U. S. Fish and Wildlife Service
Region 2

The Impact of Anthropogenic Discharges on Arkansas River Shiner (*Notropis girardi*) Habitat within the South Canadian River Watershed in the Texas Panhandle, Texas 2001-2002

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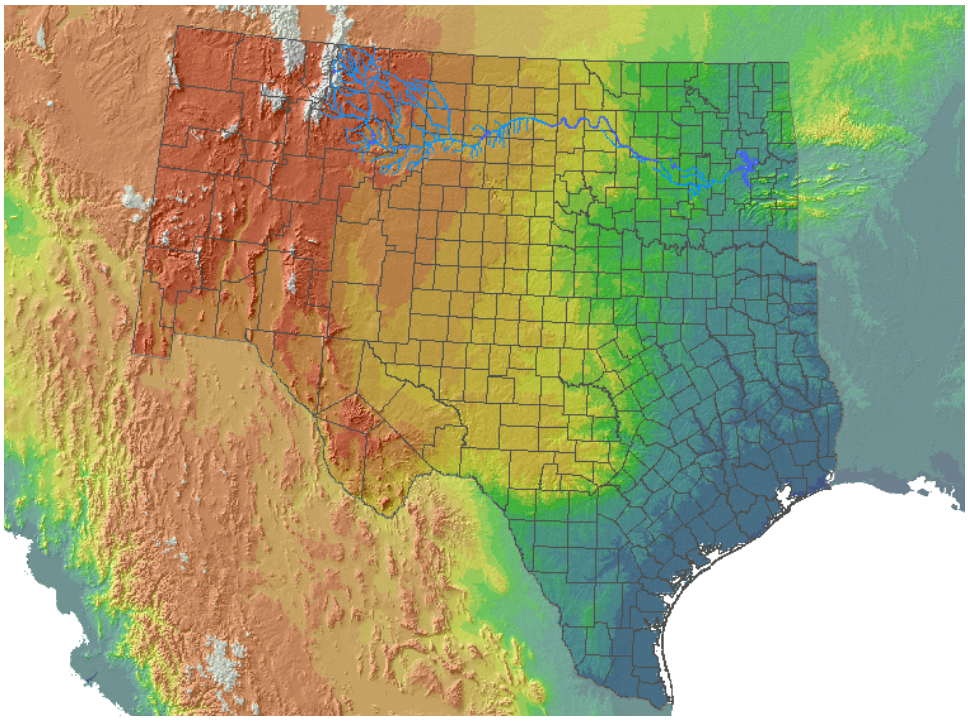

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ABSTRACT

In 2001, the USFWS Arlington, Texas Field Office initiated a one-year study on the mainstem of the South Canadian River in the Texas Panhandle to determine the impact of anthropogenic discharges on the aquatic habitat of the federally listed Arkansas River shiner. Surface water, sediment and biological samples were collected at six sites (five in Texas and one in New Mexico) on the mainstem of the South Canadian River during high flow and low flow conditions. Surface water samples were analyzed for total fecal coliforms and nutrient content. Sediment samples were analyzed for total metals and total petroleum hydrocarbons during the high flow phase and total metals, total petroleum hydrocarbons, and organochlorines during the low flow sampling phase. Resulting data from the surface water and sediment analyses were compared with other studies and criteria protective of aquatic wildlife. The biological samples consisted of fish and macroinvertebrates. Data from the fish sampling were used to calculate Indices of Biotic Integrity (IBI), while data from the macroinvertebrate sampling were used to calculate diversity indices as well as IBI.

At the time this study was conducted, anthropogenic discharges into the South Canadian River did not appear to be affecting the fish and macroinvertebrate communities in an adverse manner at the sites sampled. Residual contaminants, possibly associated with past discharges, were detected in sediments throughout the stream, but with the exception of nickel, these contaminants were below levels where adverse effects to fish and wildlife resources would be expected to occur. In comparison to other lotic systems, the fish and macroinvertebrate assemblages measured within the South Canadian River during the course of this study were classified as limited to intermediate; however, this appears to be more of a factor associated with natural conditions (elevated salinity and periods of limited surface water flow), the lowering of groundwater levels, and the construction of surface water impoundments (Meredith, Ute, and Conchas Reservoirs) within the watershed which have modified in-stream habitat and flow regimes rather than to actual discharges.

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The Impact of Anthropogenic Discharges on Arkansas River Shiner (*Notropis girardi*) Habitat within the South Canadian River Watershed in the Texas Panhandle, Texas 2001-2002

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INTRODUCTION

In 1999, informal consultations were conducted between the United States Fish and Wildlife Service (USFWS), the U.S. Environmental Protection Agency (USEPA), and the Texas Natural Resource Conservation Commission (TNRCC), concerning the implementation of TNRCC's rules (Title 30, Texas Administrative Code 321, Sub-chapter B) regulating concentrated animal feeding operations (CAFOs) within the State of Texas. Considering that documented detrimental events occurred at Buffalo Lake National Wildlife Refuge, in the Texas Panhandle (Irwin and Dodson, 1991; Baker *et al*., 1998; Giggleman, 1999) and within the Brazos River drainage in central Texas (Armstrong, 1998) that were attributed to discharges and run-off from CAFOs, the USFWS was concerned that the rules were not stringent enough to prevent possible adverse impacts to the federally listed Arkansas River shiner's (*Notropis girardi*) habitat in the South Canadian River watershed (USFWS, 1999b). According to the TNRCC's regulations (Title 30, Texas Administrative Code 321, Sub-chapter B), CAFOs are prohibited from discharging wastes from their waste management units into waters of the State except during catastrophic rainfall events which are defined as any storm events equal to or in excess of a 25-year, 24-hour rainfall event. In the Texas Panhandle, approximately 4.5 inches (11.43 centimeters (cm)) of precipitation represents a 25-year, 24-hour storm event (USFWS, 1999a). Since 1949, at least 11 rainfall events greater than 4.5 inches (11.43 cm) in intensity have been documented in this area of Texas (USFWS, 1999a). Between 1993-1998, three separate discharges from CAFOs into the Canadian River were reported to the USEPA (USFWS, 1999a). However, the only adverse impacts to fish communities attributed to releases from CAFOs documented within the Canadian River watershed occurred in 1973 and 1979 (TPWD, 1999). Considering the limited data available on impacts to fish in the Canadian River from CAFO discharges, the USFWS agreed in principal to lift its objections to the State's rules provided that the TNRCC, in conjunction with the USEPA, conduct a study to determine the impacts on surface water quality in various watersheds in Texas (Canadian River included) from CAFO discharges (USFWS, 1999c). While this full scale study was being planned, the USFWS proposed to gather site specific data for the Canadian River. In 2001, the USFWS Arlington, Texas Ecological Services Field Office (ESFO) initiated a study on the mainstem of the South Canadian River in the Texas Panhandle to determine the impact of anthropogenic discharges on the aquatic habitat of the Arkansas River shiner. Although initially focusing on the potential impact of discharges from CAFOs, additional concerns were raised during the course of this study about the potential impact of releases from the numerous gas and/or oil production facilities located throughout the watershed. Surface water, sediment, and biological samples were collected

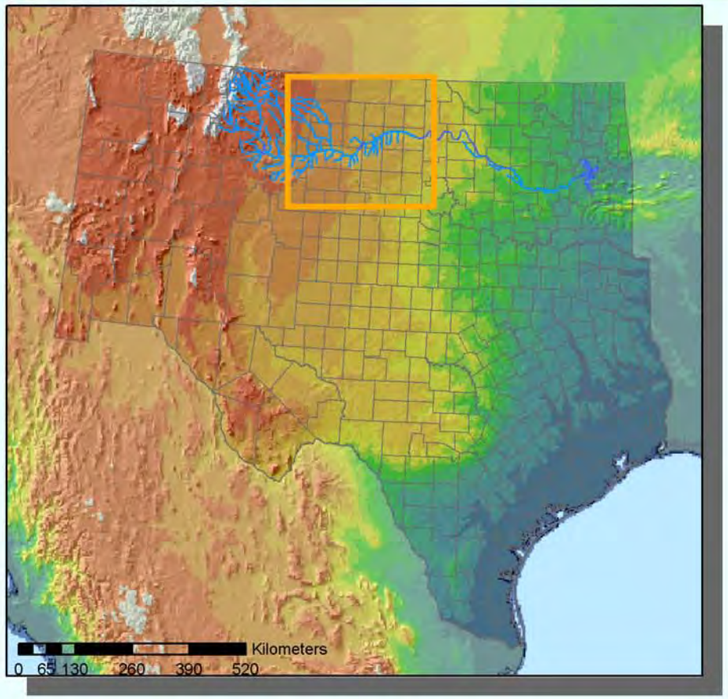
at six sites (five in Texas and one in New Mexico) on the mainstem of the South Canadian River during high flow and low flow conditions. Surface water samples were analyzed for total fecal coliforms and nutrient content. Sediment samples were analyzed for total metals and total petroleum hydrocarbons during the high flow phase and total metals, total petroleum hydrocarbons, and organochlorines during the low flow sampling phase. Resulting data from the surface water and sediment analyses were compared with other studies and criteria protective of aquatic wildlife. The biological samples consisted of fish and macroinvertebrates. Data from the fish sampling were used to calculate Indices of Biotic Integrity (IBI), while data from the macroinvertebrate sampling were used to calculated diversity indices as well as IBI.

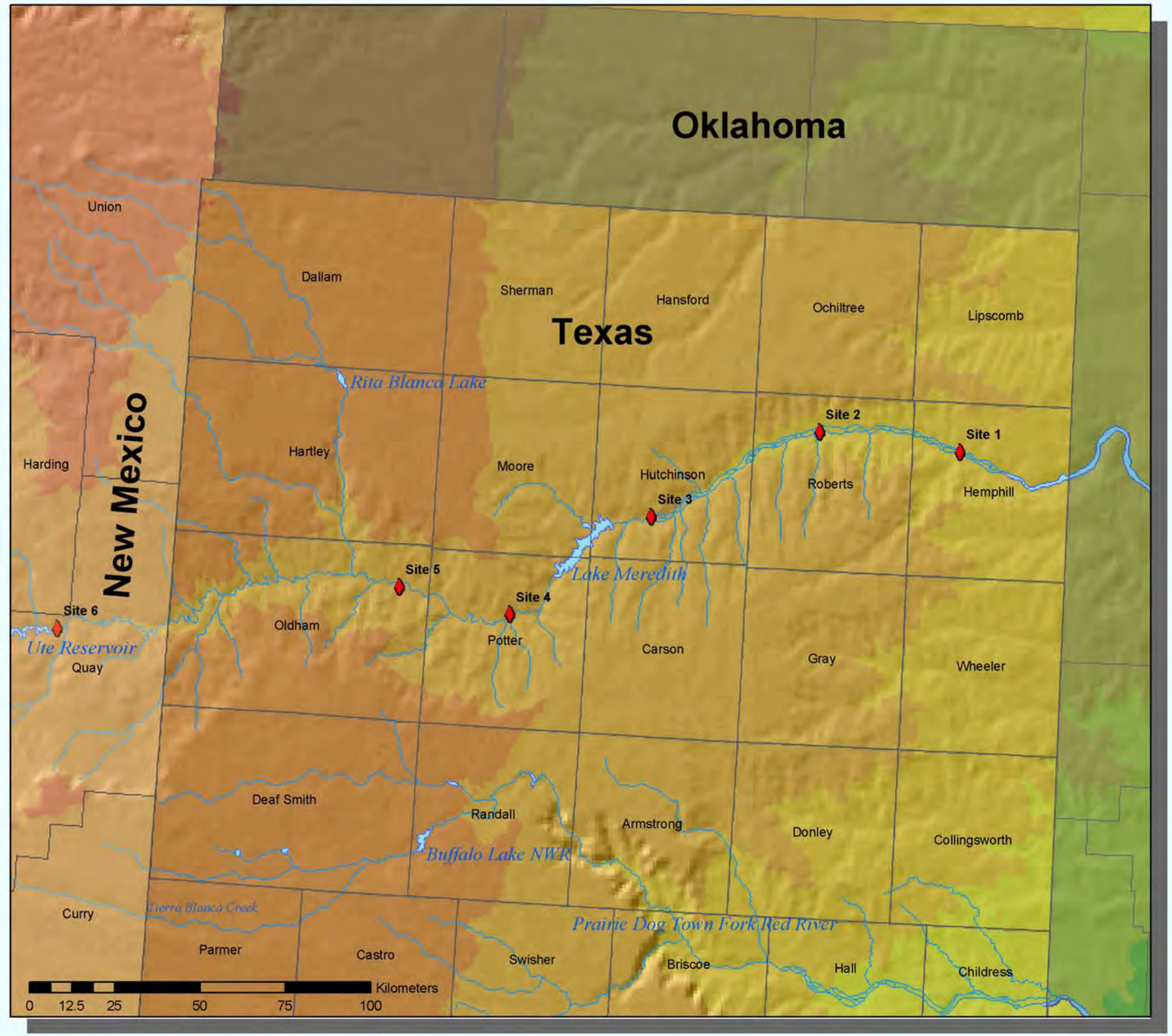
STUDY AREA & BACKGROUND INFORMATION

A component of the Arkansas River Ecosystem, the South Fork of the Canadian River originates as drainage from the northeastern slopes of the Sangre de Cristo Mountains in northeastern New Mexico (Figure 1). From its headwaters in New Mexico, this river flows approximately 906 miles (1,460 kilometers) in a general eastward direction through the Texas Pandhandle and across southern Oklahoma until it joins with the North Fork of the Canadian River at Eufala Reservoir in McIntosh County, Oklahoma (Shearer Publishing, 1997; Gandara *et al*., 2000; RRA, 2000). The total drainage area for the South Fork of the Canadian River is approximately 22,866 miles^2 (59, 223 kilometers^2) (Gandara *et al*., 2000; RRA, 2000). In Texas, the mainstem of the South Fork of the Canadian River traverses through portions of Oldham, Potter, Moore, Hutchinson, Roberts, and Hemphill Counties and receives drainage directly from portions of Dallam, Hartley, Deaf Smith, Carson, Ochiltree, Gray, and Lipscomb Counties (TWC, 1989; Texas A&M, 1995). The climate of this area is considered semi-arid. Ambient air temperatures average 21.2˚Farenheit (F) [-5.9˚Celsius (C)] in the winter and 91.7˚F (33.2˚C) in the summer. Winds are predominantly out of the south-southwest (NWS, personal communication, 1998). Average annual rainfall is approximately 16 inches (41 cm) (NMWQCC, 1994). Total population in these counties is estimated at less than250,000 people (TDED, 1997). Land use in this area consists primarily of irrigated, dry land farming, cattle ranching, and gas and oil production (RRA, 2000). Permitted wastewater treatment facilities within the watershed include 50 outfalls that discharge approximately 34.4 million gallons of treated effluent per day (130.2 million liters per day) (TNRCC, 1996). There are also 85 permitted CAFOs located in the watershed, of which, an estimated 10 have the possibility of discharging directly into the mainstem of the South Canadian River in the event of a 25-year, 24-hour storm event (Morris, personal communication, 2002). In addition to the permitted discharges, hundreds of unauthorized releases of various products (crude oil, brine, diesel, gasoline, carbon black, polychlorinated biphenyls, etc.) have been documented within the watershed since 1972 (TNRCC, 1997; TPWD, 1999).

In New Mexico, there are two principal lentic impoundments on the mainstem of the South Canadian River, Conchas Reservoir and Ute Reservoir. Conchas Reservoir was constructed in 1935 in San Miguel County and impounds approximately 9,600 acres (3,885 hectares), while Ute Reservoir was constructed in 1963 in Quay County and impounds 8,200 acres (3,318 hectares) (NMWQCC, 1994). Both of these

Figure 1: Canadian River Study Area and Sample Site Locations





Legend

- Sample Sites

Elevation in Meters

- -75 - 0
- 0 - 90
- 91 - 161
- 162 - 232
- 233 - 303
- 304 - 374
- 375 - 468
- 469 - 610
- 611 - 823
- 824 - 1,106
- 1,107 - 1,437
- 1,438 - 2,556
- 2,557 - 5,976

Sampling Site Information		
Site 1	CR1	Upstream of US 83 in Hemphill County, Texas
Site 2	CR2	Upstream of SH 70 in Roberts County, Texas
Site 3	CR3	Upstream of SH 152 in Hutchinson County, Texas
Site 4	CR4	Upstream of US 287 in Potter County, Texas
Site 5	CR5	Upstream of US 385 in Oldham County, Texas
Site 6	CR6	Upstream of SH 54 in Quay County, New Mexico

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reservoirs have been classified by the State of New Mexico as impaired surface water bodies due to potential elevated mercury levels and consequently limited fish consumption advisories have been established (NMED, 2002; USEPA, 2002). Designated uses for the mainstem of the South Canadian River in New Mexico from the Texas state line to Ute Reservoir include irrigation, limited warm-water fishing, livestock watering, wildlife habitat, and secondary recreational contact (NMED, 2001). The mainstem of the South Canadian River in Texas contains one major surface water impoundment, Meredith Reservoir (designated by the State of Texas as Texas Canadian River Segment No. 0102). This reservoir was constructed in 1965 in Hutchinson County and impounds approximately 16,505 acres (6,679.6 hectares) (TPWD, 2000).

In Texas, the annual mean flow of the South Canadian River above Meredith Reservoir is 281 feet^3/second (7.96 meters^3/second), while below Meredith the annual mean flow is 284.0 feet^3/second (8.04 meters^3/second) (Gandara *et al*., 2000). Peak flow usually occurs from June through September, while low flow conditions typically occur from December through March (Gandara *et al*., 2000). Extreme variations in surface water quality occur naturally within the Canadian River watershed. According to the Red River Authority of Texas (1996), surface waters in the South Canadian River above Ute Reservoir in New Mexico contain relatively low total dissolved solids (TDS) and low salinity values, while below Ute Reservoir and in the Texas portion of the watershed, TDS and salinity values are elevated. The primary constituents contributing to these high TDS values are elevated levels of salts (RRA, 1996). These salts are principally composed of sulfates and chlorides and are naturally released into surface waters through the discharge of brine groundwater originating from formations rich in halite as well as surface water run-off from sheet flow of storm water over exposed formations high in salt content (RRA, 1996). In 1998, the mainstem of the Canadian River in Texas above Meredith Reservoir in Oldham and Potter Counties was placed on the State §303(d) List as impaired due to elevated bacteria levels, however this segment was no longer designated as impaired on the draft 2002 §303(d) List (TNRCC, 1998; TNRCC, 2002).

The mainstem of the South Canadian River in Texas above Meredith Reservoir in Oldham County and in Potter County to the confluence with Coetas Creek has been designated as critical habitat for the federally listed Arkansas River shiner (Federal Register, 2001). The eastern portion of Hemphill County extending to the Oklahoma border has also been designated as critical habitat for this species (Federal Register, 2001). Listed as threatened in 1998 due to water quality degradation and excessive habitat modification attributed to stream dewatering, ground water pumpage, and the construction of impoundments, the Arkansas River shiner (Figure 2) originally demonstrated a wide geographic distribution throughout the entire Arkansas River watershed (Federal Register, 1998). Currently, this species is confined primarily to the Canadian River system in New Mexico, Texas, and Oklahoma. Preferred habitat for this species consists of open broad sandy channels with stable sand ridges and steady, shallow flow for adults, whereas juveniles are associated more with backwater areas with limited flow (Federal Register, 1998). Diet is dominated by small aquatic invertebrates, algae, detritus, and sand (Federal Register, 1998). The estimated life span for this species is three years with spawning usually occurring in July; however, this shiner does not appear to spawn unless conditions are favorable for survival of the larvae (Federal Register, 1998).

Figure 2. The Arkansas River Shiner (*Notropis girardi*).

MATERIALS & METHODS

To evaluate the variability of the transport of contaminants (primarily nutrients) associated with different surface water flow regimes, samples were collected on the main-stem South Fork of the Canadian River during high flow and low flow conditions in 2001. The targeted high flow conditions were within 24 hours of the initial surge of stormwater runoff associated with a significant rain event, whereas low flow conditions focused on zero to negligible flow rates. Six sampling sites were selected on the South Canadian River and are presented in Table 1 and Figure1. Three of these sites [CR4 (Figures 6A-6C), CR5 (Figures 7A-7B),

Table 1. Sampling Sites on the South Fork of the Canadian River in Texas and New Mexico.

Site 1	CR1	Upstream of U.S.83 in Hemphill County, Texas.
Site 2	CR2	Upstream of SH 70 in Roberts County, Texas.
Site 3	CR3	Upstream of SH 152 in Hutchinson County, Texas.
Site 4	CR4	Upstream of U.S.287 in Potter County, Texas.
Site 5	CR5	Upstream of U.S.385 in Oldham County, Texas.
Site 6	CR6	Upstream of SH 54 in Quay County, New Mexico.

and CR6 (Figures 8A-8B)] were upstream of Meredith Reservoir while the remaining three sites were below Meredith Reservoir [CR1 (Figures 3A-3B), CR2 (Figures 4A-4B), and CR3 (Figures 5A-5B)]. These sampling sites were selected because they contained appropriate and comparable habitat as well as

Figure 3A. CR1 (upstream of U.S.83 in Hemphill County, Texas).

Figure 3B. Facing downstream of CR1.

Figure 4A. CR2 (upstream of SH 70 in Roberts County, Texas).

Figure 4B. Facing downstream of CR2 towards SH 70.

Figure 5A. CR3 (upstream of SH 152 in Hutchinson County, Texas).

Figure 5B. Facing downstream from CR3 towards SH 152.

Figure 6A. CR 4 (upstream of U.S.287 in Potter County, Texas).

Figure 6B. Facing downstream from CR4 towards U.S. 287.

Figure 6C. Stream channel at CR4.

Figure 7A. CR5 (upstream of U.S.385 in Oldham County, Texas).

Figure 7B. U.S. 385 downstream of CR5.

Figure 8A. CR6 (upstream of SH 54 in Quay County, New Mexico).

Figure 8B. SH 54 downstream of CR6.

providing ease of access through public right-of-ways. The soils within the direct drainages of Sites 1, 2, and 5 are characterized as Lincoln loamy fine sands (Williams *et al*., 1974; Pringle, 1977; Wyrick, 1981). At Site 3, the soil type is predominantly characterized as Lincoln loamy fine sands with calcareous inclusions (Stringer, 1976), while at Site 4, the soil type is dominated by Likes loamy fine sands (Pringle, 1974).

Surface water temperature in degrees ˚C, conductivity in micromhos per centimeter (µmhos/cm), dissolved oxygen (DO) in milligrams/liter (mg/L), and pH (standard units) were measured at all six sites where water was present during each sampling period using a Hydrolab Scout 2, submersible, multi-parameter water quality instrument. Surface water grab samples and composite surficial sediment samples were collected from each of the six sites during high flow and low flow conditions. The surface water samples were collected mid-channel using 1.0 L, polypropylene containers and preserved with sulfuric acid. After collection, these samples were placed on ice in a cooler, transported to Talem, Inc. (306 West Broadway Avenue, Fort Worth, Texas), and analyzed for nutrient content (ammonia-nitrogen, nitrate-nitrite, total organic nitrogen, total kjeldahl nitrogen, and total phosphorus). Ammonia-nitrogen concentrations were determined pursuant to USEPA Method 350.1 (1979); nitrate-nitrite concentrations were determined as per USEPA Method 353.2 (1979); total kjeldahl nitrogen concentrations were determined following USEPA Method 350.3 (1979); total phosphorus concentrations were determined using USEPA Method 365.2 (1979); and total organic nitrogen values were calculated for each site by subtracting the ammonia-nitrogen concentrations from the total kjeldahl nitrogen values. Additional surface water samples were collected at each site during each sampling phase using 100.0 milliliter (mL), plastic whirl bags. These samples were placed on ice in a cooler and immediately transported to Ana-Lab Corporation (4515 South Georgia, Suite 129, Amarillo, Texas) and analyzed for total fecal coliforms per 100 mL using American Public Health Association Method 9222D (1995).

Surficial composite sediment samples were collected at a depth of 0.0 to 6.0 inches (0.0 to 15.0 cm) from depositional areas within the channel at each site during each sampling phase using disposable plastic scoops. Once collected, each sample was placed in a 950 mL, pre-cleaned glass container and placed on ice in a cooler. These samples were then transported to the USFWS Arlington, Texas ESFO and remained refrigerated at 4˚C until submitted through the Patuxent Analytical Control Facility (PACF) to be analyzed for moisture content (as a percentage), sand, silt, and clay content (as percentages), total aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, strontium, vanadium, and zinc content in milligrams/kilogram (mg/kg) dry weight, and total petroleum hydrocarbon (TPH) content in mg/kg dry weight (for analytical methods see Appendix A). Additional sediment samples were collected at the same six sites in the same manner during the low flow sampling period and submitted through the PACF to be analyzed for organochlorine content [1,2,3,4-terachlorobenzene, 1,2,4,5-tetrachlorobenzene, aldrin, hexachlorobenzene (HCB), heptachlor, total polychlorobiphenyls (PCB), alpha hexachlorocyclohexane (αBHC), alpha (α) chlordane, beta hexachlorocyclohexane (βBHC), cis-nonachlor, delta hexachlorocyclohexane (δBHC), dieldrin, endosulfan II, endrin, gamma hexachlorocyclohexane (γBHC), gamma (γ) chlordane, heptachlor epoxide, mirex, o,p'-dichloro-diphenyl-dichloroethane (o,p'-DDD),

o,p'-dichloro-diphenyl-trichloroethane (o,p'-DDT), oxychlordane, p,p'-dichloro-diphenyl-dichloroethane (p,p'-DDD), p,p'-dichloro-diphenyl-dichloroethylene (p,p'-DDE), p,p'-dichloro-diphenyl-trichloroethane (p,p'-DDT), pentachloro-anisole, toxaphene, and trans-nonachlor] in mg/kg dry weight (for analytical methods see Appendix A).

In addition to the sediment and surface water samples, fish and macroinvertebrates were collected at all six sites during both sampling periods to calculate an Index of Biotic Integrity (IBI) for each site. The fish were collected using two straight seines [one 50 feet by 6 feet seine with ¼ inch mesh (15 meters by 2 meters seine with 6.35 millimeters mesh) and one 20 feet by 4 feet seine with ⅛ inch mesh (6 meters by 1.2 meters seine with 3.18 millimeters mesh)], a bag seine [50 feet by 6 feet with ⅜ inch mesh (15 meters by 2 meters seine with 9.53 millimeters mesh)], and fine mesh dip nets. Attempts to use a back-pack shocker (Smith-Root Type VII Electrofisher) proved ineffective due to the elevated surface water conductivity. Eight successful seine hauls were conducted at each site with the exception of site CR3 (upstream of SH 152 in Hutchinson County, Texas). Each seine haul covered a distance of approximately 50.0 feet (17.0 meters) and was considered successful when minimal physical restrictions were encountered and very few fish escaped. At CR3, the narrowness of the channel [average width less than 5.0 feet (less than1.7 meters)] combined with the thick aquatic vegetation (predominantly sedges) during the high flow period, prevented the effective use of seines. Consequently, dip nets were used as a supplement to the seines at this site. Furthermore, CR3 was completely dry at the time of the low flow sampling period so no fish were collected during that phase. Once collected, all fish were identified in the field to the lowest taxanomic level practical, enumerated, and released downstream from the sampling site. If the identification of a particular fish species was undetermined in the field, a representative of this species was placed in a glass container, preserved in 10% formalin, and transported to the USFWS Arlington, Texas ESFO for further identification. All fish species were identified using Lee *et al*. (1980), Robison and Buchanan (1988), Hubbs *et al*. (1991), Pflieger (1991), Robins and *et al*. (1991), and Etnier and Starnes (1993). The resulting data were compared to statewide (Table 2) and regional IBI scoring criteria (Table 3 and Figure 9). As proposed by Karr (1981), an IBI is designed to evaluate the quality or condition of an aquatic system based on the attributes of the fish assemblage within that system using representative samples. The Texas statewide IBI was initially developed by Texas Parks and Wildlife Department (TPWD). This IBI consists of 12 attributes included in three categories: species composition, trophic composition, and health and abundance of fish (Table 2). Species composition attributes focus on the overall species richness and richness within major taxonomic groups as well as the occurrences of notably tolerant and intolerant species. Feeding strategies of a fish assemblage, as categorized by trophic composition, are products of the diversity and productivity of the lower trophic levels within the aquatic system. Linam and Kleinsasser (1991) have designated fishes into trophic and tolerance classifications within the State of Texas. Fish abundance and fish health reflect system productivity and habitat stability. Using the statewide IBI, a representative sample is assigned a value of one, three or five points for each attribute based on the comparison to expectations associated with a pristine stream of similar size within the same region. Total scores from this IBI characterize stream health into four classes ranging from exceptional (pristine) to limited (degraded). By comparison, a regional IBI accounts for aspects of local stream fish communities and species tolerances which are not considered by the statewide IBI. In Texas,

Table 2. Texas statewide index of biotic integrity scoring criteria for stream fish assemblages (Note - Total Score for Aquatic Life Use Subcategories: 58-60 = Exceptional; 48-52 = High; 40-44 = Intermediate; and ≤34 = Limited) (TPWD).

Category	Metric	Scoring		
		5	3	1
Species Richness and Composition	1. Total number of species	★	★	★
	2. Total number of darter species	≥3	1-2	0
	3. Total number of sunfish species (excluding bass)	≥2	1	0
	4. Total number of sucker species	≥2	1	0
	5. Total number of intolerant species	≥3	1-2	0
	6. Percentage of individuals as tolerants	<5	5-20	>20
Trophic Composition	7. Percentage of individuals as omnivores	<20	20-45	>45
	8. Percentage of individuals as insectivores	>80	>40-80	≤40
	9. Percentage of individuals as piscivores	>5	1-5	<1
Fish Abundance and Condition	10. Number of individuals in sample	>200	>50-200	≤50
	11. Percentage of individuals as hybrids	0	>0-1	>1
	12. Percentage of individuals with disease or other anomaly	≤2	>2-5	>5

★First-second order streams = ≥7(5), 4-6(3), ≤3(1)
Third-fourth order streams = ≥10(5), 5-9(3), ≤4(1)
Fifth-sixth order streams = ≥16(5), 8-15(3), ≤7(1)
Seventh-eighth order streams = ≥22(5), 11-21(3), ≤10(1)

Table 3. Regional index of biotic integrity scoring criteria for stream fish assemblages in the Western High Plains and Southwestern Tablelands, Texas (Note - a score ≥36 = Exceptional; a score 34-35 = High; a score 24-33 = Intermediate; and a score <24 = Limited) (Linam *et al.*, 2002).

Metric	Scoring Criteria		
	5	3	1
1. Total number of fish species	★	★	★
2. Number of native cyprinid species	>2	2	<2
3. Number of sunfish species	>1	1	0
4. % of individuals as omnivores	<9%	9-16%	>16%
5. % of individuals as insectivores	>65%	33-65%	<33%
6. Number of individuals/seine haul	>41.7	20.9-41.7	<20.9
7. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
8. % of individuals with disease or other anomaly	<0.6%	0.6-1%	>1%

★Refer to Figure 9 to obtain scoring criteria for Metic No.1.

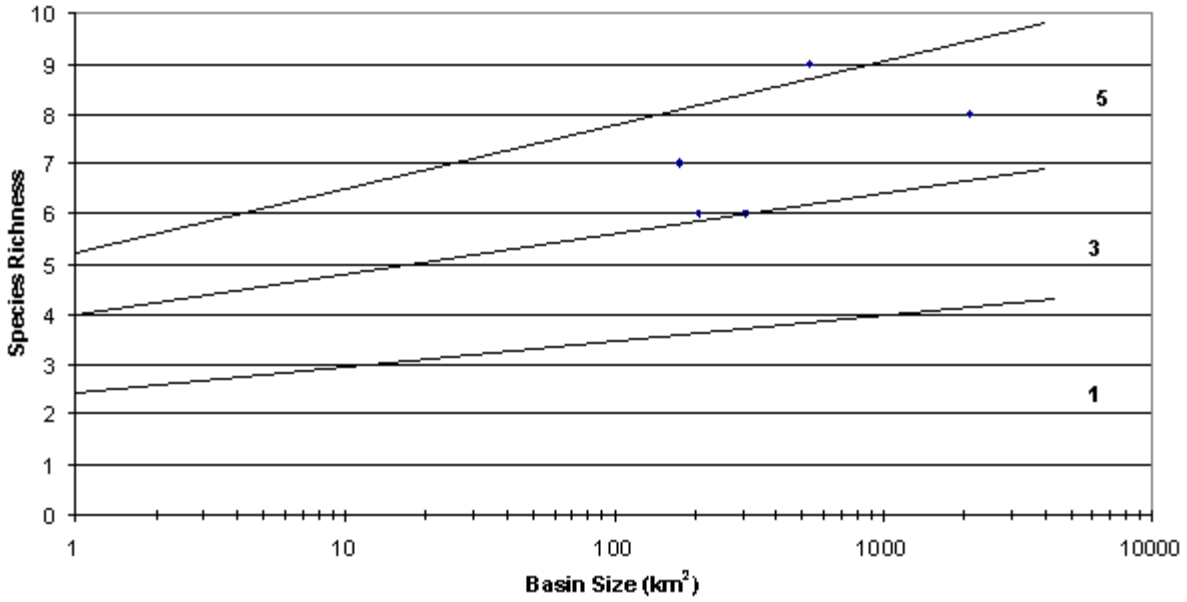


Figure 9. Fish species richness verses drainage basin area for Western High Plains and Southwestern Tablelands streams used to determine scoring criteria for Metric No. 1 in the Regional Index of Biotic Integrity (from Linam *et al.*, 2002).

Linam *et al*. (2002) have developed a proposed IBI for the geographic region (Western High Plains and Southwestern Tablelands) that is inclusive of the South Fork Canadian River. As with the statewide IBI, the total scoring of stream habitat quality ranges from exceptional to limited.

The macroinvertebrate samples were collected at each site using fine mesh dip nets following the rapid bioassessment protocols for multihabitat sampling recommended by the USEPA (1999). Once collected these samples were placed in polypropylene containers, preserved in 95% ethanol, and transported to the USFWS Arlington, Texas ESFO for identification to the lowest taxonomic level practical utilizing Usinger (1968), Brown (1976), McCafferty (1983), Pescador *et al*. (1995), Epler *et al*. (1996) and Merrit and Cummins (1996). The resulting data were compared with the statewide IBI scoring criteria for benthic macroinvertebrates in Texas streams (Table 4).

The use of macroinvertebrates, especially insects, in the evaluation of water quality has been widely used due in part to their abundance in a variety of aquatic habitats, ease of collection, sedentary nature, and an extensive range in response to environmental perturbations (Merrit and Cummins, 1996; Rosenberg and Resh, 1993). The IBI which was developed using fish (Karr, 1991), has since been expanded to macroinvertebrate studies (Table 4) that require rapid assessment and comparison to reference conditions (Merritt and Cummins, 1996). As with fish, the development of an IBI to evaluate macroinvertebrate communities is most often accomplished on a statewide or regional level and formulates metrics deemed effective in evaluating community structure, trophic relations, tolerance levels, diversity, and other stream attributes. In Texas, an IBI has been developed by the TNRCC using rapid bioassessment protocols

Table 4. Statewide index of biotic integrity scoring criteria for benthic macroinvertebrates in Texas streams (Note - a score >36 = Exceptional; a score 29-36 = High; a score 22-28 = Intermediate; and a score <22 = Limited) (Harrison, 1996).

Metric	Scoring Criteria			
	4	3	3	1
1. Taxa richness	>21	15-21	8-14	<8
2. Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness	>9	7-9	4-6	<4
3. Hilsenhoff Biotic Index	>3.77	3.77-4.52	4.53-5.27	>5.27
4. % Chironomidae	<0.79-4.10%	4.11-9.48%	9.49-16.9%	<0.79 or >16.19%
5. % Dominant taxon	<22.15%	22.15-31.01%	31.02-39.88%	>39.88%
6. % Dominant functional group	<36.5	36.5-45.3%	45.31-54.12%	>54.12
7. % Predators	4.73-15.2%	15.21-25.67%	25.68-36.14%	<4.73 or >36.14%
8. Ratio intolerant to tolerant taxa	>4.79	3.21-4.79	1.63-3.2	<1.63
9. % Trichoptera as Hydropsychids	<25.5%	25.51-50.5%	50.51-75.5%	>75.5% or no trichoptera
10. Number of non-insect taxa	>5	4-5	2-3	<2
11. % Collector - gatherers	8-19.23%	19.24-30.46%	30.47-41.68%	<8 or >41.68%
12. % Elmidae	0.88-10.04%	10.05-20.08%	20.09-30.12%	<0.88 or >30.12%

(Plafkin *et al*., 1989) for wadeable streams (Harrison, 1996). This IBI uses 12 metrics derived using data extracted from 54 kick net samples from 33 reference streams and was calibrated from an additional 60 samples from non-reference streams (Harrison, 1996). Each metric is assigned a score (1-4) based on criteria from reference stream data and the sum of all scores for a sample is compared with the ranges for Exceptional, High, Intermediate, and Limited Aquatic Life Use Designations.

In addition to using the IBI to characterize the macroinvertebrate communities at the six sites during both sampling phases, the Shannon Diversity Index was used to describe the macroinvertebrate community structures within the stream. This index (D) was calculated by using the following equation:

$$D = -\sum_{i=1}^{S} P_i \ln P_i$$

where S is the total number of taxa in the sample and P_i is the proportion of the ith taxa to the sample (Begon et. al., 1990). Evenness or equitability, describes the distribution of individuals among the species and can be quantified by the expression of diversity as a proportion of maximum diversity, which is the value obtained when all individuals in a sample are distributed evenly among species (Begon *et al.*, 1990). Maximum diversity (D_{max}) and evenness (E) are described as follows:

$$D_{max} = \ln S$$

$$E = D / D_{max}$$

In conjunction with the surface water, sediment, and biological sampling, in-stream habitat evaluations were performed at each site during each sampling phase (Appendix D). The parameters used in these evaluations were modified from the parameters recommended by the USEPA (1999) for low gradient streams. According to the USEPA (1999), low gradient streams or glide/pool prevalent streams are those in low to moderate gradient landscapes. Natural low-gradient streams have substrates of fine sediment or infrequent aggregations of more course (gravel or larger) sediment particles (USEPA, 1999). All of the parameters measured were evaluated and rated on a numerical scale of 0 to 20, with zero being the lowest score and 20 the highest.

RESULTS & DISCUSSION

Surface Water

Surface water flow rates, temperature, conductivity, DO, pH, and fecal coliforms measured at the six sites on the South Canadian River during the two sampling periods in 2001 are presented in Table 5. High flow conditions were considered during the month of April, 2001, while low flow conditions were considered during August, 2001. Peak flow rates for the month of April occurred from April 1 - April 7 (62.57 feet^3/second (1.77 meters^3/second)) with an additional surge occurring on April 12 (30.00 feet^3/second (0.85 meters^3/second)) (USGS, 2002). In the month of August, 2001, zero flow rates were recorded for the South Canadian River from August 1 - August 10 (USGS, 2002). Actual peak flow and zero flow conditions for these months were not sampled due to safety issues as well as logistical problems associated with mobilizing the sampling team.

The measured parameters were compared with surface water quality standards and/or criteria protective of aquatic life recommended by the State of Texas for Canadian River Segment 0101 (below Meredith Reservoir) and Canadian River Segment 0103 (above Meredith Reservoir) (TNRCC, 1996). All of the measured parameters from both sampling periods for all six sites were within surface water quality standards and/or comparative criteria with the exception of the fecal coliform count measured at CR2 (upstream of SH 70 in Roberts County, Texas) during high flow conditions. Though elevated, this measurement was well below the total fecal coliform count (greater than 1,016/100 mL) recorded in 1999 by USFWS personnel for Tierra Blanca Creek as it flows into Buffalo Lake National Wildlife Refuge in Randall County, Texas (Giggleman, 1999). Although not a contributor to the Canadian River watershed, Tierra Blanca Creek (Figure 1) is a component of the Red River watershed that is located within the Texas Panhandle and has documented nutrient contamination attributed to discharges and run-off from CAFOs (Irwin and Dodson, 1991; Baker *et al*., 1998).

Ammonia-nitrogen, nitrate-nitrite, total organic nitrogen, total kjeldahl nitrogen, and total phosphorus concentrations measured at the six sites during the two sampling periods are presented in Table 6. These values were compared to screening values and criteria recommended by the State of Texas to be protective of aquatic life for Canadian River Segments 0101 and 0103 as well as with other criteria and results from

Table 5. Surface water temperature, conductivity, dissolved oxygen, pH, and total fecal coliforms measured at six sites on the South Canadian River (CR1-CR6) during high flow and low flow conditions compared to water quality standards and/or criteria protective of aquatic life for Segments 0101 and 0103 (Note - DO is dissolved oxygen; HF is high flow conditions; LF is low flow conditions; nd is none detected; and na is not applicable due to lack of water at the site).

Site	Temperature (˚C)	Conductivity (μmhos/cm)	DO (mg/L)	pH	Fecal Coliform (#/100 mL)
April, 2001 - HF = 21.00 feet^3/second (0.59 meters^3/second) (USGS, 2002)					
CR1	10.5	2160.0	9.2	8.7	nd
CR2	12.8	2570.0	8.4	8.8	430
CR3	19.9	2820.0	7.6	8.2	60
CR4	21.0	3000.0	7.4	8.8	nd
CR5	12.8	3130.0	8.2	8.8	nd
CR6	17.5	2920.0	7.7	8.5	nd
August, 2001 - LF = 1.60 feet^3/second (0.04 meters^3/second) (USGS, 2002)					
CR1	21.5	1120.0	7.9	8.8	290
CR2	29.9	1301.0	8.3	9.0	10
CR3	na	na	na	na	na
CR4	20.5	1430.0	7.9	8.9	25
CR5	27.5	1830.0	8.1	9.0	80
CR6	28.1	4580.0	9.0	9.0	25
0101[1]	35.0	5294.37	5.0	6.5	400
0103[2]	35.0	2655.00	5.0	6.5	400

[1]Values from State of Texas Canadian River Segment 0101, below Meredith Reservoir (TNRCC, 1996).
[2]Values from State of Texas Canadian River Segment 0103, above Meredith Reservoir (TNRCC, 1996).
(Note - conductivity values presented for Segments 0101/0103 represent reported $\bar{X}$ values, not actual water quality standards, while actual water quality standard for pH for both segments ranges from 6.5-9.0).

comparative studies (TNRCC, 1996).

[Ammonia (NH_3-N)] Ammonia-nitrogen concentrations were not detected above the analytical detection limit at any of the six sampling sites on the South Canadian River during the high flow sampling phase in 2001. Detected ammonia concentrations from the low flow sampling period in 2001 were below the screening value (1.0 mg/L) recommended by the State of Texas for Segments 0101 and 0103 to be protective of aquatic life (TNRCC, 1996). Free ammonia present in surface waters at levels above 2.5 mg/L is toxic to most freshwater organisms (TEEX, 1989). Ammonia compounds generally occur at 1.0 mg/L or less in unpolluted waters (TNRCC, 1996), whereas raw, untreated wastewater typically contains between 12.0-50.0 mg/L ammonia-nitrogen (Qasim and Udomsinrot). The detected ammonia concentrations from the low flow sampling phase appear to be below levels of concern.

Table 6. Ammonia, nitrate-nitrite, total organic nitrogen, total kjeldahl nitrogen, and total phosphorus concentrations measured in mg/L from six sites on the South Canadian River (CR1-CR6) during high flow and low flow conditions (Note - TON is total organic nitrogen; TKN is total kjeldahl nitrogen; TP is total phosphorus; HF is high flow conditions; LF is low flow conditions; bdl is below the analytical detection limit; and na is not applicable because no samples were collected due to lack of water at the site).

Site	Ammonia[1]	Nitrate + Nitrite [2]	TON[3]	TKN[4]	TP[5]
April 2001 (HF)					
CR1	bdl	0.23	0.61	bdl	0.12
CR2	bdl	0.53	0.72	bdl	0.12
CR3	bdl	bdl	0.75	bdl	bdl
CR4	bdl	0.27	0.60	bdl	bdl
CR5	bdl	bdl	0.36	bdl	bdl
CR6	bdl	bdl	0.43	bdl	bdl
August 2001 (LF)					
CR1	0.34	bdl	1.6	bdl	bdl
CR2	0.20	bdl	2.2	2.4	bdl
CR3	na	na	na	na	na
CR4	bdl	0.62	1.3	bdl	bdl
CR5	bdl	bdl	2.2	2.2	0.57
CR6	bdl	bdl	0.91	bdl	bdl
0101[6]	1.00	1.00	no criterion	no criterion*	0.20
0103[7]	1.00	1.00	no criterion	no criterion*	0.20

[1]detection limit = 0.20 mg/L.
[2]detection limit = 0.10 mg/L.
[3]detection limit = 0.20 mg/L.
[4]detection limit = 2.00 mg/L.
[5]detection limit = 0.10 mg/L during HF and 0.25 mg/L during LF
[6]Screening values from State of Texas Canadian River Segment 0101, below Meredith Reservoir (TNRCC, 1996).
[7]Screening values from State of Texas Canadian River Segment 0103, above Meredith Reservoir (TNRCC, 1996).
*Criterion for TKN in freshwater systems recommended by U.S. Army Corps of Engineers (1994) is 1.00 mg/L.

[Nitrate-Nitrite (NO_3-NO_2)] Nitrate is the most highly oxidized form of nitrogen and typically the most abundant form of inorganic nitrogen present in freshwater systems, whereas nitrite is generally only present in trace amounts in freshwater (Horne and Goldman, 1994). Raw wastewater usually contains very little measurable nitrates (TEEX, 1989). In contrast, polluted streams can contain up to 10.0 mg/L nitrite-nitrogen (Horne and Goldman, 1994). Detected nitrate-nitrite concentrations from both sampling periods during 2001 were below the screening value (1.0 mg/L) recommended by the State of Texas for Segments 0101 and 0103 to be protective of aquatic life (TNRCC, 1996).

[Total Organic Nitrogen (TON)] In fresh water, total organic nitrogen represents nitrogen which is bound to proteins, amino acids, and urea (Qasim and Udomsinrot). In untreated wastewater, 35.0 mg/L would be considered high, while 8.0 mg/L would be considered low (Qasim and Udomsinrot). Total organic nitrogen was detected in surface water samples from all six sites on the South Canadian River during both sampling phases in 2001. These values increased in concentration almost three-fold from the high flow sampling period ($\bar{x}$ = 0.58 mg/L) to the low flow sampling period ($\bar{x}$ = 1.64 mg/L) with the

highest concentrations being recorded at sites CR2 (upstream of SH 70 in Roberts County, Texas) and CR5 (upstream of U.S.385 in Oldham County, Texas). Aquatic life criteria and/or screening values have not been established by the State of Texas for organic nitrogen levels within the South Canadian River watershed, however organic nitrogen has been designated by the Red River Authority of Texas as a contaminant of possible concern for the South Canadian River above Meredith Reservoir (RRA, 1996). The detected total organic nitrogen concentrations measured in the South Canadian River in 2001 were considerably less than 8.0 mg/L, as well as being less than the detected total organic nitrogen concentrations ($\bar{X}$ = 3.97 mg/L) measured by USFWS personnel in 1993 in Tierra Blanca Creek, upstream of Buffalo Lake National Wildlife Refuge (Baker *et al*., 1998).

[Total Kjeldahl Nitrogen (TKN)] Total kjeldahl nitrogen is considered by the Red River Authority of Texas as a contaminant of concern for the South Canadian River below Meredith Reservoir (RRA, 1996). In 2001, total kjeldahl nitrogen was not detected at any of the six sampling sites on the South Canadian River during the high flow sampling phase and only detected at two sites, CR2 (upstream of SH 70 in Roberts County, Texas) and CR5 (upstream of U.S.385 in Oldham County, Texas), during the low flow sampling phase. The measured total kjeldahl nitrogen level at these two sites exceeded the freshwater criterion (1.0 mg/L) recommended by the U.S. Army Corps of Engineers (1994) to be protective of aquatic life. In addition, the detected total kjeldahl nitrogen concentrations at both of these sites corresponded to the highest concentrations of total organic nitrogen detected during the course of the study. This point, combined with the low nitrate-nitrite levels, indicates that concentrations of nitrogen detected in the South Canadian River during the 2001 study can be attributed more to nitrogenous cellular constituents of living organisms rather than to inorganic forms of nitrogen present in the water column.

[Total Phosphorus (TP)] Considered by the Red River Authority of Texas as a contaminant of concern for the South Canadian River upstream and downstream of Meredith Reservoir (RRA, 1996), total phosphorus was detected above the analytical detection limit at sites CR1 (upstream of U.S.83 in Hemphill County, Texas) and CR2 (upstream of SH 70 in Roberts County, Texas) during the high flow stage and at site CR5 (upstream of U.S.385 in Oldham County, Texas) during the low flow phase. Of these detected values, only the total phosphorus concentration measured at CR5 (0.57 mg/L) exceeded the criterion (0.2 mg/L) recommend by the State of Texas to be protective of aquatic life for Canadian River Segment 0103 (TNRCC, 1996). In natural surface water, elevated phosphorus concentrations are indicative of excessive organic loading associated with sewage or run-off from agricultural industries such as CAFOs (USEPA, 1986). In wastewater, a total phosphorus level of 4.0 mg/L is considered a weak concentration (Qasim and Udomsinrot). Though elevated, the total phosphorus concentration detected at CR5 was well below this value. Furthermore, the detected total phosphorus level at CR5 was well below the concentration (1.20 mg/L) measured by USFWS at Tierra Blanca Creek in 1999 (Giggleman, 1999).

Sediments

Measured moisture, sand, silt, and clay content (as percentages) for the sediment samples collected from six sites on the South Canadian River during both sampling phases in 2001 are presented in Table 7. Results of the and TPH and metals analyses of the sediments collected at the six sites on the South Canadian River during both sampling phases are presented in Tables 8A and 8B, while the analytical results form the organochlorine analyses of sediments collected during the low flow sampling phase are presented in Table 9. Where applicable, these analytical results were compared with sediment criteria protective of aquatic wildlife recommended by the Ontario Ministry of the Environment, Long and others, MacDonald

Table 7. Moisture, sand, silt, and clay content as percentages measured in sediment samples collected from six sites on the South Canadian River (CR1 - CR6) during high flow and low flow conditions in 2001 (Note - HF is high flow conditions; and LF is low flow conditions).

Sample Site	% Moisture	% Sand	% Silt	% Clay
April 2001 (HF)				
CR1	12.5	98.3	0.5	1.3
CR2	14.2	98.6	0.5	0.9
CR3	44.6	9.5	59.3	31.2
CR4	14.6	98.1	1.9	0.0
CR5	13.6	95.5	4.3	0.3
CR6	17.3	96.0	4.0	0.0
August 2001 (LF)				
CR1	16.8	99.0	0.7	0.2
CR2	25.6	99.3	0.7	0.0
CR3	27.9	55.7	30.0	14.3
CR4	16.4	97.6	1.1	1.3
CR5	15.5	98.9	1.1	0.0
CR6	19.9	87.5	11.0	1.5

and others, additional screening criteria, and data from comparative studies to determine the extent and possible effects of contamination detected within sediments collected from the South Canadian River.

In defining criteria, the Ontario Ministry of the Environment (OME) considers the lowest effects level (LEL) to indicate a level of sediment contamination that is non-toxic to the majority of benthic organisms whereas the severe effect level (SEL) is indicative of contaminated sediments that would be detrimental to a majority of benthic organisms (Persaud *et al.*, 1993). In comparison, according to Long *et al*. (1995), the effects range-low (ER-L) of a detected chemical represents the lower 10th percentile of toxicological effects data for that specific chemical, whereas the effects range-median (ER-M) represents the toxicological effects data for the chemical at the 50th percentile. Concentrations detected below the ER-L represent a value where minimal effects would be expected, whereas concentrations detected at or above the ER-L but below the ER-M, represent a possible effects range (Long *et al.*, 1995). Concentrations detected at or above the ER-M represent a probable effects range where adverse toxicological effects would frequently occur (Long *et al.*, 1995). In a consensus based approach towards evaluating screening criteria in sediments, Macdonald *et al*. (2000) state that the threshold effect concentration (TEC) for a contaminant in sediments is the concentration below which adverse effects are not expected, whereas the probable effect concentration (PEC) is the level above which adverse effects would likely occur. As with the OME LEL and SEL values, ER-L, ER-M, TEC, and PEC values are non-regulatory sediment screening criteria that can be used to assess the degree of contamination in a given area (Persaud *et al.*, 1993; Long *et al.*, 1995; Macdonald *et al*., 2000).

Of the 19 metallic analytes, cadmium, mercury, molybdenum, and selenium concentrations were not

Table 8A. Results of metals and TPH analyses in mg/kg dry weight for sediment samples collected from six sites on the South Canadian River (CR1 - CR6) during high flow conditions in April, 2001 (Note bdl is below the analytical detection limit).

Analyte	Detection Limit	CR1	CR2	CR3	CR4	CR5	CR6
TPH	★	3.37	2.52	63.80	1.85	bdl	4.40
Aluminum	10.00	404.00	497.00	16,242.00	2,064.00	1,673.00	1,980.00
Arsenic	0.50	0.71	0.89	8.11	1.40	2.20	3.08
Barium	1.00	42.90	32.30	174.00	79.20	92.00	123.00
Beryllium	0.20	bdl	bdl	1.29	bdl	bdl	bdl
Boron	10.00	bdl	bdl	21.10	bdl	bdl	bdl
Cadmium	0.20	bdl	bdl	bdl	bdl	bdl	bdl
Chromium	1.00	2.82	4.17	35.20	6.92	7.23	7.30
Copper	1.00	bdl	bdl	18.40	bdl	1.70	2.57
Iron	10.00	1,143.00	1,554.00	18,899.00	2,878.00	2,835.00	4,569.00
Lead	5.00	bdl	bdl	9.07	bdl	bdl	bdl
Magnesium	10.00	445.00	671.00	29,027.00	1,857.00	1,670.00	1,426.00
Manganese	5.00	55.30	194.00	449.00	209.00	316.00	408.00
Mercury	0.20	bdl	bdl	bdl	bdl	bdl	bdl
Molybdenum	5.00	bdl	bdl	bdl	bdl	bdl	bdl
Nickel	5.00	bdl	bdl	21.50	bdl	bdl	bdl
Selenium	1.00	bdl	bdl	bdl	bdl	bdl	bdl
Strontium	5.00	16.00	23.40	129.00	48.30	84.30	82.10
Vanadium	1.00	2.31	2.53	32.70	5.60	7.41	8.08
Zinc	5.00	9.33	11.10	60.30	15.10	16.30	14.00

★Detection limits for TPH: CR1 = 1.14 mg/kg CR2 = 1.17 mg/kg CR3 = 1.81 mg/kg CR4 = 1.17 mg/kg CR5 = 1.16 mg/kg CR6 = 1.21 mg/kg

Table 8B. Results of TPH and metals analyses in mg/kg dry weight for sediment samples collected from six sites on the South Canadian River (CR1 - CR6) during low flow conditions in August, 2001 (Note - bdl is below the analytical detection limit).

Analyte	Detection Limit	CR1	CR2	CR3	CR4	CR5	CR6
TPH	★	6.35	4.17	45.40	2.18	2.34	4.19
Aluminum	10.00	577.00	912.00	17,921.00	1,140.00	2,117.00	2,333.00
Arsenic	0.50	0.68	0.96	7.50	1.01	1.66	3.69
Barium	1.00	27.10	35.10	147.00	70.50	67.40	170.00
Beryllium	0.20	bdl	bdl	1.38	bdl	bdl	0.22
Boron	10.00	bdl	bdl	28.50	bdl	bdl	bdl
Cadmium	0.20	bdl	bdl	bdl	bdl	bdl	bdl
Chromium	1.00	2.75	28.20	32.30	5.14	6.60	9.52
Copper	1.00	bdl	13.50	18.10	bdl	1.24	2.98
Iron	10.00	1,269.00	1,670.00	20,556.00	1,535.00	2,521.00	4,678.00
Lead	5.00	bdl	bdl	8.61	bdl	bdl	bdl
Magnesium	10.00	524.00	986.00	29,716.00	1,326.00	1,619.00	1,659.00
Manganese	5.00	53.00	248.00	398.00	161.00	232.00	437.00
Mercury	0.20	bdl	bdl	bdl	bdl	bdl	bdl
Molybdenum	5.00	bdl	bdl	bdl	bdl	bdl	bdl
Nickel	5.00	bdl	54.60	18.70	bdl	bdl	bdl
Selenium	1.00	bdl	bdl	bdl	bdl	bdl	bdl
Strontium	5.00	19.40	24.60	102.00	35.30	50.40	102.00
Vanadium	1.00	2.62	3.18	34.30	3.50	5.59	8.62
Zinc	5.00	12.00	9.59	45.80	7.98	8.32	14.40

★Detection limits for TPH: CR1 = 0.0006 mg/kg CR3 = 0.0007 mg/kg CR5 = 0.0006 mg/kg
CR2 = 0.0007 mg/kg CR4 = 0.0006 mg/kg CR6 = 0.0006 mg/kg

Table 9. Results of organochlorine analyses in mg/kg dry weight for sediment samples collected from six sites on the South Canadian River (CR1 - CR6) during low flow conditions in August, 2001 (Note - dl is the analytical detection limit; and bdl is below the analytical detection limit).

Analyte	CR1	CR2	CR3	CR4	CR5	CR6
1,2,3,4-tetrachlorobenzene	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
1,2,4,5-tetrachlorobenzene	0.00038	0.00026	0.00052	0.00038	0.00042	0.00015
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
aldrin	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
HCB	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
heptachlor	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
total PCB	bdl	bdl	0.02220	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
αBHC	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
αchlordane	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
βBHC	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
cis-nonachlor	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
δBHC	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
dieldrin	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
endosulfan II	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
endrin	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
γBHC	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
γchlordane	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
heptachlor epoxide	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
mirex	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
o,p'-DDD	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
o,p'-DDE	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
o,p'-DDT	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
oxychlordane	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
p,p'-DDD	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
p,p'-DDE	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
p'p'-DDT	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
pentachloro-anisole	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
toxaphene	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015
trans-nonachlor	bdl	bdl	bdl	bdl	bdl	bdl
dl	0.00015	0.00017	0.00017	0.00015	0.00015	0.00015

detected above the analytical detection limits in any of the sediment samples collected from the six sites during either sampling period. Of the six sites sampled, CR3 (upstream of SH 152 in Hutchinson County, Texas) consistently contained the highest metals concentrations. This is probably attributed to the sediment composition at this site. Sediment samples collected from CR3 were the only sediments that contained appreciable amounts of clays and silts which typically bind metals more readily than sediments dominated (greater than 90%) by sands. Of the 28 organochlorine compounds analyzed for during the low flow sampling phase, only two, 1,2,4,5-tetrachlorobenzene and total PCBs, were detected above the analytical detection limits. Detectable concentrations of 1,2,4,5-tetrachlorobenzene were measured in sediments collected from all six sites, while a total PCB concentration above the analytical detection limit was measured only at one site, CR3. Following are the individual constituents which were detected in one or more of the sediment samples collected during the sampling periods.

[Total Petroleum Hydrocarbons (TPH)] Total petroleum hydrocarbons refers to the sum of total purgeable and extractable petroleum hydrocarbons present in a given sample medium (CCME, 1997). The TPH analysis includes several hundred hydrocarbons of petroleum origin that can be broadly categorized as aliphatic and aromatic hydrocarbons (TNRCC, 2001). This analysis is a relatively inexpensive screening mechanism that is useful in determining the possible presence of petroleum contamination (TNRCC, 1995). With the exception of site CR3 (upstream of SH 152 in Hutchinson County, Texas), all detected TPH concentrations were less than 10.0 mg/kg dry weight. The detected concentrations at CR3 (63.80 mg/kg dry weight during the high flow phase and 45.40 mg/kg dry weight in the low flow phase) were less than 100.0 mg/kg, an acceptable TPH level in soils at a sensitive site [Canadian Council of Ministers of the Environment (CCME), 1997]. The CCME defines a sensitive site as an area where there exists an imminent threat to public health or safety; all residential and agricultural areas; areas which have the potential of contaminating private, municipal, or industrial water supply sources; and areas within the boundaries of a protected water supply or ecological reserve (1997). Though indicative of petroleum contamination, possibly even associated with past oil spills that occurred in the area (Glass, personal communication, 2002), the detected TPH concentrations were below levels where any adverse effect to wildlife would likely occur.

[Aluminum (Al)] Approximately 8.1% of the Earth's crust is composed of aluminum (Miller and Gardiner, 1998). Background surface soil concentrations in the western U.S. can range up to 74,000 mg Al/kg (Shacklette and Boerngen, 1984) while a soils concentration of 30,000 mg Al/kg is considered background in the State of Texas (TNRCC, 2001). According to the National Oceanic and Atmospheric Administration (NOAA) the Threshold Effects Level (TEL) for aluminum in freshwater sediments is 25,500 mg Al/kg dry weight (Buchman, 1999). Detected sediment-aluminum concentrations during high flow conditions measured on the South Canadian River in 2001 ranged from 404 mg Al/kg to 16,242 mg Al/kg dry weight, while detected aluminum concentrations during the low flow phase ranged from 577 mg Al/kg to 17,921 mg Al/kg dry weight. Site CR3 (upstream of SH 152 in Hutchinson County, Texas) contained the highest aluminum concentrations during both sampling phases. The sediment-aluminum concentrations at CR3 exceeded the highest sediment-aluminum concentration (14,900 mg Al/kg dry weight) detected by USFWS personnel at Tierra Blanca Creek in 1987 (Irwin and Dodson, 1991), but were below the lowest concentration (17,939 mg Al/kg dry weight) measured by USFWS personnel in bed sediments at Buffalo Lake National Wildlife Refuge in 1993 (Baker *et al.*, 1998) and the TEL recommended by NOAA. Based on these comparisons, the detected aluminum concentrations appear to be more attributable to the aluminum content in the surrounding soils rather than to residual contamination associated with discharges from anthropogenic sources.

[Arsenic (As)] Arsenic compounds have been widely used in agriculture as insecticides and herbicides (Richardson *et al.*, 1978). In cotton production, arsenic compounds have been used as defoliants, post-emergence herbicides, boll weevil insecticides, and as desiccants to facilitate harvesting (Richardson *et al.*, 1978; Pennington, 1991). According to Shacklette and Boerngen (1984), the estimated arithmetic mean for background elemental arsenic concentrations in surface soils in the western U.S. is 7.0 mg As/kg. Pennington (1991) reported soil-arsenic concentrations ranging up to 13.36 mg As/kg in Potter County, Texas and a maximum soil concentration of 6.83 mg As/kg in Moore County, Texas. Elemental arsenic is insoluble in water, whereas many arsenic species are highly soluble in freshwater (Schneider, 1971). Common arsenic species include arsenate, arsenite, methanearsonic acid, and dimethyl arsenic acid (USEPA, 1980). In aerobic waters, reduced forms of arsenic tend to be oxidized into arsenates (USEPA, 1980). In turn, the adsorption of arsenate by metal oxides and the formation of arsenic sulfide appears to remove arsenic from the water column, binding it to the sediments, and preventing high concentrations of arsenic being present in solution (USEPA, 1980). The OME suggest a sediment LEL of 6.0 mg As/kg dry weight and a sediment SEL of 33.0 mg As/kg dry weight (Persaud *et al.*, 1993), while Long *et al.* (1995), consider 8.2 mg As/kg dry weight as the ER-L for arsenic in sediments. MacDonald *et al.* (2000), recommend a sediment TEC of 9.79 mg As/kg dry weight and a sediment PEC of 33.0 mg As/kg dry weight. According to the TNRCC (1996), the 85th percentile screening criterion protective of aquatic wildlife for arsenic in sediments in the Canadian River below Meredith Reservoir is 6.9 mg As/kg dry weight. All six sites sampled on the South Canadian River during both high flow and low flow conditions in 2001 contained sediments with detectable arsenic concentrations. Of the six sites, only one site, CR3 which was upstream of SH 152 in Hutchinson County, Texas), contained an appreciable sediment-arsenic levels (8.11 mg As/kg dry weight during high flow and 7.50 mg As/kg dry weight during low flow) that exceeded the OME LEL and the screening criterion recommended by the TNRCC to be protective of aquatic wildlife in the Canadian River downstream of Meredith Reservoir. Though elevated at this site, the detected concentrations were still below levels where significant adverse effects to aquatic organisms would be expected (i.e. less than the SEL and PEC values).

[Barium (Ba)] Barium compounds are used in a variety of industrial applications. In nature, barium chiefly occurs as the relatively insoluble salts, barite and witherite (USEPA, 1986). Shacklette and Boerngen (1984) reported an estimated arithmetic mean of 670 mg Ba/kg as background for soils in the western U.S. while a soils concentration of 300 mg Ba/kg is considered background in the State of Texas (TNRCC, 2001). According to the TNRCC (1996), the 85th percentile screening criterion protective of aquatic wildlife in sediments of the Canadian River below Meredith Reservoir is 189 mg Ba/kg dry weight. Sediments collected from all six sites on the South Canadian River during both sampling phases in 2001 contained detectable barium concentrations. During high flow conditions, the detected concentrations ranged from 32.3 mg Bal/kg to 174 mg Ba/kg dry weight, while during the low flow phase, the measured concentrations ranged from 27.1 mg Ba/kg to 170 mg Ba/kg dry weight. All of these concentrations were below any level where adverse effects to aquatic organisms would be expected to occur.

[Beryllium (Be)] Although not truly a heavy metal, beryllium is a rare element that is considered potentially toxic (Irwin and Dodson, 1991; Manahan, 1991). The distribution of beryllium in the environment largely results from the combustion of coal and oil (Goyer, 1991; Manahan, 1991). Coal mined from the mid-west U.S. contains an average of about 2.5 mg Be/kg while crude oil can contain approximately 0.08 mg Be/kg (Goyer, 1991). Beryllium concentrations in soils in the U.S. can range up to 15.0 mg Be/kg (Shacklette and Boerngen, 1984), however according to Shacklette and Boerngen (1984), the estimated arithmetic mean for background beryllium concentrations in soils in the western U.S.

is 0.97 mg Be/kg. In the State of Texas, a beryllium-soils concentration of 1.5 mg Be/kg is considered background (TNRCC, 2001). Irwin and Dodson (1991) state that in the absence of a known source, water in lotic systems usually contains very low or non-detectable concentrations of beryllium. Sediment-beryllium concentrations were detected above the analytical detection limits at only one site, CR3 (upstream of SH 152 in Hutchinson County, Texas), during high flow conditions in 2001 and at two sites, CR3 and CR6 (upstream of SH 54 in Quay County, New Mexico), during the low flow sampling period in 2001. There is currently no freshwater criterion available for beryllium concentrations in sediments, but both of the detected concentrations at CR3 (1.29 mg Be/kg dry weight during high flow and 1.38 mg Be/kg dry weight during low flow conditions) exceeded the highest sediment-beryllium concentration (1.2 mg Be/kg dry weight) detected by USFWS personnel at Tierra Blanca Creek in 1987 (Irwin and Dodson, 1991), the highest beryllium concentration (1.25 mg Be/kg dry weight) measured in bed sediments collected by USFWS personnel from Buffalo Lake National Wildlife Refuge in 1993 (Baker *et al.*, 1998), and the highest concentration (1.2 mg Be/kg dry weight) detected by USFWS personnel in 1991 at Big Mineral Creek down gradient from a historical crude oil spill in Hagerman National Wildlife Refuge which is located in the Red River watershed in Grayson County, Texas (Baker *et al.*, 1995). However, in comparison to additional surface water bodies in the Texas Panhandle, the concentrations detected at CR3 were below the sediment-beryllium concentrations ($\bar{X}$ = 1.57 mg Be/kg dry weight) measured at three undisturbed playas by USFWS personnel in 1990 (Irwin *et al.*, 1996). It is understood that playas typically function more as seasonal lentic environments rather than lotic systems, but assuming that the constituents contained within the bed sediments in these playas are reflective of the surrounding watershed and considering that these playas received no influent or discharges from any known anthropogenic sources other than through aerial deposition (Irwin *et al.*, 1996), the bed sediments within these playas should contain elements which are characteristic of the surrounding soils. Based on this comparison and considering the high clay and silt content at CR3, the detected concentrations at this site may be attributed more to local beryllium-soil concentrations rather than to residual contamination associated with anthropogenic discharges.

[Boron (B)] Boron compounds are used in the production of fertilizers and other agricultural chemicals such as herbicides and insecticides (Moore *et al.*, 1990; USDOI, 1998). In the U.S., boron concentrations in soils typically range from 10-300 mg B/kg (USDOI, 1998). According to Shacklette and Boerngen (1984), the estimated arithmetic mean for background boron concentrations in western soils is 29 mg B/kg while a soils concentration of 30 mg B/kg is considered background in the State of Texas (TNRCC, 2001). Usually, arid, saline soils will contain higher boron concentrations in comparison to watered, loamy soils (USDOI, 1998). Furthermore, soils formed from marine sediments typically contain higher concentrations of boron than those formed from igneous rocks (Moore *et al.*, 1990). In aquatic systems, boron can react and bind with clays, suspended matter, and sediments (USDOI, 1998). Eisler (1990) reports that freshwater sediments with a high clay composition usually contain less than 10.0 mg B/kg dry weight. During both sampling periods conducted on the South Canadian River in 2001, sediment-boron concentrations were detected above the analytical detection limit at only one site (CR3 which was upstream of SH 152 in Hutchinson County, Texas). As with beryllium, there is currently no freshwater criterion for boron concentrations in sediments, but the detected concentrations at CR3 (21.1 mg B/kg dry weight and 28.5 mg B/kg dry weight during high flow and low flow conditions, respectively) were well below the highest sediment-boron concentration (54.3 mg B/kg dry weight) measured in bed sediments collected by USFWS personnel from Buffalo Lake National Wildlife Refuge in 1993 (Baker *et al.*, 1998), and below the maximum concentration (75.1 mg B/kg dry weight) detected by USFWS personnel in bed sediments of an undisturbed playa in the Texas Panhandle in 1990 (Irwin *et al.*, 1996).

[Chromium (Cr)] Chromium compounds are widely used in industrial and agriculture operations, including metallurgy, the production of fertilizers, and in tanning solutions (Eisler, 1986). Shacklette and Boerngen (1984) reported an estimated arithmetic mean of 56 mg Cr/kg as background for soils in the western U.S., while a chromium-soils concentration of 30 mg Cr/kg can be considered background in the State of Texas (TNRCC, 2001). In freshwater systems, hydrolysis and precipitation are more important physical processes in determining the fate of chromium in comparison to adsorption and bioaccumulation (Eisler, 1986). According to Eisler (1986), the majority of chromium bound in sediments is unavailable for living organisms. Molluscs accumulate chromium from contaminated sediments at comparatively low concentrations (Eisler, 1986). The OME suggest a LEL of 26 mg Cr/kg dry weight and a SEL of 110 mg Cr/kg dry weight for chromium in sediments (Persaud *et al.*, 1993), whereas MacDonald *et al.* (2000), recommend a sediment TEC of 43.4 mg Cr/kg dry weight and a PEC of 111 mg Cr/kg dry weight. The 85th percentile screening criterion recommended by the State of Texas to be protective of aquatic wildlife for the Canadian River below Meredith Reservoir is 20 mg Cr/kg dry weight (TNRCC, 1996). All sites sampled on the Canadian River in 2001 during both sampling phases contained detectable amounts of chromium. Of these sites, the measured concentration (35.2 mg Cr/kg dry weight) at CR3 (upstream of SH 152 in Hutchinson County, Texas) during the high flow phase and the detected concentrations at CR2 (upstream of SH 70 in Roberts County, Texas) and CR3 (28.2 mg Cr/kg dry weight and 32.3 mg Cr/kg dry weight, respectively) during the low flow sampling phase contained sediment-chromium concentrations which exceeded lower threshold screening criteria. Although slightly elevated, these concentrations were still below levels where significant adverse effects to aquatic organisms would be expected to occur.

[Copper (Cu)] Copper compounds are widely used in biocides, agricultural fertilizers, and in veterinary products (Eisler, 1998a). According to Shacklette and Boerngen (1984), the estimated arithmetic mean for background copper concentrations in surface soils in the western U.S. is 27.0 mg Cu/kg while a soils concentration of 15 mg Cu/kg is considered background in the State of Texas (TNRCC, 2001). In surface water, the solubility of copper and copper salts is decreased under reducing conditions and is further modified by pH, temperature, and hardness; size and density of suspended materials; rates of coagulation and sedimentation of particulates; and concentration of dissolved organics (Eisler, 1998a). Copper concentrations in sediment interstitial pore waters correlate positively with concentrations of dissolved copper in the overlying water column (Eisler, 1998a). Typically, sediment bound copper is available to benthic organisms under anoxic and low pH conditions (Eisler, 1998a). The OME recommends a sediment LEL of 16 mg Cu/kg dry weight and a SEL of 110 mg Cu/kg dry weight (Persaud *et al.*, 1993), whereas Long *et al.* (1995), consider 34 mg Cu/kg dry weight as the ER-L for copper in sediments. MacDonald *et al.* (2000), suggest a sediment TEC of 31.6 mg Cu/kg dry weight and a PEC of 149 mg Cu/kg dry weight. According to the TNRCC (1996), the 85th percentile screening criterion protective of aquatic wildlife in sediments of the Canadian River below Meredith Reservoir is 19.2 mg Cu/kg dry weight. Sediment-copper concentrations were detected above the analytical detection limits at three sites (CR3, CR5, and CR6) during high flow conditions in 2001 and at four sites (CR2, CR3, CR5, and CR6) during the low flow sampling period in 2001. Of the detected concentrations, only one site (CR3 which was upstream of SH 152 in Hutchinson County, Texas), contained sediment-copper concentrations (18.40 mg Cu/kg dry weight and 18.10 mg Cu/kg dry weight during high flow and low flow conditions, respectively) which exceeded any of the recommended lower threshold levels. However, these concentrations were still below levels where significant adverse effects to aquatic organisms would be expected to occur.

[Iron (Fe)] Iron composes approximately 5% of the Earth's crust (Miller and Gardiner, 1998). Background iron concentrations in surface soils in the western U.S. range up to 26,000 mg Fe/kg

(Shacklette and Boerngen, 1984). In Texas, median background iron-soils concentrations can range up to 15,000 mg Fe/kg (TNRCC, 2001). Under normal oxidizing conditions in freshwater, ferric iron predominates over ferrous iron, and in turn, ferric iron forms insoluble compounds that rapidly disassociate from the water column and drop to the sediments (Horne and Goldman, 1994). The OME recommends a LEL of 20,000 mg Fe/kg dry weight and a SEL of 40,000 mg Fe/kg dry weight for iron in sediments (Persaud *et al.*, 1993). According to Beyer (1990), sediments from the Great Lakes containing less than 17,000 mg Fe/kg dry weight are considered non-polluted, whereas sediments containing iron concentrations greater than 25,000 mg Fe/kg dry weight are considered extremely polluted. Though high at site CR3 (upstream of SH 152 in Hutchinson County, Texas) the detected iron concentrations (18,899 mg Fe/kg dry weight and 20,556 mg Fe/kg dry weight during high flow and low flow conditions respectively) were below levels where significant adverse effects to aquatic organisms would be expected to occur.

[Lead (Pb)] Lead compounds are widely used in industrial and agriculture operations. Pennigton (1991) states that lead arsenate is the most extensively used arsenical insecticide. According to Shacklette and Boerngen (1984), the estimated arithmetic mean for background lead concentrations in surface soils in the western U.S. is 20 mg Pb/kg while a soils concentration of 15 mg Pb/kg is considered background in the State of Texas (TNRCC, 2001). The deposition of lead to sediments in aqueous environments is attributed primarily to the strong binding capacities of many sediment components for metals (Pain, 1995). In turn, lead concentrations in aquatic plants have been directly correlated with sediment lead concentrations (Pain, 1995). The OME suggests a sediment LEL of 31 mg Pb/kg dry weight and a SEL of 250 mg Pb/kg dry weight (Persaud *et al.*, 1993), while Long *et al.* (1995), consider 47 mg Pb/kg dry weight as the ER-L for lead in sediments. MacDonald *et al.* (2000), suggest a sediment TEC of 35.8 mg Pb/kg dry weight and a PEC of 128.0 mg Pb/kg dry weight. The TNRCC recommends a lead-sediment screening criterion in the Canadian River below Meredith Reservoir of 40.0 mg Pb/kg dry weight. During both sampling phases conducted at the South Canadian River in 2001, lead was detected above the analytical detection limit only at one site (CR3 which was upstream of SH 152 in Hutchinson County, Texas), and these detected values (9.07 mg Pb/kg dry weight during high flow and 8.61 mg Pb/kg dry weight during low flow) were well below any of the proposed criteria or screening levels protective of aquatic wildlife.

[Magnesium (Mg)] Magnesium is widely used for a variety of purposes in industrial and agriculture applications and like many metals, is a component of fossil fuels. West Texas Intermediate Crude contains approximately 24.7 mg Mg/L (ETC, 2000). The Earth's crust is composed of approximately 2.1% magnesium (Miller and Gardiner, 1998). Along with calcium, magnesium is one of the two most common polyvalent metallic ions in freshwater (Irwin and Dodson, 1991). Shacklette and Boerngen (1984), estimate the arithmetic mean for background magnesium concentrations in surface soils in the western U.S. as 10,000 mg Mg/kg. Magnesium was detected above the analytical detection limits at all six sites during both sampling periods conducted on the South Canadian River in 2001. The highest sediment-magnesium concentrations were detected at CR3 (upstream of SH 152 in Hutchinson County, Texas). As with beryllium and boron, there is currently no freshwater criterion for magnesium concentrations in sediments, but both of the detected concentrations at CR3 (29,027 mg Mg/kg dry weight during high flow and 29,716 mg Mg/kg dry weight during low flow conditions) exceeded the highest sediment-magnesium concentration (19,100 mg Mg/kg dry weight) detected by USFWS personnel at Tierra Blanca Creek in 1987 (Irwin and Dodson, 1991), the highest concentration (16,267.83 mg Mg/kg dry weight) measured by USFWS personnel in bed sediments at Buffalo Lake National Wildlife Refuge in 1993 (Baker *et al.*, 1998), and the highest concentration (5,930 mg Mg/kg dry weight) measured by USFWS personnel in bed sediments of

undisturbed playa in the Texas Panhandle in 1990 (Irwin *et al.*, 1996). However, the concentrations detected at CR3 were well less than the highest concentration (53,100 mg Mg/kg dry weight) detected by USFWS personnel in 1990 from bed sediments of a saline playa located in the Texas Panhandle (Irwin *et al.*, 1996). Consequently, the high magnesium levels detected at CR3 may be attributed to the elevated salinity that naturally occurs within the South Canadian River watershed, rather than the influence of anthropogenic sources.

[Manganese (Mn)] Manganese is a widely distributed, abundant element that constitutes approximately 0.085% of the earth's crust and is used in various industrial and agricultural applications (Irwin and Dodson, 1991). According to Shacklette and Boerngen (1984), the estimated arithmetic mean for background manganese concentrations in surface soils in the western U.S. is 480 mg Mn/kg while a soils concentration of 300 mg Mn/kg is considered background in the State of Texas (TNRCC, 2001). The OME recommends a LEL of 460 mg Mn/kg dry weight and a SEL of 1,100 mg Mn/kg dry weight in sediments (Persaud *et al.*, 1993). The 85th percentile screening criterion protective of aquatic wildlife for manganese concentrations in sediments in the Canadian River below Lake Meredith in Texas is 490 mg Mn/kg dry weight (TNRCC, 1996). Sediments from the Great Lakes containing less than 300 mg Mn/kg dry weight are considered non-polluted, whereas sediments containing manganese concentrations greater than 500 mg Mn/kg dry weight are considered heavily polluted (Beyer, 1990). Irwin and Dodson (1991) reported a maximum sediment-manganese concentration of 420 mg Mn/kg dry weight in Tierra Blanca Creek in 1987. The detected manganese concentrations in sediments collected from the South Canadian River in 2001 during both sampling phases [maximum value of 449 mg Mn/kg dry weight at CR3 (upstream of SH 152 in Hutchinson County, Texas) during high flow conditions and a maximum concentration of 437 mg Mn/kg dry weight at CR6 (upstream of SH 54 in Quay County, New Mexico)] during low flow conditions) were below any level where adverse effects to aquatic organisms would be expected to occur.

[Nickel (Ni)] Nickel is used in electroplating, the production of metallic alloys, as a component of fungicides, and as a catalyst for the hydrogenation of oils (Merck, 1989; Eisler, 1998b). Nickel is also a component of fossil fuels (Eisler, 1998b). West Texas Intermediate Crude contains approximately 18.8 mg Ni/L (ETC, 2000). Background surface soil-nickel concentrations in the western U.S. range up to 19 mg Ni/kg and up to 10 mg Ni/kg in Texas (Shacklette and Boerngen, 1984; TNRCC, 2001). In aquatic systems, nickel occurs as soluble salts adsorbed onto clay particles and organic matter (Eisler, 1998b). The fate of nickel in an aqueous environment can be affected by pH, ionic strength, and availability of solid surfaces for adsorption (Eisler, 1998b). Sediments from the Canadian River below Meredith Reservoir in Texas have been documented to contain elevated levels of nickel (TNRCC, 1996). The OME recommends a sediment LEL of 16 mg Ni/kg dry weight and a SEL of 75 mg Ni/kg dry weight (Persaud *et al.*, 1993), whereas Long *et al.* (1995), recommend 21 mg Ni/kg dry weight as the ER-L for nickel in sediments. MacDonald *et al.* (2000), suggest a sediment TEC of 22.7 mg Ni/kg dry weight and a sediment PEC of 48.6 mg Ni/kg dry weight. The 85th percentile screening criterion recommended by the State of Texas to be protective of aquatic wildlife for the Canadian River below Meredith Reservoir is 15 mg Ni/kg dry weight (TNRCC, 1996). During high flow conditions, nickel was detected above the analytical detection limit only at one site, CR3 (upstream of SH 152 in Hutchinson County, Texas), and at two sites, CR2 (upstream of SH 70 in Roberts County, Texas) and CR3, during the low flow sampling phase. The detected concentrations at CR3 (21.5 mg Ni/kg dry weight during the high flow phase and 18.7 mg Ni/kg dry weight during low flow) exceeded lower threshold screening criteria, whereas the detected concentration at CR2 (54.6 mg Ni/kg dry weight) not only exceeded these lower threshold criteria but also exceeded the PEC value recommended by MacDonald *et al.* (2000). Although slightly elevated

at CR3, the nickel concentrations at this site probably do not represent a concern for wildlife resources since nickel is readily bound to clay. In contrast, considering the predominance of sand at CR2, the detected nickel concentration at CR2 could represent a potential threat to wildlife resources and further monitoring at this site may be warranted.

[Strontium (Sr)] Strontium compounds are used in the manufacturing of pyrotechnics, the production of glass and ceramics, and sugar refining (Merck, 1989). Strontium is a fairly common alkaline earth metal (Irwin and Dodson, 1991). According to Shacklette and Boerngen (1984), the estimated arithmetic mean for background strontium concentrations in western soils in the U.S. is 270 mg Sr/kg while a soils concentration of 100 mg Sr/kg is considered background in the State of Texas (TNRCC, 2001). In localities where it is abundant, like calcium, strontium is an important freshwater quality ion that contributes to water hardness (Irwin and Dodson, 1991). NOAA considers 49 mg Sr/kg dry weight to be the background level for strontium in freshwater sediments (Buchman, 1999). Strontium was detected above the analytical detection limits at all six sites during both sampling periods conducted on the South Canadian River in 2001. The highest sediment-strontium concentrations were detected at CR3 (upstream of SH 152 in Hutchinson County, Texas). Both of the detected concentrations at CR3 (129 mg Sr/kg dry weight during high flow and 102 mg Sr/kg dry weight during low flow conditions) exceeded the background concentration recommended by NOAA, but these concentrations were below 130 mg Sr/kg dry weight, which according to Irwin and Dodson (1987), was the concentration above which sediment in Tierra Blanca Creek had a likelihood of being contaminated by run-off from CAFOs. In addition, the detected concentrations at CR3 were below the average concentration measured in 1990 by USFWS personnel in bed sediments collected from four CAFO playas ($\bar{X}$ = 167.5 mg Sr/kg dry weight) and three saline playas ($\bar{X}$ = 243.67 mg Sr/kg dry weight) in the Texas Panhandle (Irwin *et al.*, 1996). Based on these comparisons, it appears that the strontium levels detected in sediments at CR3 are more likely a reflection of the surrounding natural soil chemistry rather than to the influence of anthropogenic sources.

[Vanadium (V)] Vanadium compounds are used in the production of rust-resistant metals, the manufacturing of glass, and as catalysts in the distillation of alcohols (Merck, 1989). Vanadium is a component of pigments used in dyeing and printing fabrics and is also a component of fossil fuels (Merck, 1989; ETC, 2000). West Texas Intermediate Crude contains approximately 3.2 mg V/L (ETC, 2000). Approximately 0.01% of the Earth's crust is composed of vanadium (Merck, 1989). Vanadium concentrations in soils in the U.S. can range up to 500 mg V/kg (Shacklette and Boerngen, 1984). The estimated arithmetic mean for background vanadium concentrations in western soils in the U.S. according to Shacklette and Boerngen (1984), is 88 mg V/kg while a soils concentration of 50 mg V/kg is considered background in the State of Texas (TNRCC, 2001). Vanadium was detected above the analytical detection limits at all six sites during both sampling periods conducted on the South Canadian River in 2001. The highest sediment-vanadium concentrations were detected at CR3 (upstream of SH 152 in Hutchinson County, Texas). Both of the detected concentrations at CR3 (32.7 mg V/kg dry weight during high flow and 34.3 mg V/kg dry weight during low flow conditions) exceeded the highest sediment-vanadium concentration (22 mg V/kg dry weight) detected by USFWS personnel at Tierra Blanca Creek in 1987 (Irwin and Dodson, 1991), but were below the lowest concentration (35.41 mg V/kg dry weight) measured by USFWS personnel in bed sediments at Buffalo Lake National Wildlife Refuge in 1993 (Baker *et al.*, 1998) and below the average concentration ($\bar{X}$ = 43.78 mg V/kg dry weight) detected by USFWS personnel in bed sediments of undisturbed playas in the Texas Panhandle in 1990 (Irwin *et al.*, 1996). In addition, the measured vanadium concentrations at CR3 were below 50 mg V/kg dry weight, which is the value considered by the NOAA to be the background value for vanadium in freshwater sediments

(Buchman, 1999).

[Zinc (Zn)] Zinc compounds are widely used in industrial and agricultural operations. Zinc is a common additive in many livestock feeds. Shacklette and Boerngen (1984), estimate the arithmetic mean for background zinc concentrations in surface soils in the western U.S. at 65 mg Zn/kg. In Texas, median background zinc-soils concentrations can range up to 30 mg Zn/kg (TNRCC, 2001). According to Eisler (1993), the majority of zinc introduced into an aquatic environment is partitioned into the sediment. Bioavailability of zinc from sediments is enhanced under conditions of high dissolved oxygen, low salinity, low pH, and high levels of inorganic oxides and humic substances (Eisler, 1993). In sediments, zinc concentrations less than 90 mg Zn/kg dry weight are considered supportive of aquatic biota, whereas zinc concentrations greater than 200 mg Zn/kg dry weight are harmful to aquatic biota (Eisler, 1993). The OME recommends a sediment LEL of 120 mg Zn/kg dry weight and a SEL of 820 mg Zn/kg dry weight (Persaud *et al.*, 1993), while Long *et al.* (1995), consider 150 mg Zn/kg dry weight as the ER-L for zinc in sediments. MacDonald *et al.* (2000), suggest a sediment TEC of 121 mg Zn/kg dry weight and a PEC of 459 mg Zn/kg dry weight. The screening criterion protective of aquatic wildlife for zinc concentrations in sediments in the Canadian River below Lake Meredith in Texas is 83 mg Zn/kg dry weight (TNRCC, 1996). Detected sediment-zinc concentrations from the six sites ranged from 9.33 mg Zn/kg to 60.3 mg Zn/kg dry weight during the high flow phase, and from 7.98 mg Zn/kg to 45.8 mg Zn/kg dry weight during the low flow phase. All measured zinc concentrations were well below any level where adverse effects to aquatic organisms would be expected to occur.

[1,2,4,5-Tetrachlorobenzene] Listed by the USEPA as a persistent, bio-accumulative, and toxic chemical (PBT), 1,2,4,5-tetrachlorobenzene is a common component of many herbicides, insecticides, defoliants and electrical insulation fluids (Sax and Lewis, 1987; NDDH, 2002). During the low flow sampling phase this organochlorine compound was detected in sediments collected from all six sites. These detected concentrations ranged from 0.00015 mg/kg to 0.00052 mg/kg dry weight. In freshwater, the federal water quality criterion for the protection of human health through the consumption of aquatic organisms is 0.0029 mg/L (RAIS, 2002). The 85th percentile screening criterion for sediments in freshwater lotic systems in Texas is 0.67 mg/kg dry weight (TNRCC, 2000). Buchman (1999) reports a remedial target value for agricultural soils as 0.10 mg/kg for residual chlorobenzenes as a group. Though indicative of residual contamination, possibly even associated with applications of pesticides to crop-land within the watershed, the detected 1,2,4,5-tetrachlorobenzene concentrations were below screening criteria and do not appear to be at levels that represent a threat to wildlife resources.

[Total Polychlorinated Biphenyls (PCBs)] Polychlorinated biphenyls were used in electrical transformers, capacitors, heat transfer fluids, and electrical utilities as lubricants, insulators, and coolants until production was banned in 1979 (USEPA, 1994; Moring, 1997). Total PCBs represents a quantification of approximately 209 individual congeners (Moring, 1997). These congeners are relatively stable compounds that exhibit low water solubilities, high heat capacities, low flammabilities, low electric conductivities, and low vapor pressures (USEPA, 1994; Moring, 1997). During the low flow sampling phase, total PCBs were detected above the analytical detection limit at only one site, CR3 (upstream of SH 152 in Hutchinson County, Texas). The detected total PCB concentration at CR3 was 0.022 mg/kg dry weight. The source of the total PCBs found at CR3 is unknown. It is possible these PCBs may be residual contamination from past unauthorized discharges from unknown sources located upstream of the site (Winsborough, personal communication, 2002). In comparison to the detected concentration at CR3, the OME suggest a sediment LEL of 0.07 mg/kg dry weight and a SEL of 5.3 mg/kg dry weight (Persaud

et al., 1993), while Long *et al*. (1995), consider 0.05 mg/kg dry weight as the ER-L for total PCBs in sediments. MacDonald *et al*. (2000), recommend a sediment TEC of 0.06 mg/kg dry weight and a sediment PEC of 0.68 mg/kg dry weight. The detected total PCBs concentration at CR3 was below any of the recommended screening criteria for direct toxicity, even the lower threshold values, and does not appear to represent a threat to wildlife resources at this time; however, PCBs are known to bioaccumulate/biomagnify in aquatic trophic levels.

Fish

A total of 1,532 individual fish, comprising seven families and 18 species, were collected from all six sites on the South Canadian River during the high flow and low flow sampling phases in 2001. Fish species collected and their associated tolerance levels and trophic guilds are presented in Table 10 while the

Table 10. Fish species and their associated tolerance levels and trophic guilds collected from six sites on the South Canadian River during high flow and low flow conditions, 2001 (Note - I = intermediate; N = intolerant; and T = tolerant).

Family	Taxa	Common Name	Tolerance	Trophic Guild
Clupeidae	*Dorosoma cepedianum*	Gizzard shad	T	omnivore
Cyprinidae	*Campostoma anomalum*	Central stoneroller	I	herbivore
	Hybognathus placitus	Plains minnow	T	omnivore
	Hybopsis gracilis	Flathead chub	T	invertivore
	Notropis atherinoides	Emerald shiner	I	invertivore
	Notropis girardi	Arkansas River shiner	I	invertivore
	Notropis lutrensis	Red shiner	T	invertivore
	Notropis stramineus	Sand shiner	I	invertivore
	Notropis volucellus	Mimic shiner	N	invertivore
	Pimephales vigilax	Bullhead minnow	I	invertivore
Catostomidae	*Carpoides carpio*	River carpsucker	T	omnivore
Ictaluridae	*Ameriurus melas*	Black bullhead	T	omnivore
	Ictalurus punctatus	Channel catfish	T	omnivore
Cyprinodontidae	*Fundulus zebrinus*	Plains killifish	T	invertivore
Poecillidae	*Gambusia affinis*	Western mosquitofish	T	invertivore
Centrarchidae	*Lepomis cyanellus*	Green sunfish	T	piscivore
	Lepomis macrochirus	Bluegill	T	invertivore
	Micropterus salmoides	Largemouth bass	I	piscivore

Tolerance levels and trophic guilds are from Linam and Kleinsasser (1991)

number of fish collected from each site per each sampling phase are presented in Table 11. In both sampling phases, CR1 (upstream of U.S.83 in Hemphill County, Texas) contained the most fish species (nine species collected during both phases). The lowest number of species recorded at a site was one species collected at CR4 (upstream of U.S.287 in Potter County, Texas) during high flow conditions. No fish were collected at CR3 (upstream of SH 152 in Hutchinson County, Texas) during the low flow phase because of the lack of water. The average number of fish species collected per site was 5.2 (n = 6) during the high flow period and 6.8 (n = 5) during the low flow phase. At site CR1, seven of the nine species captured were collected during both sampling phases. At site CR2 (upstream of SH 70 in Roberts County, Texas) five species were collected during the high flow phase and six species were collected during the low flow phase, of these, three were collected during both phases. Seven and six species were collected at CR5 (upstream of U.S.385 in Oldham County, Texas) during the high and low flow phases, respectively. Of these, three species were collected during both phases. At CR6 (upstream of SH 54 in Quay County, New Mexico) four species were collected during the high flow phase and six species were collected during the low flow phase, of these, three were collected during both phases. The predominant trophic group collected within the entire stream during both sampling periods was insectivorus fish (Figure 10). Arkansas River shiners were collected at every site during the high flow sampling phase with the exception of site CR1; however none were collected at any of the sites during the low flow sampling phase. The most common species collected was the plains killifish (*Fundulus zebrinus*). According to Pflieger (1975), this species normally inhabits streams with alkaline or saline waters, with few other fish species present, and occupies a variety of habitats ranging from pools and backwaters to shallow sandy areas with considerable current. Other species regularly collected were the red shiner (*Notropis lutrensis*), the sand shiner (*Notropis stramineus*), and the western mosquitofish (*Gambusia affinis*). The red shiner inhabits a variety of habitats including pools, backwaters, and riffles and is tolerant of high turbidity and siltation, whereas the sand shiner is predominantly found in streams with sandy bottoms, permanent flow, moderately clear water, and low to moderate gradients (Pflieger, 1975). In many prairie streams the sand shiner is second in abundance only to the red shiner (Pflieger, 1975). Mosquitofish inhabit a wide variety of aquatic habitats and are considered one of the most abundant and widespread species in the Southwest United States (Pflieger, 1975; Etnier and Starnes, 1993).

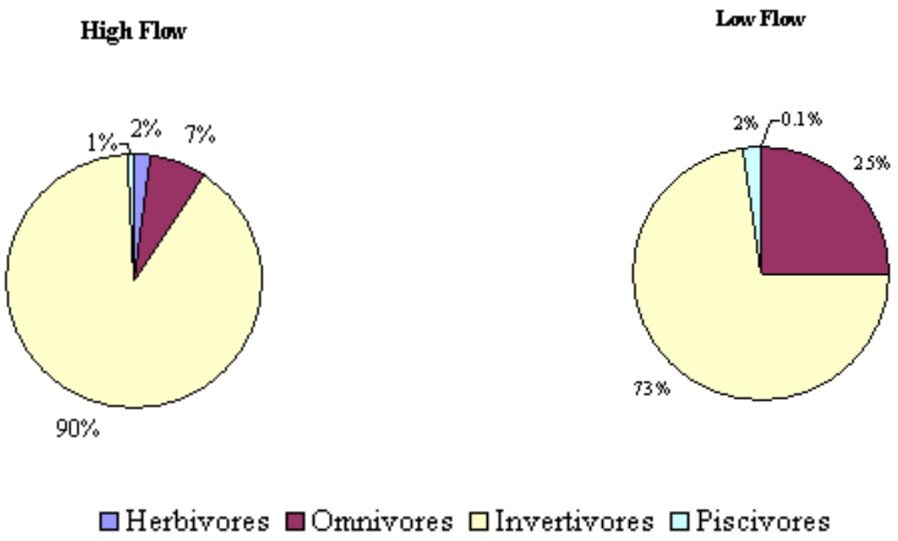
Statewide and regional indices of biotic integrity (IBI) were calculated for fish communities at each site during each sampling phase using the parameters stated in Tables 2 and 3 and are presented in Appendix B. The results of the statewide indices performed on the fish data collected during the high flow sampling period indicated that only CR1 approached an intermediate stream health category, whereas the remaining five sites were classified as limited (Figure 11). In contrast, the regional IBIs performed on the same data (Figure 12) characterized the aquatic life use at CR1 as exceptional while the remaining five sites were categorized as intermediate. At low flow conditions, the results of the Statewide IBI indicated that the fish community at CR1 was classified as intermediate, while the communities at CR2 and CR6 were classified as limited-intermediate and as limited at CR4 and CR5 (Figure 11). In contrast, the Regional IBI characterized the fish assemblages at sites CR1, CR2, CR4, and CR6 as intermediate and site CR5 as limited during the low flow phase (Figure 12). Both indices demonstrated that CR1 contained the highest aquatic life use during the two sampling phases. Both indices also indicated that overall aquatic life use values within the stream increased slightly from the high flow to low flow sampling period. This may be attributed to the different physical conditions of the stream between the high flow and low flow phases which due to the lowering of the water volume at certain sites allowed for easier capture of fish.

The predominant aquatic life use characterization of fish communities throughout the stream ranged from

Table 11. Species and number of fish collected at six sites on the South Fork Canadian River (CR1 - CR6) in 2001 during high flow (HF) and low flow (LF) conditions (Note - NC is not collected; and CR3 was not sampled during LF because of the lack of water).

Species	Sites										
	CR1 HF	CR1 LF	CR2 HF	CR2 LF	CR3 HF	CR4 HF	CR4 LF	CR5 HF	CR5 LF	CR6 HF	CR6 LF
Gizzard shad	NC	NC	NC	NC	NC	NC	NC	NC	1	NC	1
Central stonerollers	7	NC	NC	NC	NC	NC	NC	NC	NC	NC	1
Plains minnows	NC	NC	1	NC	NC	NC	240	21	59	NC	NC
Flathead chub	NC	NC	NC	NC	NC	NC	NC	1	NC	NC	NC
Emerald shiners	4	NC	NC	NC	11	NC	46	NC	4	NC	NC
Arkansas River shiners	NC	NC	36	NC	2	9	NC	6	NC	45	NC
Red shiners	2	214	5	3	NC	NC	11	15	NC	64	101
Sand shiners	21	190	11	25	20	NC	NC	1	NC	NC	NC
Mimic shiners	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	5
Bullhead minnows	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	9
River carpsuckers	NC	1	NC	NC	1	NC	NC	NC	NC	NC	NC
Black bullheads	NC	1	NC	NC	NC	NC	NC	NC	NC	NC	NC
Channel catfish	NC	NC	NC	NC	NC	NC	NC	1	1	NC	NC
Plains killifish	6	7	12	2	1	NC	5	3	1	3	3
Western mosquitofish	9	124	NC	65	NC	NC	45	NC	5	NC	7
Green Sunfish	1	4	NC	1	NC	NC	NC	NC	NC	NC	NC
Bluegill	3	3	NC	NC	NC	NC	NC	NC	NC	NC	NC
Largemouth bass	1	16	NC	6	NC	NC	NC	NC	NC	1	1

Fish



Macroinvertebrates

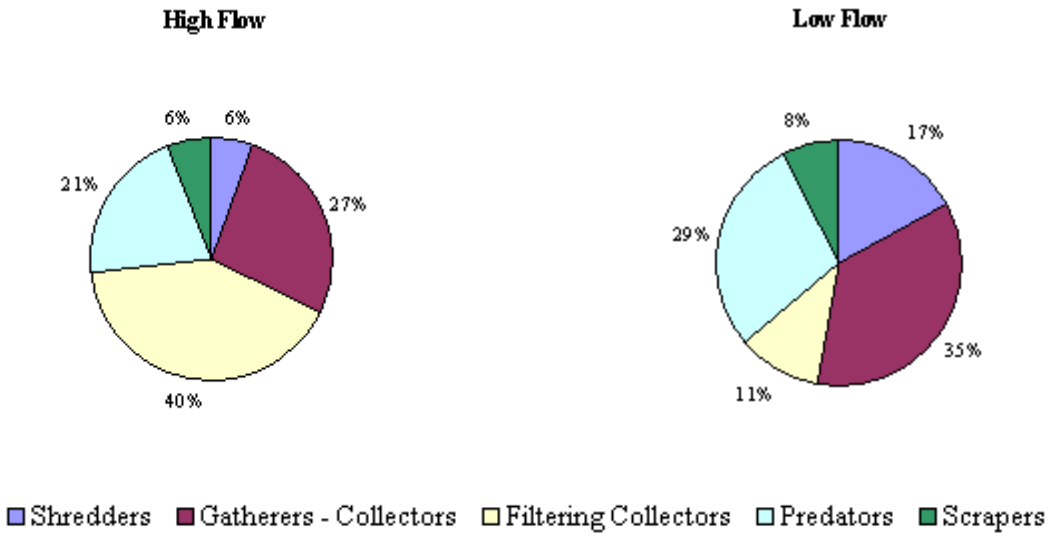


Figure 10. Fish and macroinvertebrate trophic groups from the South Canadian River during high flow and low flow conditions, 2001.

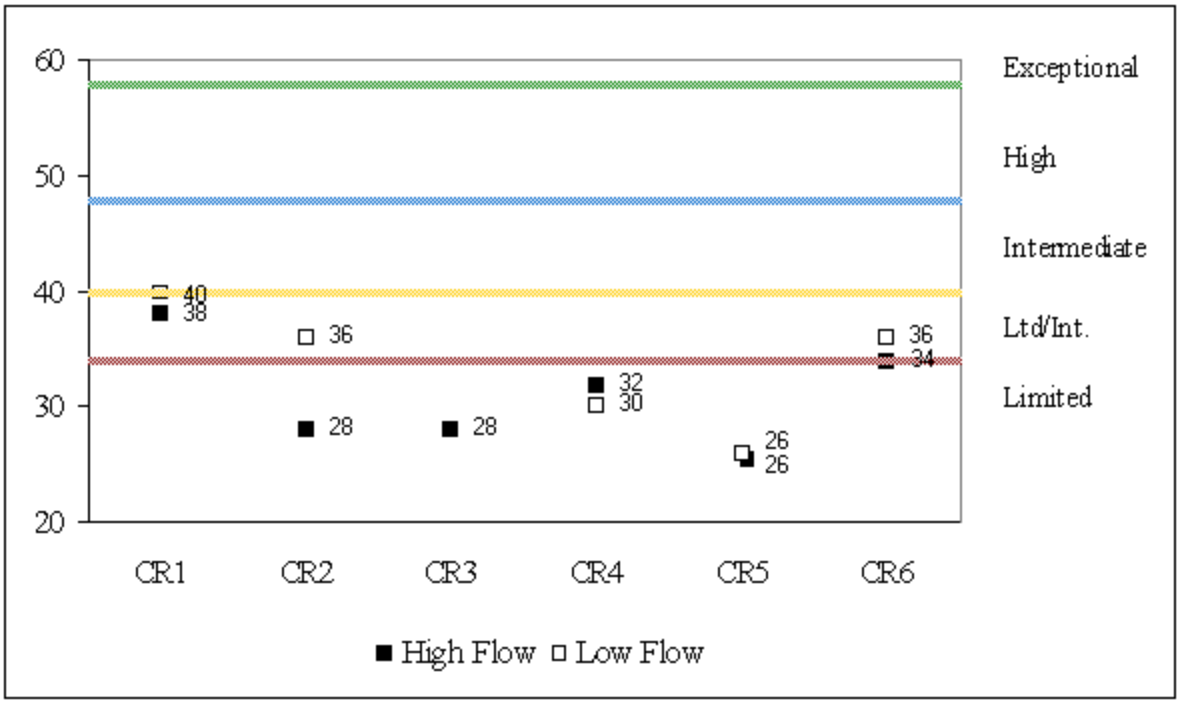


Figure 11. Statewide IBI results for fish collected from six sites (CR1-CR6) on the South Canadian River during high flow and low flow conditions in 2001.

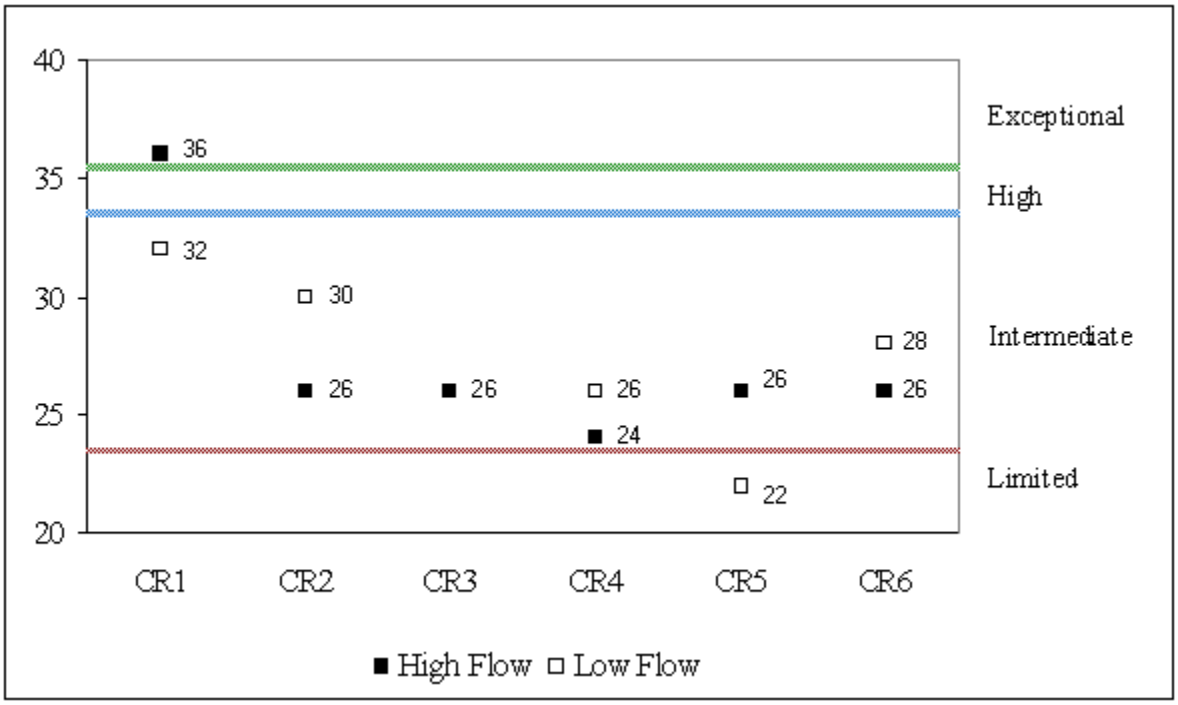


Figure 12. Regional IBI results for fish collected from sites on the South Canadian River (CR1-CR6) during high flow and low flow conditions in 2001.

limited to intermediate. This may be attributed more to natural conditions (elevated salinity and periods of limited surface water flow), the lowering of groundwater levels, and the construction of surface water impoundments (Meredith, Ute, and Conchas Reservoirs) within the watershed rather than to anthropogenic discharges. Dams and impoundments dramatically alter the physical and chemical characteristics of lotic systems (Wilde and Ostrand, 1999). Impoundments tend to serve as distributional barriers to fish communities rather than as river continuum resetting devices (Gore and Bryant, 1986). According to Winston *et al*. (1991), Wilde and Ostrand (1999), and Bonner (2000) two types of lotic fishes can be distinguished with respect to the effects impoundments: facultative riverine species and obligate riverine species which require streams for all or portions of their life histories. Facultative riverine species such as largemouth bass (*Micropterus salmoides*) and gizzard shad (*Dorosoma cepedianum*) can proliferate in reservoirs and then move upstream in large numbers, possibly causing significant changes in the upstream lotic environment (Winston *et al*., 1991; Wilde and Ostrand, 1999). In contrast, modifications in stream flows and other physical and chemical conditions associated with impoundments can adversely effect obligate riverine species such as the Arkansas River shiner, both upstream and downstream of an impoundment (Winston *et al*., 1991; Bonner, 2000).

Macroinvertebrates

A total of 13,109 macroinvertebrates representing 70 different taxa were collected, sorted, and identified from the samples collected at the six sites on the South Canadian River during high flow and low flow conditions in 2001 (Table 12). The average number of macroinvertebrates collected per sample was 1471 for the high flow phase and 857 for the low flow phase. Individual numbers of taxa collected are provided in Appendix C. The results of the diversity, evenness, maximum diversity, richness, and IBI calculations are provided in Tables 13-14 and in Appendix C. No results are given for CR3 (upstream of SH 152 in Hutchinson County,Texas) under low flow conditions due to the lack of water at the site.

The diversity indices indicate a more diverse and evenly distributed macroinvertebrate community occurring during low flow conditions within the stream. Samples collected during both sampling phases showed a decrease in diversity progressing from the downstream sites to the upstream sites in relation to the surface impoundments, with the exception of an increase at CR6 (upstream of SH 54 in Quay County, New Mexico). Sites CR1 (upstream of U.S.83 in Hemphill County, Texas) and CR2 (upstream of SH 70 in Roberts County, Texas) had the highest number of taxa of any sites during both high and low flow conditions. Richness, which is the number of taxa per sample (Figure 13), was low (less than 18) at sites CR3, CR4 (upstream of U.S.287 in Potter County, Texas), and CR5 (upstream of U.S.385 in Oldham County, Texas) for the high flow samples and at CR5 under low flow conditions. Similarly, diversity (Figure 14) was high at CR1 and CR2 during both sampling phases; however, the low flow samples showed more consistency in diversity than the high flow samples. The low flow data also received higher (except CR2) and more consistent evenness values than the high flow data (Figure 15), indicating a more equal distribution of individuals across taxa.

The highest diversity value ($D = 2.41$) occurred at CR1 during low flow sampling, which also had the highest evenness value ($E = 0.67$) and richness number (37 taxa), although 70% of the sample consisted of five taxa. The lowest diversity value ($D = 0.74$, $E = 0.29$) occurred at CR5 during high flow conditions, which contained only 13 taxa and was dominated by chironomids (76%) and simuliids (20%). Among the low flow samples, CR5 also demonstrated the lowest diversity ($D = 1.53$) and only contained 12 taxa; however, individuals were more evenly distributed among the taxa ($E = 0.62$), which was largely

Table 12. Macroinvertebrate taxa and their associated trophic guilds collected from six sites on the South Canadian River during high flow and low flow conditions, 2001 (Note - P is predator; GC is gatherer-collector; FC is filtering collector; SCR is scraper; and SHR is shredder).

Group/Family	Genus	Trophic Group	Group/Family	Genus	Trophic Group
Turbellaria		P	Haliplidae	*Haliplus sp.*	SHR/P
Oligochaeta		GC		*Peltodytes sp.*	SHR/P
Bivalvia		FC	Helophoridae	*Helophorus sp.*	SHR
Gastropoda		SCR	Hydrophilidae	*Berosus sp.*	P
Hydracarina		P		*Chaetarthria sp.*	P/GC
Amphipoda		GC/SHR		*Enochrus sp.*	GC
Cambaridae		GC		*Helochares sp.*	GC
Collembola		GC		*Paracymus sp.*	P
Baetidae		GC		*Tropisternus sp.*	P
Caenidae	*Caenis sp.*	SCR/GC	Hydrochidae	*Hydrochus sp.*	GC
Isonychidae	*Isonychia sp.*	FC	Hydraenidae	*Ochthebius sp.*	P
Tricorythidae	*Tricorythodes sp.*	GC	Scirtidae		SCR/GC/SHR
Calopterygidae	*Hetaerina sp.*	P	Staphylinidae		P
Coenagrionidae	*Argia sp.*	P	Ceratopogonidae		P/GC
	Enallagma sp.	P	Chironomidae		P/GC/FC
	Ischnura sp.	P	Culicidae		FC/GC
Gomphidae	*Erpetogomphus sp.*	P	Dolichopodidae		P
	Progomphus sp.	P	Ephydridae		GC/SHR/SCR
Macromiidae	*Macromia sp.*	P	Sciomyzidae		P
Libellulidae	*Erythemis sp.*	P	Simuliidae		FC
	Orthemis sp.	P	Stratiomyidae	*Nemotelus sp.*	GC
	Sympetrum sp.	P		*Odontomyia sp.*	GC
Perlidae	*Perlesta sp.*	P	Tabanidae		P
Belostomatidae	*Belostoma sp.*	P	Tipulidae		SHR
Corixidae		GC	Elmidae	*Dubiraphia sp.*	GC/SCR
Hebridae	*Merragata sp.*	P		*Microcylleopus sp.*	GC/SCR
Gerridae		P		*Stenelmis sp.*	GC/SCR
Veliidae	*Microvelia sp.*	P	Dytiscidae	*Agabus sp.*	P
	Rhagovelia sp.	P		*Celina sp.*	P
Hydroptilidae		GC/SHR/SCR		*Hydroporus sp.*	P
Hydropsychidae	*Cheumatopsyche sp.*	FC		*Laccophilus sp.*	P
	Hydropsyche sp.	FC		*Oreodytes sp.*	P
Leptoceridae	*Nectopsyche sp.*	SHR/GC/P	Dryopidae	*Helichus sp.*	SCR/GC
Sialidae	*Sialis sp.*	P	Gyrinidae	*Dineutus sp.*	P
Curculionidae		SHR		*Gyretes sp.*	P

represented by chironomids (40%), simuliids (34%), oligochaetes (10%), and caenids (7%).

In comparison to the diversity indices, the IBI scores for the macroinvertebrate data (Tables 13-14 and Figure 16) indicated a disparity between the downstream sites (CR1 and CR2) and the upstream sites (CR3, CR4, CR5, and CR6) in relation to Meredith Reservoir under both flow conditions, with the exception of CR4 which scored considerably higher during the low flow sampling phase. As with the diversity and richness values, the IBI scores appear to indicate that sites CR1 and CR2 were more diverse in community structure than the four remaining upstream sites. Within the range of Aquatic Life Use Designations, CR1 and CR2, under both flow conditions, were characterized in the intermediate and high categories, respectively. All other sample sites received scores within the limited range with the exception of CR4 at low flow, which ranked in the intermediate category. The samples from CR3 and CR4 scored the same under high flow conditions, which corresponds to the low diversity indices and evenness values which could be attributed to the dominance of chironomids and simuliids at both sites.

The discrepancy between the high and low flow samples at CR4 is also indicated by the diversity indices and richness values. This difference is due in part to seven additional taxa collected from the low flow samples and the even distribution of individuals ($E = 0.65$) among taxa. The variation in evenness is apparent from the proportion of dipterans in the high flow sample (88%) compared with the low flow sample (69%). Additionally, among the 21 taxa identified in the low flow sample, seven (13% of sample) of the ten taxa not occurring in the high flow sample are largely represented by species that utilize lentic-littoral, lotic-depositional, or lotic-margin habitats. The elevated diversity exhibited in the CR4 low flow data is likely the result of the variation in habitat created by low flow conditions that favors use by both lotic and lentic species. The elevated IBI score for the CR4 low flow data is in part due to an artifact of the metric scoring criteria. A single caddisfly identified from the low flow sample accounted for four of the seven point difference in scores between samples.

Both the diversity indices and IBI scores reveal a difference in community structure during flow periods, however the diversity indices demonstrated a more pronunced and consistent variation between flow conditions. All low flow samples contained a more diverse and evenly distributed macroinvertebrate fauna than the same sites at high flow conditions. During the low flow phase, the samples from CR2, CR4, and CR6 received higher IBI scores than the equivalent high flow samples, whereas the sample collected from CR1 during the high flow phase scored higher than the low flow sample.

The predominant macroinvertebrate trophic group collected throughout the entire stream during high flow conditions was filtering collectors followed by gatherer/collectors and predators (Figure 10). During the low flow phase, gatherer/collectors were predominant, followed by predators and shredders (Figure 10). According to the USEPA (1999), filter feeders are thought to be sensitive to environmental stressors (pollution; modification in flow conditions) in limited water quality streams. Gatherer/collectors employ a generalist feeding strategy which allows for a broad range of acceptable food materials, and thus, these organisms tend to be more tolerant of environmental stresses that might alter the availability of certain food items (USEPA, 1999). Specialized feeders such as scrapers, shredders, and predators rely on more specific food items and would be detrimentally impacted by stressors which affect these food sources (USEPA, 1999).

In comparison to the fish assemblages measured in 2001, the predominant aquatic life use for macroinvertebrate communities in the South Canadian River also ranged from limited to intermediate. As

Table 13. Shannon Diversity, Evenness, Maximum Diversity, Richness, and IBI Scores for macroinvertebrate samples collected from six sites on the South Canadian River (CR1-CR6) during high flow conditions in 2001.

Site	Diversity	Evenness	Maximum Diversity	Richness	IBI Score
CR1	1.40	0.41	3.40	30	28 Intermediate
CR2	1.97	0.60	3.29	27	31 High
CR3	0.93	0.33	2.83	17	20 Limited
CR4	0.98	0.37	2.64	14	20 Limited
CR5	0.74	0.29	2.56	13	19 Limited
CR6	1.36	0.45	3.04	21	18 Limited

Table 14. Shannon Diversity, Evenness, Maximum Diversity, Richness, and IBI Scores macroinvertebrate samples collected from six sites on the South Canadian River (CR1-CR6) during low flow conditions in 2001 (Note - NS is not sampled due to lack of water).

Site	Diversity	Evenness	Maximum Diversity	Richness	IBI Score
CR1	2.41	0.67	3.61	37	27 Intermediate
CR2	2.12	0.59	3.58	36	34 High
CR3	NS	NS	NS	NS	NS
CR4	1.99	0.65	3.04	21	27 Intermediate
CR5	1.53	0.62	2.48	12	19 Limited
CR6	1.84	0.61	3.00	20	21 Limited

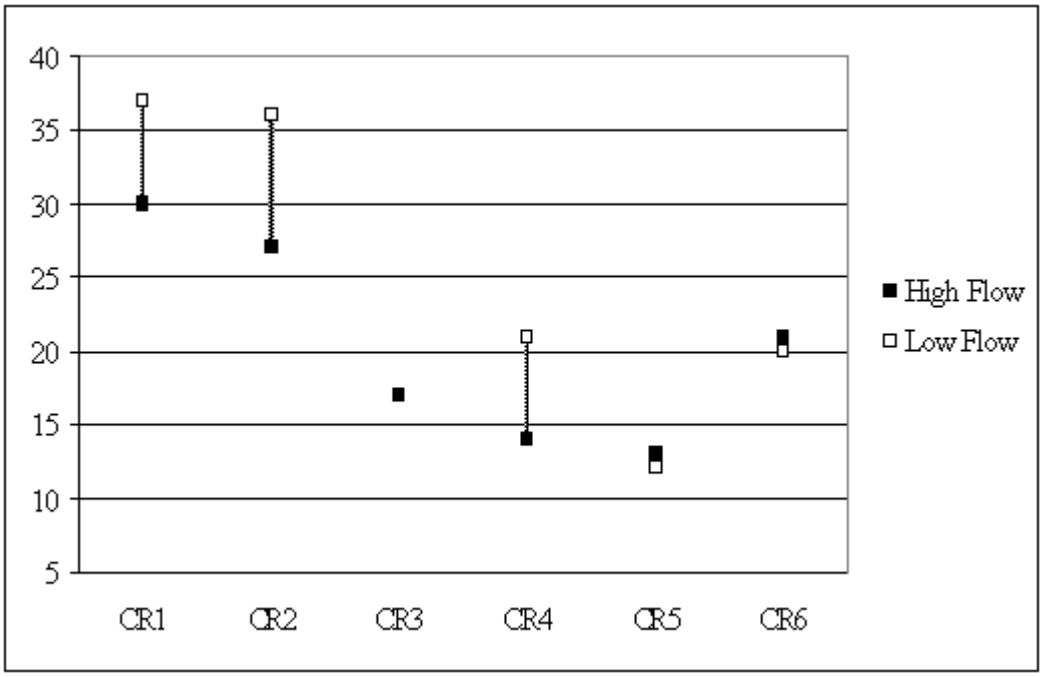


Figure 13. Richness values for macroinvertebrate samples collected from six sites on the South Canadian River (CR1-CR6) during high flow and low flow conditions in 2001.

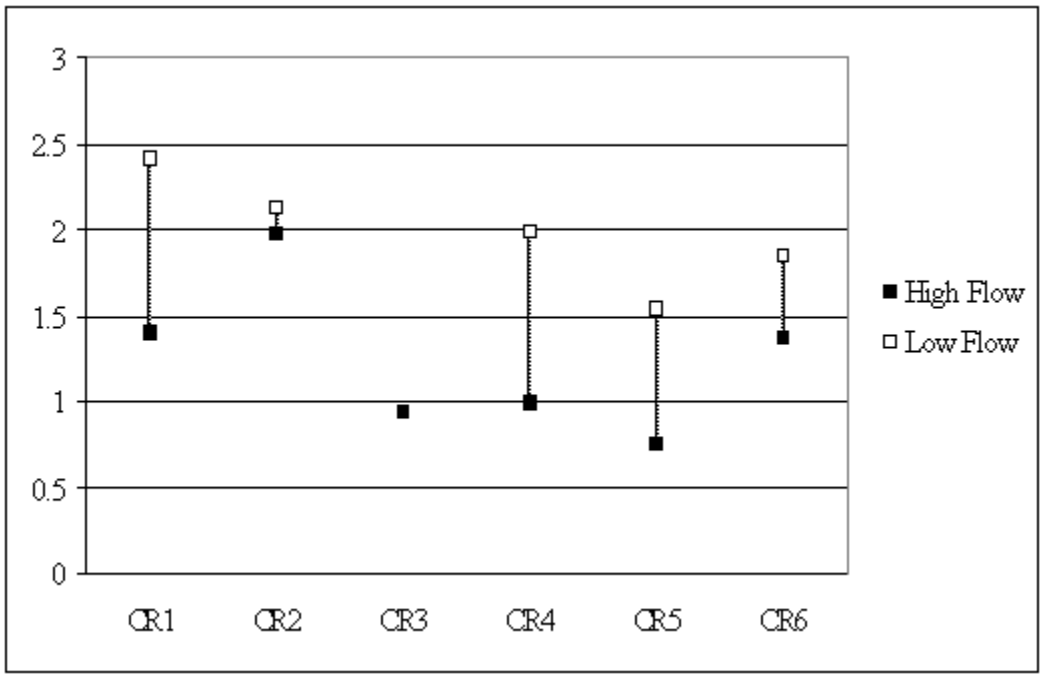


Figure 14. Diversity values for macroinvertebrate samples collected from six sites on the South Canadian River (CR1-CR6) during high flow and low flow conditions in 2001.

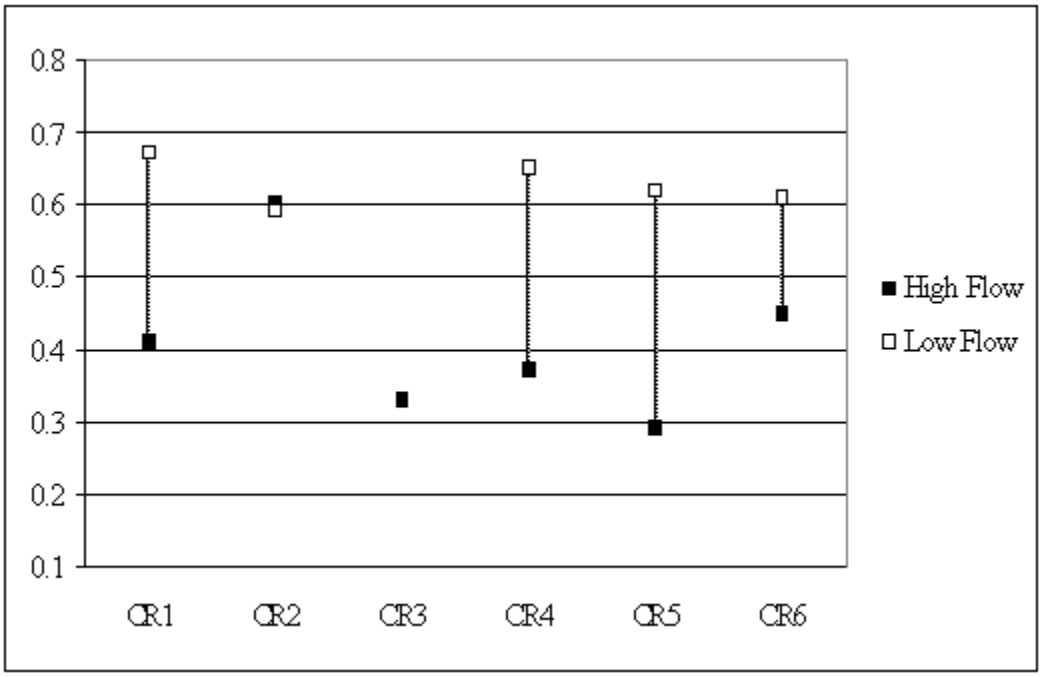


Figure 15. Evenness values for macroinvertebrate samples collected from six sites on the South Canadian River (CR1-CR6) during high flow and low flow conditions in 2001.

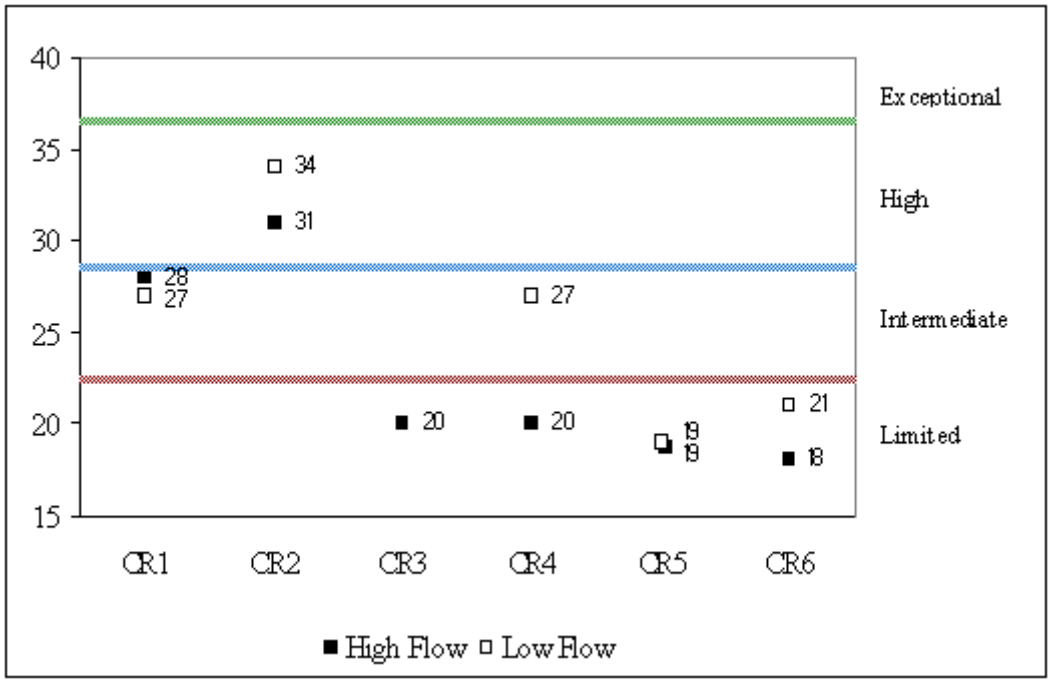


Figure 16. IBI results for macroinvertebrate samples collected from six sites on the South Canadian River (CR1-CR6) during high flow and low flow conditions in 2001.

with the the fish communities, this appears to be more attributable to natural conditions existing within the watershed (elevated salinity and periods of limited surface water flow) and the development of impoundments (Meredith, Ute, and Conchas Reservoirs) which have resulted in modifications in surface water dynamics and habitat structure, rather than to anthropogenic discharges of oil or CAFO waste.

In-stream Habitat

The results of the in-stream habitat evaluations for each site during each flow phase are presented in Appendix D. Overall scores for each site from each flow regime are presented in Table 15. Deviating

Table 15. In-stream habitat evaluation scores for six sites on the South Canadian River (CR1-CR6) during high flow (HF) and low flow (LF) conditions in 2001 (Note - NE is not evaluated due to lack of water).

Site	In-stream Habitat Evaluation Score	
	HF	LF
CR1	108	108
CR2	107	106
CR3	110	NE
CR4	86	101
CR5	104	97
CR6	118	126

from the methodology proposed by the USEPA (1999) which recommends that the results of the habitat evaluations be compared to a reference stream, the scores from each site were compared to each other. During high flow conditions, scores ranged from 86 at CR4 (upstream of U.S.287 in Potter County, Texas) to 118 at CR6 (upstream of SH 54 in Quay County, New Mexico), while during the low flow phase, scores ranged from 97 at CR5 (upstream of U.S.385 in Oldham County, Texas) to 126 at CR6. In-stream habitat at CR3 (upstream of U.S.83 in Hemphill County, Texas) was not evaluated during the low flow phase due to lack of water at the site. During both flow regimes, CR6 scored the highest, while CR1 (upstream of U.S.83 in Hemphill County, Texas) averaged the second highest score. The high scores at CR6 (during both phases) and CR3 (during the high flow phase) may be a reflection of the location of these sites in relation to surface impoundments. Site CR6 was downstream of Ute Reservoir while CR3 was downstream of Meredith Reservoir. No definitive trends or conclusions related to habitat preferences could be ascertained when comparing the fish and macroinvertebrate IBI results with the habitat evaluation results. During both sampling events, with the exception of CR3, the South Canadian River channel at the remaining five sites was characterized predominantly by long, broad, flat, and shallow runs. At CR3 the channel was narrow and braided. Overall, the substrate within the channel consisted primarily of sand with the exception of CR3 which had significant clay and silt components. Riparian vegetation throughout the stream was dominated by salt cedar (*Tamarix ramosissima*) and/or switchgrass (*Panicum virgatum*). Other than the obvious differences that would be expected between the two flow periods such as lower water depths during the low flow phase reducing the availability of aquatic habitats, no definitive adverse impacts to the aquatic habitats at the six sites were identified which could be attributed to anthropogenic discharges.

CONCLUSIONS & RECOMMENDATIONS

Definitive trends are difficult to ascertain during the course of a one-year study, but at the time this study was conducted, anthropogenic discharges from CAFOs and other sources such as gas and/or crude oil production facilities into the South Fork of the Canadian River did not appear to be affecting fish (including the Arkansas River shiner) and macroinvertebrate assemblages in an adverse manner. Residual contaminants, possibly associated with past discharges, were detected in sediments throughout the stream, but with the exception of nickel, these contaminants were below levels where significant adverse effects to fish and wildlife resources would be expected to occur. Other than this residual contamination, no other definitive detriments to the Arkansas River shiner's habitat that could be attributed to anthropogenic discharges were identified. Elevated levels of nickel were detected in sediments collected upstream of SH 70 in Roberts County, Texas (CR2). The measured nickel concentration at this site was high enough to possibly warrant further monitoring.

In comparing the different flow regimes, nutrients detected in surface water increased slightly in concentration from the high flow to the low flow phase, but no definitive pattern or trend could be determined from this data. With the exception of nickel, the metals detected in sediments remained fairly constant between the two flow regimes. Aquatic life use values for the fish and macroinvertebrate communities increased slightly from the high flow to the low flow phase. This was probably attributed to to the lower surface water depths limiting the availability of aquatic habitats.

In comparison to other lotic systems, the fish and macroinvertebrate assemblages measured within the South Canadian River during the course of this study were classified as limited to intermediate. However, this appears to be more of a factor associated with natural conditions (elevated salinity and periods of limited surface water flow), the lowering of groundwater levels, and the construction of surface water impoundments (Meredith, Ute, and Conchas Reservoirs) within the watershed which have modified in-stream habitat and flow regimes rather than to actual discharges.

Had sampling been conducted during the high flow phase within 24 hours of the initial peak surge of runoff from a significant storm event, the results (especially the surface water nutrient levels) may have changed. Therefore, the USFWS recommends that the TNRCC perform a study to determine the possible effects of CAFO discharges into surface waters within State of Texas. The TNRCC agreed to do such a study through informal consultations between the USEPA, USFWS, and TNRCC in 1999, and funding has been made available by the USEPA (Crocker, 2002). Furthermore, the USFWS would be willing to provide technical guidance to these agencies towards the implementation of this study.

REFERENCES

American Public Health Association. 1995. Standard Methods for the Examination of Water and Wastewater (19th Edition). American Public Health Association. Washington, D.C. 1268 pp.

Armstrong, M.P. 1998. A Fishery Survey of the Middle Brazos River in North Central Texas. U.S. Fish and Wildlife Service. Arlington, Texas. 26 pp.

Baker, D.L., R. Irwin, and S. Dodson. 1995. Initial Contaminants Survey of Hagerman National Wildlife Refuge, Texas. U.S. Fish and Wildlife Service. Arlington, Texas. 26 pp.

Baker, D.L., J.D. Lusk, and C.M. Giggleman. 1998. Phase II Contaminants Investigation of Buffalo Lake National Wildlife Refuge, Texas 1993-1994. U.S. Fish and Wildlife Service. Arlington, Texas. 35 pp.

Begon, M., J.L. Harper, and C.R. Townsend. 1990. Ecology: Individuals, Populations, and Communities. Blackwell Scientific Publications. Cambridge, Massachusetts. 945 pp.

Beyer, W.N. 1990. Evaluating Soil Contamination. U.S. Fish and Wildlife Service. Washington, D.C. 25 pp.

Bonner, T.H. 2000. Habitat Use and Ecology of Prairie Stream Fishes in the Canadian River, New Mexico and Texas. Texas Tech University. Lubbock, Texas. 147 pp.

Brown, H.P. 1976. Aquatic Dryopoid Beetles (Coleoptera) of the United States. Wat. Poll. Res. Ser. U.S. Environmental Protection Agency. Washington, D.C. 82 pp.

Buchman, M.F. 1999. Screening Quick Reference Tables. National Oceanic and Atmospheric Administration, Coastal Protection and Restoration Division. Seattle, Washington. 12 pp.

Canadian Council of Ministers of the Environment (CCME). 1997. Contaminated Sites Cleanup Criteria. CCME website at http://www.gov.nf.ca/env/pollprev/contaminated_sites.asp.

Eisler, R. 1986. Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (CHR Rep. No. 6). U.S. Department of the Interior, U.S. Fish and Wildlife Service. Washington, D.C. 90 pp.

Eisler, R. 1990. Boron Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (CHR Rep. No. 20). U.S. Department of the Interior, U.S. Fish and Wildlife Service. Washington, D.C. 32 pp.

Eisler, R. 1993. Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (CHR Rep. No. 26). U.S. Department of the Interior, U.S. Fish and Wildlife Service. Washington, D.C. 106 pp.

Eisler, R. 1998a. Copper Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (CHR Rep. No. 33). U.S. Department of the Interior, U.S. Geological Survey. Laurel, Maryland.

Eisler, R. 1998b. Nickel Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (CHR Rep. No. 34). U.S. Department of the Interior, U.S. Fish and Wildlife Service. Washington, D.C.

Environmental Technology Center (ETC). 2000. Properties of Crude Oils and Oil Products. ETC website at http://www.etcentre.org/cgi-win/oil_prop_cgi.exe/oil_by_name?Path=\Website\river.

Epler, J.H. 1996. Identification Manual for the Water Beetles of Florida (Coleptera: Dryopidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Noteridae, Psephenidae, Ptilodactylidae, Scirtidae). Florida Department of Environmental Protection, Division of Water Facilities. Tallalasee, Florida.

Etnier, D.A. and W.C. Starnes. 1993. The Fishes of Tennessee. The University of Tennessee Press. Knoxville, Tennessee. 681 pp.

Federal Register. 1998. Final Rule to List the Arkansas River Basin Population of the Arkansas River Shiner (*Notropis girardi*) as Threatened. Volume 63, Number 225.

Federal Register. 2001. Final Designation of Critical Habitat for the Arkansas River Basin Population of the Arkansas River Shiner, Final Rule. Volume 66, Number 65.

Gandara, S.C., W.J. Gibbons, D.L. Barbie, and R.E. Jones. 2000. Water Resources Data, Texas, Water Year 1999: Volume 1. Arkansas River Basin, Red River Basin, Sabine River Basin, Neches River Basin, and Intervening Coastal Basins (Water-Data Report TX-99-01). U.S. Geological Survey. Austin, Texas. 415 pp.

Giggleman, C.M. 1999. Nutrient and Total Fecal Coliform Levels in Surface Water Collected in July, 1999, from Buffalo Lake National Wildlife Refuge, Randall county, Texas. U.S. Fish and Wildlife Service. Arlington, Texas. 5 pp.

Gore, J.A. and R.M. Bryant. 1986. Changes in Fish and Benthic Assemblages Along the Impounded Arkansas River. Journal of Freshwater Ecology, Volume 3, Number 3. Oikos Publishers, Inc.

Goyer, R.A. 1991. Toxic Effects of Metals. In M.O. Amdur, J. Doull, and C.D. Klaassen eds. Casarett and Doull's Toxicology. Pergamon Press. New York, New York. pp 623-680.

Harrison, B. 1996. Metric Set for Use in Setting Aquatic Life Use Designations Using Benthic Macroinvertebrates Samples Collected from Texas Streams Following Rapid Bioassessment Protocols (Unpublished Draft). Texas Natural Resource Conservation Commission. Austin, Texas.

Horne, A.J. and C.R. Goldman. 1994. Limnology (2nd Edition). McGraw-Hill, Incorporated. St. Louis, Missouri. 576 pp.

Hubbs, C., R.J. Edwards, and G.P. Garrett. 1991. An Annotated Checklist of Freshwater Fishes of Texas. The Texas Journal of Science. Vol. 43(4): November 1991 supplement. 56 pp.

Irwin, R.J. and S. Dodson. 1991. Contaminants in Buffalo Lake National Wildlife Refuge, Texas. U.S. Fish and Wildlife Service. Arlington, Texas. 90 pp.

Irwin, R.J., P.J. Connor, D. Baker, S. Dodson, and C.D. Littlefield. 1996. Playa Lakes of the Texas High Plains: A Contaminants Survey and Assessment of Biological Integrity. U.S. Fish and Wildlife Service. Arlington, Texas. 94 pp.

Karr, J.R. 1981. Assessment of Biotic Integrity using fish communities. Fisheries. Vol. 6(6):21-27.

Karr, J.R. 1991. Biological Integrity: a Long-neglected Aspect of Water Resource Management. Ecol. Appl. 1:66-84.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History. 867 pp.

Linam, G.W., and L.J. Kleinsasser. 1991. Preliminary designation of fishes into trophic and tolerance classifications. Unpublished data. Texas Parks and Wildlife Department. Austin, Texas.

Linam, G.W., L.J. Kleinsasser, and K.B. Mayes. 2002. Regionalization of the Index of Biotic Integrity for Texas Streams (Draft). Texas Parks and Wildlife Department. Austin, Texas.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.C. Calder. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management Volume 19, Number 1. Springer-Verlag. New York, New York. pp 81-97.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology, Volume 39. Springer-Verlag, Inc. New York, New York. pp 20-31.

Manahan, S.E. 1991. Environmental Chemistry (5th Edition). Lewis Publishers, Inc. Chelsea, Michigan.583 pp.

McCafferty, P.W. 1983. Aquatic Entomology. Jones and Bartlett. Boston, Massachusetts. 448 pp.

Merck & Co., Inc. (Merck). 1989. The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals (11th Edition). Merck & Co., Inc. Rahway, New Jersey.

Merrit, R.W. and K.W. Cummins (eds). 1996. An Introduction to the Aquatic Insects of North America, 3rd Edition. Kendall/Hunt. Dubuque, Iowa. 862 pp.

Miller, R.W. and D.T. Gardiner. 1998. Soils In Our Environment (8th Edition). Prentice Hall. Upper Saddle River, New Jersey. 736 pp.

Moore, S.B., J. Winckel, S.J. Detwiler, S.A. Klasing, P.A. Gaul, N.R. Kanim, B.E. Kesser, A.B. DeBevec, K. Beardsley, and L.K. Puckett. 1990. Fish and Wildlife resources and Agricultural Drainage in the San Joaquin Valley, California.

Moring, J.B. 1997. Occurrence and Distribution of Organochorine Compounds in Biological Tissue and Bed Sediment from Streams in the Trinity River Basin, Texas, 1992-93 (Water Resources Investigations Report 97-4057). U.S. Geological Survey. Austin, Texas. 19 pp.

New Mexico Environment Department (NMED). 2001. Standards for Interstate and Intrastate Surface Waters (Title 20, Chapter 6, Part 4). New Mexico Environment Department. Santa Fe, new Mexico.

New Mexico Environment Department (NMED). 2002. Fish Consumption Guidelines due to Mercury Contamination. NMED website at http://www.nmenv.state.nm.us/swqb/Mercury.html.

New Mexico Water Quality Control Commission (NMWQCC). 1994. Water Quality and Water Pollution Control in New Mexico. New Mexico Water Quality Control Commission. Santa Fe, New Mexico.

North Dakota Department of Health (NDDH). 2002. Persistent, Bio-accumulative, and Toxic Chemicals. NDDH website at http://www.health.state.nd.us/ndhd/environ/wm/hwp/pbt.htm.

Pain, D.J. 1995. Lead in the Environment. In D.J. Hoffman, B.A. Rattner, G.A. Burton Jr., and J. Cairns Jr. eds. Handbook of Ecotoxicology. Lewis Publishers. Ann Arbor, Michigan. pp 356-391.

Pennington, H.D. 1991. Arsenic Survey of Texas Soils. In Comprehensive Study of Texas Watersheds and Their Impacts on Water Quality and Water Quantity. Texas State Soil and Water Conservation Board. Temple, Texas. 14 pp.

Persaud, D., R. Jaagumagi, and A. Hayton. 1993. Guidelines for the Protection and Management of aquatic Sediment Quality in Ontario. Water Resources Branch, Ontario Ministry of the Environment. Toronto, Ontario.

Pescador, M.L., A.K. Rasmussen, and S.C. Harris. 1995. Identification Manual for the Caddisfly (Trichoptera) Larvae of Florida. Florida Department of Environmental Protection. Tallahassee, Florida. 132 pp.

Pflieger, W.L. 1991. The Fishes of Missouri. Missouri Department of Conservation. 343 pp.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. U.S. Environmetal Protection Agency. Washington, D.C.

Pringle, F.B. 1974. Soil Survey of Potter County, Texas. U.S. Department of Agriculture. Texas Agricultural Experiment Station. Austin, Texas.

Pringle, F.B. 1977. Soil Survey of Oldham County, Texas. U.S. Department of Agriculture. Texas Agricultural Experiment Station. Austin, Texas.

Qasim, S.R. and K. Udomsinrot. Laboratory Manual for Water Quality Analysis. The University of Texas at Arlington, Department of Civil Engineering. Arlington, Texas.

Risk Assessment Information System (RAIS). 2002. Regulatory Guideline Values for 1,2,4,5-Tetrachlorobenzene. RAIS website at http://risk.lsd.ornl.gov/cgi-bin/guide/GUID_9709.

Red River Authority of Texas (RRA). 1996. Regional Assessment of Water Quality: Canadian River Basin of Texas Executive Summary, 1996. Red River Authority website at http://www.rra.dst.tx.us.

Red River Authority of Texas (RRA). 2000. About the Canadian River. Red River Authority website at http://www.rra.dst.tx.us.

Richardson, C.W., J.D. Price, and E. Burnett. 1978. Arsenic Concentrations in Surface Runoff from Small Watersheds in Texas. Journal of Environmental Quality. Volume 7, Number 2. pp 189-192.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and Scientific Names of Fishes from the United States and Canada, 5th Edition. American Fisheries Society, Special Publication 20, Bethesda, Maryland. 183 pp.

Robison, H.W. and T.M. Buchanan. 1988. Fishes of Arkansas. The University of Arkansas Press. Fayetteville, Arkansas. 536 pp.

Rosenberg, D.M. and V.H. Resh. 1993. Introduction to Freshwater Biomonitoring and Benthic Macroinvertebrates. In D.M. Rosenberg and V.H. Resh (eds). Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall. New York, new York. 488 pp.

Sax, N.I., and R.J. Lewis Sr. 1987. Hawley's Condensed Chemical Dictionary, 11th Edition. Van Nostrand Reinhold Company. New York, New York. 1288 pp.

Schneider, R.F. 1971. The Impact of Various Heavy Metals on the Aquatic Environment. U.S. Environmental Protection Agency. Denver, Colorado.

Shacklette, H.T. and J.G. Boerngen. 1984. Element Concentrations in Soils and Other Surficial Material of the Conterminous United States (USGS PP 1270). U.S. Geological Survey. Washington, D.C. 105 pp.

Shearer Publishing. 1997. The Roads of Oklahoma. Shearer Publishing. Fredericksburg, Texas. 136 pp.

Stringer, B.R. 1976. Soil Survey of Hutchinson County, Texas. U.S. Department of Agriculture. Texas Agricultural Experiment Station. Austin, Texas.

Texas A&M. 1995. The Roads of Texas. Shearer Publishing. Fredericksburg, Texas. 176 pp.

Texas Department of Economic Development (TDED). 1997. Estimates of the Total Populations of Counties and Places in Texas for July 1, 1996 and January 1, 1997. Texas Department of Economic Development. Austin, Texas.

Texas Engineering Extension Service (TEEX). 1989. Wastewater Laboratory. Texas Engineering Extension Service. Texas A&M University System. College Station, Texas.

Texas Natural Resource Conservation Commission (TNRCC). 1995. Guidance for Risk-Based Assessments at LPST Sites in Texas (RG-175). Texas Natural Resource Conservation Commission. Austin, Texas.

Texas Natural Resource Conservation Commission (TNRCC). 1996. The State of Texas Water Quality Inventory, 13th Edition, Volume 2 (SFA-50). Texas Natural resource Conservation Commission. Austin, Texas. 758 pp.

Texas Natural Resource Conservation Commission (TNRCC). 1997. Emergency Response Database for Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Oldham, Potter, and Roberts Counties, Texas. Texas Natural Resource Conservation Commission. Austin, Texas.

Texas Natural Resource Conservation Commission (TNRCC). 1998. The State of Texas 303(d) List. Texas Natural Resource Conservation Commission. Austin, Texas.

Texas Natural Resource Conservation Commission (TNRCC). 2000. Guidance for Screening and Assessing Texas Surface and Finished Drinking Water Quality Data, 2000. Texas Natural Resource Conservation Commission. Austin, Texas.

Texas Natural Resource Conservation Commission (TNRCC). 2001. Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Texas Natural Resource Conservation Commission. Austin, Texas.

Texas Natural Resource Conservation Commission (TNRCC). 2002. 2002 Water Quality Inventory [305(b)] and List of Impaired Waters [303(d)] (Draft). TNRCC website at http://www.tnrcc.state.tx.us/water/quality/02_303.html.

Texas Parks and Wildlife Department (TPWD). 1999. Pollution Response Inventory and Species Mortality (PRISM) Database. Texas Parks and Wildlife Department Kills and Spills Team, Resource Protection Division. Austin, Texas.

Texas Parks and Wildlife Department (TPWD). 2000. Texas Inland Lakes - Lake Meredith. TPWD website at http://www.tpwd.state.tx.us/fish/infish/lakes/meredith/lake_id.htm.

Texas Water Commission (TWC). 1989. Segment Identification Maps for Texas River and Coastal Basins. Texas Water Commission. Austin, Texas. 56 pp.

U.S. Army Corps of Engineers. 1994. Environmental Summary Report: Red River Waterway Project, Shreveport, LA to Daingerfield, TX Reach Reevaluation Study Review. U.S. Army Corps of Engineers. Vicksburg, Mississippi..

U.S. Department of the Interior (USDOI). 1998. Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment (National Irrigation Water Quality Program Information Report No. 3). U.S. Bureau of Reclamation. Denver, Colorado. 198 pp.

U.S. Environmental Protection Agency (USEPA). 1979. Methods for Chemical Analysis of Water and Waste (EPA 600/4-79-020). U.S. Environmental Protection Agency. Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 1980. Ambient Water Quality Criteria for Arsenic (EPA 440/5-80-021). U.S. Environmental Protection Agency. Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 1986. Quality Criteria for Water (EPA 440/5-86-001). U.S. Environmental Protection Agency. Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 1994. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume II: Risk Assessment and Fish Consumption Limits. U.S. Environmental Protection Agency. Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA 841-B-99-002). U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 2002. 303(d) Listed Waters. USEPA website at http://www.epa.gov/iwi/303d/1108006_303d.html.

U.S. Fish and Wildlife Service (USFWS). 1999a. Biological Opinion by the U.S. Fish and Wildlife Service Concerning the National Pollutant Discharge Elimination System (NPDES) General Permits for Concentrated Animal Feeding Operations (CAFOs) Proposed by the U.S. Environmental Protection Agency to Regulate CAFOs in the State of Texas. Consultation No. 2-12-99-F-095/March 4, 1999. U.S. Fish and Wildlife Service. Arlington, Texas.

U.S. Fish and Wildlife Service (USFWS). 1999b. The U.S. Fish and Wildlife Service's objections to the Texas Natural Resource Conservation Commission's Title 30, Texas Administrative Code 321, Subchapter B - Rules Governing Concentrated Animal Feeding Operations in Texas. May 18, 1999. U.S. Fish and Wildlife Service. Arlington, Texas.

U.S. Fish and Wildlife Service (USFWS). 1999c. The U.S. Fish and Wildlife Service's responses concerning the Texas Natural Resource Conservation Commission's modifications to Title 30, Texas Administrative Code 321, Subchapter B - Rules Governing Concentrated Animal Feeding Operations in Texas. June 24, 1999. U.S. Fish and Wildlife Service. Arlington, Texas.

U.S. Geological Survey (USGS). 2002. Water Resources at USGS 07227500 Canadian River Near Amarillo, Texas. USGS website at http://water.usgs.gov/tx/nwis/nwisman?.

Usinger, R.L. (ed). 1968. Aquatic Insects of California. University of California Press. Berkeley, California. 508 pp.

Wilde, G.R. and K.G. Ostrand. 1999. Changes in the Fish Assemblage of an Intermittent Prairie Stream Upstream from a Texas Impoundment. Texas Journal of Science, 51(3): 203-210. Lubbock, Texas.

Williams, J.C., A.J. Welker, F.F. Wheeler, and H.F. McEwen. 1974. Soil Survey of Hemphill County, Texas. U.S. Department of Agriculture. Texas Agricultural Experiment Station. Austin, Texas.

Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream Extirpation of Four Minnow Species due to Damming of a Prairie Stream. Transactions of the American Fisheries Society 120: 98-105.

Wyrick, J.C. 1981. Soil Survey of Roberts County, Texas. U.S. Department of Agriculture. Texas Agricultural Experiment Station. Austin, Texas.

Personal Communications

Crocker, P. 2002. U.S. Environmental Protection Agency. Dallas, Texas (telephone 214/665-6644).

Glass, J. 2002. Texas Parks and Wildlife Department. Waco, Texas (telephone: 254/867-7956).

Morris, G. 2002. Texas Natural Resource Conservation Commission. Amarillo, Texas (telephone: 806/468-0524).

National Weather Service (NWS). 1998. Amarillo, Texas (telephone: 806/335-1121).

Winsborough, P. 2002. Texas Natural Resource Conservation Commission. Austin, Texas (telephone: 512/239-0417).

APPENDIX A
(ANALYTICAL METHODS)

Method Code 007

Analytical Methodology for Aluminum, Arsenic, Boron, Barium, Beryllium, Cadmium, Chromium, Copper, Iron, Mercury, Magnesium, Manganese, Molybdenum, Nickel, Lead, Selenium, Strontium, Vanadium, and Zinc in Sediments.

Laboratory: Texas A&M Geochemical & Environmental Research Group

Summary: Sediments are digested with aqua regia (3:1 HCl:HNO3) in glass beakers on a hotplate and diluted to volume with distilled water. Metals in the digestate are determined by 3 techniques, depending upon concentration and element. Mercury is determined by cold vapor atomic absorption spectrometry (AAS) in which Sn2+ is used to reduce Hg0. Arsenic, selenium, cadmium, and lead are determined by graphite furnace AAS, in which electrical heating is used to produce an atomic cloud. Remaining elements (and cadmium or lead when in high concentration) are determined by atomic emission using argon plasma.

Method Code 028

Analytical Methodology for Total Petroleum Hydrocarbons (TPH) in Sediments.

Laboratory: Texas A&M Geochemical & Environmental Research Group

Summary: Sediment samples were freeze dried and extracted in a Soxhlet extraction apparatus. The freeze dried sediment samples were homogenized and a 15.0-gram sample was weighed into the extraction thimble. Surrogate standards and methylene chloride were added and the samples extracted for 12 hours. The extracts were treated with copper to remove sulfur. Extract was then rotovaped to 5.0 ml and then brought to dryness under a clean nitrogen stream. GC internal standards were added and the extract was run on gas chromatograph with a flame ionization detector. TPH was determined by summing the total unresolved complex mixture (UCM) and the total resolved (all peaks in the chromatogram). The concentration was based on the average of the response factors for alkanes from n-C10 through n-C34.

Method Code 003

Analytical Methodology for Percent (%) Moisture.

Laboratory: Texas A&M Geochemical & Environmental Research Group

Summary: Approximately 1.0 gram of wet sample is weighed into a clean, labeled, preweighed 10.0 ml beaker. The beaker is placed in a forced air oven at approximately 75˚C for 24 hours. The beaker with the dry sample is then weighed and the % dry weight is calculated by the following formula:

$$\frac{\text{(weight of dry sample and beaker) - (weight of beaker)(100)}}{\text{(weight of wet sample and beaker) - (weight of beaker)}}$$

Method Code 006

Analytical Methodology for Grain Size of Sediments.

Laboratory: Texas A&M Geochemical & Environmental Research Group

Summary: A small aliquot of sediment is treated with 30% hydrogen peroxide to remove organic coating from grains. A dispersing agent is then added to the sample. The sand/mud fractions are then separated using a 63 micron sieve. The sand fraction (greater than 63 microns) is retained on the screen and the mud fraction (silt and clay less than63 microns) is washed into a one liter volumetric cylinder. The sand fraction is dried, sieved on a 63 micron screen and weighed. The sediment which passes through the screen a second time is added to the one liter cylinder. The mud fraction is analyzed by stirring the cylinder and sampling 20 ml aliquots at 4 and 8 phi intervals. The 4 and 8 phi samples are dried and weighed. The % sand, silt, and clay fractions are determined on a dry weight basis.

Method Code 004

Analytical Methodology for 1,2,3,4-terachlorobenzene, 1,2,4,5-tetrachlorobenzene, aldrin, hexachlorobenzene (HCB), heptachlor, total polychlorobiphenyls (PCB), alpha hexachlorocyclohexane (αBHC), alpha (α) chlordane, beta hexachlorocyclohexane (βBHC), cis-nonachlor, delta hexachlorocyclohexane (δBHC), dieldrin, endosulfan II, endrin, gamma hexachlorocyclohexane (γBHC), gamma (γ) chlordane, heptachlor epoxide, mirex, o,p'-dichloro-diphenyl-dichloroethane (o,p'-DDD), o,p'-dichloro-diphenyl-trichloroethane (o,p'-DDT), oxychlordane, p,p'-dichloro-diphenyl-dichloroethane (p,p'-DDD), p,p'-dichloro-diphenyl-dichloroethylene (p,p'-DDE), p,p'-dichloro-diphenyl-trichloroethane (p,p'-DDT), pentachloro-anisole, toxaphene, and trans-nonachlor in sediments

Laboratory: Texas A&M Geochemical & Environmental Research Group

Summary: The sediment samples were freeze-dried and extracted in a Soxhlet extraction apparatus. Briefly, the freeze-dried sediment samples were homogenized and a 10-gram sample was weighed into the extraction thimble. Surrogate standards and methylene chloride were added and the samples extracted for 12 hours. The extracts were treated with copper to remove sulfur and were purified by silica/alumina column chromatography (MacLeod *et al*., 1985; Brooks *et al*., 1989) to isolate the aliphatic and aromatic/pesticide/PCB fractions.

The quantitative analyses were performed by capillary gas chromatography (CGC) with flame ionization detector for aliphatic hydrocarbons, CGC with electron capture detector for pesticides and PCB's and a mass spectrometer detector in the SIM mode for aromatic hydrocarbons (Wade *et al*., 1988).

There are specific cases where analytes requested for the pesticide and PCB analyses and are known to co-elute with other analytes in the normal CGC with electron capture. These include the pesticide Endosulfan I and the PCB congeners 114 and 157. In these cases, the samples will be analyzed by CGC with a mass spectrometer detector in the SIM mode.

References: 1. Brooks, J.M, T.L. Wade, E.L. Atlas, M.C. Kennicutt II, B.J. Presley, R.R. Fay, E.N. Powell, and G. Wolff. 1989. Analysis of Bivalves and Sediments for Organic Chemicals and Trace Elements. Third Annual Report for NOAA's National Status and Trends Program, Contract 50-DGNC-5-00262.

2. MacLeod, W.D., D.W. Brown, A.J. Friedman, D.G. Burrow, O. Mayes, R.W. Pearce, C.A. Wigren, and R.G. Borgar. 1985. Standard Analytical Procedures of the NOAA National Analytical Facility 1985-1986. Extractable Toxic Organic Compounds. 2nd Edition. U.S. Department of Commerce, NOAA/NMFS, NOAA Tech. Memo. NMFS F/NWRC-92.

3. Wade, T.L., E.L. Atlas, J.M. Brooks, M.C. Kennicutt II, R.G. Fox, J. Seicano, B. Garcia, and D. DeFreitas. 1988. NOAA Gulf of Mexico Status and Trends Program: Trace Organic Contaminant Distribution in Sediments and Oyster. Estuaries 11, 171-179.

APPENDIX B
(STATEWIDE/REGIONAL FISH IBI EVALUATIONS FOR THE SOUTH FORK CANADIAN RIVER)

Site:	Canadian River #1	**Location:**	US 83; N. of Canadian, TX; Hemphill County
Date:	17 April 2001 (HF)	**Collectors:**	M. Armstrong, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	9(3)	**7.) % of individuals as omnivores:**	0(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	67(3)
3.) Total # of sunfish species:	2(5)	**9.) % of individuals as piscivores:**	22(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	54(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	56(1)	**12.) % of individuals with disease or anomaly:**	0(5)
IBI Total Score: 38 (Limited-Intermediate)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	9(5)	**7.) % of individuals as invertivores:**	67(5)
2.) # of native cyprinid species:	4(5)	**8.) # of individuals/seine haul:**	6.8(1)
3.) # of sunfish species:	2(5)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	0(5)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 36 (Exceptional)			

Site:	Canadian River #2	**Location:**	SH 70; N. of Pampa, TX; Roberts County
Date:	17 April 2001 (HF)	**Collectors:**	M. Armstrong, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	5(3)	**7.) % of individuals as omnivores:**	20(3)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	80(3)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	0(1)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	65(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	60(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 28 (Limited)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	5(3)	**7.) % of individuals as invertivores:**	80(5)
2.) # of native cyprinid species:	4(5)	**8.) # of individuals/seine haul:**	8.1(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	20(1)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 26 (Intermediate)			

Site:	Canadian River #3	**Location:**	SH 152; N. of Borger, TX; Hutchinson County
Date:	18 April 2001 (HF)	**Collectors:**	M. Armstrong, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	5(3)	**7.) % of individuals as omnivores:**	20(3)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	80(3)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	0(1)
4.) Total # of sucker species:	1(3)	**10.) # of individuals in sample:**	35(1)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	40(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 28 (Limited)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	5(3)	**7.) % of individuals as invertivores:**	80(5)
2.) # of native cyprinid species:	3(5)	**8.) # of individuals/seine haul:**	4.4(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	20(1)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 26 (Intermediate)			

Site:	Canadian River #4	**Location:**	U.S. 287; N. of Amarillo, TX; Potter County
Date:	18 April 2001 (HF)	**Collectors:**	M. Armstrong, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	1(1)	**7.) % of individuals as omnivores:**	0(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	100(5)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	0(1)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	9(1)
5.) Total # intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	0(5)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 32 (Limited)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	1(1)	**7.) % of individuals as invertivores:**	100(5)
2.) # of native cyprinid species:	1(1)	**8.) # of individuals/seine haul:**	1.1(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	0(5)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 24 (Intermediate)			

Site:	Canadian River #5	**Location:**	US 385; S. of Channing, TX; Oldham County
Date:	19 April 2001 (HF)	**Collectors:**	M. Armstrong, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	7(3)	**7.) % of individuals as omnivores:**	29(3)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	71(3)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	0(1)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	48(1)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	57(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 26 (Limited)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	7(3)	**7.) % of individuals as invertivores:**	71(5)
2.) # of native cyprinid species:	5(5)	**8.) # of individuals/seine haul:**	6.0(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	29(1)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 26 (Intermediate)			

Site:	Canadian River #6	**Location:**	SH 54; Near Logan, NM; Quay County
Date:	19 April 2001 (HF)	**Collectors:**	M. Armstrong, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	4(3)	**7.) % of individuals as omnivores:**	0(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	75(3)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	25(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	113(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	50(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 34 (Limited)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	4(1)	**7.) % of individuals as invertivores:**	75(5)
2.) # of native cyprinid species:	2(3)	**8.) # of individuals/seine haul:**	14.1(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	0(5)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 26 (Intermediate)			

Site:	Canadian River #1	**Location:**	US 83; N. of Canadian, TX; Hemphill County
Date:	21 August 2001 (LF)	**Collectors:**	J. Lewis, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	9(3)	**7.) % of individuals as omnivores:**	22(3)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	56(3)
3.) Total # of sunfish species:	2(5)	**9.) % of individuals as piscivores:**	22(5)
4.) Total # of sucker species:	1(3)	**10.) # of individuals in sample:**	560(5)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	78(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 40 (Intermediate)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	9(5)	**7.) % of individuals as invertivores:**	56(3)
2.) # of native cyprinid species:	2(3)	**8.) # of individuals/seine haul:**	70.0(5)
3.) # of sunfish species:	2(5)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	22(1)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 32 (Intermediate)			

Site:	Canadian River #2	**Location:**	SH 70; N. of Pampa, TX; Roberts County
Date:	21 August 2001 (LF)	**Collectors:**	J. Lewis, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
!.) Total # of species:	6(3)	**7.) % of individuals as omnivores:**	0(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	67(3)
3.) Total # of sunfish species:	1(3)	**9.) % of individuals as piscivores:**	33(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	102(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	67(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 36 (Limited-Intermediate)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	6(3)	**7.) % of individuals as invertivores:**	67(5)
2.) # of native cyprinid species:	2(3)	**8.) # of individuals/seine haul:**	12.8(1)
3.) # of sunfish species:	1(3)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	0(5)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 30 (Intermediate)			

Site:	Canadian River #3	**Location:**	SH 152; N. of Borger, TX; Hutchinson County
Date:	22 August 2001 (LF)	**Collectors:**	J. Lewis, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	0()	**7.) % of individuals as omnivores:**	()
2.) Total # of darter species:	()	**8.) % of individuals as insectivores:**	()
3.) Total # of sunfish species:	()	**9.) % of individuals as piscivores:**	()
4.) Total # of sucker species:	()	**10.) # of individuals in sample:**	()
5.) Total # of intolerant species:	()	**11.) % of individuals as hybrids:**	()
6.) % of individuals as tolerants:	()	**12.) % of individuals with disease or other anomaly:**	()
IBI Total Score: N/A; Site was not sampled due to lack of water.			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	0()	**7.) % of individuals as invertivores:**	()
2.) # of native cyprinid species:	()	**8.) # of individuals/seine haul:**	()
3.) # of sunfish species:	()	**9.) % of individuals as non-native species:**	()
4.) % of individuals as omnivores:	()	**10.) % of individuals with disease or other anomaly:**	()
IBI Total Score: N/A; Site was not sampled due to lack of water.			

Site:	Canadian River #4	**Location:**	U.S. 287; N. of Amarillo, TX; Potter County
Date:	22 August 2001 (LF)	**Collectors:**	J. Lewis, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	5(3)	**7.) % of individuals as omnivores:**	20(3)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	80(3)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	0(1)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	347(5)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	80(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 30 (Limited)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	5(3)	**7.) % of individuals as invertivores:**	80(5)
2.) # of native cyprinid species:	3(5)	**8.) # of individuals/seine haul:**	4.4(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	20(1)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 26 (Intermediate)			

Site:	Canadian River #5	**Location:**	US 385; S. of Channing, TX; Oldham County
Date:	22 August 2001	**Collectors:**	J. Lewis, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	6(3)	**7.) % of individuals as omnivores:**	50(1)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	50(3)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	0(1)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	71(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	83(1)	**12.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 26 (Limited)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	6(3)	**7.) % of individuals as invertivores:**	50(3)
2.) # of native cyprinid species:	2(3)	**8.) # of individuals/seine haul:**	8.9(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	50(1)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 22 (Limited)			

Site:	Canadian River #6	**Location:**	SH 54; Near Logan, NM; Quay County
Date:	22 August 2001 (LF)	**Collectors:**	J. Lewis, C. Giggleman, O. Bocanegra, & J. Hughes

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	8(3)	**7.) % of individuals as omnivores:**	13(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	63(3)
3.) Total # of sunfish species:	0(1)	**9.) % of individuals as piscivores:**	13(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	128(3)
5.) Total # of intolerant species:	1(3)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	50(1)	**12.) % of individuals with disease of other anomaly:**	0(5)
IBI Total Score: 36 (Limited-Intermediate)			

Western High Plains and Southwestern Tablelands IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	8(5)	**7.) % of individuals as invertivores:**	63(3)
2.) # of native cyprinid species:	4(5)	**8.) # of individuals/seine haul:**	16.0(1)
3.) # of sunfish species:	0(1)	**9.) % of individuals as non-native species:**	0(5)
4.) % of individuals as omnivores:	13(3)	**10.) % of individuals with disease or other anomaly:**	0(5)
IBI Total Score: 28 (Intermediate)			

APPENDIX C
(MACROINVERTEBRATE DATA FOR THE SOUTH FORK CANADIAN RIVER)

Site: CR1	Canadian River at US 83 Hemphill County, Texas	Date: 17-Apr-2001 (HF)

Specimen ID #	Taxon	# of Individuals
CR1.1H3	Amphipoda	66
CR1.1C5	Bivalvia	26
CR1.1F4	Gastropoda	344
CR1.1B4	Oligochaeta	35
CR1.1H1	Turbellaria	1
CR1.1G5	Collembola	2
CR1.1G2	Baetidae	9
CR1.1G1	*Caenis sp.*	35
CR1.1F5	*Perlesta sp.*	1
CR1.1G3	*Nectopsyche sp.*	19
CR1.1H2	Corixidae	4
CR1.1E1	*Agabus sp.*	6
CR1.1C3	*Berosus sp.*	21
CR1.1E4	Curculionidae	1
CR1.1C2	*Dubiraphia sp.*	9
CR1.1F2	*Hydrochus sp.*	1
CR1.1E2	*Oreodytes sp.*	32
CR1.1C4	*Peltodytes sp.*	24
CR1.1E5	Scirtidae	1
CR1.1F1	*Tropisternus sp.*	2
CR1.1B2B3	Ceratopogonidae	29
CR1.1A5B1	Chironomidae	511
CR1.1B5	Ephydridae	6
CR1.1F3	Sciomyzidae	1
CR1.1A1A2A3A4	Simuliidae	1854
CR1.1C1	Tabanidae	2
CR1.1D1	*Argia sp.*	9
CR1.1D5	Gomphidae	3
CR1.1D3	*Hetaerina sp.*	3
CR1.1D4	*Sympetrum sp.*	1

# of Taxa	30
# of Individuals	3058
Diversity	1.40
Maximum Diversity	3.40
Evenness	0.41
Hilsenhoff Index	6.03
EPT	4
% Chironomidae	16.7
% Dominant Taxon	60.6
% Dominant Functional Group	67
% Predator	9.3
Intolerant/Tolerant	0.03
% Trichoptera =Hydropsychids	0
# Non-insect Taxa	5
% Collector-gatherers	9.8
% Elmidae	0.29
IBI Score	28 - Intermediate

Site: CR2	Canadian River at SH 70 Roberts County, Texas	Date: 17-Apr-2001 (HF)

Specimen ID #	Taxon	# of Individuals
CR2.1E1	Amphipoda	744
CR2.1G3	Cambaridae	1
CR2.1A5	Gastropoda	42
CR2.1B3	Oligochaeta	164
CR2.1F5	Turbellaria	25
CR2.1C5	*Caenis sp.*	4
CR2.1D1	Baetidae	57
CR2.1D2	*Hydropsyche sp.*	1
CR2.1G1G2	*Nectopsyche sp.*	115
CR2.1C1	*Agabus sp.*	2
CR2.1B1	*Berosus sp.*	13
CR2.1B4	*Dubiraphia sp.*	36
CR2.1E2	*Helichus sp.*	9
CR2.1E3	*Hydrochus sp.*	4
CR2.1F4	*Hydroporus sp.*	2
CR2.1B5	*Microcylloepus sp.*	65
CR2.1E4	Staphylinidae	1
CR2.1G4	*Tropisternus sp.*	3
CR2.1E5F1	Ceratopogonidae	13
CR2.1A3A4	Chironomidae	394
CR2.1F2	*Nemotelus sp.*	2
CR2.1A2A3	Simuliidae	305
CR2.1F3	Tabanidae	1
CR2.1D3	*Argia sp.*	1
CR2.1C3	*Erpetogomphus sp.*	3
CR2.1B2	*Hetaerina sp.*	13
CR2.1C2	*Progomphus sp.*	5

# of Taxa	27
# of Individuals	2025
Diversity	1.97
Maximum Diversity	3.29
Evenness	0.60
Hilsenhoff Index	5.30
EPT	4
% Chironomidae	19.5
% Dominant Taxon	36.7
% Dominant Functional Group	41.1
% Predator	12.1
Intolerant/Tolerant	0.39
% Trichoptera =Hydropsychids	0.86
# Non-insect Taxa	5
% Collector-gatherers	41.1
% Elmidae	5
IBI Score	31 - High

Site: CR3	Canadian River at SH 152 Hutchinson County, Texas	Date: 18-Apr-2001 (HF)

Specimen ID #	Taxon	# of Individuals
CR3.1D1	Hydrocarina	1
CR3.1C4	Amphipoda	1
CR3.1A1A2	Cambaridae	30
CR3.1A3	Gastropoda	7
CR3.1A4	Oligochaeta	41
CR3.1B4	Collembola	22
CR3.1D2	*Caenis sp.*	4
CR3.1D3	Corixidae	2
CR3.1B5	*Agabus sp.*	31
CR3.1C2	*Hydroporus sp.*	2
CR3.1C1	*Oreodytes sp.*	4
CR3.1C5	Ceratopogonidae	13
CR3.1A5B1	Chironomidae	1207
CR3.1B3	Culicidae	19
CR3.1D4	Dolichopodidae	2
CR3.1D5	Ephydridae	1
CR3.1B2	Simuliidae	157

# of Taxa	17
# of Individuals	1544
Diversity	0.93
Maximum Diversity	2.83
Evenness	0.33
Hilsenhoff Index	6.13
EPT	1
% Chironomidae	78.2
% Dominant Taxon	78.2
% Dominant Functional Group	36.8
% Predator	29
Intolerant/Tolerant	0.01
% Trichoptera =Hydropsychids	0
# Non-insect Taxa	5
% Collector-gatherers	33.4
% Elmidae	0
IBI Score	20 - Limited

Site: CR4	Canadian River at US 287 Potter County, Texas	Date: 18-Apr-2001 (HF)

Specimen ID #	Taxon	# of Individuals
CR4.1B5	Amphipoda	1
CR4.1B2	Cambaridae	1
CR4.1B1	Gastropoda	14
CR4.1A5	Oligochaeta	10
CR4.1B4	*Caenis sp.*	4
CR4.1C3	*Gyretes sp.*	1
CR4.1B3	*Haliplus sp.*	4
CR4.1C4	*Helichus sp.*	3
CR4.1C5	*Hydroporus sp.*	3
CR4.1C5	*Oreodytes sp.*	1
CR4.1A4	Ceratopogonidae	1
CR4.1A2A3	Chironomidae	266
CR4.1A1	Simuliidae	42
CR4.1C1	*Argia sp.*	1

# of Taxa	14
# of Individuals	352
Diversity	0.98
Maximum Diversity	2.64
Evenness	0.37
Hilsenhoff Index	5.99
EPT	1
% Chironomidae	75.6
% Dominant Taxon	75.6
% Dominant Functional Group	37.1
% Predator	27.6
Intolerant/Tolerant	0.02
% Trichoptera =Hydropsychids	0
# Non-insect Taxa	4
% Collector-gatherers	29.6
% Elmidae	0
IBI Score	20 - Limited

Site: CR5	Canadian River at US 385 Oldham County, Texas	Date: 19-Apr-2001 (HF)

Specimen ID #	Taxon	# of Individuals
CR5.1B1	Cambaridae	1
CR5.1A5	Gastropoda	5
CR5.1B2	Oligochaeta	1
CR5.1C1	*Caenis sp.*	5
CR5.1B5	*Hydropsyche sp.*	1
CR5.1C3	Corixidae	1
CR5.1A4	*Berosus sp.*	2
CR5.1C5	Ceratopogonidae	3
CR5.1A2A3	Chironomidae	449
CR5.1A1	Simuliidae	115
CR5.1B4	*Argia sp.*	2
CR5.1C2	Gomphidae	1
CR5.1B3	*Ischnura sp.*	1

# of Taxa	13
# of Individuals	587
Diversity	0.74
Maximum Diversity	2.56
Evenness	0.29
Hilsenhoff Index	6.02
EPT	2
% Chironomidae	76.5
% Dominant Taxon	76.5
% Dominant Functional Group	45.3
% Predator	26.8
Intolerant/Tolerant	0.003
% Trichoptera =Hydropsychids	100
# Non-insect Taxa	3
% Collector-gatherers	26.7
% Elmidae	0
IBI Score	19 - Limited

Site: CR6	Canadian River at SH 54 Quay County, New Mexico	Date: 19-Apr-2001 (HF)

Specimen ID #	Taxon	# of Individuals
CR6.1C2	Hydracarina	1
CR6.1A4	Gastropoda	34
CR6.1D4	Oligochaeta	14
CR6.1C1	Turbellaria	1
CR6.1C4	Baetidae	2
CR6.1D5	*Belostoma sp.*	1
CR6.1E3	Corixidae	1
CR6.1D5	Gerridae	1
CR6.1A5C3	*Berosus sp.*	132
CR6.1D3	*Enochrus sp.*	3
CR6.1D2	*Oreodytes sp.*	3
CR6.1C5	*Paracymus sp.*	1
CR6.1B1F2F3	Ceratopogonidae	565
CR6.1A2A3	Chironomidae	450
CR6.1E5	Dolichopodidae	15
CR6.1A1	Simuliidae	2
CR6.1E2	Tabanidae	1
CR6.1F4	Tipulidae	1
CR6.1B3	*Argia sp.*	3
CR6.1B4	*Enallagma sp.*	27
CR6.1E1	Libellulidae	2

# of Taxa	21
# of Individuals	1260
Diversity	1.36
Maximum Diversity	3.04
Evenness	0.45
Hilsenhoff Index	6.31
EPT	1
% Chironomidae	35.7
% Dominant Taxon	44.8
% Dominant Functional Group	49.2
% Predator	49.2
Intolerant/Tolerant	0.02
% Trichoptera =Hydropsychids	0
# Non-insect Taxa	4
% Collector-gatherers	35.9
% Elmidae	0
IBI Score	18 - Limited

Site: CR1	Canadian River at US 83 Hemphill County, Texas	Date: 21-Aug-2001 (LF)
Specimen ID #	Taxon	# of Individuals
CR1.2D3	Amphipoda	255
CR1.2B2	Gastropoda	100
CR1.2A4	Oligochaeta	14
CR1.2E3	Baetidae	14
CR1.2C5	*Caenis sp.*	87
CR1.2G1	*Isonychia sp.*	3
CR1.2D1	*Tricorythodes sp.*	100
CR1.2C4	*Hydropsyche sp.*	22
CR1.2H4	*Nectopsyche sp.*	198
CR1.2C3	*Belostoma sp.*	2
CR1.2C5	*Rhagovelia sp.*	7
CR1.2B4	*Sialis sp.*	1
CR1.2D5	*Berosus sp.*	27
CR1.2H3	*Celina sp.*	1
CR1.2E5	*Chaetarthria sp.*	1
CR1.2F2	*Dubiraphia sp.*	3
CR1.2I3	*Enochrus sp.*	1
CR1.2E2	*Haliplus sp.*	37
CR1.2G3	*Helichus sp.*	1
CR1.2I4	*Helochares sp.*	2
CR1.2G2	*Helophorus sp.*	1
CR1.2E4	*Hydrochus sp.*	11
CR1.2F5	*Laccophilus sp.*	1
CR1.2F1G4	*Paracymus sp.*	2
CR1.2E1	*Peltodytes sp.*	76
CR1.2F3	*Stenelmis sp.*	4
CR1.2D2	*Tropisternus sp.*	14
CR1.2A5	Ceratopogonidae	35
CR1.2A2A3	Chironomidae	452
CR1.2H2	Dolichopodidae	1
CR1.2A1	Simuliidae	1
CR1.2D4	Tabanidae	5
CR1.2C1	*Argia sp.*	4
CR1.2C2	*Erpetogomphus sp.*	13
CR1.2B1	*Hetaerina sp.*	13
CR1.2B3	*Macromia sp.*	5
CR1.2B5	*Progomphus sp.*	42
# of Taxa		37
# of Individuals		1556
Diversity		2.41
Maximum Diversity		3.61
Evenness		0.67
Hilsenhoff Index		5.62
EPT		6
% Chironomidae		29
% Dominant Taxon		29
% Dominant Functional Group		35.4
% Predator		27.6
Intolerant/Tolerant		0.53
% Trichoptera =Hydropsychids		10
# Non-insect Taxa		3
% Collector-gatherers		35.4
% Elmidae		0.45
IBI Score		27 - Intermediate

Site: CR2	Canadian River at SH 70 Roberts County, Texas	Date: 21-Aug-2001 (LF)
Specimen ID #	Taxon	# of Individuals
CR2.2A3	Amphipoda	543
CR2.2H2	Cambaridae	1
CR2.2B3	Gastropoda	74
CR2.2A2	Oligochaeta	39
CR2.2B4	Turbellaria	2
CR2.2C1	Baetidae	18
CR2.2B5	*Isonychia sp.*	11
CR2.2C2	*Tricorythodes sp.*	18
CR2.2H3	*Cheumatopsyche sp.*	1
CR2.2H1	*Hydropsyche sp.*	7
CR2.2H4H5I1I2	*Nectopsyche sp.*	583
CR2.2B1	*Rhagovelia sp.*	53
CR2.2A5	*Berosus sp.*	11
CR2.2G3	Curculionidae	1
CR2.2E5	*Dineutus sp.*	7
CR2.2D3	*Dubiraphia sp.*	3
CR2.2I3	*Enochrus sp.*	2
CR2.2B2	*Haliplus sp.*	1
CR2.2D2	*Helichus sp.*	19
CR2.2C5	*Helophorus sp.*	12
CR2.2D1	*Hydrochus sp.*	22
CR2.2D5G1	*Microcylloepus sp.*	89
CR2.2J1	*Ochthebius sp.*	1
CR2.2D4	Staphylinidae	2
CR2.2G5	*Stenelmis sp.*	1
CR2.2F3	*Tropisternus sp.*	2
CR2.2E2J2	Ceratopogonidae	10
CR2.2A1E3	Chironomidae	193
CR2.2E1	*Nemotelus sp.*	3
CR2.2F4	Tabanidae	2
CR2.2F1	*Argia sp.*	6
CR2.2C4	*Erpetogomphus sp.*	6
CR2.2A4F2F5	*Hetarina sp.*	92
CR2.2G2	Libellulidae	2
CR2.2J5	*Macromia sp.*	2
CR2.2C3	*Progomphus sp.*	43
# of Taxa		36
# of Individuals		1882
Diversity		2.12
Maximum Diversity		3.58
Evenness		0.59
Hilsenhoff Index		4.13
EPT		6
% Chironomidae		10.3
% Dominant Taxon		31
% Dominant Functional Group		36.9
% Predator		26.3
Intolerant/Tolerant		2.07
% Trichoptera =Hydropsychids		1.3
# Non-insect Taxa		5
% Collector-gatherers		36.9
% Elmidae		4.9
IBI Score		34 - High

Site: CR3 Canadian River at SH 152 Date: 22-Aug-2001 (LF)
Hutchinson County, Texas

No specimens collected due to absence of water in channel.

Site: CR4	Canadian River at US 287 Potter County, Texas	Date: 22-Aug-2001 (LF)

Specimen ID #	Taxon	# of Individuals
CR4.2G4	Amphipoda	1
CR4.2F1	Cambaridae	2
CR4.2G1	Gastropoda	8
CR4.2G2	Oligochaeta	2
CR4.2H2	Baetidae	9
CR4.2G5	*Caenis sp.*	7
CR4.2H2	*Tricorythodes sp.*	1
CR4.2J3	Leptoceridae	1
CR4.2J1	*Microvelia sp.*	1
CR4.2G3	*Berosus sp.*	3
CR4.2F2	*Dineutus sp.*	2
CR4.2H4	*Helichus sp.*	2
CR4.2H3	*Helophorus sp.*	1
CR4.2H5	*Hydroporus sp.*	6
CR4.2F3	*Tropisternus sp.*	1
CR4.2I4	Ceratopogonidae	3
CR4.2F5	Chironomidae	62
CR4.2I5	*Nemotelus sp.*	2
CR4.2F4	Simuliidae	56
CR4.2I1	*Argia sp.*	2
CR4.2I2	*Enallagma sp.*	6

# of Taxa	21
# of Individuals	178
Diversity	1.99
Maximum Diversity	3.04
Evenness	0.65
Hilsenhoff Index	5.91
EPT	4
% Chironomidae	34.8
% Dominant Taxon	34.8
% Dominant Functional Group	43.1
% Predator	24.4
Intolerant/Tolerant	0.16
% Trichoptera =Hydropsychids	0
# Non-insect Taxa	4
% Collector-gatherers	24.4
% Elmidae	0
IBI Score	27 - Intermediate

Site: CR5	Canadian River at US 385 Oldham County, Texas	Date: 22-Aug-2001 (LF)

Specimen ID #	Taxon	# of Individuals
CR5.2G4	Amphipoda	4
CR5.2G5	Oligochaeta	16
CR5.2I1	Baetidae	2
CR5.2H5	*Caenis sp.*	12
CR5.2H1	*Berosus sp.*	1
CR5.2G1	*Dineutus sp.*	1
CR5.2H4	*Laccophilus sp.*	1
CR5.2H3	Ceratopogonidae	2
CR5.2H2	Chironomidae	66
CR5.2G3	Simuliidae	55
CR5.2G2	Tabanidae	1
CR5.2I2	Coenagrionidae	2

# of Taxa	12
# of Individuals	163
Diversity	1.53
Maximum Diversity	2.48
Evenness	0.62
Hilsenhoff Index	6.14
EPT	2
% Chironomidae	40.5
% Dominant Taxon	40.5
% Dominant Functional Group	47.2
% Predator	17.8
Intolerant/Tolerant	0.02
% Trichoptera =Hydropsychids	0
# Non-insect Taxa	2
% Collector-gatherers	30.1
% Elmidae	0
IBI Score	19 - Limited

Site: CR6	Canadian River at SH 54 Quay County, New Mexico	Date: 22-Aug-2001 (LF)

Specimen ID #	Taxon	# of Individuals
CR6.2H1	Amphipoda	2
CR6.2G1	Gastropoda	26
CR6.2J1	Oligochaeta	10
CR6.2J3	Baetidae	1
CR6.2H2	Hydroptilidae	2
CR6.2J2	Corixidae	27
CR6.2H3	*Merragata sp.*	1
CR6.2G2I3	*Berosus sp.*	62
CR6.2I5	*Enochrus sp.*	3
CR6.2I2	*Haliplus sp.*	1
CR6.2G3	Ceratopogonidae	164
CR6.2G4G5	Chironomidae	161
CR6.2H5	*Nemotelus sp.*	7
CR6.2H4	*Odontomyia sp.*	1
CR6.2I1	Tipulidae	1
CR6.2F1	*Argia sp.*	7
CR6.2F2	*Enallagma sp.*	19
CR6.2F3	*Erpetogomphus sp.*	6
CR6.2F5	*Erythemis sp.*	1
CR6.2F4	*Orthemis sp.*	2

# of Taxa	20
# of Individuals	504
Diversity	1.84
Maximum Diversity	3.00
Evenness	0.61
Hilsenhoff Index	6.53
EPT	2
% Chironomidae	31.9
% Dominant Taxon	32.5
% Dominant Functional Group	46.5
% Predator	46.5
Intolerant/Tolerant	0.02
% Trichoptera =Hydropsychids	0
# Non-insect Taxa	3
% Collector-gatherers	37
% Elmidae	0
IBI Score	21 - Limited

APPENDIX D
(IN-STREAM HABITAT EVALUATIONS)

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Hemphill County, Texas
STATION #	CR1	**STREAM CLASS**	4th Order
LAT	35.93537	**RIVER BASIN**	Canadian River
LONG	-100.3742	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Mike Armstrong		

FORM COMPLETED BY Craig Giggleman	**DATE** 04/17/2001 **TIME** 0800 hrs	**REASON FOR SURVEY** Off-Refuge Study

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 51 °F
85 % ☒ % cloud cover	☒ 95 %	Other
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem: ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater ☒ Warmwater

Stream Type

Stream Origin: ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km^2

WATERSHED FEATURES

Predominant Surrounding Landuse: ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☒ Agricultural ☐ Other _____ ☐ Residential

Local Watershed NPS Pollution: ☒ No evidence ☐ Some potential sources ☐ Obvious sources

Local Watershed Erosion: ☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present

☒ Trees ☒ Shrubs ☒ Grasses ☐ Herbaceous

dominant species present Salt cedar and Russian olive

INSTREAM FEATURES

Estimated Reach Length 100 m

Estimated Stream Width 50 m

Sampling Reach Area 5000 m^2

Area in km^2 ($m^2/10^6$) 0.005 km^2

Estimated Stream Depth 1.0 m

Surface Velocity 0.59 m^3/sec

Canopy Cover: ☒ Partly open ☐ Partly shaded ☐ Shaded

High Water Mark 2 m

Proportion of Reach Represented by Stream Morphology Types: ☒ Riffle 10 % ☒ Run 85 % ☒ Pool 5 %

Channelized ☐ Yes ☒ No

Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 10 m^2

Density of LWD 2000 m^2/km^2 (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present

☐ Rooted emergent ☐ Rooted submergent ☒ Rooted floating ☐ Free floating ☐ Floating Algae ☐ Attached Algae

dominant species present unknown

Portion of the reach with aquatic vegetation 5 %

WATER QUALITY

Temperature 10.5 °C

Conductivity 2160

Dissolved Oxygen 9.2

pH 8.7

Turbidity not measured

WQ Instrument hydrolab

Water Odors: ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other

Turbidity (if not measured): ☒ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other _____

Water Surface Oils: ☐ Slick ☐ Flecks ☐ Sheen ☒ None ☐ Globs ☐ Other _____

SEDIMENT/ SUBSTRATE

Odors: ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____

Oils: ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits: ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☐ Other _____

Looking at stones which are not deeply embedded, are undersides black? ☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	95%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	5%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	99%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	1%			
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 13	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 5	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	**5** 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 19	20 **19** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 5 **(RB)**	Right Bank 10 9	8 7 ***6***	**5** 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 6 **(RB)**	Right Bank 10 9	8 7 **6**	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 10 **(LB)**	Left Bank **10** 9	8 7 6	5 4 3	2 1 0
SCORE 10 **(RB)**	Right Bank **10** 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE **108**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Roberts County, Texas
STATION #	CR2	**STREAM CLASS**	4th Order
LAT	35.96786	**RIVER BASIN**	Canadian River
LONG	-100.8587	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Mike Armstrong		

FORM COMPLETED BY Craig Giggleman	**DATE** 04/17/2001 **TIME** 1230 hrs	**REASON FOR SURVEY** Off-Refuge Study

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 60 °F
75 % ☒ % cloud cover	☒ 95 %	Other _____
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem: ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater ☒ Warmwater

Stream Type

Stream Origin: ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km^2

WATERSHED FEATURES

Predominant Surrounding Landuse: ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other _____ ☐ Residential

Local Watershed NPS Pollution: ☒ No evidence ☐ Some potential sources ☐ Obvious sources

Local Watershed Erosion: ☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present

☐ Trees ☐ Shrubs ☒ Grasses ☐ Herbaceous

dominant species present Switch grass

INSTREAM FEATURES

Estimated Reach Length 100 m
Estimated Stream Width 15 m
Sampling Reach Area 1500 m^2
Area in km² ($m^2/10^6$) 0.0015 km^2
Estimated Stream Depth 0.5 m
Surface Velocity 0.59 m^3/sec

Canopy Cover: ☒ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 1.0 m
Proportion of Reach Represented by Stream Morphology Types
☒ Riffle 2 % ☒ Run 95 %
☒ Pool 3 %
Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 5 m^2
Density of LWD 3333 m^2/km^2 (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present

☐ Rooted emergent ☐ Rooted submergent ☒ Rooted floating
☐ Free floating ☐ Floating Algae ☐ Attached Algae

dominant species present unknown

Portion of the reach with aquatic vegetation 5 %

WATER QUALITY

Temperature 12.8 °C
Conductivity 2570
Dissolved Oxygen 8.4
pH 8.8
Turbidity not measured
WQ Instrument hydrolab

Water Odors: ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other

Water Surface Oils: ☐ Slick ☐ Flecks ☐ Sheen ☒ None ☐ Globs ☐ Other _____

Turbidity (if not measured): ☒ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other _____

SEDIMENT/ SUBSTRATE

Odors: ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____

Deposits: ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☐ Other _____

Oils: ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Looking at stones which are not deeply embedded, are undersides black? ☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	98%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	98%	Marl	grey, shell fragments	2%
Silt	0.004-0.06 mm	1%			
Clay	<0.004 mm (slick)	1%			

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 4	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 **4** 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 9	20 19 18 17 16	15 14 13 12 11	10 **9** 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 20	**20** 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 4 **(RB)**	Right Bank 10 9	8 7 6	5 **4** 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 6 **(LB)**	Left Bank 10 9	8 7 **6**	5 4 3	2 1 0
SCORE 6 **(RB)**	Right Bank 10 9	8 7 **6**	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 9 **(LB)**	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 **(RB)**	Right Bank 10 **9**	8 7 6	5 4 3	2 1 0

TOTAL SCORE **107**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Hutchinson County, Texas
STATION #	CR3	**STREAM CLASS**	4th Order
LAT	35.73453	**RIVER BASIN**	Canadian River
LONG	-101.4177	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Mike Armstrong		

FORM COMPLETED BY Mike Armstrong	**DATE** 04/18/2001 **TIME** 1030 hrs	**REASON FOR SURVEY** Off-Refuge Study

WEATHER CONDITIONS	**Now** ☐ storm (heavy rain) ☐ rain (steady rain) ☐ showers (intermittent) 80 % ☒ % cloud cover ☐ clear/sunny	**Past 24 hours** ☐ ☐ ☐ ☒ 75 % ☐	**Heavy rain in last 7 days** ☐ Yes ☒ No Air Temperature 54 °F Other _____
STREAM CHARACTERIZATION	**Stream Subsystem** ☐ Perennial ☒ Intermittent ☐ Tidal ☐ Coldwater ☒ Warmwater **Stream Origin** ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____	**Stream Type** **Catchment Area** 59,223 km²	
WATERSHED FEATURES	**Predominant Surrounding Landuse** ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☒ Agricultural ☐ Other _____ ☐ Residential	**Local Watershed NPS Pollution** ☒ No evidence ☐ Some potential sources ☐ Obvious sources **Local Watershed Erosion** ☐ None ☐ Moderate ☐ Heavy	
RIPARIAN VEGETATION	Indicate the dominant type and record the dominant species present ☒ Trees ☒ Shrubs ☒ Grasses ☒ Herbaceous dominant species present Salt cedar		
INSTREAM FEATURES	**Estimated Reach Length** 100 m **Estimated Stream Width** 2 m **Sampling Reach Area** 200 m² **Area in km² (m²/10⁶)** 0.0002 km² **Estimated Stream Depth** 0.4 m **Surface Velocity** 0.59 m³/sec	**Canopy Cover** ☒ Partly open ☐ Partly shaded ☐ Shaded **High Water Mark** 1.0 m **Proportion of Reach Represented by Stream Morphology Types** ☒ Riffle ____ % ☒ Run ____ % ☒ Pool ____ % **Channelized** ☐ Yes ☒ No **Dam Present** ☒ Yes ☐ No	
LARGE WOODY DEBRIS	LWD 5 m² Density of LWD 25000 m²/km² (LWD/reach area)		
AQUATIC VEGETATION	Indicate the dominant type and record the dominant species present ☒ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free floating ☐ Floating Algae ☐ Attached Algae dominant species present Sedges Portion of the reach with aquatic vegetation 60 %		
WATER QUALITY	Temperature 19.9 °C Conductivity 2820 Dissolved Oxygen 7.6 pH 8.2 Turbidity not measured WQ Instrument hydrolab	**Water Odors** ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other **Turbidity (if not measured)** ☐ Clear ☐ Slightly turbid ☒ Turbid ☐ Opaque ☐ Stained ☐ Other _____	**Water Surface Oils** ☐ Slick ☐ Flecks ☐ Sheen ☒ None ☐ Globs ☐ Other _____
SEDIMENT/ SUBSTRATE	**Odors** ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____ **Oils** ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse	**Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☒ Other Clay **Looking at stones which are not deeply embedded, are undersides black?** ☐ Yes ☒ No	

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	15%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	20%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	70%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	25%			
Clay	<0.004 mm (slick)	5%			

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 9	20 19 18 17 16	15 14 13 12 11	10 **9** 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 5	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	**5** 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 9 **(LB)**	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 **(RB)**	Right Bank 10 **9**	8 7 ***6***	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 9 **(LB)**	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 **(RB)**	Right Bank 10 **9**	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 5 **(LB)**	Left Bank 10 9	8 7 6	**5** 4 3	2 1 0
SCORE 5 **(RB)**	Right Bank 10 9	8 7 6	**5** 4 3	2 1 0

TOTAL SCORE **110**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Potter County, Texas
STATION #	CR4	**STREAM CLASS**	4th Order
LAT	35.46958	**RIVER BASIN**	Canadian River
LONG	-101.8811	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Mike Armstrong		

FORM COMPLETED BY	**DATE**	**REASON FOR SURVEY**
Mike Armstrong	04/18/2001	Off-Refuge Study
	TIME 1430 hrs	

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 76 °F
15 % ☒ % cloud cover	☒ 30 %	Other
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem: ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater ☒ Warmwater

Stream Type

Stream Origin: ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km^2

WATERSHED FEATURES

Predominant Surrounding Landuse: ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☐ Agricultural ☒ Other ATV use ☐ Residential

Local Watershed NPS Pollution: ☐ No evidence ☐ Some potential sources ☒ Obvious sources

Local Watershed Erosion: ☐ None ☐ Moderate ☒ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present

☒ Trees ☒ Shrubs ☒ Grasses ☒ Herbaceous

dominant species present Salt cedar, switch grasses

INSTREAM FEATURES

Estimated Reach Length 100 m

Estimated Stream Width 50 m

Sampling Reach Area 5000 m^2

Area in km^2 ($m^2/10^6$) 0.005 km^2

Estimated Stream Depth 1.0 m

Surface Velocity 0.59 m^3/sec

Canopy Cover: ☒ Partly open ☐ Partly shaded ☐ Shaded

High Water Mark 2.0 m

Proportion of Reach Represented by Stream Morphology Types: ☐ Riffle ____ % ☒ Run 100 % ☐ Pool ____ %

Channelized ☐ Yes ☒ No

Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 0 m^2

Density of LWD 0 m^2/km^2 (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present

☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free floating ☐ Floating Algae ☐ Attached Algae

dominant species present none

Portion of the reach with aquatic vegetation 0 %

WATER QUALITY

Temperature 21.0 °C

Conductivity 3000

Dissolved Oxygen 7.4

pH 8.8

Turbidity not measured

WQ Instrument hydrolab

Water Odors: ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other

Water Surface Oils: ☐ Slick ☐ Flecks ☐ Sheen ☒ None ☐ Globs ☐ Other _____

Turbidity (if not measured): ☐ Clear ☒ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other _____

SEDIMENT/ SUBSTRATE

Odors: ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____

Deposits: ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☐ Other _____

Oils: ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Looking at stones which are not deeply embedded, are undersides black? ☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	2%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	10%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	100%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 1	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 **1** 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 4	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 **4** 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 9	20 19 18 17 16	15 14 13 12 11	10 **9** 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 19	20 **19** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 8 **(LB)**	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 2 **(RB)**	Right Bank 10 9	8 7 ***6***	5 4 3	**2** 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 8 **(LB)**	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 2 **(RB)**	Right Bank 10 9	8 7 6	5 4 3	**2** 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 8 **(LB)**	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 3 **(RB)**	Right Bank 10 9	8 7 6	5 4 **3**	2 1 0

TOTAL SCORE **86**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Oldham County, Texas
STATION #	CR5	**STREAM CLASS**	4th Order
LAT	35.52047	**RIVER BASIN**	Canadian River
LONG	-102.2626	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Mike Armstrong		

FORM COMPLETED BY Omar Bocanegra	**DATE** 04/19/2001 **TIME** 0900 hrs	**REASON FOR SURVEY** Off-Refuge Study

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 62 °F
95 % ☒ % cloud cover	☒ 80 %	Other _____
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem: ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater ☒ Warmwater

Stream Type

Stream Origin: ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km^2

WATERSHED FEATURES

Predominant Surrounding Landuse: ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other _____ ☐ Residential

Local Watershed NPS Pollution: ☒ No evidence ☐ Some potential sources ☐ Obvious sources

Local Watershed Erosion: ☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present

☒ Trees ☒ Shrubs ☒ Grasses ☒ Herbaceous

dominant species present Reed canary grass, cottonwoods, salt cedar, and willow

INSTREAM FEATURES

Estimated Reach Length 100 m
Estimated Stream Width 10 m
Sampling Reach Area 1000 m^2
Area in km^2 ($m^2/10^6$) 0.001 km^2
Estimated Stream Depth 0.5 m
Surface Velocity 0.59 m^3/sec

Canopy Cover: ☒ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 2.0 m
Proportion of Reach Represented by Stream Morphology Types: ☒ Riffle 10 % ☒ Run 87 % ☒ Pool 3 %
Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 0 m^2
Density of LWD 0 m^2/km^2 (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present

☒ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☐ Free floating ☐ Floating Algae ☐ Attached Algae

dominant species present Reed canary grass

Portion of the reach with aquatic vegetation 20 %

WATER QUALITY

Temperature 12.8 °C
Conductivity 3130
Dissolved Oxygen 8.2
pH 8.8
Turbidity not measured
WQ Instrument hydrolab

Water Odors: ☒ Normal/None ☐ Sewage ☐ Slick ☐ Petroleum ☐ Chemical ☐ Sheen ☐ Fishy ☐ Other ☐ Globs ☐ Other _____

Water Surface Oils: ☐ Flecks ☒ None

Turbidity (if not measured): ☒ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other _____

SEDIMENT/ SUBSTRATE

Odors: ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____

Oils: ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits: ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☐ Other _____

Looking at stones which are not deeply embedded, are undersides black? ☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	5%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")	1%	Muck/Marl	black, very fine organic (FPOM)	10%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	99%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 2	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 **2** 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 9	20 19 18 17 16	15 14 13 12 11	10 **9** 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 19	20 **19** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 5 **(LB)**	Left Bank 10 9	8 7 6	**5** 4 3	2 1 0
SCORE 5 **(RB)**	Right Bank 10 9	8 7 ***6***	**5** 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 2 **(LB)**	Left Bank 10 9	8 7 6	5 4 3	**2** 1 0
SCORE 2 **(RB)**	Right Bank 10 9	8 7 6	5 4 3	**2** 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 9 **(LB)**	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 **(RB)**	Right Bank 10 **9**	8 7 6	5 4 3	2 1 0

TOTAL SCORE **104**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Quay County, New Mexico
STATION #	CR6	**STREAM CLASS**	3rd Order
LAT	35.52047	**RIVER BASIN**	Canadian River
LONG	-103.4151	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Mike Armstrong		

FORM COMPLETED BY	**DATE**	**REASON FOR SURVEY**
Mike Armstrong	04/19/2001	Off-Refuge Study
	TIME 1215 hrs	

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 80 °F
50 % ☒ % cloud cover	☒ 60 %	Other 20-30 mph winds
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater **Stream Type** ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☒ Mixture of origins
☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km²

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☒ Agricultural ☐ Other _____
☐ Residential

Local Watershed NPS Pollution
☐ No evidence ☒ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☒ None ☐ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present
☐ Trees ☒ Shrubs ☒ Grasses ☒ Herbaceous
dominant species present Willow

INSTREAM FEATURES

Estimated Reach Length 100 m
Estimated Stream Width 12 m
Sampling Reach Area 1200 m²
Area in km² (m²/10⁶) 0.0012 km²
Estimated Stream Depth 0.9 m
Surface Velocity 0.59 m³/sec

Canopy Cover
☒ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 2 m
Proportion of Reach Represented by Stream Morphology Types
☒ Riffle 15 % ☒ Run 70 % ☒ Pool 15 %
Channelized ☐ Yes ☒ No
Dam Present ☒ Yes ☐ No

LARGE WOODY DEBRIS

LWD 0 m²
Density of LWD 0 m²/km² (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☒ Rooted emergent ☐ Rooted submergent ☐ Rooted floating
☐ Free floating ☐ Floating Algae ☐ Attached Algae
dominant species present Sedges
Portion of the reach with aquatic vegetation 10 %

WATER QUALITY

Temperature 17.5 °C
Conductivity 2920
Dissolved Oxygen 7.7
pH 8.5
Turbidity not measured
WQ Instrument hydrolab

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other _____

Water Surface Oils
☐ Slick ☐ Flecks
☐ Sheen ☒ None
☐ Globs
☐ Other _____

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other _____

Oils
☒ Absent ☐ Slight ☐ Moderate
☐ Profuse

Deposits
☐ Sludge ☐ Sawdust
☐ Paper fiber ☒ Sand
☐ Relict shells ☐ Other _____

Looking at stones which are not deeply embedded, are undersides black?
☒ Yes ☐ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	15%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	30%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	100%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 15	20 19 18 17 16	**15** 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 13	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 20	**20** 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 4 **(RB)**	Right Bank 10 9	8 7 ***6***	5 **4** 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 3 **(LB)**	Left Bank 10 9	8 7 6	5 4 **3**	2 1 0
SCORE 3 **(RB)**	Right Bank 10 9	8 7 6	5 4 **3**	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 8 **(LB)**	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 8 **(RB)**	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0

TOTAL SCORE **118**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Hemphill County, Texas
STATION #	CR1	**STREAM CLASS**	4th Order
LAT	35.93537	**RIVER BASIN**	Canadian River
LONG	-100.3742	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Jacob Lewis		

FORM COMPLETED BY	**DATE** 08/21/2001	**REASON FOR SURVEY**
Omar Bocanegra, Craig Giggleman	**TIME** 0800 hrs	Off-Refuge Study

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 85 °F
5% ☒ % cloud cover	☐ ? %	Other
☒ clear/sunny	☒	

STREAM CHARACTERIZATION

Stream Subsystem ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater **Stream Type** ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☒ Mixture of origins
☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km^2

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☒ Agricultural ☐ Other _____
☐ Residential

Local Watershed NPS Pollution
☒ No evidence ☐ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present
☒ Trees ☒ Shrubs ☒ Grasses ☐ Herbaceous
dominant species present Salt cedar and Russian olive

INSTREAM FEATURES

Estimated Reach Length 100 m
Estimated Stream Width 40 m
Sampling Reach Area 4000 m^2
Area in km^2 ($m^2/10^6$) 0.004 km^2
Estimated Stream Depth 0.15 m
Surface Velocity 0.59 m^3/sec

Canopy Cover
☒ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 2 m
Proportion of Reach Represented by Stream Morphology Types
☒ Riffle 20 % ☒ Run 75 %
☒ Pool 5 %
Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 10 m^2
Density of LWD 2500 m^2/km^2 (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☐ Rooted submergent ☒ Rooted floating
☐ Free floating ☐ Floating Algae ☐ Attached Algae
dominant species present unknown
Portion of the reach with aquatic vegetation <5 %

WATER QUALITY

Temperature 21.5 °C
Conductivity 1120
Dissolved Oxygen 7.9
pH 8.8
Turbidity not measured
WQ Instrument hydrolab

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other _____

Water Surface Oils
☐ Slick ☐ Flecks
☐ Sheen ☒ None
☐ Globs
☐ Other _____

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other _____

Oils
☒ Absent ☐ Slight ☐ Moderate
☐ Profuse

Deposits
☐ Sludge ☐ Sawdust
☐ Paper fiber ☒ Sand
☐ Relict shells ☐ Other _____

Looking at stones which are not deeply embedded, are undersides black?
☒ Yes ☐ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	90%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	10%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	99%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	1%			
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 5	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	**5** 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 19	20 **19** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 9	20 19 18 17 16	15 14 13 12 11	10 **9** 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 4 **(RB)**	Right Bank 10 9	8 7 ***6***	5 **4** 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 7 **(RB)**	Right Bank 10 9	8 **7** 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 10 **(LB)**	Left Bank **10** 9	8 7 6	5 4 3	2 1 0
SCORE 10 **(RB)**	Right Bank **10** 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE **108**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Roberts County, Texas
STATION #	CR2	**STREAM CLASS**	4th Order
LAT	35.96786	**RIVER BASIN**	Canadian River
LONG	-100.8587	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Jake Lewis		

FORM COMPLETED BY	**DATE** 08/21/2001	**REASON FOR SURVEY**
Omar Bocanegra, Craig Giggleman	**TIME** 1230 hrs	Off-Refuge Study

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 95 °F
10 % ☒ % cloud cover	☒ 10 %	Other
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem: ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater ☒ Warmwater

Stream Type

Stream Origin: ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km²

WATERSHED FEATURES

Predominant Surrounding Landuse: ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other _____ ☐ Residential

Local Watershed NPS Pollution: ☒ No evidence ☐ Some potential sources ☐ Obvious sources

Local Watershed Erosion: ☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present

☐ Trees ☒ Shrubs ☒ Grasses ☐ Herbaceous

dominant species present Switch grass

INSTREAM FEATURES

Estimated Reach Length 100 m
Estimated Stream Width 12 m
Sampling Reach Area 1200 m²
Area in km² (m²/10⁶) 0.0012 km²
Estimated Stream Depth 0.25 m
Surface Velocity 0.04 m³/sec

Canopy Cover: ☒ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 2.0 m
Proportion of Reach Represented by Stream Morphology Types: ☒ Riffle 15 % ☒ Run 80 % ☒ Pool 5 %
Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 5 m²
Density of LWD 4166 m²/km² (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present

☐ Rooted emergent ☐ Rooted submergent ☒ Rooted floating
☒ Free floating ☐ Floating Algae ☐ Attached Algae

dominant species present unknown

Portion of the reach with aquatic vegetation 5 %

WATER QUALITY

Temperature 29.9 °C
Conductivity 1301
Dissolved Oxygen 8.3
pH 9.0
Turbidity not measured
WQ Instrument hydrolab

Water Odors: ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other

Turbidity (if not measured): ☒ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other _____

Water Surface Oils: ☐ Slick ☐ Flecks ☐ Sheen ☒ None ☐ Globs ☐ Other _____

SEDIMENT/ SUBSTRATE

Odors: ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____

Oils: ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits: ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☐ Other _____

Looking at stones which are not deeply embedded, are undersides black? ☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	97%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	2%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	98%	Marl	grey, shell fragments	1%
Silt	0.004-0.06 mm	1%			
Clay	<0.004 mm (slick)	1%			

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 4	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 **4** 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 20	**20** 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 4 **(RB)**	Right Bank 10 9	8 7 6	5 **4** 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 6 **(LB)**	Left Bank 10 9	8 7 **6**	5 4 3	2 1 0
SCORE 6 **(RB)**	Right Bank 10 9	8 7 **6**	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 9 **(LB)**	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 **(RB)**	Right Bank 10 **9**	8 7 6	5 4 3	2 1 0

TOTAL SCORE **106**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Potter County, Texas
STATION #	CR4	**STREAM CLASS**	4th Order
LAT	35.46958	**RIVER BASIN**	Canadian River
LONG	-101.8811	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Jacob Lewis		

FORM COMPLETED BY	**DATE**	**REASON FOR SURVEY**
Omar Bocanegra, Craig Giggleman	08/22/2001 **TIME** 0915 hrs	Off-Refuge Study

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 80 °F
25 % ☒ % cloud cover	☒ ? %	Other
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem: ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater ☒ Warmwater

Stream Type

Stream Origin: ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km²

WATERSHED FEATURES

Predominant Surrounding Landuse: ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other _____ ☐ Residential

Local Watershed NPS Pollution: ☒ No evidence ☐ Some potential sources ☐ Obvious sources

Local Watershed Erosion: ☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present

☒ Trees ☒ Shrubs ☒ Grasses ☐ Herbaceous

dominant species present Salt cedar, switch grasses

INSTREAM FEATURES

Estimated Reach Length 100 m
Estimated Stream Width 50 m
Sampling Reach Area 5000 m²
Area in km² (m²/10⁶) 0.005 km²
Estimated Stream Depth 0.15 m
Surface Velocity 0.04 m³/sec

Canopy Cover: ☒ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 2.0 m
Proportion of Reach Represented by Stream Morphology Types: ☒ Riffle 10 % ☒ Run 85 % ☒ Pool 5 %
Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 0 m²
Density of LWD 0 m²/km² (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present

☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating
☒ Free floating ☐ Floating Algae ☐ Attached Algae

dominant species present unknown

Portion of the reach with aquatic vegetation 2 %

WATER QUALITY

Temperature 20.5 °C
Conductivity 1430
Dissolved Oxygen 7.9
pH 8.9
Turbidity not measured
WQ Instrument hydrolab

Water Odors: ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other

Turbidity (if not measured): ☐ Clear ☒ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other _____

Water Surface Oils: ☐ Slick ☐ Flecks ☐ Sheen ☒ None ☐ Globs ☐ Other _____

SEDIMENT/ SUBSTRATE

Odors: ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____

Oils: ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits: ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☐ Other _____

Looking at stones which are not deeply embedded, are undersides black? ☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	10%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	90%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	99%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	1%			
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 4	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 **4** 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 19	20 **19** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 7 **(RB)**	Right Bank 10 9	8 **7** ***6***	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 7 **(RB)**	Right Bank 10 9	8 **7** 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 10 **(LB)**	Left Bank **10** 9	8 7 6	5 4 3	2 1 0
SCORE 10 **(RB)**	Right Bank **10** 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE **101**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Oldham County, Texas
STATION #	CR5	**STREAM CLASS**	4th Order
LAT	35.52047	**RIVER BASIN**	Canadian River
LONG	-102.2626	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Jacob Lewis		

FORM COMPLETED BY Omar Bocanegra	**DATE** 08/22/2001 **TIME** 1229 hrs	**REASON FOR SURVEY** Off-Refuge Study

WEATHER CONDITIONS	**Now** ☐ storm (heavy rain) ☐ rain (steady rain) ☐ showers (intermittent) 5 % ☒ % cloud cover ☐ clear/sunny	**Past 24 hours** ☐ ☐ ☐ ☐ 80 % ☐	**Heavy rain in last 7 days** ☐ Yes ☒ No Air Temperature 90 °F Other _____
STREAM CHARACTERIZATION	**Stream Subsystem** ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater **Stream Origin** ☐ Glacial ☐ Spring-fed ☐ Non-glacial montane ☒ Mixture of origins ☐ Swamp and bog ☐ Other _____	**Stream Type** ☒ Warmwater **Catchment Area** 59,223 km²	
WATERSHED FEATURES	**Predominant Surrounding Landuse** ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☐ Agricultural ☐ Other _____ ☐ Residential	**Local Watershed NPS Pollution** ☒ No evidence ☐ Some potential sources ☐ Obvious sources **Local Watershed Erosion** ☐ None ☒ Moderate ☐ Heavy	
RIPARIAN VEGETATION	Indicate the dominant type and record the dominant species present ☒ Trees ☒ Shrubs ☒ Grasses ☐ Herbaceous dominant species present grasses		
INSTREAM FEATURES	**Estimated Reach Length** 100 m **Estimated Stream Width** 25 m **Sampling Reach Area** 2500 m² **Area in km² (m²/10⁶)** 0.0025 km² **Estimated Stream Depth** 0.15 m **Surface Velocity** 0.04 m³/sec	**Canopy Cover** ☒ Partly open ☐ Partly shaded ☐ Shaded **High Water Mark** 2.5 m **Proportion of Reach Represented by Stream Morphology Types** ☒ Riffle 15 % ☒ Run 85 % ☒ Pool 5 % **Channelized** ☐ Yes ☒ No **Dam Present** ☐ Yes ☒ No	
LARGE WOODY DEBRIS	LWD 2 m² Density of LWD 800 m²/km² (LWD/reach area)		
AQUATIC VEGETATION	Indicate the dominant type and record the dominant species present ☐ Rooted emergent ☐ Rooted submergent ☐ Rooted floating ☒ Free floating ☐ Floating Algae ☐ Attached Algae dominant species present unknown Portion of the reach with aquatic vegetation 0.5 %		
WATER QUALITY	Temperature 27.5 °C Conductivity 1830 Dissolved Oxygen 8.1 pH 9.0 Turbidity not measured WQ Instrument hydrolab	**Water Odors** ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other **Turbidity (if not measured)** ☒ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other _____	**Water Surface Oils** ☐ Slick ☐ Flecks ☐ Sheen ☒ None ☐ Globs ☐ Other _____
SEDIMENT/ SUBSTRATE	**Odors** ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other _____ **Oils** ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse	**Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☒ Sand ☐ Relict shells ☐ Other _____ **Looking at stones which are not deeply embedded, are undersides black?** ☐ Yes ☒ No	

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	1%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	15%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	99%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	1%			
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 **7** 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 3	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 **3** 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 20	**20** 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 13	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 3 **(LB)**	Left Bank 10 9	8 7 6	5 4 **3**	2 1 0
SCORE 4 **(RB)**	Right Bank 10 9	8 7 ***6***	5 **4** 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 4 **(RB)**	Right Bank 10 9	8 7 6	5 **4** 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 10 **(LB)**	Left Bank **10** 9	8 7 6	5 4 3	2 1 0
SCORE 10 **(RB)**	Right Bank **10** 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE **97**

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA

STREAM NAME	South Canadian River	**LOCATION**	Quay County, New Mexico
STATION #	CR6	**STREAM CLASS**	3rd Order
LAT	35.52047	**RIVER BASIN**	Canadian River
LONG	-103.4151	**AGENCY**	U.S. Fish & Wildlife Service
INVESTIGATORS	Craig Giggleman, Omar Bocanegra, John Hughes, and Jacob Lewis		

FORM COMPLETED BY Craig Giggleman	**DATE** 08/22/2001 **TIME** 1615 hrs	**REASON FOR SURVEY** Off-Refuge Study

WEATHER CONDITIONS

Now	**Past 24 hours**	**Heavy rain in last 7 days**
☐ storm (heavy rain)	☐	☐ Yes ☒ No
☐ rain (steady rain)	☐	
☐ showers (intermittent)	☐	Air Temperature 90 °F
5 % ☒ % cloud cover	☒ ? %	Other
☐ clear/sunny	☐	

STREAM CHARACTERIZATION

Stream Subsystem ☒ Perennial ☐ Intermittent ☐ Tidal ☐ Coldwater **Stream Type** ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☒ Mixture of origins
☐ Swamp and bog ☐ Other _____

Catchment Area 59,223 km²

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☒ Agricultural ☐ Other _____
☐ Residential

Local Watershed NPS Pollution
☐ No evidence ☒ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☒ None ☐ Moderate ☐ Heavy

RIPARIAN VEGETATION

Indicate the dominant type and record the dominant species present
☐ Trees ☒ Shrubs ☒ Grasses ☒ Herbaceous
dominant species present Willow

INSTREAM FEATURES

Estimated Reach Length 100 m
Estimated Stream Width 10 m
Sampling Reach Area 1000 m²
Area in km² (m2/10⁶) 0.001 km²
Estimated Stream Depth 0.5 m
Surface Velocity 0.04 m³/sec ☒ Riffle 15 % ☒ Run 70 %
☒ Pool 15 %

Canopy Cover
☒ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 2.5 m
Proportion of Reach Represented by Stream Morphology Types
Channelized ☐ Yes ☒ No
Dam Present ☒ Yes ☐ No

LARGE WOODY DEBRIS

LWD 0 m²
Density of LWD 0 m²/km² (LWD/reach area)

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☒ Rooted emergent ☐ Rooted submergent ☐ Rooted floating
☐ Free floating ☐ Floating Algae ☐ Attached Algae
dominant species present Sedges
Portion of the reach with aquatic vegetation 10 %

WATER QUALITY

Temperature 28.1 °C
Conductivity 4580
Dissolved Oxygen 9.0
pH 9.0
Turbidity not measured
WQ Instrument hydrolab

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other _____

Water Surface Oils
☐ Slick ☐ Flecks
☐ Sheen ☒ None
☐ Globs
☐ Other _____

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other _____

Oils
☒ Absent ☐ Slight ☐ Moderate
☐ Profuse

Deposits
☐ Sludge ☐ Sawdust
☐ Paper fiber ☒ Sand
☐ Relict shells ☐ Other _____

Looking at stones which are not deeply embedded, are undersides black?
☒ Yes ☐ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach	Substrate Type	Characteristic	% Composition in Sampling Area
Bedrock			Detritus	stitcks, wood, coarse plant materials (CPOM)	15%
Boulder	>256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck/Marl	black, very fine organic (FPOM)	40%
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2 mm (gritty)	80%	Marl	grey, shell fragments	
Silt	0.004-0.06 mm	20%			
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS AT SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (May rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 15	20 19 18 17 16	**15** 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 13	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	>Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 13	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA - LOW GRADIENT STREAMS BEYOND SAMPLING REACH

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present; no recent channelization present	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 18	20 19 **18** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 3 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems.<5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 4 **(LB)**	Left Bank 10 9	8 7 6	5 **4** 3	2 1 0
SCORE 7 **(RB)**	Right Bank 10 9	8 **7** ***6***	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immdeiate riparian zone covered by native vegetation, including trees, shrubs, or nonwoody macrophytes; disruption by grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 5 **(LB)**	Left Bank 10 9	8 7 6	**5** 4 3	2 1 0
SCORE 5 **(RB)**	Right Bank 10 9	8 7 6	**5** 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 6 **(LB)**	Left Bank 10 9	8 7 **6**	5 4 3	2 1 0
SCORE 5 **(RB)**	Right Bank 10 9	8 7 6	**5** 4 3	2 1 0

TOTAL SCORE **126**