Coastal Hydrology for the Brazos River Estuary

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Bays & Estuaries Program
Surface Water Resources Division
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Purpose

This technical memo documents the Texas Water Development Board's (TWDB) procedure for estimating combined freshwater inflow and the specifics related to producing hydrology dataset version #TWDB201004 for the Brazos River Estuary.

Introduction

The goal of the Texas Water Development Board Coastal Hydrology program is to provide estimates of historical freshwater inflows into Texas bays and estuaries to support environmental and water planning studies. The earliest freshwater inflow estimates were compiled in a series of reports published by the Texas Department of Water Resources between 1980 and 1983, in which monthly inflows to the seven major estuaries in Texas for the period from 1941 – 1976 were estimated. However, the minor estuaries were not addressed in those early studies. The TWDB began estimating inflows to the minor estuaries, including the Brazos River Estuary in 2003, while continuing to update inflows to the major estuaries as well.

This report describes the most recent version of freshwater inflow estimates for the Brazos River Estuary which includes hydrology through 2009. Complete hydrology is available for this estuary for the period of 1977 – 2009 in the form of daily, monthly, or annual estimates.

Estimates of Combined Freshwater Inflows

Estimates of hydrology for the areas draining to the Brazos River Estuary include gaged and ungaged portions of the Brazos River basin. The combination of *Gaged Inflows + Modeled Runoff + Return Flows - Diversions* below the lowest gage station provides for estimates of **Combined Freshwater Inflow** to the estuary. For a typical estuary, the **Freshwater Inflow Balance** consists of *Combined Inflows + Precipitation* onto the estuary – *Evaporation* from the estuary. However, since the Brazos River drains directly into the Gulf of Mexico, there is no bay surface area from which to estimate precipitation or evaporation. Thus, the freshwater inflow balance is equal to the combined freshwater inflow of the Brazos River Estuary.

1977-2009 Period of Record

The 1977 - 2009 period of record uses measurements from the U.S. Geological Survey (USGS) stream gages to determine flows in gaged watersheds and rainfall-runoff estimates from the Texas Rainfall-Runoff (TxRR) model to determine flows in ungaged watersheds. These estimates are adjusted for known agricultural, municipal, and industrial diversion and return flows obtained from the Texas Commission on Environmental Quality (TCEQ) and TWDB Irrigation Water Use estimates.   In some cases, diversion and return data may be obtained through other entities, such as in the TWDB report on *Coastal Hydrology for the Guadalupe Estuary: Updated Hydrology with Emphasis on Diversion and Return Flow Data for 2000-2009* (Guthrie and Lu 2010) where recent diversion and return data were obtained from HDR, Inc. Data on inflows to the Brazos River Estuary for 1977 - 2009 are available as daily, monthly, or annual estimates.

Gaged Watersheds

One USGS stream gage was used to develop the gaged inflow component of combined inflows to the Brazos River Estuary. Data from USGS gage #08116650 in the Brazos River near Rosharon was utilized from January 1977 through December 2009. For TWDB hydrology version #TWDB201004, approved USGS stream gage data was available through November 2009 and was provisional for the month of December 2009. However, the Rosharon gage was inactive from 1981 through 1983, resulting in missing gage data for those years.

Ungaged Watersheds

The Brazos River Estuary consists of two ungaged watersheds, which are used to estimate ungaged inflows and include watersheds #12001 and #12002. Figure 1 shows the delineation of watershed boundaries for the period from 1977 to 2009. The ungaged inflow component is estimated using the Texas Rainfall-Runoff Model (TxRR).   The model is conceptually similar to the Agricultural Research Service (ARS) rainfall-runoff model which is based on the Soil Conservation Service's curve number method to estimate direct runoff from a precipitation event. TxRR, however, has four key differences: (1) use of simpler and more straightforward mathematics, (2) introduction of 12 monthly depletion factors, instead of a single depletion factor as used in the ARS Model, and (3) introduction of a base flow component into the model, and (4) calculation of daily runoff. TxRR has been used to estimate daily stream flows from over 50 coastal ungaged watersheds as a part of the Coastal Hydrology program to study the effect of freshwater inflows to Texas bays and estuaries.

The Thiessen polygons and TWDB Quadrangles that would have been used to estimate precipitation and evaporation, respectively, on an estuary surface were also used for estimates in the TxRR rainfall-runoff model. Figures 2 and 3 display the Thiessen polygons for precipitation estimates and TWDB Quadrangles for evaporation estimates that were used in the TxRR model to develop the ungaged flow component.
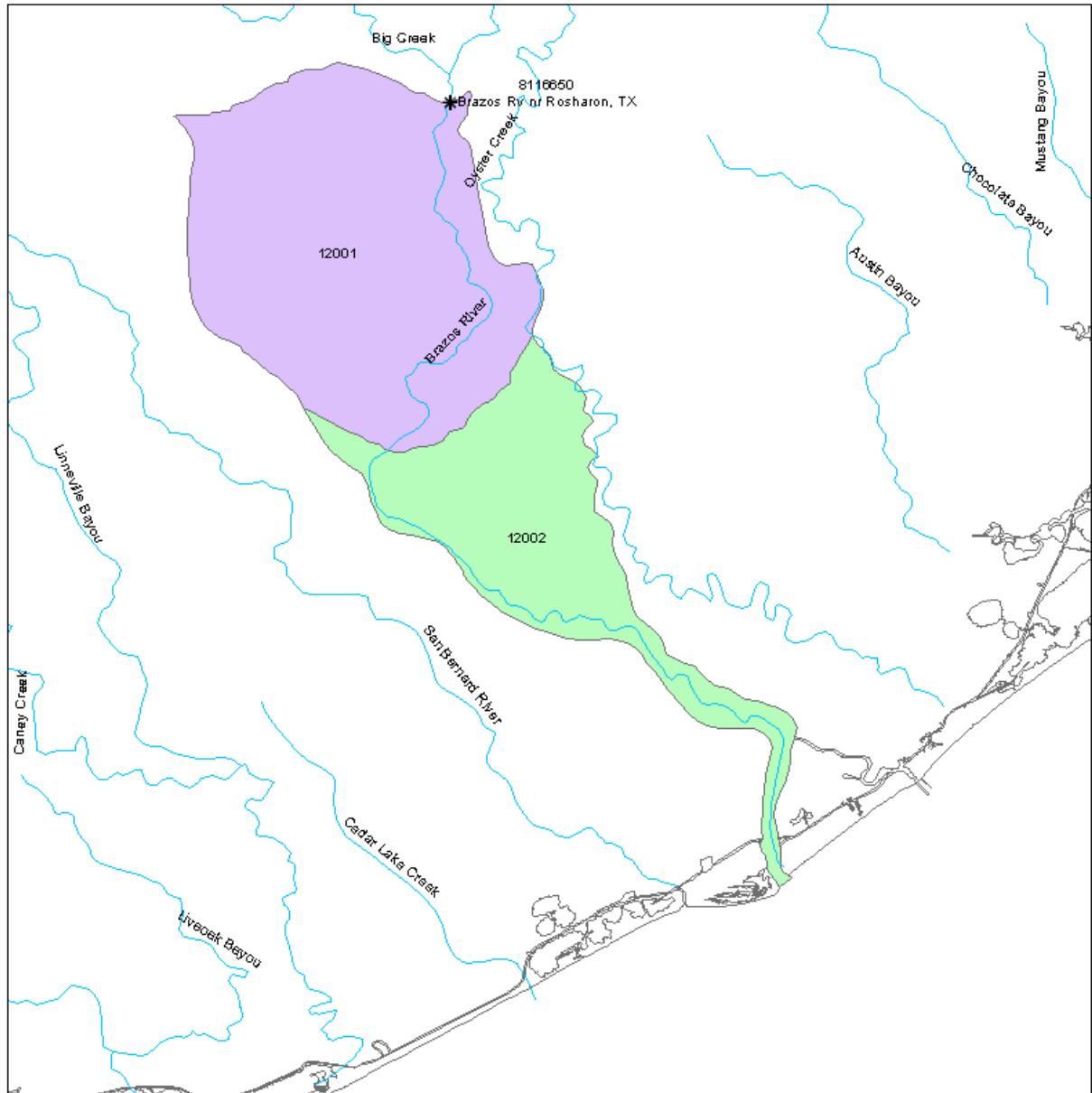
Figure 1. Ungaged watershed delineation used to determine ungaged inflows to the Brazos River Estuary from 1977 to 2009.
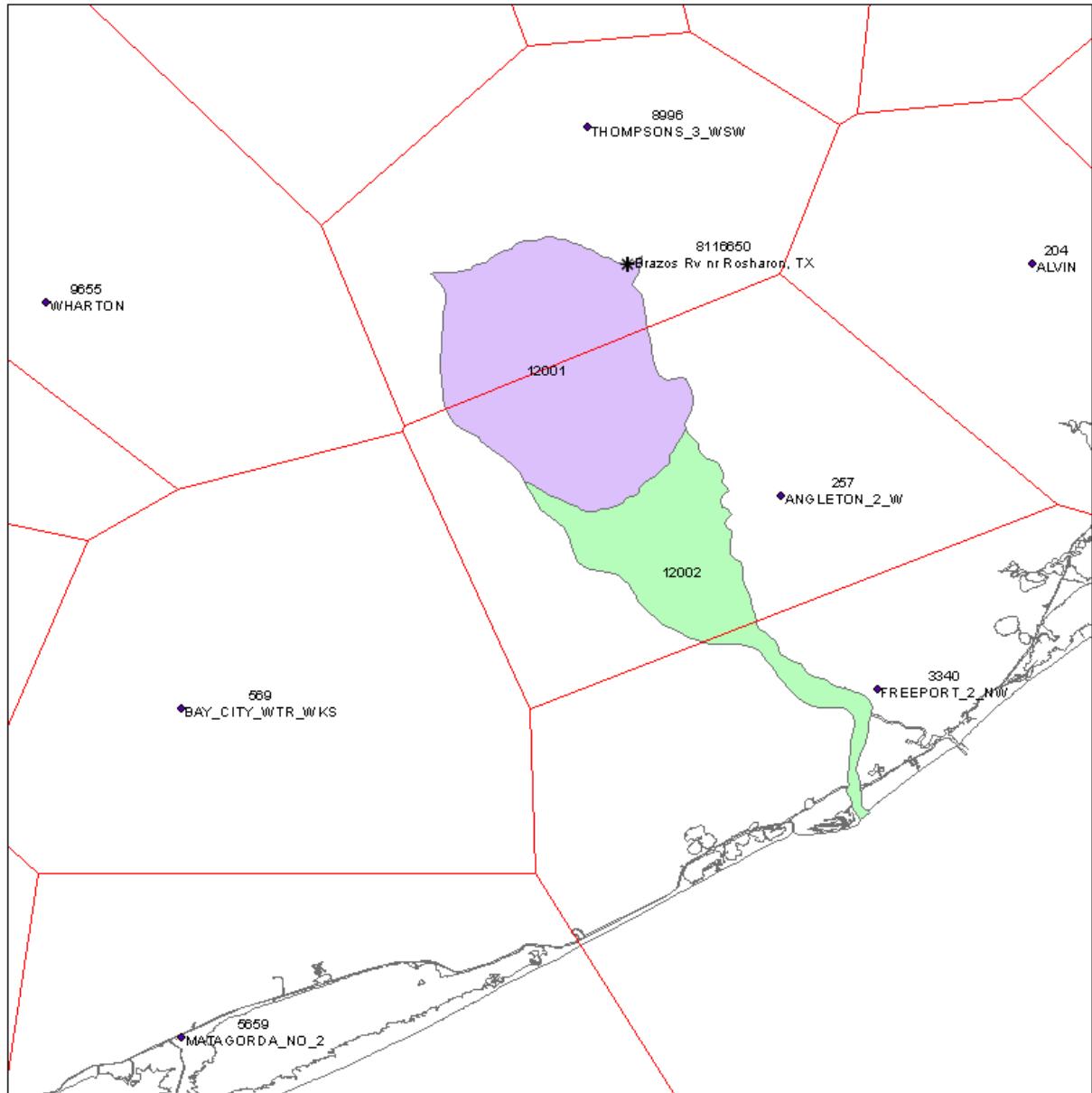
Figure 2. Rainfall stations (♦) and Thiessen polygons (red lines) used to estimate precipitation in the Texas Rainfall Runoff (TxRR) model, which was used to develop the ungaged flow component in this system.
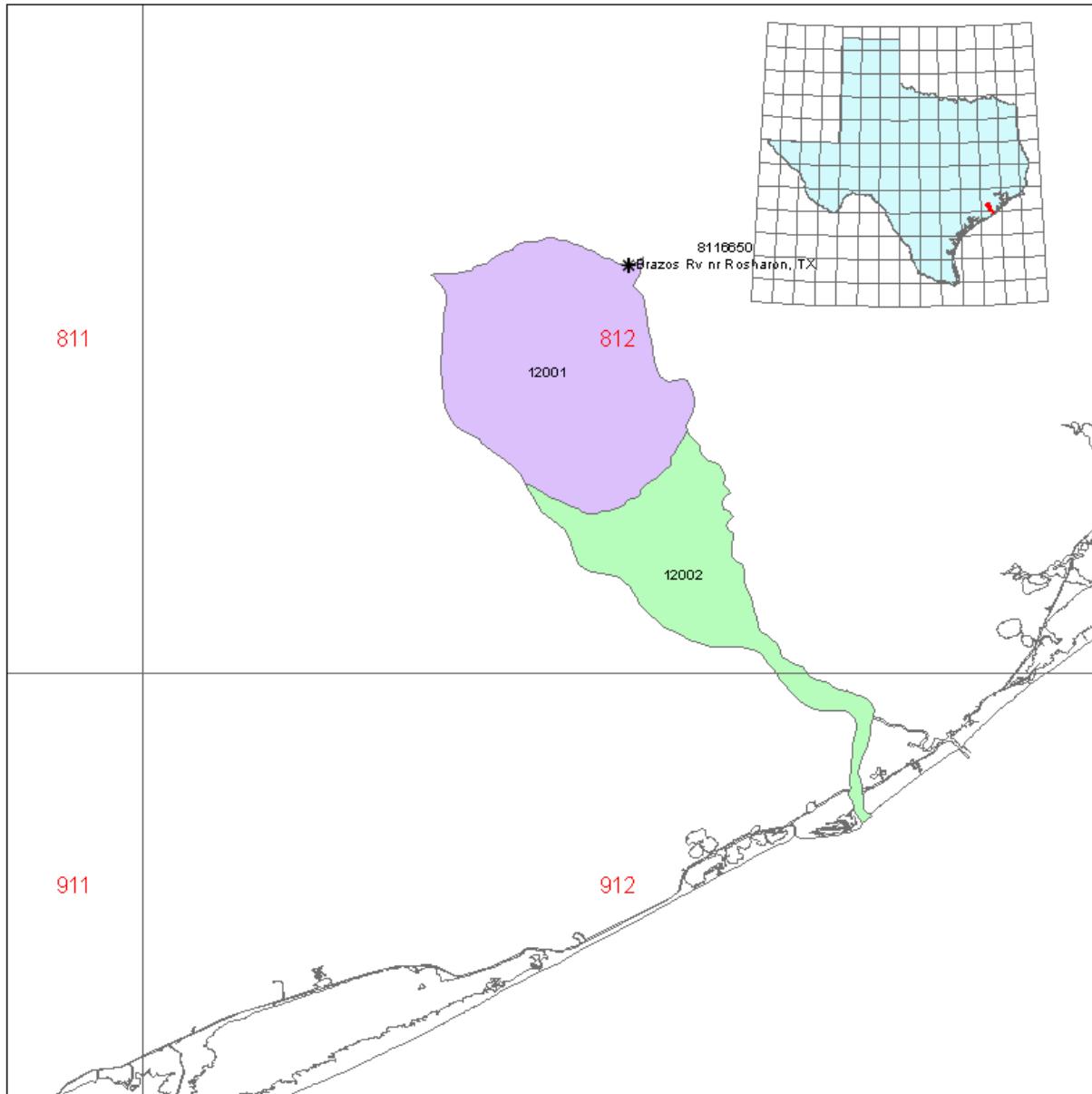
Figure 3. TWDB evaporation quadrangles used to estimate evaporation in the TxRR model, which was used to develop the ungaged flow component in this system.

Diversion and Return Points

Rainfall-runoff estimates from the TxRR model are adjusted for known diversion and return flows below the Rosharon gage. The major water rights and holders and the major discharge permits and dischargers providing return flows to the Brazos River Estuary are listed in Table 1, with locations of those permits shown in Figure 4. The dataset contains missing data that appear as not applicable (n/a) in Appendix B.

Table 1. Major water rights and discharge permits in the Brazos River basin below the downstream-most USGS stream gage.

	Water Right Number	Owner
	5327	Texas Department of Criminal Justice
	5328	Dow Chemical Co.
	5329	W C Kelly Jr. Trustee
DIVERSIONS	5330	Troy Lake Inc.
	5332	United States Department of Energy
	5365	CLT Properties Inc.
	5366	Brazosport Water Authority
	5492	Spanish Trail Land & Cattle Co. LP
	NPDES Number*	OWNER
	TX0006483	Dow Chemical Co.
	TX0008788	BASF Corp.
RETURNS	TX0025798	City of Lake Jackson
	TX0026182	City of West Colombia
	TX0032425	Brazoria County FWSD 1
	TX0033332	City of Freeport

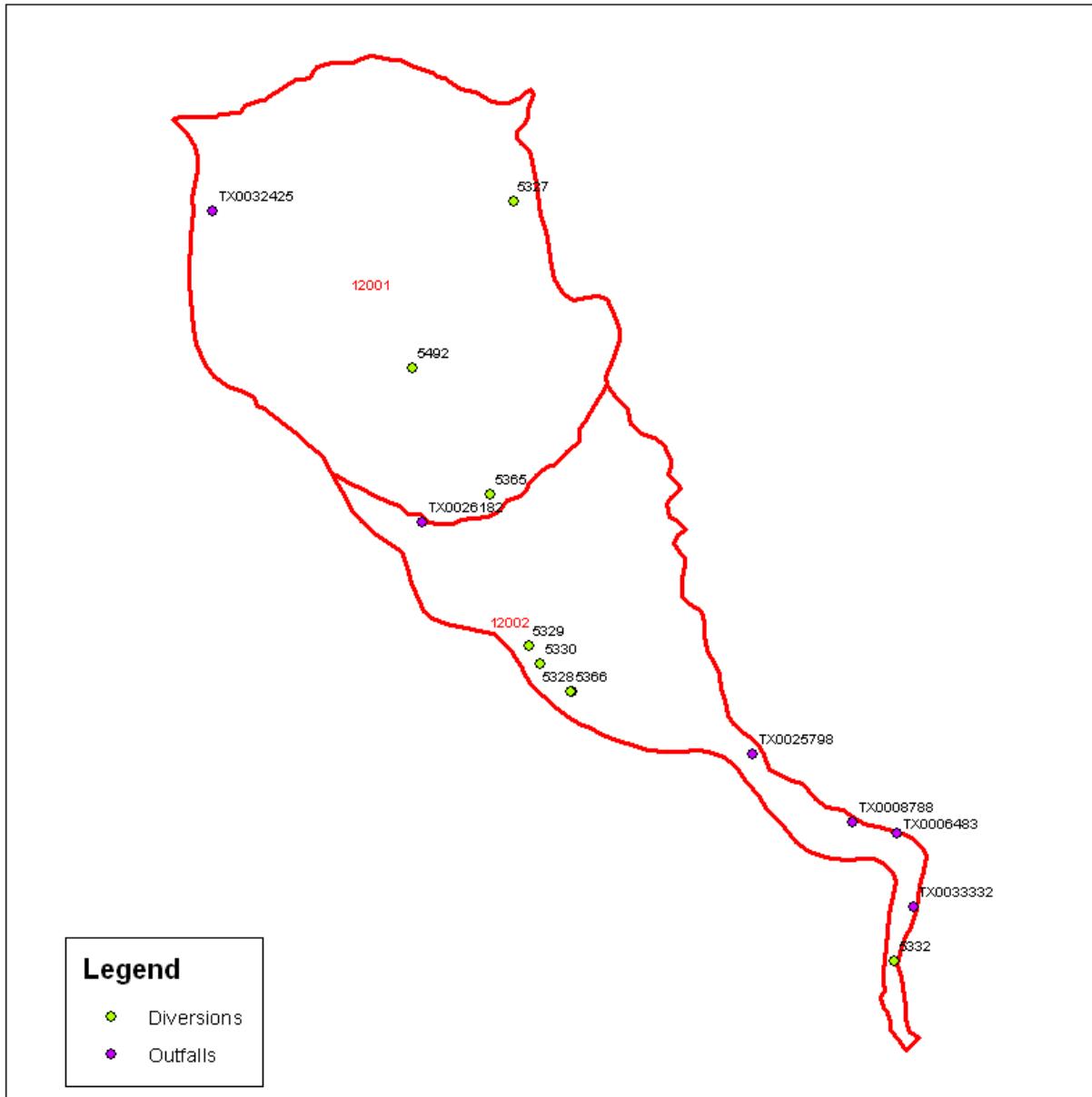*National Pollutant Discharge Elimination System (NPDES)

Figure 4. Location of permitted diversion points and wastewater outfalls in ungaged Brazos River watersheds #12001 and #12002.

Estimates of Freshwater Inflow Balance

For a typical estuary, *Total Freshwater Inflow* may include estimates of **Combined Freshwater Inflow** to the estuary + precipitation on the estuary. The **Freshwater Inflow Balance**, then, considers the effect of evaporation from the estuary.   However, there are no estimates of precipitation or evaporation for the Brazos River Estuary since there is no bay surface area from which to calculate these estimates. The freshwater inflow balance then, is equal to the combined surface inflow for this system.

Hydrology: Version #TWDB201004

TWDB coastal hydrology version #TWDB201004 for the Brazos River Estuary included gaged data through November 2009 and used provisional data for December 2009. There are no data for the period from 1981 - 1983, as the Rosharon gage was inactive during those years. Ungaged inflows used approved daily precipitation data from the National Weather Service through November 2009, with provisional data for December 2009. Diversion data were obtained from TCEQ for the period from 1977 through 2009, but there are missing data for 1981 through 1983. Return flow data were obtained from TCEQ for the 1977-2009 period and agricultural return flow data were obtained from TWDB Irrigation Water Use estimates from 1977 through December 2007. Missing data appear as not applicable (n/a) in the dataset. Figure 5 displays the combined annual surface inflow to the Brazos River Estuary as calculated by version #TWDB201004. This dataset and a watershed map can be obtained on the TWDB website: http://midgewater.twdb.state.tx.us/bays_estuaries/hydrologypage.html.
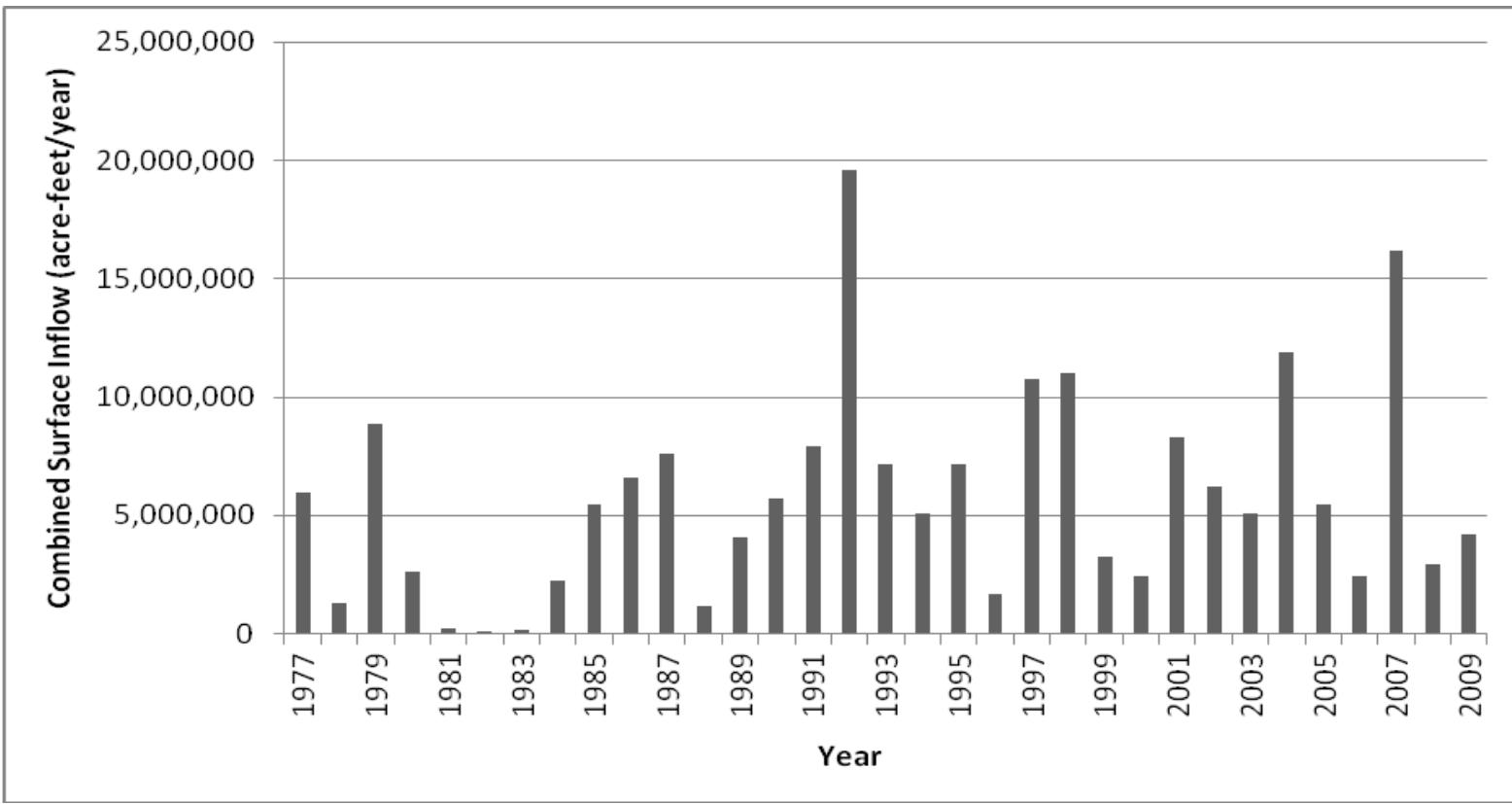
Figure 5. Combined annual surface inflow to the Brazos River Estuary as calculated for version #TWDB201004 for the period from 1977 through 2009. The USGS gage on the Brazos River at Rosharon was inactive from 1981 through 1983, resulting in missing gaged data during those years.

Discussion

Version #TWDB201004 of coastal hydrology for the Brazos River Estuary is the most up-to-date data set representing not only combined freshwater inflows but also the individual components of inflows (*i.e*., gaged flows, ungaged flows, diversions, return flows) for this estuary.   Appendix A summarizes the data used to develop hydrology version #TWDB201004 for the Brazos River Estuary. Appendix B lists the annual combined freshwater inflow, along with the four components, and the total freshwater inflow balance of the Brazos River Estuary as calculated by version #TWDB201004. Appendix C lists summary statistics for the inflow components over the 1977 through 2009 period.

Over the period from 1977 to 2009, gaged inflow from the Brazos River accounted for approximately 93 percent of combined inflow, while ungaged flows accounted for almost three percent of combined inflow. In the Brazos River basin, average annual diversions were about one percent of combined freshwater inflows, and average annual return flows were approximately five percent of inflows. Average combined surface inflow to the Brazos River Estuary over the study period was 6.3 million acre-feet per year, and ranged from a minimum of 1.2 million acre-feet in 1988 to a maximum of 19.6 million acre-feet in 1992.

Finally, when considering total freshwater inflow balance, evaporation from and precipitation onto the surface of the estuary also must be considered. In the Brazos River Estuary, however, there is no estuary surface from which to consider these effects. Thus, there are no "bay" precipitation or evaporation estimates in the system. As such, the freshwater inflow balance estimates are equal to those calculated for combined surface inflow.

Literature Cited

Guthrie, C.G. and Q. Lu.   2010. *Coastal Hydrology for the Guadalupe Estuary: Updated Hydrology with Emphasis on Diversion and Return Flow Data for 2000 - 2009*. Texas Water Development Board, Austin, Texas.

Appendix A. Record of coastal hydrology versions developed by the TWDB Bays & Estuaries Program for the Brazos River Estuary.

Estuary	Version	Date Range	Gaged Flows	Ungaged Flows	Diversions	Return Flows	Creation Date
Brazos	TWDB201004	1977 - 2009	1977 - 2009 USGS, provisional for 12/09 (Missing data for 1981 - 1983 due to inactive gage)	1977 - 2009 provisional for 12/09	1977 - 2009 TCEQ	1977 - 2009 TCEQ 1977 - 12/2009 TWDB 1977 - 12/2007 (Agricultural)	9/2010

Appendix B: Annual Hydrology for the Brazos River Estuary, version #TWDB201004. Included are estimates of gaged and ungaged (modeled) inflows, diversions and return flows, combined surface inflow to the estuary and total freshwater balance of the estuary. All values are in units of acre-feet.

Year	Gage	Ungaged	Diversion	Return	Combined Surface Inflow*	Evaporation	Precipitation	Freshwater Balance**
1977	5,911,918	31,974	n/a	n/a	5,943,892	n/a	n/a	5,943,892
1978	1,288,622	38,279	n/a	n/a	1,326,901	n/a	n/a	1,326,901
1979	8,459,502	386,639	n/a	n/a	8,846,141	n/a	n/a	8,846,141
1980	2,577,992	57,945	n/a	n/a	2,635,937	n/a	n/a	2,635,937
1981	n/a	237,502	n/a	n/a	237,502	n/a	n/a	237,502
1982	n/a	92,253	n/a	n/a	92,253	n/a	n/a	92,253
1983	n/a	138,473	n/a	n/a	138,473	n/a	n/a	138,473
1984	2,066,108	193,601	n/a	n/a	2,259,709	n/a	n/a	2,259,709
1985	5,338,491	144,250	n/a	n/a	5,482,741	n/a	n/a	5,482,741
1986	6,453,379	122,068	n/a	n/a	6,575,447	n/a	n/a	6,575,447
1987	7,494,440	111,566	n/a	n/a	7,606,006	n/a	n/a	7,606,006
1988	1,089,046	77,105	471	n/a	1,165,680	n/a	n/a	1,165,680
1989	3,973,219	124,774	6,777	n/a	4,091,216	n/a	n/a	4,091,216
1990	5,630,306	65,175	9,934	n/a	5,685,547	n/a	n/a	5,685,547
1991	7,764,516	213,762	40,774	n/a	7,937,504	n/a	n/a	7,937,504
1992	19,591,530	261,283	250,011	n/a	19,602,802	n/a	n/a	19,602,802
1993	7,056,517	278,970	170,864	n/a	7,164,623	n/a	n/a	7,164,623
1994	5,168,172	61,121	160,409	n/a	5,068,884	n/a	n/a	5,068,884
1995	7,085,448	248,317	175,052	n/a	7,158,713	n/a	n/a	7,158,713
1996	1,715,346	119,901	162,372	n/a	1,672,875	n/a	n/a	1,672,875
1997	10,642,074	298,058	156,101	n/a	10,784,031	n/a	n/a	10,784,031
1998	9,198,510	264,434	136,033	1,699,022	11,025,933	n/a	n/a	11,025,933
1999	2,118,118	30,055	185,533	1,319,162	3,281,802	n/a	n/a	3,281,802
2000	1,798,812	72,670	162,126	749,156	2,458,512	n/a	n/a	2,458,512
2001	7,439,891	229,613	163,994	783,653	8,289,163	n/a	n/a	8,289,163
2002	5,054,219	475,289	137,995	805,790	6,197,303	n/a	n/a	6,197,303
2003	4,206,050	156,011	145,999	860,236	5,076,298	n/a	n/a	5,076,298
2004	10,739,853	289,587	39,292	883,454	11,873,602	n/a	n/a	11,873,602
2005	4,721,524	25,704	45,162	774,630	5,476,696	n/a	n/a	5,476,696
2006	1,547,742	110,420	41,753	818,407	2,434,816	n/a	n/a	2,434,816
2007	15,057,476	222,864	39,594	929,052	16,169,798	n/a	n/a	16,169,798
2008	2,320,424	91,007	41,519	596,291	2,966,203	n/a	n/a	2,966,203
2009	3,618,640	44,083	37,872	558,034	4,182,885	n/a	n/a	4,182,885

*Combined Surface Inflow = Gage + Model - Diversion + Return
**Freshwater Balance = Surface Inflow - Evaporation+ Precipitation.

Appendix C. Summary statistics for annual freshwater inflow (in acre-feet) over the 1977 - 2009 period for the Brazos River Estuary, version #TWDB201004.

	Gage	Ungaged	Diversion	Return	Combined Surface Inflow*	Evaporation	Precipitation	Freshwater Balance*
Minimum	1,089,046	25,704	471	558,034	1,165,680	n/a	n/a	1,165,680
5%ile	1,405,226	31,206	6,935	579,075	1,482,589	n/a	n/a	1,482,589
10%ile	1,698,586	39,440	12,728	611,578	2,201,026	n/a	n/a	2,201,026
25%ile	2,384,816	72,670	39,889	768,262	3,045,103	n/a	n/a	3,045,103
Median	5,253,332	124,774	137,014	812,099	5,584,144	n/a	n/a	5,584,144
Mean	5,904,263	161,053	104,984	898,074	6,348,055	n/a	n/a	6,348,055
75%ile	7,480,803	237,502	162,311	894,854	7,854,630	n/a	n/a	7,854,630
90%ile	10,651,852	287,464	174,633	1,280,151	11,110,700	n/a	n/a	11,110,700
95%ile	13,114,546	333,490	185,009	1,490,099	14,236,510	n/a	n/a	14,236,510
Maximum	19,591,530	475,289	250,011	1,699,022	19,602,802	n/a	n/a	19,602,802
TOTAL	177,127,885	5,314,753	2,309,637	10,776,887	190,441,660	n/a	n/a	190,441,660

*Gaged inflow data are missing for a three year period, from 1981 through 1983, due to the Rosharon gage being inactive during this time. As such, these years were not included in the summary statistics for Combined Surface Inflow and Freshwater Balance.