendix C).

2) Vegetation removal - A large amount of clipped vegetation is probably coming from areas upstream of Pecan Island. Preventing the entrance of this vegetation into the canal should reduce the amount of floating vegetation in the canal and the harvesting effort. One method of doing this is to establish a barrier upstream of the canal that maintains the present flow of water into the canal, but prevents floating vegetation from entering. The barrier should be checked regularly and any accumulated vegetation removed. Vegetation could be removed by hand from a non-motorized boat. The removed vegetation should be shaken over the water's surface to dislodge entangled fountain darters.

When it is necessary to remove floating vegetation from the canal, it is essential to do so with minimal disturbance to the plants that are rooted in the canal. Rooted aquatic plants are an important part of fountain darter habitat. Uprooting these plants will likely negatively impact fountain darters in the canal. Operating from a non-motorized boat, personnel could use pitch forks to remove floating vegetation from the surface of the water. The spacing of the pitch fork tines should allow fish trapped in the vegetation to escape. Alternatively, a seine, pulled along the water surface by two people wading in the water, would collect the floating vegetation from the canal without uprooting plants. Once collected, the vegetation should be shaken over the water's surface to dislodge any trapped fountain darters (see Section II.H). Vegetation removed from the canal and the upstream barrier could be used in a compost program for the golf course and the city parks.

3) Golf ball retrieval - Limiting golf ball retrieval to two golf course staff members and two days a week is a good practice as it reduces the number of personnel involved and the frequency of activity. Optimally, golf balls could be retrieved using a non-motorized boat and a tool made to retrieve golf balls. If there are areas in which vegetation is too thick to see the golf balls, golf course personnel could snorkel. Snorkeling would allow them to sort through the vegetation without standing on or walking through aquatic habitat. Prior to snorkeling, the personnel involved should be informed of the presence of fountain darters and reminded to keep habitat disturbances (for example, uprooting vegetation and stirring-up sediments) to a minimum.

H. MANAGEMENT OF AQUATIC VEGETATION

<u>Objective</u>: Maintain an attractive park for recreational users, as well as preserve the submerged plant stands that are needed for the healthy functioning of the ecosystem and minimize the amount of floating vegetation that is transported downstream into other recreational areas of the river.

<u>Current practice</u>: Landa Lake usually has abundant vegetation, which can become quite thick. While this provides excellent habitat for aquatic animals, it is considered a

nuisance and unattractive by some residents and park visitors. Prior to the increase in non-native giant ramshorn snail populations in 1989-90, the Parks and Recreation Department used a cutter boat to cut submerged vegetation in Landa Lake. In recent years, this has not been needed because the giant ramshorn snail and tilapia have reduced, and in some areas eliminated, stands of submerged vegetation in the lake *is this still true?*. The New Braunfels Parks and Recreation Department no longer manages the submerged vegetation because it has remained below the level where its management is desirable for recreational use of the lake.

During the summer the amount of floating, dead vegetation transported downstream into the river can be a nuisance to people using the river downstream. The vegetation apparently originates from private individuals cutting vegetation in the upper part of the lake, vegetation management by the golf course, and primarily from natural uprooting and fragmentation of plants. During the summer of 2000, the City contracted the use of the existing conveyor belt upstream of the reservoir dam to remove floating vegetation.

<u>Problems and concerns</u>:

1) Dense, submerged aquatic plant communities were found by Barnett and Schneider (1974) to support higher numbers of animals than most other aquatic habitats. Aquatic vegetation provides food and/or refuge for many aquatic animals, and plays an important role in the health of the river system (Wetzel 1983). Many studies recognize the importance of aquatic vegetation and state that management efforts should be focused on control rather than elimination of plant life (Terrell and Terrell 1975, Addor and Theriot 1977).

Care must be taken when managing aquatic vegetation because it is used by the fountain darter as a refuge from predators and as a place to deposit their eggs. It also provides habitat for many of the darter's invertebrate prey (see Section I.C.2. - Target Organisms), as well as other species of fish. Strawn (1956) *in captivity?* observed that fountain darters grew to maturity only when dense vegetation was available for cover from predation.

Recommendations:

1) The current practice of not cutting vegetation is the best practice for the Comal ecosystem.

2) Limited vegetation cutting - The Parks and Recreation Department may decide to begin cutting the vegetation if it becomes more abundant and starts emerging above the water surface. Any cutting using a cutting boat should be limited to no more frequently than once a week and a maximum of 2 feet below the water surface. If water depths are 2 feet or less (such as the canal running between Pecan Island and the golf course), plants could be cut at the surface by hand from a boat, and the clipped plant material could be skimmed from the surface of the water. Surveys by the Service have found fountain darters in plant material on the water surface, so clippings need to be shaken to dislodge any darters before being removed from the water. Removed vegetation could be used in a compost program for the golf course and the city parks. Practices that uproot vegetation from the bottom, such as dredging or raking, should be avoided.

The use of herbicides to control submerged aquatic vegetation in this system is an undesirable management practice because of possible unintended impacts to the habitat. Even if the herbicide is selective and not toxic to the fountain darter or its prey species, there could still be impacts from loss of habitat and other secondary impacts from vegetation control (such as increased decomposition and subsequent decreased dissolved oxygen levels). There are also other unique organisms in the Comal River that could be impacted by chemical methods of vegetation control.

3) The City should provide qualified personnel on site as a biological monitor during vegetation removal using the conveyor belt. This person will sort through the vegetation as it is removed and search for fountain darters.

I. NUISANCE SPECIES

Objective: Control introduced species that have direct or indirect negative effects on native populations and habitat.

Current practice: Attempts have been made to control only two nuisance species in Landa Lake (nutria and elephant ear). The Parks and Recreation Department calls a Wildlife Damage Control Specialist at the U.S. Department of Agriculture if nutria populations seem to be increasing, such as when the normally nocturnal nutria are noticed coming out during the day in increased numbers. In the past, elephant ears were sprayed with Rodeo(R), an herbicide with low toxicity for aquatic organisms (Briggs 1992). The Parks and Recreation Department no longer sprays the elephant ears. No other management practices have been established for control of nuisance species.

Problems and concerns:

1) Some of the problems associated with non-native species are outlined in Section I.C.3. - Problematic Organisms. As water levels and flows decrease with decreasing spring discharge, physical and chemical conditions in the Comal River could change (see Section I.B.4. - Water Quality). In a system that exhibits relatively constant water quality parameters, changing conditions could give a competitive advantage to different species. Some non-native species that may not be causing a problem at average flows could become a problem as flows decrease and some that do have an impact at high and medium flows could have a larger impact under the stress of low flows. Under low flows, competition for remaining resources may increase; predation due to increased accessibility to prey may also increase.

The species discussed in this section are either presently a nuisance in the river, or there are concerns that they could have significant negative impacts in the future. For these reasons they should be controlled. The specific problems posed by these species are identified in Section I. C.3. - Problematic Species *are they? Check*.

Recommendations: The following recommendations are organized by species. See Section I. C. (Problematic Species) for the scientific name and native range of each species.

1) Tilapia - Tilapia are abundant in Landa Lake (Patrick Connor, USFWS, personal communication, 1996) and have an extremely high reproductive potential (Courtenay and Stauffer 1984). One method to help control tilapia would be to host an annual "Tilapia Round-up". This type of event could also serve to educate people about negative impacts of non-native species. Bag seines or gill nets could be used to block-off an area with an abundance of tilapia, such as the channel between Pecan Island and the golf course or the Blieder's Creek area, and the tilapia could be herded into the nets. Such events should be carefully planned and supervised to minimize impact to other aquatic life. Such precautions include limiting the number of people in the water at any given time and specifying how the fish are captured to avoid harming aquatic vegetation. Local food banks may be willing to take the removed tilapia. If done in the area near the golf course, additional safety considerations may be necessary and the event should be coordinated with golf course personnel.

2) Giant Ramshorn Snail - As spring flows decrease, current velocity in many areas of the Comal ecosystem will also decrease. This will likely make more areas accessible to the giant ramshorn snail and increase their populations in the river, especially in Landa Lake. Arsuffi et al. (1993) discuss three possible ways to control or eliminate the snail from Landa Lake: 1) introducing a predator; 2) using a **molluscicide**; and 3) manual harvest. They concluded that introducing a predator is unacceptable because the impacts on the ecosystem cannot be predicted, and using a molluscicide is unacceptable because it could eliminate native snail species. The manual harvest method may not eliminate the giant ramshorn snail, but it may control populations without seriously impacting the ecosystem. A seasonal harvest of the snails may keep populations under control and avoid a significant increase in their numbers as water levels drop. The best time of year to harvest the snails is probably from March through July. The snail population is composed primarily of adults at this time, and it is a peak reproductive period (Badough 1992). Studies to determine the most effective harvesting method should be undertaken. The numbers of the snails have declined since the flood of 1998 *update*.

3) <u>Elephant Ear</u> - Small stands of elephant ear along the river banks could be safely controlled with certain herbicides by wicking when there is no chance of rain in the forecast. Wicking allows the application of the herbicide to specific plants and thus helps reduce the risk of exposing the herbicide to desirable plants. Wicking also reduces the risk of the herbicide entering the river. The herbicide that the Parks and Recreation Department previously used (Rodeo®) is acceptable if wicked on carefully. It may take repeated application s to kill elephant ear plants because of their large colms. Because the roots of the elephant ear hold soil in place and prevent erosion of soil into the river, removing stands of elephant ear from the bank of the river could necessitate the re-establishment of native plants. After an elephant ear stand has died, native plants should be planted. Once a stand of elephant ears has died and their above ground stalks have been removed, the remaining colms will stabilize the bank until the native plants can take hold. A list of native plant species, some of which would be suitable for planting in the place of elephant ear, is provided in Table 7. Plants for reestablishment should come from a source free of undesirable species.

4) <u>Hydrilla</u> - Hydrilla has been found in the new channel of the Comal River below the hydroelectric plant (Linam et al. 1993). It could be eliminated from the river more easily at this point than if allowed to spread. Manual harvesting is the recommended method of removal. Depending on the depth of the river, snorkelers or scuba divers could gather the plants into mesh bags, being careful not to allow fragments of the plant, which can re-root, to float downstream. The use of herbicides to control plant populations is not advisable in this situation. Herbicides are often broad spectrum and could affect native plant populations. Also, in deep, flowing water they are ineffective.

5) <u>Nutria</u> - Nutria destabilize stream banks through digging and consumption of vegetation. If the Parks and Recreation Department decide nutria populations need to be controlled, the current practice, which does not involve the wide-spread introduction of harmful chemicals to the lake or the destruction of habitat, is acceptable.

6) <u>Domesticated waterfowl</u> - Domesticated waterfowl concentrated in an area can cause numerous problems, including bank destabilization from uprooting vegetation and

increased nutrient input into waterways. There have been as many as 200 or more waterfowl seen in Landa Park at any one given time (Nathan Allan and Patrick Connor, USFWS, personal communication, 2000). While migratory waterfowl are a natural part of the Comal ecosystem and not a problem, the non-migratory, domesticated waterfowl are problematic. These domesticated waterfowl could be controlled through live trapping and relocation or by lethal means.

7) Monitor for “watch list” of species to control if they show up.

8) Educate public about not dumping bait buckets or aquaria.

9) Work with TPWD to control use of live fish for bait in Landa Lake?*

J. RECREATIONAL ACTIVITIES

Objective: Provide safe and fun recreational activities on the Comal River for the public.

Current practice: The use of motorized boats for recreational purposes is not allowed on the Comal River (including Landa Lake). Motorized boats are only used for search and rescue emergency operations. Paddle boating, glass-bottom boat tours, and fishing are the only recreational activities that occur in the public section of Landa Lake. Swimming is allowed in the spring-fed pool and children's wading pool in Landa Lake. Public swimming, canoeing, snorkeling, scuba diving, fishing, and tubing occur from the reservoir dam downstream to the Union Street takeout (see Section I.B. - Public Recreation).

Problems and concerns:

Habitat alteration can occur from some recreational activities through either direct or indirect impacts. Examples of direct impacts are stream bottom disturbance and aquatic vegetation removal. Indirect impacts are things such as the introduction of non-native bait fish through fishing, or streamside influences such as increased compaction, erosion, litter, pollution and runoff from parking areas and support facilities.

The areas of the river most susceptible to impacts from recreational use are shallow spots with abundant vegetation. Vegetation provides good fountain darter habitat and shallow areas are convenient places for people to stand, walk, and enter or exit the river. Generally, the deeper areas of the river are less likely to be directly impacted by human activities. Swimming, snorkeling, scuba diving, and tubing are the types of recreation most likely to have impacts in shallow areas. Swimming, snorkeling, and scuba diving are usually done in Prince Solms Park and Hinman Island Park *check to see if in figure* and thus are confined to a smaller area than tubing. At the current level of activity and normal to high flows, additional damage is not likely to occur to areas already impacted. However, at below normal flows the impacts of recreation could be greater.

<u>Recommendations</u>:

Recommendations for some of the concerns identified above are covered in other parts of Section II. For bait fish recommendations see Section II.M. - Human Activity in Spring Runs, for recommendations on bank compaction and erosion see Section II.N. - Bank Stabilization, and for recommendations on litter, pollution, and runoff see Section II.K. - Stormwater Runoff.

1) Not allowing motorized boats on the river is good for public safety, and also eliminates the many negative impacts of motorized boats on aquatic life. We recommend this ban be continued. We also recommend the continuance of current policies on recreational activities in public sections of Landa Lake, which have no more than minimal habitat disturbance.

2) Fountain darters have been collected throughout the river. To reduce the potential for impacts from the existing activities, signs could be set up requesting that people avoid the edges and that tubers not get out of their tubes until they are ready to exit the river.

3) As flows decrease, the amount of shallow area in the river will increase, making more area susceptible to impact from recreational activities. It would be helpful to develop a plan that looks at recreational use and its potential impacts as flows decrease. The plan could establish a flow level at which signs would be set up along the river asking guests to avoid specific areas. While this does not restrict recreationists from the river, it may help reduce their impact on fountain darter habitat during times of reduced flow.

4) We also recommend coordination with resource agencies (such as the Service and TPWD) if plans are made to increase or expand recreational activities. The planning of new or expanded activities should include an analysis of their impacts on fountain darter habitat during times of low flow (a "worst case scenario"). The plans could identify a critical level of flow at which steps are taken to minimize impacts.

K. STORM WATER RUNOFF

<u>Objective</u>: Prevent or reduce degradation of Comal River water quality from pollutants and sediment in storm water runoff.

<u>Current practice</u>: Runoff can enter the Comal River through point and non-point sources. Point source discharges are from storm water culverts located at various places in the river. These culverts drain runoff from large areas into specific locations in the river. Non-point sources include runoff from construction sites, roads, parking lots, and other facilities built along the river. The City does have regulations dealing with runoff from construction sites and runoff from materials stored in the floodplain.

<u>Problems and concerns</u>:

Most of the Comal River's banks have been developed. Parks, roads, parking lots, buildings, recreational facilities, and other structures are located along the river. Runoff from these urban areas may contain many types and forms of pollutants. It may include pesticides and herbicides, fertilizers, litter, hydrocarbon and inorganic/metal compounds from vehicles and machinery, and household solvents and paints (Urban Drainage and Flood Control District 1992). Runoff from the developed areas along the Comal River could contain some of these pollutants. **Sediment** runoff is most often associated with construction activities.

Pollutants and sediment do become diluted and dispersed to some extent when they enter the Comal River. During normal and high spring flows this may be enough to minimize the impacts associated with the current level of activity. However, if the level of pollution and **sedimentation** increases or the level of spring flow and current velocities decrease, the dilution effect of the river will be reduced. Negative impacts to the river will then be more likely or more severe.

<u>Recommendations</u>:

There is currently no data to suggest that the current level of runoff is causing significant degradation of habitats in the Comal River, however, this issue has not been evaluated *check*. However, in the event of a reduction of spring flow this could change. The discussion that follows will therefore concentrate on preventative measures and not address specific current practices.

Prevention is often a more cost effective management practice than cleanup. The Urban Drainage and Flood Control District (1992) manual and the City of Austin Public Works Department (1982) manual outline many preventative measures for controlling stormwater runoff. A few of these measures are discussed below.

1) Methods for preventing pollutants from reaching the river include: (a) establishing a year-round hazardous disposal site(s) for household wastes; (b) installing trash racks in the storm drains (see Appendix E for more information); and (c) minimizing directly connected impervious areas (DCIA). An example of DCIA is storm water flowing from a roof to a parking lot to the street. This concentrates runoff quickly. Instead storm water should be directed over landscaped areas or grass buffer strips. This reduces the rate and volume of storm water runoff entering the river, encourages filtering and infiltration of storm water, and improves water quality. For specific guidance on minimizing DCIA, reference the Urban Drainage and Flood Control District's (1992) manual.

2) There are numerous structural methods that can be used to prevent or reduce sedimentation. For details on these techniques, refer to the Urban Drainage and Flood Control District (1992) manual and the City of Austin Public Works Department (1982) manual. The EPA and the Corps of Engineers can also be contacted for further management practices (see Appendix F).

3) Public education of runoff reduction techniques can be accomplished in a number of ways. Education is an effective tool for increasing the public's willingness to use these techniques. One possible educational forum is a "Clean River Festival". A festival can be a fun way of providing information to the public. In Austin, the LCRA has an annual festival for this purpose that includes free music, informational booths, food booths, water quality testing demonstrations, riverboat rides, and a children's stage. Several agencies, such as LCRA, TCEQ, GBRA, TPWD, and EUWD, have public outreach and educational programs designed to support this type of activity. The City could also contact the Water Oriented Recreation District (WORD) and Friends for Rivers (see Appendix C) who have a large volunteer base for river cleanup activities. Local businesses and large corporations in the area could be contacted for financial support. Plant nurseries could set up booths with organic gardening and xeriscape information. The festival would be most beneficial for local residents, so holding it during the non-tourist season may be optimal. It could possibly be held in conjunction with an established festival, such as Wurstfest.

Another educational tool could be integrated into the interpretive trail in Landa Park. The City could put a kiosk on the trail that details how pollutants end up in the river, what the impacts are, and how to reduce the input. However, keeping visuals to a minimum is important to maintain a more natural-appearing environment.

L. TRASH FEST AND LANDA LAKE CLEANUP

Objective: Remove litter that has accumulated in Landa Lake and downstream to the confluence with the Guadalupe River to maintain a clean, attractive environment.

Current practice: The Parks and Recreation Department periodically removes trash from Landa Lake. Parks personnel patrol the lake by boat and snorkel to recover litter. This practice takes place once or twice a week during the summer season (May to September) and less often during the off-season.

An annual cleanup (TrashFest) is held during the fall, usually the first Saturday in October. SCUBA divers, sponsored by the Houston Gulf Coast Council of Divers, pick up trash from the river bottom. They cover the Comal River from the hydroelectric plant downstream to the Guadalupe River, excluding the old channel. Their coverage area includes both public and private areas of the river. About 20 to 60 divers usually participate.

Problems and concerns:

1) Excessive disturbances (like sediment disturbance or plant damage) during trash removal in some parts of Landa Lake may have negative impacts on fountain darter habitat.

2) The high number of SCUBA divers and snorkelers in the river simultaneously during Trash Fest could cause habitat impacts. If the SCUBA divers are unaware of habitat concerns, beds of aquatic plants might be torn apart and bottom sediments stirred up. However, many of the SCUBA divers are experienced and are involved in the Trash Fest every year.

Recommendations:

1) Landa Lake, on average, contains only a minimal amount of litter and its removal using the current procedures probably has no impact on fountain darter habitat. It is important to keep the number of people involved to a minimum and inform them of potential impacts to fountain darter habitat.

2) The Trash Fest, as currently conducted, is a beneficial activity for the ecosystem, and as an annual event it probably does not result in substantial impact to fountain darter

habitat. However, large scale cleanup activities should be monitored, and SCUBA divers asked to help avoid habitat destruction.

M. HUMAN ACTIVITY IN SPRING RUNS

Objective: Encourage enjoyment by visitors to Landa Park and discourage activities that impact spring run habitat.

Current practice: Park rules prohibit people from entering the spring runs, with the exception of the wading pool. However, park visitors have been frequently observed wading in the restricted areas of the spring runs. In the past, occasional observations (*by whom*)have been made of some park visitors building dams to create small ponds, collecting plants, collecting bait fish with cast nets, shampooing their hair, brushing their teeth, and depositing bodily waste in the spring runs. These activities are against park policy and violators can be fined.

Problems and concerns:

The spring runs not only contain fountain darter habitat, but are the most common location in the Comal ecosystem for the Comal Springs salamander (*update*), and the only location in the Comal ecosystem for the Comal Springs riffle beetle and aquifer-dwelling invertebrates (see Section I.B. - Target Organisms). The vegetation in these shallow areas can be easily disturbed by human activities such as wading and swimming. Vegetation is an important habitat component for many of the aquatic animals. The practice of casting a net to capture baitfish is also a problem because of the potential for catching fountain darters.

Recommendations:

1) The Parks and Recreation Department is not able to maintain a continuous presence in the spring run area, so they could organize volunteer groups to monitor the spring runs. The Parks and Recreation Department could also encourage park rangers to consistently enforce the regulations when they are in the spring run area and use fines for repeat violators. If these methods are not effective, then adding barriers, such as a

simple bar across the upstream side of the wading pool and a railing along the side of the spring runs, may help to remind visitors of the boundaries of the wading area. Railings along the spring runs could be designed so as to not detract from the natural setting. For instance, two-rail cedar or rough hewn lumber fence might appear very attractive and still allow for easy observation of the spring runs by visitors. It may also help if signs that delineate restricted areas are printed in both English and Spanish.

2) While enforcement is necessary and should continue, park rangers cannot always be on the scene when a violation occurs. Education, therefore, plays an important role. The uniqueness of the spring runs and the impacts of activities previously discussed could be explained through the use of educational tools such as kiosks or interpretive activities using volunteers.

3) The preferred alternative to eliminate the capture of bait from the spring runs is banning the use of live fish for fishing in Landa Lake. This would also eliminate the risk of introducing non-natives to the ecosystem through bait release. An alternative could be an on-site bait shop selling crickets and worms. The boat dock might be a good location for a bait stand.

N. BANK STABILIZATION

<u>Objective</u>: Provide bank stability to slow down the erosional processes by maintaining existing retaining walls, while maximizing opportunities to protect and restore natural near shore habitats.

<u>Current practice</u>: Banks can be destabilized through the process of erosion. Stacked concrete bags or rocks, and vertical retaining walls are methods often used in the Comal River to slow down the erosion process where bank stabilization has become a problem. Some areas along the river have enough riparian vegetation to prevent excessive erosion.

<u>Problems and concerns</u>:

There are numerous techniques available for stabilizing stream banks. These techniques vary in their effectiveness and in the amount of impact they have on the bank and adjacent shallow water habitat. Retaining walls, for instance, cause the loss of shallow water and riparian habitat bank. They also have a less "natural" appearance than banks stabilized by some other methods. The method chosen for a bank stabilization project should be one that will minimize habitat impacts and loss while still resulting in a stable bank. The usage of a section of stream bank should be considered in selecting a stabilization technique. Areas with high public access may require a different method than areas of low public access.

<u>Recommendations</u>:

The following discussion is intended to highlight some of the various methods available for bank stabilization. The method chosen for a specific project will depend on factors such as land usage, habitat type present, and stream characteristics (for instance, stream flow).

1) Banks that need erosion control measures are often those that are subjected to high human activity (for example, in Prince Solms Park). Bank impacts can be reduced by providing access to the river, such as stairways, and vegetating the banks between access points in a way that encourages people to use only the designated entrance. Banks that are steeper than a 2:1 ratio (that is, bank height is twice the slope) are also highly susceptible to erosion (City of Austin Public Works Dept. 1982). Even banks with a 1:1 ratio can become an erosion problem. The Austin Public Works Department recommends that the City of Austin stabilize critical areas with native trees, shrubs and grasses. Table 7 lists plants native to the Comal area that could be used for erosion control.

2) Riparian vegetation plays an extremely important role in controlling erosion and stabilizing banks and is the preferred method of bank stabilization. Roots bind particles together and the underbrush reduces raindrop impact forces on the soil. Riparian vegetation increases infiltration and reduces runoff velocity. Vegetation also reduces wind velocity at the ground surface and provides a rougher surface, which traps

particles moving along the ground (Urban Drainage and Flood Control District 1992). Below the waterline, the root system helps to hold the soil together and exposed stalks and stems slow the stream flow which reduces erosion and does not remove shallow water habitat. Riparian vegetation is relatively easy to establish and maintain, appears more natural than many other bank stabilization structures, and is the only bank protection method that can repair itself after some types of damage. See Appendix C for sources of information on using plants for bank stabilization and erosion control.

3) Criblock could also be used to stabilize banks. These are cellular blocks that are cast with openings to provide for drainage and to allow vegetation to grow through the blocks thus permitting the root structure to strengthen the bank (U.S. Army Engineers Waterways Experiment Station 1983). This method, in contrast to a vertical concrete wall, provides some surface for habitat.

4) The current method of overlapping concrete bags is also better than vertical walls, because it can provide shallow habitat. However, unlike criblock, soil does not fill in and it is more difficult for plants to establish themselves on concrete bags.

5) Another technique to stabilize banks that is especially useful until vegetation becomes established, is using large tree trunks and boulders placed at the water's edge (Briggs et. al. 1994). This also improves fish habitat by providing cover for fish as well as a habitat for their prey. However, erosion can continue to occur underneath and between the trunks and boulders. Little pools can also form, which provide good habitat for pests such as mosquitos.

O. BASKING HABITAT FOR TURTLES

Objective: Preserve turtle **basking** habitat in the Comal River, while considering public safety.

Current practice: Turtle basking habitat often includes trees and branches that have fallen into the river. These are removed by the Parks and Recreation Department if deemed unsafe for the public or at the request of local citizens.

Problems and concerns:

Turtle populations have been decreasing at an alarming rate in North America (Ernst et al. 1994). Two major factors causing their rapid decline are habitat destruction and over-collection for pet trade (Ernst et al. 1994).

Recommendations:

1) Habitat for aquatic turtles is generally characterized by slow to moderate current, soft bottoms, and easy access to basking areas. Wide areas of water that receive at least some daylight are typical (Ernst et al. 1994). Flavius Killebrew (West Texas State Univ., personal communication, 1995) suggested that the most significant activity the City could do for some turtle species in the Comal ecosystem is provide basking areas by

(1) not mowing or clearing bank riparian zones and

(2) letting trees fall into the water, except where public safety is compromised. Another advantage of allowing fallen logs to remain in the water is they serve as good habitat for fish and aquatic invertebrates.

2) Certain areas could be set aside for turtle habitat and possibly used as part of the nature walk in Landa Park and tourist attractions (turtle viewing areas) in parts of the river where safety is not a concern. Creating and maintaining habitat in the heavy-traffic areas like Prince Solms Park above and below the tube chute might not be successful because of interference from the public and safety concerns. However, many portions of the old channel and Landa Lake are good sites.

3) Pathway signs could provide species identification and life history information for turtles that are found in each area.

P. RIPARIAN VEGETATION

Objective: Maintenance or restoration of native vegetation as a way of repairing and maintaining riparian wildlife habitat, preventing bank erosion, and maintaining a pleasant aesthetic quality for humans.

Current practice: No specific preservation or restoration plans are in place for riparian zones.

Problems and concerns:

1) Maintaining riparian vegetation - Riparian communities have many values, including reducing downstream flooding by slowing down and reducing runoff from storm events; recharging aquifers; as a source of nutrition for stream residents; reducing erosion; storing sediments, heavy metals, and toxins which may otherwise reach the river and adversely affect water quality; recreation; and aesthetics (Malanson 1993). Woody-deciduous riparian zones are also important in supporting wildlife diversity, especially migratory songbirds (Maser et al. 1984).

Riparian zones in the U.S. have been greatly altered in the last 200 years. The dominant factor has been hydrologic alteration (such as reservoirs), but timber clearing, overgrazing by livestock, agricultural conversion, and urban growth are other important causes of change in riparian habitat (Malanson 1993). The Comal River has experienced severe alterations in its riparian zones primarily due to urban growth. Only a thin border (if any) of riparian vegetation remains along the banks of the Comal River.

2) Safety - A specific city management concern in public areas is the use of wooded areas along the bank for hiding stolen goods.

Recommendations:

1) Maintaining vegetation - Based on the benefits provided by maintaining a riparian zone, we recommend that the City

(1) maintain existing riparian communities, and

(2) restore impacted riparian areas where possible. Briggs (1994) discusses several restoration projects and provides clear directions for beginning such a project. Native plants should be used in these projects. Table 7 lists many plants native to this area.

2) We recommend that riparian areas being used to hide stolen items not be totally cleared, but rather just clear the underbrush so it is more difficult to hide stolen items. Care should be taken to not clear the next generation of trees, as they are essential for the continuance of the riparian zone.

Q. GAME FISH ENHANCEMENT

Objective: To enhance fishing in the Comal River.

Current practice: The New Braunfels Parks and Recreation Department currently does not stock game fish in the Comal River.

Problems/concerns:
Stocked fish (both native and non-native) can reduce fish populations already in the river through crowding, competition, predation, and habitat modification or destruction (see Section I.C.3. - Problematic Organisms). Many of the desirable game fish, such as largemouth bass, are predators on smaller fish, such as fountain darters. Also, there is the possibility of introducing fish diseases and parasites to the river when introducing native or non-native fish.

Recommendations: The current status of game fish populations in the Comal River, including Landa Lake, is not known. It is possible that the population levels are at or near optimum for this system based on the food and habitat available. Stocking should be considered only when the target species have been identified, their current populations have been assessed, and the impact of adding more individuals to the system has been estimated.

1) We recommend that a fish community study be done on the Comal River, including Landa Lake. This study should determine the present population levels of desirable game fish and tilapia, as well as the amount of resources available to them. The Service should be allowed to review and comment on the study design early, and throughout, the development process. Some important resources to identify are spawning habitat, nursery areas, prey availability, and competition with other species. The role of game fish as predators of fountain darters should also be determined. This data should be used to answer some basic questions considering the feasibility of stocking additional fishes: (a) Are there enough resources available to support more fishes than presently occur here; (b) Will the introduction of additional fishes negatively impact fountain darters; and (c) Can higher populations of game fishes be attained using a management practice, other than stocking, that does not negatively impact fountain darters (for instance, removing tilapia and giant ramshorn snails might increase the habitat available for game fishes and fountain darters). Negative impacts to fountain darters can be direct, such as predation, and indirect, such as loss of habitat or competition for food with young game fishes. Possibly, such a study could be done in cooperation with a university as part of a graduate degree project.

2) If, after completing a study as described above, it is determined that fish stocking is feasible, only native fish species should be considered. The approach should be one that develops the native fish populations for fishing and not one that introduces non-native species or subspecies or fish with parasites or diseases. Possible acceptable activities should be discussed with the Service after an accurate assessment has been completed.

Table 1. Monthly statistics of historical daily spring flow at Comal Springs for 1929-1992 (USGS records **NEED DATE**). The readings are independent of storm events.

Month	Minimum (cfs)	Maximum (cfs)	Mean (cfs)
January	34	478	269.9
February	39	514	300.0
March	55	500	298.2
April	32	506	294.1
May	19	506	294.4
June	0	503	288.0
July	0	495	271.3
August	0	476	257.5
September	0	468	262.8
October	0	534	272.3
November	0	462	282.2
December	18	483	291.2
TOTAL	0	534	284.0

[WILL BE UPDATED FOR 1929-2000 FIGURES - WAITING FOR PAT]

Table 2. Water quality readings for the Comal River at Hinman Island from November 1994 to May 1995 (GBRA 1995 records).

Parameter	11/94	12/94	1/95	2/95	3/95	4/95	5/95
Fecal coliform (org/100ml)	108	64	88	44	78	6	23.3
Suspended solids (mg/l)	1.6	3.6	4.3	4	1.2	2	10.2
Turbidity	0.9	1.6	2.3	2.5	1.5	1.2	7
pH	7.4	7.5	7.4	7.5	7.8	7.6	7.5
Temperature (°C)	22	22	21	21.6	22.8	23	23.2
Dissolved Oxygen (mg/l)	9.42	8.8	8.7	9.6	8.9	9.1	9.7
Conductivity (umhos/cm)	560	558	563	631	560	590	520
Total Phosphorus (mg/l)	.04	.04	.09	.03	.08	.08	.09
Nitrate (mg/l as N)	1.5	1.1	1.7	2.7	1.8	1.5	1.9

[WILL BE UPDATED WITH BETTER DATA - WAITING FOR PAT]

Table 3. Fishes collected from the Comal River (Hubbs et al. 1991, Whiteside 1974-1990)

FAMILY	COMMON NAME	SCIENTIFIC NAME
MINNOWS - CYPRINIDAE	central stoneroller	*Campostoma anomalum*
	gold fish*	*Carassius auratus*
	red shiner	*Cyprinella (=Notropis) lutrenis*
	blacktail shiner	*Cyprinella (=Notropis) venusta*
	common carp*	*Cyprinus carpio*
	roundnose minnow	*Dionda episcopa*
	golden shiner*	*Notemigonus crysoleucas*
	Texas shiner	*Notropis amabilis*
	pallid shine*	*Notropis (=Hybopsis) amnis*
	fathead minnow*	*Pimephales promelas*
	bullhead minnow*	*Pimephales vigilax*
SUCKERS - CATOSTOMIDAE	gray redhorse	*Moxostoma congestum*
CHARACINS - CHARACIDAE	mexican tetra*	*Astyanax mexicanus*
BULLHEAD CATFISHES - ICTALUIDAE	black bullhead	*Ameiurus (=Ictalurus) melas*
	yellow bullhead*	*Ameiurus (=Ictalurus) natalis*
	channel catfish	*Ictalurus punctatus*
	tadpole madtom	*Noturus gyrinus*
	flathead catfish	*Pylodictis olivaris*
SUCKERMOUTH CATFISHES -LORICARIIDAE	suckermouth catfish*	*Hypostomus spp.*
KILLIFISHES - CYPRINODONTIDAE	blackstripe topminnow	*Fundulus notatus*
LIVEBEARERS - POECILIIDAE	largespring gambusia	*Gambusia geiseri*
	amazon molly*	*Poecilia formosa*
	sailfin molly*	*Poecilia latipinna*
SUNFISHES - CENTRARCHIDAE	rock bass*	*Ambloplites rupestris*
	redbreast sunfish*	*Lepomis auritis*
	green sunfish*	*Lepomis cyanellus*

	warmouth*	*Lepomis gulosus*
	bluegill	*Lepomis macrochirus*

Table 3 continued.

	longear sunfish*	*Lepomis megalotis*
	redear sunfish	*Lepomis microlophus*
	spotted sunfish*	*Lepomis punctatus*
	smallmouth bass*	*Micropterus dolomieui*
	largemouth bass	*Micropterus salmoides*
	guadalupe bass	*Micropterus treculi*
	white crappie	*Pomoxis annularis*
PERCHES - PERCIDAE	fountain darter	*Etheostoma fonticola*
	greenthroat darter	*Etheostoma lepidum*
	orangethroat darter	*Etheostoma spectabile*
	texas logperch	*Percina carbonaria (caprodes)*
	dusky darter	*Percina sciera*
	river darter	*Percina shumardi*
CICHLIDS - CICHLIDAE	Rio Grande perch*	*Cichlasoma cyanoguttatum*
	blue tilapia*	*Oreochromis aurea*
	Mozambique tilapia*	*Oreochromis) mossambica*

* species not considered native to the Comal River

Table 4. Amphibians and reptiles observed/documented or potentially found in the Comal ecosystem (Dixon 1987; Andy Price, TPWD, personal communication, 1995).

FAMILY	COMMON NAME	SCIENTIFIC NAME
TREEFROGS - HYLIDAE	Blanchard's cricket frog	*Acris crepitans blanchardi*
	Gray treefrog	*Hyla versicolor*
	Green treefrog	*Hyla cinerea*
	Strecker's chorus frog	*Pseudacris streckeri*
TRUE FROGS - RANIDAE		
	Rio Grande leopard frog	*Rana berlandieri*
	bullfrog*	*Rana pipiens*
WATER TURTLES AND BOX TURTLES - EMYDIDAE		
	Texas river cooter*	*Pseudemys texana*
	Red-eared slider*	*Trachemys scripta elegans*
MUD AND MUSK TURTLES - KINOSTERNIDAE		
	Yellow mud turtle	*Kinosternon flavescens flavescens*
	Mississippi mud turtle	*Kinosternon subrubrum hippocrepis*
SOFTSHELL TURTLES - RANIDAE		
	Guadalupe spiny softshell*	*Trionys spiniferus guadalupensis* (also observed by Roemer in 1847)
AQUATIC SNAKES - COLUBRIDAE		
	Blotched watersnake*	*Nerodia erythrogaster transversa*
	Diamondback watersnake*	*Nerodia rhombifera rhombifera*
MOCCASINS - VIPERIDAE		
	Western cottonmouth	*Agkistrodon piscivorus leucostoma* (also observed by Roemer in 1847)

* Species documented in the Comal ecosystem

Table 5. Invertebrates sampled from the Comal ecosystem (Espey, Huston & Assoc. 1975, Bosse 1988, Barr 1992-1994).

LOCATION	ORDER	SPECIES (years collected)	
1	Decapoda	*Palaemonetes sp.* (1975)	
	Macrobrachium carcinus		
mphipoda	*Hyallela azteca* (1991)		A
phemeroptera	*Centroptilium sp.* (1975)		E
		Tricorythodes sp. (1975, 1991)	
	Caenis sp. (1990)		
astropoda	*Amnicola comalensis* (1975)		G
		Heliosoma trivolvis (1975)	
		Marisa cornuarietis (1990)	
		Thiara granifera (1975)	
		Elimia comalensis (1990)	
		Cincinattia comalensis (1990)	
		Gyraulus parvus (1990)	
donata	*Nehalennia sp.*		O
		Argia sp. (1990)	
iptera	Chironomidae (1990)		D
2	Amphipoda	*Hyallela azteca* (1990, 1991)	
iptera	Chironomidae (1990, 1991)		D
phemeroptera	*Hexagenia sp.* (1990, 1991)		E
		Tricorythodes (1990, 1991)	
donata	*Argia sp.* (1991)		O
astropoda	*Marisa cornuarietis*(1990,1991)		G
		Thiara granifera (1990,1991)	
		Thiara tuberculata (1990,1991)	
		C. comalensis (1990,1991)	
		Gyraulus parvus (1990)	
		Elimia comalensis (1990,1991)	

Physa virgata (1990)
Heliosoma anceps (1990)

D
ecapoda *Palaemonetes sp.* (1990)
Macrobrachium carcinus

---

3 Amphipoda *Hyallela azteca*

Table 5 continued.

LOCATION	ORDER	SPECIES (years collected)

D
ecapoda *Procambarus sp.* (1975,1990-91)
Macrobrachium carcinus
Palaemonetes sp. (1975,90-91)

E
phemeroptera *Centroptilium sp.*
Tricorythodes sp.

---

3 Gastropoda *Amnicola comalensis*
Goniobasis comalensis
Thiara granifera (1975,90-91)
Marisa cornuarietis (1990-91)
Thiara tuberculata (1990-91)
Cincinattia comalensis (90-91)
Gyraulus parvus (1990-91)
Elimia comalensis (1990-91)
Physa virgata (1990-91)
Heliosoma anceps (1990-91)

O
donata *Argia sedula*

D
iptera Chironomidae (1990)
Oligochaeta (1990-91)

---

4 Diptera Oligochaeta (1990-91)
Hirudinea (1990)

G
astropoda *Marisa cornuarietis* (1990-91)
Thiara granifera (1990-91)
Thiara tuberculata (1990-91)
Elimia comalensis (1990-91)
Heliosoma anceps (1990-91)

		Cincinattia comalensis (90-91)	
		Gyraulus parvus (1990-91)	
5	Oligochaeta (1990-91)		
			D
iptera	Chironomidae (1990-91)		
			O
donata	*Argia sp.* (1990)		
			G
astropoda	*Marisa cornuarietis* (1990-91)	*Thiara granifera* (1990-91)	
		Thiara tuberculata (1990-91)	
		Cincinattia comalensis (90-91)	

Table 5.continued.

LOCATION	ORDER	SPECIES (years collected)	
		Gyraulus parvus (1990-91)	
		Elimia comalensis (1990-91)	
		Physa virgata (1990-91)	
		Heliosoma anceps (1990-91)	
			D
ecapoda	*Palaemonetes sp.* (1990-91)		
		Macrobrachium carcinus	
6	Amphipoda	*Hyallela azteca* (1975, 1990)	
		Stygobromus pecki (1992-94)	
		Stygobromus russelli (1992-94)	
		Mexiweckelia hardeni (1992-94)	
		Seborgia relicta (1992-94)	
7	Coleoptera	*Psephenus texanus* (1975,90,92-94)	
		Elmidae (1990, 92-94)	
		Microcylloepus pusillus (92-94)	
		Heterelmis comalensis (92-94)	
		Stygoparnus comalensis (92-94)	
		Phanocerus clavicornis (92-94)	
		Neoelmis sp. (1992-94)	
		Haideoporus texanus (92-94)	
		Bessinae (1992-94)	
		Hydroporus rufilabris (92-94)	
		Neoclypeodytes discretus (1992-94)	
			H
emiptera	*Rhagovelia sp.* (1992-94)		

		Gerridae (1992-94)	
		Hydrometridae (1992-94)	
			G
astropoda	*Thiara granifera*		
			M
egaloptera	*Sialis sp.*		
			O
donata	*Argia sedula*		
		Argia translata	
		Argia sp. (1990)	
		Brechmorrhoga mendax	
		Hetearicana sp.	
		Nehalennia sp.	
	Diptera	*Prosimulium sp.*	
		Chironomidae (1990)	
			E
phemeroptera	*Baetis sp.* (1975, 1990)		
		Centroptilium sp.	
		Psuedocleon sp.	

Table 5.continued.

LOCATION	ORDER	SPECIES (years collected)	
		Tricorythodes sp. (1975, 1990)	
			T
ricladida	triclad flatworms		
8	Ephemeroptera	*Tricorythodes sp.*	

* Locations:
1 = LL near confluence of Bleider's Creek
2 = LL just above Spring Island
3 = north side and below Spring Island
4 = LL between gazebo and bird island
5 = LL across from boat dock
6 = spring runs
7 = Comal River between LL and final reach (USFWS-not available)
8 = final reach before Guadalupe River

Table 6. Caddisflies (Trichoptera) sampled by Dr. David Bowles (TPWD) in 1993 & 1994 at five sites in the Comal springs and river.

FAMILY	SPECIES	Collection Sites*	Abundance
Glossosomatidae	*Protoptila alexanderi*	1,2,3,4,5	Common
Helicopsychidae	*Helicopsyche borealis*	1,2,3,4,5	Common
	H. piroa	1,2,3,4,5	Common
Hydrobiosidae	*Atopsyche erigia*	2,3,4	Common
Hydropsychidae	*Cheumatopsyche pettiti*	3,4	Uncommon
	Smicridea fasciatella	1,2,3,4,5	Common
Hydroptilidae	*Hydroptila ajax*	1,2,3,4,5	Common
	H. waubesiana	2,4,5	Uncommon
	Leucotrichia sarita	1,2,3,4,5	Common
	Neotrichia edalis	4	Rare
	Ochrotrichia nigritta	1,2,3,4,5	Common
	O. tarsalis	1,2,3,4,5	Common
	Oxyethira azteca	3,5	Rare
	O. pallida	2,3,4,5	Common
	O. ulmeri	2,3,4,5	Common
Family Leptoceridae	*Nectopsyche gracilis*	1,2,3,4,5	Common
	Oecetis inconspicua	2,3,4,5	Common
	O. persimilis	4	Uncommon
	Triaenodes ignitus	4	Uncommon
Family Philopotarridae		*Chimarrra feria*	1,2,3,4,5Common
	C. obscura	2,3,5	Uncommon
	C. texana	1,2,3,4,5	Common
Family Polycentropodidae			
	Cemotina astera	4	Uncommon
	C. calcea	3	Rare
	Nyctiophylax affinis	1,4	Uncommon
	Polyplectropus santiago	4	Rare

*Collection Sites

1. near head of spring run 3
2. at confluence of spring run 3 and Landa Lake
3. at new channel near park pavillion across from Parks and Recreation office
4. at spillway between Landa Lake and the golf course west of Golf Course Rd bridge
5. halfway between the head of spring run 1 and California Boulevard bridge

Table 7. Partial list of plants native to the Comal River area (Soil Conservation Service 1984, Cox and Leslie 1988, Hatch et al. 1990).

Type	Common name	Scientific name
ferns	Southern maidenhair	*Adiantum capillus-veneris*
grasses	bearded sprangle-top	*Leptochloa fascicularis*
	fall panic grass	*Panicum dichotomiflorum*
sedges	awned flatsedge	*Cyperus aristatus*
	creeping spikerush	*Eleocharis macrostachya*
	saltmarsh bulrush	*Scirpus maritimus*
	three-square bulrush	*Scirpus pungens*
herbs/shrubs	spiny water-starwort	*Callitriche verna*
	dotted smartweed	*Polygonum punctatum*
	Nuttall's poverty weed	*Monolepis nuttalliana*
	mexican summer cypress	*Kochia scoparia*
	seaside heliotrope	*Heliotropium curassavicum*
	buttonbush	*Cephalanthus occidentalis*
	beautyberry	*Callicarpa americana*
	snowberry	*Symphoricarpos orbiculatus*
trees	bald cypress	*Taxodium distichum*
	black willow	*Salix nigra*
	eastern cottonwood	*Populus deltoides*
	Texas oak	*Quercus buckleyi*
	Shumard oak	*Quercus shumardii*
	Bur oak	*Quercus macrocarpa*
	post oak	*Quercus stellata*
	live oak	*Quercus virginiana*
	American elm	*Ulmus americana*
	cedar elm	*Ulmus crassifolia*
	sugar hackberry	*Celtis laevigata*
	Lindheimer hackberry	*Celtis lindheimeri*
	osage-orange	*Maclura pomifera*
	red mulberry	*Morus rubra*
	American sycamore	*Platanus occidentalis*
	yaupon holly	*Ilex vomitoria*

possumhaw	*Ilex decidua*
Eastern redbud	*Cercis canadensis*
Texas redbud	*Cercis canadensis texensis*
Texas mountain laurel	*Sophora secundiflora*
Eve's necklace	*Sophora affinis*
huisache	*Acacia farnesiana*
pecan	*Carya illinoensis*

Table 7 continued

western soapberry	*Sapindus drummondii*
Mexican buckeye	*Ungnadia speciosa*
box elder	*Acer negundo*
red buckeye	*Aesculus pavia*
yellow buckeye	*Aesculus pavia flavescens*
Texas buckeye	*Aesculus arguta*
Texas ash	*Fraxinus texensis*
elderberry	*Sambucus canadenis*

Table 8. Surface Water Rights in the Comal River (TNRCC records, 1994).
C = consumptive; NC = nonconsumptive; NB = New Braunfels

TNRCC Permit No.	Ownership	Use	Amount (ac-ft/yr)
3823	City of NB	municipal (C)	1,289
3826	City of NB	irrigation (C)	100
3827	City of NB	recreation (NC)	N/A
3824(400)	NB Utilities	irrigation (C)	200
3824(401)	NB Utilities	industry (NC)*	139,198
3824(402)	NB Utilities	hydro (NC)	124,870
3824(403)	NB Utilities	municipal (C)	**2,240
3828	Bad Schloess Inc.	irrigation (C)	3
3818A	Bad Schloess Inc.	recreation (NC)	5,000

* 3,418 ac-ft of the 139,198 ac-ft authorized can be consumptively used annually.

** NBU transferred this amount of water from Comal River to Guadalupe River. NBU's diversion point is now on the Guadalupe River.

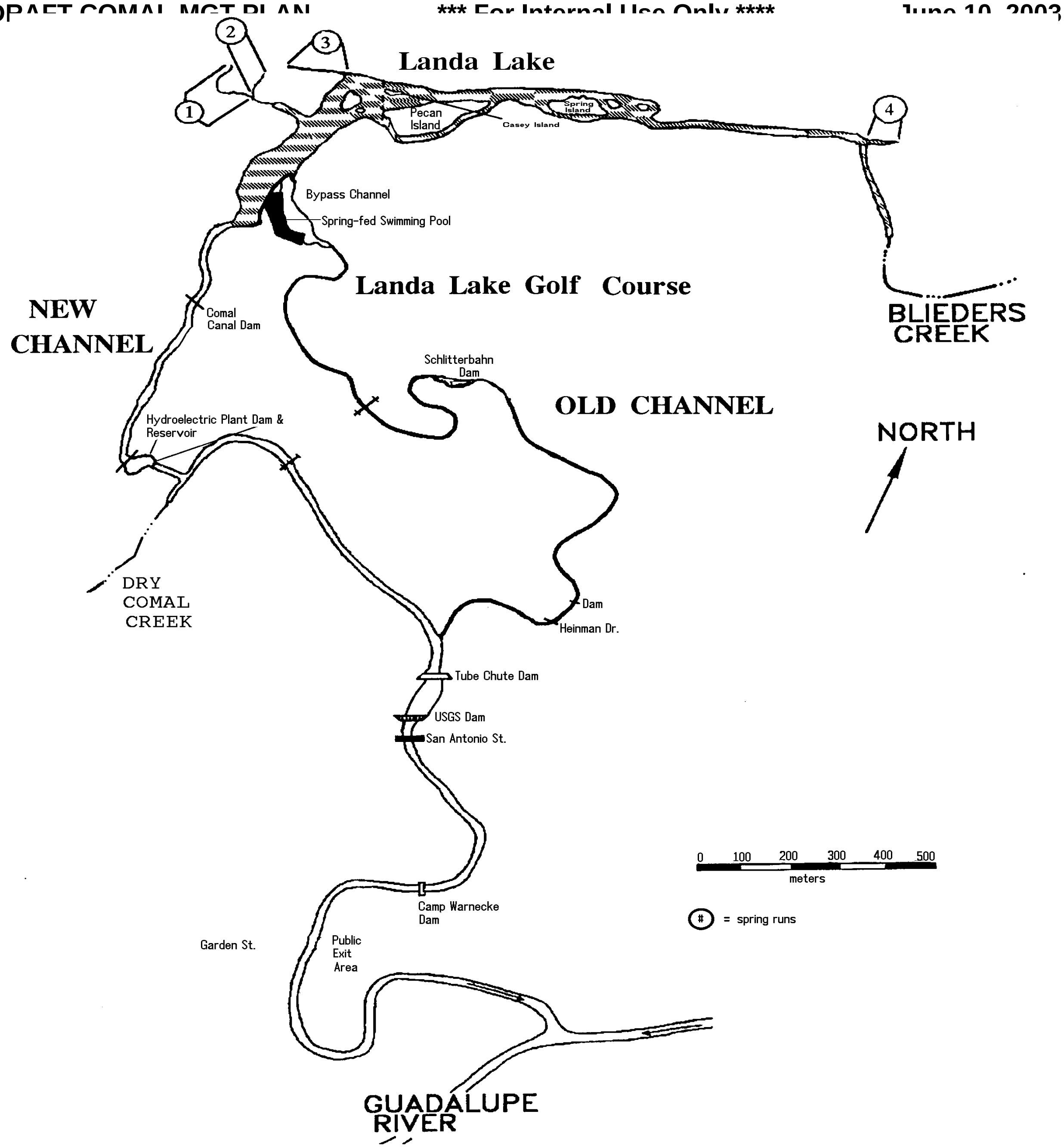


Figure 1. Comal Springs and River

Figure 1. Map of Comal Springs and River (USFWS 1996).

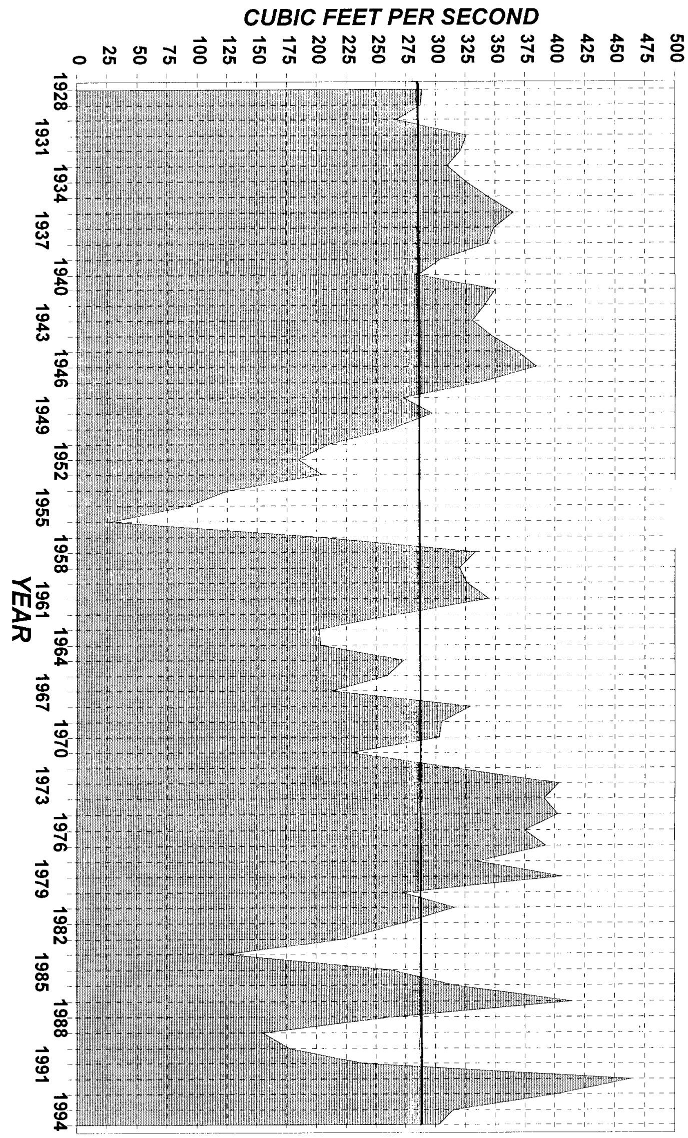
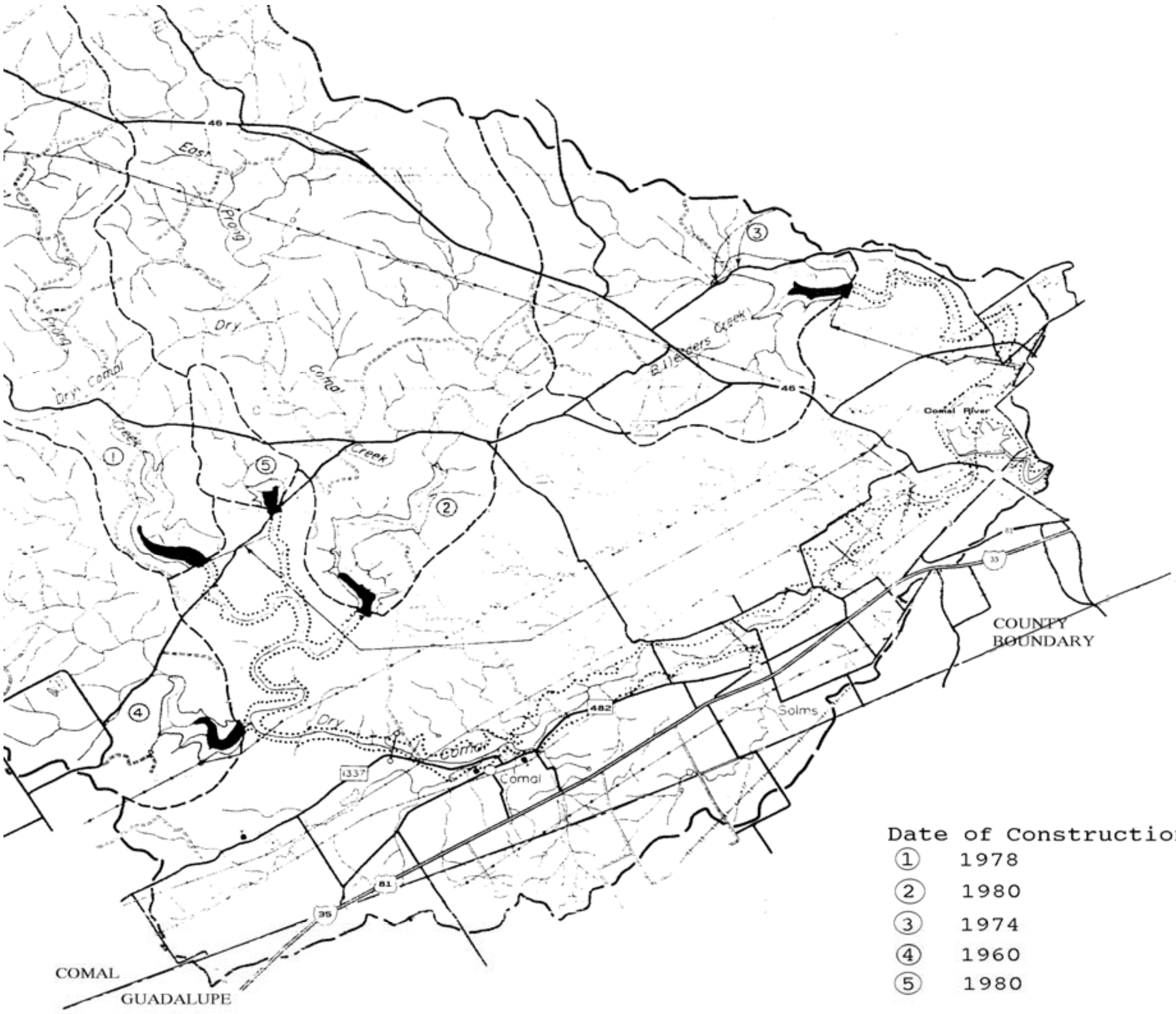


Figure 2. Comal River 1928 – 1995 Yearly Median Flow (cfs)

Figure 2. Annual median flows on the Comal River, 1928-1995.
[UPDATE W/MONTHLY FLOWS - WAITING FOR PAT]

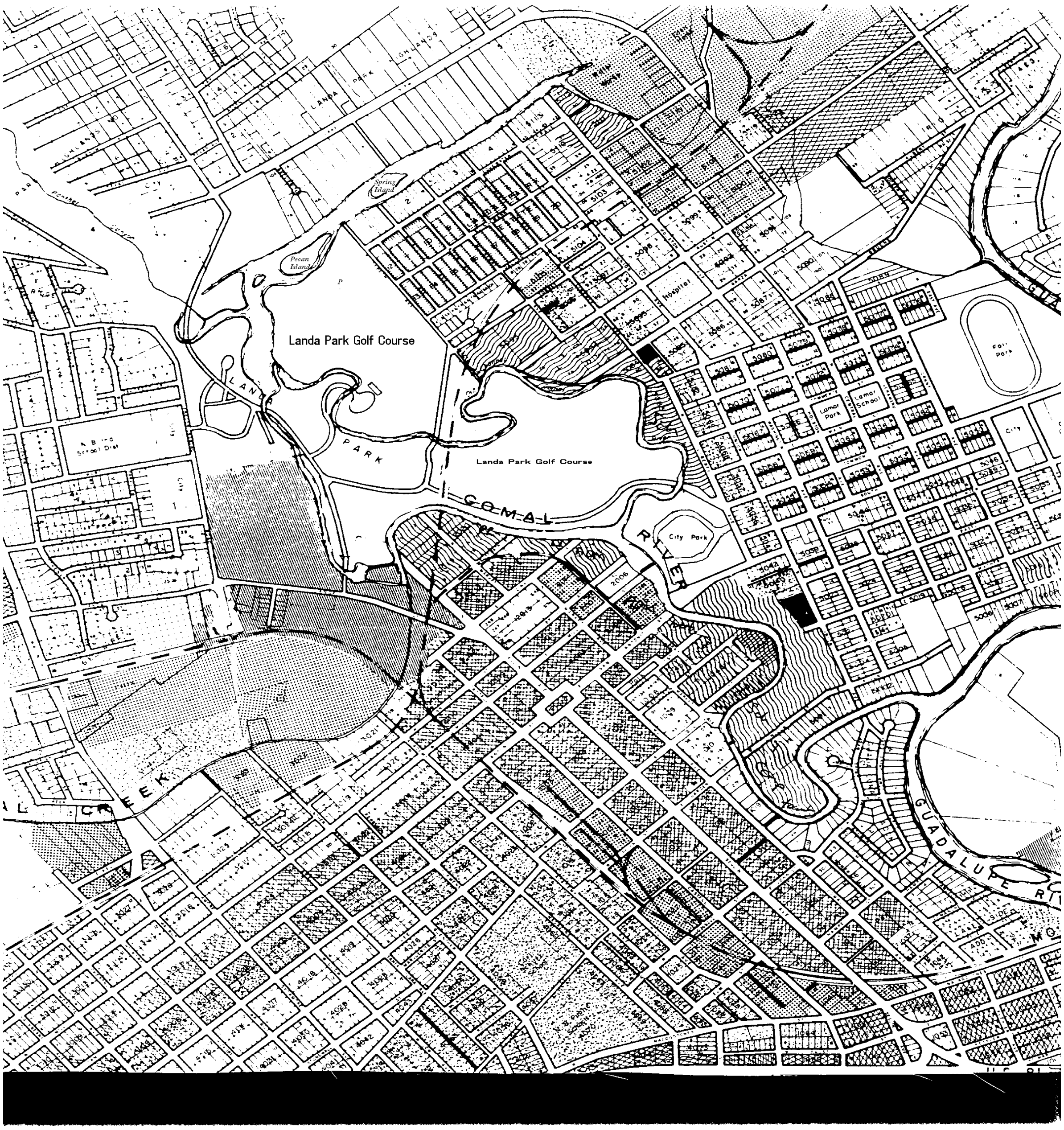
Figure 3. **[LOCATION OF SPRINGS & SEEPS - WAITING FOR PAT]**



COMAL AND GUADALUPE COUNTIES
USDA SCS TEMPLE, TEXAS

APPROXIMATE SCALE IN MILES

Figure 5. Flood control structures in the Comal River watershed.


Landa Park Golf Course
Landa Park Golf Course
Spring Island
Pecan Island
PARK
COMAL
RIVER
City Park
Hospital
Lamar Park
Lamar School
Fair Park
CREEK
GUADALUPE

80%

Figure 6. Land use in the Comal River Watershed, City of New Braunfels.

[GET UP DATE/CLEARER PICTURE OF LAND USE PATTERNS FROM CITY ENGINEER]

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Appendix A

ACRONYMS AND MONIKERS USED IN THE COMAL ECOSYSTEM MANAGEMENT PLAN

ADM	Archer Daniels Midland
cfs	cubic feet per second
City	City of New Braunfels
Comal Plan	Comal Springs Ecosystem Management Plan
DCIA	directly connected impervious areas
EPA	Environmental Protection Agency
ESA	Endangered Species Act
EUWD	Edwards Underground Water District
fps	feet per second
GBRA	Guadalupe-Blanco River Authority
IPM	integrated pest management
LCRA	Lower Colorado River Authority
NBS	National Biological Service
NBU	New Braunfels Utilities
NRCS	Natural Resources Conservation Service
Parks and Recreation Department	New Braunfels Parks and Recreation Department
ppm	parts per million (equal to milligrams per liter, mg/L)
Recovery Plan	San Marcos/Comal Springs and Associated Aquatic Ecosystems (Revised) Recovery Plan - 1996
Service	United States Fish and Wildlife Service
TCEQ	Texas Commission on Environmental Quality
TNRCC	Texas Natural Resource Conservation Commission
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
USDA	United State Department of Agriculture

USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WORD	Water Oriented Recreation District

Appendix B

GLOSSARY OF TERMS APPEARING IN BOLDFACE TYPE

allele - the two individual members of a gene pair

allozyme electrophoresis - a method of determining genetic differences between organisms

amphipods - a type of small crustacean

backwashing - a method of filter cleaning that uses a reverse flow of water

backwater effect - a reversal in streamflow direction and subsequent buildup of water that occurs as a result of a downstream barrier, such as a dam

basking - as related to turtles, the act of leaving the water to sun themselves

brackish - water that is saline, but less so than sea water

cavitation - the formation of partial vacuums in a liquid by a swiftly moving solid body (i.e. a propeller)

cubic feet / second (cfs) - a measurement of the rate of flowing water (1 cfs = 0.0283 cubic meters / second)

***Dionda episcopa* complex** - a group of closely related species of fish that occupy the Colorado and Guadalupe River basins

down drop - a section of land that drops below surrounding areas as a result of geological activity

emboli - accumulation of internal bubbles in the cardiovascular system

entrainment - being drawn in and transported by the flow of a fluid

estuary - a coastal body of water that has a connection with the open ocean, and where fresh water derived from land drainage is mixed with sea water

fairway - on a golf course, the mowed part of the course between a tee and a green

flow type - the physical characteristics of the flow in a body of water which can include riffles, pools, and runs

forebay - the enlarged part of the river adjacent to the hydroelectric plant intake

green - on a golf course, a smooth grassy area at the end of a fairway that contains the hole

habitat - the living place of an organism, or community, characterized by its physical and biological properties

intermittent stream - a stream that ceases to flow on the surface during dry periods

larvae - an early form of some animals that is unlike the parent; in insects, the first stage after leaving the egg, preceding the pupa

low volume spring -

macrophyte - as used in the text, non-algae plants

molluscicide - a chemical used for killing molluscs

non-native species - plants or animals that did not naturally occur in the Comal River

prawn - a freshwater decapod (having five sets of appendages) crustacean

ribosomal RNA - these are the strands of RNA that are assembled into ribosomes. They are extracted to supply genetic data on a particular organism or species.

riparian - the strict definition of riparian is "streambank". In a broader sense, the riparian zone is an area of transition from riverine to upland vegetation.

rough - on a golf course, the grounds bordering a fairway

runoff - that portion of the precipitation on a drainage area that is discharged from the area in stream channels

run-of-river hydroelectric plant - a hydroelectric plant whose power is dependent upon natural daily, weekly, or seasonal flow patterns and on upstream regulation. The river runs through the facility and over an associated dam

sediment - solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice, and has come to rest at a new location.

sedimentation - deposition of detached soil particles

spring run - a stream fed directly by a spring

substrate - sediments, rocks, etc. at the bottom of a body of water

tee - on a golf course, the area from which a golf ball is struck at the beginning of play on a hole

turbidity - a measure of water clarity. Turbid waters contain suspended particles and have low clarity

volatilize - to pass off in vapor.

Appendix C

Contacts for more information on selected topics in the Comal Springs Ecosystem Management Plan. The contacts are listed by section and topic.

Section B. Reopening the NBU Hydroelectric Plant

Supersaturation and its effects on fountain darters:

r. Tom Brandt U.S. Fish and Wildlife Service
San Marcos National Fish Hatchery and Technology Center
500 E. McCarty Ln.
San Marcos, TX 78666
(512) 353-0011
tom_brandt@fws.gov

Section D. Maintenance of Dams on the Comal River Below Landa Lake

Dam safety and inspection:

exas Commission on Environmental Quality (TCEQ) Dam Safety Unit
(512) 239-4763

Section E. Fishing Derby in Olympic and Spring-fed Pools

Availability of Texas Parks and Wildlife (TPWD) biologist to examine catfish:

A. E. Wood Fish Hatchery
507 Staples Road
San Marcos, TX 78666
(512) 353-0572

Section G. Landa Lake Golf Course Management Practices

L

ost Pines Golf Course (Bastrop, TX):

ike McCracken
Course Integrated Pest Management information
(512) 321-2327

Information on irrigation rates:

ettye Urban
Texas Commission on Environmental Quality (TCEQ)
(512) 239-6659

A

udubon Cooperative Sanctuary System:

udubon Society of New York State
46 Rarick Road
Selkirk, NY 12158
(518) 767-9051

Section K. Stormwater Runoff

Information on river clean-up activities:

im Inman
Water Oriented Recreation District
(210) 907-2300

Information on river clean-up activities:

avid Davenport
Friends for Rivers
(210) 609-0543

Information on the use of trash racks on storm drains:

ecilia Martinez
City of Austin
(512) 499-7188

Information on sediment control techniques:

iane Evans
U.S. Environmental Protection Agency
(214) 665-6677

Information on sediment control techniques:

ary Landen
U. S. Army Corps of Engineers
(601) 634-2942

Section N. Bank Stabilization

Information on plants for erosion control:

ames Alderson
Natural Resources Conservation Service
(817) 774-1291

Information on a native grass mix for bank stabilization:

ennis Markwardt

Texas Department of Transportation
(512) 416-3090

Appendix D

PHOTOS (FIGURES D1-D8) OF THE DAMS ON THE COMAL RIVER