EXECUTIVE SUMMARY

The Texas Natural Resource Conservation Commission is required by Senate Bill 1 (SB1) of the 75th Texas Legislature to develop new reservoir/river basin simulation models in order to determine water availability in accordance with the Texas Water Code. The objective of SB1 is to create fully documented reservoir/river basin models for twenty-two river basins within Texas to be used and maintained for each basin to facilitate the evaluation of existing permits, approval of permit applications, and development or review of overall management strategies. In February of 1999, the TNRCC authorized Espey, Padden Consultants, Inc. to estimate naturalized inflows and develop a water availability model for the San Jacinto River Basin in Southeast Texas.

STUDY OBJECTIVES

The TNRCC mandated by Senate Bill 1, is to conduct a water availability analysis, to determine the:

- Projected amount of water available for all water rights during extended dry periods.
- Projected amount of water that would be available if cancellation procedures were instigated under the provisions of Subchapter E, Chapter 11, of the Texas Water Code.
- Potential impact of reusing municipal and industrial effluent on existing water rights, instream uses, and freshwater inflows to bays and estuaries.

As stated under Chapter 11.173 of the Texas Water Code, water rights cancellations can be performed:

a) Except as provided by Subsection (b) of this section, if all or part of the water authorized to be appropriated under a permit, certified filing, or certificate of adjudication has been put to beneficial use at any time during the 10-year period immediately preceding the cancellation proceedings authorized by this subchapter, then the permit, certified filing, or certificate of adjudication is subject to cancellation in whole or in part, as provided by this subchapter, to the extent of the 10 years of nonuse.

b) A permit, certified filing, or certificate of adjudication or a portion of a permit, certified filing or certificate of adjudication is exempt from cancellation under Subsection (a) of this section:
   1) to the extent of the owner's participation in the Conservation Reserve Program authorized by the Food Security Act, Pub. L. No. 99-198, Secs. 1231-1236,99 Stat.1354, 1509-1514 (1985) or a similar governmental program; or
   2) if any portion of the water authorized to be used pursuant to a permit, certified filing, or certificate of adjudication has been used in accordance with a regional water plan approved pursuant to Section 16.053 of this code.

Nine different scenarios were analyzed in this study to simulate the effects of the above-described parameters. Scenarios 1 through 8 were legislatively mandated, while Scenario 9 is basin specific. The eight mandated scenarios include: three reuse scenarios, four cancellation scenarios and one current conditions scenario (which includes term permits). The basin specific scenario is a firm yield determination for all permitted reservoirs with capacities greater than 5,000 ac-ft per year.

SAN JACINTO BASIN

The San Jacinto Basin encompasses all or part of 8 counties in Southeast Texas with water flowing from the headwaters in Fort Bend, Waller, Grimes, Walker, San Jacinto, and Liberty counties, through Montgomery and Harris counties to Galveston Bay. The basin has a drainage area of approximately 4,000 square miles and has two major streams, Buffalo Bayou and the San Jacinto River. The San Jacinto River has 7 major tributaries, Cypress Creek, Spring Creek, West Fork San Jacinto River, Caney Creek, Peach Creek, East Fork San Jacinto River, and Luce Bayou.

The San Jacinto River Basin is the second most populated basin in Texas with a 1990 population of 2.771 million. From 1980 to 1990, the basin population increased by 401,812 residents, representing an increase of 17 percent. Population of the basin is projected to double over the 1990-2050 planning horizon with a year 2050 population of more than 5.782 million. Major population centers in the basin and their latest population estimates include all or portions of Houston (1,741,257), Pasadena (129,483), Baytown (68,505), Missouri City (49,170), The Woodlands (48,950), Conroe (37,761), Huntsville (33,467), Deer Park (29,917), South Houston (15,160), Bellaire (14,722), and West University Place (13,502).

There are 110 separate existing water rights located within the San Jacinto River Basin. Locations of individual water rights are identified on the map in Appendix K, and are listed with general descriptive information, including permittee name and authorized diversion amounts, in Appendix A. The total authorized diversion amount for these rights is approximately 629,000 ac-ft/yr as shown in the following table.

Use Category	Authorized Diversion ac-ft/yr
Municipal	289,000[a]
Industrial	316,973[b]
Irrigation	16,556
Mining	5,500
Recreational	160
Other	967
Total	629,156

[a] Includes all WR 4964 and WR 4965 as municipal use (permit allows use to be municipal, industrial, and/or irrigation).
[b] Includes all Saline water rights in San Jacinto Basin

The total amount of water rights modeled in this study is 347,736 ac-ft/yr. The difference in diversion amounts is the amount of saline water rights in the basin. A full discussion of the exclusion of saline water rights is found in Section 4.2.3.5.

There are 4 existing major reservoirs in the San Jacinto River Basin with capacities ranging from 5,420 to 430,260 acre-feet. The San Jacinto River Basin's total permitted reservoir storage capacity is 612,614 acre-feet.

PROCEDURES

Procedures and criteria for undertaking the water availability analyses for all basins in Texas have been developed by the WAM Management team, consisting of representatives from the TNRCC, Texas Parks and Wildlife Department (TPWD), and the Texas Water Development Board (TWDB). These procedures include the development of naturalized streamflows from historical hydrological information, utilization of the Water Rights Analysis Package (WRAP) program, and adhering to the Texas prior appropriation system, the Texas Water Code, and water management and regulatory policies set by the TNRCC.

Naturalized streamflows are the flows that would have occurred in the absence of human activities such as reservoir development, diversions, and return flows. Naturalized flows are used so that historical diversions, impoundments, and returns do not affect the water availability analysis. Naturalized flows at primary control points are based on historical hydrologic records, adjusted to remove the impact of human activities. The flows are used as input to the water availability model, which simulates the operation of existing water rights considering their location, characteristics, and priority under Texas water law. Naturalized streamflows were developed for selected USGS gage locations as well as specific reservoir sites in the San Jacinto River Basin for each month over a 57-year historical period of record. The locations where naturalized streamflows were developed are called primary control points, and basically describe the spatial configuration of the river basin. Section 4.2.1 of the report gives a more detailed explanation of primary and secondary control points in WRAP (VER 10/99).

Water availability calculations were performed using the WRAP (VER 10/99) model, developed by Dr. Ralph A. Wurbs at Texas A & M University. The WRAP model incorporates the Prior Appropriation Doctrine and was selected by TNRCC in 1998 to simulate the water availability in Texas. WRAP has been used in a wide variety of different types of water rights throughout Texas. Specifically for TNRCC, the Sulphur, Neches, and San Antonio Basins have been modeled to determine the water availability in accordance with SB1 time requirements. WRAP utilizes monthly time steps, historical hydrologic river basin characteristics, and the specific water right information to determine the available water. The model performs a sequential monthly water volume accounting computation by determining if TNRCC permitted water diversions can be made at a particular location during a specified hydrologic period of analysis under given historic hydrologic conditions. The model is set up to allow water rights that have seniority the first right at diversion ("first in time, first in right")

The specific steps taken to develop the San Jacinto River Basin Water Availability Model were to collect, analyze, and compile data needed for input into WRAP (VER 10/99). Data required for input into the model include primary and secondary control points, naturalized flows, classified stream segments, evaporation, water rights information, reservoir area-capacity curves, return flows for facilities permitted above 1 million gallons per day (MGD), locations of water rights and return flows and water use demand patterns. Nine scenarios were analyzed using WRAP (VER 10/99) to determine the effects of the parameters as outlined in the study objectives.

The principal results from the water availability analyses are:

- Reliability of existing water rights
- Monthly estimates of unappropriated water that would be available for diversion and/or storage.

The results of the water availability analysis under varied cancellation and reuse policies satisfies the requirements of SB1. Results presented in this draft report are only a partial summary of the complete output generated by WRAP (VER 10/99). The complete water availability output for existing water rights in the San Jacinto River Basin are available from the TNRCC.

Existing data on the San Jacinto River Basin are limited prior to 1940; therefore, this study will use hydrologic data from January 1940 through December of 1996 as the period of record. This period of record was selected because sufficient data are available to make the modeling effort reliable and because it encompasses the droughts of 1951-1956, 1963-1964, 1965-1967, 1980, 1984, 1988, and 1996.

RESULTS

Reliability results from the water availability analysis, for the eight base scenarios for the San Jacinto River Basin are presented in Tables ES-1 through ES-3, at the end of this Executive Summary. These tables list all water rights in the San Jacinto River Basin with authorized diversions and give a unique identification number for each water right. In many cases a water right has multiple entries which result from a water right having multiple diversion locations, use types, and priority dates, all of which are used in the WRAP (VER 10/99) model to simulate the written permit. The results tables list the authorized diversion amount, the simulated mean annual shortage, and the period and volumetric reliability for the 57-year period of record. Period reliability, expressed in percent is defined as the ratio of number of months for which no shortages occurred to the total number of months in the simulation period. Volumetric reliability, expressed as a percent, represents the ratio of the mean actual annual diversion to the corresponding authorized annual diversion amount. For Tables ES-2 and ES-3, an #N/A indicates a partial or total cancellation of that portion of the water right.

There are four existing permitted reservoir projects within the San Jacinto River Basin with capacities over 5,000 acre-feet (ac-ft). These reservoirs are Lake Conroe, Lake Houston, Sheldon Reservoir, and Lewis Creek Reservoir. The remaining reservoirs (permitted under 5,000 ac-ft) are all used for impoundment for individual water rights in the basin. Results of Scenario 9 indicate the yield of Lake Conroe to be approximately 79,825 ac-ft/yr and a yield of approximately 200 ac-ft/yr for Sheldon Reservoir. Yields for the remaining two reservoirs were not analyzed because the water rights on each reservoir could be met in all simulations.

CONCLUSIONS

The Texas A&M WRAP model (VER 10/99) has been applied to the San Jacinto River Basin in Texas to determine the water availability. All of the 110 water rights in the basin were included in the model including saline rights with zero diversion. Water availability was calculated in three basic scenarios: (1) Reuse Runs (full authorized diversions with varying return flow amounts), (2) Cancellation Runs (varying diversion and return flow amounts based on cancellation of water rights), and (3) Current Conditions Runs (maximum use diversions with return flows using year-2000 area-capacity reservoir relationships. All scenarios utilized:

- 57-year period of naturalized flows (1940 thought 1996).
- Water rights information for all water rights issued by the TNRCC through February 1999.

The WR, WS and OR records in WRAP (VER 10/99) characterize the written permit and other pertinent information required for input into the computer model. No system operations were modeled unless authorized in the written permit. Nine scenarios were performed; eight base scenarios and one basin specific scenario (firm yield). The primary conclusions of this water availability study of the San Jacinto Basin are as follows:

- The San Jacinto River Basin, located in southeastern Texas, drains an area of approximately 4,000 square miles. There are a total of 110 water rights with approximately 629,156 acre-feet per year (ac-ft/yr) authorized annual diversions. Of this total diversion, only 347,736 ac-ft/yr was included in the model. The remaining diversions were located in the estuarine segment and considered saline rights; therefore, they were not included in the water availability model.

- The majority of the smaller irrigation and industrial rights (under 500 ac-ft/yr) frequently had shortages in available water. However, the majority of these rights with shortages still maintained reliabilities over 90 %.

- Comparisons of the three reuse scenarios show that varying levels of wastewater reuse do impact water supply. The reliability of a water right generally decrease as the level of reuse increases. Reuse of wastewater decreases the amount of storage in the reservoirs as well (See Figures P-1 through P-4).

- Hypothetical cancellation of water rights has a negligible effect on the reliability of water supply for most rights in the basin. The magnitude of simulated cancellations totaled 3,413 ac-ft/yr, and accounts for only 1 % of the full authorized diversion amount. The majority of the simulated cancellations occurred in water rights whose reliability is less than 100 percent (i.e. unreliable junior rights).

- Scenarios that utilize the 10-year maximum use as the diversion amount can significantly effect the amount of unappropriated flow and reservoir storage because the actual historical diversions during the last ten years were substantially less than the fully appropriated amounts. The diversion amount used in these runs (Scenarios 5 and 7) was 58,983 ac-ft/yr less than the demand in Scenarios 4 and 6. The cancellation runs with this large change in diversion amounts had a greater impact on the water availability than the cancellation runs with full authorized amounts (Scenarios 4 and 6).

- Simulated results from the WRAP model indicate that there is significant quantities of unappropriated and regulated flow that varies based on the location of the control point. The largest difference in the unappropriated and regulated flows (to Run 1) is shown in Figure P-8. In general, wastewater reuse has a greater effect on unappropriated and regulated flows for those locations in the lower portions of the basin. Future appropriations will be subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code.

- Over the 57-year period of record, the average naturalized flows discharging into Galveston Bay from the San Jacinto River Basin as approximately of 2,206,748 ac-ft/yr, with a minimum annual inflow of 270,623 ac-ft occurring in 1956, and a maximum annual inflow of approximately 5,405,963 ac-ft/yr in 1973.

- The yield of Lake Conroe is approximately 79,825 ac-ft/yr and approximately 200 ac-ft/yr for Sheldon Reservoir. Yields for the remaining two reservoirs were not analyzed because the water rights on each reservoir could be met in all simulations.

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1.0 INTRODUCTION

1.1 Description of the Basin

The San Jacinto River Basin is bounded on the North and East by the Trinity River Basin and Trinity-San Jacinto Coastal Basin, on the South by the San Jacinto-Brazos Coastal Basin, and on the West by the Brazos River Basin. The basin encompasses all or part of 8 counties in Southeast Texas with water flowing from the headwaters in Fort Bend, Waller, Grimes, Walker, San Jacinto, and Liberty counties, through Montgomery and Harris counties to Galveston Bay. The San Jacinto River Basin has a drainage area of approximately 4,000 square miles and has two major streams, Buffalo Bayou and the San Jacinto River. The San Jacinto River has 7 major tributaries, Cypress Creek, Spring Creek, West Fork San Jacinto River, Caney Creek, Peach Creek, East Fork San Jacinto River, and Luce Bayou. A map of the basin can be viewed in Figure 1.

Predominate sectors of the basin economy are manufacturing, finance, services, retail and wholesale trade, commercial shipping, commercial fishing, and tourism. The San Jacinto River Basin is the second most populated basin in Texas with a 1990 population of 2.771 million. From 1980 to 1990, the basin population increased by 401,812 residents, representing an increase of 17 percent. Population of the basin is projected to double over the 1990-2050 planning horizon with a year 2050 population of more than 5.782 million. Major population centers in the basin and their latest population estimates include all or portions of Houston (1,741,257), Pasadena (129,483), Baytown (68,505), Missouri City (49,170), The Woodlands (48,950), Conroe (37,761), Huntsville (33,467), Deer Park (29,917), South Houston (15,160), Bellaire (14,722), and West University Place (13,502).

Ground-water resources supply about 59 percent of the water used for all purposes in the basin with surface water resources supplying the remaining 41 percent. In 1990, total water use in the basin was 786,351 acre-feet (ac-ft) which represents a decline of about 36,000 ac-ft from the 1980 total basin water use. This decline was attributable to a reduction of about 37,000 ac-ft of water requirements for irrigated agriculture. Municipal and manufacturing water use increased slightly over this same period of time. Municipal water use is the largest water use category in the basin, accounting for about 62 percent, followed by manufacturing, which accounts for about 29 percent. In 1990, over 67,000 ac-ft of water was exported to the Trinity-San Jacinto Coastal Basin and 18,574 ac-ft was exported to the San Jacinto-Brazos Coastal Basin from the San Jacinto River Basin for municipal and industrial purposes (Water for Texas, 1997).

There are 4 existing major reservoirs in the San Jacinto River Basin with capacities ranging from 5,420 to 430,260 acre-feet. The San Jacinto River Basin's total permitted conservation storage is 612,614 acre-feet.

Figure 1 San Jacinto River Basin

Lewis Creek is authorized as a 17,000 acre-foot cooling-water reservoir in northern Montgomery County owned and operated by Entergy, Inc. (formally Gulf States Utilities Company). Construction of the reservoir was completed in August 1969, and impoundment began in February 1969. Entergy holds a water right (WR 10-4966) for Lewis Creek Reservoir that allows the use of the reservoir for recreational and industrial purposes associated with the maintenance and operation of a thermal-electric power plant. Under this water right they are also authorized to impound waters of Lewis Creek and divert and use water contracted from the San Jacinto River Authority from Lake Conroe at a maximum rate of 26.67 cfs. No existing yield studies for Lewis Creek were identified.

Lake Conroe is authorized as a 430,260 acre-foot reservoir on the West Fork San Jacinto River in Montgomery County. The lake is owned jointly by the San Jacinto River Authority and the City of Houston, and the water is used for municipal and industrial purposes in the Houston metropolitan area. The dam was completed September 1, 1972, and deliberate impoundment began January 9, 1973. The owners hold a water right (WR 10-4963) for Lake Conroe that allows the use of the reservoir for recreational, municipal, industrial, and mining purposes. The total permitted diversion for the reservoir is 100,000 acre-feet per year.

Lake Houston is authorized as a 160,000 acre-foot reservoir on the San Jacinto River in Harris County. The lake is owned and operated by the City of Houston, and the water is used for municipal and industrial purposes in the Houston metropolitan area. The San Jacinto River Authority, under Certificate of Adjudication 10-4964, is authorized to divert 55,000 acre-feet from the San Jacinto River at Lake Houston and is authorized to store water diverted from the San Jacinto River in a 3,800 acre-foot off-channel reservoir (Highlands Reservoir) for subsequent diversion and use. The San Jacinto River Authority water right (WR 10-4964) is not backed by storage in Lake Houston The City of Houston holds water rights for the Lake Houston (WR 10-4965). The total permitted diversion from Lake Houston is 168,000 acre-feet per year. The City is also authorized to store water diverted from the Trinity River Basin in Lake Houston for subsequent diversion and use.

Sheldon Reservoir is authorized as a 5,354 acre-foot reservoir in Harris County. The reservoir is owned by the Texas Parks and Wildlife Department and is operated as the Sheldon Wildlife Management Area for irrigation, industrial, and recreational purposes (WR 10-3995). The total permitted diversion from Sheldon Reservoir is 2,688 acre-feet per year. No existing yield studies for Sheldon Reservoir were identified.

Total water use in the basin is projected to increase by 73 percent over the 1990-2050 planning horizon resulting in a year 2050 water use of about 1.36 million ac-ft. Municipal water use will continue to be the major water use category, being projected to account for 69 percent of the total basin water use by the year 2050. Municipal water conservation practices and programs, along with increased efficiencies in manufacturing water use, are projected to reduce future annual municipal and manufacturing water use by more than 149,000 ac-ft by the year 2020 and more than 282,000 ac-ft by the year 2050.

The basin will need new water supplies in the future. Almost all of the additional supplies will be imported into the basin from the Sabine and Trinity River basins, which will require the development of a major conveyance pipeline from the Sabine River to either the Trinity River or to terminal storage within the San Jacinto Basin. Over 92,000 ac-ft is anticipated to be imported from the Sabine Basin by 2050. In addition, by 2050, over 66,500 ac-ft per year of the total water used in the basin will be supplied by reuse of wastewater (Water for Texas, 1997).

1.2 Study Objectives

The objective of this study is to meet the requirements placed on the Texas Natural Resource Conservation Commission (TNRCC) by Senate Bill 1. Senate Bill 1, passed by the 75th Texas Legislature, requires that the TNRCC develop or acquire new reservoir/river basin simulation models in order to determine water availability in twenty-two river basins within Texas. In February of 1999, the TNRCC authorized Espey, Padden Consultants, Inc., to estimate naturalized inflows and develop a water availability model for the San Jacinto River Basin in Southeast Texas. Freese and Nichols, Inc., Brown and Root, Inc., Crespo Consulting Services, and GSG, Inc. served as sub-consultants to Espey, Padden Consultants, Inc. on this project.

In order to meet the study objectives for the San Jacinto River Basin Water Availability Study two tasks had to be performed:

- Calculation of naturalized flows.
- Development of a water availability model using Texas A&M's Water Rights Analysis Package (WRAP (VER 10/99)).

As mandated by Senate Bill 1, the TNRCC is to determine, through the water availability analysis, the:

- Projected amount of water available for all water rights during extended dry periods.
- Projected amount of water *that would b*e available if cancellation procedures were instigated under the provisions of Subchapter E, Chapter 11, of the Texas Water Code.
- Potential impact of reusing municipal and industrial effluent on existing water rights, instream uses, and freshwater inflows to bays and estuaries.

1.3 Study Approach

Procedures and criteria for undertaking the water availability analyses for all basins in Texas have been developed by the WAM Management team, consisting of representatives from the TNRCC, Texas Parks and Wildlife Department (TPWD), and the Texas Water Development Board (TWDB). These procedures include the development of naturalized streamflows from historical hydrological information, utilization of the Water Rights Analysis Package program, and adhering to the Texas prior appropriation system, the Texas Water Code, and water management and regulatory policies set by the TNRCC.

The model selected for use in this study by the TNRCC was WRAP (VER 10/99). The WRAP (VER 10/99) program, developed by Dr. Ralph A. Wurbs at Texas A & M University, simulates a basin using monthly time steps, historical hydrologic river basin characteristics, and the Texas prior appropriation system. The model performs a sequential monthly water volume accounting computation by determining if TNRCC permitted water diversions can be made at a particular location during a specified hydrologic period of analysis given historic hydrologic conditions. The model is set up to allow water rights that have seniority the first right of diversion ("first in time, first in right").

The steps taken to develop the San Jacinto River Basin Water Availability Model were to collect, analyze, and compile data for a period from 1940 through 1996. Data required for input into the model include control points, naturalized flows, evaporation rates, water right data, reservoir area-capacity curves, return flows, and water use demand patterns. Once the data were obtained, 9 model scenarios were analyzed using WRAP (VER 10/99) to determine the water availability for the 1940-1996 hydrologic period.

Naturalized streamflows are the flows that would have occurred in the absence of human activities such as reservoir development, diversions, and return flows. Naturalized flows are used so that historical diversions, impoundments, and returns do not affect the water availability analysis. Naturalized flows at primary control points are based on historical hydrologic records, adjusted to remove the impact of human activities. They are used as input to the water availability model, which simulates the operation of existing water rights considering their location, characteristics, and priority under Texas water law. Naturalized flows at secondary control points are estimated from nearby primary control points.

The principal results from the water availability analyses are:

1. *Reliability of existing water rights*

   The results of the water availability analysis under varied cancellation and reuse policies satisfies the requirements of SB1. Results presented in this draft report are only a partial summary of the complete output generated by WRAP (VER 10/99).

The complete water availability output for existing water rights in the San Jacinto River Basin are available from the TNRCC.

2. *Monthly estimates of unappropriated water that would be available for diversion and/or storage.*

Existing data on the San Jacinto River Basin are limited prior to 1940; therefore, this study will use hydrologic data from January 1940 through December of 1996 as the period of record. This period of record was selected because sufficient data are available to make the modeling effort reliable and because it encompasses the droughts of 1951-1956, 1963-1964, 1965-1967, 1980, 1984, 1988, and 1996.

2.0 EXISTING WATER AVAILABILITY INFORMATION

Key data for water availability modeling include water rights, historical water use, historical return flows, historical streamflow, reservoir data, and evaporation rates. This section discusses available information for the key data as well as previous water availability and planning studies.

2.1 Water Rights

There are 110 water rights in the San Jacinto River Basin. Table 1 provides a summary of water rights by sub-watershed. Information regarding water rights was obtained from the TNRCC master water rights database and from hard copies of the water rights. Appendix A lists water rights in the San Jacinto River Basin sorted by river order number and sequenced from downstream to upstream. Appendix B is the same database sorted by priority date from the most senior water right to the most junior water right. Current water rights documents (all certificates of adjudication and permits issued by the TNRCC through February 1999) were reviewed and compared to the TNRCC database and the database was revised when appropriate. A memorandum was prepared and submitted to the TNRCC with suggested corrections to the master water rights database and is shown in Appendix C.

2.2 Historical Water Use

Groundwater resources supply about 59 percent of the water used for all purposes in the basin with surface water resources supplying the remaining 41 percent. Surface water is supplied by the four major reservoirs and the San Jacinto River. Groundwater used in the basin is obtained primarily from the Gulf Coast Aquifer for municipal, manufacturing, and agricultural purposes. However, the area within the Harris-Galveston Coastal Subsidence District has been given a mandate to convert to between 80 to 90 percent surface water usage by 2010. Total water use, as obtained from the TWDB, in the basin has decreased by 36,000 acre-feet in the period between 1980 and 1990. Municipal water use is the largest water use category in the basin accounting for about 62 percent, followed by manufacturing which accounts for about 29 percent (Water for Texas, 1997).

Table 1 Summary of Water Rights by Sub-Watershed (ac-ft/yr)

Sub-Watershed	Upstream Control Points	Downstream Control Points	Municipal	Industrial	Irrigation	Others	Total
WS_CO		West Fork San Jacinto below Lake Conroe near Conroe	66,000	28,500	140	5,500	100,140
WS_CN	West Fork San Jacinto below Lake Conroe near Conroe	West Fork San Jacinto River near Conroe			482		482
SP_SP		Spring Creek near Spring			1,617	160	1,777
CY_CY		Cypress Creek at House and Hahl Roads near Cypress			3,667		3,667
CY_WE	Cypress Creek at House and Hahl Roads near Cypress	Cypress Creek near Westfield			100		100
ES_CL		East Fork San Jacinto River near Cleveland					0
CA_SP		Caney Creek near Splendora			56		56
PE_SP		Peach Creek at Splendora					0
SR_HF	West Fork San Jacinto River near Humble Caney Creek near Splendora Peach Creek at Splendora East Fork San Jacinto River near Cleveland	San Jacinto River near Huffman		10	6,838		6,848
BB_AD		Buffalo Bayou near Addicks			1,268		1,268
BB_HO	Buffalo Bayou near Addicks	Buffalo Bayou at Houston			829	967	1,796
WB_HO		Whiteoak Bayou at Houston			230		230
BR_HO		Brays Bayou at Houston			345		345
SB_HO		Sims Bayou at Houston		230			230
GB_HO		Greens Bayou near Houston					0
SR_GB	San Jacinto River near Huffman Buffalo Bayou at Houston Whiteoak Bayou at Houston Brays Bayou at Houston Sims Bayou at Houston Greens Bayou near Houston	San Jacinto River at Galveston Bay	223,000[a]	288,233[b]	984		512,217
TOTAL			289,000	316,973	16,556	6,627	629,156

[a] Total use for WR 4964 and WR 4965 is reported in the TNRCC water rights master database as municipal use (permits state that this use can be municipal, industrial, and/or irrigation).
[b] All saline rights are included in this reported number.

Water use data were collected to be utilized in the naturalization process. Surface water use records were obtained in a digital format for the study period from 1940 through 1996 from the TNRCC. The permit files were also reviewed to obtain water use data for water rights with large diversion amounts as well as to identify water rights with missing data. Holders of water rights with incomplete records were contacted to obtain additional information to fill in the missing data. If no data was available, water use data was estimated on a per capita basis for municipal water rights. Per capita water use estimations were determined by dividing the water use in a given year by the population of the community using the water in that same year. These per capita values were then multiplied by the population of the community during the period of missing data. Estimates for water use for industrial and irrigation water rights were based on historical use patterns of those water rights or rights with similar uses and diversion amounts. When a good estimate could not be formed, the historical use was estimated to be zero. This estimation provided a conservatively low estimate in the naturalized streamflow calculations.

In accordance with TNRCC requirements, surface water use records for all water rights in the San Jacinto River Basin were summarized for the ten-year period from 1986 through 1996 from the TNRCC permit files. This period of record was selected because data records were readily available and comprehensive. The water use data obtained from the TNRCC is data provided to the TNRCC by all permittees. This data set included the county in which the diversion occurred and the use type. A summary of water use by county for a ten-year use period of 1986 through 1996 is shown in Appendix E.

Groundwater was represented by 35% of the total for each return flow facility for the City of Houston and was input through the CI card for each of those facilities. Historical groundwater use records from 1986 to 1996 were obtained from the Texas Water Development Board (TWDB). The groundwater data are presented by county, defined by use type, and summarized by year in Appendix E.

2.3 Historical Return Flows and Treated Wastewater Effluent Discharge

Available records for return flows of treated municipal and industrial wastewater effluent discharges were obtained from TNRCC for the time period of 1978 through 1996. Prior to 1978, return flow records were generally not available. The following techniques were used to estimate return flows where records were not available:

- For major return flows (more than 1.0 MGD), the entity was contacted to determine whether any records or estimates of flows existed for the time frame not covered by the TNRCC database.
- For cities without such records and with an estimated return flow over 1.0 MGD, return flows were estimated on the basis of water use or a per capita value.
- For industries without such records and with an estimated return flow over 1.0 MGD, return flows were estimated on the basis of water use.
- Return flows less than 1.0 MGD were not estimated.
- Agricultural return flows were neglected.

Estimates of return flow were then calculated for all major return flow locations from the date in which the discharge began up through 1978.

Return flows were located using latitude and longitude coordinates provided by TNRCC for all facilities greater than 1.0 MGD. These locations are shown in Appendix K, denoted by "AXXX". XXX represents the Center for Research and Water Resources' return flow identification numbers.

In addition to the above scoped items, smaller (0.2 – 1.0 MGD) wastewater treatment plants upstream of Lake Houston in the San Jacinto River Basin were added because they were found to represent a large portion of the total return flows in the upper part of the watershed. Smaller treatment plant return flows were not included in the other sub-watersheds in the San Jacinto Basin. The TNRCC provided available records of return flows of treated municipal and industrial wastewater from 1978 through 1996 for these facilities.

2.4 Previous Water Availability and Planning Studies

There are four existing major reservoirs in the San Jacinto River Basin: Lewis Creek, Conroe, Houston, and Sheldon. A bibliography of water supply studies of these reservoirs and a summary of the results from these studies is presented in Appendix F. According to these studies, the combined water supply from reservoirs in the San Jacinto River Basin is between 200,000 and 360,000 acre-feet per year. The combined water supply depends on the definition of water supply yield (i.e. how much reserve content remained in the reservoir at the end of the critical period), assumed basin development, and other factors.

Agencies that have modeled water availability in the San Jacinto River Basin include: predecessors of the TNRCC, the United States Survey Commission (USSC), and the Texas Water Development Board. These studies have included development of hydrologic data for periods before 1940 to 1980 and availability analyses that accounted for prior appropriations. The results of these studies and the current study are compared, where possible, in Section 5 of this report.

2.5 Significant Considerations Affecting Water Availability in the Basin

Assumptions made in this study which may affect water availability include:

- Filling of downstream reservoirs with senior water rights take precedence over diversion by upstream junior water rights. The firm yield analysis of this study maximizes the amount of diversions that could be made from the reservoir under their respective priority dates up to the authorized diversion amount. Lake Houston is senior to Lake Conroe, therefore water is passed through Lake Conroe to fill Lake Houston.
- Watershed parameters used in this study to distribute naturalized flows between control points have not been reviewed and are assumed to be correct.
- Saline water rights located in the Houston Ship channel rely primarily on water from Galveston Bay and do not affect water availability in the rest of the basin.
- All water rights and currently permitted reservoirs, as of February 1999, are modeled.
- Reservoirs less than 5,000 ac-ft are modeled using a regression relationship shown in Figure 11 to relate reservoir storage to surface area.
- Channel losses are assumed to be negligible and are not included in the model.
- The model uses a monthly time step. Therefore, this type of analysis does not account for travel times between control points or flow requirements that depend on instantaneous flows, such as instream flow requirements or prevention of salt-water intrusion.
- In general, the amounts of appropriated water covered by existing rights are determined by the permitted diversion for each water right and are not based on firm yields, geographical location, or other practical limits. Thus, the remaining unappropriated water at any point in the basin is based on the assumption that all rights are taking their full paper values of diversions whenever that much water is available.
- For water rights with off-channel storage, WRAP limits the streamflow depletions which are made to meet diversions and refill storage on a monthly and annual basis.

3.0 HYDROLOGIC DATA REFINEMENT

3.1 Natural Streamflow at Gaged Locations

USGS Gage locations served as primary control points for the water availability model. Naturalized flows were estimated at primary control points in the San Jacinto River Basin. The location of most of the control points corresponds to USGS streamflow gages with relatively extensive historic records as shown in Figure 2. To estimate naturalized flows, the gage records were adjusted to account for upstream diversions, return flows, changes in reservoir content, and net reservoir evaporation.

3.1.1 Streamflow Naturalization Methodology

Whenever possible, naturalized streamflows at the primary control points are based on available streamflow records using the methodology described herein. A primary task undertaken in this water availability study was to calculate naturalized streamflows.

Naturalized flow data is based on historical flows, adjusted to remove the effects of human activity. A general equation for naturalized flow is as follows:

Naturalized Flow = Historical Flow + Upstream Diversions – Upstream Return Flows + Changes in Upstream Reservoir Contents + Upstream Reservoir Evaporation

The elements of the equation are determined as follows:

- ***Historical Flow*** – Flow recorded at USGS streamflow gages.

- ***Upstream Diversions*** – Upstream diversions as recorded in TNRCC records (or as estimated when records are missing).

- ***Upstream Return Flows*** – Upstream return flows as recorded in TNRCC records (or as estimated when records are not available). Return flows under 0.2 MGD were always ignored.

- ***Changes in Upstream Reservoir Contents*** – Changes in contents for major upstream reservoirs are based on USGS records, records kept by others, or estimates of content changes if records were not available. The sources of data utilized for reservoir content changes are listed in Table 2. Content changes for reservoirs with less than 5,000 acre-feet of conservation storage were not considered.

- ***Upstream Reservoir Evaporation*** – Monthly evaporation from upstream reservoirs is estimated by multiplying the net reservoir evaporation rate by the average reservoir surface area. Evaporation from reservoirs with less than 5,000 acre-feet of conservation storage is neglected. Section 3.3 includes a discussion of the development of net reservoir evaporation rates.

Table 2 Sources of Data Utilized for Reservoir Content Changes

Reservoir	Period	Method
Lewis Creek	Before 2/69 2/69-Present	No impact Gulf States Utilities Company data
Conroe	Before 1/73 1/73-Present	No impact USGS data
Houston	Before 4/54 4/54-Present	No impact USGS data
Sheldon	Before 12/43 12/43-Present	No impact Texas Parks and Wildlife Department data

3.1.2 Streamflow Data Sources

Streamflow data in the San Jacinto River Basin were obtained from U.S. Geological Survey gage flows. The U.S. Geological Survey maintains a network of streamflow gages throughout the United States. USGS gage measurements are the most reliable source of historical streamflow data. Table 3 lists USGS streamflow gages in the San Jacinto River Basin. Figure 2 shows the length of record for each USGS streamflow gage in the basin. Reference Figure 1 for primary control points selected in this study.

3.1.3 Delivery Factors and Channel Loss Rates

Based on known hydrologic conditions and previous experience, channel losses in the San Jacinto Basin were assumed to be negligible. This assumption was borne out in the investigation of negative incremental inflows during the creation of naturalized flows. In most cases, the negative incremental inflows could be explained by problems with a particular gage, inaccurate spill estimates from reservoirs, or timing problems. There is no evidence of consistent channel losses in the San Jacinto River Basin; therefore, channel losses were not derived in this study.

3.1.4 Completion of Streamflow Records and Quality Control

Most of the primary control points in the San Jacinto River Basin do not have a complete flow record for 1940 through 1996. The length of record and periods of missing data for the

Table 3 USGS Streamflow Gages in the San Jacinto River Basin

Gage	USGS Number	Drainage Area (Square Miles)	Period of Record	Remarks
Lake Conroe at Outlet Weir near Conroe	67610	445	10/73-9/74 & 10/76-9/89	
West Fork San Jacinto River below Lake Conroe near Conroe	67650	451	9/74-9/89	
Caney Creek near Dobbin	67700	40.4	4/63-9/65	
West Fork San Jacinto near Conroe	68000	809	5/24-9/27 & 8/39-Present	
West Fork San Jacinto River above Lake Houston near Porter	68090	962	5/84-Present	
Willow Creek near Tomball	68325	41	4/91-8/92 & 10/92-5/95 & 7/95-2/98 & 4/98-4/98	
Swale No. 8 at Woodlands	68438	0.55	11/85-11/95 & 6/87-4/88	
Panther Branch near Conroe	68400	25.9	3/74-9/76	
Lake Harrison at Drop Inlet at Woodlands	68440	0.71	10/74-12/75	
Panther Branch near Spring	68450	34.5	4/72-12/75	
Spring Creek near Spring	68500	409[a]	4/39-9/75 & 10/95-Present	
Spring Creek at (formerly near) Spring	68520	419[a]	10/75-9/95	
Cypress Creek at Sharp Rd near Hockley	68700	80.7	6/75-12/75	
Cypress Creek at Katy-Hockley Rd near Hockley	67820	110	6/75-7/83	
Cypress Creek at House and Hahl Roads near Cypress	68740	131	6/75-Present	
Little Cypress Creek near Cypress	68780	41 [b]	5/82-10/92	
Cypress Creek at Grant Rd near Cypress	68800	214 [c]	10/82-10/92	
Cypress Creek at Stuebner-Airline Rd near Westfield	68900	248 [d]	9/87-10/89	
Cypress Creek near Westfield	69000	285	7/44-Present	
West Fork San Jacinto River near Humble	69500	1,811	10/28-9/54	
East Fork San Jacinto River near Cleveland	70000	325	5/39-Present	
East Fork San Jacinto River near New Caney	70200	388	5/84-Present	
Caney Creek near Splendora	70500	105 [e]	10/43-Present	
Peach Creek at Splendora	71000	117	10/43-9/77	
San Jacinto River near Huffman	71500	2,791	10/36-9/53	
Garners Bayou near Humble	76180	32	2/86-Present	
Luce Bayou above Lake Houston near Huffman	71280	218	5/84-Present	
Goose Creek at Baytown	67525	15.8	10/91-8/92, 10/92-1/93, 3/93-3/98	
Buffalo Bayou near Katy	72300	63.3	7/77-Present	
Bear Creek near Barker	72730	21.5 [f]	7/77-Present	
Langham Creek at West Little York Rd near Addicks	72760	24.6	6/87-1/89, 3/89-11/89	
Buffalo Bayou near Addicks	73500	293 [g]	9/45-Present	
Buffalo Bayou at West Belt Dr at Houston	73600	307	9/71-Present	
Buffalo Bayou at Piney Point	73700	317	10/63-9/76, 10/84-5/87, 10/87-Present	
Buffalo Bayou at Houston	74000	358 [h]	6/36-9/57 & 1/62-9/75	

Gage	USGS Number	Drainage Area (Square Miles)	Period of Record	Remarks
Whiteoak Bayou at Alabonson Rd at Houston	74020		9/96-8/98	
Bingle Rd Storm Sewer at Houston	74145	0.21	5/87-12/87	
Cole Creek at Deihl Rd, Houston	74150	8.05	5/64-9/86, 6/87-9/87, & 10/94-Present	
Brickouse Gully at Costa Rica St at Houston	74250	11.6	9/64-10/81, 10/95-Present	
Whiteoak Bayou at Houston	74500	84.7 (i)	6/36-Present	
Little Whiteoak Bayou at Trimble St, Houston	74540	18	10/91-5/92, 7/92-8/94, 10/94-5/95	
Brays Bayou at Alief	74760	12.9	10/91-1/96 & 3/96-9/98	
Keegans Bayou at Keegan Rd near Houston	74780	8.63	10/91-Present	
Keegans Bayou at Roark Rd near Houston	74800	11.6	9/64-10/81, 10/84-4/85 & 8/95-11/98	
Brays Bayou at Gessner Drive, Houston	74810	52.5	12/87-8/92 & 10/92-Present	
Brays Bayou at Houston	75000	94.9 (j)	6/36-Present	
Simms Bayou at Hiram Clarke St at Houston	75400	20.2 (k)	9/64-12/78, 9/79-7/93, 9/93-3/96, 5/96-10/98	
Simms Bayou at Houston	75500	64	10/52-3/96	
Berry Bayou at Forest Oaks St at Houston	75650	11.1 (l)	5/64-9/66	
Vince Bayou at Pasadena	75730	8.21	10/71-Present	
Hunting Bayou at I-H 610 at Houston	75770	16.8	5/64-Present	
Greens Bayou at Cutten Rd near Houston	75780	8.65	10/95-Present	
Greens Bayou at U.S. Highway 75 near Houston	75900	34.8 (m)	8/65-11/80 & 3/81-10/92	
Greens Bayou near Houston	76000	72.7 (n)	10/52-Present	
Garners Bayou near Humble	76180	31 (o)	2/86-Present	
Halls Bayou at Houston	76500	24.7 (p)	10/52-Present	
Greens Bayou at Lay Rd at Houston	76700	182 (q)	1/71-12/75	No data available
Carpenters Bayou near Channelview	76900	25.8	10/92-9/93	
Carpenters Bayou at IH10 near Channelview	76902	25.9	12/90-8/92 & 10/92-10/94 & 12/94-12/94 & 4/98-4/98	
Turkey Creek near Friendswood	77520	6.48	10/91-7/92 & 10/92-5/95	

Notes:

(a) From February 16, 1976 to September 30, 1995, Spring Creek near Spring was called the Spring Creek At Spring and was 3.6 miles downstream of the present site. The drainage area of the Spring Creek at Spring gage was 419 square miles.

(b) Little Cypress Creek near Cypress reported peak discharges above base flow since October 1, 1992.

(c) Cypress Creek at Grant Road near Cypress reported peak discharges above base flow since October 1, 1992.

(d) Cypress Creek at Stuebner-Airline Road near Westfield reported annual maximum discharge between October 1989 to September 1992, and peak discharges above base flow since October 1, 1992.

(e) Prior to June 17, 1965, Caney Creek near Splendora was 170 feet upstream of present site.

(f) Between March 1, 1984 and March 12, 1985, Bear Creek near Barker was 1,100 feet downstream of present site.

(g) Prior to February 2, 1948, Buffalo Bayou near Addicks was in a natural channel 1,200 feet to the right of the existing site.

(h) Between October 1957 and December 1961 and since October 1975, Buffalo Bayou at Houston reports only high-water discharge measurements.

(i) Prior to April 28, 1965, Whiteoak Bayou at Houston was 480 feet upstream of the present site.

(j) Prior to November 25, 1959, Brays Bayou at Houston was 0.8 miles downstream of the present site.

(k) Between December 6, 1978 and August 31, 1979, Sims Bayou at Hiram Clarke Street, Houston reported peak discharge only. From October 1991 to September 1992 it reported annual maximum, and from October 1992 to September 1996 it reported peak discharges greater than the base flow.

(l) From October 1967 to September 1982, Berry Bayou at Forest Oaks Street, Houston reported peak discharge greater than base discharge.

(m) Since October 1992, Greens Bayou near U.S. Highway 75 Near Houston has reported only peak discharges greater than base flow.

(n) Drainage areas for Greens Bayou near Houston have changed due to relocation of drainage ditches. From October 1952 to September 30, 1973 the drainage area was 72.7 square miles. From October 1, 1973 to September 30, 1988, the drainage area was 69.6 square miles.

(o) Since October 1993, Garnes Bayou near Humble reports only peaks above base discharge.

(p) Since October 1993, Halls Bayou at Houston reports only peaks above base discharge. From October 1, 1973, to September 30, 1977, the drainage area was 28.3 square miles. From October 1, 1977 to September 30, 1988, the drainage area was 27.6 square miles. Prior to October 1, 1973, that drainage area was 24.7 square miles.

(q) Since August 12, 1992, Greens Bayou at Ley Road, Houston reports highwater records only.

Figure 2 Hydrological Records for USGS Gages in the San Jacinto River Basin

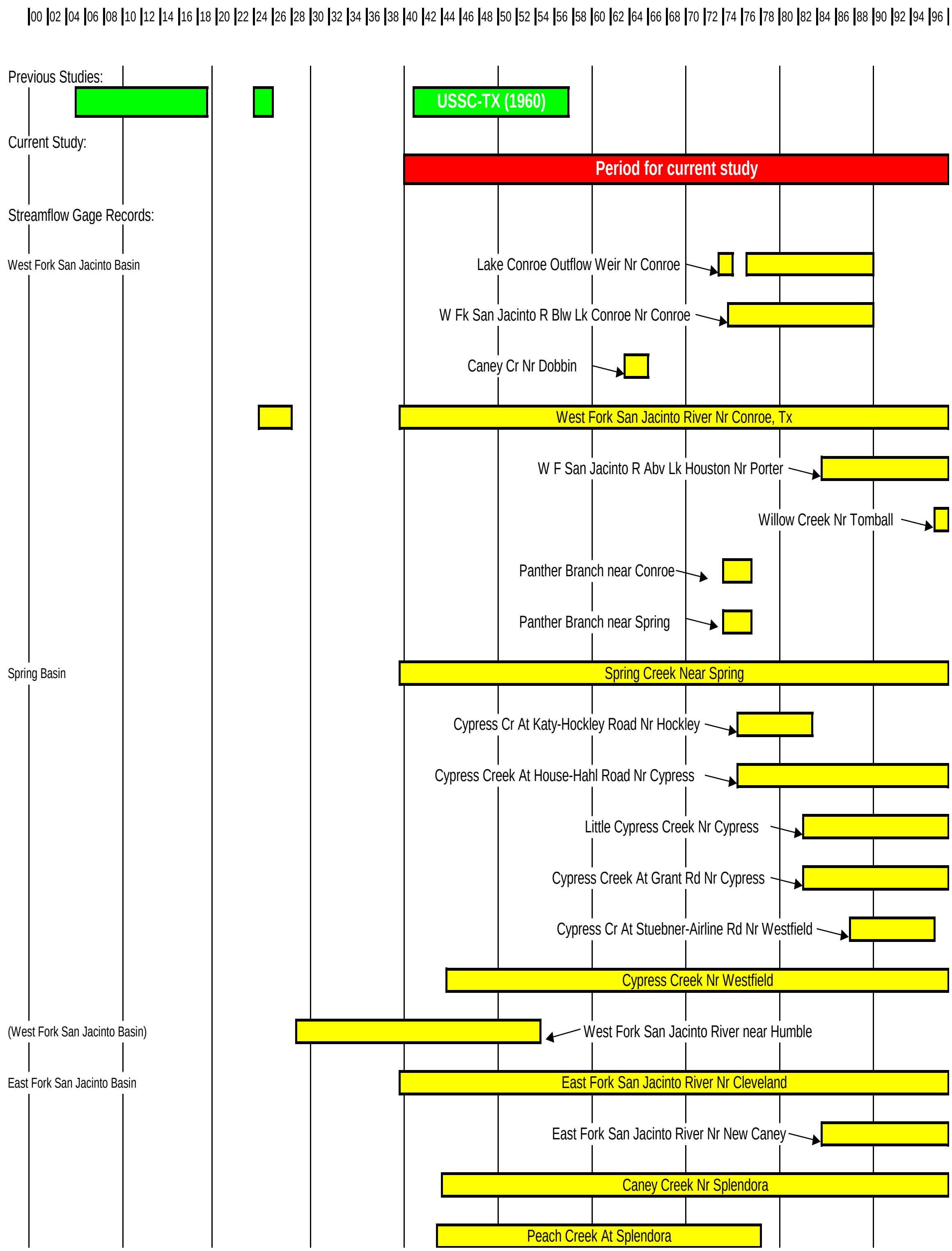


Figure 2 Hydrological Records for USGS Gages in the San Jacinto River Basin (Continued)

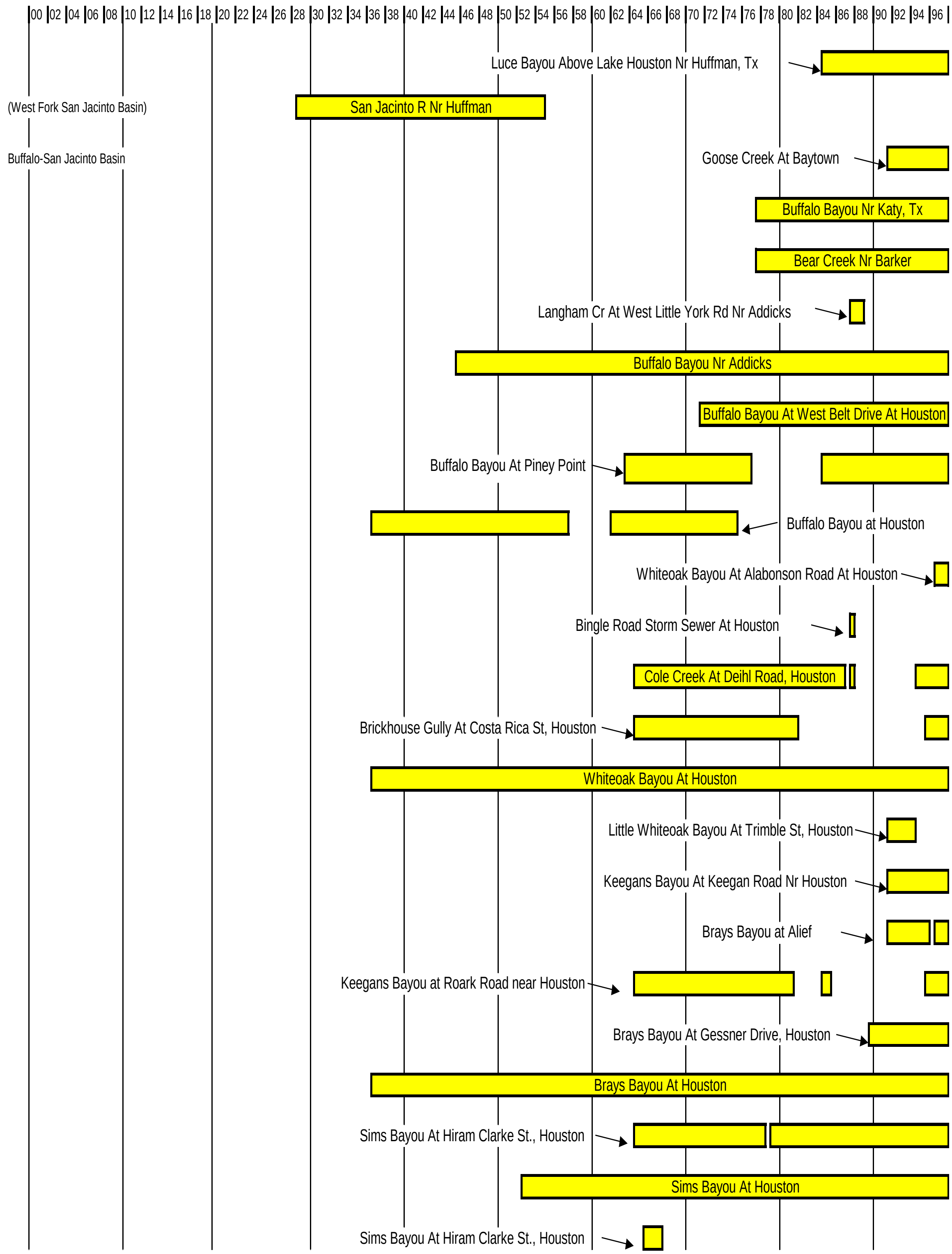
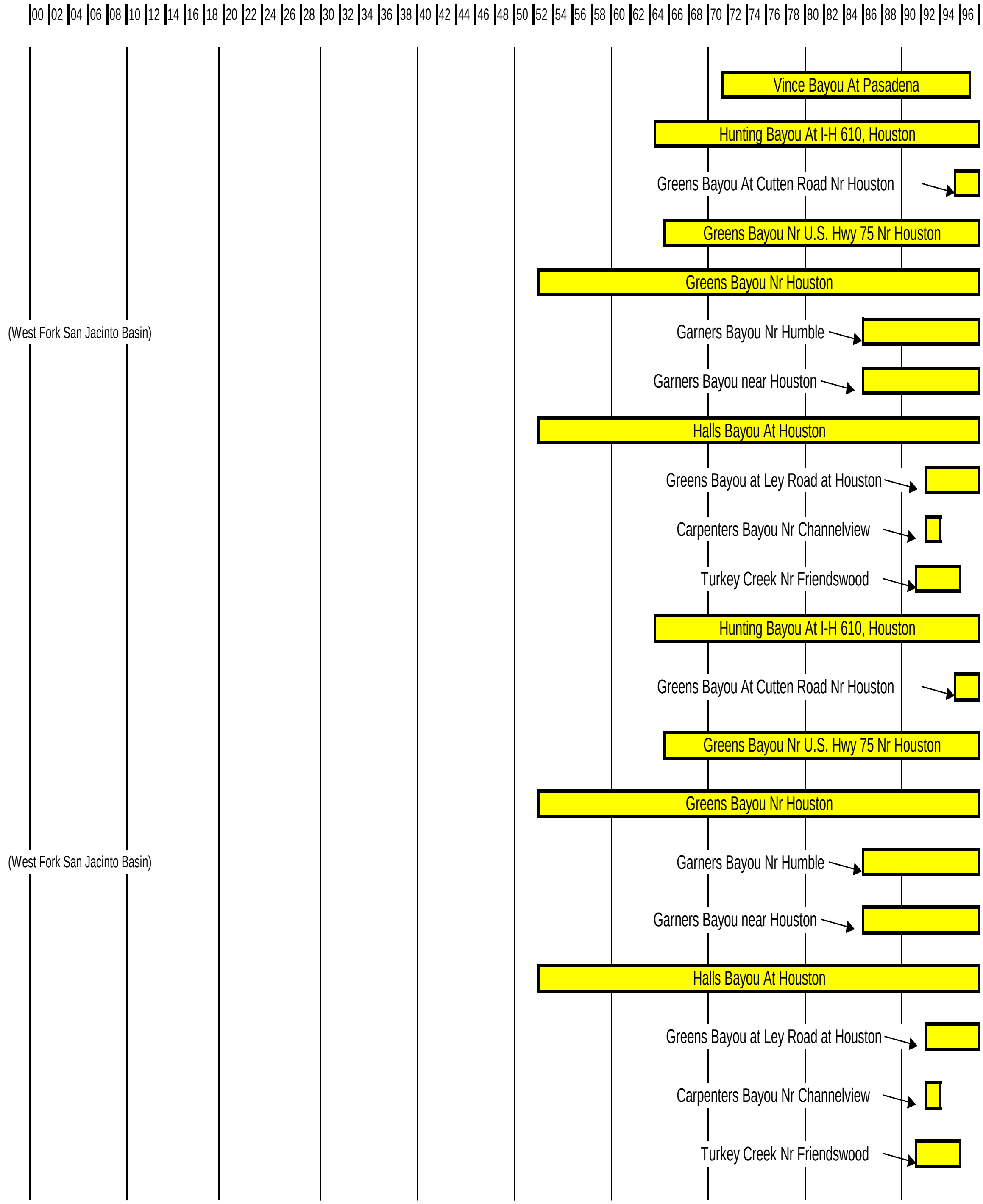


Figure 2 Hydrological Records for USGS Gages in the San Jacinto River Basin (Continued)



primary control points are shown in Figure 3. When USGS streamflow records were not available for a particular gaging station, naturalized flows were estimated using nearby control points in adjacent watersheds. Double mass curves and scatter plots were created between control points for periods when they were available. Linear regressions were used to estimate the naturalized flow when one of the measurements was not available. Table 4 illustrates possible sources considered in filling missing records for each control point. The linear regression equations used to fill the missing naturalized flow estimates are summarized in Table 5. Appendix G gives a complete list of the options considered to fill in missing data. Appendix I shows the San Jacinto River Basin naturalized flows for the primary control points.

There are no records of historical streamflow at the mouth of the San Jacinto River at Galveston Bay. Naturalized flows for this location were estimated on the basis of naturalized incremental flows of primary control points immediately upstream. These include the gages on Buffalo Bayou, Brays Bayou, Sims Bayou, Greens Bayou, White Oak Bayou, and the San Jacinto River.

A comparison of flow at the Brays Bayou control point (BR_HO) to flow at the Buffalo Bayou at Addicks (BB_AD) and Sims Bayou near Houston (SB_HO) control points indicates a change in the runoff characteristics for the Brays Bayou gage in 1984. This change could result from a change in drainage areas, runoff characteristics, diversions, or return flows. The scatter plots and regression were split into two time periods to reflect the observed change. Naturalized flows for the Sims Bayou control point (SB_HO) were estimated using values from BR_HO. Because of the change in the runoff characteristics for BR_HO, a different relationship was used to fill the two periods of missing data (1940 - 1952 and 1995 - 1996). The Sims Bayou at Hiram Clark Street gage was not used to estimate SB_HO flows because it does not overlap the first eight years.

Incremental flows for each primary control point were calculated by subtracting all naturalized flows at upstream control points from the naturalized flow at the primary control point. Appendix M-1 summarizes sub-watershed intervening flows for the San Jacinto Basin before any adjustments were made to remove negative incremental flows. The control point of the San Jacinto River at Galveston Bay (SR_GB) was not included in this calculation because its values are calculated from the final incremental flow values of upstream stations.

Figure 3 Hydrology Records for Control Points in the San Jacinto River Basin

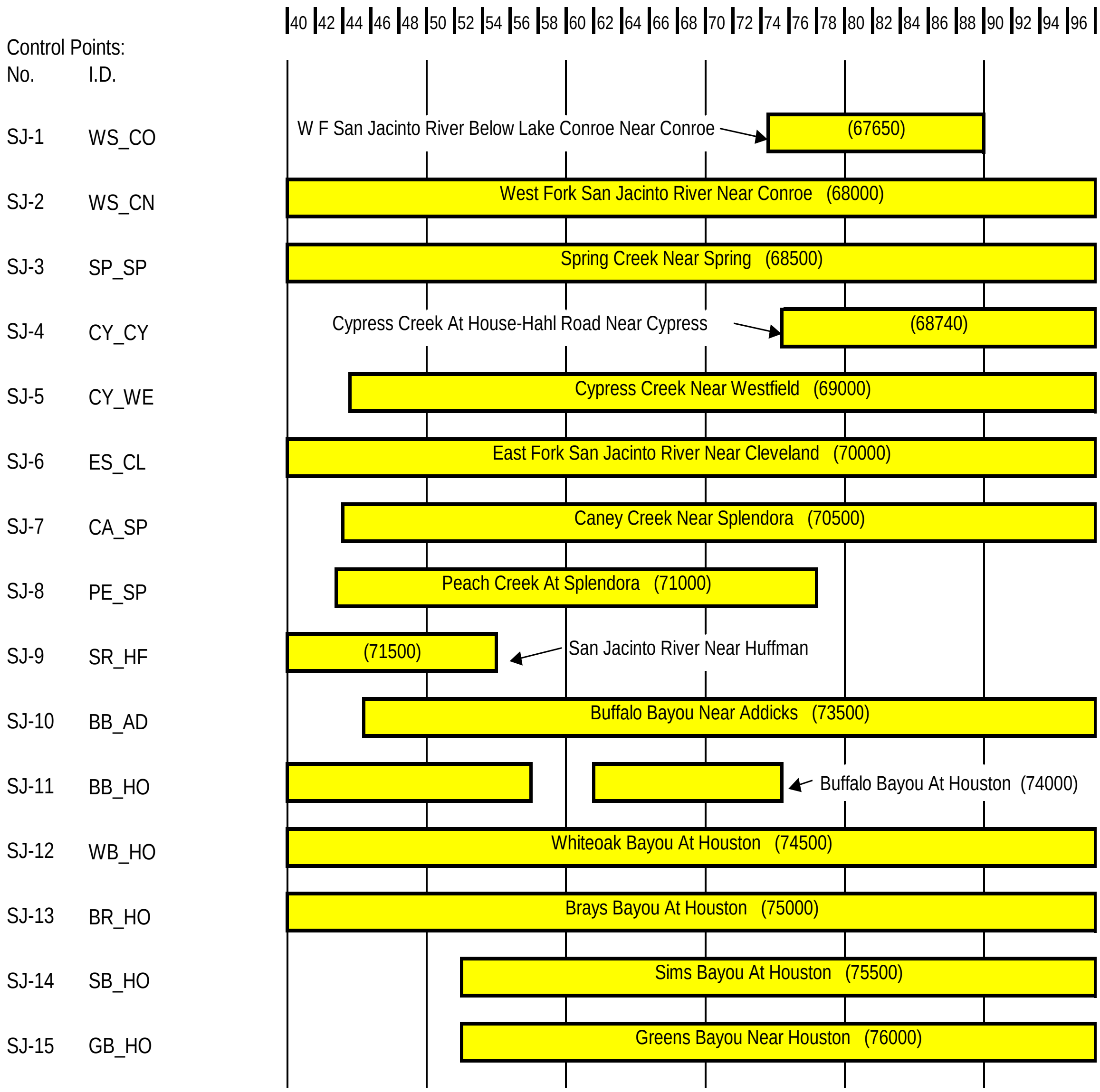


Table 4 Estimation of Missing Naturalized Flow Data

Control Point		Missing Data	Possible Source(s) to Fill in Data	Period of Overlap
WS_CO	West Fork San Jacinto below Lake Conroe near Conroe	1/40-9/43 10/43-8/74 10/89-12/96	West Fork San Jacinto River near Conroe Caney Creek near Splendora *or* West Fork San Jacinto River near Conroe Caney Creek near Splendora *or* West Fork San Jacinto River near Conroe	9/74-9/89 9/74-9/89 9/74-9/89 9/74-9/89 9/74-9/89
WS_CN	West Fork San Jacinto River near Conroe	None	---	---
SR_HF	San Jacinto River near Huffman	10/53-12/96	Spring Creek near Spring	10/36-9/53
SP_SP	Spring Creek near Spring	10/75-9/95	use Spring Creek at Spring (formerly near) x 409/419	---
CY_CY	Cypress Creek at House and Hahl Roads near Cypress	1/40-6/44 7/44-5/75	Spring Creek near Spring Spring Creek near Spring *or* Cypress Creek near Westfield	6/75-Present 6/75-Present 6/75-Present
CY_WE	Cypress Creek near Westfield	1/40-6/44	Spring Creek near Spring *or*	7/44-Present
ES_CL	East Fork San Jacinto River near Cleveland	None	---	---
CA_SP	Caney Creek near Splendora	1/40-9/43	West Fork San Jacinto River near Conroe *or* Spring Creek near Spring *or* East Fork San Jacinto River near Cleveland	10/43-Present 10/43-Present 10/43-Present
PE_SP	Peach Creek at Splendora	1/40-9/43 10/77-12/96	East Fork San Jacinto River near Cleveland *or* West Fork San Jacinto River near Conroe East Fork San Jacinto River near Cleveland *or* Caney Creek near Splendora	10/43-9/77 10/43-9/77 10/43-9/77 10/43-9/77
BB_AD	Buffalo Bayou near Addicks	1/40-8/45	Buffalo Bayou at Houston	9/45-9/57 & 1/62-9/75
BB_HO	Buffalo Bayou at Houston	10/57-1/61 10/75-12/96	Whiteoak Bayou at Houston *or* Brays Bayou at Houston or Buffalo Bayou near Addicks Whiteoak Bayou at Houston *or* Brays Bayou at Houston *or* Buffalo Bayou near Addicks	6/36-9/57 & 1/62-9/75 6/36-9/57 & 1/62-9/75 9/45-9/57- & 1/62-9/75 6/36-9/57 & 1/62-9/75 6/36-9/57 & 1/62-9/75 9/45-9/57- & 1/62-9/75
WB_HO	Whiteoak Bayou at Houston	None	---	---

Control Point		Missing Data	Possible Source(s) to Fill in Data	Period of Overlap
BR_HO	Brays Bayou at Houston	None	---	---
SB_HO	Sims Bayou at Houston	1/40-9/52 4/96-12/96	Brays Bayou at Houston Brays Bayou at Houston	10/52-3/96 10/52-3/96
GB_HO	Greens Bayou near Houston	1/40-9/52 10/73-9/88	Whiteoak Bayou at Houston adjust by 72.7/69.6	10/52-Present
SR_GB	San Jacinto River at Galveston Bay	1/40-12/96		

Table 5 Summary of Equations used to Complete Naturalized Flow Data

Control Point	Missing Data	SLOPE
WS_CO	1/40-9/40	**0.4973 * WS_CN**
	10/43-8/74	**0.4973 * WS_CN**
	10/89-12/96	**0.4973 * WS_CN**
CY_CY	1/40-6/44	**0.315 * SP_SP**
	7/44-5/75	**0.4697 * CY_WE**
CY_WE	1/40 - 6/44	**0.7396 * SP_SP**
CA_SP	1/40-12/43	**0.2758 * ES_CL + 694**
PE_SP	1/40-9/43	**0.2693 * ES_CL + 1429.6**
	10/77-12/96	**0.19681*ES_CL + 0.3856*CA_SP + 692**
SR_HF	10/53-12/96	**1.4321 (SP_SP + WS_CN + CY_WE + CA_SP + ES_CL + PE_SP)**
BB_AD	1/40-8/45	**0.7628 * BB_HO**
BB_HO	10/57-12/61	**1.2915 * BB_AD**
	10/75-12/96	**1.2915 * BB_AD**
GB_HO	1/40-9/52	**0.7386 * WB_HO**
SB_HO	1/40-9/52	**0.66 * BR_HO**
	4/96-12/96	**0.5879 * BR_HO**
SR_GB	1/140-12/96	**y = (1 + 510.7/1160) * (SB_HO + BR_HO + BB_HO + WB_HO + GB_HO + SR_HF) - (510.7/1160) * (BB_AD + CY_WE + SP_SP + WS_CN + CA_SP + ES_CL + PE_SP)**

The West Fork San Jacinto River near Humble was originally considered as a primary control point, but it was removed to make flow distributions more consistent throughout the San Jacinto River Basin. The incremental flows for the West Fork San Jacinto River near Humble watershed were inexplicably larger than the other watersheds in the San Jacinto Basin. The high incremental flows above Humble reduced the apparent incremental flows for the SR_HU control point. Without the West Fork San Jacinto River near Humble control point, the incremental flows for SR_HU are very consistent with the other gages in San Jacinto River Basin, as shown in Appendix M-1.

Negative incremental flows (i.e., cases where there is less flow at the downstream control point of a sub-watershed than the sum of the flows at the upstream control points during a given month) were eliminated for this study because they are undesirable for WRAP. Negative incremental flows were eliminated by making equal and opposite changes in two successive flows at a single control point. Shifting flow between adjacent months changes the timing but not the total annual flow originating from an area. These adjustments are not automatically a sign of incorrect data, and they can result from a variety of causes. For example:

a. Storm timing that catches part of the runoff in passage through the sub-watershed at the end of the month.
b. Lack of precision in USGS gage records.
c. Channel losses.

Appendix M-2 shows intervening flows for the San Jacinto River Basin after making adjustments for negative incremental flows. Naturalized flow values for SR_GB were calculated from the final incremental flow values of upstream stations.

3.1.5 Comparison with Other Naturalized Streamflow

Comparison of Naturalized Flows to TNRCC Legacy WAM

The TNRCC developed a water availability model, the Legacy WAM, for the San Jacinto River Basin in 1983. The TNRCC modeling effort included estimates of naturalized flow for the period between 1940 and 1980. As a quality control, the new naturalized flow estimates were compared to the previous TNRCC estimates. Appendix H contains the double mass curves of the two estimates for the period of overlap.

Double mass curves identify when naturalized flows at different control points are well correlated, when the correlation changes, and when they are poorly correlated. If the double mass curve is a straight line, the two control points are well correlated. In addition, the slope of a double mass curve identifies the ratio of flow values. We consider a difference in slope of less than 5% to be consistent with the Legacy WAM data. The control points with double mass curves having more than a 5% difference in slope are discussed below.

Discussion of the current study Double Mass Curves and TNRCC Legacy WAM

The West Fork of the San Jacinto River at Lake Conroe (WS_CO) flows differed from the TNRCC Legacy WAM. The ratio of the cumulative flow values through January 1973 is 0.9237. After 1973, the values differ quite significantly. The difference prior to 1973 is due to the approach to filling data. The WS_CN gage was used as the basis for our filled data. Lake Conroe was built and began to retain water in January 1973, and the ratio between the current values and the TNRCC Legacy WAM values decreased after this date. The Legacy WAM data for WS_CO and WS_CN were compared using a double mass curve. The Legacy WAM data for WS_CO are inconsistent with the Legacy WAM data for WS_CN, as indicated in Appendix H-1.

The Caney Creek at Splendora (CA_SP) gage record for June of 1973 was misprinted in the U.S.G.S. streamflow records. The corrected value is ten times the old flow record. The TNRCC Legacy WAM used the uncorrected flow and the current analysis used the corrected flow. This error is shown in the jump on the double mass curve for CA_SP in Appendix H-1. The slope of the line is otherwise consistent.

The Brays Bayou near Houston (BR_HO) ratio is 0.907. The next figure in Appendix H-1 is a double mass curve of the raw historical flows measured by the USGS with the Legacy WAM values. The resulting ratio is 1.002, which indicates that the Legacy WAM flows did not account for return flows or diversions within the basin. The bend in the double mass curve of our adjusted flows and the Legacy WAM also shows the influence of increasing return flows.

The San Jacinto River near Huffman (SR_HF) gage double mass curve has a ratio of 1.076. Although this ratio has an overall high value, the ratio is inconsistent through the data set. Control points upstream of this gage have consistent values. The data are similar to the USGS data for the first 12 years. However, the Legacy WAM flows do not match the USGS data well. The source of this difference is unknown. It appears that the Legacy WAM did not use the Huffman gage as a control point. As will be discussed below, the current values match the naturalized flow estimates of the US Study Commission very well.

The San Jacinto River at Galveston Bay ratio was 1.108. This is a substantial difference in the cumulative flow between the current values and the TNRCC Legacy WAM flows. This ratio and the ratio observed for the SR_HF control point indicate that the current study has significantly more naturalized flow in the basin than did the TNRCC Legacy WAM. This difference in naturalized flows is entirely the result of different incremental flows for the SR_HF and SR_GB control points.

The last downstream gages data used in the TNRCC Legacy WAM appear to be the West Fork San Jacinto River near Conroe (WS_CN), Cypress Creek near Westfield (CY_WE), Spring Creek near Spring (SP_SP), East Fork San Jacinto River near Cleveland (ES_CL), Caney Creek near Splendora (CA_SP), Peach Creek at Splendora (PE_SP), Buffalo Bayou at Houston (BB_HO), Sims Bayou at Houston (SB_HO), Whiteoak Bayou at Houston (WB_HO), and Greens Bayou at Houston (GB_HO). Appendix H-1 contains a double mass curve comparing the current study's total flows at these control points with the Legacy WAM flows. The ratio of cumulative flows for the upstream gages is 0.988 and shows that there is very close agreement between the naturalized flow estimates for these gages.

The following figure in Appendix H-1 is a double mass curve of flows below these gages (i.e. incremental flow to the San Jacinto River near Huffman and the San Jacinto River at Galveston Bay). Unlike the flows at the upstream control points, these incremental flows show large differences. The current values are consistently higher than the Legacy WAM.

In a comparison between unit runoff for the period of overlapping records (1940-1980), the values for the upstream control points are similar, but the current values for SR_HF and

SR_GB are much higher than the Legacy WAM. It seems unlikely that the Legacy WAM values are correct for several reasons.

- The general pattern in the San Jacinto Basin is for incremental unit runoff to increase from upstream to downstream. The Legacy WAM incremental unit runoff values for SR_HF and SR_GB are significantly lower than the total for upstream gages, which seems unlikely to be correct.

- Rainfall in the San Jacinto Basin increases from West to East, which makes it less likely that extremely low runoff values are correct for SR_HF and SR_GB, which are in the eastern part of the watershed.

- As will be discussed below, current total runoff values for SR_HF are very close to the US Study Commission runoffs.

Comparison of Naturalized Flows to US Study Commission

The United States Study Commission-Texas published naturalized flow estimates for the San Jacinto River Basin in September, 1960. The period of overlap between the USSC and current study is from 1941 to 1956. In its study, the USSC reports naturalized flow estimates at the 15 control points, normally corresponding to proposed dam sites in the basin. Three of the USSC control points are included in the current study: Buffalo Bayou near Addicks (BB_AD), San Jacinto River near Huffman (SR_HF), and San Jacinto River at Galveston Bay (SR_GB).

Current estimates of naturalized flow at BB_AD agree very well with the USSC estimates after the USGS gage is present. Prior to 1945, it appears that the USSC used a drainage area ratio of 0.856 between BB_AD and BB_HO to predict runoff at BB_AD. This difference in modeling approach is the primary difference between the current study's estimates and USSC estimates shown in Appendix H-2. The Legacy WAM results are generally closer to the USSC estimates prior to 1945, but they are not consistent. For the current study a lower ratio than the USSC was used to estimate unknown flows at BB_AD that improved the goodness of fit between the predicted and observed values for the period of overlap.

The naturalized flow estimates for SR_HF and SR_GB are much closer to USSC data than they are to the Legacy WAM. The flows at SR_HF are very similar, as shown in Appendix H-2. Ultimately, the TNRCC Legacy WAM flow estimates for SR_HF and SR_GB are much different than both the current study's naturalized flows and the USSC estimates. Double mass curves comparing flow estimates for these control point are shown in Appendix H-2. The slight differences from the USSC estimates for the SR_GB control point probably result from differences in analysis approach.

3.1.6 Statistical Assessment of Trends in Streamflow

Trends in streamflow were analyzed by comparing historical to naturalized flows at control points that are also USGS gages. For these control points, the historical gaged flows were compared to the estimated natural flows for the corresponding years with actual gaged data. The minimum, 90 percent exceedance, 75 percent exceedance, median, 25 percent exceedance, 10 percent exceedance, maximum, and average flows were calculated for each month. Complete tables for each of these control points are in Appendix J, along with the double mass curve comparing the gage flow to the naturalized flow.

Table 6 lists the control points along with the comparison periods, the median annual flows for both the gaged and naturalized flows, and the ratio of the cumulative naturalized flow to the cumulative gaged flow.

Table 6 Naturalized Streamflow Comparison Summary San Jacinto Basin Control Points

No.	I.D.	Gage	USGS Number	Drainage Area (Square Miles)	Comparison Period	Median Annual Gage Flow (acre-ft)	Median Annual Naturalized Flow (acre-ft)	Cumulative Naturalized Flow/Gage Flow Ratio
SJ-1	WS_CO	West Fork San Jacinto below Lake Conroe near Conroe	67650	451	1975-1988	150,004	176,991	1.124
SJ-2	WS_CN	West Fork San Jacinto River near Conroe	68000	809	1940-1996	324,916	334,265	1.047
SJ-3	SP_SP	Spring Creek near Spring	68500	409	1940-1993 & 1996	138,097	138,090	0.982
SJ-4	CY_CY	Cypress Creek at House and Hahl Roads near Cypress	68740	131	1976-1996	50,101	51,658	1.025
SJ-5	CY_WE	Cypress Creek near Westfield	69000	285	1945-1996	116,498	113,201	0.970
SJ-6	ES_CL	East Fork San Jacinto River near Cleveland	70000	325	1940-1996	162,200	162,203	1.000
SJ-7	CA_SP	Caney Creek near Splendora	70500	105	1944-1996	49,953	49,953	1.000
SJ-8	PE_SP	Peach Creek at Splendora	71000	117	1944-1976	41,772	41,772	1.000
SJ-9	SR_HF	San Jacinto River near Huffman	71500	2,791	1940-1952	1,604,584	1,604,584	1.000
SJ-10	BB_AD	Buffalo Bayou near Addicks	73500	293	1946-1996	150,190	145,986	0.978
SJ-11	BB_HO	Buffalo Bayou at Houston	74000	358	1940-1956 & 1962-1974	176,946	173,549	0.979
SJ-12	WB_HO	Whiteoak Bayou at Houston	74500	84.7	1940-1996	74,436	61,057	0.915
SJ-13	BR_HO	Brays Bayou at Houston	75000	94.9	1940-1996	110,216	88,676	0.780
SJ-14	SB_HO	Sims Bayou at Houston	75500	64	1953-1994	71,140	60,868	0.860
SJ-15	GB_HO	Greens Bayou near Houston	76000	72.7	1953-Present	50,661	46,408	0.913

The annual statistics are shown in Figure 4, Figure 5 and Figure 6 for WS_CN, ES_CL and BB_HO, respectively. The 90 percent exceedance, median and 10 percent exceedance flows for control points WS_CN, ES_CL and BB_HO are displayed graphically in Figure 7, Figure 8, and Figure 9, respectively. The figures for WS_CN are generally representative of control points effected by the combination of upstream reservoirs and diversion. The figures for ES_CL are generally representative of areas minimally affected by changes to flow. The figures for BB_HO are generally representative of the areas with high return flows in the Houston area.

The naturalized flows show a fairly consistent relationship with the gaged flows when considering the various mechanisms affecting the gaged flows. The gaged and naturalized flows for the West Fork of the San Jacinto near Conroe (WS_CN) have a reasonable relationship considering the effects of Lake Conroe. The gaged flows at San Jacinto River below Lake Conroe near Conroe (WS_CO) control point is significantly affected by a combination of diversions, return flows, changes in reservoir content and evaporative losses associated with Lake Conroe operations. These changes in flow are translated downstream to the West Fork of the San Jacinto River near Conroe control point.

Many control points have identical or nearly identical gaged and naturalized flows because of the lack of flow modifications within the sub-basins. Control points where the naturalized flows are essentially the same as the gaged flows are East Fork of the San Jacinto River near Cleveland (ES_CL), Caney Creek near Splendora (CA_SP), and Peach Creek near Splendora (PE_SP). These control points are located in the relatively undeveloped northeastern portion of the San Jacinto Basin. San Jacinto River near Huffman (SR_HF) has a very close relation between the naturalized and gaged flows primarily as a result of the early gaging period (1940 to 1953) prior to upstream modifications.

Control points with relatively close relationships between gaged and naturalized flows include Spring Creek near Spring (SP_SP), Cypress Creek at House and Hahl Roads near Cypress (CY_CY), and Cypress Creek near Westfield (CY_WE). Spring Creek near Spring has nearly identical naturalized and gaged flows up through 1974. After 1974, the gaged flows are slightly higher due to return flows. At Cypress Creek at House and Hahl Roads near Cypress, the naturalized flows are slightly higher than the gaged flows due to upstream diversions from 1959 to present. Gaged flows are somewhat higher than the naturalized flows for Cypress Creek near Westfield, a result of increasing return flows after 1973.

The control points in and around Houston exhibit the effects of significant return flows. Typically, the return flows become increasingly significant after 1970. Buffalo Bayou near Addicks (BB_AD) and Buffalo Bayou at Houston (BB_HO) have slightly higher gaged flows compared to the naturalized flow resulting from moderate rates of return flows. High return flows result in gaged flows being somewhat higher than naturalized flows for Whiteoak Bayou near Houston (WB_HO) and Greens Bayou near Houston (GB_HO). Brays Bayou near Houston (BB_HO) and Sims Bayou near Houston (SB_HO) are affected by very high amounts of return flows.

Figure 4 WS_CN Statistical Comparison of Annual Historical and Naturalized Flows

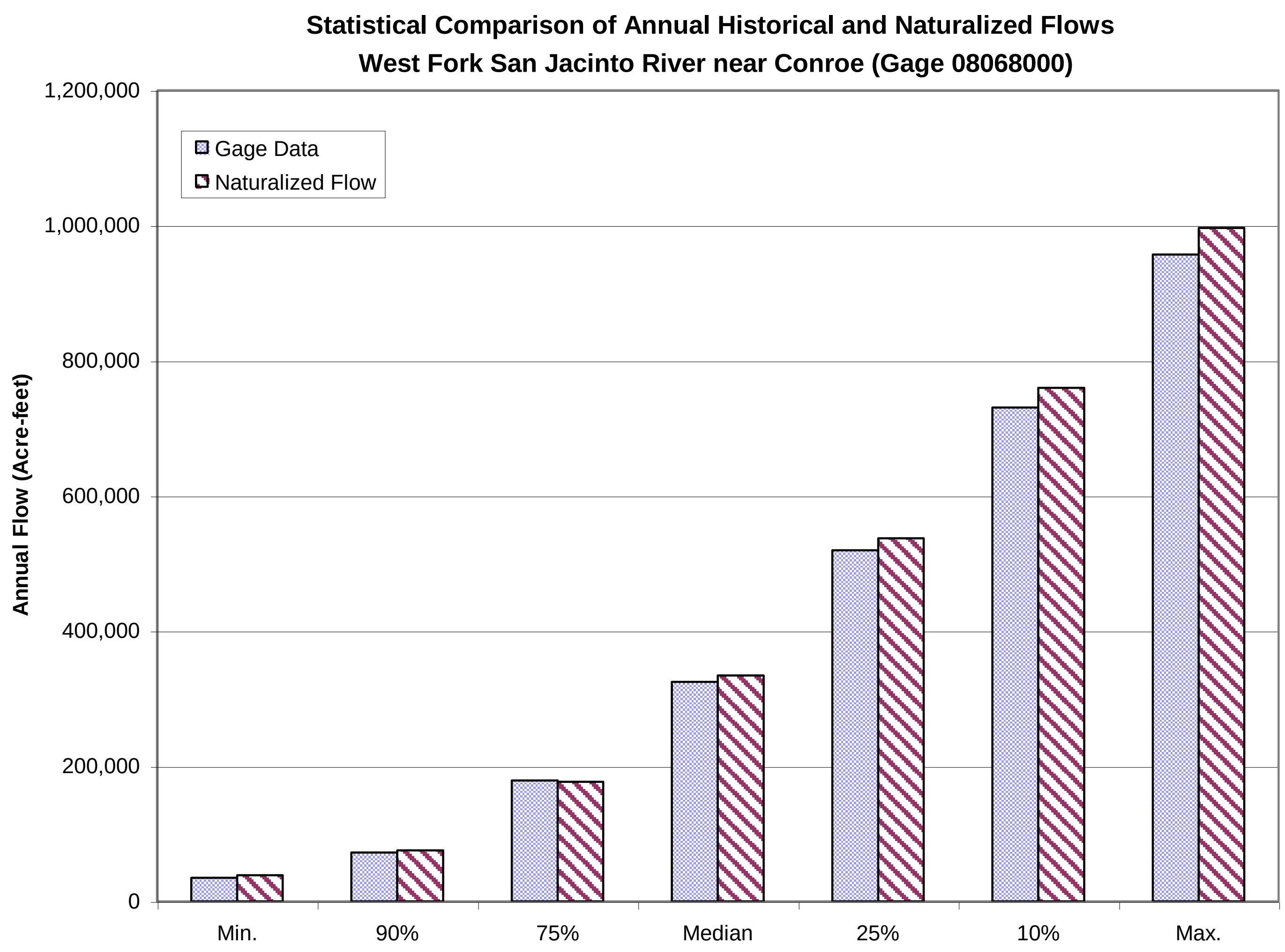


Figure 5 ES_CL Statistical Comparison of Annual Historical and Naturalized Flows

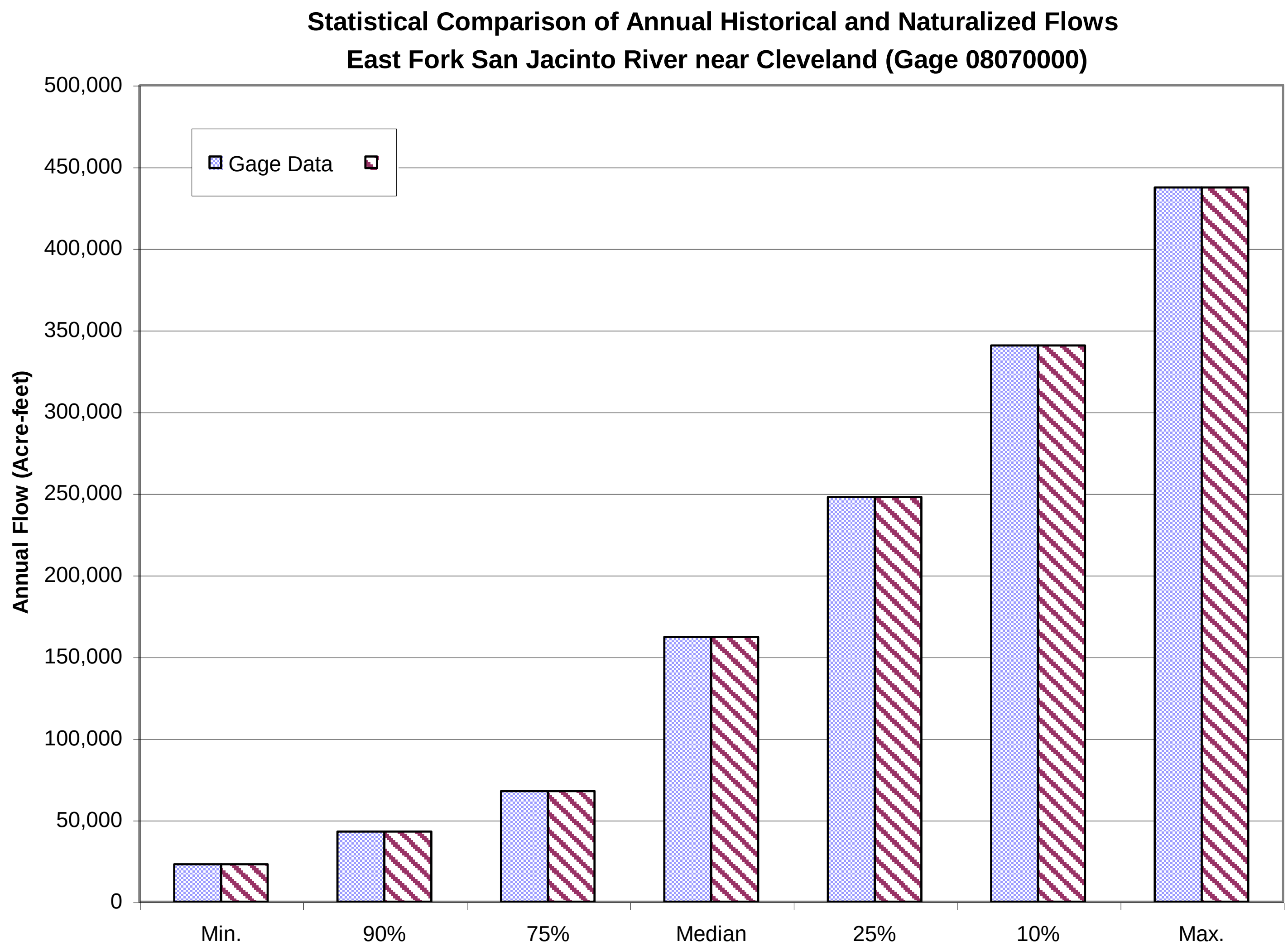


Figure 6 BB_HO Statistical Comparison of Annual Historical and Naturalized Flows

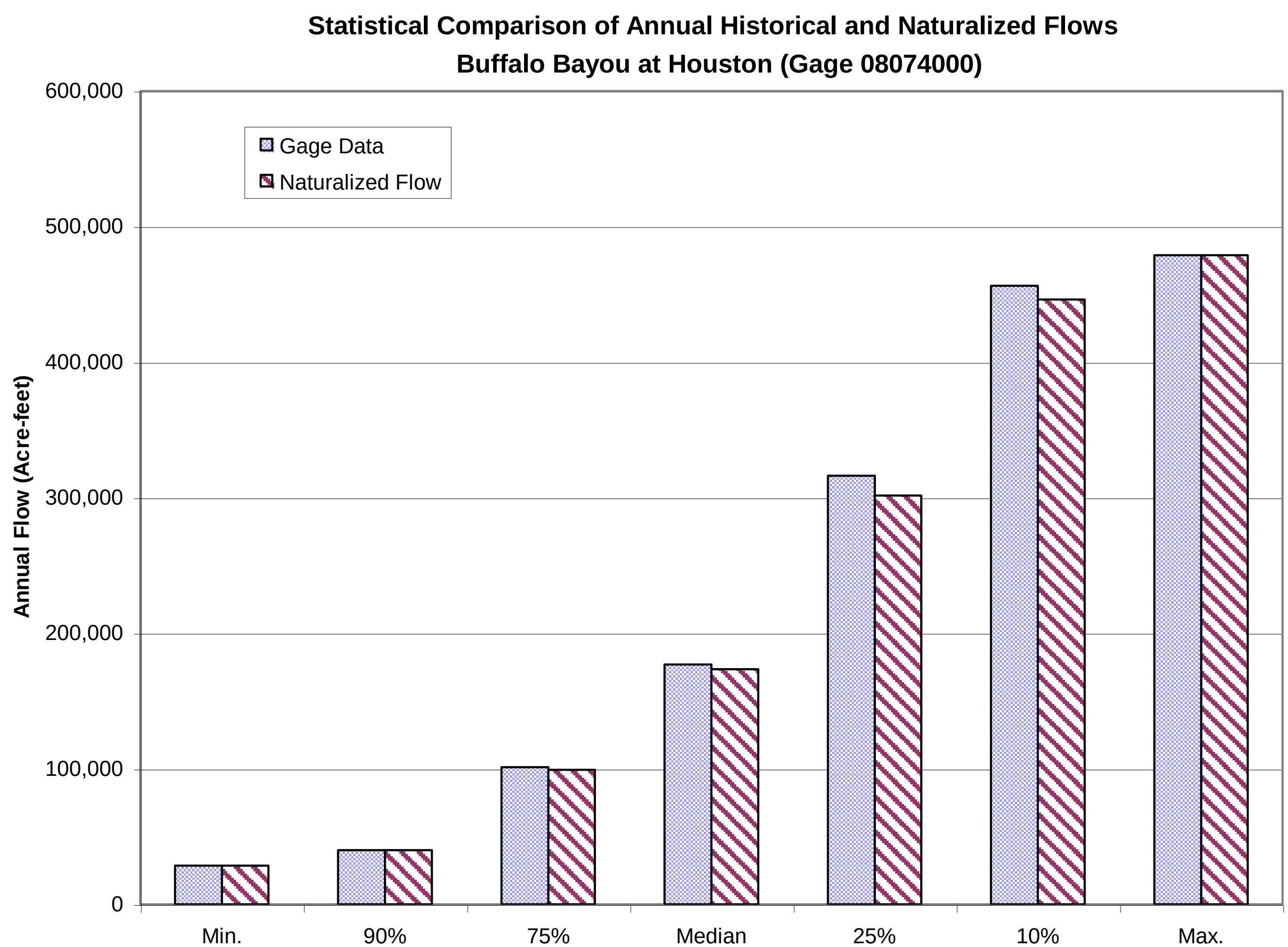


Figure 7 Monthly Statistics for WS_CN

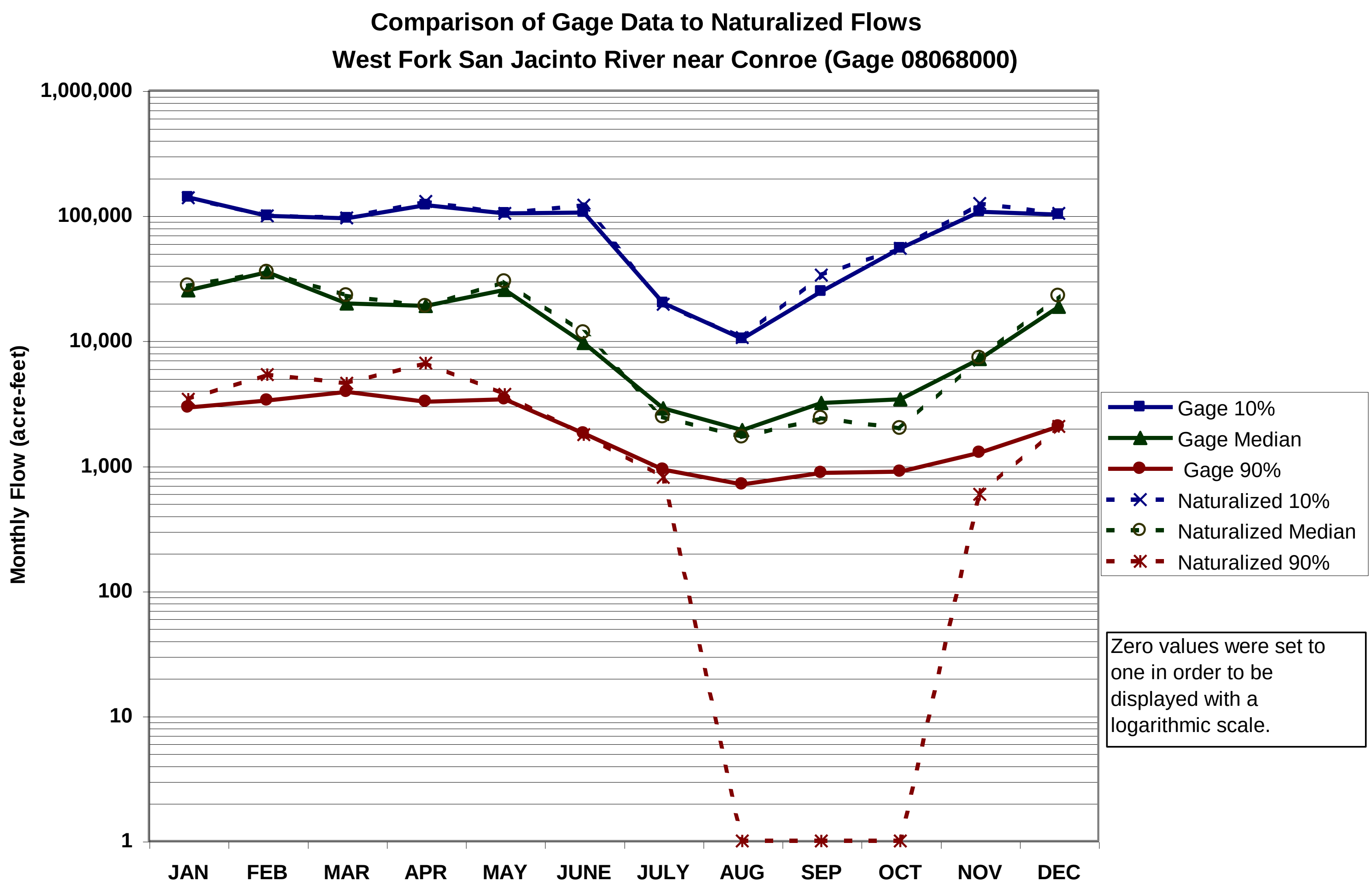


Figure 8 Monthly Statistics for ES_CL

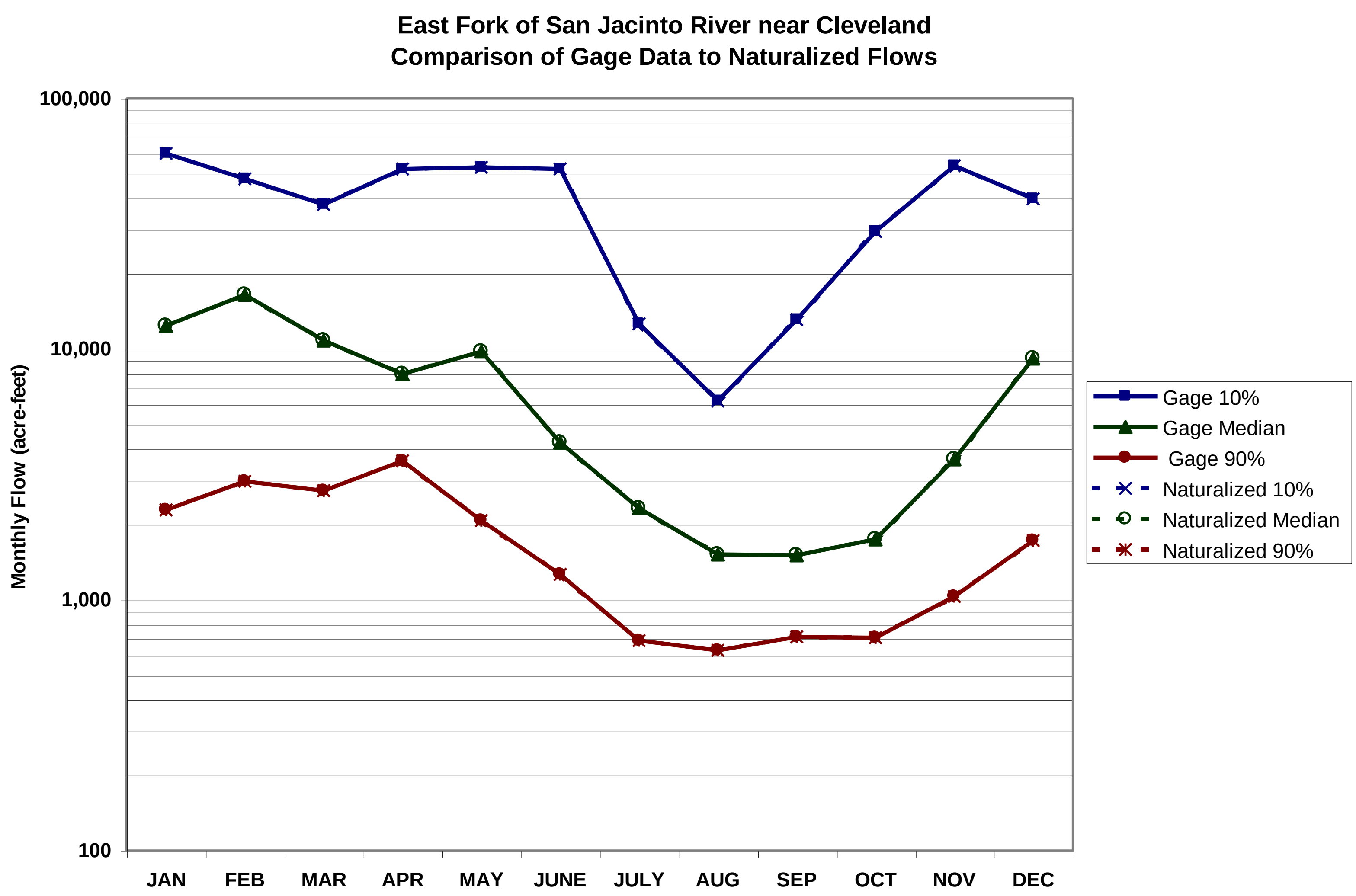
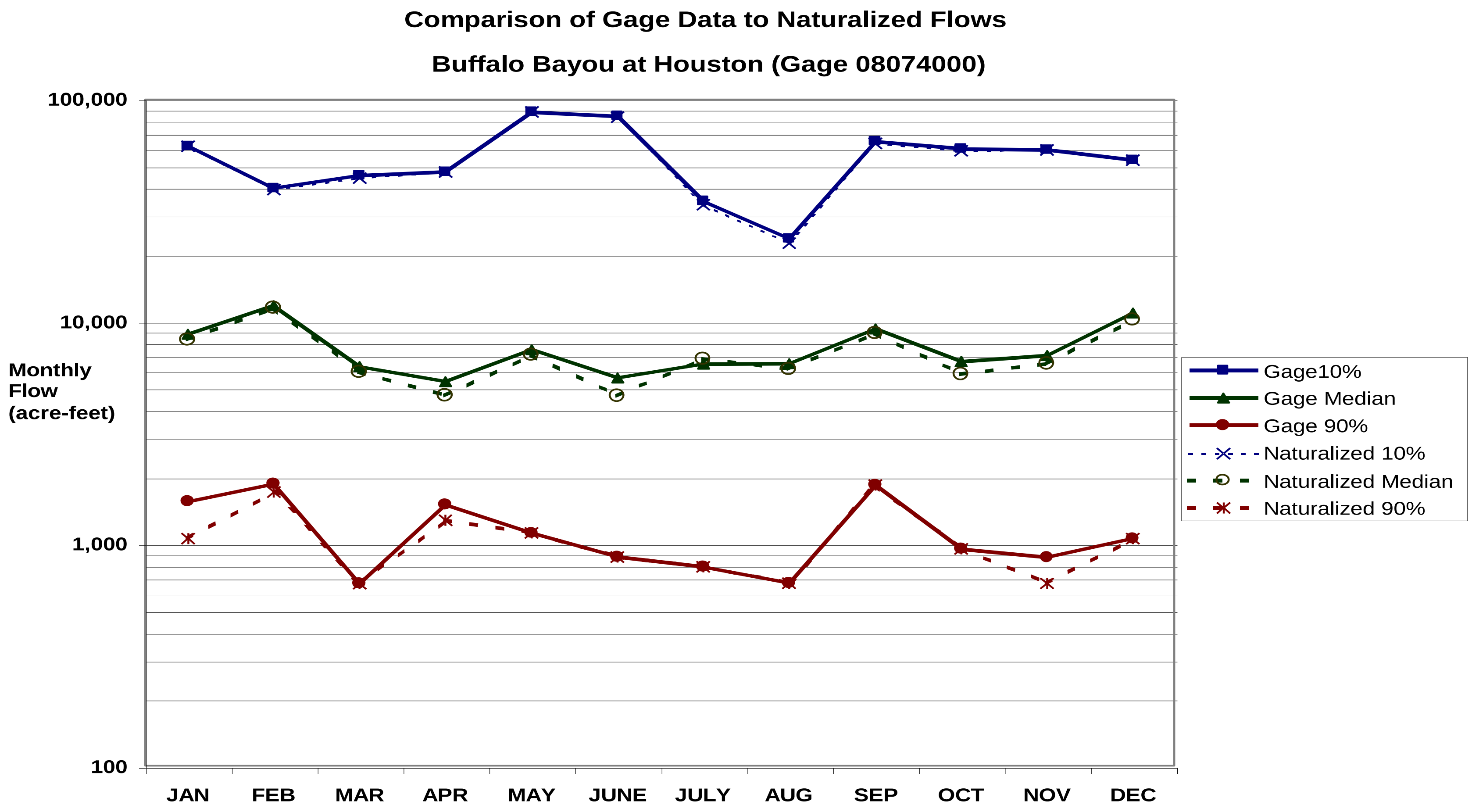


Figure 9 Monthly Statistics for BB_HO



3.2 Natural Streamflow at Ungaged Locations

Naturalized streamflow was derived at ungaged locations in the San Jacinto River Basin utilizing data from gaged sites and watershed parameters at ungaged sites within the WRAP (VER 10/99) program. Ungaged sites, or secondary control points, include any ungaged locations within the basin where water availability calculations need to be performed including diversion locations for water rights, the ends of classified stream segments, and return flow or groundwater inflow locations. The map attached in Appendix K provides the locations of all primary (gaged) and secondary (ungaged) control points.

WRAP (VER 10/99), developed by Dr. Ralph A. Wurbs at Texas A & M University, has the capability to compute naturalized flows at ungaged sites by utilizing the U. S. Natural Resources Conservation Service (NRCS) curve number (CN) method. Specifically, naturalized flows or inflows at gaged sites are input into the program along with curve numbers, mean annual precipitation, and total drainage areas of gaged and ungaged points. Watershed parameters were obtained from the University of Texas Center for Research Water Resources (CRWR). The specific methods used in this program are described in the WRAP (VER 10/99) user's manual. Secondary control points located at off-channel reservoirs were assumed to have no drainage areas so inflows at these points were set to zero. Table 7 provides the watershed parameters at all control points.

The NRCS CN method was developed in the 1950's by the Soil Conservation Service as a means of evaluating the effects of agricultural activities on runoff volumes. It has since been used to incorporate the effects of soil type and land cover, and mean precipitation to determine flow at ungaged sites. These parameters allow for localized effects in the computation of flows instead of determining flows at a point based solely on the ratio of the ungaged and gaged sites drainage areas. The NRCS CN method reduces to the drainage area method if the CN and precipitation at the ungaged and gaged sites are the same. The drainage area method distributes flow from a gaged to an ungaged location utilizing the following equation:

$$Q_{ungaged} = Q_{gaged}\left(\frac{A_{ungaged}}{A_{gaged}}\right)$$

The NRCS Curve Number method adds an adjustment for watershed characteristics is as follows:

$$Q = \left[\frac{(P-0.2S)^2}{(P+0.8S)}\right]$$

$$if\;\; P \geq 0.2S$$

$$Q = 0 \longrightarrow if\;\; P \leq 0.2S$$

$$where\;\; S = \left(\frac{1000}{CN}\right) - 10$$

In this equation S represents the potential maximum retention, an upper limit on the amount of water that can be removed through surface storage, infiltration, or other hydrologic methods by the watershed. The value for S is derived from the curve number. The CN is a dimensionless parameter ranging in value from 0 to 100 that represents the ability of the watershed to absorb water. A CN of zero represents a watershed that is capable of absorbing all rainfall regardless of amount while a CN of 100 represents an impervious watershed that is incapable of absorbing any rainfall.

WRAP (VER 10/99) utilizes the following algorithm to calculate flows at ungaged sites:

1. The runoff at the gage (Q) is computed by dividing streamflow at the gage by the drainage area of the gage and multiplying the product by a conversion factor to change the units of runoff from acre-feet per month to inches per month.

2. The precipitation depth (P) at the gage is calculated through an iterative solution of the above equation given the runoff computed in step 1 and the value of S.

3. The precipitation depth at the ungaged site is computed by adjusting the precipitation depth at the gaged site by the ratio of the mean precipitation depth (M) at the ungaged and gaged sites.

$$P_{ungaged} = P_{gaged}\left(\frac{M_{ungaged}}{M_{gaged}}\right)$$

4. The runoff at the ungaged site is then computed by inputting the values for P and S at the ungaged site in the NRCS CN method equation. The computed value for the runoff is then converted to streamflow at the ungaged site by multiplying it by the drainage area of the ungaged site. Finally, a conversion factor is used to change the units of streamflow from inches per month to acre-feet per month.

In this study, the watershed parameters (the CN, mean precipitation, and drainage areas at gaged and ungaged sites) were derived by the CRWR using a geographic information system (GIS) grid basis. The CRWR used USGS digital elevation models (DEMs), Environmental Protection Agency (EPA) river reach segments, USGS gauging locations, U.S. Department of Agriculture-Parameter-elevation Regressions on Independent Slopes Model (PRISM) for mean annual precipitation, TNRCC water right diversion locations, and curve numbers derived by the NRCS at the Blackland Research Center at Texas A & M to create a geospatial database and model of the basin. From this geospatial model, the CRWR delineated drainage areas, curve numbers and mean annual precipitation for each water right diversion location within the basin.

Table 7 Control Points and Corresponding Watershed Parameters

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A4963A	450.02	64.77	44.61
WP	A4964A	2837.06	64.89	46.18
WP	A3995A	16.56	63.98	49.97
WP	1006	1036.64	77.55	46.61
WP	A3969A	0.26	62.32	45.16
WP	A3969B	0.42	66.80	45.16
WP	A3969C	0.04	56.09	45.16
WP	ESCL	324.58	60.77	47.19
WP	A5498A	341.09	60.67	47.35
WP	A3970A	358.92	60.75	47.48
WP	A3970B	358.94	60.75	47.48
WP	1003	393	60.93	47.66
WP	PESP	117.42	55.77	48.56
WP	1011	157.08	57.96	48.75
WP	A4309A	0.13	56.38	46.68
WP	A4309B	0.20	55.36	46.83
WP	A3971A	0.36	58.69	46.77
WP	A3972A	1.11	63.39	46.24
WP	A3973A	0.24	75.49	46.61
WP	A4255B	0.16	82.72	46.61
WP	A4255A	0.20	74.16	46.61
WP	A3974A	0.49	55.70	46.93
WP	A3975A	0.29	75.24	47.01
WP	A3976A	2.58	55.00	47.23
WP	A4255C	0.06	55.70	46.61
WP	A3977A	11.12	55.70	47.31
WP	A3978A	12.51	56.04	47.34
WP	CASP	105.35	60.59	46.86
WP	A260	3.29	71.06	49.03
	1010	374.83	60.09	48.14
WP	A3979A	194.11	58.17	50.41
WP	A199	0.44	55.00	45.00
WP	A3927A	1.66	65.25	44.96
WP	A3928A	2.25	63.60	44.96
WP	A3929A	4.16	60.56	44.95
WP	A3930A	3.03	71.34	44.98
WP	A3930B	3.88	69.59	44.98
WP	A3930C	4.97	67.65	44.98
WP	A3931A	14.72	60.95	45.09
WP	A5261A	0.09	63.18	46.30
WP	A3932A	0.44	55.00	44.25
WP	A3933A	0.97	58.30	44.25

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A3934A	0.30	61.88	44.25
WP	A3935A	0.45	71.49	46.57
WP	A4966A	3.72	75.77	46.35
WP	A4523A	0.20	59.48	45.91
WP	A3936A	0.08	78.88	44.53
WP	A3936B	0.40	71.33	44.53
WP	A3937A	0.82	56.73	44.61
WP	A3938A	1.05	57.97	44.60
WP	A3939A	1.12	64.91	44.98
WP	A3939B	0.35	67.57	45.00
WP	A3939C	0.09	76.28	45.00
WP	1012	450.02	64.77	44.61
WP	A3940A	1.86	60.97	45.28
WP	WSCO	456.86	64.70	44.63
WP	A4038A	1.78	63.40	46.96
WP	A147	488.28	64.58	44.76
WP	A3941A	6.06	63.37	43.34
WP	A3942D	0.02	77.93	44.17
WP	A3942C	0.07	81.12	44.17
WP	A3942A	0.14	86.85	44.17
WP	A3942B	0.02	88.91	44.17
WP	A3943A	0.03	61.59	44.49
WP	1015	276.38	63.75	44.00
WP	A3944A	0.63	74.02	44.97
WP	A3945A	1.80	58.02	44.69
WP	A3946A	1.29	62.18	45.03
WP	A3947A	3.03	58.53	45.13
WP	WSCN	828.74	63.92	44.56
WP	A4248A	3.20	60.38	46.57
WP	A3948B	0.16	55.00	46.85
WP	A3948A	4.51	60.79	46.63
WP	A3950A	0.85	67.35	47.13
WP	A3949A	0.48	72.50	46.84
WP	A3951A	0.42	76.97	47.24
WP	A256	3.43	62.88	46.61
WP	1004	998.36	63.64	45.05
WP	A3952A	0.12	85.61	43.16
WP	A3953A	0.64	55.70	43.16
WP	A5572A	0.10	55.00	43.94
WP	A3954A	0.14	73.76	43.90
WP	A5471A	4.99	57.15	43.95
WP	A3955B	0.93	55.03	44.45

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A3955A	5.69	60.45	44.29
WP	A3956A	0.33	81.98	43.70
WP	A3957B	0.06	84.00	44.41
WP	A3957A	0.35	82.93	44.41
WP	A3957D	0.36	82.57	44.41
WP	A3957C	0.45	81.24	44.41
WP	A5408B	0.75	66.60	44.45
WP	A5408A	2.11	73.47	44.45
WP	A3958A	75.04	60.66	44.10
WP	A5576A	1.95	60.65	44.76
WP	A196	0.01	85.00	44.61
WP	A202	50.50	78.32	44.86
WP	A4188A	9.55	62.25	45.43
WP	A265	9.57	59.93	46.11
WP	A3959A	29.76	60.63	45.86
WP	A3960B	0.52	85.45	45.98
WP	A3960A	0.03	84.00	45.98
WP	A221	33.87	62.67	45.87
WP	A3961A	34.70	62.83	45.87
WP	SPSP	403.28	65.37	44.21
WP	A237	0.72	64.06	46.73
WP	A3962A	5.84	85.14	42.04
WP	A3963A	69.94	79.73	41.90
WP	A3964A	3.89	85.19	42.70
WP	A5514A	2.67	85.22	43.07
WP	A5514B	3.38	85.17	43.16
WP	A5514C	3.41	85.17	43.17
WP	A3966A	2.04	85.09	44.14
WP	A3965A	131.07	79.97	42.65
WP	CYCY	131.09	79.97	42.65
WP	A3967A	135.01	79.68	42.74
WP	A274	0.17	85.00	45.77
WP	A209	229.02	80.23	43.60
WP	A270	229.48	80.21	43.60
WP	A3968A	7.82	78.11	45.29
WP	A204	0.01	70.00	45.91
WP	A223	247.80	80.04	43.74
WP	A210	249.42	80.01	43.75
WP	A248	3.70	85.07	45.27
WP	A278	262.87	80.09	43.84
WP	A208	0.39	87.10	45.94
WP	A238	2.97	81.27	45.35

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A217	282.62	80.18	43.98
WP	A246	283.17	80.19	43.99
WP	CYWE	284.13	80.17	44.00
WP	A239	284.31	80.17	44.00
WP	A5055A	297.86	79.94	44.10
WP	A212	1.39	70.90	46.72
WP	A5055B	300.19	79.86	44.12
WP	A266	0.11	85.00	46.61
WP	A258	1.08	84.82	46.58
WP	A263	1.24	84.84	46.59
WP	A262	2.36	84.61	46.60
WP	A211	0.16	63.16	46.80
WP	1009	328.47	79.43	44.36
WP	A205	0.39	77.83	46.57
WP	A222	765.03	71.46	44.40
WP	1008	770.59	71.46	44.42
WP	A170	1771.56	67.06	44.78
WP	A5437A	4.84	78.09	48.81
WP	A5436A	5.01	78.41	48.82
WP	A5436B	5.04	78.28	48.82
WP	A5436C	7.71	78.67	48.88
WP	A172	3.42	76.97	48.87
WP	SRHF	2813.56	64.78	46.15
WP	A3980A	2813.61	64.78	46.15
WP	1002	2837.05	64.89	46.18
WP	A3981A	0.37	64.43	50.47
WP	A105	0.26	81.20	50.60
WP	A220	16.16	67.85	50.37
WP	A154	2896.01	64.97	46.27
WP	A145	1.16	67.25	50.66
WP	A146	1.16	67.25	50.66
WP	A5340A	2900.34	65.00	46.28
WP	A159	2900.61	65.00	46.28
WP	A5299A	2900.72	65.00	46.28
WP	1001	2900.72	65.00	46.28
WP	A5334A	2901.02	65.00	46.28
WP	A5334Z	2901.02	65.00	46.28
WP	A197	12.20	70.54	41.75
WP	A276	83.92	70.44	42.26
WP	A273	85.02	70.42	42.28
WP	A3982A	86.87	70.41	42.31
WP	A242	4.93	70.00	43.32

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A231	0.02	70.00	42.60
WP	A241	24.39	70.31	42.22
WP	A213	2.30	73.32	42.87
WP	A264	30.33	70.56	42.39
WP	A218	14.58	69.76	42.81
WP	A247	1.36	70.00	43.36
WP	A171	19.95	69.63	42.97
WP	A234	2.44	70.00	43.56
WP	A275	5.51	79.50	46.02
WP	A268	6.26	78.35	46.00
WP	A134	2.16	73.37	45.98
WP	A245	13.48	74.46	45.91
WP	A280	10.32	70.80	45.55
WP	A3984A	2.79	73.82	45.41
WP	A3984B	2.92	74.19	45.41
WP	A3984C	5.59	78.61	45.66
WP	A224	7.87	78.64	45.52
WP	A244	4.51	71.41	44.76
WP	A233	15.63	74.78	45.23
WP	A271	18.83	73.97	45.22
WP	A225	20.56	73.66	45.20
WP	A3983A	1.40	70.00	43.63
WP	A236	22.18	70.91	44.11
WP	A4066A	27.36	70.68	44.06
WP	A5332A	28.05	70.65	44.06
WP	A219	1.54	70.00	44.57
WP	BBAD	285.28	70.75	43.58
WP	A5257A	287.38	70.85	43.60
WP	A5257Z	287.49	70.84	43.60
WP	A5363A	289.75	70.98	43.61
WP	A5363Z	291.24	71.00	43.62
WP	A181	291.57	71.02	43.63
WP	A195	308.93	71.66	43.78
WP	A5336A	314.15	71.96	43.83
WP	A3985A	344.44	73.12	44.11
WP	A3986A	345.45	73.13	44.12
WP	1014	345.79	73.13	44.13
WP	BBHO	346.06	73.13	44.13
WP	A200	1.02	80.94	45.83
WP	A201	5.11	77.75	45.84
WP	A251	9.71	79.79	45.88
WP	A229	0.92	70.00	46.03

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A254	12.42	77.70	45.91
WP	A279	21.98	75.22	45.91
WP	A227	22.15	75.27	45.91
WP	A277	0.44	70.00	46.34
WP	A188	37.95	73.38	46.10
WP	A5209A	39.64	73.62	46.13
WP	A214	0.26	70.04	46.65
WP	A5565A	50.95	74.46	46.32
WP	A215	0.08	77.79	46.02
WP	A184	10.93	73.08	46.37
WP	WBHO	86.76	78.36	46.60
WP	1017	110.46	81.26	46.88
	1013	461.21	75.27	44.83
WP	A3987B	0.18	92.00	48.35
WP	A3987A	468.62	75.53	44.89
WP	A186	469.78	75.57	44.90
WP	A250	3.15	70.04	44.90
WP	A187	6.81	70.33	45.05
WP	A166	8.64	70.82	45.16
WP	A207	1.75	73.92	45.55
WP	A133	2.03	74.43	45.64
WP	A5362A	4.62	74.94	45.75
WP	A168	17.79	73.07	45.44
WP	A232	2.45	70.00	44.80
WP	A249	2.36	72.07	45.03
WP	A191	14.97	71.37	45.04
WP	A190	1.53	74.87	45.72
WP	A259	0.45	70.75	45.08
WP	A5311A	53.10	73.66	45.44
WP	A5505B	8.95	81.45	46.37
WP	A5505A	70.21	77.84	45.76
WP	A182	79.34	78.28	45.84
WP	A193	79.34	78.28	45.84
WP	A152	93.95	80.36	46.08
WP	BRHO	94.41	80.42	46.09
WP	A5432C	609.28	77.38	45.33
WP	A5432B	609.30	77.38	45.33
WP	A5432A	609.30	77.38	45.33
WP	A121	609.32	77.38	45.33
WP	A160	0.08	92.00	49.02
WP	A5430A	611.61	77.41	45.34
WP	A5430B	612.86	77.43	45.35

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A120	612.94	77.43	45.35
WP	A5362B	4.42	73.59	46.01
WP	A5362Z	4.44	73.57	46.01
WP	A153	1.75	74.55	45.94
WP	A228	0.07	70.00	46.26
WP	A189	5.07	72.42	46.27
WP	A161	22.52	75.17	46.28
WP	A4375A	33.42	76.54	46.49
WP	A4375Z	33.43	76.55	46.49
WP	A178	34.30	76.47	46.51
WP	A179	47.38	76.41	46.88
WP	SBHO	65.80	78.03	47.50
WP	A183	3.64	79.21	50.24
WP	A162	1.89	82.32	50.05
WP	A157	2.07	76.31	50.24
WP	A158	2.07	76.31	50.24
WP	A124	88.79	80.44	48.13
WP	A119	91.01	80.70	48.16
WP	A108	91.19	80.72	48.16
WP	A281	91.19	80.72	48.16
WP	A177	5.47	91.99	48.85
WP	A5353Z	711.51	78.00	45.75
WP	A5353A	711.52	78.00	45.75
WP	A3988A	713.67	78.03	45.76
WP	A151	8.83	86.89	49.96
WP	A3988Z	15.96	88.90	49.99
WP	10071	15.96	88.90	49.99
WP	A137	730.01	78.27	45.86
WP	A180	12.76	91.88	48.11
WP	A138	15.43	91.48	48.12
WP	A156	27.40	87.05	48.43
WP	A3989A	768.64	78.63	46.00
WP	A144	768.66	78.63	46.00
WP	A118	768.75	78.63	46.00
WP	A3990A	768.76	78.63	46.00
WP	A130	0.75	77.02	50.09
WP	A3991A	771.79	78.64	46.02
WP	1007	771.83	78.64	46.02
WP	A216	1.03	72.67	45.95
WP	A174	6.27	72.97	46.02
WP	A252	10.07	71.66	46.08
WP	A240	0.87	70.00	46.46
WP	A243	16.42	72.66	46.17
WP	A173	17.61	72.65	46.21
WP	A206	2.05	83.68	46.04
WP	A167	23.24	72.00	46.31
WP	A253	0.84	70.22	46.29
WP	A257	1.99	75.58	46.40
WP	A261	9.05	72.46	46.39
WP	A164	34.96	72.43	46.36
WP	A255	0.15	70.00	46.77
WP	A269	0.73	70.00	46.77
WP	A230	42.25	72.68	46.43
WP	A163	5.92	78.86	46.61
WP	GBHO	63.94	74.80	46.58
WP	A198	2.85	72.05	47.30
WP	A226	0.08	55.81	49.09
WP	A169	4.05	79.17	46.82
WP	1016	124.26	71.78	47.30
WP	A165	2.26	59.00	49.09
WP	A203	2.56	73.50	47.02
WP	A272	2.71	73.31	47.02
WP	A176	40.5	84.28	47.44
WP	A235	1.72	72.26	49.55
WP	A185	194.69	74.10	47.62
WP	A5507A	200.72	74.38	47.68
WP	A5560A	201.04	74.41	47.69
WP	A128	0.41	87.33	49.83
WP	A3992A	975.63	77.76	46.37
WP	A3992Y	975.63	77.76	46.37
WP	A100	0.05	70.14	50.51
WP	A150	0.01	92.00	50.51
WP	A149	6.15	81.48	50.43
WP	A3992X	7.57	80.52	50.37
WP	A3992Z	7.66	80.65	50.37
WP	A117	7.67	80.66	50.37
WP	A132	983.65	77.79	46.41
WP	A141	984.17	77.79	46.41
WP	A142	0.31	70.00	50.51
WP	A3993A	985.83	77.79	46.41
WP	A3993Z	985.83	77.79	46.41
WP	A140	986.99	77.79	46.42
WP	A112	987.04	77.79	46.42
WP	A110	987.96	77.80	46.42

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

	WAM CP ID	Area (sq. mi.)	NRCS Curve No.	Precip. (in.)
WP	A192	1.46	84.77	50.63
WP	A5522A	1.49	84.93	50.63
WP	A127	1.56	85.14	50.63
WP	A111	2.47	85.67	50.63
WP	A109	2.49	85.73	50.63
WP	A101	3.86	84.40	50.66
WP	A102	3.89	84.46	50.66
WP	A103	4.04	84.74	50.65
WP	10061	4.25	85.12	50.66
WP	A3994A	988.33	77.80	46.42
WP	A104	992.69	77.83	46.44
WP	A3994Z	992.69	77.83	46.44
WP	A114	993.13	77.84	46.44
WP	A135	1.58	73.48	50.79
WP	A116	2.05	77.60	50.80
WP	A5191Z	996.27	77.85	46.46
WP	A5191A	996.28	77.85	46.46
WP	A267	22.94	65.77	50.07
WP	A148	29.24	66.17	50.11
WP	A194	1.04	69.96	50.54
WP	A155	2.1	79.89	50.68
	A122	0.18	79.91	50.79
	A123	0.41	77.04	50.79
	A136	0.02	70.00	50.83
WP	A143	3958.58	68.39	46.39
WP	A3996A	3959.26	68.39	46.39
WP	A3996Z	3959.42	68.39	46.39
WP	A126	3968.64	68.43	46.40
WP	A125	3973.15	68.44	46.41
WP	SRGB	3977.81	68.47	46.41

3.2.1 Distribution of Natural Flows Considering Channel Losses

No specific channel losses were discovered in the San Jacinto River Basin. Refer to the discussion in Section 3.1.3.

3.2.2 Impacts on Instream Flows

The impacts on instream flows were monitored by comparing unappropriated and regulated flows for the various model scenarios at key points in the watershed for each model scenario.

Key control points at which these comparisons were made include:

- West fork San Jacinto River near Conroe (WS_CN)
- San Jacinto River near Huffman (SR_HF)
- Buffalo Bayou at Houston (BB_HO)
- San Jacinto River at Galveston Bay (SR_GB)

3.3 Adjusted Net Reservoir Evaporation

Adjusted Net Evaporation data are utilized in water availability modeling in two ways,

1. Computation of naturalized streamflows to remove the effects of reservoirs on flow
2. Water availability computations at primary and secondary control points located at reservoirs.

Adjusted Net Evaporation for reservoirs, explained in Section 3.3.2, was derived from gross reservoir evaporation data and precipitation data obtained from the TWDB, and runoff data from available USGS gage data or available naturalized flow data. Table 8 summarizes the method utilized for estimating the quadrangle runoff. The lower portion of the basin overlies the Gulf Coast aquifer.

Table 8 Methods for Estimating Quadrangle Runoff

Quadrangle	Gage	Basin	USGS Number	Drainage Area (Square Miles)	Period
712	East Fork San Jacinto River near Cleveland	San Jacinto	8070000	325	1/40-Present
713	Neches Naturalized Flow for Village Creek near Kountze (VI_KO)	Neches	8041500	860	1/40 - Present
812	Buffalo Bayou at Houston	San Jacinto	8074000	358	1/40 - 9/57
	Chocolate Bayou near Alvin	San Jacinto -Brazos	8078000	87.7	10/57-Present
813	Neches Naturalized Flow for Pine Island Bayou near Sour Lake (PI_SL)	Neches	8041700	336	1/40-Present

3.3.1 Evaporation Data Sources

The TWDB has developed historical evaporation rates for the State of Texas since the 1960s. Their most recent data set is for gross evaporation rates from 1950 through 1996 using an improved methodology not used in previous evaporation data sets. Evaporation data for the period from 1940 through 1953 are not available using the new method, so previously developed data was used. Precipitation data were also obtained from TWDB. The evaporation and precipitation data are available by 1 degree quadrangle. Runoff data were developed based on USGS gaged flows and naturalized flow data from adjacent basins.

3.3.2 Procedures for Estimation of Adjusted Net Reservoir Evaporation

Adjusted Net reservoir evaporation is the rate at which water is lost to evaporation from the surface of a reservoir. It represents the net impact of evaporation and of rainfall directly on the reservoir surface. The equation for adjusted net reservoir evaporation used in this study is:

$$ANE = GE - R + xR$$

where *ANE* is the adjusted net reservoir evaporation rate, *GE* is the gross reservoir evaporation rate, *R* is the rate of precipitation, and *xR* is the fraction of rainfall that would have been in the runoff in the absence of a reservoir. Table 8 shows the quadrangles used for estimation and Table 9 shows the methodology for derivation of *xR* for each quadrangle.

Table 9 Sources of Data for Deriving Net Evaporation Rates

San Jacinto River Basin	**Quadrangle Factors (**)**
Lewis Creek	1.000 (712)
Conroe	1.000 (712)
Houston	0.286 (712) + 0.228 (713) + 0.275 (812) + 0.211 (813)
Sheldon	0.236 (712) + 0.192 (713) + 0.348 (812) + 0.223 (813)

(**) Numbers in parentheses indicate evaporation quadrangles.

The sources of the data needed to determine reservoir evaporation rates are as follows:

Gross Reservoir Evaporation – The TWDB recently revised its estimate of gross reservoir evaporation rates for 1954-1996. Previous TWDB data, computed by slightly different methods, are available for 1940-1953. The TWDB gross evaporation data are available by quadrangle for the entire state, and monthly values for a specific location are derived by taking a weighted average for up to four nearby quadrangles.

Precipitation – Precipitation data by quadrangle are available from the TWDB for 1940 through 1996.

The Portion of Rainfall That Would Have Run Off in the Absence of a Reservoir – Runoff (expressed as inches) is generally obtained from a nearby USGS gage or gages. Table 8 shows the source of runoff data for each quadrangle bordering the San Jacinto Basin.

For this study, adjusted net reservoir evaporation values were derived for the four Texas Water Development Board evaporation quadrangles in or bordering the San Jacinto River Basin. Table 9 summarizes the method utilized for estimating quadrangle runoff for each evaporation quadrangle.

3.3.3 Comparison of Evaporation Data Sets

Monthly values of Adjusted Net Evaporation for each of the four major reservoirs were used as input to the 57-year period WRAP (VER 10/99) model of the San Jacinto River Basin. In addition, Adjusted Net Evaporation for each 1 degree quadrangle was input for simulation of the minor reservoirs. The average annual adjusted net evaporation rates for the reservoirs in the upper watershed and lower watershed are plotted on the graph in Figure 10. The upper watershed includes Lewis Creek and Conroe. The lower watershed includes Houston and Sheldon. As expected, the general trend exhibited by this data is for the adjusted net evaporation for each area to track fairly close since this is a small basin.

3.4 Reservoir Elevation-Area-Capacity Relationships

Area-capacity relationships in this study were derived from two primary sources; original area-capacities were used for reservoirs with capacities over 5,000 acre-feet and a standard generic area-capacity relationship was developed for reservoirs with capacities less than 5,000 acre-feet. Table 10 is a list of major reservoirs in the San Jacinto River Basin (over 5,000 acre-feet of conservation storage). The table also shows data sources for these reservoirs.

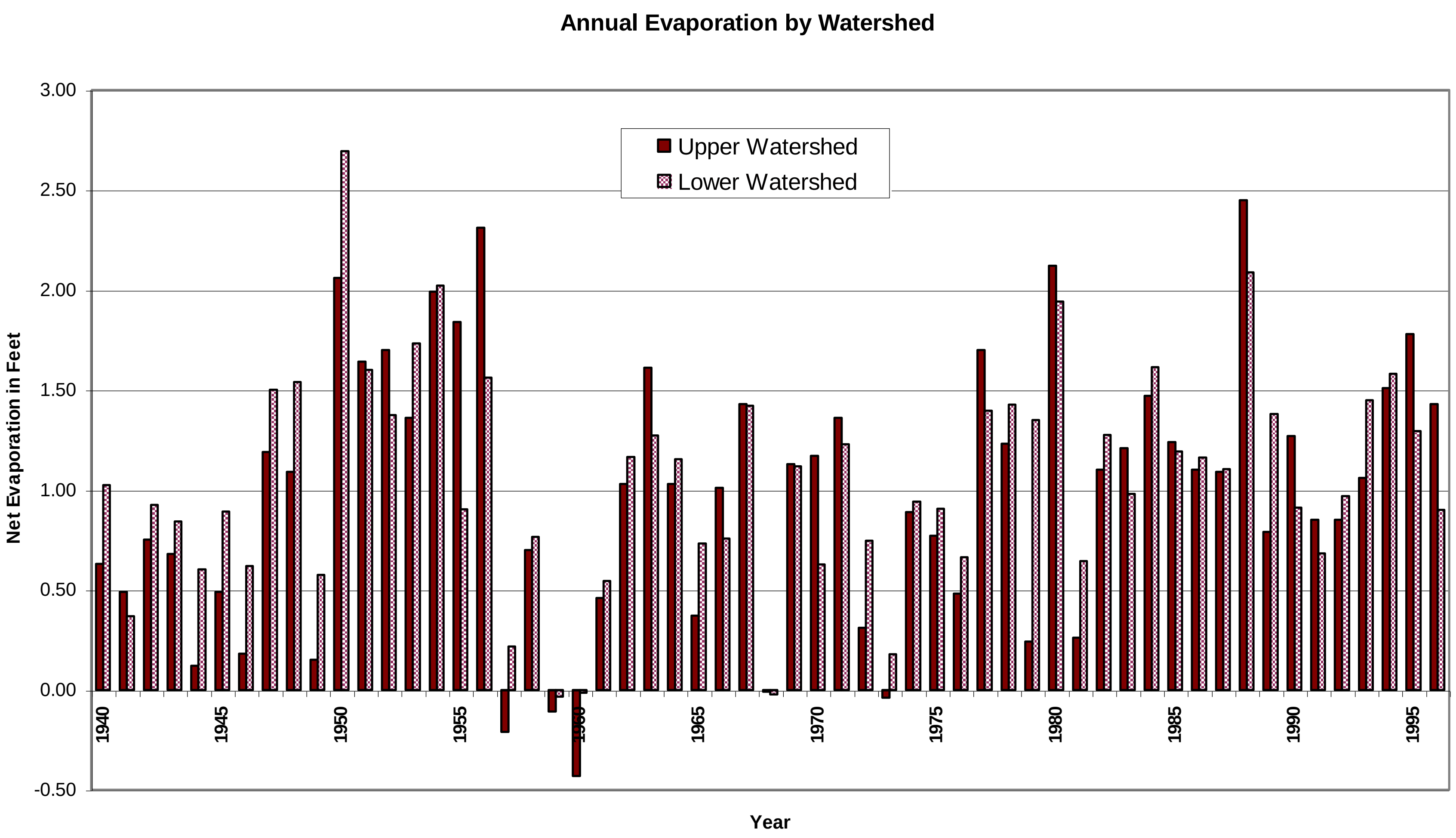
The elevation-area-capacity relationship for a reservoir is necessary to describe the storage capacities of the reservoir along with the evaporation potential. This relationship, which is also referred as the area-capacity curve, is typically developed during the reservoir design phase from the topography of the inundated area of the reservoir. The original capacity at the normal operating pool of a reservoir generally complies with the authorized capacity of the water use permit. Once impoundment of a reservoir begins, the reservoir accumulates sediment carried by the upstream inflow. The sediment successively deposited within the reservoir reduces the capacity and water surface area of the reservoir at various storage stages, thereby reducing the yield and changing evaporative characteristics of the reservoir.

Table 10 Major Reservoirs in the San Jacinto River Basin

Reservoir	Drainage Area (Square Miles)	Stream	Date of Impoundment	Records		Sources	Conservation Storage (Ac-Ft)			Sediment Survey Date	Remarks
				Source	Period		Permitted	Original	Surveyed		
Lewis Creek	4.4	Lewis Creek	2/12/69			Gulf States Utilities Company	17,000	16,400[a]			Pump from Lake Conroe to maintain levels
Conroe	445	West Fork San Jacinto	1/73	USGS	1/73-Present	San Jacinto River Authority	430,260	430,260[b]	416,228 [c]	7/96	Conservation storage includes 370 ac-ft of unusable storage
Houston	2,828	San Jacinto	4/9/54	USGS	4/54-Present	Houston	160,000	158,550[d]	96,880[e]	2/94	
Sheldon Reservoir	9.3	Carpenters Bayou	12/43			Texas Parks & Wildlife Dept	5,354	5,420[f]	5,354[g]		

[A] Original survey by Brown & Root for 267 ft. above msl, published in Texas Water Development Board *Report 126*.
[B] Original survey by Freese & Nichols for 201 ft. above msl, published in Texas Water Development Board *Report 126*.
[C] 7/1996 resurvey by Texas Water Development Board for 201 ft. above msl.
[D] Original survey by Ambursen Engineering Company. Includes 147,920 ac-ft of usable conservation storage and 10,630 ac-ft of sediment reserve.
[E] 2/1994 resurvey by Texas Water Development Board for spillway crest elevation of 40.7 ft above msl, reported in Turner Collie & Braden 1982 report. Includes f 92,813 ac-ft of usable conservation storage and 4,067 ac-ft of sediment reserve.
[F] 1971 Texas Parks & Wildlife Department area-capacity data for an elevation of 50.5 ft. above msl.
[G] 1976 U.S. Corps of Engineer Dam Safety Report area-capacity data for an elevation of 50.5 ft. above msl.

Figure 10 Annual Adjusted Net Evaporation by Watershed



3.4.1 Large Reservoirs

San Jacinto Basin has four major reservoirs, Lake Conroe, Lake Houston, Lewis Creek Lake, and Lake Sheldon. The area-capacity curves of the original design and the recent survey were published by Texas Water Development Board (TWDB), as specified in Table 11. Lakes Conroe and Houston were impounded in 1973 and 1954, respectively. TWDB resurveyed these two lakes in July 1996 and February 1994, respectively. Lewis Creek Lake is owned by the Gulf States Utilities Company for maintenance and operation of a steam-electric generating plant. The Company indicated that this lake has been well maintained in order to keep its original storage capacity at about 16,400 acre-feet. Lake Sheldon was impounded in December 1943. The original capacity of the reservoir at 50.5 feet above mean sea level is 5,420 acre-feet, in accordance with the 1971 Texas Parks and Wildlife Department area-capacity data. The 1976 dam safety report of U.S. Army Corp of Engineers, however, indicates that the lake has a storage capacity of 5,354 acre-feet at the same elevation.

The storage capacity data for the above-mentioned reservoirs were further reviewed for consistency with other available information, such as the “water resource” data published by U.S. Geological Survey. All the area-capacity data, including those of year 2000 condition, were plotted and fitted to power-type equations. A number of twelve or less data points (depending on data availability) were selected as input to the WRAP model.

The method for developing the year 2000 area-capacity curve or relationship for each of the major reservoirs can be described as follows:

- The conservation storage capacity of each reservoir for year 2000 is to be reduced by the accumulated amount of sediment entering the reservoir between the date of the latest survey and year 2000. The amount of accumulated sediments is equal to the product of annual sedimentation rate, drainage area of the reservoir, and number of years between the latest survey and year 2000. The sedimentation rate can be obtained from data of the latest survey and the original design (see Table 12).

- For Sheldon Lake, the sedimentation rate was estimated from data published in a TWDB report entitled ”Erosion and Sedimentation by Water in Texas, 1979.” The drainage area used for the calculation of sedimentation is the total drainage area above the reservoir minus the areas controlled by any upstream reservoirs.

- It is assumed that the sediment accumulated within a reservoir is distributed at all elevations of the reservoir. The surface area of the reservoir at each elevation is then reduced due to sediment accumulation. The reductions of surface area at all

Table 11 Major Reservoirs in the San Jacinto River Basin Area Capacity Source Information

Reservoir	Date of Impoundment	Conservation Storage Original (acre-feet)	Original Area-Capacity Source	Conservation Storage Surveyed (acre-feet)	Date	Surveyed Area-Capacity Source
Conroe	1973	430,260	Freese & Nichols; data published in Texas Water Development Board (TWDB) Report 126, 1973	416,228	7/96	TWDB Report, Volumetric Survey for Lake Conroe; report prepared for San Jacinto River Authority
Houston	1954	158,550	Ambursen Engineering Company; data published in TWDB Report 126, 1973	128,700	2/94	TWDB Report, Volumetric Survey for Lake Houston; report prepared for City of Houston
Lewis Creek	1969	16,400	Brown and Root; data published in TWDB Report 126, 1973	No survey	None	Storage maintained at about the same level; information provided by Gulf States Utilities Company
Sheldon	1943	5,420	Texas Parks & Wildlife Department, 1971; data published in TWDB Report 126, 1973	No survey	None	N/A

Table 12 Sedimentation Rates for Major Reservoirs in the San Jacinto River Basin

Reservoir	Original Capacity (Ac-Ft)	Date of Impoundment	Surveyed Capacity (Ac-Ft)	Date of Survey	Period (Years)	Drainage Area (Square Miles)	Sedimentation Rate (Ac-Ft per S.M. Per year)
Lake Conroe	430,260	1973	416,228	July 1996	23	441	1.37
Lake Houston	146,769	1954	128,700	Feb 1994	40	2,383	0.16

Note: Surveyed capacities are from TWDB surveys

elevations are assumed to be equal. This assumption constitutes the basis of the "area increment" method.

- This "area increment" method is an empirical procedure that reduces the water surface area from the area-capacity curve of the latest survey by a constant area until the new calculated storage capacity is reduced by the total volume of accumulated sediment.

The year 2000 area-capacity data and relationships for three lakes were derived using the "equal area" method. For Lewis Creek Reservoir, the original area-capacity curve was used to represent year 2000 condition since the reservoir has been maintained to retain its original capacity.

3.4.2 Small Reservoirs

Standard elevation-area-capacity relationships have been used in the water availability analyses for small reservoirs with less than 5,000 acre-feet of storage. The Natural Resource Conservation Service was involved in the design and construction of many similar impoundments within the San Jacinto River Basin, and area-capacity curves for these impoundments were obtained from the NRCS office in Temple, Texas. The TNRCC Dam Safety files and water rights files were examined to locate additional area-capacity curves for small impoundments within the San Jacinto River Basin.

For small reservoirs, standardized area-capacity curves have been generated using an equation of the form:

$$Area = a(Capacity)^b + c$$

This form of equation, known as a power function, is the only equation form available to represent area-capacity relationships in WRAP (VER 10/99). To obtain the coefficients a, b, and c, regression analyses of available area-capacity data for existing small reservoirs have been performed. All available area-capacity curves for the small reservoirs in the San Jacinto River Basin were plotted, and power function regression analyses were performed to obtain the best-fit equation. The best-fit equation for all the data resulted in the following coefficients. The R^2 for the best-fit line is also shown below.

a = 0.912 b = .6742 c = 0 R^2 = 0.9052

The graphs for the equation shown above and the original data points are shown in Figure 11. The area capacity relationship developed for small reservoirs with capacities less than 5,000 acre-feet is:

$$Area = 0.912(Capacity)^{0.6742} + 0.00$$

3.5 Aquifer Recharge

Aquifer recharge was not analyzed in this study (see section 3.1.3).

3.5.1 Historical Recharge

Not Applicable

3.5.2 Enhanced Recharge

Not Applicable

Figure 11 San Jacinto River Basin Standard Area-Capacity Curve Reservoirs Less Than 5,000 acre-feet

4.0 WATER AVAILABILITY MODEL OF THE BASIN

WRAP (VER 10/99) was used to model the water availability of the San Jacinto River Basin, utilizing input data specific to the San Jacinto River Basin including water rights, reservoir information, and naturalized streamflows. The WRAP (VER 10/99) program was originally developed by Dr. Ralph Wurbs at the Texas A & M University in March 1986. Throughout the evolution of the WAM process and completion of six river basins, WRAP has undergone numerous improvements and upgrades. The WRAP program was initially recommended by Espey, Padden Consultants, Inc., and a group of engineers contracted by TNRCC to evaluate a number of water availability models. WRAP was selected by the WAM Management Team as the best model available to model the Texas prior appropriation system as well as meet the requirements set forth by Senate Bill 1. Specific parameters utilized in WRAP will be described in the following sections.

4.1 Description of WRAP Model

The WRAP program was designed to simulate management and use of the streamflow and reservoir storage resources of one or more river basins under the prior appropriation system. The WRAP program is capable of evaluating river basins that have numerous diversions and use types (including hydropower), systems with multiple-reservoirs, complex allocation systems, and reservoirs with multiple users. The model may be applied to various types of planning and management situations to evaluate alternative management strategies.

WRAP simulates a river basin by performing water accounting computations at each water right and control point based on the prior appropriation system in monthly time steps. This water accounting system tracks the effects of reservoir storage, instream flow, diversions and return flows on streamflow data. Simulations using the model are typically based on the following assumptions:

1. Basin hydrology is represented by an assumed repetition of historical period of record naturalized streamflows and reservoir evaporation rates.
2. The full amounts of all permitted water rights requirements are met as long as water is available from streamflow and/or specified reservoir storage.

Characteristics of specific water rights are incorporated as assumptions in the input data, such as in the WR record, WS record, and the OR record. These input cards describe how a water right will be simulated (from run of river, reservoir storage, or both), how the water rights will be divided (into use types and priority), and how multiple-reservoir operations will be defined.

4.1.1 Base WRAP Model

The WRAP model works by performing a water accounting simulation utilizing a series of loops. Specifically, the WRAP simulation is composed of the following loops:

1. **Loop 1:** The input data including water rights, storage-area tables, basin configuration, use types, return flow factors, and gains and losses in the basin are read into the program and water rights are then ranked in priority order.
2. **Loop 2:** The hydrology records, inflow and evaporation, are read and adjustments for negative incremental flows and December return flows (made to January flows) are performed in an annual loop.
3. **Loop 3:** A monthly loop is performed in which net-evaporation-precipitation adjustments are made, spills are computed based on monthly varying storage capacities, flow adjustments for constant inflow/outflows are computed, a water right loop is performed, and then control point and reservoir records are developed. The water rights loop is run for each water right in priority order and is composed of determining the amount of water available for each water right, checking unappropriated and regulated flows, making diversions, reservoir releases, and return flows, adjusting available streamflows at all control points, and creating output records for each water right.

4.1.2 Basin Specific WRAP Model

No changes were made to the WRAP (VER 10/99) program for modeling the San Jacinto River Basin.

4.2 Development of WRAP Water Rights Input File

Water rights, input files, and river basin control point schematic were created using the revised TNRCC master water rights list, the written certificates of adjudication and water rights permits, TNRCC adjudication maps, and geo-referenced data from the TNRCC (obtained from the CRWR). The basic steps included in creating the water right input card include:

- Identifying primary and secondary control points.
- Obtaining all water right diversion locations from TNRCC.
- Determining diversion amounts, use types, and priority dates for all water rights within the basin.
- Determining impoundment amounts for water rights, storage, and reservoir information (input in the WS card).
- Compiling and computing return flows for all industrial and municipal water

right diversions including interbasin transfers.

- Computing monthly distribution factors to distribute annual diversion amounts.
- Creating a Control Point Schematic.
- Input naturalized streamflow and evaporation data.

Each task methodology is described in the following sections.

4.2.1 Control Points

Control points are used in the WRAP program as a means of spatially referencing the position of all inflows and outflows in a river basin. The actual formulation of the basin schematic used for the WRAP program is done in the CP record. The CP record lists control points from upstream to downstream. The river layout is reproduced in the CP record by listing each control point and following it with the next downstream control point. In the San Jacinto River Basin Water Availability Model, control points were segregated into two distinct types:

- Primary control points – points located at USGS streamflow gage locations as of September 30, 1996, or as of the discontinuation of the gage.
- Secondary control points – points located at water right diversions or impoundments, water import locations, groundwater return flow sites, return flow sites, and classified stream segments that are not primary control points. Naturalized streamflow is distributed by WRAP to these secondary control points based on drainage area, curve number, and precipitation.

Table 1 lists the suggested primary control points for the basins. Figure 1 shows the primary control point locations and their drainage areas. (Primary control point locations are locations of USGS gages as of September 30, 1996, or as of the discontinuation of the gage.) Figure 3 shows the period of record for the suggested primary control points. These primary control points were developed using the following general criteria:

- Streamflow gages with over 25 years of record and drainage areas over 80 square miles.
- Spatial distribution of primary control points throughout the basins
- Reservoir control points were avoided if possible due to the difficulty in obtaining accurate information on reservoir discharges

There are several exceptions to the above criteria. The following gages did not meet the criteria but were added as primary control points:

- West Fork San Jacinto below Lake Conroe near Conroe. This gage will be used to estimate inflow to Lake Conroe

- San Jacinto River near Huffman. This gage will be used to estimate inflow to Lake Houston.

The following gages met the criteria but were not included as primary control points.

- Buffalo Bayou at West Belt Drive at Houston. There is very little difference in the drainage area of this gage and the Buffalo Bayou at Houston gage, which is a primary control point (307 square miles vs. 358 square miles).
- Buffalo Bayou at Piney Point. There is very little difference in the drainage area of this gage and the Buffalo Bayou at Houston gage, which is a primary control point (317 square miles vs. 358 square miles).

The West Fork San Jacinto River near Humble gage was included in the original workplan because it is historically an important gage upstream of Lake Houston. It was removed from the naturalized flow analysis when the unit runoff calculations from the watershed were not consistent with other gages in the basin.

The control points with calculated flows (Primary) are discernable from control points with estimated flows at ungaged sites (Secondary). Also, the two types of control points were labeled in different manners in the model. Primary control points were labeled using a four-letter acronym that represents the name of the USGS gage (Ex. PE_SP - Peach Creek at Splendora). Secondary control points were labeled using an alphanumeric six-digit code.

The six-digit code is in the form: AXXXXY, and is defined below:

- A identifies the point as a water right
- XXXX represents the water right Identification number
- Y represents the configuration of the water right

The stream segment control points were identified as part of the CRWR dataset and used as secondary control points with no diversions at the points. The classified stream segments are numbered differently. Classified segments were given an alphanumeric code in the form of CLASS, defined as :

CLASS represents that it is a classified stream segment, i.e. classified stream segment 1006 is identified as 1006.

4.2.2 Monthly Demand Distribution Factors

Diversion amounts associated with each water right were input into the WR record in WRAP (VER 10/99) as an annual amount in acre-feet per year (ac-ft/yr). The annual values are then distributed by the monthly distribution factors for each use type as specified in the UC record in WRAP. Seasonal use (demand) patterns were determined for municipal, industrial, irrigation, mining, and other water uses. Historical water consumption data was used to derive the seasonal pattern for each type of water use. The historical consumption data were derived from water use records submitted annually to the Texas Natural Resource Conservation Commission (TNRCC) by the water right holders as required by permits. Table 13 shows the corresponding distributions for the different categories of water use.

For each individual water right corresponding to a specific type of water use, averages were computed for water consumption for each of the twelve months. The monthly average was then divided by the annual average to produce a percent value to represent monthly consumption. The monthly percent values were further averaged over a period of years.

For municipal use, seasonal demand patterns in the San Jacinto basin were developed based on City of Houston water use and other smaller users in the basin. This basin-wide “monthly average” distribution represented the demand pattern for municipal use in the basin.

No significant trend of water demand pattern was indicated from one region to another in the San Jacinto Basin. Therefore, only one set of use data for each type of water use for the entire basin was used.

Table 13 Seasonal Distribution Factors for the San Jacinto River Basin

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	Annual Average
Municipal													
Constant %	**0.083**	**0.083**	**0.083**	**0.083**	**0.084**	**0.084**	**0.084**	**0.084**	**0.083**	**0.083**	**0.083**	**0.083**	**12**
Industrial													
P5430	15.6	13.4	13.4	13.4	13.4	20.1	27.7	33.4	33.4	29.7	20.1	11.5	245.2
P5340	1.0	0.8	1.0	0.9	0.8	0.9	0.9	0.8	0.9	0.9	0.8	0.8	10.4
P5299	2.8	1.9	2.1	2.2	2.1	2.0	2.0	2.1	1.8	1.5	1.7	1.5	23.8
P5191	5.5	5.5	6.5	6.7	6.1	8.0	10.9	9.6	8.8	8.2	5.9	6.2	87.9
CA 4966	41.8	40.7	124.1	101.8	163.0	350.0	533.9	629.1	283.2	415.2	75.8	57.0	2815.6
CA 4964	3253.3	2882.3	3118.1	3131.9	3324.1	3239.0	3443.3	3454.6	3381.3	3333.3	3188.0	3287.2	39036.6
CA 3996	5507.7	5488.3	5844.1	6158.8	6212.8	6790.0	9731.3	10222.9	6767.7	5077.7	4913.0	4761.6	77476.0
CA 3994	3120.4	3530.2	3577.8	3830.9	3965.5	4409.1	4319.7	4510.3	4325.1	3659.4	3486.2	4159.1	46893.6
IND. Dist. %	**0.072**	**0.072**	**0.076**	**0.079**	**0.082**	**0.089**	**0.109**	**0.113**	**0.089**	**0.075**	**0.070**	**0.074**	166589.0
IND 4964 %	**0.083**	**0.074**	**0.080**	**0.080**	**0.085**	**0.083**	**0.088**	**0.088**	**0.087**	**0.085**	**0.082**	**0.084**	
Irrigation													
CA 3980	0	0	32.91	107.04	210.39	285.55	295.76	158.12	37.81	4.44	0	0	1132.01
CA 3979	290.75	230.44	262.56	333.4	576.52	529.9	256.41	171.41	127.69	397.56	240.93	260.02	3677.59
CA 3965	0	11.61	52.25	81.27	99.54	151.28	99.16	59	24.65	7.04	0	0	585.81
CA 3964	0	0.02	0	0	70.22	83.3	140.75	63.43	24.45	16.06	0.01	0	398.23
CA 3963	6.29	13.36	60.75	77.57	81.04	31.93	10.5	9.11	24.11	8.64	6.61	5.18	335.07
IRR. Dist. %	**0.048**	**0.042**	**0.067**	**0.098**	**0.169**	**0.177**	**0.131**	**0.075**	**0.039**	**0.071**	**0.040**	**0.043**	6128.71

4.2.3 Water Rights

Water rights are defined in the WRAP model with parameters for permitted diversions, priority, reservoir storage, and diversion location. This is accomplished in the WR records of WRAP, which formulates the manner in which a particular water right is configured. In the WR records, a permitted diversion is segmented into several water rights based on the language of the Permit or Certificate of Adjudication (CA). For example, a water right with more than one diversion point, or having multiple uses will have more than one WR record to represent the permit in the model.

Water rights are identified using a eleven digit alphanumeric code in the form of XXYAAAAABBB, as defined below:

- XX represents the Basin Number.
- Y represents the type, where:
    - 6 is for Certificate of Adjudication.
    - 1 is for an Application.
- AAAAA represents the Water Right Number
- BBB represents the Diversion Point Numbers, where:
    - 001-100 water right location (regular diversion point)
    - 101-200 downstream boundary of diversion area
    - 201-300 upstream boundary of diversion area
    - 301-400 on-channel reservoir
    - 401-500 off-channel reservoir
    - 501-600 return flow points
    - 601-700 off-channel diversion point
    - 901-999 other

Water rights in the San Jacinto River Basin for Scenario 1 are listed in Table 14. This table gives each water right location, permitted diversion amount, use type, priority date, and how each water right permit was segregated into multiple parts. The specific locations of the water rights can be geo-referenced on the map of the San Jacinto River Basin attached as Appendix K.

4.2.3.1 Priority Dates

Priority dates were derived directly from hard copies of water rights obtained from the TNRCC. While most water rights have only one priority date, some have multiple priority dates. Multiple priority dates may be found on water rights with multiple diversions, with multiple reservoir impoundments, or in amended water rights.

Some water rights were characterized by multiple entries based on priority dates for storage, use types, as well as diversion locations. The priority date for each water right, as well as the instream flow requirements and the synthetic water rights utilized to distribute the return flows, is listed in Table 14. The format of the priority dates is YYYYMMDD, defined as:

- YYYY represents the four-digit year for Y2K compliance.
- MM represents the month by the two-digit code
- DD represents the day of the month in a two–digit code.

4.2.3.2 Treatment of Reservoir Storage

The maximum storage for a reservoir is specified in the TNRCC water right permit or certificate of adjudication. For reservoirs having multiple priority dates for storage, WRAP requires multiple WR and WS records to represent the different priority dates assigned to reservoir storage. Storage in a reservoir is filled only after meeting the needs of senior water rights. Incorporating these different reservoir storage levels by priority date allows the WRAP (VER 10/99) model to fill a reservoir only when flow is available based on the specific priority date.

Table 14 Water Right Information

RECORD (WR/IF)	WATER RIGHT NUMBER	CONTROL POINT	ANNUAL DIVERSION / INSTREAM FLOW	USE TYPE	PRIORITY DATE
WR	10603927301	A3927A	0	REC	19660907
WR	10603928301	A3928A	0	REC	19720214
WR	10603929301	A3929A	0	REC	19501108
WR	10603930301	A3930A	140	SJIRR	19781127
WR	10603930302	A3930B	0	REC	19781127
WR	10603930303	A3930C	0	REC	19781127
WR	10603931301	A3931A	0	REC	19550502
WR	10603932301	A3932A	0	REC	19760412
WR	10603933301	A3933A	0	REC	19750609
WR	10603933302	A3933A	0	REC	19890714
WR	10603934301	A3934A	0	REC	19750818
WR	10603935301	A3935A	0	REC	19750120
WR	10603936301	A3936A	0	REC	19740603
WR	10603936302	A3936B	0	REC	19740603
WR	10603937301	A3937A	0	REC	19750303
WR	10603938301	A3938A	0	REC	19750127
WR	10603939301	A3939A	0	REC	19750203
WR	10603939302	A3939B	0	REC	19750203
WR	10603939303	A3939C	0	REC	19750203
WR	10603940301	A3940A	0	REC	19750203
WR	10603941301	A3941A	300	SJIRR	19740701
WR	10603942301	A3942A	0	REC	19741202
WR	10603942302	A3942B	0	REC	19741202
WR	10603942303	A3942C	0	REC	19741202
WR	10603943301	A3943A	0	REC	19750707
WR	10603944301	A3944A	0	REC	19751201
WR	10603945301	A3945A	0	REC	19750408
WR	10603946301	A3946A	0	REC	19551108
WR	10603947301	A3947A	0	REC	19781010
WR	10603948302	A3948B	0	REC	19750120
WR	10603948301	A3948A	0	REC	19750120
WR	10603949301	A3949A	0	REC	19750120
WR	10603950301	A3950A	0	REC	19790604
WR	10603951301	A3951A	0	REC	19750728
WR	10603952301	A3952A	32	SJIRR	19750623
WR	10603953301	A3953A	0	REC	19751027
WR	10603954301	A3954A	0	REC	19751222
WR	10603955301	A3955A	0	REC	19750721
WR	10603955302	A3955B	0	REC	19830124
WR	10603957301	A3957A	0	REC	19750217

Table 14 Water Right Information (Continued)

RECORD (WR/IF)	WATER RIGHT NUMBER	CONTROL POINT	ANNUAL DIVERSION / INSTREAM FLOW	USE TYPE	PRIORITY DATE
WR	10603957302	A3957B	0	REC	19750217
WR	10603957303	A3957C	0	REC	19750217
WR	10603957304	A3957D	0	REC	19750217
WR	10603958301	A3958A	0	REC	19750408
WR	10603959301	A3959A	750	SJIRR	19720905
WR	10603960301	A3960A	0	REC	19740124
WR	10603960302	A3960B	310	SJIRR	19740124
WR	10603961001	A3961A	25	SJIRR	19741104
WR	10603962301	A3962A	0	REC	19790212
WR	10603963401	A3963A	501	SJIRR	19500531
WR	10603964301	A3964A	0	REC	19520728
WR	10603964302	A3964A	200	SJIRR	19611231
WR	10603965401	A3965A	2941	SJIRR	19511231
WR	10603966301	A3966A	25	SJIRR	19770620
WR	10603967001	A3967A	100	SJIRR	19630630
WR	10603968401	A3968A	0	REC	19560430
WR	10603969301	A3969A	0	REC	19750630
WR	10603969302	A3969B	0	REC	19750630
WR	10603969303	A3969C	0	REC	19750630
WR	10603970001	A3970B	15	SJIRR	19620731
WR	10603971301	A3971A	0	REC	19750707
WR	10603972301	A3972A	0	REC	19750127
WR	10603973301	A3973A	0	REC	19750106
WR	10603974301	A3974A	40	SJIRR	19741007
WR	10603975301	A3975A	0	REC	19750106
WR	10603976301	A3976A	0	REC	19750224
WR	10603977301	A3977A	0	REC	19740325
WR	10603978301	A3978A	0	REC	19750715
WR	10603979401	A3979A	4999	SJIRR	19650802
WR	10603980401	A3980A	1600	SJIRR	19421207
WR	10603981301	A3981A	0	REC	19770613
WR	10603982001	A3982A	45	SJIRR	19520630
WR	10603983401	A3983A	800	SJIRR	19161231
WR	10603984101	A3984C	26	SJIRR	19630630
WR	10603985401	A3985A	460	SJIRR	19780130
WR	10603986001	A3986A	19	SJIRR	19720911
WR	10603987001	A3987A	0	SJIND	19761004
WR	10603988001	A3988A	0	SJIND	19650407
WR	10603989001	A3989A	0	SJIND	19701102
WR	10603990001	A3990A	0	SJIND	19440412

Table 14 Water Right Information (Continued)

RECORD (WR/IF)	WATER RIGHT NUMBER	CONTROL POINT	ANNUAL DIVERSION / INSTREAM FLOW	USE TYPE	PRIORITY DATE
WR	10603991001	A3991A	0	SJIND	19600404
WR	10603992001	A3992A	0	SJIND	19711026
WR	10603993001	A3993A	0	SJIND	19761101
WR	10603994001	A3994A	0	SJIND	19480630
WR	10603995301	A3995A	1813	SJIND	19470414
WR	10603995302	A3995A	259	SJIRR	19470414
WR	10603995303	A3995A	616	SJIRR	19721120
WR	10603996001	A3996A	0	SJIND	19650407
WR	10104038301	A4038A	0	REC	19800331
WR	10104038302	A4038A	0	REC	19830418
WR	10104038303	A4038A	66	SJIRR	19951130
IF	4066N1	A4066A	362	IFCON	19800811
WR	10104066401	A4066A	45	SJIRR	19800811
WR	10104188301	A4188A	500	SJIRR	19820217
WR	10104248301	A4248A	116	SJIRR	19820920
WR	10104255301	A4255A	0	REC	19821101
WR	10104255302	A4255B	0	REC	19821101
WR	10104255303	A4255C	0	REC	19821101
WR	10104309301	A4309A	6	SJIRR	19830124
WR	10104309302	A4309B	10	SJIRR	19830124
WR	10104375001	A4375A	230	SJIND	19830620
WR	10104523301	A4523A	0	REC	19841204
WR	10604963301	A4963A	66000	SJMUN	19590112
WR	10604963302	A4963A	34000	SJIND	19590112
WR	10604963303	A4963A	0	SJMUN	19650628
WR	4963MUNCOH	4963MN	44000	SJMUN	19590113
WR	4963MUNSJRA1	4963MN	7333	SJMUN	19590113
WR	4963MUNSJRA2	4963MN	14667	SJMUN	19590113
WR	4963INDCOH	4963IN	22667	SJIND	19590113
WR	4963INDSJRA1	4963IN	6333	SJIND	19590113
WR	4963INDSJRA2	4963IN	5000	SJIND	19590113
WR	10604964001	A4964A	16800	INDCON	19420725
WR	10604964002	A4964A	38200	INDCON	19420725
WR	10604965301	A4964A	33333	SJIND	19400507
WR	10604965302	A4964A	78667	SJMUN	19400507
WR	10604965303	A4964A	56000	SJMUN	19440226
WR	COHMUN01	COHMUN	16542	SJMUN	19600101
WR	COHMUN02	COHMUN	9965	SJMUN	19600101
WR	COHMUN03	COHMUN	3832	SJMUN	19600101
WR	COHMUN04	COHMUN	615	SJMUN	19600101

Table 14 Water Right Information (Continued)

RECORD (WR/IF)	WATER RIGHT NUMBER	CONTROL POINT	ANNUAL DIVERSION / INSTREAM FLOW	USE TYPE	PRIORITY DATE
WR	COHMUN05	COHMUN	1182	SJMUN	19600101
WR	COHMUN06	COHMUN	668	SJMUN	19600101
WR	COHMUN07	COHMUN	0	SJMUN	19600101
WR	COHMUN08	COHMUN	5076	SJMUN	19600101
WR	COHMUN09	COHMUN	1619	SJMUN	19600101
WR	COHMUN10	COHMUN	2380	SJMUN	19600101
WR	COHMUN11	COHMUN	1433	SJMUN	19600101
WR	COHMUN12	COHMUN	16090	SJMUN	19600101
WR	COHMUN13	COHMUN	6886	SJMUN	19600101
WR	COHMUN14	COHMUN	1410	SJMUN	19600101
WR	COHMUN15	COHMUN	457	SJMUN	19600101
WR	COHMUN16	COHMUN	1066	SJMUN	19600101
WR	COHMUN17	COHMUN	968	SJMUN	19600101
WR	COHMUN18	COHMUN	5072	SJMUN	19600101
WR	COHMUN19	COHMUN	4385	SJMUN	19600101
WR	COHMUN20	COHMUN	14440	SJMUN	19600101
WR	COHMUN21	COHMUN	552	SJMUN	19600101
WR	COHMUN22	COHMUN	20779	SJMUN	19600101
WR	COHMUN23	COHMUN	42263	SJMUN	19600101
WR	COHMUN24	COHMUN	118779	SJMUN	19600101
WR	COHMUN25	COHMUN	46475	SJMUN	19600101
WR	COHMUN26	COHMUN	5143	SJMUN	19600101
WR	COHMUN27	COHMUN	13440	SJMUN	19600101
WR	COHMUN28	COHMUN	3749	SJMUN	19600101
WR	COHMUN29	COHMUN	3264	SJMUN	19600101
WR	COHMUN30	COHMUN	15880	SJMUN	19600101
WR	COHMUN31	COHMUN	2220	SJMUN	19600101
WR	COHMUN32	COHMUN	1564	SJMUN	19600101
WR	COHMUN33	COHMUN	5272	SJMUN	19600101
WR	COHMUN34	COHMUN	5126	SJMUN	19600101
WR	COHMUN35	COHMUN	8263	SJMUN	19600101
WR	COHMUN36	COHMUN	9146	SJMUN	19600101
WR	COHMUN37	COHMUN	1880	SJMUN	19600101
WR	COHMUN38	COHMUN	1360	SJMUN	19600101
WR	COHMUN39	COHMUN	1648	SJMUN	19600101
WR	COHMUN40	COHMUN	2535	SJMUN	19600101
WR	COHMUN41	COHMUN	39446	SJMUN	19600101
WR	COHIND100	COHIND	6045	SJIND	19600101
WR	COHIND101	COHIND	8028	SJIND	19600101
WR	COHIND102	COHIND	162864	SJIND	19600101

Table 14 Water Right Information (Continued)

RECORD (WR/IF)	WATER RIGHT NUMBER	CONTROL POINT	ANNUAL DIVERSION / INSTREAM FLOW	USE TYPE	PRIORITY DATE
WR	COHIND103	COHIND	9346	SJIND	19600101
WR	COHIND104	COHIND	1083	SJIND	19600101
WR	COHIND106	COHIND	0	SJIND	19600101
WR	COHIND108	COHIND	1572	SJIND	19600101
WR	COHIND109	COHIND	0	SJIND	19600101
WR	COHIND110	COHIND	12894	SJIND	19600101
WR	COHIND111	COHIND	600	SJIND	19600101
WR	COHIND112	COHIND	10730	SJIND	19600101
WR	COHIND113	COHIND	0	SJIND	19600101
WR	COHIND114	COHIND	11314	SJIND	19600101
WR	COHIND115	COHIND	0	SJIND	19600101
WR	COHIND116	COHIND	2159	SJIND	19600101
WR	COHIND117	COHIND	3920	SJIND	19600101
WR	COHIND118	COHIND	2175	SJIND	19600101
WR	COHIND119	COHIND	3948	SJIND	19600101
WR	COHIND122	COHIND	2318	SJIND	19600101
WR	COHIND123	COHIND	1148	SJIND	19600101
WR	COHIND124	COHIND	7085	SJIND	19600101
WR	COHIND127	COHIND	2035	SJIND	19600101
WR	COHIND128	COHIND	1030	SJIND	19600101
WR	COHIND130	COHIND	0	SJIND	19600101
WR	COHIND131	COHIND	0	SJIND	19600101
WR	COHIND132	COHIND	34498	SJIND	19600101
WR	COHIND135	COHIND	2573	SJIND	19600101
WR	COHIND137	COHIND	83103	SJIND	19600101
WR	COHIND138	COHIND	278	SJIND	19600101
WR	COHIND140	COHIND	0	SJIND	19600101
WR	COHIND141	COHIND	602	SJIND	19600101
WR	COHIND142	COHIND	182	SJIND	19600101
WR	COHIND143	COHIND	1707	SJIND	19600101
WR	COHIND145	COHIND	0	SJIND	19600101
WR	COHIND146	COHIND	4155	SJIND	19600101
WR	**10604966301**	**A4966A**	**5000**	SJIND	19590114
WR	**10604966302**	**A4966A**	**0**	SJIND	19670808
WR	10105055401	A5055A	0	REC	19860410
WR	10105191001	A5191A	0	SJIND	19880725
WR	10105209401	A5209A	230	SJIRR	19881215
IF	5257N1	A5257A	21719	IFCON	19890913
WR	10105257401	A5257A	175	SJIRR	19890913
WR	10105257001	A5257A	160	REC	19910531

Table 14 Water Right Information (Continued)

RECORD (WR/IF)	WATER RIGHT NUMBER	CONTROL POINT	ANNUAL DIVERSION / INSTREAM FLOW	USE TYPE	PRIORITY DATE
WR	10105299001	A5299A	0	SJIND	19900622
WR	10105311401	A5311A	200	SJIRR	19900907
WR	10105311402	A5311A	20	SJIRR	19940708
IF	5332N1	A5332A	941	IFCON	19901128
WR	10105332401	A5332A	378	SJIRR	19901128
WR	10105334001	A5334A	0	SJIND	19901127
IF	5336N1	A5336A	44886	IFCON	19901205
WR	10105336401	A5336A	175	SJIRR	19901205
WR	10105340001	A5340A	0	SJIND	19910116
WR	10105353001	A5353A	0	SJIND	19910320
WR	10105362001	A5362A	0	FLOOD	19910606
IF	5363N1	A5363A	23652	IFCON	19910528
WR	10105363001	A5363A	967	OTHER	19910528
WR	10105408301	A5408A	0	REC	19920310
WR	10105408302	A5408A	0	REC	19930318
WR	10105408303	A5408B	0	REC	19930318
WR	10105430001	A5430B	0	SJIND	19920901
WR	10105432001	A5432A	0	SJIND	19920928
WR	10105436301	A5436A	0	REC	19921109
WR	10105436302	A5436B	0	REC	19921109
WR	10105436303	A5436C	138	SJIRR	19921109
WR	10105437301	A5437A	0	REC	19921109
WR	10105471301	A5471A	0	REC	19931018
WR	10105471302	A5471A	0	REC	19940726
WR	10105498001	A5498A	10	SJIND	19940811
IF	5505N1	A5505A	15927	IFCON	19941025
WR	10105505401	A5505A	125	SJIRR	19941025
WR	10105507001	A5507A	0	SJIND	19941207
IF	5514N1	A5514C	475	IFCON	19950131
WR	10105514401	A5514C	0	OTHER	19950131
WR	10105522401	A5522A	109	SJIRR	19950227
WR	10105560001	A5560A	0	SJIND	19961017
IF	5565N1	A5565A	5430	5565IF	19961219
WR	10105565401	A5565A	60	SJIRR	19961219
WR	10105572301	A5572A	0	REC	19970117
WR	10105576301	A5576A	0	REC	19970220

4.2.3.3 Return Flows

Return flow in the San Jacinto Basin associated with water right diversions and groundwater use were input into WRAP as a constant monthly amount or as a percentage of the diversion amount of each water right. All groundwater return flows were modeled using the constant inflow (CI) record to provide continuous return flows throughout the simulation period. Constant inflow records are shown in Appendix O for each control point, and include:

- Return flow for individual facilities,
- Summary of all groundwater in each control point,
- Distribution of annual groundwater amount to monthly amounts for each return flow facility.

For this study, the CI records are used for wastewater discharge facilities that discharge groundwater only or with facilities that have combined surface and groundwater discharge. In the combined case, the CI record only represents the groundwater portion of the return flow. In Scenarios 5 and 8, the CI records represents groundwater and surface water return flows. Groundwater return flow input into the CI record is the minimum return flow amount for each facility over the last five (5) years of the period of record (1992 to 1996). The underlying assumption used for the CI record is that municipal use will be continuous throughout the period of record and this water will always be returned. The amount returned is only a function of the return flow percentage (100%, 50%, 0%), depending on the individual modeling scenarios amount of groundwater.

As stated in an earlier section, return flow from irrigation water rights was not modeled. Industrial and municipal water rights were assigned return flow percentages as described in the following discussion.

Currently, the City of Houston (COH) uses about 540,000 acre-feet per year (ac-ft/yr.), which represents about 45% of the City's Trinity and San Jacinto surface water supplies, totaling 1,220,467 acre-feet. Thus, total current return flows from the COH represent about 50% of what return flows would be under full utilization of their surface water rights.

<u>Municipal Use</u>

The City of Houston currently uses about 35% groundwater and 65% surface water for its municipal supply. The groundwater portion (35%) of the current COH wastewater return flows remained constant within each existing COH, and is represented by the CI record in WRAP (VER 10/99). Surface water return flows were distributed to the current COH WWTP, as well as utilities having surface water contracts with the COH, based upon weighting the existing discharges. Table 15 shows the magnitude and spatial distribution of the municipal return flows resulting from surface water use.

Industrial Use

Industries having surface water contracts with the City of Houston are supplied from both San Jacinto and Trinity surface water sources. The return flows originating from industrial use are primarily located in the SRGB watershed, with a small amount being returned in the San Jacinto-Brazos Coastal basin. Return flows were distributed to industrial facilities having surface water contracts with the COH, based upon weighting their existing discharges. Table 16 shows the magnitude and spatial distribution of the industrial return flows resulting from surface water use.

This methodology was utilized for scenarios associated with *full authorized diversions,* as simulated in Scenarios 1, 2, 4, 6 (since the COH has historic use in all use types, diversions for Scenarios 4 & 6 will be the full authorized amount) and firm yield. For Scenarios 5 and 8, which represent maximum use conditions, all return flows (surface and groundwater) were based upon current discharge locations and the historical five-year minimum, and input in the CI records. This methodology assumed that the COH Trinity river supplies were 100% reliable for purposes of the San Jacinto model.

Water Right 10-4964

This is the SJRA run-of-river water right for 55,000 ac-ft/yr. Per SJRA, 15 mgd (16,800 ac-ft/yr) is diverted to the Trinity-San Jacinto Coastal Basin, and returned with a return factor of 0.70 to control point TSJOUT which is outside of the San Jacinto WAM, but will become incorporated into the combined Trinity-San Jacinto WAM. The remaining 38,200 ac-ft/yr is returned at control point A126 (Exxon), per contract, with a return flow factor of 0.7.

Water Right 10-4963

This is the Lake Conroe water right for 100,000 ac-ft/yr. The COH owns 2/3 and SJRA owns 1/3. In order to report reliability independent of owner, the water rights for the reliability tables are 10604963301 for municipal and 10604963302 for industrial. In the model, these two water rights return 100% to imaginary control points 4963MN and 4963IN. From 4963MN and 4963IN, the flow is split between the COH and SJRA as follows.

WR 10-4963 SJRA portion

The SJRA portion of municipal diversions is 22,000 ac-ft/yr. From control points 4963MN, a diversion of 7,333 ac-ft/yr is made and returned with 0.7 RF factor to the Conroe SW Regional WWTP, and a diversion of 14,667 is made and returned with a 0.7 RF factor to the Woodlands 2 WWTP. (1/3 of SJRA municipal 10-4963 returns to Conroe, 2/3 to Woodlands.)

The SJRA portion of industrial diversions is 11,333 ac-ft/yr. Per contract, 5,000 goes to Lewis Creek, return factor 1.00. The remaining 6,333 is returned to A126 per contract with return factor of 0.7.

WR 10-4963 COH portion

The COH portion of municipal diversions (44,000 ac-ft/yr) is returned to imaginary control point COHMUN with a return flow factor of 0.7. The COH portion of industrial diversions (22,667 ac-ft/yr) is returned to imaginary control point COHIND with a return flow factor of 0.7. The distribution of return flows from control points COHMUN and COHIND (the COH return flow "hubs") is explained later in this section.

WR 10-4965

Water right 10-4965 (Lake Houston) is owned entirely by the City of Houston. The municipal diversions (78,667 + 56,000 ac-ft/yr) are returned to COHMUN with return flow factor of 0.7. The industrial diversions (33,333 ac-ft/yr) are returned to COHIND with a return flow factor of 0.7)

Trinity River water supplied to City of Houston

Constant Inflow (CI) cards are used to return water supplied from the Trinity River to the COH return flow hubs. The values in the CI cards are adjusted to simulate a return flow factor of 0.7. For the San Jacinto WAM, it is assumed that the water supplied from the Trinity River is 100% reliable.

Distribution of Return Flows in the City of Houston

Municipal water rights for the City of Houston are all initially returned to the distribution hub COHMUN with a return flow factor of 0.7 (as described above). From control point COHMUN, 41 synthetic water rights are modeled in order to return the municipal water to the multiple COH WWTPs. These synthetic water rights making diversions from COHMUN have a return flow factor of 1.0 because when diversions were returned to COHMUN from the actual COH water rights, a return flow factor of 0.7 was applied. The distribution of return flows to the multiple COH WWTPs is per the above reference.

Industrial water rights for the City of Houston are similarly all initially returned to the hub COHIND with a return flow factor of 0.7. From COHIND, 42 synthetic water rights are modeled in order to return the industrial water to the multiple return flow points. The water rights diverting from COHIND have return flow factors fo 1.0 because when diversions from the paper water rights were returned to COHIND, a return flow factor of 0.7 was applied. The distribution of COH industrial return flows is also per the above reference.

Table 15 City of Houston – Surface Water Supply Municipal Return Flows

Wastewater Treatment Plant	CRWR Number	% Weight	Municipal Return Flows Current Dry (1) (Ac-ft/yr)	Municipal Return Flows Full Authorization (Ac-ft/yr)
Almeda Sims	178	3.7%	10136	16,542
Beltway	190	2.3%	6106	9,965
Chocolate Bayou	179	0.9%	2348	3,832
Clinton Park	160	0.1%	377	615
Easthaven	162	0.3%	724	1,182
Forest Cove	170	0.2%	409	668
FWSD - 23	176	0.0%	0	-
Greenridge	189	1.1%	3110	5,076
Homestead	180	0.4%	992	1,619
Imperial Valley	165	0.5%	1458	2,380
Intercontinental Airport	163	0.3%	878	1,433
Keegans Bayou	168	3.6%	9859	16,090
Kingwood Central	172	1.6%	4219	6,886
MUD 123	166	0.3%	864	1,410
MUD 203	173	0.1%	280	457
Northbelt	169	0.2%	653	1,066
Northborough	167	0.2%	593	968
Northeast	185	1.1%	3108	5,072
Northgate	164	1.0%	2687	4,385
Northwest	184	3.3%	8848	14,440
Park Ten	171	0.1%	338	552
Sims Bayou N	177	4.7%	12732	20,779
Sims Bayou S	281	9.5%	25896	42,263
69th St.	186	26.8%	72780	118,779
Southwest	182	10.5%	28477	46,475
Turkey Creek	280	1.2%	3151	5,143
Upper Brays	191	3.0%	8235	13,440
WCID 47	183	0.8%	2297	3,749
WCID 111	187	0.7%	2000	3,264
West District	181	3.6%	9730	15,880
White Oaks	188	0.5%	1360	2,220
City of Baytown	159	0.4%	958	1,563
City of Deer Park	192	1.2%	3230	5,271
City of Pasadena	149	1.2%	3141	5,126
City of Pasadena	150	1.9%	5063	8,263
City of Pasadena	151	2.1%	5604	9,146
Jacinto City	156	0.4%	1152	1,880
City of South Houston	157	0.3%	833	1,359
City of South Houston	158	0.4%	1010	1,648
City of West University Place	152	0.6%	1553	2,535
EXPORTS (2)				
San Jac - Brazos Mun	SJBOUT	8.9%	24170	39,446
Total		100%	271,359	442,867

(1) based upon minimum reported (TNRCC) flow in last 5 years
(2) exports to Baybrook MUD #1, Clear Brook City MUD, Clear Lake City, Friendswood, Harris County MUD #55, La Porte, League City, NASA/JSC, Nassau Bay and Webster

Table 16 City of Houston – Surface Water Supply Industrial Return Flows

NAME ON PERMIT	CRWR Number	% Weight	Dry Weather (1) Return Flows (ac-ft/yr)	Full Authorization Return Flows (Ac-Ft/Yr)
Occidental Chemical Corp.	100	1.5%	2886.4	6,045
Occidental Chemical Corp.	101	2.0%	3833	8,028
Occidental Chemical Corp.	102	40.5%	77762.9	162,864
Occidental Chemical Corp.	103	2.3%	4462.2	9,345
Occidental Chemical Corp.	104	0.3%	517.2	1,083
Equistar Chemicals, L.P.	105	2.8%	5346.3	11,197
Equistar Chemicals, L.P.	106	0.0%		-
Equistar Chemicals, L.P.	107	0.0%		-
Mobil Chemical Company, Inc..	108	0.4%	750.6	1,572
Shell Oil Company	109	0.0%		-
Shell Oil Company	110	3.2%	6156.5	12,894
Deer Park Refining Ld Partnership and Shell Oil Co.	111	0.1%	286.6	600
Deer Park Refining Ld Partnership and Shell Oil Co.	112	2.7%	5123.1	10,730
ELF ATOCHEM NORTH AMERICA Inc.	113	0.0%		-
ROHM AND HAAS TEXAS, Inc..	114	2.8%	5402.3	11,314
ROHM AND HAAS TEXAS, Inc..	115	0.0%		-
ROHM AND HAAS TEXAS, Inc..	116	0.5%	1030.6	2,158
Albemarle Corp. (Ethyl)	117	1.0%	1871.7	3,920
ARMCO Inc.	118	0.5%	1038.5	2,175
The Goodyear Tire & Rubber Company	119	1.0%	1884.8	3,947
Valero Refining Company - Texas	120	0.5%	1016.6	2,129
Rhone-Poulenc, Inc..	121	0.3%	653.5	1,369
SOLVAY POLYMERS Inc.	122	0.6%	1106.8	2,318
SOLVAY POLYMERS Inc.	123	0.3%	548	1,148
Miles Inc.. and Texas Petrochemical Corp.	124	1.8%	3383.1	7,085
The Lubrizol Corp.	127	0.5%	971.8	2,035
GB Biosciences Corp.	128	0.3%	492	1,030
Phillips Petroleum Company	129	1.1%	2116	4,432
Phillips Petroleum Company	130	0.0%		-
Fina Oil and Chemical Company	131	0.0%		-
Champion International Corp.	132	8.6%	16471.9	34,498
ROLLINS ENVMNTL SER. (TX), Inc.	135	0.6%	1228.5	2,573
Occidental Chemical Corportion	136	0.8%	1611.3	3,375
Gulf Coast Waste Disposal Authority	137	20.7%	39679.2	83,103
Proler International Corp.	138	0.1%	132.8	278
Oiltanking Houston, Inc.	140	0.0%		-
Georgia Gulf Corp.	141	0.1%	287.5	602
Georgia Gulf Corp.	142	0.0%	86.8	182
The Geon Company	143	0.4%	815	1,707
Phillips Pipe Line Company	144	0.5%	1044.6	2,188
Arco Chemical Company	145	0.0%		-
Arco Chemical Company	146	1.0%	1983.7	4,155
Total		100%	191,982	402,080

(1) based upon minimum reported (TNRCC)flow in last 5 years

Return flow example calculation

The return flow example calculation utilizes the COH facility Park Ten. Park Ten is located upstream of control point BB_AD and the historical return flow data is shown in Appendix O. Park Ten has return flow from groundwater and surface water. The identification number for Park Ten is (CRWR) A171. The CI record was calculated based on the minimum discharge between 1992 and 1996. A minimum value of 337.9 ac-ft/yr for a combined surface and groundwater discharge was reported in 1996. Of this 337.9 ac-ft/yr return flow, approximately 35% or 118.3 ac-ft/yr is input as groundwater in the CI record. The annual number of 118.3 ac-ft/yr is divided into a monthly value based on the twelve monthly distribution factors defined in the summary page of BB_AD in Appendix O. The surface water component of Park Ten (A171) is input in the WRAP input card. For Scenario 1 (full authorized diversion, full return flow), the return flow from the full diversion amount was returned to Park Ten through the City of Houston water right. Surface water return flow from the full diversions amount was 552 ac-ft/yr as shown in the water rights input deck for Scenario 1 (WR Run 1) in Appendix L. The surface water return flow was also distributed into monthly values. This is true only to the extent that surface water diversions have a monthly use factor. Therefore, a constant current use return flow was used when returning the groundwater through the CI record and a full authorized diversion amount return flow was used through the water right input card for surface water.

4.2.3.4 Multiple Diversion Locations

A large number of water rights contained in the San Jacinto River Basin have multiple diversion points and/or multiple use types. Water rights with multiple diversion points include:

CA 3965	CA 3970	CA 3987	CA 4966
P 5055	P 5362	P 5430	P 5432
P 5514			

4.2.3.5 Saline Water Rights

Table D-1 (see Appendix D) represents those water rights having diversions located in the estuarine segments of the San Jacinto River Basin. These water rights are used for industrial purposes including: tank-cleaning operations, hydrostatic testing, dust control, once-through cooling, fire-fighting and for barge washing and/or ballast. The total authorized use allowed for all 18 water rights as stated in the certificates/permits is 286,420 ac-ft/yr, and a consumptive use of 39,595.2 ac-ft/yr.

The water quality of Buffalo Bayou, Greens Bayou, portions of the San Jacinto River and Houston Ship Channel varies considerably throughout the season. As reported in “Water

Quality Segment Summaries" by the Houston–Galveston Area Council and Galveston Bay National Estuary Program (May 1993), the salinity variability in the classified stream segments is shown in Table D-2.

Throughout most of the year these water rights divert fresh/brackish water, however during periods of low flow they will be diverting water with salinity equal to or exceeding that of seawater. For the San Jacinto River Basin WAM, these 18 water rights will be included in the model, however their diversion amounts will be set equal to 0, in order eliminate the priority claim on those junior water rights which are dependent upon water quality.

4.2.3.6 Rights Requiring Special Consideration

Table 21 contains a brief discussion of the assumptions utilized in representing selected water rights in WRAP.

4.2.4 Data for Basin-Specific Features Added to WRAP (VER 10/99)

Not Applicable

4.3 Significant Assumptions Affecting Water Availability Modeling

The single most significant assumption in this study regarding water availability is the manner in which naturalized flows are distributed from gaged to ungaged sites. The key assumptions in this case are the parameters which are used to distribute the flows, as described earlier in Section 2.5. Additional modeling assumptions which have a significant impact on water availability are described in the following sections.

4.3.1 Reuse

Wastewater reuse in the model was formulated for 100 percent, 50 percent, and 0 percent reuse of return flows. It was assumed that all existing reuse projects are included in the historical return flow data obtained from the TNRCC and TWDB. This data was analyzed for the past five to six years for all water rights with permitted diversions. The manner in which reuse was calculated is described in section 4.2.3.3.

4.3.2 Return Flow/Constant Inflow Assumptions

The gain/loss CI Card is utilized by the WRAP (VER 10/99) model to account for inflow of surface water to the basin. In the this study, the gain/loss CI Card was used to incorporate inflows from groundwater as well as water imported from other basins. Appendix O lists which control points had constant inflows to represent groundwater sources.

4.3.3 Off-channel reservoirs

There are numerous off-channel reservoirs in the San Jacinto River Basin. Generally, for those water rights with multiple off-channel reservoirs, a single reservoir representing the sum total of all capacities was simulated. A total of 21 off-channel reservoirs were modeled in the San Jacinto Basin. WRAP simulates off-channel reservoirs by limiting the streamflow depletions which are made to meet diversions and refill storage. These constraints are defined as annual limits, which limits the cumulative annual streamflow depletion and a monthly limit, which defines the maximum streamflow depletion for any given month. Water rights with off-channel impoundment and how they were modeled are described below:

CA 10-3963	220 acre foot off channel res.	
CA 10-3965	214 acre foot off channel res. 314 acre foot off channel res. 580 acre foot off channel res. 300 acre foot off channel res.	4 off-channel reservoirs modeled as 1
CA 10-3968	90 acre foot off channel res.	
CA 10-3979	2508.75 acre foot off channel res.	
CA 10-3980	100 acre foot off channel res. 300 acre foot off channel res.	2 off-channel reservoirs modeled as 1
CA 10-3983	150 acre foot off channel res.	
CA 10-3985	35 acre foot off channel res. 10 acre foot off channel res. 30 acre foot off channel res.	3 off-channel reservoirs modeled as 1
P 3779	5 acre foot off channel res.	
P 3937	4.6 acre foot off channel res.	
CA 10-4964	3800 acre foot off channel res. 34 acre foot off channel res.	
P 5055	3 acre foot off channel res. 2.95 acre foot off channel res.	2 off-channel reservoirs modeled as 1
P 5209	2.95 acre foot off channel res. 4.02 acre foot off channel res. 2.00 acre foot off channel res. 3.49 acre foot off channel res. 3.94 acre foot off channel res.	5 off-channel reservoirs modeled as 1
P 5257	off channel res. 1.43 ac. ft., 1.81 ac. ft., .75 ac. ft., 10.01 ac. ft., 5.89 ac. ft., 1.33 ac. ft., 38.72 ac. ft., 15.35 ac. ft.	8 off-channel reservoirs modeled as 1
P 5311	off channel res. 6.10 ac. ft., 4.60 ac. ft., 2.50 ac. ft.	3 off-channel reservoirs modeled as 1

P 5332	35 acre foot off channel res.	
P 5336	off channel res. 6.49 ac. ft., 13.69 ac. ft.	2 off-channel reservoirs modeled as 1
P 5436	7 acre foot off channel res.	
P 5505	off channel res. 6.46 ac. ft., 1.39 ac. ft.	
P 5514	500 acre foot off channel res.	
P 5522	10 off channel res. w/total capacity of 119.3 ac.ft.	
P 5565	4 acre foot off channel res. complex	

4.3.4 Term Permits

There are no water rights containing term permits in the San Jacinto River Basin.

4.3.5 Interbasin Transfers

The TNRCC maintains a list of interbasin transfers in the State of Texas. According to the list there are four permitted interbasin transfers in the San Jacinto River Basin. Table 17 lists those water rights which are authorized to divert water from the Trinity River for subsequent use in other basins, including the San Jacinto Basin.

Table 17 Interbasin Transfers in the San Jacinto River Basin

CA Number	Permittee	Authorization (Ac-Ft)	Basin of Origin	Watersheds of Use
08-1248A	Trinity River Authority	403,200	Trinity	Trinity, San Jacinto, Neches, Neches-Trinity
08-4261	City of Houston	940,800	Trinity	San Jacinto, Trinity-San Jacinto, San Jacinto-Brazos, Western portion of Neches-Trinity
10-4965	City of Houston	-		Trinity, San Jacinto
08-5271B	San Jacinto River Authority	56,000	Trinity	Trinity, San Jacinto, Trinity-San Jacinto, Neches-Trinity

Certificate of Adjudication 08-4248A, authorizes the Trinity River Authority (TRA) of Texas to use any portion of the water included in the certificate for diversion and use from

Lake Livingston in Trinity, Polk, San Jacinto, Liberty, Chambers, Jefferson, Galveston, Leon, Houston, Walker, Grimes, Freestone and Madison counties. All or portions of these counties are within the Trinity River Basin, San Jacinto River Basin, Neches-Trinity Coastal Basin, and Neches River Basin. Currently, the only interbasin transfer is due to surface water contracts between the TRA (Huntsville Regional Water Supply System) and the City of Huntsville. The City of Huntsville, which has a conjunctive use of 25% groundwater and 75% surface water, distributes flows to two Wastewater Treatment Plants (WWTP), the A.J. Brown WWTP and the NB Davidson WWTP. The A.J. Brown WWTP discharges to the Trinity River basin and the NB Davidson WWTP discharges to the San Jacinto River basin. The return flows from the NB Davidson South Wastewater Treatment Plant (represented by control point A199 in the model), are approximately 1,124 ac. ft./yr. To maintain simplicity in the model return flows from the NB Davidson South Plant were assumed to be constant and were represented as constant inflows in the CI record of the WRAP model.

Certificate of Adjudication 08-4261, authorizes the City of Houston to use all of the water diverted from the Trinity River in the San Jacinto River Basin, the Trinity-San Jacinto, the San Jacinto-Brazos, and the western portion of the Neches-Trinity Coastal Basins. The water right authorizes multiple mechanisms for transfers from the Trinity River, the two conveyance schemes are, the existing Coastal Water Authority (CWA) Canal System and the future (not constructed) Luce Bayou diversion. The existing Coastal Water Authority system distributes Trinity River water directly to Lynchburg reservoir, an off-channel reservoir, and then to the City of Houston's Water Treatment plants, as well as supplying contract raw water to the industrial complex in the Houston metropolitan area. The Luce Bayou conveyance scheme allows for Trinity water to be diverted by pipeline, canal and the bed and banks of Luce Bayou for temporary storage in Lake Houston for subsequent diversion and use. While the Luce Bayou diversion has not been constructed, the return flows which result from this interbasin transfer should not change appreciably from the existing CWA system since the distribution system is basically the same for both interbasin conveyance facilities.

Certificate of Adjudication 10-4965, authorizes the storage of water from the Trinity River Basin in Lake Houston. The reliability of this right is not dependent on water from the Trinity Basin.

The control point distribution and magnitude of return flows from the City of Houston's combined surface water sources (Lake Conroe, Lake Houston, and Trinity supplies) are described in Table 15 and 16.

Certificate of Adjudication 08-5271B, authorizes the San Jacinto River Authority (SJRA) to use all of the water diverted from the Trinity River to be used in the Trinity River Basin, San Jacinto River Basin, the Trinity-San Jacinto and the Neches-Trinity Coastal Basins. Currently, this interbasin transfer is the supply for the raw water contract with the Exxon Corporation along the SJRA Highlands Canal Division. The resulting return flows from this interbasin transfer discharge into San Jacinto Bay (represented by control points 125 and 126 in the model) within the San Jacinto River Basin. A return flow factor was used to represent this interbasin transfer.

5.0 WATER AVAILABILITY IN THE BASIN

5.1 Descriptions of Scenarios Models

The purpose of the TNRCC Water Availability Modeling (WAM) effort is to determine the water availability and/or reliability of individual water rights in the San Jacinto River Basin based on a number of different scenarios. A total of 9 water availability scenarios were developed for the San Jacinto River Basin: eight TNRCC "Base" scenarios and one basin specific scenario. The nine different scenarios include: three simulating various levels of reuse, four simulating partial/total cancellation, a current conditions scenario, and a firm yield determination for all permitted reservoirs with capacities greater than 5,000 ac-ft per year.

A summary table containing all nine runs and the respective diversion amounts is shown in Table 18. Table 19 describes the parameters simulated in each of the 9 model scenarios. Scenario 9 determines the firm yield of the major existing reservoirs in the basin based on the priority date of impoundment. There are basically three different annual diversion amounts entered into the modeling scenarios. The three categories include:

- full authorized diversions as defined in the water rights (excluding term permits).
- total and partial cancellation of water rights (total cancellation simulated for those water rights reporting 0 use in the last 10 years, and partial cancellation of water rights simulated by limiting the modeled diversion amount to the maximum use in the last 10 years)

A description of the reuse and cancellation scenarios is outlined in the following sections.

Table 18 Summary of Diversions by Run

Count	Water Right ID Number	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)[1,2]	Authorized Annual Use (ac-ft/yr)[3]	Total Annual Diversions Included in Each Model Run (ac-ft/yr)								
						Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
	Total		None	285,340	347,736	347,736	347,736	347,736	344,323	285,340	344,323	285,340	285,340	327,561
1	10603927301	A3927A		0	0	0	0	0	0	0	0	0	0	0
2	10603928301	A3928A		0	0	0	0	0	0	0	0	0	0	0
3	10603929301	A3929A		0	0	0	0	0	0	0	0	0	0	0
4	10603930301	A3930A		108	140	140	140	140	140	108	140	108	108	140
5	10603930302	A3930B		0	0	0	0	0	0	0	0	0	0	0
6	10603930303	A3930C		0	0	0	0	0	0	0	0	0	0	0
7	10603931301	A3931A		0	0	0	0	0	0	0	0	0	0	0
8	10603932301	A3932A		0	0	0	0	0	0	0	0	0	0	0
9	10603933301	A3933A		0	0	0	0	0	0	0	0	0	0	0
10	10603933302	A3933A		0	0	0	0	0	0	0	0	0	0	0
11	10603934301	A3934A		0	0	0	0	0	0	0	0	0	0	0
12	10603935301	A3935A		0	0	0	0	0	0	0	0	0	0	0
13	10603936301	A3936A		0	0	0	0	0	0	0	0	0	0	0
14	10603936302	A3936B		0	0	0	0	0	0	0	0	0	0	0
15	10603937301	A3937A		0	0	0	0	0	0	0	0	0	0	0
16	10603938301	A3938A		0	0	0	0	0	0	0	0	0	0	0
17	10603939301	A3939A		0	0	0	0	0	0	0	0	0	0	0
18	10603939302	A3939B		0	0	0	0	0	0	0	0	0	0	0
19	10603939303	A3939C		0	0	0	0	0	0	0	0	0	0	0
20	10603940301	A3940A		0	0	0	0	0	0	0	0	0	0	0
21	10603941301	A3941A		188	300	300	300	300	300	188	300	188	188	300
22	10603942301	A3942A		0	0	0	0	0	0	0	0	0	0	0
23	10603942302	A3942B		0	0	0	0	0	0	0	0	0	0	0
24	10603942303	A3942C		0	0	0	0	0	0	0	0	0	0	0
25	10603943301	A3943A		0	0	0	0	0	0	0	0	0	0	0

Count	Water Right ID Number	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)[1,2]	Authorized Annual Use (ac-ft/yr)[3]	Total Annual Diversions Included in Each Model Run (ac-ft/yr) Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
26	10603944301	A3944A		0	0	0	0	0	0	0	0	0	0	0
27	10603945301	A3945A		0	0	0	0	0	0	0	0	0	0	0
28	10603946301	A3946A		0	0	0	0	0	0	0	0	0	0	0
29	10603947301	A3947A		0	0	0	0	0	0	0	0	0	0	0
30	10603948302	A3948B		0	0	0	0	0	0	0	0	0	0	0
31	10603948301	A3948A		0	0	0	0	0	0	0	0	0	0	0
32	10603949301	A3949A		0	0	0	0	0	0	0	0	0	0	0
33	10603950301	A3950A		0	0	0	0	0	0	0	0	0	0	0
34	10603951301	A3951A		0	0	0	0	0	0	0	0	0	0	0
35	10603952301	A3952A		32	32	32	32	32	32	32	32	32	32	32
36	10603953301	A3953A		0	0	0	0	0	0	0	0	0	0	0
37	10603954301	A3954A		0	0	0	0	0	0	0	0	0	0	0
38	10603955301	A3955A		0	0	0	0	0	0	0	0	0	0	0
39	10603955302	A3955B		0	0	0	0	0	0	0	0	0	0	0
40	10603957301	A3957A		0	0	0	0	0	0	0	0	0	0	0
41	10603957302	A3957B		0	0	0	0	0	0	0	0	0	0	0
42	10603957303	A3957C		0	0	0	0	0	0	0	0	0	0	0
43	10603957304	A3957D		0	0	0	0	0	0	0	0	0	0	0
44	10603958301	A3958A		0	0	0	0	0	0	0	0	0	0	0
45	10603959301	A3959A		#N/A	750	750	750	750	0	0	0	0	0	750
46	10603960301	A3960A		0	0	0	0	0	0	0	0	0	0	0
47	10603960302	A3960B		300	310	310	310	310	310	300	310	300	300	310
48	10603961001	A3961A		#N/A	25	25	25	25	0	0	0	0	0	25
49	10603962301	A3962A		0	0	0	0	0	0	0	0	0	0	0
50	10603963401	A3963A		501	501	501	501	501	501	501	501	501	501	501
51	10603964301	A3964A		0	0	0	0	0	0	0	0	0	0	0
52	10603964302	A3964A		200	200	200	200	200	200	200	200	200	200	200
53	10603965401	A3965A		762	2941	2941	2941	2941	2941	762	2941	762	762	2941

Count	Water Right ID Number	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)[1,2]	Authorized Annual Use (ac-ft/yr)[3]	Total Annual Diversions Included in Each Model Run (ac-ft/yr) Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
54	10603966301	A3966A		#N/A	25	25	25	25	0	0	0	0	0	25
55	10603967001	A3967A		#N/A	100	100	100	100	0	0	0	0	0	100
56	10603968401	A3968A		0	0	0	0	0	0	0	0	0	0	0
57	10603969301	A3969A		0	0	0	0	0	0	0	0	0	0	0
58	10603969302	A3969B		0	0	0	0	0	0	0	0	0	0	0
59	10603969303	A3969C		0	0	0	0	0	0	0	0	0	0	0
60	10603970001	A3970B		11	15	15	15	15	15	11	15	11	11	15
61	10603971301	A3971A		0	0	0	0	0	0	0	0	0	0	0
62	10603972301	A3972A		0	0	0	0	0	0	0	0	0	0	0
63	10603973301	A3973A		0	0	0	0	0	0	0	0	0	0	0
64	10603974301	A3974A		#N/A	40	40	40	40	0	0	0	0	0	40
65	10603975301	A3975A		0	0	0	0	0	0	0	0	0	0	0
66	10603976301	A3976A		0	0	0	0	0	0	0	0	0	0	0
67	10603977301	A3977A		0	0	0	0	0	0	0	0	0	0	0
68	10603978301	A3978A		0	0	0	0	0	0	0	0	0	0	0
69	10603979401	A3979A		4890	4999	4999	4999	4999	4999	4890	4999	4890	4890	4999
70	10603980401	A3980A		1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
71	10603981301	A3981A		0	0	0	0	0	0	0	0	0	0	0
72	10603982001	A3982A		#N/A	45	45	45	45	0	0	0	0	0	45
73	10603983401	A3983A		398	800	800	800	800	800	398	800	398	398	800
74	10603984101	A3984C		#N/A	26	26	26	26	0	0	0	0	0	26
75	10603985401	A3985A		212	460	460	460	460	460	212	460	212	212	460
76	10603986001	A3986A		#N/A	19	19	19	19	0	0	0	0	0	19
77	10603987001	A3987A		0	0	0	0	0	0	0	0	0	0	0
78	10603988001	A3988A		0	0	0	0	0	0	0	0	0	0	0
79	10603989001	A3989A		0	0	0	0	0	0	0	0	0	0	0
80	10603990001	A3990A		0	0	0	0	0	0	0	0	0	0	0
81	10603991001	A3991A		0	0	0	0	0	0	0	0	0	0	0

Count	Water Right ID Number	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)[1,2]	Authorized Annual Use (ac-ft/yr)[3]	Total Annual Diversions Included in Each Model Run (ac-ft/yr) Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
82	10603992001	A3992A		0	0	0	0	0	0	0	0	0	0	0
83	10603993001	A3993A		0	0	0	0	0	0	0	0	0	0	0
84	10603994001	A3994A		0	0	0	0	0	0	0	0	0	0	0
85	10603995301	A3995A		319	1813	1813	1813	1813	1813	319	1813	319	319	200
86	10603995302	A3995A		0	259	259	259	259	259	0	259	0	0	0
87	10603995303	A3995A		0	616	616	616	616	616	0	616	0	0	0
88	10603996001	A3996A		0	0	0	0	0	0	0	0	0	0	0
89	10104038301	A4038A		0	0	0	0	0	0	0	0	0	0	0
90	10104038302	A4038A		0	0	0	0	0	0	0	0	0	0	0
91	10104038303	A4038A		57	66	66	66	66	66	57	66	57	57	66
92	10104066401	A4066A		#N/A	45	45	45	45	0	0	0	0	0	45
93	10104188301	A4188A		#N/A	500	500	500	500	0	0	0	0	0	500
94	10104248301	A4248A		116	116	116	116	116	116	116	116	116	116	116
95	10104255301	A4255A		0	0	0	0	0	0	0	0	0	0	0
96	10104255302	A4255B		0	0	0	0	0	0	0	0	0	0	0
97	10104255303	A4255C		0	0	0	0	0	0	0	0	0	0	0
98	10104309301	A4309A		0	6	6	6	6	6	0	6	0	0	6
99	10104309302	A4309B		5	10	10	10	10	10	5	10	5	5	10
100	10104375001	A4375A		#N/A	230	230	230	230	0	0	0	0	0	230
101	10104523301	A4523A		0	0	0	0	0	0	0	0	0	0	0
102	10604963301	A4963A		31293	66000	66000	66000	66000	66000	31293	66000	31293	31293	54825
103	10604963302	A4963A		15647	34000	34000	34000	34000	34000	15647	34000	15647	15647	25000
104	10604963303	A4963A		0	0	0	0	0	0	0	0	0	0	0
105	10604964001	A4964A		16800	16800	16800	16800	16800	16800	16800	16800	16800	16800	16800
106	10604964002	A4964A		38200	38200	38200	38200	38200	38200	38200	38200	38200	38200	38200
107	10604965301	A4964A		33333	33333	33333	33333	33333	33333	33333	33333	33333	33333	33333
108	10604965302	A4964A		78667	78667	78667	78667	78667	78667	78667	78667	78667	78667	78667
109	10604965303	A4964A		56000	56000	56000	56000	56000	56000	56000	56000	56000	56000	56000

Count	Water Right ID Number	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)[1,2]	Authorized Annual Use (ac-ft/yr)[3]	Total Annual Diversions Included in Each Model Run (ac-ft/yr)								
						Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
110	**10604966301**	**A4966A**		5000	**5000**	**5000**	**5000**	**5000**	**5000**	5000	**5000**	5000	5000	**5000**
111	**10604966302**	**A4966A**		0	**0**	**0**	**0**	**0**	**0**	0	**0**	0	0	**0**
112	10105055401	A5055A		0	0	0	0	0	0	0	0	0	0	0
113	10105191001	A5191A		0	0	0	0	0	0	0	0	0	0	0
114	10105209401	A5209A		102	230	230	230	230	230	102	230	102	102	230
115	10105257401	A5257A		167	175	175	175	175	175	167	175	167	167	175
116	10105257001	A5257A		0	160	160	160	160	160	0	160	0	0	160
117	10105261301	A5261A		0	0	0	0	0	0	0	0	0	0	0
118	10105299001	A5299A		0	0	0	0	0	0	0	0	0	0	0
119	10105311401	A5311A		200	200	200	200	200	200	200	200	200	200	200
120	10105311402	A5311A		20	20	20	20	20	20	20	20	20	20	20
121	10105332401	A5332A		#N/A	378	378	378	378	0	0	0	0	0	378
122	10105334001	A5334A		0	0	0	0	0	0	0	0	0	0	0
123	10105336401	A5336A		35	175	175	175	175	175	35	175	35	35	175
124	10105340001	A5340A		0	0	0	0	0	0	0	0	0	0	0
125	10105353001	A5353A		0	0	0	0	0	0	0	0	0	0	0
126	10105362001	A5362A		0	0	0	0	0	0	0	0	0	0	0
127	10105363001	A5363A		#N/A	967	967	967	967	0	0	0	0	0	967
128	10105408301	A5408A		0	0	0	0	0	0	0	0	0	0	0
129	10105408302	A5408A		0	0	0	0	0	0	0	0	0	0	0
130	10105408303	A5408B		0	0	0	0	0	0	0	0	0	0	0
131	10105430001	A5430B		0	0	0	0	0	0	0	0	0	0	0
132	10105432001	A5432A		0	0	0	0	0	0	0	0	0	0	0
133	10105436301	A5436A		0	0	0	0	0	0	0	0	0	0	0
134	10105436302	A5436B		0	0	0	0	0	0	0	0	0	0	0
135	10105436303	A5436C		#N/A	138	138	138	138	0	0	0	0	0	138
136	10105437301	A5437A		0	0	0	0	0	0	0	0	0	0	0
137	10105471301	A5471A		0	0	0	0	0	0	0	0	0	0	0

Count	Water Right ID Number	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)[1,2]	Authorized Annual Use (ac-ft/yr)[3]	Total Annual Diversions Included in Each Model Run (ac-ft/yr) Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
138	10105471302	A5471A		0	0	0	0	0	0	0	0	0	0	0
139	10105498001	A5498A		8	10	10	10	10	10	8	10	8	8	10
140	10105505401	A5505A		#N/A	125	125	125	125	0	0	0	0	0	125
141	10105507001	A5507A		0	0	0	0	0	0	0	0	0	0	0
142	10105514401	A5514C		0	0	0	0	0	0	0	0	0	0	0
143	10105522401	A5522A		109	109	109	109	109	109	109	109	109	109	109
144	10105560001	A5560A		0	0	0	0	0	0	0	0	0	0	0
145	10105565401	A5565A		60	60	60	60	60	60	60	60	60	60	60
146	10105572301	A5572A		0	0	0	0	0	0	0	0	0	0	0
147	10105576301	A5576A		0	0	0	0	0	0	0	0	0	0	0

1. #N/A denotes no use reported in TNRCC historical use database for 1986-1996. Diversions set to zero for Runs 4 through 8.
2. When maximum use reported greater than permitted diversion amount, permitted diversion amount assumed.
3. The authorized annual use includes all rights at their annual authorized diversion amounts.

Table 19 TNRCC San Jacinto River Basin Water Availability Model

#	Title	Diversion Amount	Area - Capacity	Return Flows	Term Water Rights
Re-Use					
1	0% Reuse	A	A	All	No
2	50% Reuse	A	A	50%	No
3	100% Reuse	A	A	None	No
Cancellation					
4	Total	M	A	All	No
5	Partial	MAX	A	All	No
6	Total	M	A	None	No
7	Partial	MAX	A	None	No
Current Conditions					
8	Current	MAX	Yr 2000	All	Yes
Alternative					
9	Firm Yield	A/Yld	A	None	No

Definition

A	Authorized area-capacities (original) and Authorized diversion amounts (full permitted)
M	Modified diversion amounts (10 years nonuse = 0)
MAX	Modified diversion amounts (Max use for last10 years)
Yr 2000	Year 2000 area-capacity curve
All	Return Flow factor determined based on minimum historical flows
50%	50% of computed return flow above
None	No return flow
No	No use to term water rights
Yes	Term water rights used
Yld	Diversions at reservoir set to firm yield amounts

5.1.1 Reuse

Scenarios 1, 2, and 3 evaluate the impact of wastewater reuse on water availability in the basin. This is accomplished by varying the return flow percentage between each model scenario while using permitted diversion amounts and authorized reservoir area-capacity relationships.

Scenario 1 assumes existing levels of reuse based on the levels of return flow for the past five years. The full return flow factor was utilized to estimate return flows occurring from surface water diversions and no adjustment was made to return flows which appear as a result of groundwater use and/or interbasin transfers. Scenarios 2 and 3 assume 50 percent and 100 percent reuse, respectively. The 50 percent reuse in Scenario 2 was calculated by decreasing return flow factors and constant return flows originated by groundwater and/or interbasin transfer return flows to half the initial value as set in Scenario 1. In Scenario 3, all return flows were assumed to be zero to represent the full reuse of diverted water.

5.1.2 Cancellation

Scenarios 4, 5, 6 and 7 evaluate the impact of simulated cancellation of water rights, in addition to wastewater reuse on water availability in the basin. Water rights which have not been used within the last 10 years (the statutory minimum) have been canceled in the four model scenarios listed above. Water rights utilized which reported a partial non-use of permitted diversions were *not* cancelled in any of the scenarios. Table 20 lists the water rights authorized diversion amount, maximum ten-year-use, and whether the right was cancelled.

Scenario 4 simulates water availability if specific water rights were cancelled (no reported use in ten years). In the scenario, all remaining rights were set to permitted authorized diversions and return flows were based on no reuse. Scenario 5 is identical to Scenario 4, with the exception that the diversion amounts for those water rights which were not cancelled were set to the maximum reported use in the last ten years.

Scenarios 6 and 7 are similar to Scenarios 4 and 5 in terms of diversion amount; but no return flows were incorporated, in order to represent 100% wastewater reuse.

Table 21 lists specific assumptions made for selected water rights.

Table 20 Cancellation of Water Rights in the San Jacinto River Basin (excluding recreational rights)

WATER RIGHT NUMBER	CONTROL POINT	USE TYPE	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
10603930301	A3930A	SJIRR	140	108	No
10603941301	A3941A	SJIRR	300	188	No
10603952301	A3952A	SJIRR	32	32	No
10603959301	A3959A	SJIRR	750	0	Yes
10603960302	A3960B	SJIRR	310	300	No
10603961001	A3961A	SJIRR	25	0	Yes
10603963401	A3963A	SJIRR	501	501	No
10603964302	A3964A	SJIRR	200	200	No
10603965401	A3965A	SJIRR	2941	762	No
10603966301	A3966A	SJIRR	25	0	Yes
10603967001	A3967A	SJIRR	100	0	Yes
10603970001	A3970B	SJIRR	15	11	No
10603974301	A3974A	SJIRR	40	0	Yes
10603979401	A3979A	SJIRR	4999	4890	No
10603980401	A3980A	SJIRR	1600	1600	No
10603982001	A3982A	SJIRR	45	0	Yes
10603983401	A3983A	SJIRR	800	398	No
10603984101	A3984C	SJIRR	26	0	Yes
10603985401	A3985A	SJIRR	460	212	No
10603986001	A3986A	SJIRR	19	0	Yes
10603995301	A3995A	SJIND	1813	319	No
10603995302	A3995A	SJIRR	259	0	No
10603995303	A3995A	SJIRR	616	0	No
10104038303	A4038A	SJIRR	66	57	No
10104066401	A4066A	SJIRR	45	0	Yes
10104188301	A4188A	SJIRR	500	0	Yes
10104248301	A4248A	SJIRR	116	116	No
10104309301	A4309A	SJIRR	6	0	No
10104309302	A4309B	SJIRR	10	5	No
10104375001	A4375A	SJIND	230	0	Yes
10604963301	A4963A	SJMUN	66000	31293	No
10604963302	A4963A	SJIND	34000	15647	No
10604963303	A4963A	SJMUN	0	0	No
10604964001	A4964A	INDCON	16800	16800	No
10604964002	A4964A	INDCON	38200	38200	No
10604965301	A4964A	SJIND	33333	33333	No
10604965302	A4964A	SJMUN	78667	78667	No
10604965303	A4964A	SJMUN	56000	56000	No

WATER RIGHT NUMBER	CONTROL POINT	USE TYPE	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
10604966301	A4966A	SJIND	5000	5000	No
10604966302	A4966A	SJIND	0	0	No
10105209401	A5209A	SJIRR	230	102	No
10105257401	A5257A	SJIRR	175	167	No
10105257001	A5257A	REC	160	0	No
10105311401	A5311A	SJIRR	200	200	No
10105311402	A5311A	SJIRR	20	20	No
10105332401	A5332A	SJIRR	378	0	Yes
10105336401	A5336A	SJIRR	175	35	No
10105363001	A5363A	OTHER	967	0	Yes
10105436303	A5436C	SJIRR	138	0	Yes
10105498001	A5498A	SJIND	10	8	No
10105505401	A5505A	SJIRR	125	0	Yes
10105522401	A5522A	SJIRR	109	109	No
10105565401	A5565A	SJIRR	60	60	No

Note: Although some records indicate the maximum reported use the last 10 years as being zero, the water right was not canceled because another portion of the water right was used.

Table 21 Water Rights Issues and Assumptions

WR Number	Water Right Issue	Assumptions / Comments
10-3941	Special Condition: In times of low stream flow owner may maintain reservoir level by pumping ground water into the reservoir.	Reliability of water right does not take into account conjunctive use of groundwater as allowed under the special conditions of the water right
10-3942	Certificate includes two reservoirs created by Dams Nos. 3 and 4 with a combined capacity of 2.9 acre-feet. Individual capacities are not given.	Reservoirs created by Dams 3 & 4 are combined in the model, with a combined capacity of 2.9 acre-feet, and located at the downstream reservoir
10-3959	Special Conditions: B: Owner shall provide and maintain as part of this project a well with a pump capacity of not less than 700 gallons per minute. C: All water loss and diversions from the aforesaid reservoir shall be replenished from the well.	Permit is ambiguous in regards to actual use. Therefore, total diversion of 750 acre-feet is modeled as a diversion to allow for a conservative assumption.
10-3960	Special Conditions: B: Owner shall provide and maintain as part of this project a well with a pump capacity of not less than 1000 gallons per minute. C: All water loss from the reservoirs shall be replenished from the well, or by treated effluent from the Woodlands Sewage Treatment Plant.	Permit is ambiguous in regards to actual use. Therefore, total diversion of 750 acre-feet is modeled as a diversion to allow for a conservative assumption.
10-3965	Impoundment includes 4 off-channel reservoirs with capacities of 214, 314, 580 & 300 acre-feet. Amendment allows diversions from either bank of Cypress Creek at any point on the land described in the certificate.	4 off-channel reservoirs modeled as a single off-channel reservoir with a volume of 1408 acre-feet. Diversion location may be anywhere along owners land, modeled as 1 point
10-3966	Special Condition: Owner is authorized to store groundwater in the aforesaid reservoir for subsequent diversion and use for irrigation purposes.	To be conservative, reliability of water right does not take into account conjunctive use of groundwater as allowed under the special conditions of the water right
10-3968	Impoundment is an off-channel reservoir with a capacity of 90 acre-feet. Owner is authorized to divert and use 96 acre-feet of water per annum into the off-channel reservoir for recreation purposes. No maximum diversion rate given for off-channel reservoir.	Although diversion amount is stated in certificate, the use is for recreation only. The diversion is only to keep off-channel reservoir full. Thus model with zero diversion amount, and use the written diversion amount as the annual streamflow depletion limit in the model. Set monthly depletion limit equal to the annual depletion limit.
10-3970	Diversion allowed at two locations, amount to be diverted at each location not stated in certificate.	Modeled entire diversion amount at downstream diversion point
10-3979	Water right includes a 25 acre-feet on-channel and a 2508.75 acre-feet off-channel reservoir.	On-channel reservoir considered as a forebay for the diversion of 5,000 acre-feet/yr. The reservoirs are combined in the model as an off-channel reservoir only, with a capacity of 2534 acre-feet.
10-3980	Impoundment includes 2 off-channel reservoirs with capacities of 100 and 300 acre-feet.	2 off-channel reservoirs modeled as a single off-channel reservoir with a capacity of 400 acre-feet.
10-3984	Diversion allowed at three locations, amount to be diverted at each location not stated in certificate	Modeled entire diversion amount at most downstream diversion point

WR Number	Water Right Issue	Assumptions / Comments
10-3985	Impoundment includes 3 off-channel reservoirs with capacities of 35, 10 and 30 acre-feet.	3 off-channel reservoirs modeled as a single off-channel reservoir with a capacity of 75 acre-feet.
10-3987	Diversion allowed at two locations, amount to be diverted at each location not stated in certificate. Location of diversion point is in an estuarine stream segment.	Modeled entire diversion at diversion point on Buffalo Bayou Saline water right, modeled as zero diversion.
10-3988	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
10-3989	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
10-3990	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
10-3991	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
10-3992	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
10-3993	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
10-3994	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
10-3995	Diversion allowed at two locations, amount to be diverted at each location not stated in certificate.	Modeled entire diversion amount at most downstream diversion point
10-3996	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
P-4066	Amendment to certificate adds a second off-channel reservoir at a later date. WRAP does not have option to have a cumulative streamflow depletion limit applied to two or more WR cards.	Streamflow depletion limit is unchanged, and set as the permitted diversion amount. Combined the two off-channel reservoirs and used earlier priority date of diversion and 1st off-channel reservoir.
P-4248	Impoundment includes 88 acre-feet on-channel reservoir and 4.6 acre-feet off-channel reservoir. Streamflow depletion limits in WRAP do no limit releases from storage.	Modeled as 92.6 acre-feet on-channel reservoir.
P-4375	Permit states maximum diversion amount of 230 acre-feet per annum, with consumptive use not to exceed 35 acre-feet.	Model diversion amount of 230 acre-feet per year with return flow factor of 0.85 to represent max consumptive use of 35 ac-ft/yr
10-4963	Certificate includes multiple owners. SJRA has contract to divert to Lewis Creek Reservoir.	Split 2/3 to City of Houston, 1/3 to SJRA. Split SJRA portion of industrial flows with 5,000 ac-ft/yr diversion returning 100% to Lewis Creek.
10-4964	Certificate includes off-channel reservoir at a later priority date than the diversion. WRAP does not allow streamflow depletion limits to be applied to cumulative depletions on separate WR/WS cards to meet diversion & refill storage at different priority dates. Certificate allows for industrial, municipal and irrigation use.	Streamflow depletion limit is set as the permitted diversion amount. Water right, including the off-channel reservoir is modeled at the priority date of the diversion. Modeled use type is industrial only per San Jacinto River Authority.

WR Number	Water Right Issue	Assumptions / Comments
10-4965	Certificate allows for industrial, municipal and irrigation uses. Special condition allows storage of water diverted from the Trinity River Basin for subsequent diversion and use. Certificate allows for impoundment of 160,000 acre-feet.	Modeled use type is split between municipal and industrial per City of Houston Reliability of water right does not include transfers from the Trinity River Basin. Model reservoir based on permitted storage amount.
10-4966	Water right is for storage of water purchased from the San Jacinto River Authority and the diversion and use of that water for industrial purposes.	SJRA diversion of 5,000 ac-ft/yr made from Lake Conroe, returning 100% to Lewis Creek Reservoir. Water right at Lewis Creek Reservoir of 5,000 ac-ft/yr with no return flows.
P-5055	Impoundment includes 2 off-channel reservoirs with 34 and 3 acre-feet capacities. Diversion allowed at two locations, amount to be diverted at each location not stated in certificate. Off-channel reservoir with use type of recreation only.	2 off-channel reservoirs modeled as a single off-channel reservoir with a capacity of 37 acre-feet. Modeled entire diversion amount at most downstream diversion point. Authorized diversion amount from permit is used for annual streamflow depletion limit, while model has zero for diversion amount;
P-5191	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
P-5209	Impoundment includes 5 off-channel reservoirs with capacities of 2.95, 4.02, 2.00, 3.49 & 3.94 acre-feet	5 off-channel reservoirs modeled as a single off-channel reservoir with a capacity of 16.4 acre-feet.
P-5257	Special condition requires the diversion structure to be constructed to ensure that it will not receive water from Buffalo Bayou when the flow at Buffalo Bayou near Addicks is less than 30 cfs. Impoundment includes 8 off-channel reservoirs with capacities of 1.43, 1.81, 0.75, 10.01, 5.89, 1.33, 38.72, & 15.35 acre-feet. Authorized diversion of 160 acre-feet per annum for non-consumptive use to provide flow within an unnamed tributary to Buffalo Bayou for recreation (aesthetic) purposes. Original permit includes a maximum pump rate of 2.67 cfs (161 acre-feet/month) and a authorized diversion amount of 175 acre-feet per year for irrigation/off-channel reservoirs. Amendment includes 160 acre-feet diversion, with no stated change in maximum pump rate.	Instream flow requirement modeled at diversion point. 8 off-channel reservoirs modeled as a single off-channel reservoir with a capacity of 75.29 acre-feet. Diversion of 160 acre-feet is modeled with a return flow factor of 1.0. Model with maximum pump rate split between the monthly streamflow depletion limits for the 2 WR cards. The 160 acre-ft/yr diversion for recreation /aesthetic use is modeled with a constant use factor, thus monthly use is 13.3 acre-feet. Set monthly streamflow depletion limit for this WR card as 14 acre-feet. Model with remainder of maximum pump rate set as monthly streamflow depletion limit of 147 acre-feet for WR/WS card representing the 175 acre-feet/year diversion and off-channel reservoirs. This amount still exceeds the greated possible monthly need which is to refill the reservoir from being dry (75 ac-ft) and meet the greatest monthly irrigation amount (175*0.23 = 40 ac-ft)
P-5299	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.

WR Number	Water Right Issue	Assumptions / Comments
P-5311	Impoundment includes 3 off-channel reservoirs with capacities of 6.10, 4.60, & 2.50 acre-feet. Amendment increases authorized diversion from 200 to 220 acre-feet per year. Max diversion rate of 2.7 cfs (163 ac-ft/month) from original permit unchanged by the amendment.	3 off-channel reservoirs modeded as a single off-channel reservoir with a capacity of 13.2 acre-feet. Monthly streamflow depletion limit for the WR card representing the additional 20 acre-feet/year diversion amount set to 5 acre-feet per month to meet the maximum month for irrigation. Remaining 158 ac-ft/month assigned as monthly streamflow depletion limit for the original 200 acre-ft/yr diversion and off-channel reservoirs.
P-5334	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
P-5336	Impoundment includes 2 off-channel reservoirs with capacities of 6.49 & 13.69 acre-feet. Diversion allowed between two locations, amount to be diverted at each location not stated in permit. Special condition requires the diversion structure to be constructed to ensure that it will not receive water from Buffalo Bayou when the flow at Buffalo Bayou near Piney Point is less than 62 cubic feet per second.	2 off-channel reservoirs modeled as a single off-channel reservoir with a capacity of 20.18 acre-feet. Modeled at a single most downstream diversion point Instream flow requirement modeled at diversion point.
P-5340	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
P-5353	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
P-5362	Permit is to divert flood flows of Keegans Bayou & channel (D140-00-00) to Sims Bayou to the Blue Ridge Detention Facility for flood protection. Low flows (more frequent than about the 2-year flood event) and the first part of all flood flows shall not be diverted.	Flood control use only, zero diversion normal flows, thus no diversion modeled
P-5363	Use is for water quality to flush out Cove Creek, which prior to channelization was a segment of Buffalo Bayou. Water which is diverted, less evapo-transporation losses, is returned to Buffalo Bayou. Special conditions authorize diverion of water only when remaining flow of Buffalo Bayou near Addicks is above 32.67 cfs.	Assume negligible evapo-transporation losses, model with a return flow factor of 1.0 Instream flow requirement modeled at diversion point.
P-5430	Diversion allowed at two locations, amount to be diverted at each location not stated in certificate. Location of diversion point is in an estuarine stream segment.	Modeled entire diversion at most downstream diversion point. Saline water right, modeled as zero diversion.
P-5432	Authorized diversion of 245 acre-feet per year. No water is authorized for consumption as all of the water used is returned to Buffalo Bayou. Location of diversion point is in an estuarine stream segment.	Modeled with a return flow factor of 1.0 Saline water right, modeled as zero diversion.

WR Number	Water Right Issue	Assumptions / Comments
P-5436	Impoundment includes 72 acre-feet on-channel reservoir and 7 acre-feet off-channel reservoir. Streamflow depletion limits in WRAP do no limit releases from storage. Diversion from streamflow/on-channel reservoir through 18-inch diameter pipe. Max pump rate from off-channel reservoir 4.9cfs (196 acre-feet/month). Authorized diversion amount of 138 acre-feet per year from on-channel reservoir.	Modeled as 79 acre-feet on-channel reservoir. Monthly streamflow depletion limit set to annual authorized diversion amount.
P-5498	Authorized diversion of 10 acre-feet per year, with a consumptive use of one acre-foot.	Modeled with a return flow factor of 0.90.
P-5505	Impoundment includes 2 off-channel reservoirs with capacities of 6.46 and 1.39 acre-feet. Diversion allowed at two locations, amount to be diverted at each location not stated in permit or amendment. Special conditions authorize diverion of water only when remaining flow of Brays Bayou downstream of permitees existing diversion point equals or exceeds 22 cfs.	2 off-channel reservoirs modeled as a single off-channel reservoir with a capacity of 7.85 acre-feet. Modeled entire diversion amount at most downstream diversion (on Brays Bayou, no diversion modeled on tributary). Instream flow requirement modeled at downstream diversion point.
P-5507	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
P-5514	Special Condition: To allow normal flows to pass through the three authorized dams, permittee shall maintain a pipe through each of the dams at the streambed that has a diameter of at least 12 inches. Off-channel reservoir complex to impound not to exceed 500 acre-feet. Three diversion dams constructed on tributary of Cypress Creek. No maximum rate stated in permit.	Based on evaluation of naturalized flows, the "normal" flows at the dams is 39 acre-feet per month. Instream flow requirement modeled at diversion dam locations, with a constant seasonal factor. Off-channel reservoir complex modeled as a single reservoir at the most downstream diversion dam location with no streamflow depletion limits.
P-5560	Location of diversion point is in an estuarine stream segment.	Saline water right, modeled as zero diversion.
P-5565	Special conditions authorized diversion of water during the months of December through September only when the flow downstream of the diversion point is at least 8 cfs and during other months when the flow is at least 5 cfs. No reported use is shown for this water right for the period ending in 1996 as the priority date for this water right is December 19, 1996.	Instream flow requirement modeled at diversion point. The model has monthly distribution factors to represent the varying instream flow requirements. Use full permitted diversion amount for all cancellation scenarios.

5.1.3 Current Conditions Scenario

Scenario 8, a TNRCC base scenario, was performed to estimate water availability under current conditions of water use and storage capacity. There are no term permits in the San Jacinto Basin; therefore, Scenario 8 is identical to Scenario 5 with year 2000 capacities utilized. Conditions of this scenario include:

- Setting the annual diversion amounts to the maximum reported use in the last ten years
- Basing return flows on no wastewater reuse.
- Developing area-capacity relationships for all major reservoirs to reflect year 2000 conditions, as a result of sedimentation.

Appendix N contains the tables showing the original and the estimated area-capacity relationship as of the year 2000 for each major reservoir in the San Jacinto River Basin

The current condition scenario consists of diverting the maximum amount used by a water right holder in the last ten years, using year 2000 area-capacity curves, with no term permits.

5.1.4 Firm Yield Scenario

The firm yield run (Scenario 9) is a basin specific scenario to identify the yield of any major reservoir which has shortages under its authorized diversion amount. Diversions, or drafts from reservoirs were made such that the remaining volume left in storage was within 1 percent of the total original storage capacity. Diversions were adjusted up or down, maintaining the existing seasonal use patterns and existing priority dates until the reservoir went dry. The priority dates given to major reservoirs in the firm yields analysis were generally those as defined in the water rights.

Although there are four major reservoirs in the San Jacinto Basin (Conroe, Houston, Lewis Creek, and Sheldon Reservoir), only the Lake Conroe yield required analysis. Lake Houston firm yield was always the maximum allowable diversion (168,000 ac-ft/yr). The firm yield of Sheldon Reservoir was 200 ac-ft/yr. Lewis Creek was not analyzed for firm yield because it is only used for forced evaporation and has no other diversions. The firm yield of Lake Conroe was 79,825 acre-feet/year. This represents less than 1% of reservoir storage remaining in firm yield determination, as stated in paragraph above.

5.2 Results of Water Availability Model

Appendix P provides the results from the various WRAP (VER 10/99) models and illustrates the reliability of individual water rights. The tables in Appendix P list all water rights in the San Jacinto River Basin with permitted diversions along with their period and volume reliability. Period reliability, expressed in percent is defined as the ratio of number of months for which no shortages occurred to the total number of months in the simulation period. Volumetric reliability, expressed as a percent, represents the ratio of the mean volume of shortages divided by the corresponding annual diversion amount.

Specific large water rights were analyzed to supplement the reliability results shown in Tables P-1 through P-3. For this effort four reservoirs were selected:

- Lake Conroe located on the West Fork San Jacinto River.
- Lake Houston located on the San Jacinto River.
- Lewis Creek Reservoir located in Montgomery County.
- Sheldon Reservoir located in Harris County.

The monthly storage for these reservoirs, under Scenarios 2 through 8 are compared to the monthly storage for Scenario 1, considered here only as a baseline scenario.

Of additional concern are the regulated and unappropriated flows at four control points:

- USGS gage West Fork San Jacinto near Conroe (WSCN).
- USGS gage San Jacinto River near Huffman (SRHF).
- USGS gage Buffalo Bayou at Houston (BBHO).
- San Jacinto River at Galveston Bay (SRGB).

Regulated flows are defined as the actual streamflows at that control point, including releases from upstream reservoirs for downstream water rights and instream flow requirements that are not available for appropriation. Unappropriated flows are those streamflows at a control point which remain after all water rights in the simulation have made their depletions. Unappropriated streamflows reflect that amount of water, which may be available for future use. Unappropriated flows and regulated flows under Scenarios 2 through 8 are compared to those streamflows for Scenario 1. Future appropriations are subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code. Environmental flow needs will be considered when granting new water rights or amending existing water rights, thereby affecting the amount of water available for appropriation.

Appendix P contains the study results for selected reservoirs and control points in order to compare the impacts of various scenarios.

5.2.1 Reuse

The results showing the reliability of supply for Scenarios 1, 2, and 3 are presented in Table P-1. Graphical plots for selected reservoirs and control points are presented in Appendix P, Figures P-1 through P-12. The effects of wastewater reuse on the four selected reservoirs varies considerably, as shown in Figures P-1 through P-4. There is a significant impact on Lake Conroe as a result of reuse. Monthly reservoir storage declined between Scenario 1 and Scenario 3 approximately 50,000 ac-ft in 1955. Lake Houston Reservoir shows no impact on water supply reliability, but end of period storage is affected by approximately 45,000 ac-ft between Scenarios 1 and 3.

Varying levels of reuse does not affect Sheldon Reservoir because there are no large return flows upstream of the reservoir. As shown in Figure P-3, all three reuse scenarios are approximately equivalent and therefore, there is no impact on Sheldon Reservoir from reuse.

Lake Conroe does show effects of 50% and 0% return flow during the critical period. When hydrologic conditions are normal or greater (non-critical period) the impact on Lake Conroe from reuse is minimal (see Figure P-1). However, during the drought of 1954 the difference from 100% return flow to 50% and 0% is approximately 10,000 acre-feet/year and 40,000 acre-feet/year, respectively. The only return flow entering Lake Conroe is from the City of Huntsville. The change in reservoir content is primarily due to water bypassing Lake Conroe to fill the senior impoundment of Lake Houston.

Likewise for Lake Houston, during the critical period of record the reservoir is effected by the 50% and 0% return flow simulations (see Figure P-2). Return flows into Lake Houston are from the numerous wastewater facilities in the Cypress and Spring Creek watersheds. The largest difference in the three reuse scenarios is in 1956. The difference from Run 1 to the 50% and 0% return flow is 15,000 acre-feet/year and 45,000 acre-feet/year, respectively.

Lewis Creek had differences from Run 1 to 50% and 0% return flow of approximately 1,000 acre-feet/year and 2,000 acre-feet/year, respectively (see Figure P-4).

5.2.1.1 Specific Large Rights

Water rights 4964 and 4965 (SJRA and COH) were located at control point A4964A. Generally, the reliability for the industrial part of the water right decreases as the reuse increases in Scenarios 1 through 3. SJRA water rights in Lake Conroe also had a decrease in reliability from 99.13 to 98.26 between Run 1 and Run 3.

5.2.1.2 Unappropriated Flows at Selected Locations

Annual unappropriated flows using varying levels of wastewater reuse are shown in Figures P-5 through P-8. Control points WSCN and SRHF show minimal effects on unappropriated flows from reuse scenarios, but reuse does have a significant impact at control point SRGB. Control point BBHO shows differences of 25,000 acre-feet/year to 30,000 acre-feet/year in 1963 between run one and run three. This difference is caused by the small wastewater facilities located on the upper portion of the Buffalo Bayou. The main reason for the difference in unappropriated flows at SRGB is the difference in the return flow associated with the City of Houston as described in Table 15 and Table 16.

5.2.1.3 Regulated Flows at Selected Locations

Annual regulated flows using varying levels of wastewater reuse are shown in Figures P-9 through P-12 for control points WSCN, SRHF, BBHO, and SRGB. The effects of wastewater reuse on regulated flows at the selected control points are consistent with those at unappropriated flows described in the previous section.

5.2.2 Cancellation Scenarios

There are 28 water rights with authorized diversion amounts of approximately 344,323 ac-ft/yr modeled in the cancellation Scenarios 4 and 6. The diversion amount for Scenario 5 and 7 is approximately 285,340 ac-ft/yr. Water rights that have been cancelled are shown in Table 20.

5.2.2.1 Specific Large Rights

The reliability of each water right in Scenarios 4, 5, 6 and 7 is shown in Table P-2. Reservoir storage, unappropriated and regulated flows for the cancellation scenarios are presented in Figures P-13 through P-36. The following discussion describes the effects of the cancellation scenarios on each of the four reservoirs in the San Jacinto Basin.

- Lake Conroe – Figure P-13 illustrates that cancellation Scenario 4 is approximately the same as reuse run one. Both scenarios utilize full return flows and full authorized amounts. The only difference is 3,405 ac-ft/yr of cancelled water rights. This small amount of cancellation, along with the return flow into Lake Conroe, does not change the reservoir storage between the two runs. Scenario five utilizes full return flows and the maximum use demand (see Table 18 for demand changes). The scenario drastically changes the reservoir storage during the critical period. The maximum change between run one and run five is in 1956 and is approximately 225,000 ac-ft (See Figure P-13). Scenario 6 is equivalent to Scenario 3 (no return flow), again the only difference between the scenarios is the 3,405 ac-ft of cancelled water rights. Scenario 7 is similar to Scenario 5 with a maximum change between scenario one and seven of approximately 175,000 ac/ft in 1956. Scenarios 6 and 7 are shown in Figure P-25.

- Lake Houston – Scenarios 4 and 5 for the cancellation scenarios for Lake Houston are illustrated in Figure P-14. Scenario 4 diversion amount is 3,405 ac-ft/yr less than that of Scenario 1. The majority of this difference does not effect Lake Houston diversions and therefore the two runs are similar. Run five has full return flow with maximum use diversions. Scenario 6 and 7 are shown in Figure P-26. Scenario 7 illustrates that maximum use and no return flow deplete reservoir storage to the lowest point of approximately 50,000 ac-ft in 1956. Scenario 7 is equivalent to reuse Scenario 3, indicating that Lake Houston storage is driven more by return flow than the cancellation of water rights upstream.

- Sheldon Reservoir – Scenarios 4 and 5 are shown in Figure P-15 and Scenarios 6 and 7 in Figure P-27. Sheldon reservoir is not impacted substantially by the cancellation of water rights in the San Jacinto Basin. Scenarios 5 and 7 show slightly higher monthly storage values in the critical time periods. Both scenarios are increased a maximum 1,700 ac-ft/yr in 1954.

- Lewis Creek - – Scenarios 4 and 5 are shown in Figure P-16 and Scenarios 6 and 7 in Figure P-28. Again, Scenario 1 and 4 are similar, and storage in Scenario 5 is increased by the water right cancellations and difference in maximum use demand. Storage increases appear larger in this reservoir due to the lower reservoir content. Scenario 6 is equal to reuse Scenario 3 and reservoir storage in Scenario 7 increased because of cancellation and the lower demand values (maximum use).

The two industrial portions of 4964 varied in reliability from 91.38 % to 81.89 % and from 88.39 % to 78.84 from Scenarios 4 to 7. SJRA water right 4963 increased reliability from 99.13 % to 100 % from Scenario 4 to 5 and 98.25 % to 100 % from Scenario 6 to 7.

5.2.2.2 Unappropriated Flows at Selected Locations

The effect on annual unappropriated flows differed in all four cancellation scenarios. The difference was from minimal to significant. The difference in magnitude is due to the varying levels of return flow, cancellation of water rights, and the maximum historical use being significantly less than the authorized diversion amount. Figures P-17 through P-20 and Figures P-29 through P-32 illustrate the unappropriated flow at selected control points (defined in a previous section) for Scenarios 4 and 5, and 6 and 7, respectively. In general, reuse and maximum historical use had significant effect on unappropriated flows while cancellation of individual water rights had a negligible effect.

5.2.2.3 Regulated Flows at Selected Locations

Annual regulated streamflow values for cancellation Scenarios 4 and 5 are illustrated in Figures P-21 though P-24, and Figures P-33 through P-36 for Scenarios 6 and 7. Patterns in the regulated flows were similar to those in the unappropriated flows.

5.2.3 Current Conditions Scenario

Results from Scenario 8 are shown in Table P-3. Scenario 8 is the current conditions scenario including maximum use demands, current reservoir capacities, and full return flows. This scenario was developed for term permits; however, the San Jacinto Basin has no term permits to include. Scenario 8 results for reservoir storage, unappropriated and regulated streamflow if shown in Figures P-37 through P-48.

5.2.3.1 Specific Large Rights

There are significant differences in reservoir storage, unappropriated and regulated flows between reuse Scenario 1 and current condition Scenario 8. Differences in reservoir storage are shown in Figure P-37 through P-40.

- Lake Conroe – Scenario 8 is similar to Scenario 5 (maximum use demand, all return flow, and cancellation), the reservoir capacity is the current condition and therefore, Scenario 8 begins at a lower monthly storage value than Scenario 1.

- Lake Houston – Same as Lake Conroe.

- Sheldon Reservoir and Lewis Creek did not change significantly in capacity from the original to the current condition. Therefore, Scenario 8 is both reservoirs matches Scenario 5 in both cases.

5.2.3.2 Unappropriated Flows at Selected Locations

Annual unappropriated flows for WSCN, SRHF, BBHO, and SRGB are shown in Figures P-41 through P-44. Total unappropriated flows into Galveston Bay (SRGB) increase from Scenario 8 to Scenario 1. The increase in streamflow is a direct result of the amount of water being diverted in Scenario 8. Diversions are based on maximum use and therefore are significantly less than the full authorized amount in Scenario 1.

5.2.3.3 Regulated Flows at Selected Locations

Regulated streamflow values are shown in Figures P-45 through P-48. Results are similar to those described in the previous section.

5.2.4 Firm Yield Scenario

The firm yield run (Scenario 9) is a basin specific scenario to identify the yield of any reservoir which goes dry under authorized diversions. Diversions, or drafts, from Lake Conroe were made such that the remaining volume left in storage was within 1 percent of the total original storage capacity. Diversions were adjusted up or down, maintaining the existing seasonal use patterns and existing priority dates until the reservoir went dry. The priority dates given to major reservoirs in the firm yields analysis were generally those as defined in the water rights.

Although there were four (4) major reservoirs in the San Jacinto Basin (Conroe, Houston, Lewis Creek, and Sheldon Reservoir), only the Lake Conroe and Sheldon Reservoir yield required analysis. The Lake Houston firm yield was always the maximum allowable diversion (168,000 ac-ft/yr). Sheldon Reservoir has a firm yield of 200 ac-ft/yr. Lewis Creek was not analyzed for firm yield because it is only used for forced evaporation and has no other diversions. The firm yield of Lake Conroe was 79,825 ac-ft/yr. This represents less than 1% of reservoir storage remaining in firm yield determination.

5.3 Comparison to Existing River Basin Model

Dr. Ralph Wurbs created a water availability model for the San Jacinto Basin in 1996.

5.4 Galveston Bay Freshwater Inflows

There are numerous sources of freshwater inflow into Galveston Bay. Major contributors to the bay are the Trinity and San Jacinto Rivers. The San Jacinto River Basin contributes approximately 27.5 % of the freshwater inflow through the San Jacinto River and the Houston Ship Channel – Buffalo Bayou. Annual unappropriated flows are illustrated at the control point SRGB. Control point SRGB is located at the intersection of the San Jacinto River and Galveston Bay. Annual unappropriated flows into Galveston Bay for Runs 1 though 3 is shown in Figure P-8. As the amount or reuse increases that amount of unappropriated flow decreases. In some cases between Run 1 and Run 3, the difference in annual unappropriated flow entering Galveston is approximately 1,000,000 ac-ft/yr (1986). Annul unappropriated flow for Galveston Bay for Runs 4 and 5 are shown in Figure P-24. Again, as the reuse increased the amount of unappropriated flow decreased. However, the amount of change between Runs 1 and 5 was significantly less than those seen in Figure P-8. Unappropriated flows for Runs 6 and 7 are shown in Figure P-32. Unappropriated flows in Runs 1, 6 and 7 were identical because water rights were cancelled and reuse was 100%. The greatest influence to unappropriated flow was the change in reuse percentage.

For a description of Galveston Bay inflow demands see Deliverable 3. Monthly statistical distributions for all runs will be included in the Final Report to be submitted to the TNRCC. Annual unappropriated flows for the naturalized case will also be included in the Final Report.

5.5 Factors Affecting Water Availability and Modeling Results

There are several factors that affect the water availability modeling. One of the most important issues with regard to the water availability analyses performed for the San Jacinto Basin and the results from the WRAP model relates to naturalized streamflow development. Under current TNRCC contracts, contractors are required to analyze all return flow facilities permitted above 1 MGD. For this project, return flow facilities with historical discharge above 0.5 MGD (regardless of permitted amount) were included in the naturalization process. Further analysis indicated that in the upper portions of the San Jacinto Basin, above control point SRHF, wastewater facilities between 0.2 and 0.5 MGD contributed 15-20 % of the return flow. Therefore, these facilities had to also be included in the naturalization process. By including these facilities in the naturalization process, the naturalized streamflows are better estimations.

Distribution of naturalized flows can also affect the results of the modeling process. The TNRCC has required that the calculated naturalized streamflow be distributed based on three watershed parameters – drainage areas, curve numbers and mean annual precipitation. These watershed parameters are developed by the CRWR at the University of Texas and have a direct effect on the results of the WAM model. The accuracy of the drainage areas derived using GIS procedures must be manually checked and verified. For this study, refined digital elevation data (30 meter-square cells) were used to create the drainage areas. With regard to NRCS curve numbers assigned to the watersheds of individual control points in the model, the small watersheds may only have enough area to cover one curve number type. Therefore, it is extremely important to verify the correct curve number is being used for these areas.

The following assumptions were made:

1. Interbasin transfer from the Trinity River Basin is 100% reliable.
2. COH groundwater usage is 35% of demand, which will change to 20% of demand in the near future.
3. COH return flows will increase at existing wastewater treatment plants, and not be distributed to new future wastewater treatment plants.

5.6 Requirements for Model Re-run and/or Model Update

At the time of this report there are no reasons for re-running or updating the models.

6.0 SUMMARY AND CONCLUSIONS

The Texas A&M WRAP model (VER 10/99) has been applied to the San Jacinto River Basin in Texas to determine water availability. All of the 110 water rights in the basin were included in the model, including saline rights with no diversion. Water availability was calculated in three basic scenarios: (1) Reuse Runs (full authorized diversions with varying return flow amounts), (2) Cancellation Runs (varying diversion and return flow amounts based on cancellation of water rights), and (3) Current Conditions Runs (maximum use diversions with return flows using year-2000 area-capacity reservoir relationships. All scenarios utilized:

- 57-year period of naturalized flows from 1940 through 1996.
- Water rights information for all water rights issued by the TNRCC through February 1999.

The WR, WS and OR records in WRAP (VER 10/99) characterize the written permit and other pertinent information required for input into the computer model. No system operations were modeled unless authorized in the written permit. Nine scenarios were performed; eight base scenarios and one basin specific scenario (firm yield). The primary conclusions of this water availability study of the San Jacinto Basin are as follows:

- The San Jacinto River Basin, located in southeastern Texas, drains an area of approximately 4,000 square miles. There are a total of 110 water rights with approximately 629,252 acre-feet per year (ac-ft/yr) authorized annual diversions. Of this total diversion amount, only 347,736 ac-ft/yr was included in the model. The remaining diversion amounts were located in the estuarine segment and considered saline rights; therefore, they were not included in the water availability model.

- The majority of the smaller irrigation and industrial rights (under 500 ac-ft/yr) frequently had shortages in available water. However, the majority of these rights with shortages still maintained reliabilities over 90 %.

- Comparisons of the three reuse scenarios show that varying levels of wastewater reuse do impact water supply. The reliability of a water right generally decrease as the level of reuse increases. Reuse of wastewater decreases the amount of storage in the reservoirs as well (See Figures P-1 through P-4).

- Hypothetical cancellation of water rights has a negligible effect on the reliability of water supply for most rights in the basin. The magnitude of simulated cancellations totaled 3,413 ac-ft/yr, and accounts for only 1 % of the full authorized diversion amount. The majority of the simulated cancellations occurred in water rights whose reliability is less than 100 percent (i.e. unreliable junior rights).

- Scenarios that utilize the 10-year maximum use as the diversion amount can significantly effect the amount of unappropriated flow and reservoir storage because the actual historical diversions during the last ten years were substantially less than the fully appropriated amounts.. The diversion amount used in these runs (Runs five and seven) was 58,983 ac-ft/yr less than the demand in Runs four and six. The cancellation runs with this large change in diversion amounts had a greater impact on the water availability than the cancellation runs with full authorized amounts (Runs four and six).

- Simulated results from the WRAP model indicate that there are significant quantities of unappropriated and regulated flowin the basin. The largest difference in the unappropriated and regulated flows (to Run one) is shown in Figure P-8. In general, wastewater reuse has a greater effect on unappropriated and regulated flows for those locations in the lower portions of the basin. Future appropriations will be subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code.

- Over the 57-year period of record, the average naturalized flows discharging into Galveston Bay from the San Jacinto River Basin as approximately of 2,206,748 ac-ft/yr, with a minimum annual inflow of 270,623 ac-ft occurring in 1956, and a maximum annual inflow of approximately 5,405,963 ac-ft/yr in 1973.

- The yield of Lake Conroe is approximately 79,825 ac-ft/yr. The firm yield of Sheldon Reservoir is approximately 200 ac-ft/yr. Yield for the remaining two reservoirs was not analyzed because the water rights on each reservoir could be met in all simulations.

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