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1.0 SANTA CRUZ RIVER NEAR TUCSON, ARIZONA

1.1 STUDY AREA OVERVIEW

1.1.1 Study Area Description

The Pima County Roger Road Wastewater Treatment Plant (WWTP) and the Pima County Ina Road Water Pollution Control Facility (WPCF) are both located in the Tucson metropolitan area. Tucson is centrally located within a 1,000-square-mile basin comprised of a northwest-sloping valley bordered by rugged mountain ranges. The surrounding mountains range from 4,000 to 9,000 feet above mean sea level (amsl). The land surface at the downstream end of the basin is at an altitude of 2,140 feet amsl.

The Tucson basin has a semi-arid climate, and the annual potential evaporation greatly exceeds the annual precipitation (Burkham 1939). Summer storms produce 30 to 60 percent of total annual rainfall. These local convective thunderstorms produce high-intensity, short-duration rainfall. During winter months, storms moving eastward from the Pacific Ocean produce widespread, low-intensity storms (Betancourt and Turner 1985a).

Both the Roger Road WWTP and Ina Road WPCF discharge into the Santa Cruz River. The Santa Cruz River originates as a small southerly flow in the San Rafael Valley, looping down into Mexico, and then back up into the United States (Arizona Department of Environmental Quality [ADEQ] 1995). Historically, the Santa Cruz River was perennial until it reached Tubac, where it went subsurface (Tellman et al.). From the late 1800s to the mid-1900s, the Santa Cruz River re-emerged where the stream intersected near-surface water tables directly opposite Tucson and 9.3 miles upstream near the San Xavier Mission. Perennial flow in these sections of the Santa Cruz River maintained marshes, or cienegas. These segments of lush vegetation and plentiful water were localized and the other segments of the channel were characterized as dry, sandy riverbed (Betancourt and Turner 1985a).

The Santa Cruz River underwent a period of pronounced arroyo entrenchment during the late 1800s (Betancourt and Turner 1985a; Lacher 1996). Human manipulation of the Santa Cruz River channel for irrigation is one of the primary reasons for the extensive erosion that occurred in the Tucson area. As the channel eroded southward, it cut deeper and deeper into the alluvium. Consequently, the water table dropped to the elevation of the channel bottom (Lacher 1996). This downcutting created a dependence on groundwater for irrigation, domestic, and industrial uses. After 1940, agricultural, mining, and urban water supply needs resulted in a groundwater overdraft (Betancourt and Turner 1985a), and the lowered water table resulted in the drying up of marshes and cienegas and their associated vegetation. The last naturally occurring, permanent water in the Santa Cruz River at Tucson occurred in 1941 (Lowe 1985).

In the years preceding modern development, it is known that the river was intermittent in time and location, deriving its flow from two primary components: event storm flows (including limited snowmelt), and base flow created by the water table intersecting the upstream channels,

often forced to surface by geologic structure. This was occasionally sufficient to sustain flows downstream of Tucson, but seldom reached the Gila River.

In a larger perspective, it should be noted that for a prolonged period—perhaps a thousand years prior to European settlement—natural baseflows in the middle Santa Cruz River were diverted along its course for irrigation by Native American communities. Thus, there has not been a wholly "natural" condition over the long duration. Nevertheless, these flow regimens and resulting instream processes formed the pre-existing river and floodplain environment and the aquatic habitat along the river corridor.

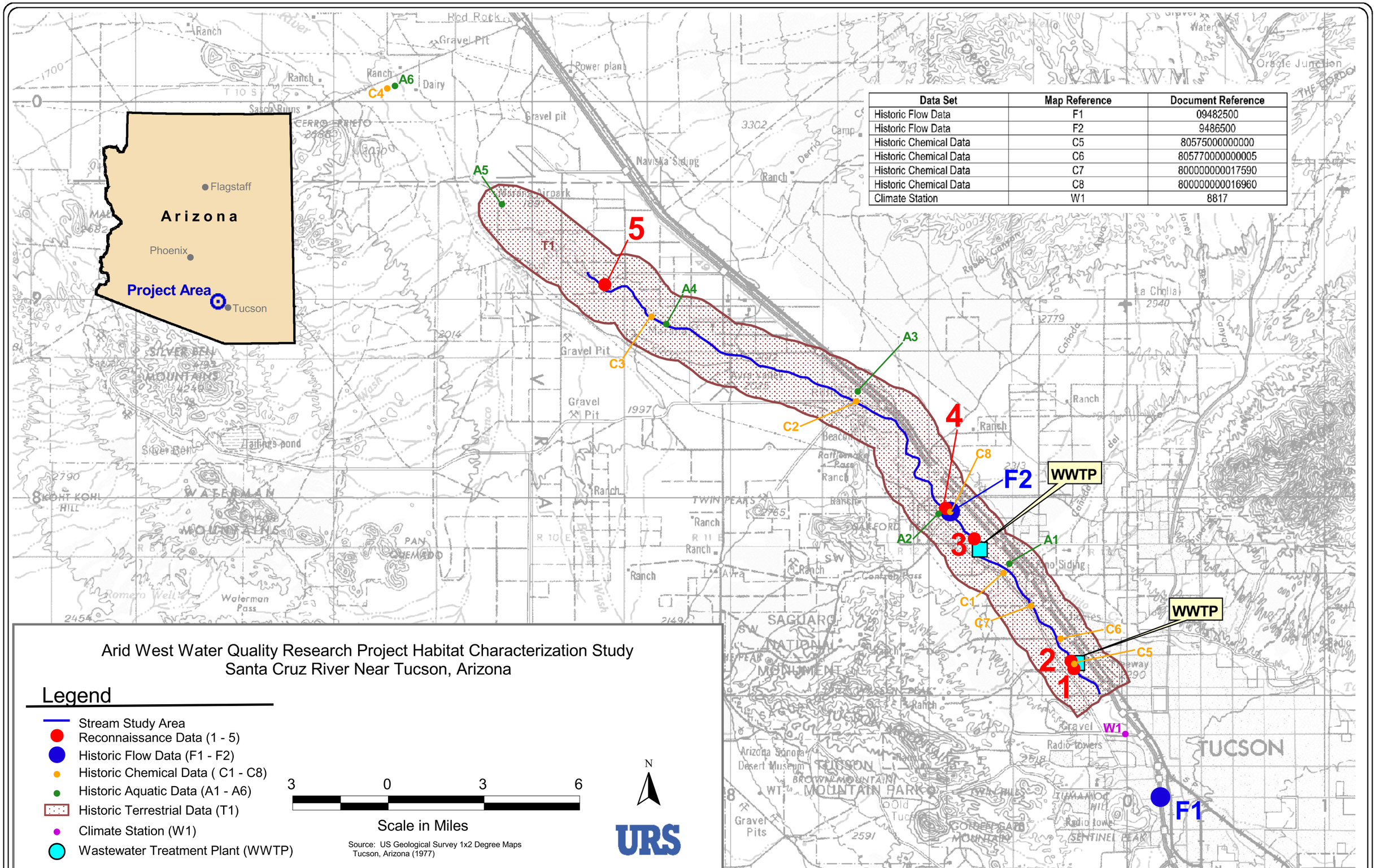
Today, the main sources of flow in the Santa Cruz watershed are precipitation, groundwater discharge, irrigation return flow, and treated sewage effluent. The majority of the river and tributary streams are intermittent or ephemeral (Cordy et al. 1998). Perennial flows in the Santa Cruz below the Roger Road WWTP result from the discharge of effluent.

Figure C-3-1 shows the locations of the site reconnaissance sites (red numbers 1 through 5) and the locations of historical data. Table C-3-1 describes each data point.

Table C-3-1
Historical Data Locations for Santa Cruz River near Tucson, Arizona

Data Label	Data Summary	Reference
09482500	Historical flow data	USGS
8827	Historical precipitation and temperature data	NCDC
805770000000005	Historical chemical data	*STORET*
80575000000000	Historical chemical data	*STORET*
800000000016960	Historical chemical data	*STORET*
800000000017590	Historical chemical data	*STORET*
C1	Chemical data	Harding Lawson Associates 1986
A1	Invertebrates, algae, and fish data	Harding Lawson Associates 1986, 1997
A2	Invertebrates	ADEQ 1990; USGS 1998
09486500	Historical flow data	USGS
C2	Chemical data	Harding Lawson Associates 1986
A3	Invertebrates, algae, and fish data	Harding Lawson Associates 1986, 1997
A4	Invertebrates, algae, and fish data	Harding Lawson Associates 1986, 1997
C3	Chemical data	Harding Lawson Associates 1986
A5	Invertebrates, algae, and fish data	Harding Lawson Associates 1986, 1997
C4	Chemical data	Harding Lawson Associates 1986
A6	Invertebrates, algae, and fish data	AGFD 1987; Harding Lawson Associates 1986, 1997

AGFD – Arizona Game and Fish Department
NCDC – National Climatic Data Center
STORET – EPA's Storage and Retrieval Database
USGS – U.S. Geological Survey



Data Set	Map Reference	Document Reference
Historic Flow Data	F1	09482500
Historic Flow Data	F2	9486500
Historic Chemical Data	C5	80575000000000
Historic Chemical Data	C6	805770000000005
Historic Chemical Data	C7	800000000017590
Historic Chemical Data	C8	800000000016960
Climate Station	W1	8817

X:\PimaCounty\WQRP\Projects\Tucson.apr

Figure C-3-1

1.1.2 Ecoregion Description

Tucson and the lower end of the Santa Cruz River are in Ecoregion 81, Sonoran Basin and Range (Omernick and Bailey 1997). Ecoregion 81 covers southeastern California and much of southern Arizona, and it grades into the Mojave Basin and Range Ecoregion across a long boundary. The Sonoran Basin and Range ecoregion is characterized by hot summers and mild winters, with distinct summer and winter rainy seasons. Ecoregion 81 is at the southern end of the Basin and Range physiographic province, with a land surface that includes broad, low basins separated by mountain ranges. Natural vegetation in this ecoregion is Sonoran desertscrub, including both the Arizona Upland subdivision and the Lower Colorado River Valley subdivision. Some characteristic plant species of this region include saguaro, blue palo verde, desert ironwood, catclaw acacia, triangle bursage, and purple three-awn. Grazing by domestic livestock is limited by lack of water and forage. Some of the vertebrate wildlife species that are characteristic of Ecoregion 81 include western yellow bat, antelope jackrabbit, Harris' antelope squirrel, Bailey's pocket mouse, elf owl, Gila woodpecker, Sonoran Desert toad, Gila monster, banded sand snake, and tiger rattlesnake (URS 2000).

1.2 WATER QUALITY STANDARDS

The Santa Cruz River from the Roger Road WWTP outfall to Baumgartner Road has the following designated uses:

- aquatic and wildlife-effluent dependent water (A&Wedw)
- partial Body Contact (PBC)

The criteria that apply to these uses are presented in Table C-3-2.

Table C-3-2
Water Quality Standards for Constituents of Concern for the Santa Cruz River Near Tucson, Arizona

Constituent of Concern	Criteria to protect A&Wedw	Criteria to protect PBC
Ammonia	–	–
Arsenic	360 µg/L dissolved (acute) 190 µg/L dissolved (chronic)	2,800 µg/L total recoverable
Beryllium	65 µg/L dissolved (acute) 5.3 µg/L dissolved (chronic)	700 µg/L total recoverable
Cadmium	24 µg/L dissolved (acute)* 1.1 µg/L dissolved (chronic)*	70 µg/L total recoverable
Chlorine	11 µg/L (total residual)	–
Copper	17.7 µg/L dissolved (acute)* 11.8 µg/L dissolved (chronic)*	5,200 µg/L dissolved
DDT	1.1 µg/L (acute) 0.001 µg/L (chronic)	700 µg/L
Mercury	2.6 µg/L dissolved (acute) 0.2 µg/L dissolved (acute)	42 µg/L total recoverable

Table C-3-2 Water Quality Standards for Constituents of Concern for the Santa Cruz River Near Tucson, Arizona		
Constituent of Concern	**Criteria to protect A&Wedw**	**Criteria to protect PBC**
PCBs	2 µg/L (acute) 0.02 µg/L (chronic)	–
Selenium	50 µg/L total recoverable (acute) 2 µg/L total recoverable (chronic)	420 µg/L total recoverable
Fecal Coliform Bacteria	200 cfu/100 mL (30-day geometric mean) 400 cfu/100 mL (10% of samples for 30-day period) 800 cfu/100 mL (single sampling maximum)	1,000 cfu/100 mL (30-day geometric mean) 2,000 cfu/100 mL (10% of samples for 30-day period) 4,000 cfu/100 mL (single sampling maximum)
Ph	9.0 (maximum) 6.5 (minimum) 0.5 (max change to due discharge)	9.0 (maximum) 6.5 (minimum) 0.5 (max change to due discharge)
Temperature	3.0°C (max increase due to a discharge)	–
Turbidity	50 NTU	50 NTU
Dissolved Oxygen	1.0 (single sample minimum)	–
Total Dissolved Solids	–	–
Nutrients	–	–
Salinity	–	–

1.3 WASTEWATER TREATMENT PLANTS DISCHARGING TO THE SANTA CRUZ RIVER, TUCSON, ARIZONA

Pima County, Arizona owns and operates two WWTPs that discharge to the Santa Cruz River in Tucson. Together, the Ina Road and Roger Road plants (refer to **Figure C-1-1**) serve greater Tucson with a combined rated capacity of 66 million gallons per day (mgd). The Ina Road WPCF is currently being expanded to provide an additional 12.5 mgd of capacity. Significant quantities of effluent are reused in Tucson, affecting the stream discharges as further detailed below.

1.3.1 National Pollutant Discharge Elimination System Discharge Permits

A summary of selected National Pollutant Discharge Elimination System (NPDES) permit parameters for the two plants is provided in Table C-3-3. Both the Roger Road WWTP permit and the Ina Road WPCF permit expire on November 2, 2004.

Table C-3-3
Summary of Selected NPDES Permit Parameters for Ina Road and Roger Road WWTPs

Parameter	Units	Limit Type	Ina Road WPCF	Roger Road WWTP
BOD_5	mg/L	30-day average 7-day average	30 45	30 45
Total Suspended Solids	mg/L	30-day average 7-day average	30 45	30 45
Fecal Coliform Bacteria	#/100 mL	30-day average Daily maximum	200 800	200 800
Total Residual Chlorine	mg/L	Daily maximum	0.011*	0.011*
pH	s.u.	Maximum Minimum	9 6.5	9 6.5
Copper (total recoverable)	µg/L	Daily maximum	38	38
Whole Effluent Toxicity (WET) Testing		Required/Not Required	Required	Required

* The permit grants a variance for chlorine, citing the use of dechlorination and difficulties measuring the specified concentrations.

In addition, the permits include dissolved oxygen (DO) standards. The Ina Road discharge is not allowed to lower the DO of the receiving water to below 3 mg/L or 1 mg/L, depending on the time of day. For Roger Road, the discharge is not to lower the DO of the receiving water to less than 1 mg/L at any time. Effluent flows are not limited in the permits, but must be monitored. Additional parameters and constraints are detailed in the permits. A copy of each of these permits is included in **Appendix L**.

1.3.2 Effluent Quality

The U.S. Environmental Protection Agency's (EPA's) Permit Compliance System (PCS) database was queried to obtain historical data on effluent quality as reported by the WWTP of interest. This system is a holding of Discharge Monitoring Reports that are submitted to EPA by state NPDES programs. Tables C-3-4 and C-3-5 summarize the discharge monitoring data for the Ina Road WPCF and Roger Road WWTP.

Table C-3-4
Summary of Selected PCS Parameters for Ina Road WPCF

Parameter	Units	Average Reporting Concentrations	Number of Measurements	Period of Record
Arsenic, Dissolved	mg/L	Minimum Average Maximum 0.008	 32	1989-1991
Total Recoverable Arsenic	µg/L	Minimum Average Maximum 10	 65	1992-1999
BOD_5	mg/L	Minimum 9 Average 21 Maximum 57	134 134 134	1989-2000

Table C-3-4
Summary of Selected PCS Parameters for Ina Road WPCF

Parameter	Units	Average Reporting Concentrations	Number of Measurements	Period of Record
Total Cadmium (as CD)	mg/L	Minimum Average Maximum 0.005	23	1989-1991
Chromium, Dissolved	mg/L	Minimum Average Maximum 0.006	25	1989-1991
Total Copper (as Cu)	mg/L	Minimum Average Maximum 0.25	30	1989-1991
Fecal Coliform Bacteria	#/100 mL	Minimum Average 12.7 Maximum 5,400	134 134	1989-2000
Total Mercury (as Hg)	mg/L	Minimum Average Maximum 0.0008	18	1989-1991
Nitrogen	mg/L	Minimum Average Maximum 49.3	36	1989-1991
Nitrate (as NO_3)	mg/L	Minimum Average Maximum 1.3	25	1989-1991
pH	S.U.	Minimum 6.1 Average Maximum 8.8	135 135	1989-2000
Total Selenium (as Se)	mg/L	Minimum Average Maximum <0.005	18	1989-1991
Total Recoverable Cadmium	µg/L	Minimum Average Maximum 2.7	13	1992-1999
Total Recoverable Chromium	µg/L	Minimum Average Maximum 25	25	1992-1999
Total Recoverable Copper	µg/L	Minimum Average Maximum 46	87	1992-2000
Total Recoverable Mercury	µg/L	Minimum Average Maximum 0.9	1	1992-1999
Total Recoverable Selenium	µg/L	Minimum Average Maximum 5	9	1992-1999
Total Residual Chlorine	mg/L	Minimum Average <1.2 Maximum 6.24	76 82	1989-2000

Table C-3-4
Summary of Selected PCS Parameters for Ina Road WPCF

Parameter	Units	Average Reporting Concentrations		Number of Measurements	Period of Record
Total Dissolved Solids	mg/L	Minimum			1989-1991
		Average			
		Maximum	715	36	
Total Settleable Solids	mg/L	Minimum			1989-1991
		Average <0.2		128	
		Maximum	40	128	
Total Suspended Solids	mg/L	Minimum	11	135	1989-2000
		Average 21.1		135	
		Maximum	70	135	

Table C-3-5
Summary of Selected PCS Parameters for Roger Road WWTP

Parameter	Units	Average Reporting Concentrations		Number of Measurements	Period of Record
BOD_5	mg/L	Minimum	9	135	1989-2000
		Average 24		135	
		Maximum	50	135	
Fecal Coliform Bacteria	#/100 mL	Minimum			1989-2000
		Average <13		135	
		Maximum	9,000	135	
pH	s.u.	Minimum	6.4	136	1989-2000
		Average			
		Maximum	8	136	
Total Recoverable Copper	µg/L	Minimum			1992-1999
		Average			
		Maximum	126	86	
Dissolved Copper (as CU)	mg/L	Minimum			1989-1991
		Average			
		Maximum	0.033	33	
Total Residual Chlorine	mg/L	Minimum			1989-2000
		Average <1.3		73	
		Maximum	4.8	80	
Total Suspended Solids	mg/L	Minimum	10	136	1989-2000
		Average 23.1		136	
		Maximum	55	136	
Settleable Solids	mg/L	Minimum			1989-1999
		Average 0.105		125	
		Maximum	1.8	125	
Dissolved Arsenic (as AS)	mg/L	Minimum			1989-1991
		Average			
		Maximum	0.009	13	
Total Recoverable Arsenic	µg/L	Minimum			1992-1999
		Average			
		Maximum	19	81	
Total Recoverable Cadmium	µg/L	Minimum			1992-1999
		Average			
		Maximum	2.3	16	
Dissolved Cadmium (as CD)	mg/L	Minimum			1989-1991

Table C-3-5
Summary of Selected PCS Parameters for Roger Road WWTP

Parameter	Units	Average Reporting Concentrations	Number of Measurements	Period of Record
		Average Maximum 0.0013	7	
Total Mercury (as HG)	mg/L	Minimum Average Maximum 0.0002	4	1989-1991
Total Nitrate Nitrogen (as NO_3)	mg/L	Minimum Average Maximum 56.3	38	1989-1991
Total Nitrogen (as N)	mg/L	Minimum Average Maximum 38.3	38	1989-1992
Total Selenium (as SE)	µg/L	Minimum Average Maximum 9	0 0 26	1989-1999

1.3.3 WWTP Processes

A summary of the liquid-side treatment processes and plant history at each of the two Pima County WWTPs discharging to the Santa Cruz River in Tucson is provided in the following subsections. Processes to treat and/or dispose of sludge and other residuals are not discussed because they have little or no effect on the quality of effluent discharged to the river.

1.3.3.1 Ina Road WPCF

The Ina Road WPCF, now rated at 25 mgd capacity, began operations in 1975, and was put into full operation in 1977. The plant is a Pressure Swing Adsorption Process, sometimes called a Pure Oxygen Activated Sludge Treatment process. Since its construction, no major improvements have been made to the Ina Road WPCF except improved grit removal in 1980 and the addition of dechlorination in about 1991.

Liquid train processes currently in place at the Ina Road plant include the following:

- bar screens
- grit removal
- primary clarification
- secondary treatment in aeration basins (pure oxygen) without nitrification or denitrification
- secondary clarification

- chlorination and dechlorination

Upgrades currently being constructed at the plant will increase the plant's capacity to 37.5 mgd by adding a parallel treatment train. As part of these upgrades, new coarse and fine bar screens are being added, as will new grit removal facilities. The new parallel secondary treatment train will include nitrification and denitrification using suspended growth biological nutrient removal (BNR) technology. Thus, once the new facilities are online, one-third of the plant's overall treatment capacity will be capable of removing ammonia and nitrate. A future expansion phase is also planned, which would add another parallel train, and bring the total plant capacity up to 50 mgd.

1.3.3.2 Roger Road WWTP

The Roger Road WWTP currently has a rated capacity of 41 mgd. The Roger Road plant has undergone numerous upgrades since its initial completion in 1951. The initial plant consisted of primary clarification, aeration basins, secondary clarification, activated sludge, and chlorination. Until the late 1960s, most of the effluent was used to irrigate farmland; discharges to the Santa Cruz River did not begin until 1977. Major upgrades since the plant was constructed include the following:

- 1956: Added a parallel treatment train with trickling filters instead of aeration basins, raising total plant capacity from 12 mgd to 24 mgd.

- 1965: Added a third parallel train based on aeration basins, bringing the total plant capacity to 36 mgd.

- 1979: Major plant upgrades, including conversion of trickling filters to biotowers, abandonment of original aeration basins, and use of the 1965 aeration basins only for supplemental capacity. Plant was rerated to 30 mgd.

- 1990s: Additional primary and secondary clarification facilities added, bringing total rated plant capacity to 35 mgd and 41 mgd in 1993 and 1999, respectively.

- 1993: Added dechlorination facilities.

The resulting liquid train processes currently in place at the Roger Road WWTP include the following:

- bar screens

- grit removal

- primary clarification

- secondary treatment in biotowers/aeration basins

- secondary clarification
- chlorination and dechlorination

Nitrogen removal (nitrification and/or denitrification) was not included in the process design for the Roger Road WWTP. However, the plant does observe a small amount of ammonia removal (nitrification) during the summer months. This is likely caused by the increase in wastewater temperatures during the summer months, which can promote nitrifying conditions.

In a future phase of expansion, Pima County plans to increase the capacity of the Roger Road WWTP to 50 mgd. The County is presently considering the need for additional treatment upgrades.

1.3.4 WWTP Flows to Receiving Water and Reuse

Effluent from the Ina Road WPCF is primarily discharged to the Santa Cruz River at the plant's outfall, although some effluent is conveyed to the Arthur Pack golf course for turf irrigation and a small amount of effluent is used onsite at the WPCF for irrigation and other nonpotable uses. Additional reuse is likely in the future, given the value of effluent as a water resource and the progressive nature of reuse in Tucson.

A significant portion of Roger Road's treated effluent goes to reuse. The remainder is discharged to the Santa Cruz River at the plant's outfall. Prior to dechlorination, a portion of the plant's flow is diverted to an adjacent tertiary treatment plant for reuse owned and operated by Tucson Water, consisting of filtration and disinfection. Like the Ina Road WPCF, additional reuse of effluent from the Roger Road WWTP is likely in the future.

Hard copy daily plant influent and effluent flow data are available for the mid-1980s through the present for the Roger Road WWTP, and for 1989 through 1996 for the Ina Road WPCF. Pima County staff report that daily reuse flows are approximately equal to the difference between influent and effluent flows. Daily effluent flows to the Santa Cruz River are available electronically for both plants for 1997 through the present.

In 1996, the most recent year for which reuse flows can be calculated for Ina Road, reuse flows from this plant averaged approximately 2.9 mgd, or 11.5 percent of the total average influent flow of 25.3 mgd. Effluent discharges from the Ina Road plant to the Santa Cruz River averaged 22.4 mgd and 22.6 mgd in 1996 and 1999, respectively.

In 1999, Roger Road reuse flows averaged approximately 12.1 mgd, or approximately 33 percent of the plant's total average influent flow of 36.6 mgd. The reuse water is used for landscape irrigation, golf courses, some onsite irrigation, and other non-potable uses. This plant discharged an average of 24.5 mgd to the Santa Cruz River in 1999.

1.4 PHYSICAL DATA OVERVIEW

This section summarizes available historic hydrologic and geomorphology data. A summary of the geomorphology site reconnaissance effort is also included.

1.4.1 Hydrologic Data and Geomorphology Summary

A major treatment plant effluent contribution to the Santa Cruz River occurs at the City of Tucson, downstream of Nogales. Streamflow statistics for nearby USGS flow gages indicate that the mean monthly streamflow above the Tucson WWTP outfall ranges from 0 cubic feet per second (cfs) (May) to 94 cfs (August), and that the mean monthly streamflow below the WWTP ranges from 15 cfs (May) to 128 cfs (August). Mean monthly flows for these two sites, as well as the gaged period of records, are presented on **Figure C-3-2**. A summary of the hydrologic and hydraulic data availability is provided in Table C-3-6.

Table C-3-6
Available Hydrologic and Hydraulic Data for the Santa Cruz River near Tucson, Arizona

Gage ID	Gage Name	Average Daily Flow Period of Record	Annual Peak Daily Flow Period of Record	Partial Duration Peak Daily Flow Period of Record	Stage-Discharge Relationship Availability
09482500 (upstream)	Santa Cruz River at Tucson, AZ	1905-1998	1915-1996	1915-1996	1985-2000
09486500 (downstream)	Santa Cruz River at Cortaro, AZ	1939-1998	1940-1996	1940-1996	1982-2000

Since the 1950s, the Santa Cruz River channel has undergone severe (several yards) sediment degradation in Tucson, while downstream reaches have experienced a period of aggradation. Gradual arroyo cutting over the past century has produced a channel that is now up to 30 feet below the historical floodplain. Effluent discharge has caused increased channel roughness due to vegetation and increased incision in the low-flow channel. Storm scouring can occur up to depths of 25 to 30 feet. During the flood of 1993, for example, scour at the Congress Street Bridge in Tucson was estimated to be between 8 and 23 feet.

Hydrologic controls upstream of Tucson appear to be primarily irrigation withdrawals, return flows, and the Nogales treatment plant discharge. Additionally, a dam near Nogales (Kino Springs) and a dam approximately 30 miles upstream of Tucson (Green Valley) were identified in the National Inventory of Dams (U.S. Army Corps of Engineers [USACE] 1996).

Air temperature and precipitation data were recorded in Tucson at NCDC station number 8817 (refer to **Figure C-3-1**) from 1982 through 1998. The estimated average annual precipitation at this station is 12.4 inches. The estimated average temperature at this station is 69.1°F. Table C-3-7 presents the average monthly precipitation and temperature.

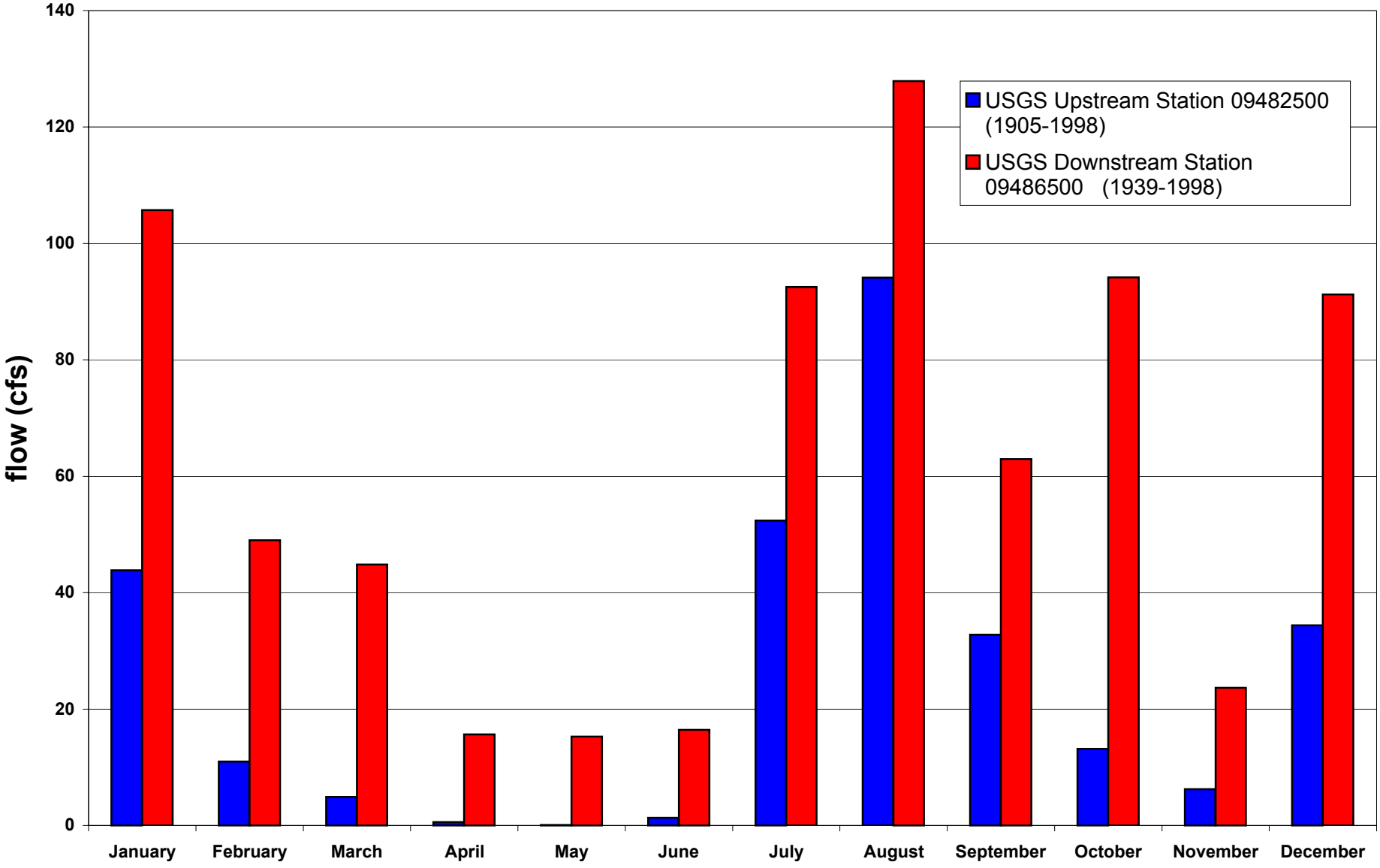


Figure C-3-2
Mean Monthly Streamflow for the Santa Cruz River Near Tucson, Arizona

Table C-3-7
Tucson Average Monthly Precipitation and Temperature - NCDC Station 8817 (1982 - 1998)

Month	Precipitation (Inches)	Temperature (°F)
January	1.1	52
February	1.3	55
March	1.0	61
April	0.3	67
May	0.2	75
June	0.1	84
July	1.6	87
August	2.6	86
September	1.3	81
October	0.9	71
November	0.8	59
December	1.4	52

1.4.2 Geomorphological Site Reconnaissance Summary

The Santa Cruz River at the Roger Road WWTP drains an area of approximately 2,240 square miles, of which approximately 348 square miles are in Mexico. The semi-arid climate in northwest Tucson is one of hot summers, cool winters, and mean annual precipitation of approximately 12 inches; basinwide, mean annual precipitation may be nearly 20 inches. The Santa Cruz River drainage basin above Tucson, with contributions downstream to Trico-Marana Road, are in the Basin and Range Physiographic Province, characterized by fault-block mountains separated by valley-fill alluvium. Along the reach northwest of Tucson, the river generally incises poorly cemented Quaternary valley-fill deposits, whereas the river and its tributaries, upstream of the treatment plant in many places, incise moderately cemented fan deposits of Tertiary age. Alluvium within 325 feet or more of the river between Roger Road and Trico-Marana Road is generally of Holocene age and reflects recent conditions of fluvial-sediment transport and deposition.

A site visit was conducted in May 2000 to collect data at the following five sites within the study area (all shown on **Figure C-3-1**):

- Site 1 – Upstream of Roger Road WWTP discharge.
- Site 2 – Downstream of Roger Road WWTP discharge.
- Site 3 – Downstream of the Cortaro Road Bridge.
- Site 4 – Downstream of the Ina Road Bridge Crossing.
- Site 5 – Downstream of Trico-Marana Bridge Crossing.

Data collected during the reconnaissance investigation are provided in Table C-3-8.

Table C-3-8
Morphometric Data from Santa Cruz River near Tucson, Arizona

	Site 1	Site 2	Site 3	Site 4	Site 5
Site description	**Upstream of Rogers Road WWTP**	**Downstream of Rogers Road WWTP**	**Ina Road**	**Cortaro Road**	**Trico-Manera Road**
Discharge (cfs)	10.6	24.7	70.6	70.6	53.0
Bedload texture	Fine to medium sand	Fine sand w/organic matter	Coarse sand to fine gravel	Coarse sand to fine gravel	Medium to coarse sand
Channel texture	Coarse sand to cobbles	Fine sand	Gravel w/sand, silt, and clay sand	Sandy to silty gravel	Medium sand
Bank texture	West bank-sand w/gravel, east bank- soil cement	West bank-medium sand w/gravel, east bank- soil cement	Fine sand w/gravel	Fine sand w/gravel	Fine to medium sand
Sinuosity	1.06	1.07	1.07	1.02	1.12
Channel gradient	0.0030	0.0026	0.0027	0.0026	0.0021
Channel width (ft)	36.0	29.5	114.8	82.0	65.6
Channel depth (ft)				1.6	
Channel incision (ft)	5.3	8.2	6.6		3.3
Floodplain width (ft)			492.1	738.2	229.7
Floodplain bank height (ft)			14.8	13.1	6.6
Channel vegetation	Obligate upland	Willows, w/cattails	Willows, w/cattails		Grasses, forbs, salt cedar
Floodplain vegetation	Obligate upland	Willows	Reeds and aquatic plants	Cottonwood/ willow	Cottonwood/willow w/salt cedar, grass
Terrace vegetation	Obligate upland			Cottonwoods and mesquite	

1.4.2.1 Reach Streamflow

Streamflow of the Santa Cruz River in recent years at Site 1, immediately upstream from effluent inputs, has been ephemeral, occurring less than 10 percent of the time and averaging approximately 10.6 cfs. Estimated effluent input to Site 2, at the time of field inspection (May 2, 2000), was 24.7 cfs. Additional inputs of unknown quantity enter the Santa Cruz River downstream near Ina Road. May is generally a month of low precipitation (averaging approximately approximately 0.2 inch per year) and storm-generated streamflow is unusual. At Sites 3 (Ina Road), 4 (Cortaro Road), and 5 (Trico-Marana Road), respectively, estimated discharges in the Santa Cruz River were 70.6, 70.6, and 53.0 cfs. These three estimated discharges reflect variable releases from the Roger Road treatment plant as well as other inputs of wastewater and irrigation-return flow downstream to Trico-Marana Road. In addition, transmission loss along the Santa Cruz River channel varies with time following a flood. High flow mobilizes bed sediment and tends to clean it of algae and other attached micro-organisms that lower infiltration. As a consequence of flooding along the Santa Cruz River in October

2000, bed sediment was disturbed, infiltration potential was temporarily increased, and higher rates of transmission loss prevented wastewater to flow downstream as far as Site 5. At a gage site at Cortaro Road (Site 4), wastewater-derived streamflow in May typically averages 35.3 to 70.6 cfs (67.1 cfs in May 1999). At a gage site at Trico Road (1.9 miles downstream from Site 5 at Trico-Marana Road), streamflow in May typically averages less than 35.3 cfs (12.4 cfs in May 1999). Streamflow in the Santa Cruz River near Laveen, Arizona, approximately 62 miles farther downstream, is generally less than 0.4 cfs; discharge was not recorded at the Laveen gage during May 1999. Thus, present streamflows along this reach of the Santa Cruz River suggest ephemeral conditions above the treatment plant, variable rates of transmission, loss of discharge (dependent on recent flood history) wherever streamflow occurs, and local increases in streamflow due to other sources of wastewater and irrigation-return flow.

1.4.2.2 Sites 1 and 2 Field Observations

From the Roger Road WWTP near Sites 1 and 2, sewage effluent enters a single, flood-dominated channel of the Santa Cruz River that has a bed mostly of coarse sand and cobbles; less than 5 percent of the bed material appears to be finer than sand. Sediment forming the left bank is largely fine sand but includes other sand sizes and gravel; the right bank at Sites 1 and 2 is an artificial cement plaster preventing bank erosion and channel encroachment on the WWTP grounds. Sinuosity is 1.06 to 1.07 and channel gradients above and below the wastewater input are, respectively, 0.0030 and 0.0026. Channel widths at Sites 1 and 2 are 36.0 and 29.5 feet, respectively, and do not signify adjusted conditions owing to modifications including the effluent channel, reduced bottomland area and heightened flood peaks due to urbanization, a right bank that is cement-stabilized as a levee, and other bottomland disturbances. Floodplain to the left of the channel at both sites suggests a modern surface and recent fluvial processes. At Site 1 the floodplain is approximately 5.3 feet above the thalweg and at Site 2 it is approximately 8.2 feet higher; causes for this difference may be both stream incision and greater amounts of overbank sediment deposition in the pheatophytic riparian-zone vegetation of Site 2. Vegetation on this surface at Site 1 is typical desert species of this area, whereas at Site 2 the floodplain vegetation, such as willows, is indicative of perennial water. Species lining the channel include emergents such as cattails.

Modification of the channel and other bottomland features by recent floods at Sites 1 and 2 does not appear to have been extensive. The levee that forms the right bank prevents bank erosion and restricts floods, and flood deposition, from covering the now-isolated right floodplain. Flood flows, therefore, are accentuated on the left floodplain and moderate terrace-bank erosion along the left edge of the floodplain is apparent. This concentration of flood flow probably has the effect of increasing damage to riparian-zone vegetation at Sites 1 and 2.

At Site 2, the left channel bank is formed largely of medium-grained sand that is stabilized by silt and clay, organic matter, and shrubs and trees. Sediment forming the bed at Site 2 is mostly fine-grained and highly organic. Sediment transport is minor, most being suspended organic material; bed load does not occur except when flow events from upstream replenish supplies of coarse sand and gravel. Consequently, bed forms are largely absent and channel activity is minimal. Sediment-free wastewater inputs have caused a small amount of channel cutting, and a tendency for this incision has extended upstream as well toward Site 1.

1.4.2.3 Site 3 Field Observations

The Santa Cruz River downstream from Ina Road (Site 3) has a channel gradient of 0.0027, a sinuosity of 1.07, and is 114.8 feet wide. The area of floodplain averages approximately 492 feet in width and is bounded by alluvial-terrace surfaces 14.8 feet higher. The channel bed is approximately 6.6 feet lower than floodplain level. The entire bottomland in the vicinity of Site 3 has been highly disturbed by sand and gravel mining, an activity that almost certainly increases rates of bed-load discharge. Downstream from Ina Road, the position of the Santa Cruz River channel has been shifted to the southwest to facilitate sand and gravel extraction.

Channel incision by the Santa Cruz River upstream is prevented by a grade-control dam at the Ina Road Bridge. As a consequence, the river channel is swampy due to sediment storage behind the dam and the bottomland area has abundant marsh-type plants. The median size of bed material at Site 3 (below Ina Road) is medium sand; the silt-clay fraction is approximately 10 percent and the coarse fraction is largely gravel and a smaller amount of cobbles. Sand movement as bed load both above and below the dam is substantial, resulting in numerous bed forms including ripples, dunes, and longitudinal bars. Suspended sediment, bed load, and sediment stored as active channel deposits are provided by flow events of the Santa Cruz River augmented by significant inputs during flows of Rillito Creek, Cañada del Oro, and several smaller tributaries. Discharges of wastewater effluent only do not appear great enough to mobilize the gravel and cobbles of bed material.

1.4.2.4 Site 4 Field Observations

Channel width below Cortaro Road (Site 4) is 82.0 feet and the distance between recent floodplain edges is 738.2 feet. Recent flows, including those of wastewater, have caused channel incision, thereby transforming the floodplain of several decades ago into a low terrace 4.9 feet higher than a newly formed floodplain. Recently deposited sand adjacent to the channel is supportive of this interpretation. Paired terraces approximately 13 feet higher than the former floodplain surface border the bottomland. The gradient is 0.0026 and the sinuosity is 1.02. Channel depth is 1.6 feet below the evolving floodplain. Lowland surfaces, with lush riparian-zone vegetation, on both sides of the channel have been much disturbed, and bank-stabilization structures (cement) on the alluvial terraces reduce the potential for bank erosion during floods, but appear to have no significant effect on channel morphology at any flow rate.

The median-particle size of bed material at Site 4 is gravel; the maximum size is 1.6-foot cobbles, and matrix sediment of fine sand, silt, and clay accounts for perhaps 15 percent of the bed material. Bank material is mostly fine sand with gravel, but little silt and clay. Bed load is substantial and is composed largely of coarse sand and fine gravel. Results are borderline braiding, dunes, and minor pool-riffle sequences. The riffles tend to be vegetated, suggestive of increased elevation owing to downcutting. Vegetated channel islands are common and also appear to be parts of the channel isolated by incising streamflow on either side.

1.4.2.5 Site 5 Field Observations

Presumably because of transmission loss and thus flow reductions, channel width at Trico-Marana Road (Site 5) narrows to 65.6 feet. A narrow floodplain area averaging approximately 229.7 feet is bounded by paired terraces 6.6 feet higher. The channel depth below the floodplain is 3.3 feet. Channel gradient is 0.0021 and the sinuosity is 1.12. Bed material is mostly medium sand and includes lesser amounts of gravel and finer sand and silt. Bank material is largely medium-grained sand incorporating minor amounts of gravel. The Santa Cruz River channel is very sandy and active at Site 5, showing much bed load of medium to coarse sand and therefore ripples, dunes, many small, low islands, and a poorly defined thalweg. Vegetation in the channel includes grasses and forbs and Bermuda grass and salt cedar occupy low-lying surfaces adjacent to the channel. Banks are formed of medium sand and lesser amounts of gravel, are unstable, and show signs of recent deposition (channel narrowing).

Much of the Santa Cruz River northwest of Tucson is erosional (downcutting) due probably to constant flow entraining stored sand and gravel of the channel. At Site 5, however, the hydrologic environment is slightly depositional, in part because of streamflow abstractions (reductions due to transmission loss), and partly because the bridge of Trico-Marana Road causes local bank erosion resulting from the constriction. The entrained sand is quickly redeposited below the bridge in an expanding reach of the river.

1.5 PHYSICAL ANALYSIS

1.5.1 Climate Assessment

Air temperature and precipitation data were recorded in Tucson at NCDC station number 8817 (refer to **Figure C-3-1**) from 1982 through 1998. The estimated average annual precipitation at this station is 12.4 inches. The estimated average temperature at this station is 69.1°F, the minimum daily temperature is 19°F, and the maximum daily temperature is 114°F. Table C-3-9 presents the average monthly precipitation and maximum daily precipitation. Table C-3-10 presents minimum, mean, and maximum daily temperature.

Table C-3-9
Mean Monthly Precipitation and Maximum Daily Precipitation
Near Tucson, Arizona

NCDC Station 8817 (1982-1998)		
Month	**Mean Monthly Precipitation (Inches)**	**Maximum Daily Precipitation (Inches)**
January	1.1	1.37
February	1.3	1.02
March	1.0	0.82
April	0.3	0.84
May	0.2	0.40
June	0.1	0.81
July	1.6	1.44
August	2.6	2.81

Table C-3-9
Mean Monthly Precipitation and Maximum Daily Precipitation
Near Tucson, Arizona

NCDC Station 8817 (1982-1998)		
Month	**Mean Monthly Precipitation (Inches)**	**Maximum Daily Precipitation (Inches)**
September	1.3	0.98
October	0.9	3.05
November	0.8	0.83
December	1.4	1.62
Annual Precipitation Total (inches)	12.4	

Table C-3-10
Mean, Maximum, and Minimum Monthly Temperature
Near Tucson, Arizona

NCDC Station 8817 (1982-1998)			
Month	**Minimum Temperature (°F)**	**Mean Temperature (°F)**	**Maximum Temperature (°F)**
January	22	52	85
February	21	55	89
March	28	61	97
April	32	67	104
May	39	75	107
June	47	84	114
July	59	87	113
August	61	86	110
September	51	81	106
October	35	71	102
November	25	59	90
December	19	52	84
Min/Mean/Max	19	69	114

1.5.2 Flow Assessment

Figure C-3-3 presents the mean daily flow versus time for the Roger Road WWTP and Ina Road WPCF and USGS gages upstream and downstream of the facilities. The mean annual flow in the Santa Cruz River has increased both upstream and downstream of the facilities (**Figure C-3-4**). The increase in flow over time could be attributed to an increase in urbanization in the area. With an increase in urbanization, the amount of impervious surface within the watershed increases thereby increasing runoff to the stream system.

The Santa Cruz mean monthly streamflow near Tucson, shown on **Figure C-3-5**, varies upstream of the treatment facilities from zero flow in the months of January, May, June, October, and November to a high flow of approximately 45 cfs in July. The downstream flow also has a peak in July. The peak flow pattern is consistent with the peak rainfall observed at the climate station near Tucson (NCDC 8817). For portions of the year, **Figure C-3-5** shows that the flows at the downstream gage (09486500) are less than the combined flow of the Ina and Roger Road

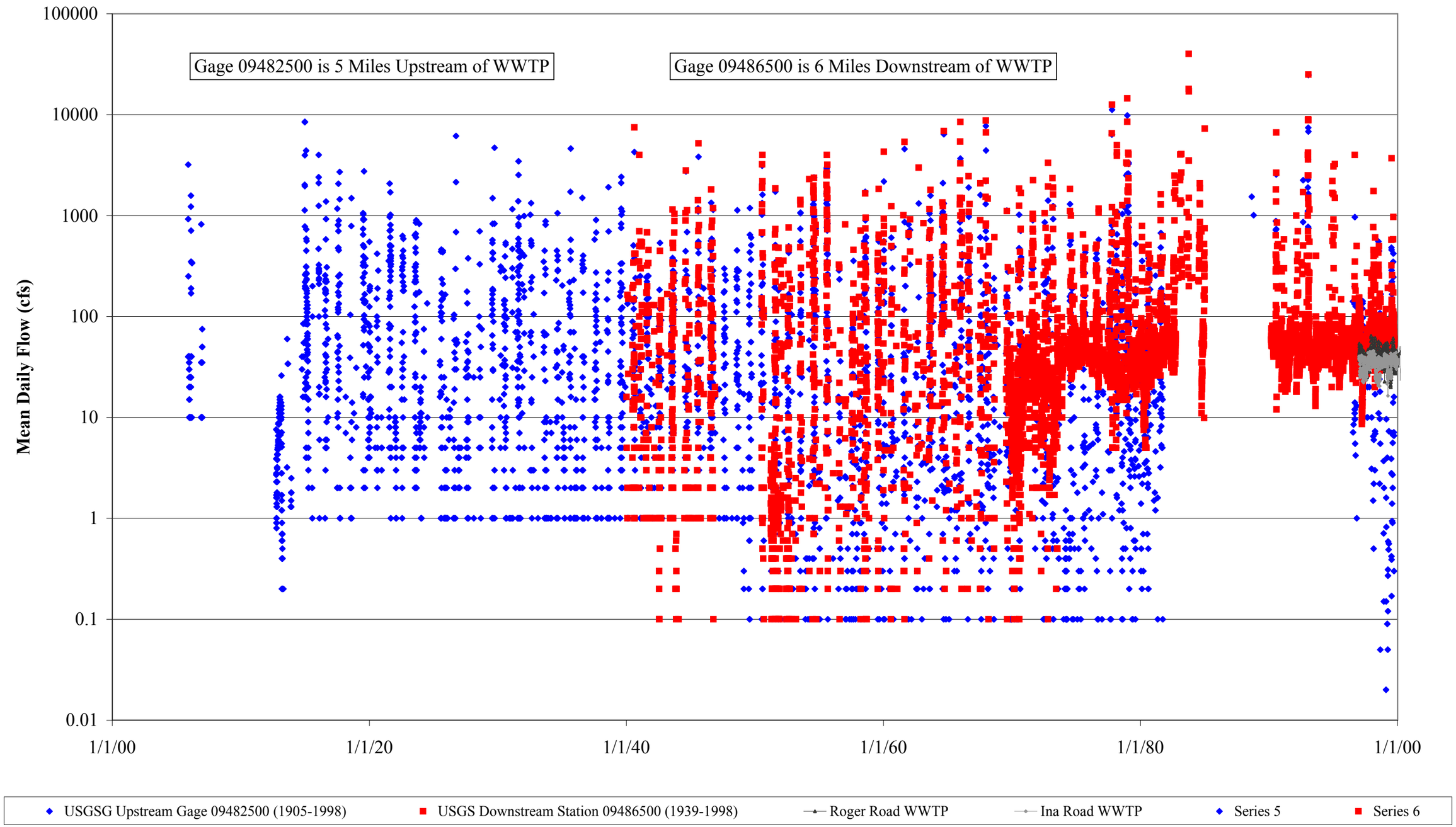


Figure C-3-3
Mean Daily Flow Values
Santa Cruz River Near Tucson, Arizona

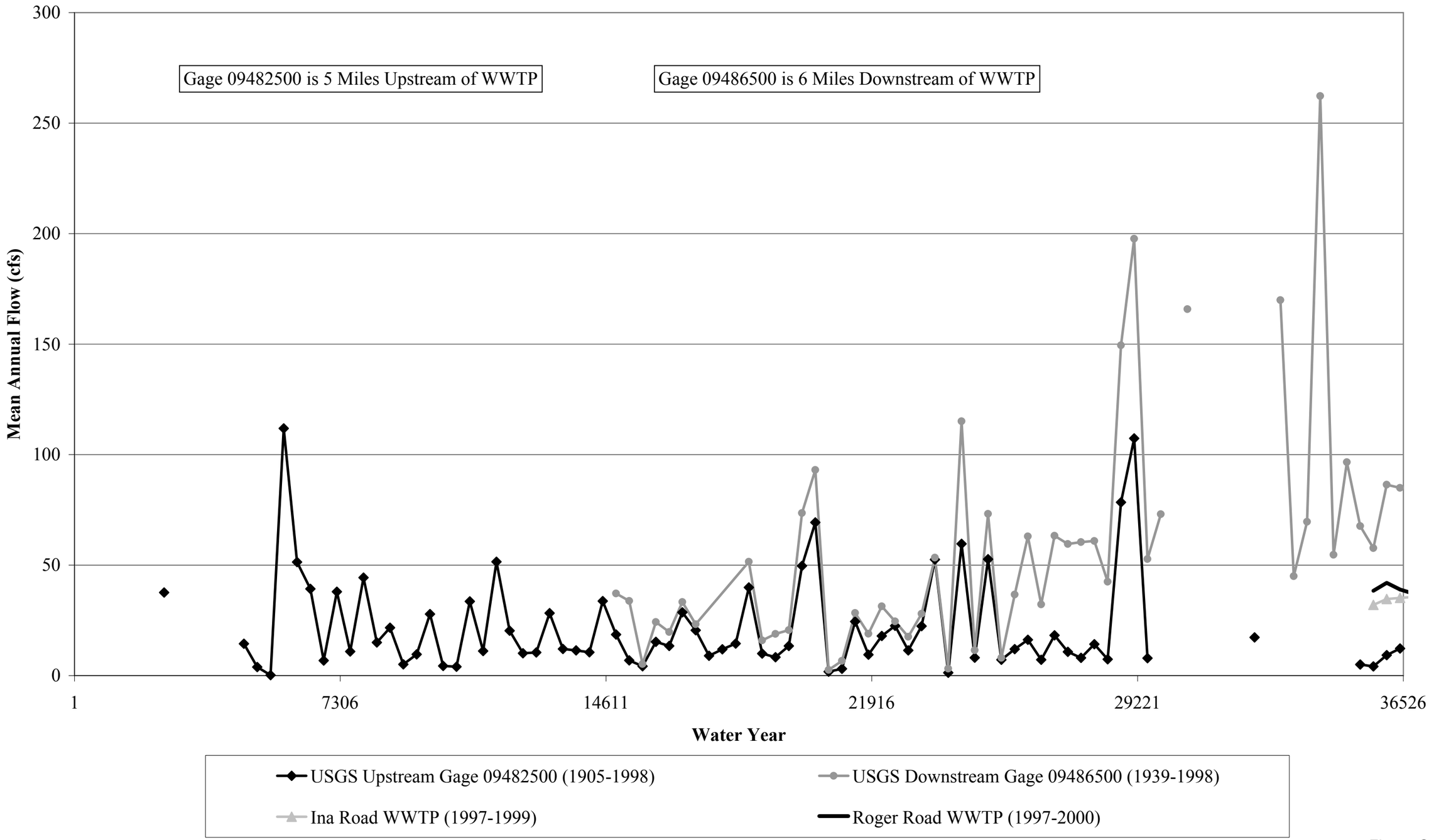


Figure C-3-4
Mean Annual Flow Values
Santa Cruz River Near Tucson, Arizona

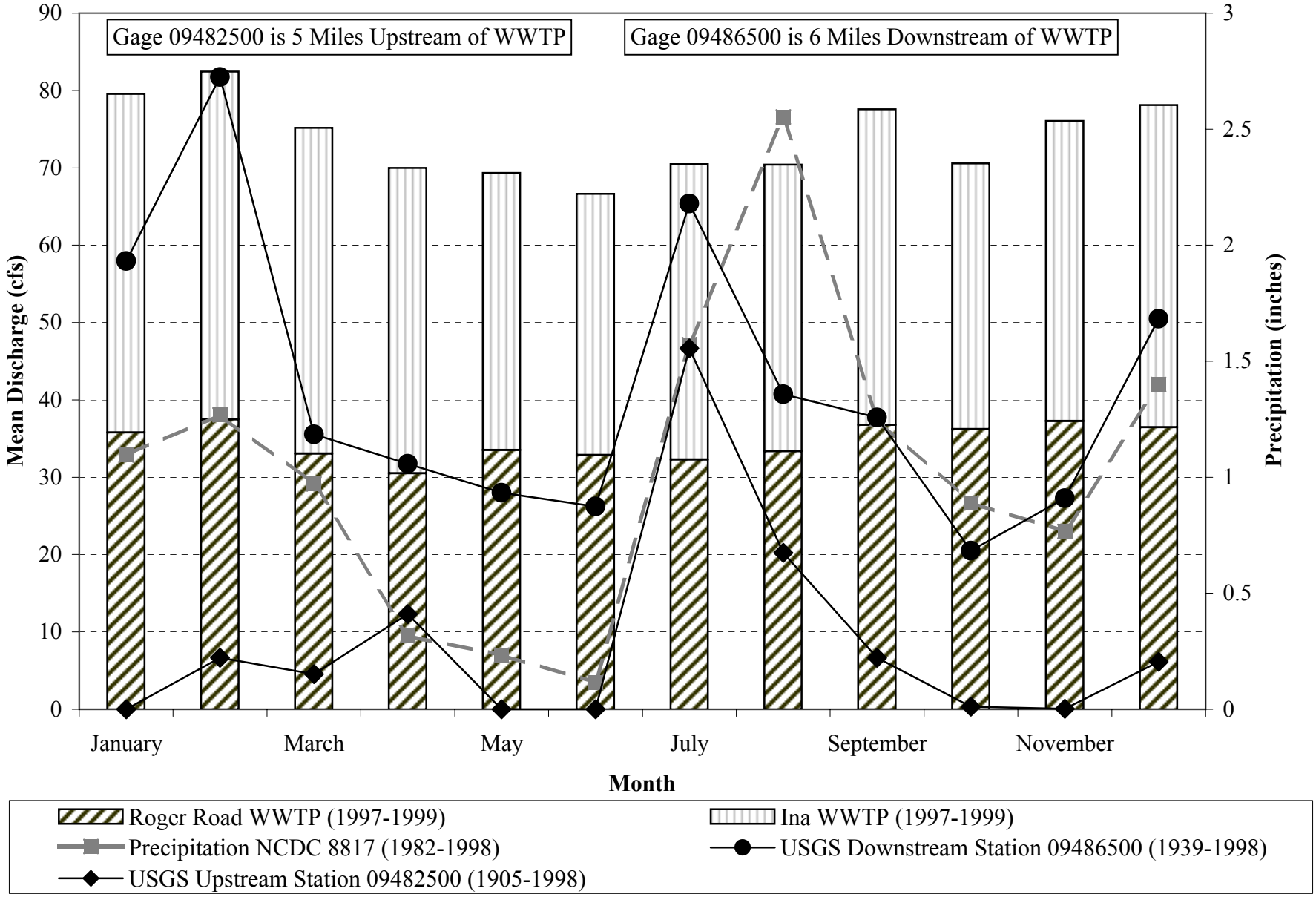


Figure C-3-5
Mean Monthly Flow
Santa Cruz River Near Tucson, Arizona

facilities. This is an indication that this portion of the stream is losing flow to the groundwater systems or other withdrawals.

Log Pearson Type III flood frequency analysis was performed on both the upstream and downstream gages of the Santa Cruz River (**Figure C-3-6**). Results of this analysis for a range of flood events is presented in Table C-3-11. There is little variation in flood values between the upstream and downstream gages. The drainage size for the upstream gage is 2,222 square miles versus the downstream gage area of 3,503 square miles.

Table C-3-11
Flood Frequency Analysis for the Santa Cruz River
Near Tucson, Arizona

USGS Gage	2-Year Flood (cfs)	10-Year Flood (cfs)	50-Year Flood (cfs)	100-Year Flood (cfs)
09482500 (upstream of WWTP)	5,000	12,500	22,000	26,000
09486500 (downstream of WWTP)	8,000	17,000	25,000	28,000

Log Pearson Type III low flow frequency analysis was completed using a lowflow duration of 7 days and 30 days for the stream gage downstream of both treatment facilities (**Figure C-3-7**) for the period of record from 1978 through 1997. The analysis was only performed on the downstream gage because the recurrence interval of zero flow is less than 1 year for the 30-day, 7-day, and 1-day durations at this location. The 3-year low flow at the downstream gage is approximately 12 cfs for the 7-day duration and 23 cfs for the 30-day duration. The 10-year low flow is 8 cfs for the 7-day duration and 14 cfs for the 30-day duration.

In addition to flood frequency and low flow frequency analysis, flow duration curves were used to establish the percent of time that mean daily flows occur. The flow was analyzed on a daily, 7-day, and 30-day duration of occurrence. **Figures C-3-8, C-3-9, and C-3-10** show the duration frequency curves for USGS gage upstream of the Ina and Roger Road facilities (09482500). These curves show the percent of time that a given flow occurs. For example from **Figure C-3-8** it is shown that the daily flow in the Santa Cruz River upstream of the Roger Road WWTP is less than or equal to 10 cfs 90 percent of the time. **Figures C-3-8, C-3-9, and C-3-10** show cumulative frequency curves during different periods of time. In recent decades (1980-1999), **Figures C-3-6, C-3-7, and C-3-8** show that upstream of the Roger Road WWTP, flow occurs less frequently than in early decades. For example, on **Figure C-3-8** a flow of 40 cfs or more in the Santa Cruz River upstream of the Roger Road WWTP occurred 15 percent of the time during 1959 through 1979 and 10 percent of the time during 1980 to 1999. This may indicate that upstream uses of the water resource have increased over time.

Figures C-3-11, C-3-12, and C-3-13 show the frequency duration curves for the USGS gages downstream of the Roger Road and Ina Road facilities. These figures also indicate that flows in the Santa Cruz River downstream of the Tucson treatment facilities have increased through time. **Figures C-3-14, C-3-15, and C-3-16** show the frequency duration curves for upstream and

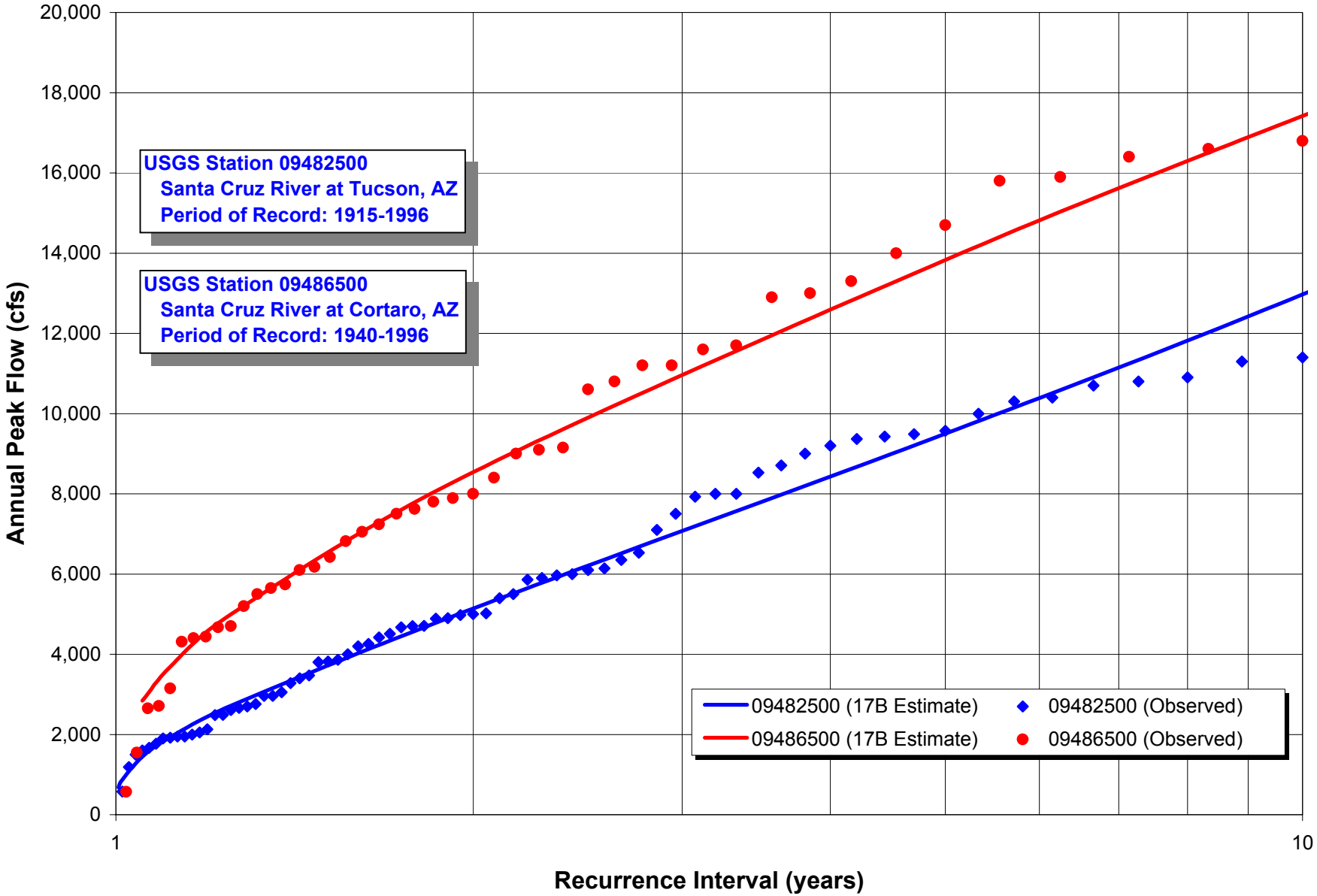


Figure C-3-6
Annual Peak Flow Frequency Analysis
Santa Cruz River Near Tucson, Arizona

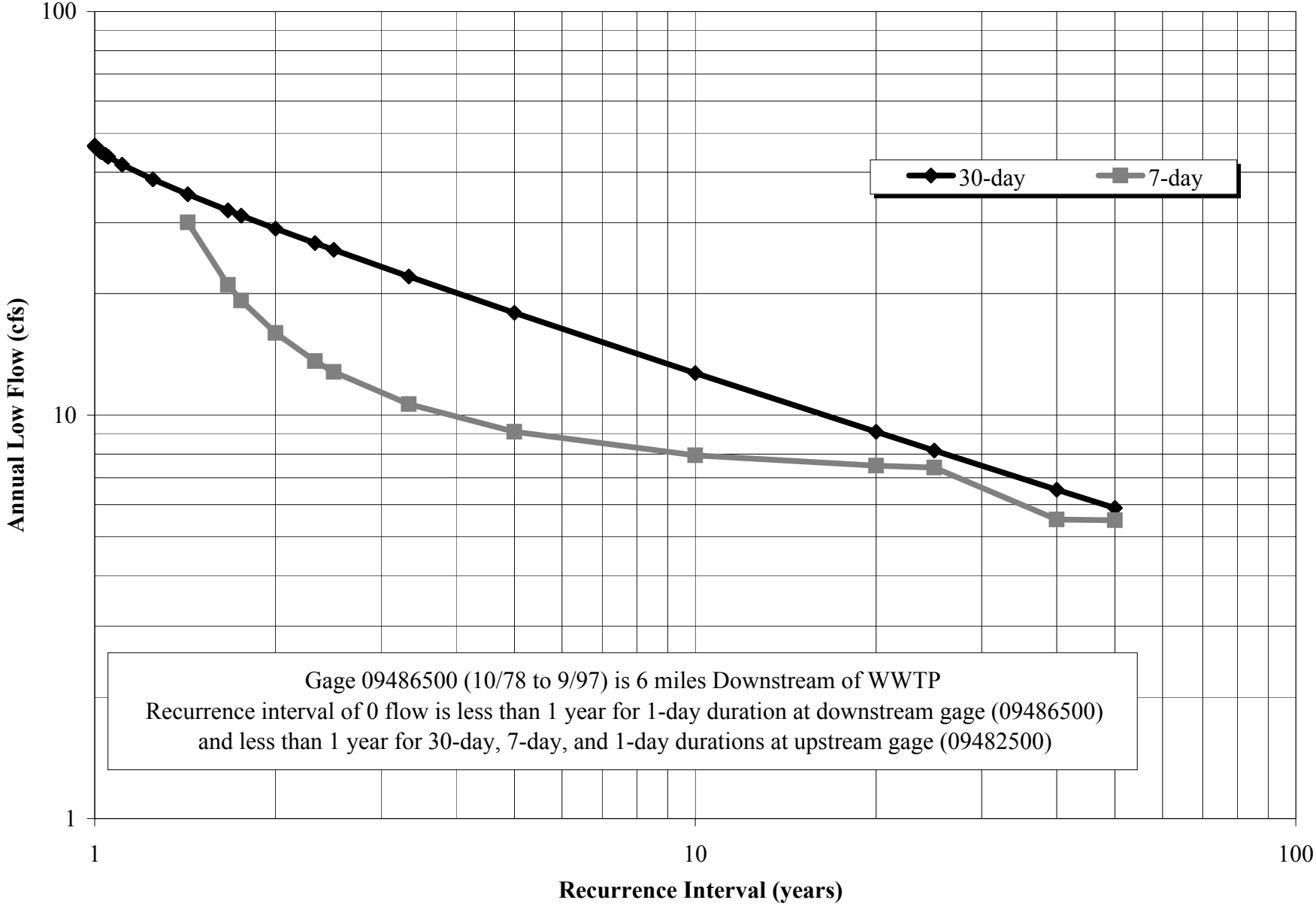


Figure C-3-7
Low Flow Duration Frequency Analysis
Santa Cruz River Near Tucson, Arizona

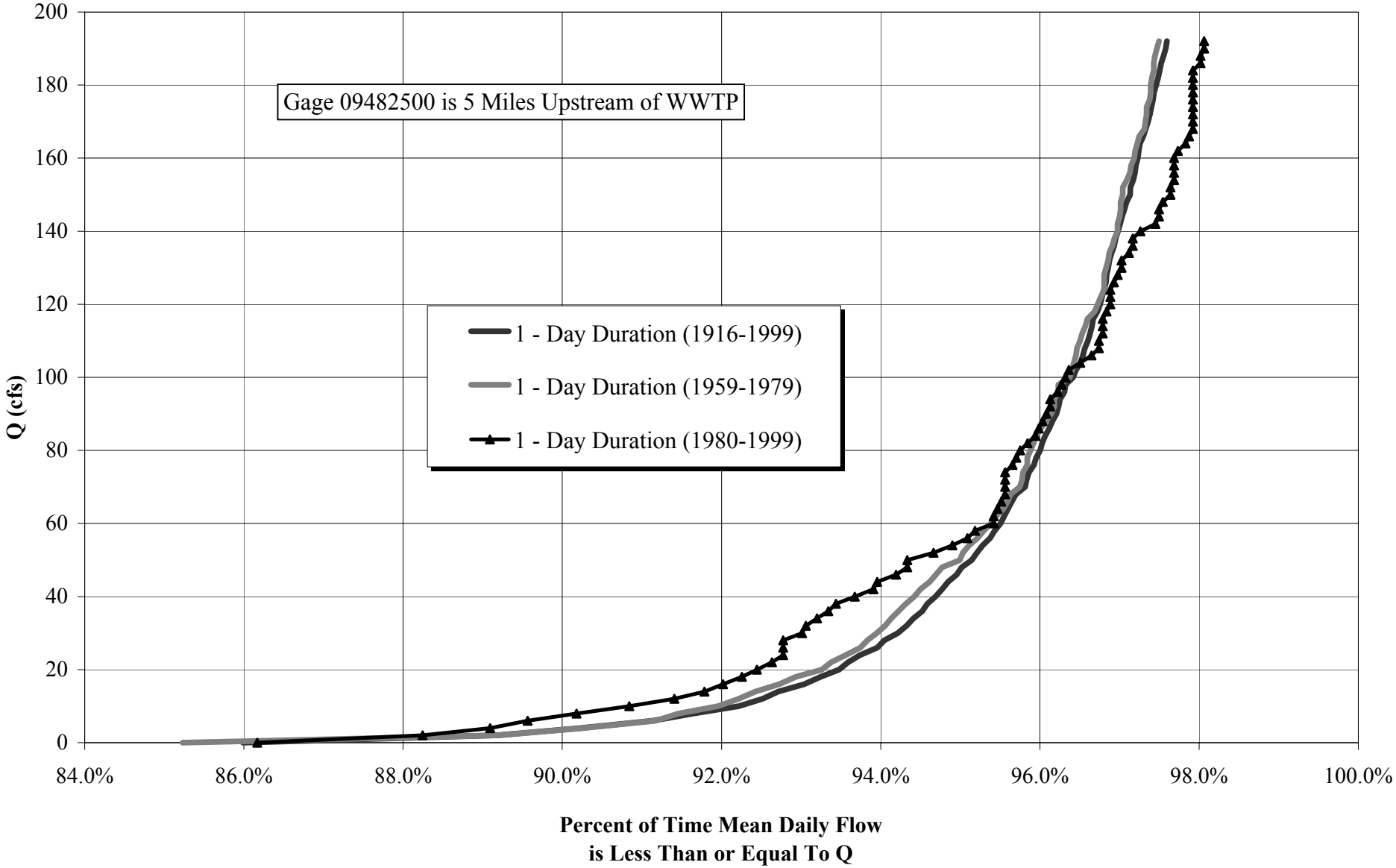


Figure C-3-8
1-Day Mean Daily Flow Cumulative Frequency Distribution
USGS Station 09482500
Santa Cruz River Near Tucson, Arizona

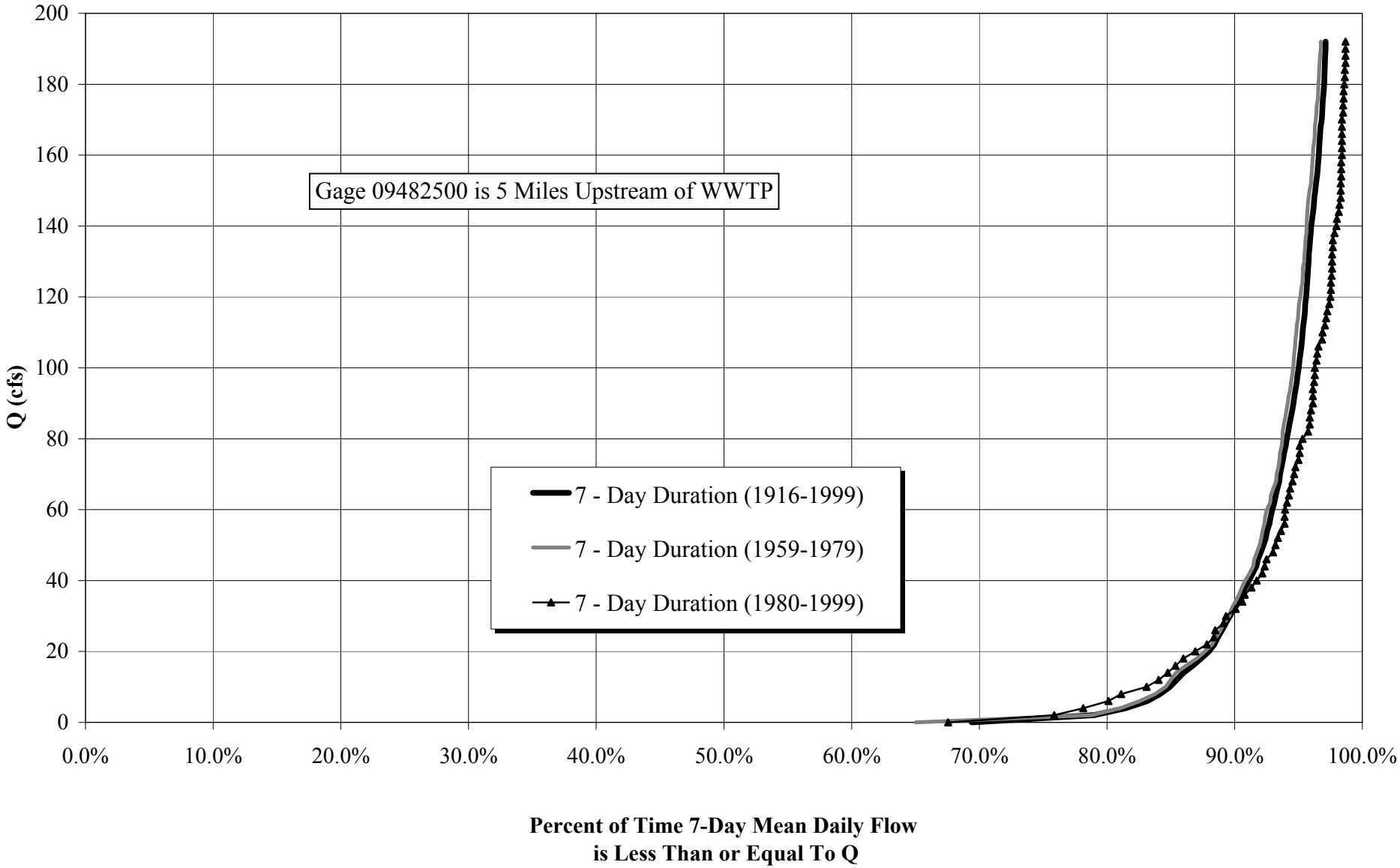


Figure C-3-9
7-Day Mean Daily Flow Cumulative Frequency Distribution
USGS Station 09482500
Santa Cruz River Near Tucson, Arizona

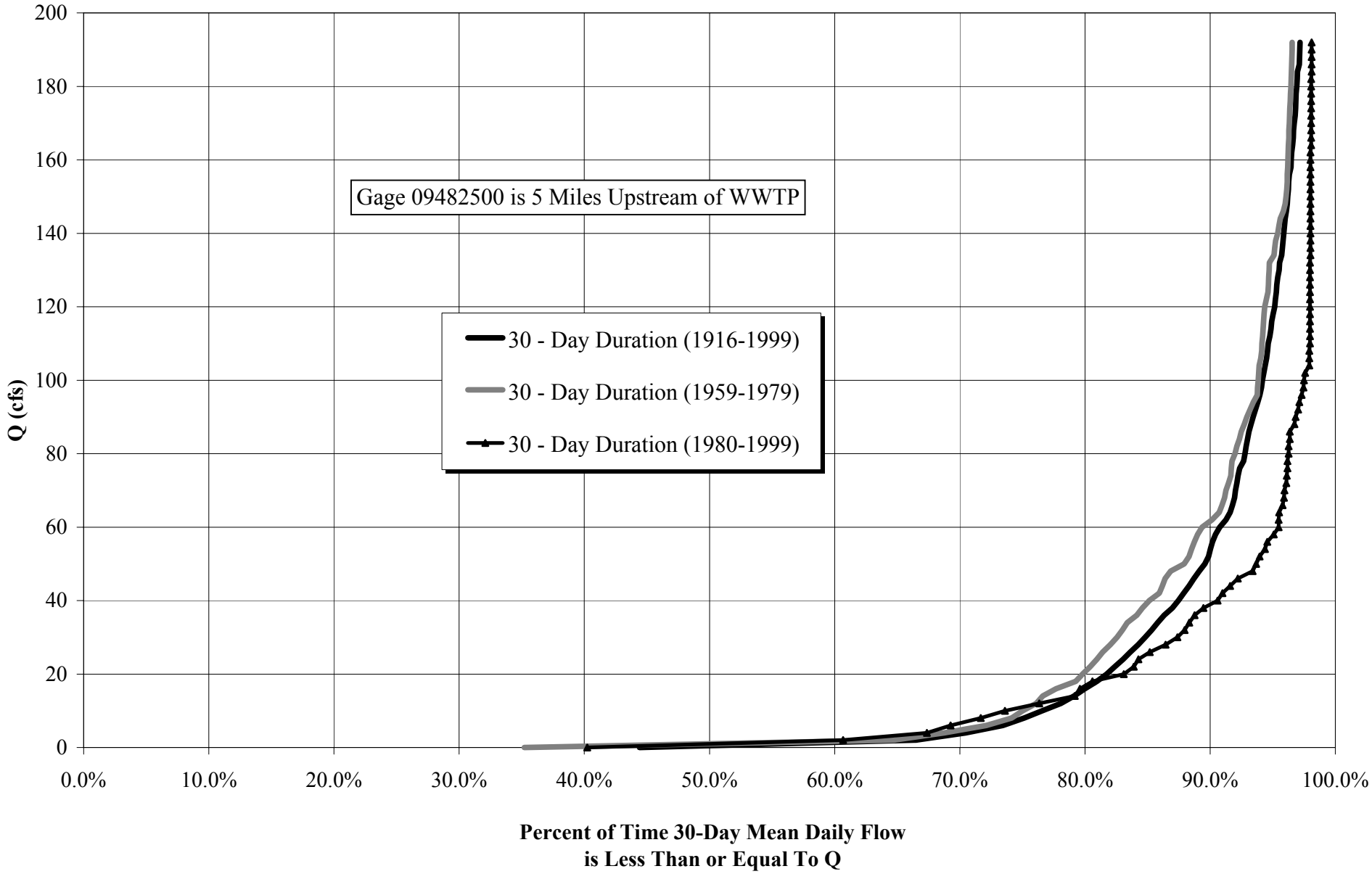


Figure C-3-10
30-Day Mean Daily Flow Cumulative Frequency Distribution
USGS Station 09482500
Santa Cruz River Near Tucson, Arizona

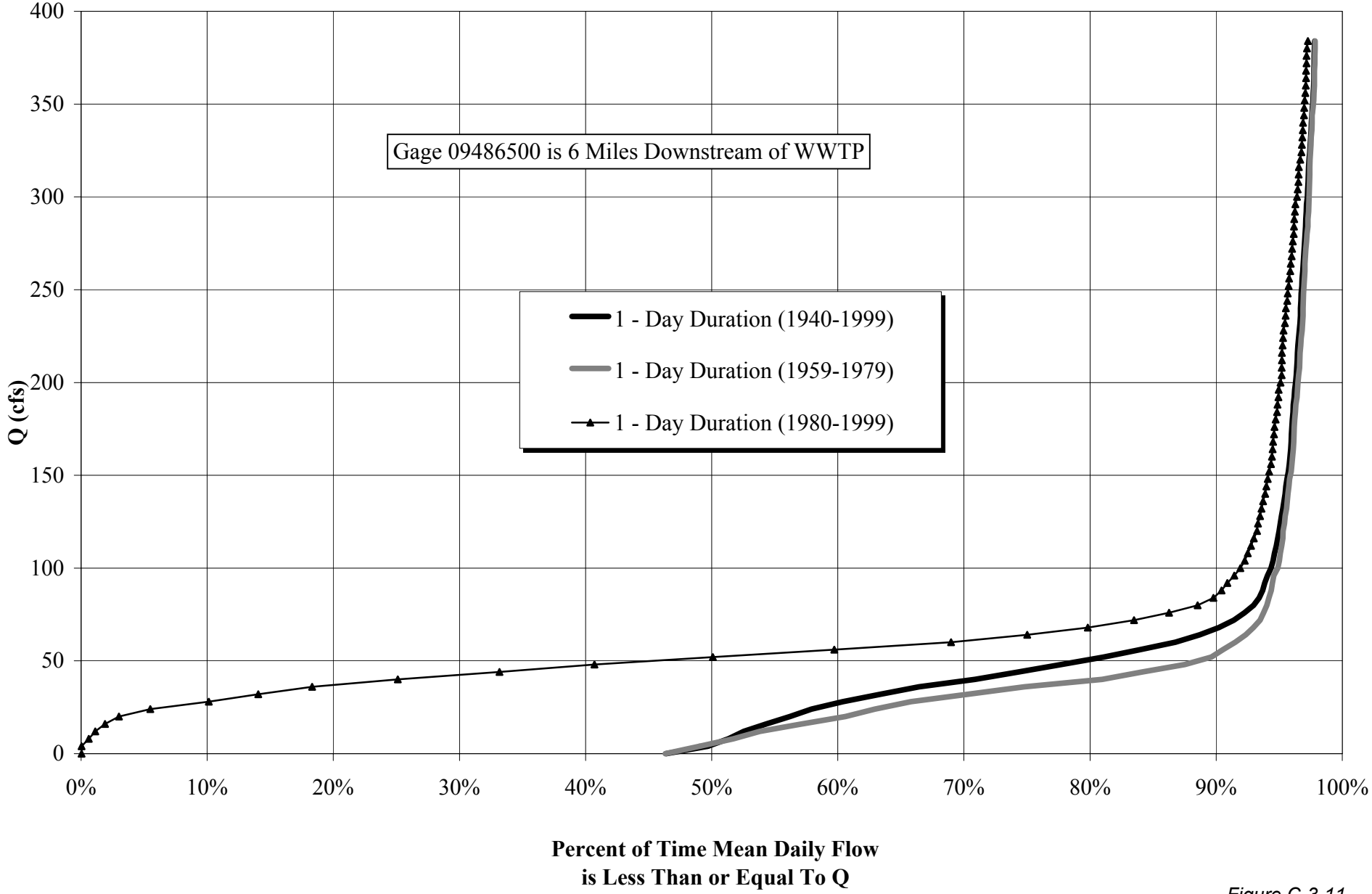


Figure C-3-11
1-Day Mean Daily Flow Cumulative Frequency Distribution
USGS Station 09486500
Santa Cruz River Near Tuscon, Arizona

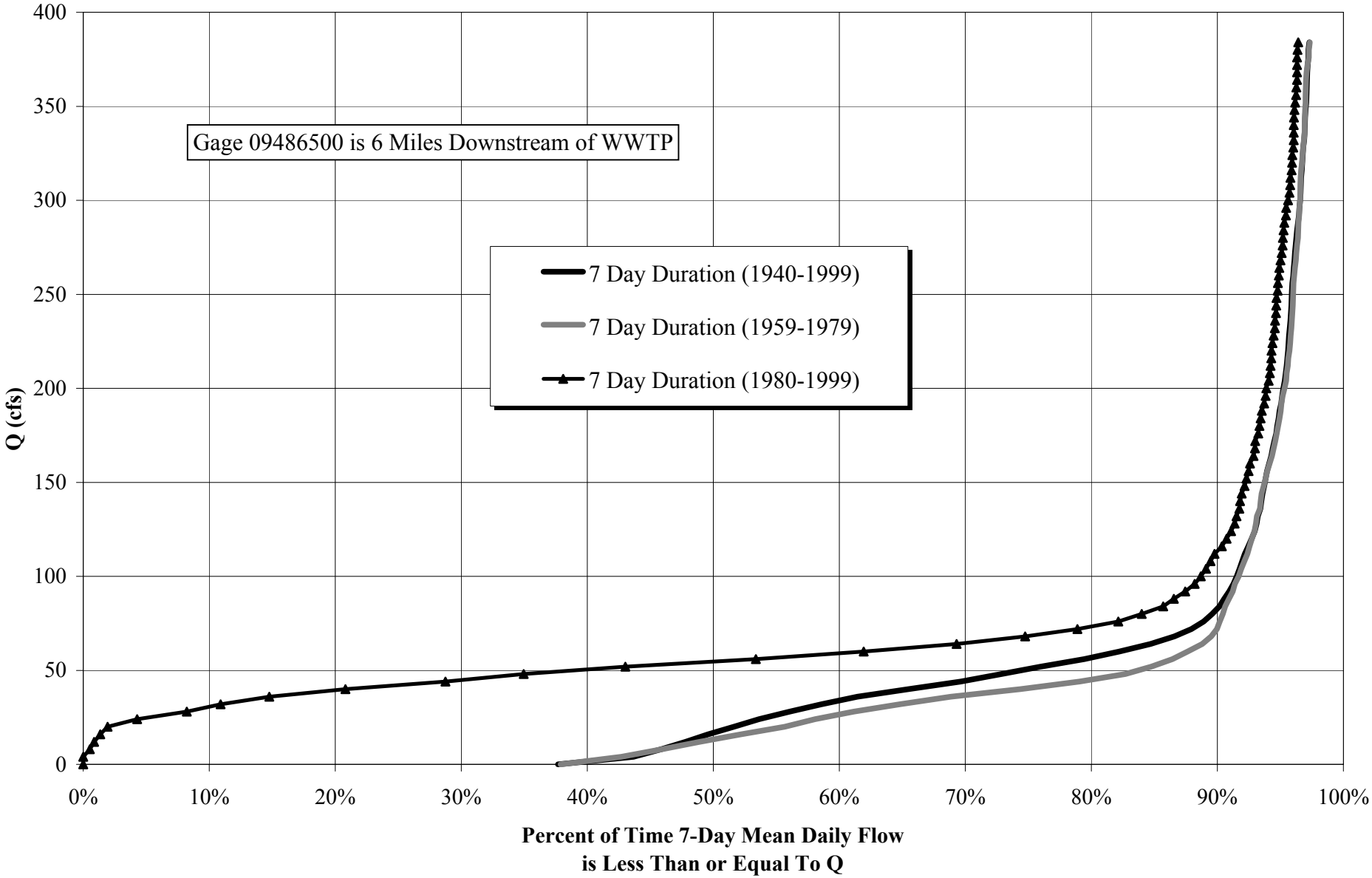


Figure C-3-12
7-Day Mean Daily Flow Cumulative Frequency Distribution
USGS Station 09486500
Santa Cruz River Near Tucson, Arizona

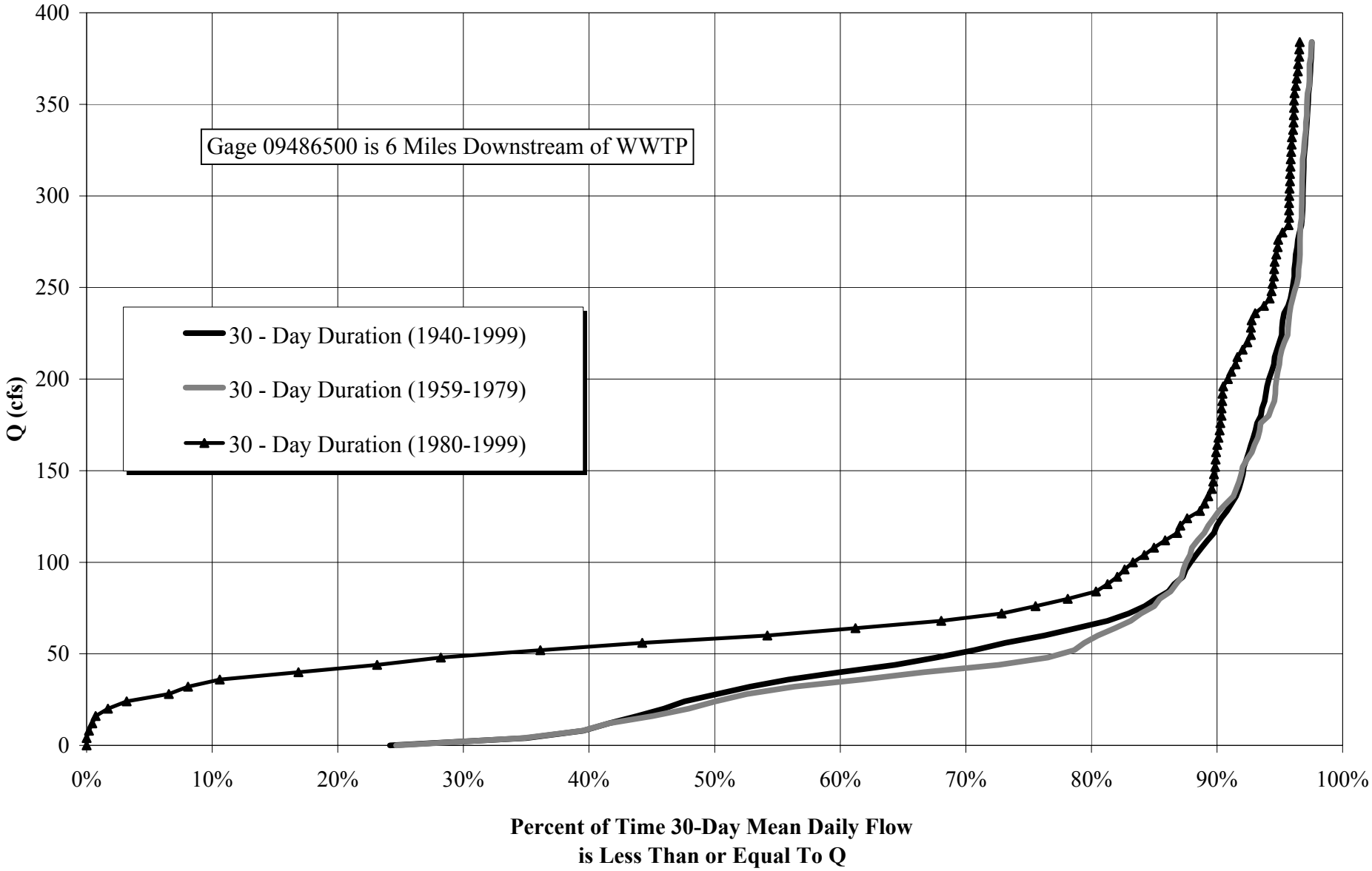


Figure C-3-13
30-Day Mean Daily Flow Cumulative Frequency Distribution
USGS Station 09486500
Santa Cruz River Near Tucson, Arizona

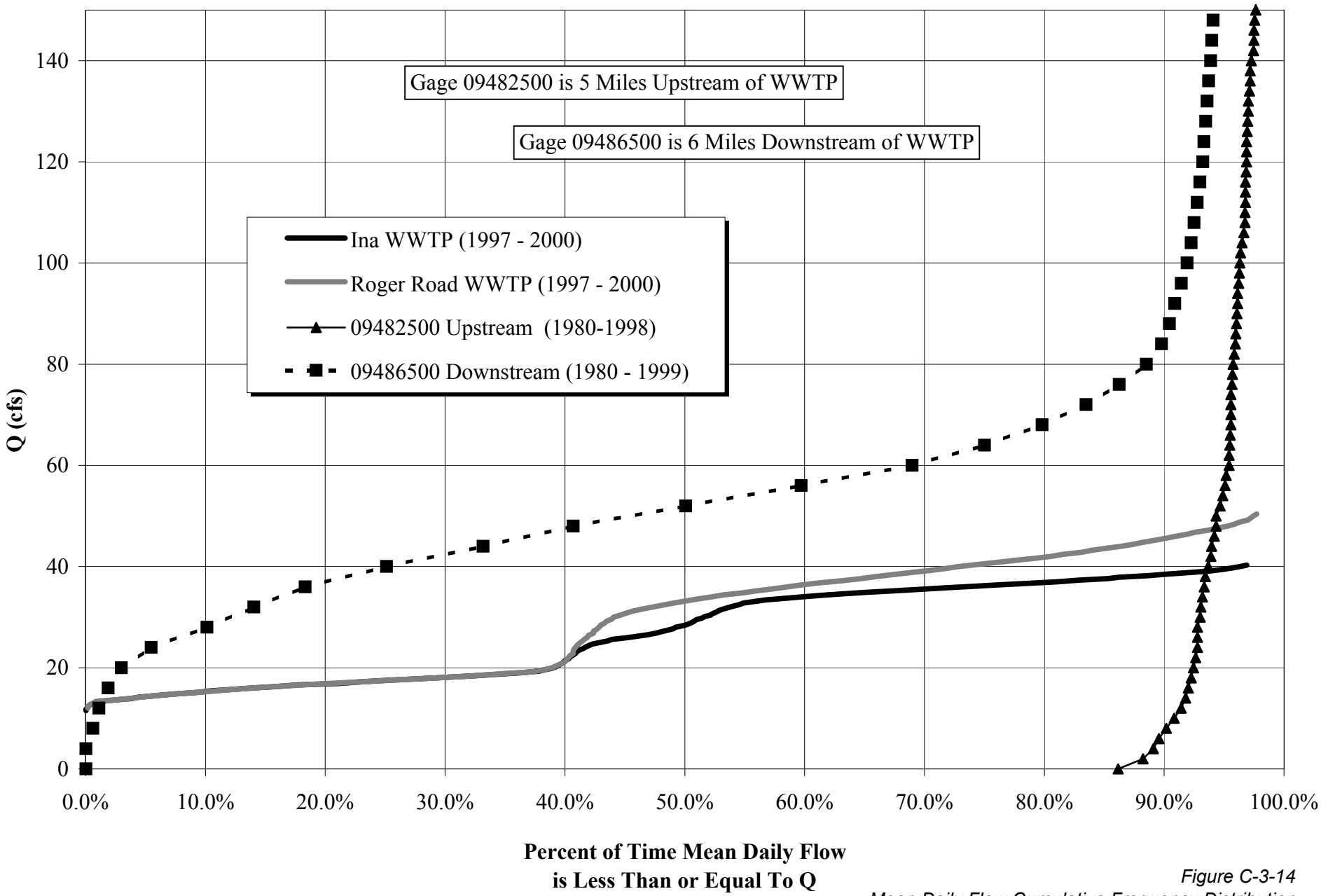


Figure C-3-14
Mean Daily Flow Cumulative Frequency Distribution
WWTPs and Upstream and Downstream Gages
Santa Cruz River Near Tucson, Arizona

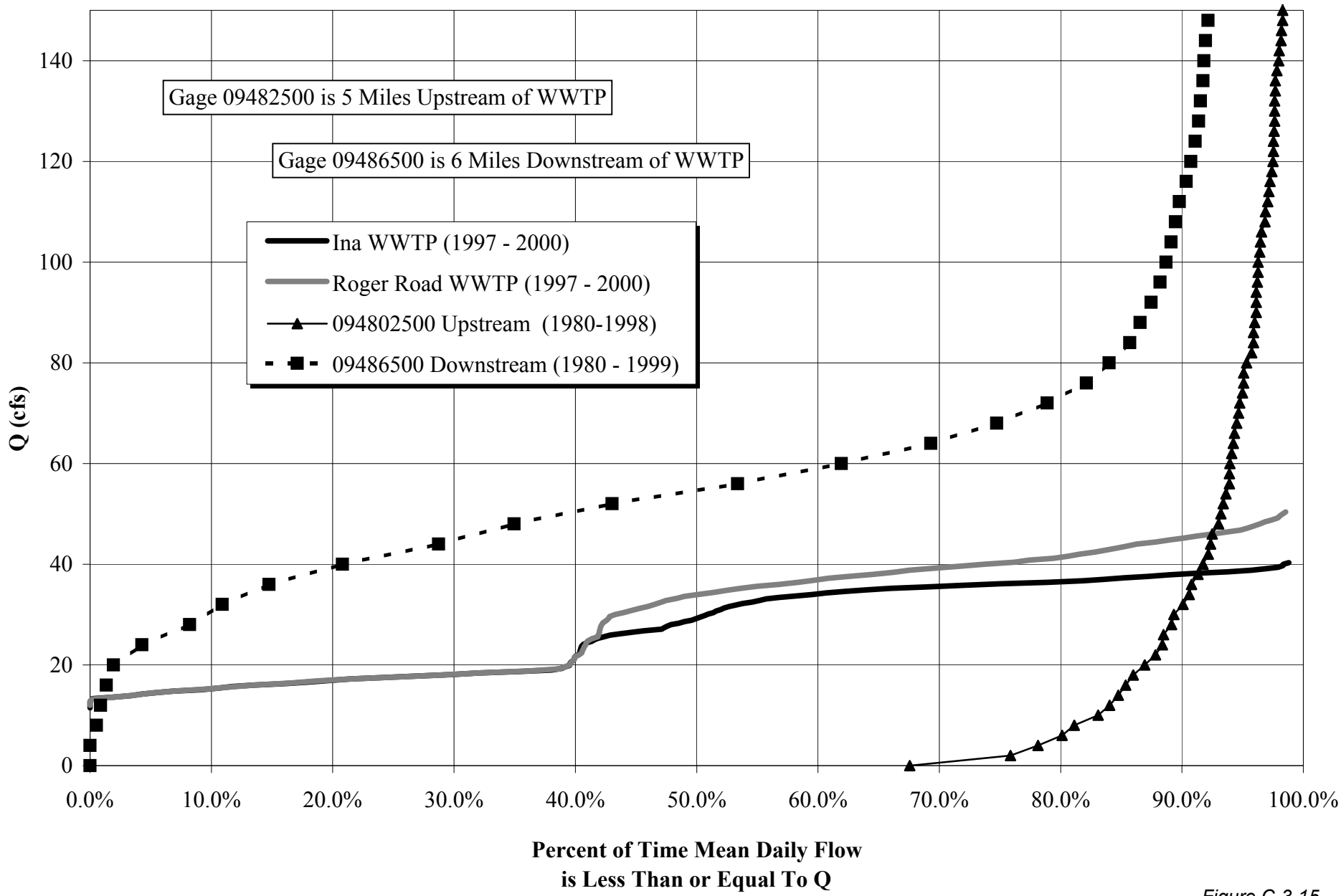


Figure C-3-15
7-day Mean Daily Flow Cumulative Frequency Distribution
WWTPs and Upstream and Downstream Gages
Santa Cruz River Near Tucson, Arizona

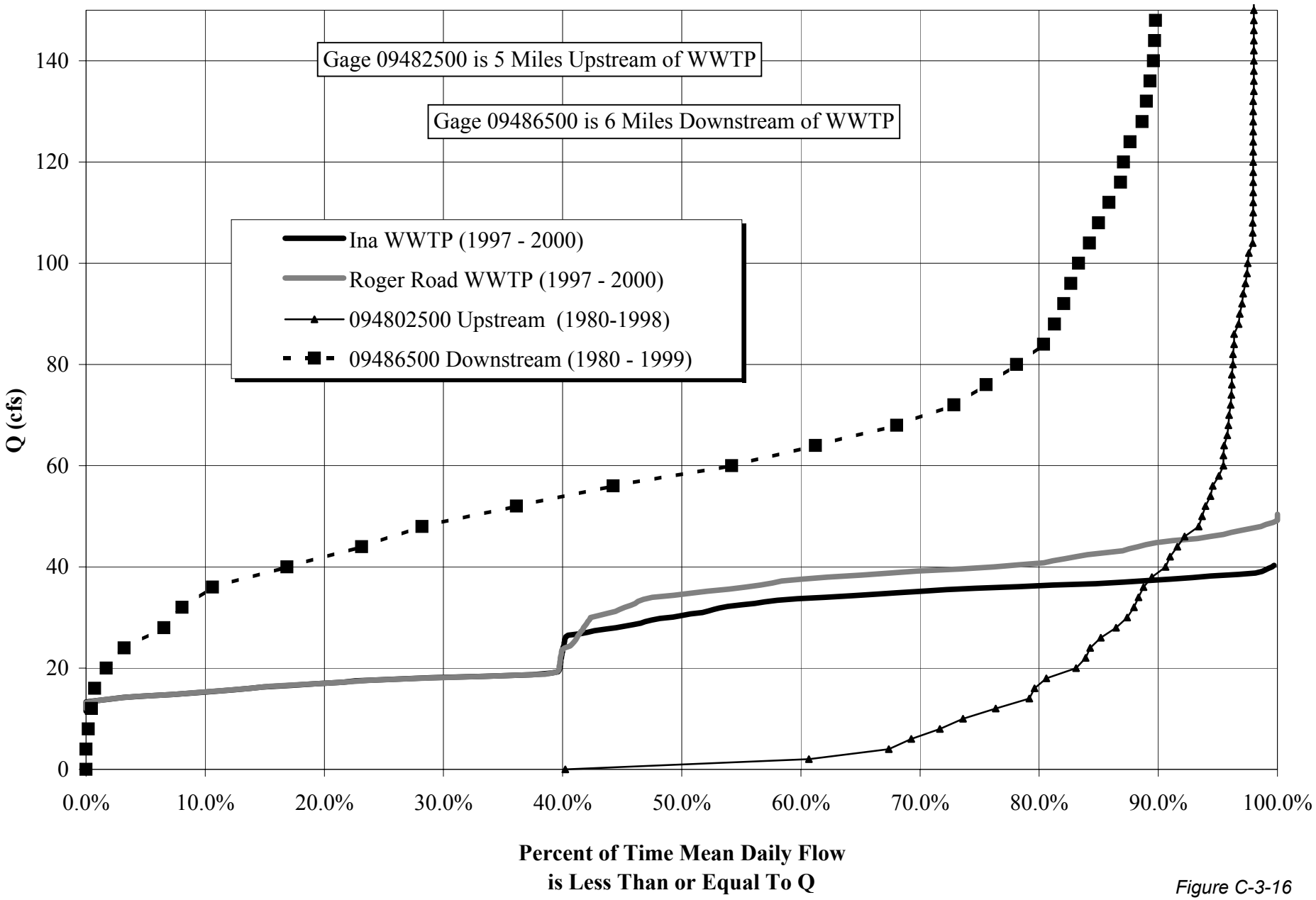


Figure C-3-16
30-day Mean Daily Flow Cumulative Frequency Distribution
WWTPs and Upstream and Downstream Gages
Santa Cruz River Near Tucson, Arizona

downstream of the facilities for recent history and also include frequency duration of the treatment facility flows.

1.5.3 Depth and Velocity

The project team utilized stage discharge relationship data provided from USGS to establish power equations relating discharge, velocity, and depth for USGS gage 09482500 (upstream of the facilities) and 09486500 (downstream of the facilities). From these relationships and the maximum mean daily flow for each gage, the maximum velocity to occur upstream and downstream of the facilities is shown in Table C-3-12. Velocities and depths that occur 50 percent and 80 percent of the time or more are also presented in Table C-3-13. These values were estimated using frequency duration data provided on **Figure C-3-14**.

Table C-3-12
Velocities and Depths of the Santa Cruz River Near Tucson

Gage	Max Velocity	Velocity and depth that occur 50% of time or more	Velocity and depth that occur 80% of time or more
09482500 (upstream of WWTPs)	8 ft/s	0 ft/s and 0 ft	0 ft/s and 0 ft
09486500 (downstream of WWTPs)	6 ft/s	2 ft/s and 0.8 ft	1.9 ft/s and 0.75 ft

Using the classification provided by Novotny et al. (1997) the Santa Cruz River near Tucson could be categorized as a fast and shallow stream system.

1.6 CHEMICAL DATA OVERVIEW

The Santa Cruz River near Tucson is included in the Central Arizona Basins National Water Quality Assessment (NAWQA) study. The NAWQA sampling station upstream of Tucson (station ID: 09481740) was located at Tubac, Arizona, approximately 50 miles from Tucson. The downstream NAWQA sampling station was located at Cortaro, Arizona (Site 4; station ID: 09486500). Both sites were designated as basic fixed sites. The sampling station at Tubac was sampled monthly for major ions, nutrients, organic carbon, and suspended sediment from October 1995 to September 1997. The sampling station at Cortaro was sampled monthly for the same parameters but from February 1996 to January 1997.

ADEQ has also collected chemical data at four sites within the study reach. Two of these sites were associated with the Roger Road WWTP (station 805770000000005 upstream of the WWTP and station 80575000000000 downstream) and the other two stations are upstream (80000000001690) and downstream (800000000017590) of the Ina Road WPCF. Because all data from these stations were collected and analyzed by ADEQ, we believe that EPA-acceptable methods and quality control procedures were adhered to during sampling and analysis. The period of record (POR) at each station and a summary of the data available for each parameter category is shown in Table C-3-13.

Table C-3-13
Summary of Records Available for the Santa Cruz River near Tucson, Arizona

Consti-tuent Group	805770000000005 (Upstream)		805750000000000 (Downstream)		800000000016960 (Upstream)		800000000017590 (Downstream)	
	POR	Description	POR	Description	POR	Description	POR	Description
Physical Parameters	4/75	Minimal data available*	4/75	Minimal data available	8/86-9/92	Significant records available for all parameters except turbidity (field)	3/75-4/75	Minimal data available
Nutrients	4/75	Minimal data available		Minimal data available	8/86-9/92	Significant records available for all parameters except nitrogen (as NO_2 and NO_3) and phosphate	3/75-4/75	Minimal data available
Trace Elements	4/75	Minimal data available	4/75	Minimal data available	3/75-9/92	Significant records available for total barium, boron, copper, manganese, and zinc	3/75-4/75	Minimal data available
Major Ions	4/75	Minimal data available	4/75	Minimal data available	3/75-9/92	Significant records available for all parameters except dissolved calcium, fluoride, magnesium, and sodium	3/75-4/75	Minimal data available
Organics		None available		None available		None available		None available
Sediments		None available		None available		None available		None available
Biological	4/75	Minimal data available	4/75	Minimal data available	4/89-7/92	Minimal data available	3/75-4/75	Minimal data available
Radiological		None available		None available		None available		None available
Isotopical		None available		None available		None available		None available

* Less than 10 records available for each parameter within a parameter category.

1.7 CHEMICAL ANALYSIS

Five stations were used in the chemical analysis for this study area. Two stations were located upstream from the WWTP (09482500 and 805750000000000), and three stations were located downstream from the WWTP (805770000000005, 800000000017590, and 800000000016960).

Table C-3-14 contains a brief description of the chemical data available at these stations. A more thorough summary of the data available is located in **Appendix R**.

Table C-3-14
Brief Summary of the Data Available for the Tucson Study Area

Station	POR	Average Number of Measurements								
		Physical	Nutrients	Major Ions	Trace Elements	Organics	Biological	Sediments	Radiological	Isotopical
09482500 (upstream)	12/65 - 8/89	14	13	–	–	–	–	–	–	–
805750000000000 (upstream)	4/75	4	3	3	3	–	3	–	–	–
805770000000005 (downstream)	4/75	2	1	1	1	–	2	–	–	–
800000000017590 (downstream)	3/75 - 4/75	4	2	3	3	–	3	–	–	–
800000000016960 (downstream)	3/75 - 9/92	36	22	33	26	–	5	–	–	–

Table C-3-15 summarizes the data quality assessment for the Tucson study area. Overall, the data quality is rated as marginal.

Table C-3-15
Data Quality Assessment for Santa Cruz River Near Tucson, Arizona

Station ID	Major Ion Charge Balance	Specific Conductance vs TDS	Measured TDS vs Calculated TDS	Anions or Cations to Specific Conductivity
09482500 (upstream)	–	–	–	–
805750000000000 (upstream)	–	OVERALL: Good (n=3) Good:3 Marginal:0 Poor:0	–	OVERALL: Marginal (n=3) Good:1 Marginal:0 Poor:2
805770000000005 (downstream)	–	OVERALL: Good (n=1) Good:1 Marginal:0 Poor:0	–	OVERALL: Poor (n=1) Good:0 Marginal:0 Poor:1
800000000017590 (downstream)	–	OVERALL: Marginal (n=3) Good:1 Marginal:2 Poor:0	–	OVERALL: Marginal (n=3) Good:1 Marginal:0 Poor:2
800000000016960 (downstream)	OVERALL: Marginal (n=41) Good:23 Marginal:11 Poor:7	OVERALL: Good (n=45) Good:32 Marginal:9 Poor:4	OVERALL: Marginal (n=41) Good:16 Marginal:14 Poor:11	OVERALL: Marginal (n=45) Good:26 Marginal:8 Poor:11

For station 09482500, the data quality could not be determined due to insufficient data. For station 805750000000000, two of the four assessment methods (specific conductance versus total

dissolved solids (TDS) and anions/cations to specific conductivity) could be completed and indicated that the data quality was good and marginal, respectively. These conclusions were based on three data sets.

For station 805770000000005, two of the four assessment methods (specific conductance versus TDS and anions/cations to specific conductivity) could be completed and indicated that the quality of the data collected at this station was good and poor, respectively. These conclusions were based on only one data set.

For station 800000000017590, again two of the four assessment methods (specific conductance versus TDS and anions/cations to specific conductivity) could be completed and indicated that the quality of the data collected at this station was marginal based on three data sets.

For station 800000000016960, all four assessment methods could be completed. Three of the four methods (major ion charge balance, measured TDS versus calculated TDS, and anions/cations to specific conductivity) indicated that the quality of the data was marginal based on 41, 41, and 45 data sets, respectively. The remaining assessment method (specific conductance versus TDS) indicated that the quality of the data collected at this station was good based on 45 data sets.

Figure C-3-17 is the Piper diagram for this study area. The data used to construct the Piper diagram consisted of 34 samples from one downstream location in which complete sets of anion and cation data were available. An additional four samples from two downstream locations and three samples from one upstream location in which only complete sets of anion data was reported were also included on the diagram.

The anion data shows a slight bicarbonate (HCO_3+CO_3) enrichment relative to sulfate (SO_4) and chloride (Cl). The cation data indicate that the waters are predominantly sodium plus potassium (Na+K) type waters.

1.8 AQUATIC HABITAT AND SPECIES OVERVIEW

This section provides an overview of the historic aquatic species and habitat data available for the Santa Cruz River near Tucson. A summary of the aquatic biology site reconnaissance is also provided.

1.8.1 Historical Data Summary

The following is a summary of known historical aquatic biological records for the Santa Cruz River in the Tucson area:

- Harding Lawson Associates (HLA 1986) prepared a report to support the development of site-specific water quality criteria for the Santa Cruz River below Roger Road WWTP. In addition to collecting fish, algae, and invertebrate data, the report documented historical biological records from the Santa Cruz River in the Tucson area.

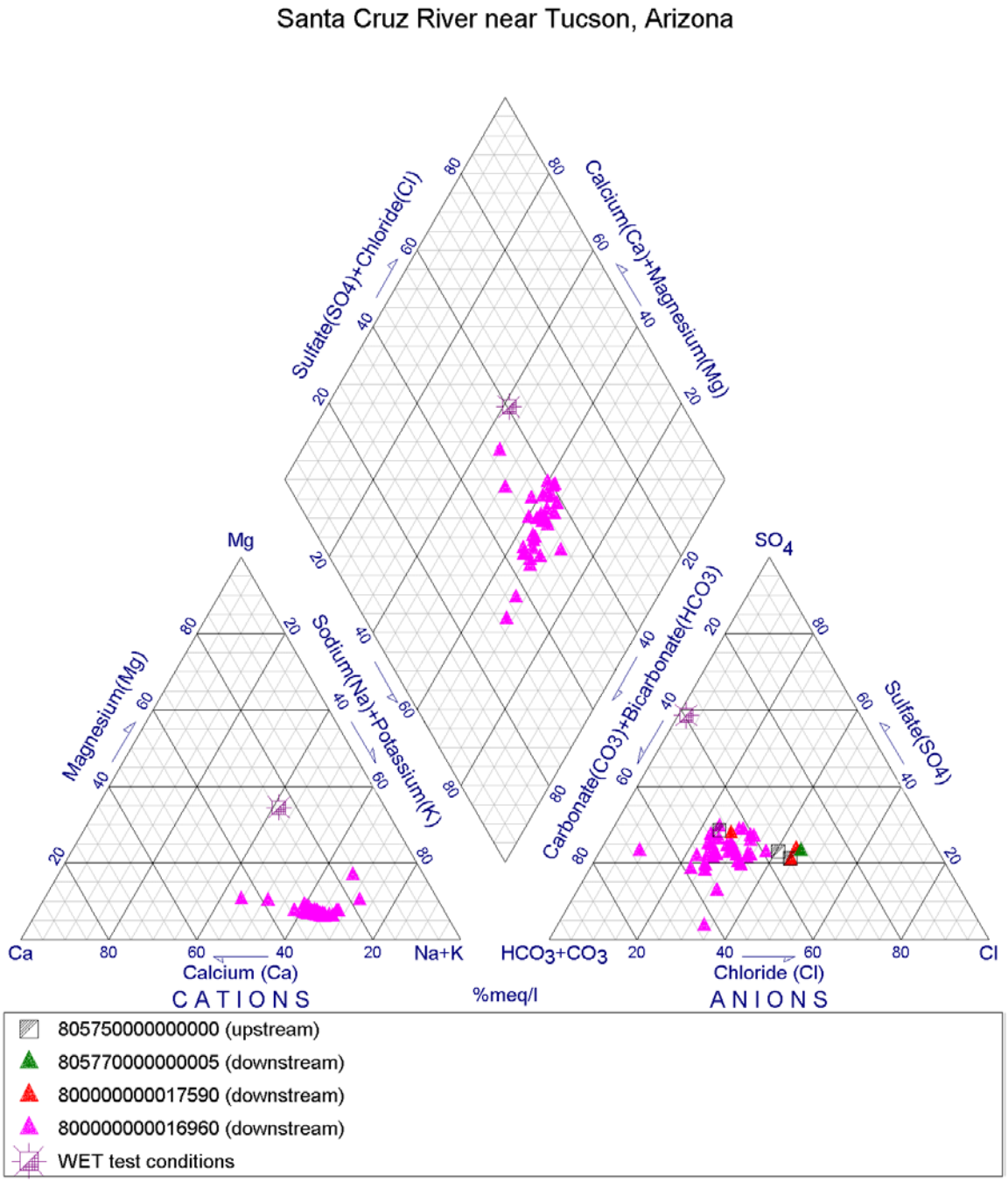


Figure C-3-17
Piper Diagram for the Tucson Study Area

HLA (1986) summarizes the flow history for the Santa Cruz River in the Tucson area. Historically, the reach of the Santa Cruz River, from just upstream of Tucson to the Rillito area (12 to 18 miles downstream of Tucson), was dry several months of the year, but water was always intermittently present. Two tributaries, Rillito Creek and Canada del Oro, were perennial at that time and were important water sources to the Santa Cruz River in this reach. From the Rillito area downstream to its confluence with the Gila River, the Santa Cruz River was ephemeral, and only once every 10 to 20 years did sufficient storm flows occur to allow the Santa Cruz River to flow to the Gila River.

HLA (1986) summarizes fish survey records from that intermittent portion of the Santa Cruz River between San Xavier Del Bac Mission (approximately 15 miles south of Tucson) to just north of Tucson from the mid-1800s to the early 1900s. Documented native fish species included longfin dace (*Agosia chrysogaster*), sonora sucker (*Pantosteus clarki*), desert sucker (*Catastomus insignis*), roundtail chub (*Gila robusta robusta*), and gila topminnow (*Poeciliopsis occidentalis*). One additional native species believed to have also occurred in the Santa Cruz River, but which was not formally documented, is the desert pupfish (*Cyprinodon macularius*). This assumption is based on documentation that this fish was collected from two Santa Cruz River tributaries: Rillito Creek and Sonoita Creek. One introduced species was documented in the early 1900s, the common carp (*Cyprinus carpio*). Although fish were originally present in this portion of the Santa Cruz, the river in the Tucson area had completely dried up by 1950 (HLA 1986).

The Roger Road WWTP began discharging effluent to the Santa Cruz River in 1977 returning a permanent source of water to the river for the first time in more than at least two decades. The Ina Road effluent discharge was added later, increasing the volume of water in the Santa Cruz River. At the time that the discharge from Roger Road began, the Santa Cruz River in the Tucson area was ephemeral. Thus, the discharge created an effluent-dependent water.

HLA (1986) represented the first study of aquatic organisms in the river since effluent discharge began. Invertebrates, including zooplankton, fish, and algae were sampled from the Roger Road WWTP to Sasco Road (Redrock Road), 32.5 miles downstream. The findings from this study are discussed in more detail below.

- ADEQ (1990) conducted two informal macroinvertebrate surveys to support the state's development of toxic pollutant water quality criteria for effluent-dominated streams. The purpose of the sampling was to document the types of invertebrates that should be protected by water quality criteria being developed specifically for effluent-dominated waters. An October 3, 1990 memo documented the presence of "a small number of *Daphnia* [zooplankton]" in the Santa Cruz River at Cortaro Road. A subsequent October 23, 1990 memo documented four taxa at Cortaro Road: *Belostoma* (giant water bug); *Tropisternus lateralis* (hydrophild beetle); *Ischnura* (damselfly); and *Chironomus* (chironomid or non-biting midge).

- HLA (1997a) prepared a report to update the findings of HLA (1986). Invertebrate, algae, and fish samples were collected to characterize the resident aquatic community present 10 years after the original study. These results are discussed in more detail below.

- USGS (1998) reported some of the results of the Central Arizona Basins NAWQA Study. The 1998 report compared chlorophyll *a* levels and aquatic invertebrate community characteristics of effluent-dependent and non-effluent-dependent streams. Macroinvertebrate results are discussed in more detail below. ADEQ. 1990. Inter-Office Memorandum dated October 3, 1990.

- Harding Lawson Associates. 1997. Field Sampling and Analysis Report, Site Survey of the Santa Cruz River, Pima County, Arizona. Report prepared for the Pima County Wastewater Management Department.

- USGS. 1998. Water Quality of Selected Effluent-Dependent Stream Reaches in Southern Arizona as Indicated by Concentrations of Periphytic Chlorophyll *a* and Aquatic-Invertebrate Communities.

- AGFD conducted a fish survey in 1987 from the Roger Road WWTP to Redrock Road Crossing, approximately 10 miles downstream. Three fish species were collected at the Redrock Road Crossing site. No subsequent fish surveys have been conducted by AGFD on this reach of the Santa Cruz River.

- A USGS NAWQA study is being conducted in central and southern Arizona (Central Arizona Basins Study). A report published in 1998 compared chlorophyll a levels and aquatic invertebrate community characteristics of effluent-dependent and non-effluent-dependent streams.

1.8.2 Site Reconnaissance

Appendix N reports the habitat scoring results using the RBP Habitat Assessment method and the Project Habitat Assessment method, respectively. The results of the macroinvertebrate sampling as well as descriptive information gathered from each sample site is also contained in **Appendix N**.

1.8.2.1 Evaluation of Aquatic Habitat Quality

Site 1 – Roger Road WWTP Outfall (Upstream). Except during stormwater runoff events, the Santa Cruz River is normally dry upstream of the Roger Road WWTP outfall. As indicated in the study area overview, this reach of the Santa Cruz River has not had perennial flow since approximately 1941. The lack of water naturally results in a low habitat quality score because the within-channel habitat factors are not applicable under dry conditions. Even when flow occurs after a

Tucson Site 1 - Upstream.

runoff event, instream habitat quality will remain poor because of the temporary nature of the water and the harsh physical conditions that occur. This portion of the Santa Cruz River has been channelized for flood control purposes.

Site 2 - Roger Road WWTP Outfall (Downstream). Although flow from the Roger Road WWTP provides permanent instream habitat for aquatic organisms, the overall habitat score remains fairly low. Instream habitat diversity is limited because substrate particle sizes are generally small (sand and gravel), and algae, woody debris, and submergent and emergent macrophytes are absent. The streambed at Site 2 is channelized to help move flood flows from storm events, and the flow regime consists only of runs.

Site 3 - Downstream of Ina Road Bridge. The Santa Cruz River is somewhat channelized at Ina Road. A drop structure has been constructed immediately below the bridge to dissipate energy from flood flows. Submergent and emergent vegetation were present at Site 3, and filamentous algae was abundant. Substrate size is relatively fine, but instream vegetation provides habitat for aquatic organisms. Photographs taken above and below the Ina Road Bridge illustrate the effect manmade instream structures can have on aquatic habitat. The drop structure enhances water retention upstream of the bridge, and increased water availability supports denser riparian vegetation.

Tucson Site 3 - Downstream.

Tucson Site 3 - Cross-section.

Site 4 - Downstream of Cortaro Road Bridge. Habitat quality scores involving channel morphology and riparian vegetation are higher at Site 4. However the instream substrate particle size decreased and sand and silt are dominant. Algae, as well as emergent and submergent macrophytes, are abundant. The flow regime is classified as a run averaging between 1.0 and 1.6 feet deep; pools and riffles are absent. Invertebrates in this flow regime and fine sediments are primarily limited to vegetative substrates.

Tucson Site 4 – Upstream.

Tucson Site 4 – Downstream.

Tucson Site 5 – Downstream.

Site 5 - Downstream of Marana Road Bridge. Although instream habitat quality scores are similar between Sites 4 and 5, riparian habitat quality is lower at Site 5. Bank erosion is evident on the left bank upstream of the bridge where manmade structures have been installed to slow the rate of erosion. Instream substrates are dominated by sand; and the flow regime is dominated by runs. Pools are absent and riffles are uncommon. The uniformity of the flow and sandy substrates is illustrated in the photograph of Site 5 taken from the Marana Road Bridge. Instream vegetation also declined considerably between Sites 4 and 5.

Tucson Site 5 – Upstream.

1.8.2.2 Comparison of Results of Habitat Scoring Methods

With the exception of Site 4, the results of the Rapid Bioassessment Protocol (RBP) and Project Habitat Assessments were similar (**Appendix N**). Poor habitat quality (an obvious expectation given the lack of water) was indicated at Site 1. Habitat scores improved in the flowing reach, but scores varied little among Sites 2, 3, and 5. Habitat scores at Site 4 differed somewhat between scoring methods. According to the RBP scoring method, habitat improved markedly between Sites 3 and 4 but declined again at Site 5. The Project Habitat Assessment Method indicated no change in habitat quality among Sites 3, 4, and 5.

1.8.2.3 Evaluation of Macroinvertebrate Community

Macroinvertebrate samples were taken at each site as a screening-level assessment (**Appendix N**). The identification of aquatic organisms was limited to field recognition, and no organisms were taken to a laboratory for complete identification. Consequently, many of the organisms observed could only be identified to the class or order level and comparisons with the results of historical data collection efforts are limited.

Site 1 – Roger Road WWTP Outfall (Upstream). This sample site was dry; no aquatic macroinvertebrates were present.

Site 2 – Roger Road WWTP Outfall (Downstream). Immediately downstream of the WWTP, the macroinvertebrate community was limited to two taxa: chironomid midges and oligochaete worms. The midges were predominately "bloodworms" (typically genus *Chironomus*), which indicate a low oxygen environment.

Site 3 – Downstream of Ina Road Bridge. Four taxa were identified from Site 3. The macroinvertebrate community continued to be dominated by chironomid midges and oligochaete worms, but the relative importance of oligochaete worms increased between Sites 2 and 3. "Bloodworm"-type midges continued to be the predominant type of chironomid midge. Certapogonidae (biting midge) and Anisoptera (dragonflies) were also present at Site 3.

Site 4 – Downstream of Cortaro Road Bridge. Three taxa were present at Site 4. Chironomid midges and oligochaete worms dominated the community in relatively equal proportions. A few cladoceran zooplankton were also collected from this site.

Site 5 - Downstream of Marana Road Bridge. Site 5, with seven taxa, had the greatest taxonomic richness of all sample sites. In addition to the increased number of taxa, the types of organisms were different from the other sites. Baetid mayflies and cladoceran zooplankton dominated the macroinvertebrate community. Chironomid midges were the third most abundant group, but this group was not dominated by the "bloodworm" type that was prevalent at Sites 2 and 3. Other taxa represented at this site included Hemiptera (true bugs), Coleoptera (beetles), Oligochaetes (worms), and Megaloptera (Dobsonflies).

1.8.2.4 Summary of Changes Downstream of Outfall

The improvements in habitat quality downstream of Sites 1 and 2 were predominately tied to improvements in channel morphology and riparian vegetation. Instream habitat quality changed little and actually slightly declined with increased distance downstream of the outfall as a result of the increasingly sandy substrate.

Tucson Site 5 - Looking downstream (north) on the Santa Cruz River from the Cortaro Road Bridge. The dominant herbaceous vegetation here is cattail and the larger trees are Goodding's willows. Other herbaceous plants present include pigweed, yellow water plant, water speedwell, water cress, poison hemlock, and Johnson grass.

Instream vegetation changed from an almost complete absence of instream vegetation at Site 2 to the presence of abundant vegetation (filamentous algae and macrophytes) at Sites 3 and 4. The abundance of vegetation declined at Site 5, and the majority of aquatic organisms at Site 5 were collected from edge habitats where vegetation was relatively abundant compared to mid-channel. Given the very sandy nature of the substrates at Site 5 (see photo: Tucson Site 5 – Downstream), it would be expected that vegetative substrates would have an increased importance as habitat for aquatic organisms.

The macroinvertebrate community remained highly limited until Site 5 when there was a distinct shift in the community from chironomid midges (dominated by "bloodworms") and oligochaete worms to baetid mayflies and Cladocera. The change in dominance to baetid mayflies at Site 5 is significant given their relatively low tolerance to wastewater effluent.

1.9 AQUATIC BIOLOGY ANALYSIS

1.9.1 Analysis of Available Data

1.9.1.1 Macroinvertebrates

1.9.1.1.1 Comparability of Methods

Table C-3-16 summarizes the sample methods used for each study discussed in the following sections. Every documented study has used a different method for collecting benthic invertebrates, including the HLA (1986) and (1997) surveys. Key differences included: (1) Samplers varied between a Surber sampler and kick nets of varying sizes; (2) varying mesh sizes in the sampler from 250 microns to 1,000 microns; and (3) the number and/or area of habitat sampled at each site.

Table C-3-16
Comparison of Invertebrate Collection and Identification Methods

Invertebrate Study	Sample Period	Sample Method	Sample Processing	Reported Taxonomic Identification
Harding Lawson Associates (1986)	Sampled on May 20 and May 24, 1985	Benthic Invertebrates: Samples collected from runs and riffles (mostly runs) with a 1-m kick net held in place in the current. A 1-m^2 area was agitated upstream of the net to a depth of 10-20 cm. In addition, grab samples were collected and screened through a 250-micron mesh sieve. Zooplankton: Clarke-Bumpus plankton tow net. Two samples/site. 400 L collected from deepest part of channel.	Invertebrates: Kick net and grab samples - sugar water method used to separate animals from debris. Zooplankton: No processing necessary.	Appears to be the lowest level practical for all groups.
Harding Lawson Associates (1997)	April 2 and 3, 1997	Benthic Invertebrates: Two Surber samples (1 ft^2) collected from runs and riffles (mostly runs) at each site. Sampler fitted with a 1,000-micron mesh net. Zooplankton: Two samples per site with a 15-in LaMotte plankton tow net. Samples collected for 1-2 minute period at each site.	No information available	Lowest taxonomic level practical, mostly family level.

Table C-3-16
Comparison of Invertebrate Collection and Identification Methods

Invertebrate Study	Sample Period	Sample Method	Sample Processing	Reported Taxonomic Identification
USGS (1998)	January 1996	NAWQA method: Five semiquantitative riffle samples using modified Surber sampler with 425-micron mesh net. Samples composited (1.25 m^2). Qualitative sample from all habitat types using 210-micron mesh D-frame kick net.	No information available	Insects - family level; non-insects - lowest level practical - usually order and class
Site Reconnaissance	June 2000	D-frame kick net with 500-micron mesh; Three 1-minute kick nets from variety of habitat types.	Field counted; subsampled as necessary (see text for details)	Field identification to lest practical level - typically, family for insects; order or class for non-insects

Sample processing methods as well as the level of taxonomic identification varied among studies. The HLA studies attempted to identify all invertebrates to the lowest practical taxonomic level, but the USGS (1998) and site reconnaissance efforts limited taxonomic identification to the family/order level. All surveys, except the site reconnaissance effort, relied on a laboratory for taxonomic identifications.

1.9.1.1.2 Comparability of Data Sets

The following is a description of the sites sampled by HLA (1986, 1997) and the site reconnaissance effort:

- HLA (1986) – Data were collected at the following six sites on May 20 and May 24, 1985:
  - Canada del Oro confluence – Site A1 on **Figure C-3-1**, approximately 3 miles downstream of the Roger Road WWTP.
  - Avra Valley Bridge Crossing – Site A3 on **Figure C-3-1**, approximately 11 miles downstream of the Roger Road WWTP.
  - Sandario Road – Site A4 on **Figure C-3-1**, approximatelty 16 miles downstream of the Roger Road WWTP.
  - Trico-Marana Bridge Crossing – Site A5 on **Figure C-3-1**, approximately 21 miles downstream of the Roger Road WWTP. Same location as Reconnaissance Site 5.
  - Hardin Road – Site A6 on **Figure C-3-1**, approximately 25 miles downstream of the Roger Road WWTP.
  - Sasco Road (Redrock Road) Crossing – Site A7 on **Figure C-3-1**, approximately 32.5 miles downstream of the Roger Road WWTP.

- HLA (1997a) – Data were collected at the following seven sites on April 2 and 3, 1997:
  - Canada del Oro confluence – Site A1 on **Figure C-3-1**, approximately 3 miles downstream of Roger Road WWTP.
  - Cortaro Road Crossing – Site A2 on **Figure C-3-1**.
  - Avra Valley Bridge Crossing - Site A3 on **Figure C-3-1**, approximately 11 miles downstream of the Roger Road WWTP.
  - Sandario Road – Site A4 on **Figure C-3-1**, approximately 16 miles downstream of the Roger Road WWTP.
  - Trico-Marana Bridge Crossing – Site A5 on **Figure C-3-1**, approximately 21 miles downstream of the Roger Road WWTP. Same location as Reconnaissance Site 5.
  - Hardin Road – Site A6 on **Figure C-3-1**, approximately 25 miles downstream of the Roger Road WWTP.
  - Sasco Road (Redrock Road) Crossing – Site A7 on **Figure C-3-1**, approximately 32.5 miles downstream of the Roger Road WWTP. No aquatic biology samples were actually collected because the site was dry in 1997.
- Site Reconnaissance – Data were collected from the following five sites in May 2000 (all shown on **Figure C-3-1**):
  - Site 1 – Upstream of the Roger Road WWTP discharge.
  - Site 2 – Downstream of the Roger Road WWTP discharge.
  - Site 3 – Downstream of the Cortaro Road Bridge. Same location as Cortaro Road Crossing site in HLA (1997a).
  - Site 4 – Downstream of the Ina Road Bridge Crossing.
  - Site 5 – Downstream of the Trico-Marana Bridge Crossing. Same location as Trico-Marana Bridge Crossing sampled by HLA (1986, 1997a).

Each historical study, including the reconnaissance study, represents a very brief snapshot in time since sampling was conducted only once for each study. While the various data sets may not be directly comparable because of method differences, the data are useful for evaluating spatial patterns in community structure downstream of the Roger Road and Ina Road effluent discharges to the Santa Cruz River.

1.9.2 Data Analysis Results

1.9.2.1 Macroinvertebrates

Four aquatic biological measures were used to compare data results: total number of taxa, Hilsenhoff Biotic Index (HBI), percent Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa, and relative abundance of the following major taxonomic groups: Oligochaetes (segmented worms); Diptera (flies); other (primarily Crustacea, Gastropoda [snails], Odonata [dragonflies and damselflies], Hemiptera [true bugs] and Coleoptera (beetles)].

1.9.2.1.1 Effect of Varying Levels of Taxonomic Identification

Differences in levels of taxonomic identification effort exist between the HLA studies, especially HLA (1986) and other studies. To evaluate the significance of this issue, analysis of the HLA data was conducted at the lowest practical taxonomic level, and then these results were compared with the same data using a more coarse level of taxonomic identification (i.e., the family/order level of identification).

Figure C-3-18 shows the difference between the number of taxa at the lowest practical taxonomic level and the number of taxa at the family/order level. Although the number of taxa at a given site is generally higher with greater taxonomic resolution, the spatial pattern of taxa richness is the same. Specifically, taxa richness is highest at the Hardin Road site and lowest at the Sasco Road Site (**Figure C-3-18**). The results shown on **Figure C-3-18** suggest that regardless of the level of taxonomic identification of aquatic invertebrates, the outcome of data interpretation will be the same since the spatial or longitudinal patterns are the same. Consequently, subsequent data analysis comparing site reconnaissance data to the HLA studies can be carried out at a common level of taxonomic identification (i.e., family/order level).

1.9.2.1.2 Longitudinal Patterns in Invertebrate Community Structure

Sample methods vary among studies. As a consequence, only overall patterns can be discussed, not specific results (e.g., 12 taxa versus 15 taxa at a given site). Also, all historical data sets as well as site reconnaissance data represent points in time rather than a time series. Thus, it can only be assumed that the longitudinal patterns observed on the day of sampling consistently occur during all months or seasons of the year.

Number of Families/Orders. The number of families/orders at any given site on any given date has been typically less than eight (**Figure C-3-19**). The only exception was the results from the Hardin Road site in 1985, where 11 families/orders were collected. The HLA studies conducted in 1985 and 1997 yielded similar results—the lowest numbers of families/orders were found near the WWTP effluent discharges; the highest number were found at the Avra Valley Bridge and downstream. Exceptions included (1) the results from Sandario Road in 1985 when only two taxa were collected and (2) the results from Sasco Road in 1985 when reported poor habitat and low water conditions limited the aquatic community (Note: site was dry in 1997).

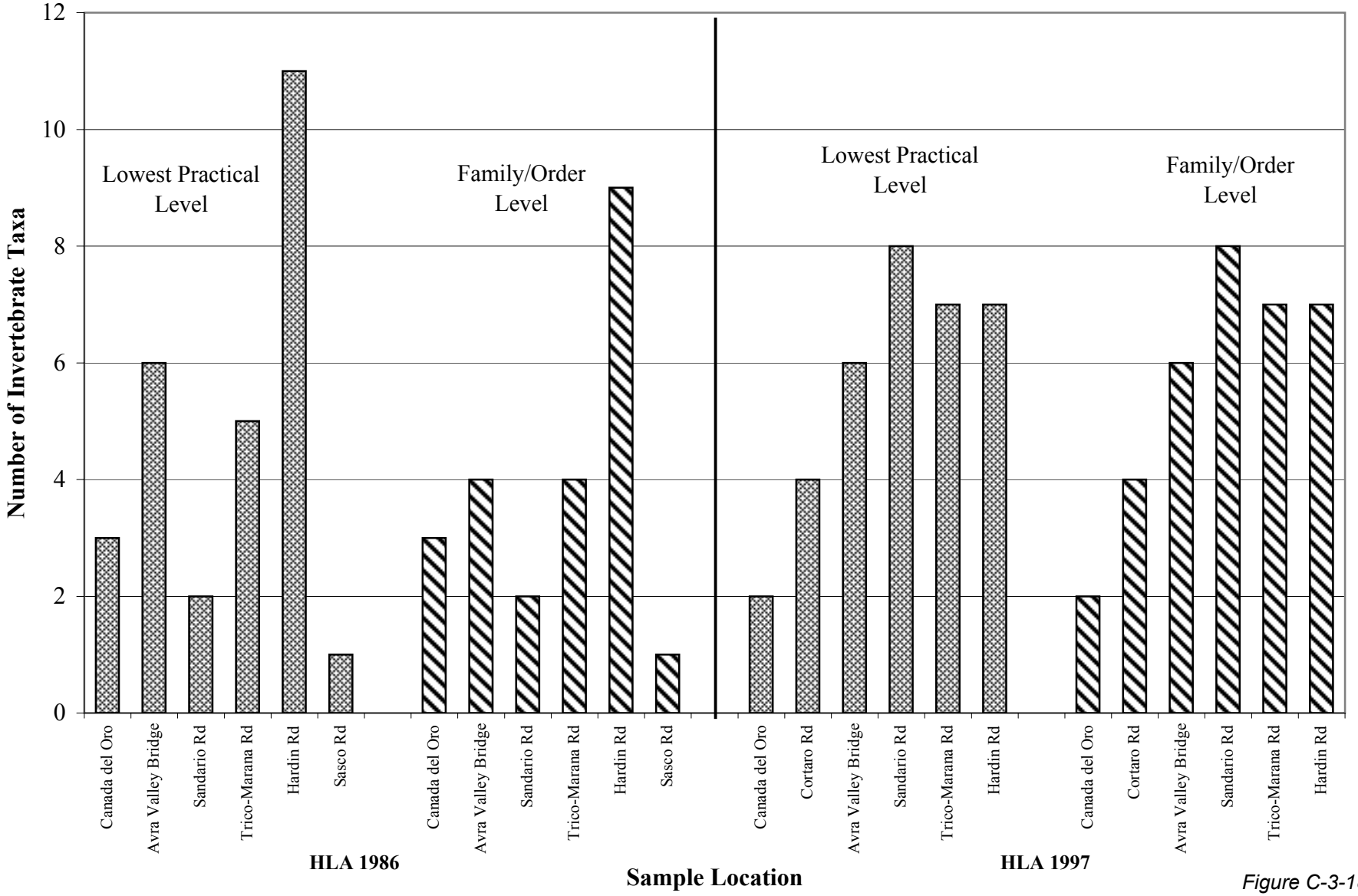


Figure C-3-18
Number of Invertebrate Taxa:
Taxonomic Identification to Lowest Level Practical vs.
Family/Order Level (HLA 1986, 1997)
Santa Cruz River Near Tucson, Arizona

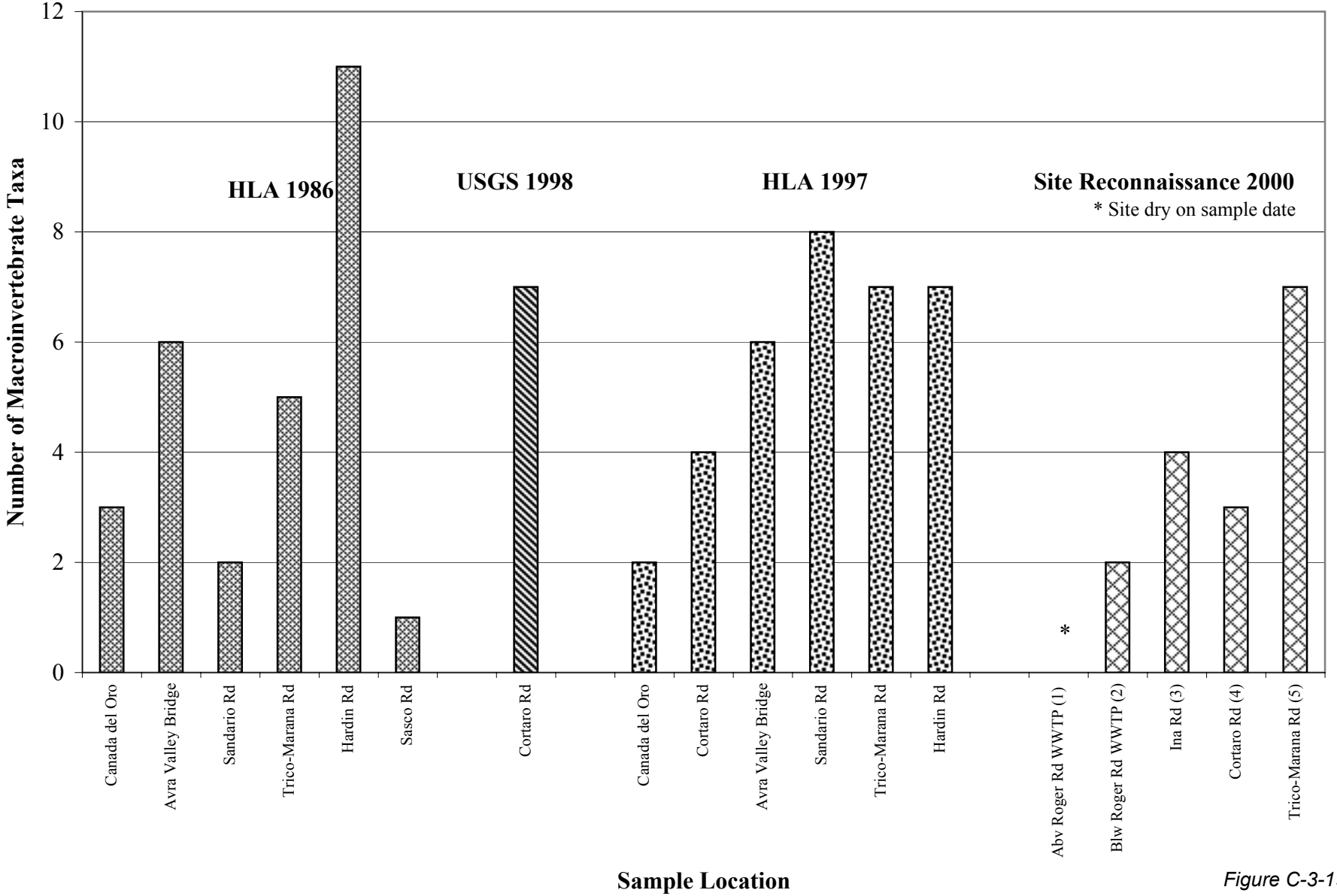


Figure C-3-19
Number of Macroinvertebrat Taxa:
1985 (HLA 1986), 1996 (USGS 1998), 1997 (HLA 1997) and
Site Reconnaissance 2000 (Taxa Identified at Family/Order Level)
Santa Cruz River Near Tucson, Arizona

The results from the site reconnaissance suggest that fewer taxa were present in 2000 than were collected from the same or nearby sites by HLA in 1985 and 1997 (refer to **Figure C-3-19**). However, the HLA results include the results of both the benthic and zooplankton samples, while the site reconnaissance effort did not include specific zooplankton samples. Inclusion of zooplankton sample results slightly elevated the HLA results. [Note: the zooplankton samples were included in the analysis because the HLA 1997 results (HLA 1997a) included a number of non-planktonic taxa, suggesting that the tow net was dragging bottom substrates or submergent vegetation.]

Hilsenhoff Biotic Index (HBI) Values. Data limitations from most studies (i.e., lack of taxon-specific abundance data) limit reporting of HBI results to the current site reconnaissance effort. The results suggest that the HBI values generally increase downstream of the effluent discharge (**Figure C-3-20**). However, this interpretation is likely erroneous because of the level of taxonomic identification coupled with the limited number of taxa. At the "Below Roger Road WWTP" and "Ina Road" sites the aquatic community was dominated by *Oligochaetes* and chironomid midges. Midges are routinely given a tolerance value of 6 at the family level of identification. However, actual tolerance values for genera or species vary between 0 and 10. Field notes indicate a predominance of "bloodworm"-type midges at the "Below Roger Road WWTP" and "Ina Road" sites. These midges are typically the genus *Chironomus,* which has a tolerance value of 10 (note: this would be consistent with HLA [1986], which reported that the midge present at all sites was the genus *Chironomus*). If the value of 10 were substituted into the HBI value calculation, the result would be much higher HBI values at these two sites than what is reported at the family/order level of identification.

Percent EPT Taxa. Data limitations from most studies (i.e., lack of taxon-specific abundance data) generally limit reporting of percent EPT to the site reconnaissance effort. The site reconnaissance study found EPT taxa only at the most downstream site, Trico-Marana Road, where baetid mayflies comprised almost 25 percent of the organisms collected (**Figure C-3-21**). No other studies have reported mayflies from any site on the Santa Cruz River below Tucson. However, the presence of other EPT taxa was reported by HLA: (1) the stonefly Sweltsa (*Plecoptera*) was reported at Trico-Marana and Hardin Roads in 1985; and (2) an unidentified caddisfly (*Trichoptera*) was reported at Canada del Oro, Cortaro Road, and Sandario Road in 1997.

Relative Abundance. Data limitations from most studies (i.e., lack of taxon-specific abundance data) again limit the analysis of relative abundance to the site reconnaissance effort. The aquatic community was dominated by Oligochaetes and Diptera (primarily Chironomidae) at all sites except the most downstream site at Trico-Marana Road where baetid mayflies and Cladocera were abundant (**Figure C-3-22**). Total abundance also varied with high numbers of aquatic organisms present at Ina Road versus other sites. Because the collection method was qualitative, the site reconnaissance data cannot be directly translated into a density value. However, the area collected was approximately 10.75 square feet. The only other abundance data available were from HLA (1986), which found extremely low densities (i.e., the site with the highest density was Hardin Road where the study reported only 17 animals per 10.75 square feet).

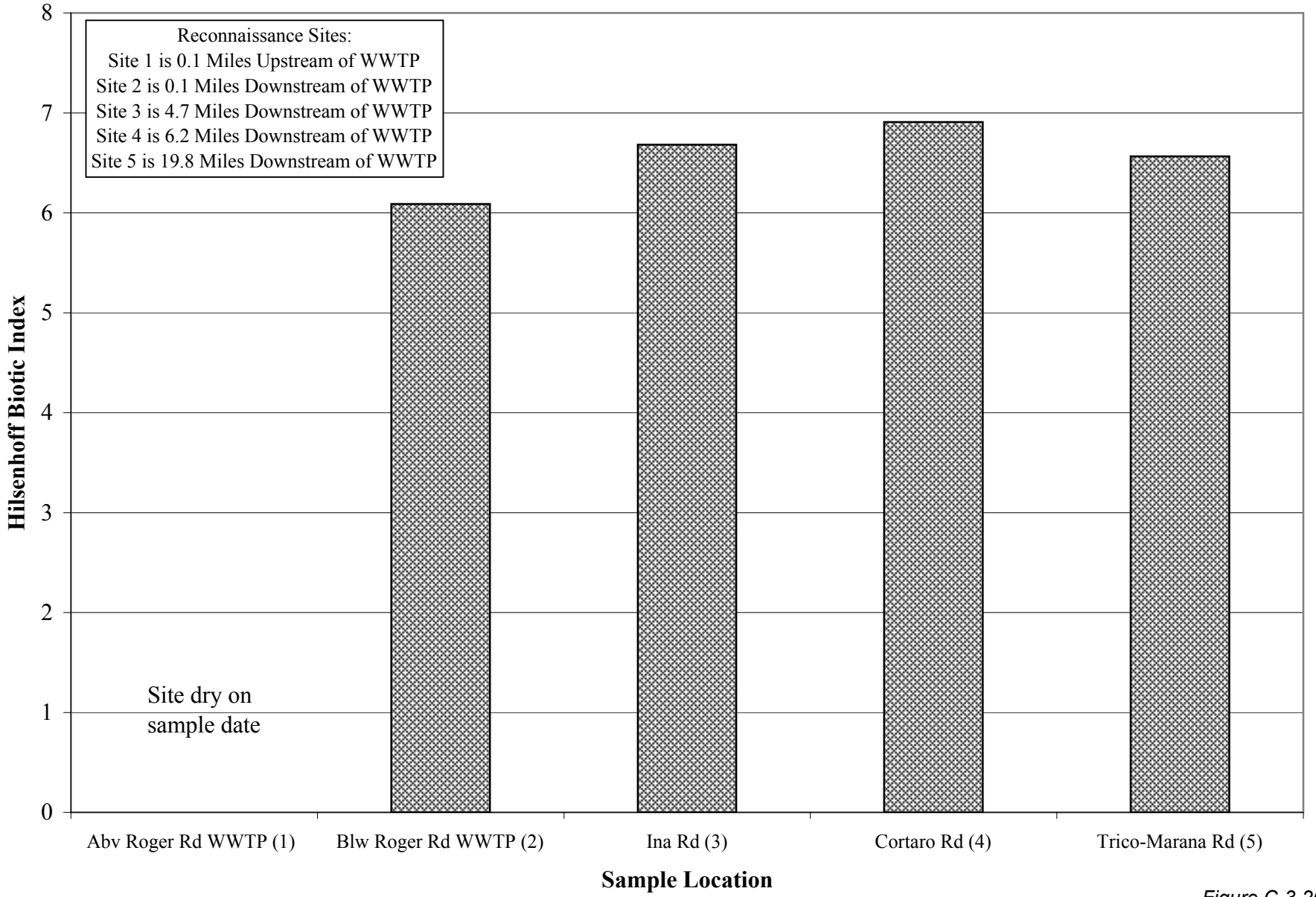


Figure C-3-20
Hilsenhoff Biotic Index:
Site Reconnaissance 2000
Santa Cruz River Near Tucson, Arizona

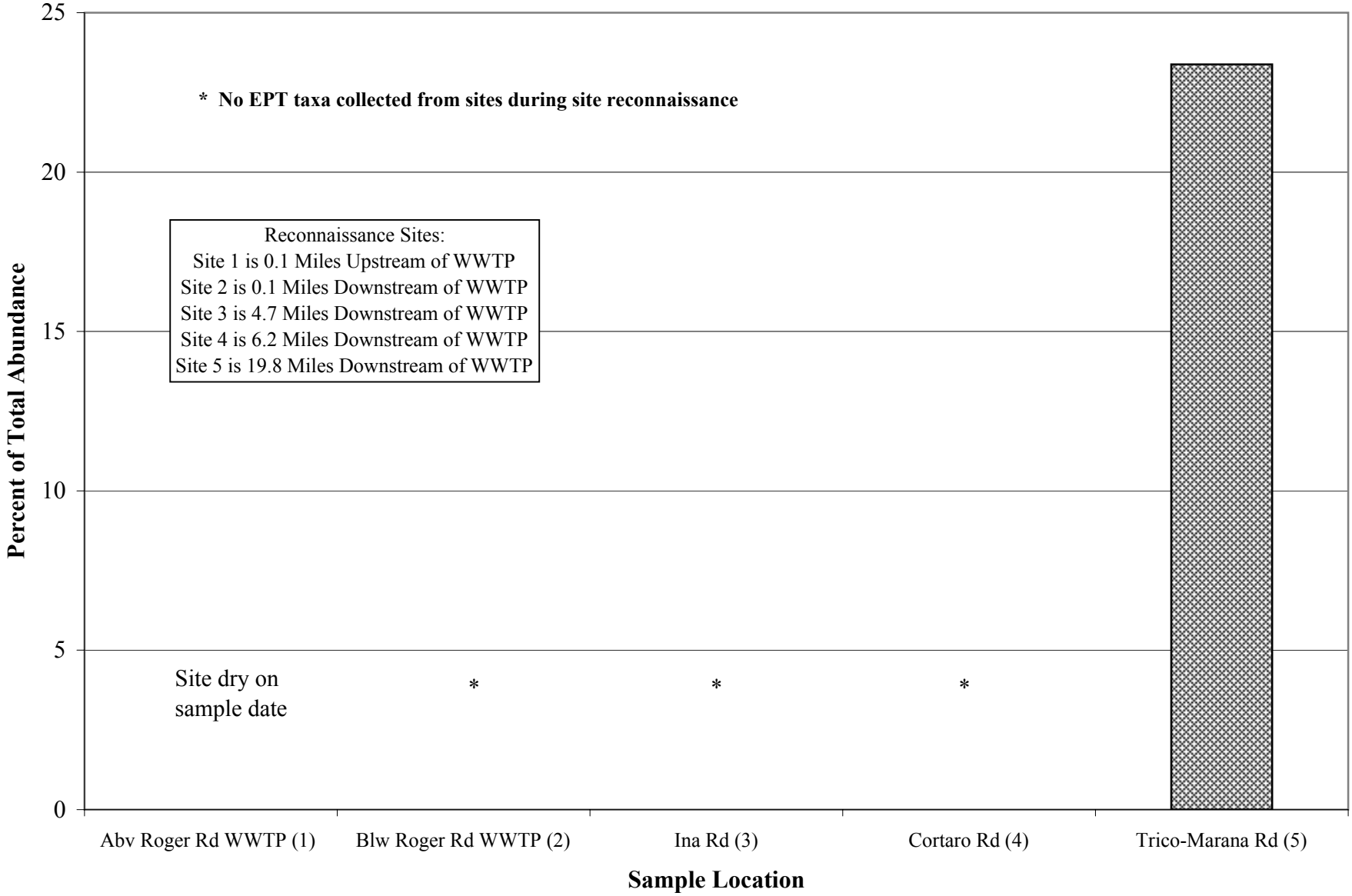


Figure C-3-21
Percent Mayflies, Stoneflies and Caddisflies
(EPT Taxa): Site Reconnaissance 2000
Santa Cruz River Near Tucson, Arizona

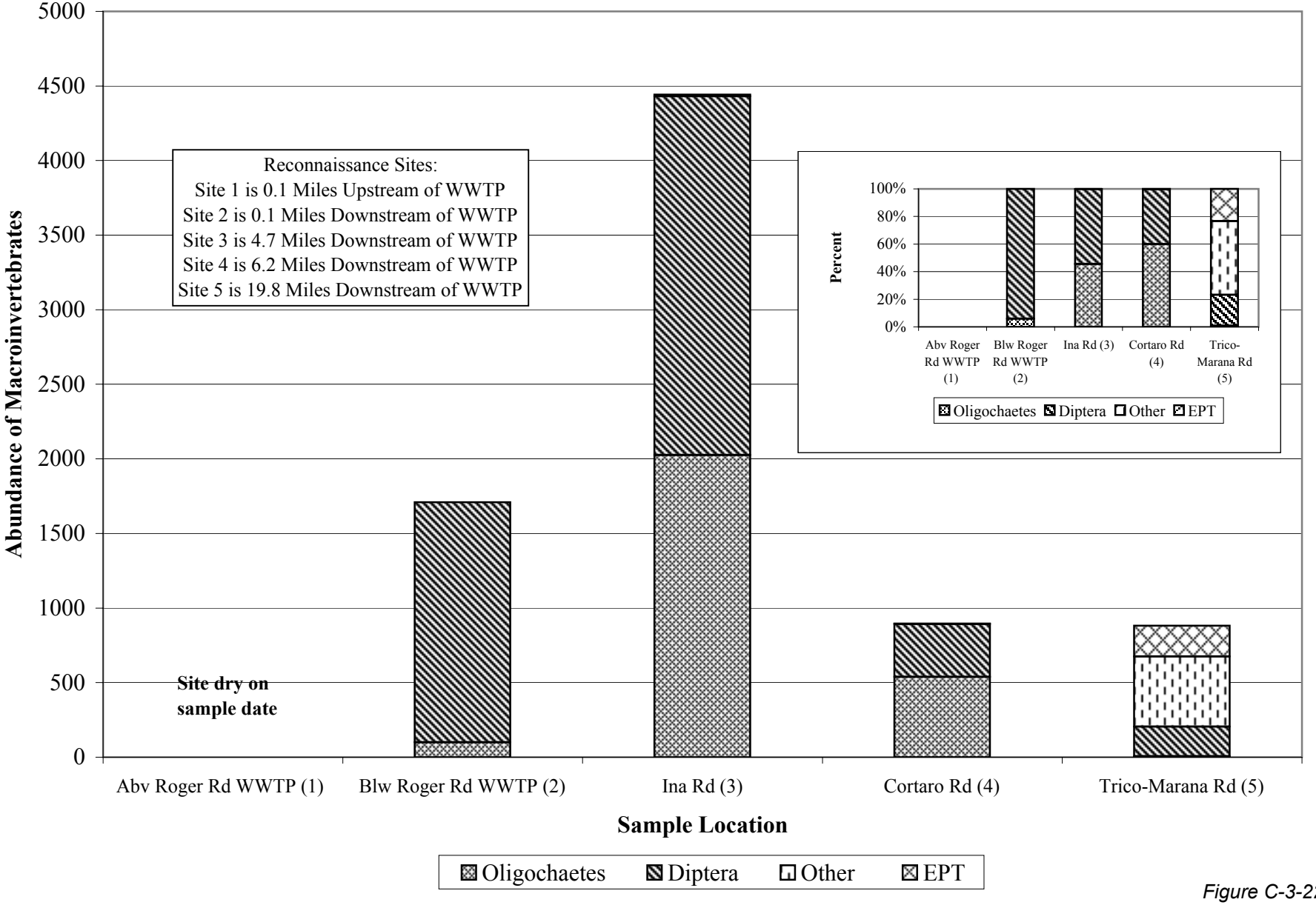


Figure C-3-22
Relative (Percent of Total Abundance) and
Total Abundance of Macroinvertebrates: Site Reconnaissance 2000
Santa Cruz River Near Tucson, Arizona

1.9.2.2 Fish Community

Fish data are limited from this effluent-dominated water. HLA (1986, 1997) conducted fish surveys as part of their studies. For both studies a 15-meter-long, 60-millimeter mesh seine was used. In 1985, three 75-meter seine hauls were made at each site (except Sasco Road, where only one haul was made). In 1997, seine hauls were made "where suitable habitat for fish was determined to be present (based on flow, depth, and temperature)," but no information was provided as to the number or length of seine hauls actually conducted at any sites. Both HLA (1986, 1997) reported finding no fish at any sites during their studies.

The only other fish data result from a brief survey conducted by AGFD in 1987. The fish survey was conducted from the Roger Road WWTP to Redrock Road Crossing (Sasco Road). No methods were provided. Fish were only found at the Redrock Road Crossing location: Four black bullhead (*Ictalurus melas*); 13 green sunfish (*Lepomis cyanellus*); and "large numbers" of mosquito fish (*Gambusia affinis*). No subsequent fish surveys have been carried out by AGFD (Marc Dahlberg, personal communication, 2000).

1.9.2.3 Habitat Quality

The Project and RBP habitat quality assessment methods generally scored the reconnaissance sites similarly (i.e., with increased distance downstream of the WWTPs, habitat quality improved) (**Figure C-3-23**). One minor exception was the result of the RBP score at Site 4 (Cortaro Road) where the RBP score was much higher than Sites 3 and 5; but the Project method score at Site 4 was similar to Sites 3 and 5. However, this difference was insignificant given that a linear regression between the results of the two habitat assessment methods found a significant positive relationship (r2 = 0.8302), meaning that the methods yielded similar results (**Figure C-3-24**).

A review of habitat factors affecting the overall Project habitat quality scores showed that riparian zone and channel morphology factors improved with increased distance downstream from the WWTPs (**Figure C-3-25**). Instream habitat also generally improved downstream, but there was less consistency in the pattern. The RBP factors showed similar patterns except that the quality of the instream habitat varied less among sites (**Figure C-3-26**). The factors contributing most to the much higher RBP habitat score at Site 4 were primarily associated with the riparian zone and channel morphology.

1.10 TERRESTRIAL HABITAT AND SPECIES OVERVIEW

This section provides a summary of historic terrestrial species and habitat data near Tucson, Arizona. A summary of the site reconnaissance is also provided. **Appendix O** contains a list of species that could occur near Tucson, a list of special status species for Pima County, and a list of species observed during site reconnaissance efforts.

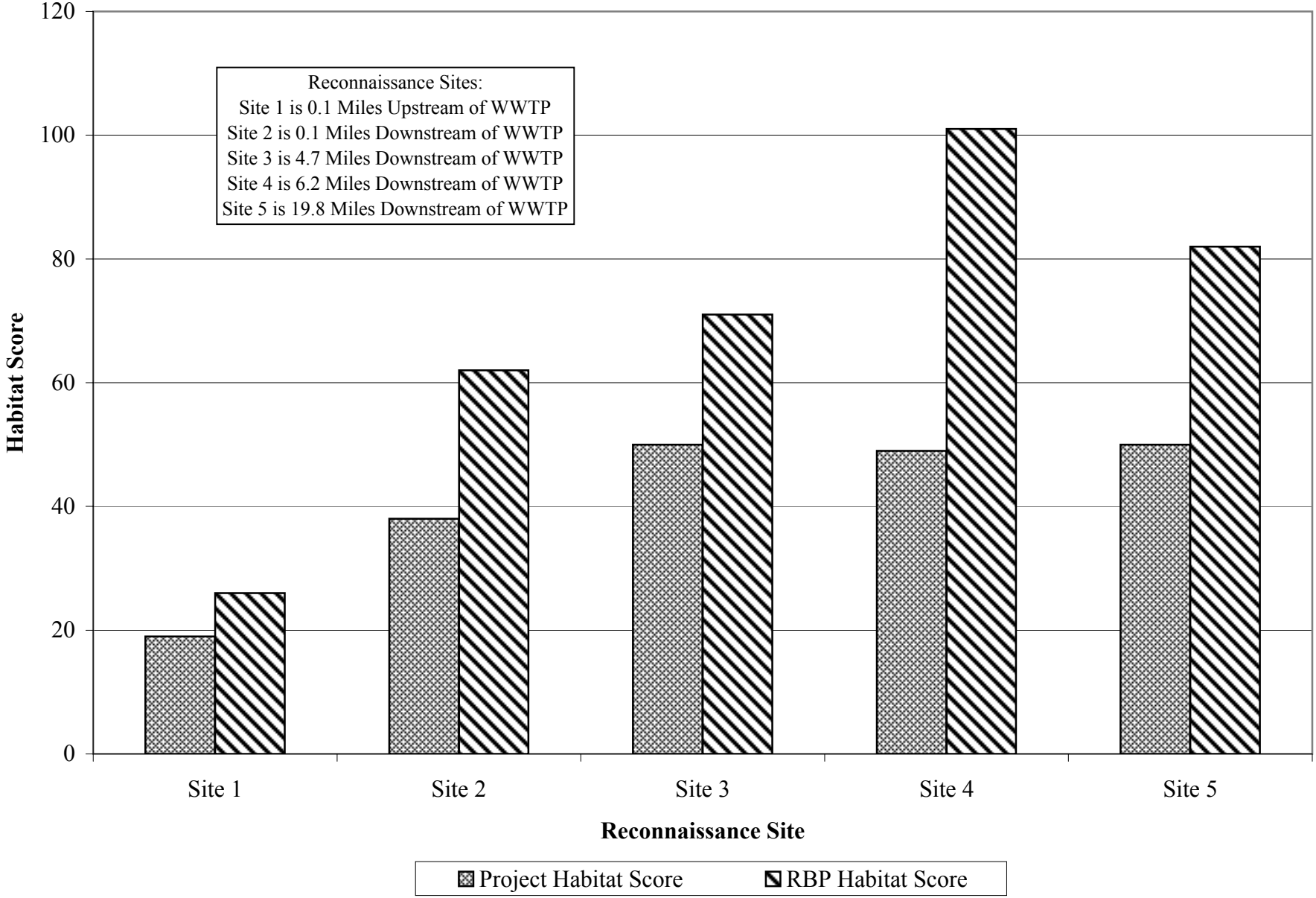


Figure C-3-23
Project Habitat vs. RBP Habitat Scores
Santa Cruz River Near Tucson, Arizona

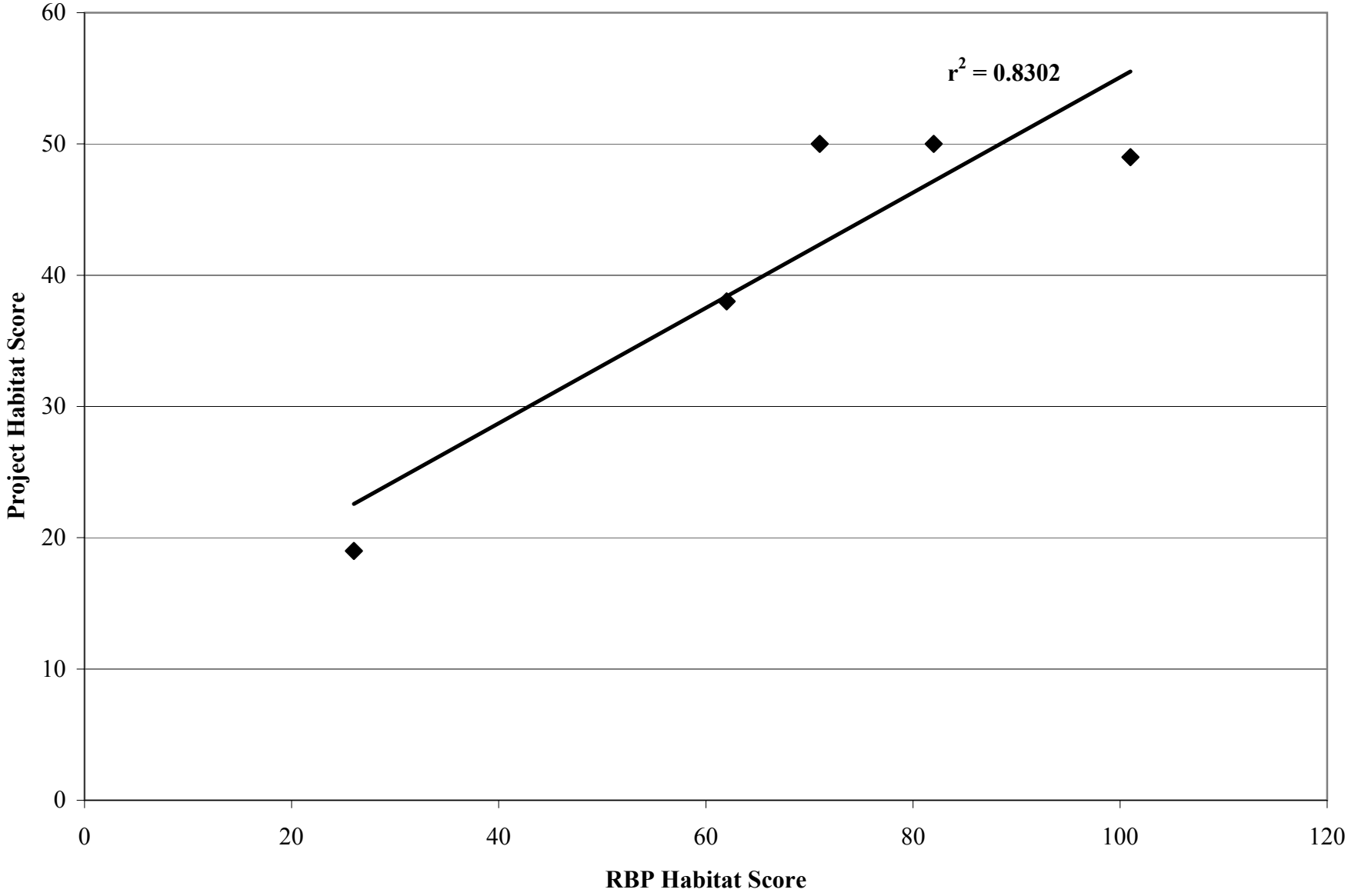


Figure C-3-24
Linear Regression:
RBP vs. Project Habitat Scores
Santa Cruz River Near Tucson, Arizona

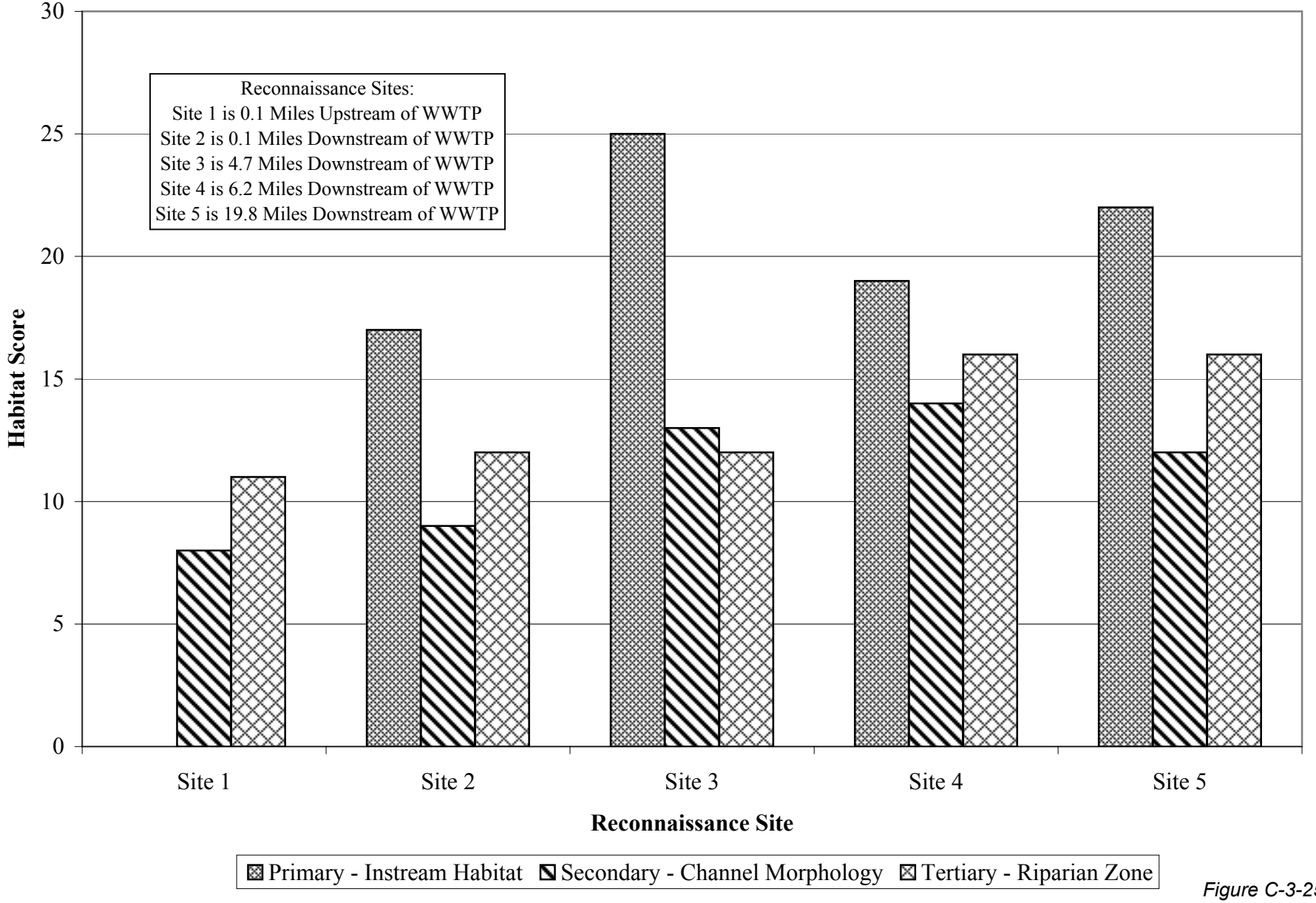


Figure C-3-25
Project Habitat Scores:
Comparison Among Primary, Secondary and Tertiary Factors
Santa Cruz River Near Tucson, Arizona

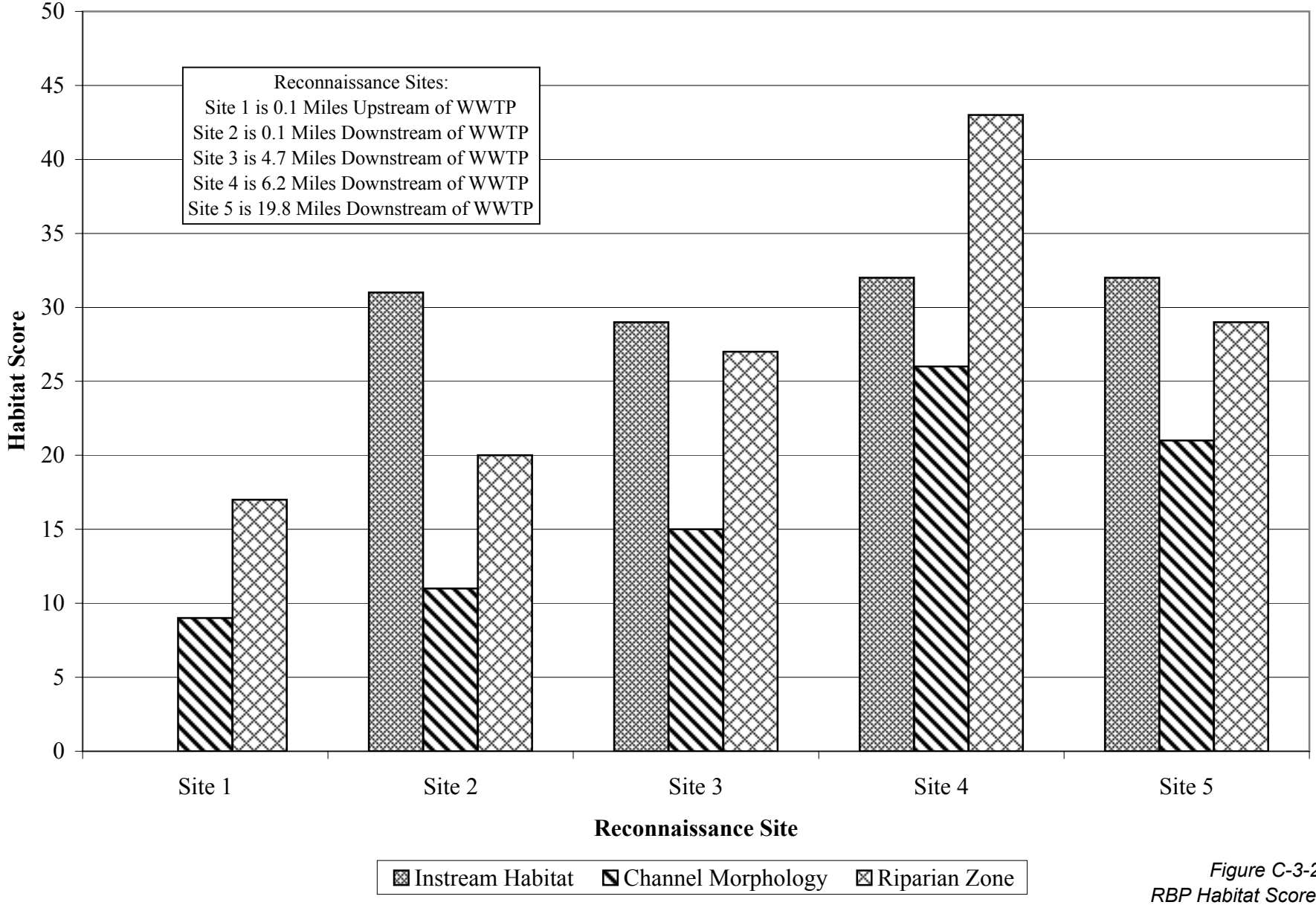


Figure C-3-26
RBP Habitat Scores:
Comparison Among Instream Habitat,
Channel Morphology and Riparian Zone Factors
Santa Cruz River Near Tucson, Arizona

1.10.1 Historical Data Summary

Until 1890, extensive mesquite bosques were prevalent along the Santa Cruz River between San Xavier Mission and Tucson (upstream from the Roger Road WWTP) (Dobyns 1985). Exploitation of this resource for fuel by military posts and by a growing population at Tucson occurred from 1775 to 1880. During the mid 1800s, the remaining mesquite bosques were cleared for agricultural land.

As discussed in the introduction, small areas of perennial flow existed along the Santa Cruz River in what is now the Tucson metropolitan area until the mid 1900s. Areas with perennial flow supported riparian vegetation (Betancourt and Turner 1985b; Tellman et al. 1997). Riparian vegetation is present along the Lower Santa Cruz River today, however, it is primarily effluent-dependent (Baker 2000).

Present-day vegetation communities along the Santa Cruz River include species characteristic of the Arizona Uplands subdivision of the Sonoran Desertscrub region (Turner and Brown 1994) as well as riparian species. Riparian plant species present along the Santa Cruz River include Goodding willow, salt cedar, Fremont cottonwood, velvet mesquite, and willowweed. Burro brush and desert broom are found in more sparsely vegetated areas along the channel. Vegetation found on the river's floodplain or alongside drainages includes: velvet mesquite, salt cedar, desert willow, ironwood, saguaro, buckhorn cholla, catclaw acacia, burro brush, desert broom, blue paloverde, foothill paloverde, creosotebush, all-scale, and various grasses and forbs (Baker 2000).

A study of vegetation along the Lower Santa Cruz River (Baker 2000) identified and mapped vegetation associations from the Roger Road WWTP to below the Trico-Marana Road river crossing. This study found that upland species accounted for 49 percent of the total vegetation cover. The remaining 51 percent was classified as hydromesic (dependent on above regionally-normal soil moisture), of which 61 percent was riparian woodland. Based on a comparison of these data with a study completed by Omhart in 1977, Baker determined that there is currently a greater acreage of riparian woodland within the Lower Santa Cruz River than in 1977. There has been an increase in the structural diversity of riparian woodland since 1979 (Baker 2000).

There is limited historical wildlife data for the Lower Santa Cruz River. Prior to 1976, a robust population of checkered garter snake was present on the western floodplain of the Santa Cruz River between Grant Road and Sweetwater Drive. The causes of this population's disappearance are agricultural and urban encroachment (Lowe 1985).

Before 1890, a considerable amount of habitat for the Huachuca water umbel was most likely present in areas of perennial flow along the Santa Cruz. Entrenchment of the Santa Cruz River in the late 1800s resulted in the loss of habitat required by this species (U.S. Fish and Wildlife Service [USFWS] 1999).

The Tucson study site includes potential habitat for a variety of federal and state special status species (USFWS 2000; AGFD 1996). The study site may provide habitat for the following bird

species; violet-crowned hummingbird, snowy plover, peregrine falcon, western yellow-billed cuckoo, cactus ferruginous pygmy-owl, southwestern willow flycatcher, thick billed kingbird, and tropical kingbird. The southwestern willow flycatcher and cactus ferruginous pygmy-owl are both federally-listed as endangered and state-listed as species of special concern. All other bird species are state species of special concern. The study site includes habitat for the lowland leopard frog, western red bat, and the desert tortoise. These species are listed as species of special concern by the state of Arizona.

1.11 TERRESTRIAL BIOLOGY ANALYSIS

A site reconnaissance was completed at five sites along the Santa Cruz River on May 2, 2000. The five sites are located between the Roger Road outfall and the Trico-Marana Bridge. The descriptions in the following section summarize the results of the site visit and include vegetation present and human influences. **Appendix O** lists wildlife species observed during site visits.

1.11.1 Site 1 – Roger Road WWTP Outfall (Upstream)

The Santa Cruz River channel immediately above the Roger Road WWTP outfall is vegetated by shrubs and small trees. There is no riparian band present. The active floodplain is approximately 226 feet wide. Species characterized as common or abundant at the site include burro brush, desert broom, common lambs quarters, creosotebush, Bermuda grass and canyon ragweed. Species that are uncommon on the site are big sacaton and salt cedar. Canopy on both banks of the channel is sparse and understory cover is moderate. Between 40 and 75 percent of the ground on both banks is bare dirt, although the left bank does have some ground cover provided by shrubs and grasses. The Christopher Columbus Park and a landfill are located on the left bank. The outfall pipe for the Roger Road WWTP is on the right bank. Buildings are present on both banks.

This site is not described with the riparian classification system because it has no distinct riparian vegetation. The riparian vegetation score is low because of low percent cover in all layers, but the site has moderate species diversity. The score for other habitat characteristics is very low because of low continuity, low contrast with adjacent vegetation, few special habitat types or features, and a very narrow riparian zone. The wildlife score is very low because very few species in any class were observed during the site visit, the lists of potential species include relatively few species, and there is little potential habitat for threatened or endangered species. The score for disturbance characteristics is low because of a high intensity of disturbances in the riparian zone and in the adjacent areas.

1.11.2 Site 2 - Roger Road WWTP Outfall (Downstream)

The channel immediately below the Roger Road WWTP outfall includes a riparian band that is approximately 50 feet wide. The riparian plant community contains multiple vertical layers and demonstrates some regeneration. Vegetation present in the riparian zone includes Goodding willow and Fremont cottonwood. Trees on the floodplain include salt cedar and blue palo verde. On the left bank, large trees provide very heavy canopy cover and small trees provide moderate canopy cover. Canopy cover is absent from the right bank. Desert broom, common lambs

quarters and burro brush are also present in the flood plain. Wolf tail is common on the site. Species characterized as uncommon include giant reed, big sacaton, and canyon ragweed. Understory cover and ground cover are moderate on the left bank and absent from the right bank. Special habitat features present include snags and dead limbs. The Christopher Columbus Park is located on the left bank. Buildings, roads, and the outlet pipe for the Roger Road WWTP are present on the right bank.

With the riparian classification system, this site is described as a forested, mixed deciduous, community. The riparian vegetation score is low because of low percent cover in all vegetative layers, although there is moderate species diversity. The score for other habitat characteristics is relatively low because of a lack of special habitat types and a narrow riparian zone, although the habitat continuity and contrast with adjacent vegetation are relatively high. The wildlife score is relatively low because relatively few species were observed during the site visit, but there is potential habitat for some threatened or endangered species. The score for disturbance characteristics is moderate because of some invasive species and moderate levels of human-caused disturbances.

1.11.3 Site 3 - Ina Road (Downstream)

The channel downstream from Ina Road includes a riparian band approximately 115 feet wide. This segment of the channel is degrading, and both banks are eroded. Mature vegetation within the riparian band is characterized as uncommon and includes Goodding willow. Emergent vegetation present includes cattail, yellow water weed, water speedwell, water primrose, and buckwheat. These species are common on the site. Vegetation present on the floodplain includes blue palo verde, seep willow, burro brush, and *Rumex den*tatus. Other species that are common at the site include Bermuda grass, wolf tail, and Russian thistle. Canyon ragweed and salt cedar are uncommon at the site. Canopy cover is moderate on both banks. Understory cover and ground cover are heavy on both banks. Human influences at the site include roads and evidence of livestock grazing. The right bank also shows signs of recreational use.

With the riparian classification system, Site 3 is described as a scrub-shrub, deciduous, willow community. The riparian vegetation score is relatively high because of high species diversity and high percent cover in the understory and shrub layers. The score for other habitat characteristics is very high because of continuous riparian habitat, high contrast with adjacent vegetation, and a wide riparian zone. The wildlife score is relatively high because numerous bird species were observed during the site visit, and there is potential habitat for several threatened, endangered, or sensitive species. The score for disturbance characteristics is relatively low because of invasive species and moderate levels of disturbances in the riparian zone and adjacent areas.

1.11.4 Site 4 - Cortaro Road

The riparian band at Cortaro Road is approximately 26 feet wide. Fremont cottonwood, Goodding willow, salt cedar, and seep willow are common or abundant in the riparian band. Big trees provide sparse canopy cover on both banks. Small trees provide moderate canopy cover on the left bank and sparse canopy cover on the right bank. Emergent vegetation is common at the site and includes cattail, yellow water weed, water speedwell, *Rumex dentatus*, and water

primrose (*Ludwigia palustris*). Wetland obligate species present include poison hemlock and curly dock. Shrubs found on the floodplain include desert broom, burro brush, and Mexican palo verde. Johnson grass, common lambs quarters, wolf tail, and Bermuda grass are common at the site. Blue grass, *Sisymbrium orientale*, and Russian thistle are uncommon. Understory cover and ground cover are very heavy on both banks. Roads are present within 10 meters of both banks. Signs of wood-cutting were observed on both banks.

With the riparian classification system, this site is described as a scrub-shrub, mixed deciduous community. The riparian vegetation score is high because of high species diversity and high percent cover in the emergent, herbaceous, and shrub layers. The score for other habitat characteristics is high because of high continuity of habitat, high contrast with adjacent vegetation, and a relatively wide riparian zone. The wildlife score is moderate because several species were observed during the site visit, and there is potential habitat for several threatened, endangered, or sensitive species. The score for disturbance characteristics is low because of invasive species, some grazing, and moderate levels of other disturbances.

1.11.5 Site 5 - Trico-Marana Bridge

The channel at the Trico-Marana bridge includes a 75-foot-wide riparian band on the right bank. Riparian vegetation on the left bank is poorly developed. Land adjacent to riparian vegetation contains mesquite scrub or agricultural fields. Mesquite, Mexican palo verde, seep willow, burro brush, and Bermuda grass are all common or abundant. Less common species include salt cedar, cocklebur, goosefoot, and timothy. Canopy cover is heavy on both banks. Understory cover and ground cover are very heavy on both banks. Pavement and signs of livestock grazing are present on both banks.

With the riparian classification system, this site is described as a forested, mixed deciduous community. The riparian vegetation score is high because of high species diversity but only moderate percent cover in the emergent and tree layers. The score for other habitat characteristics is high because of high continuity, high contrast with adjacent vegetation, and a wide riparian zone. The wildlife score is moderate because several species were observed during the site visit, and there is potential habitat for several threatened, endangered or sensitive species. The score for disturbances characteristics is relatively high because of no grazing or recreation use, and moderate levels of other disturbances.