Coastal Hydrology for the Nueces Estuary: Hydrology for Version #TWDB201101 with Updates to Diversion and Return Data for 2000-2009

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Purpose

This technical memo documents the Texas Water Development Board's (TWDB) procedure for estimating combined freshwater inflow data and the specifics related to producing hydrology dataset versions #TWDB201001, #TWDB201004, and #TWDB201101 for the Nueces Estuary. The most recent update, version #TWDB201101, includes newly acquired diversion and return data obtained from the Nueces River Authority (NRA), but compiled by HDR, Inc.

Introduction

The goal of the Texas Water Development Board's 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. Monthly inflows to the seven major estuaries in Texas for the period from 1941 - 1976 were estimated in those studies, with estimates for the Nueces Estuary published in Chapter 4 of LP-108, *Nueces and Mission-Aransas Estuaries: A Study of the Influence of Freshwater Inflows* (TDWR 1981, available on the TWDB website or upon request).

Inflow records for each estuary have been updated periodically since then in support of ongoing research and planning studies both within and external to TWDB. Additionally, subsequent updates are provided in daily, as well as monthly format. This report covers the most recent update of freshwater inflow estimates for the Nueces Estuary and extends the hydrology through 2009. Therefore, complete hydrology is available for this estuary for 1941 - 2009, with daily estimates of inflows available only after 1977.

Estimates of Combined Freshwater Inflows

Estimates of hydrology for the areas draining to the Nueces Estuary include gaged and ungaged portions of the Nueces river basin, as well as several small coastal basins. The combination of *Gaged Inflows* + *Ungaged Inflows* + *Return Flows* - *Diversions* below the last gage station provide for estimates of ***Combined Freshwater Inflow*** to the estuary. In addition to the aforementioned water budget components, an interbasin transfer of water since 1998 from Lake Texana in the Lavaca-Navidad River basin is an important component of additional flow in the Nueces River basin. The accounting of this additional water is discussed in the diversion and return section of this report. The ***Freshwater Inflow Balance*** of the estuary consists of *Combined Inflows* + *Precipitation* on the estuary – *Evaporation* from the estuary. Although inflow estimates are updated on an ongoing basis, there are two distinct periods of estimation. Before 1977, inflow estimates are available only in monthly intervals. Starting in 1977 and thereafter, inflow estimates became available on a daily basis.

1941 - 1976 Period of Record

This period of record uses measurements from U.S. Geological Survey (USGS) stream gages along with rainfall-runoff estimates from a water yield model to determine flows in gaged and ungaged watersheds (TDWR 1981). In these early estimates of coastal hydrology, flows in ungaged areas were adjusted for known municipal, and industrial return flows obtained from the Texas Department of Water Resources (TDWR) self reporting system (TDWR 1981). Diversion records and agricultural return flow from the TDWR Water Usage System also were used in estimates of flows in ungaged areas. Data on inflows to the Nueces Estuary for 1941 - 1976 are available as monthly or annual estimates.

1977 - 2009 Period of Record

The 1977 - 2009 period of record uses measurements from USGS stream gages along with rainfall-runoff estimates from the Texas Rainfall-Runoff (TxRR) model, adjusted for known diversion and return flows obtained from the Texas Commission on Environmental Quality (TCEQ) or equivalent agency, the South Texas Water Master (STWM), and the TWDB Irrigation Water Use estimates. In some cases, diversion and return data may be obtained through other entities, such as in this report where recent diversion and return data were obtained from the Nueces River Authority (NRA) and compiled by HDR, Inc. for the period from 2000 - 2009. These data augment the official data reported by the TCEQ and STWM by filling in missing or incomplete data records. Data on inflows to the Nueces Estuary for 1977 - 2009 are available as daily, monthly, or annual estimates.

Gaged Watersheds

Two USGS stream gages have been used to develop the gaged inflow component of combined inflows to the Nueces Estuary. Table 1 lists the USGS stream gages and the corresponding period of record utilized in estimating combined inflows. For recently updated hydrology (version #TWDB201101), approved USGS stream gage data was available through November 2009 and was provisional for the month of December 2009. The USGS gage on the Nueces River at Calallen was not used to develop the gaged inflow component of this hydrology dataset, because the gage became operational in 1989, which was after the last TWDB watershed delineation effort. However, it may be used to estimate inflow in other studies, such as to estimate inflows for hydrodynamic and salinity transport model simulations.

Table 1. USGS stream gages used to develop the gaged inflow component of combined inflows to the Nueces Estuary. Gage number, location, and period of record utilized in estimating inflows are shown.

Estuary	Gage Station Number	Gage Location	Utilized Period of Record
Nueces	08211000	Nueces River near Mathis	1941 – 2009*
	08211520	Oso Creek at Corpus Christi	1977 – 2009*

*Stream gage data were provisional for the month of December 2009.

Ungaged Watersheds

The number of ungaged watersheds for which ungaged inflows are estimated has changed through time. Initial estimates were determined based on seven ungaged watersheds (watersheds #20005, #21010, #22010, #22011, #22012, #22013, and #22014; Figure 1). In 1972, USGS streamgage #08211520 became gaged, and thus, ungaged watershed #22010 became gaged; However, TWDB did not use this data until 1977. Also, in 1977, watershed #22015 was added to the division of watersheds (Figure 2). Therefore, current estimates also are based on seven ungaged watersheds (#20005, #21010, #22011, #22012, #22013, #22014, and #22015). Additionally, the area of the ungaged watersheds changed from initial estimates that were used in LP-108 (TDWR 1981; Table 2). The change in area of ungaged watersheds from the LP-108 estimate of 697 square miles to current estimates of 547 square miles affect estimates of the ungaged flow component.

Table 2. Estimates of ungaged watershed area from initial LP-108 (TDWR 1981) estimates to current estimates. These changes affect the ungaged flow component estimates.

Watershed ID Number	LP-108 (Square Miles) 1941 - 1976	Current Area (Square Miles) 1977 - 2009
20005	133	74.18
21010	290	272.83
22010	90.3	Gaged Watershed
22011	100	134.21
22012	24.5	18.5
22013	5.9	25.67
22014	53.1	21.96
22015	Not Applicable	7.47
Total Ungaged (except 22015)	**696.8**	**547.4**

The ungaged inflow component is estimated using a rainfall-runoff model. Before 1977, stream flows in ungaged watersheds were obtained using a *water yield model* which required daily precipitation, Soil Conservation Service average curve numbers, and a soil depletion index (TDWR 1981). This water yield model provided for monthly estimates of ungaged inflows – not daily. TWDB does not have daily estimates of ungaged inflows for the period prior to 1977.

Since 1977, however, TWDB has used the Texas Rainfall-Runoff (TxRR) model to estimate daily stream flows in ungaged watersheds. This 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 three 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. 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.

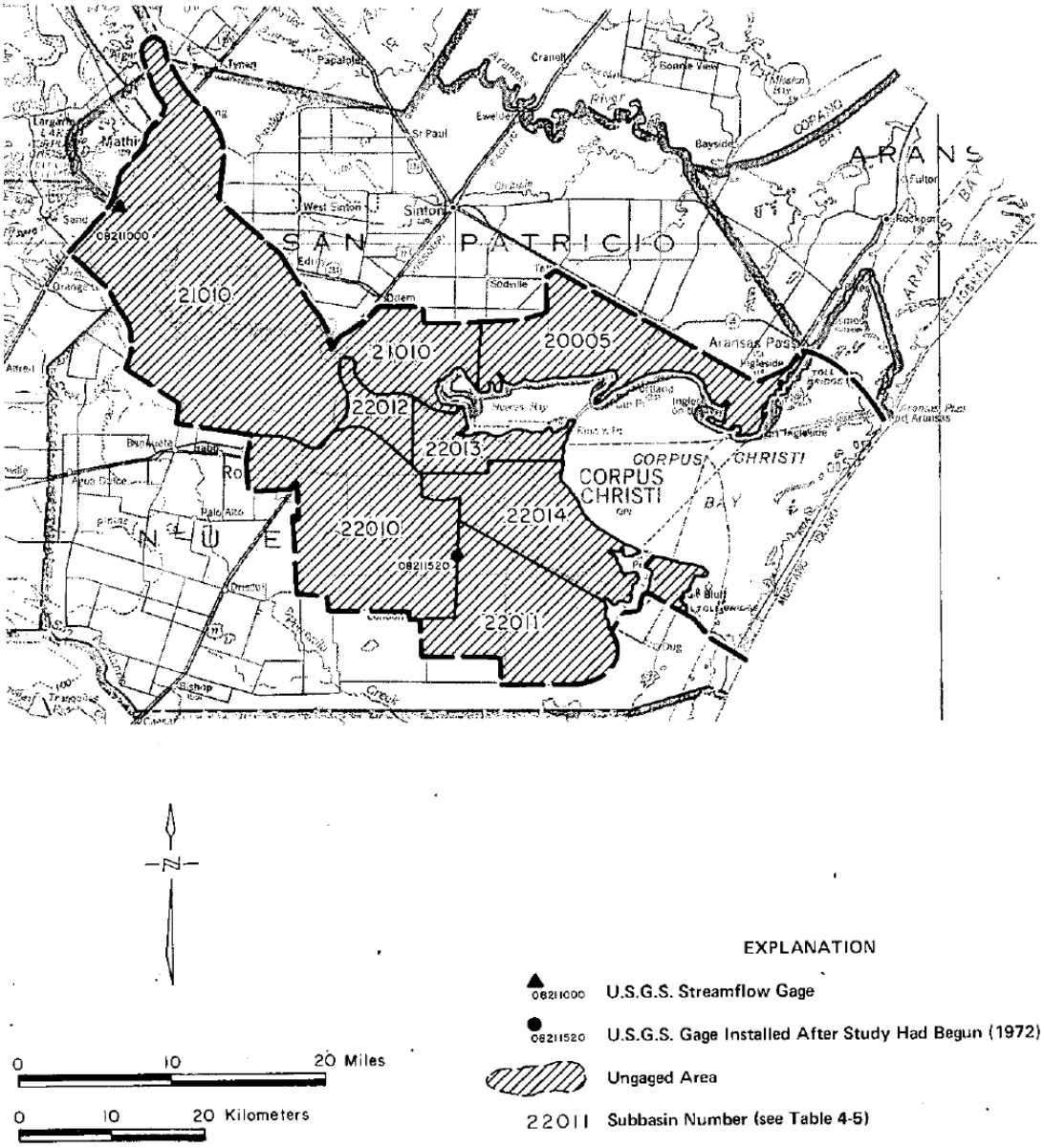

Figure 1. Ungaged watershed delineation used to determine ungaged inflows to the Nueces Estuary from 1941 to 1976. Solid triangle and circle represent USGS Streamflow Gages. Ungaged watersheds are identified by hatching. *Please note*: watershed #22010 became gaged in 1972, but TWDB did not use this data until 1977.

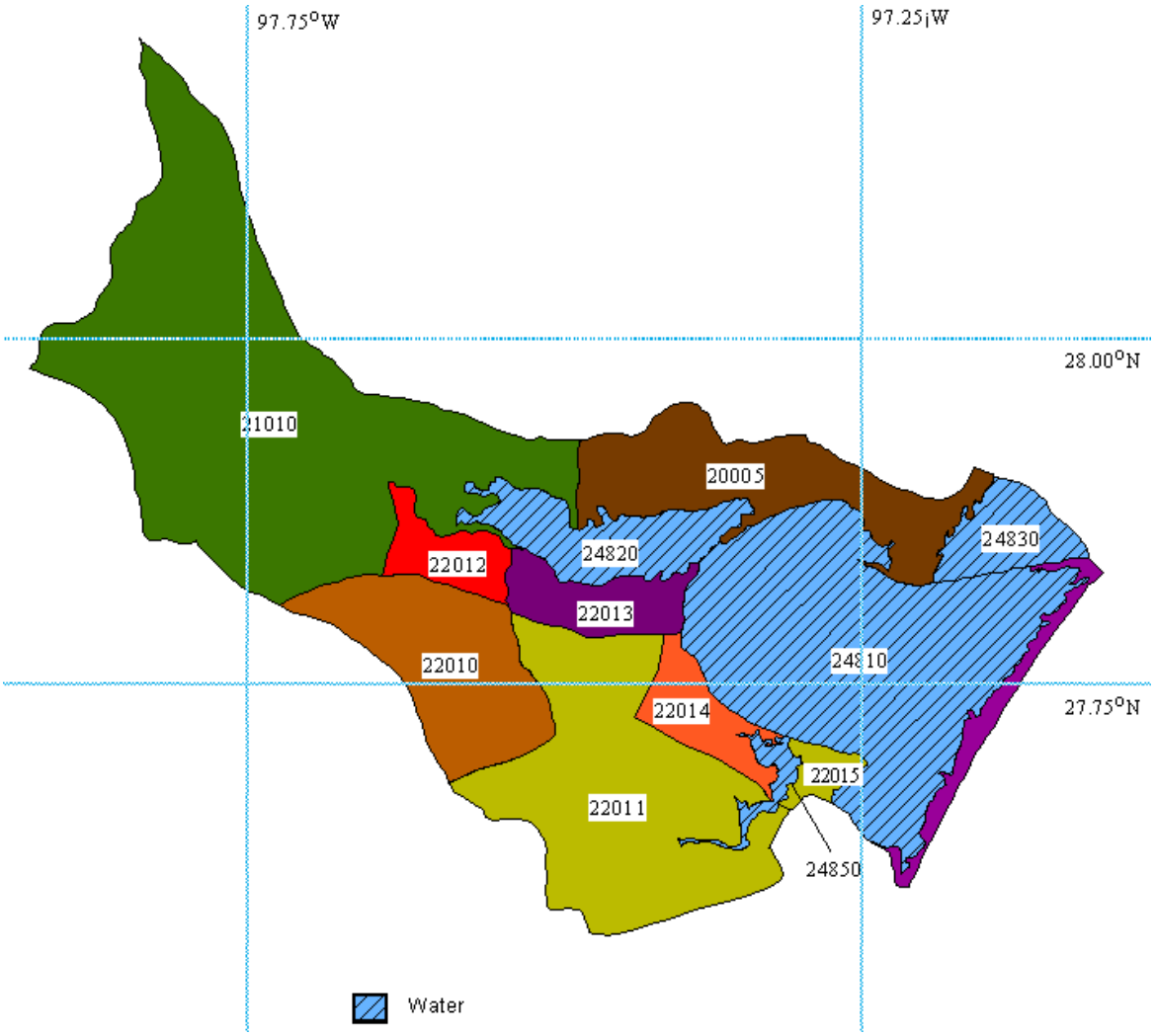

Figure 2. Ungaged watershed delineation used from 1977 to 2009 to determine ungaged inflows to the Nueces Estuary. Watershed #22015 was added to the watershed delineation. Watershed areas also changed from previous estimates used in LP-108. *Please note:* watershed #22010 is actually a gaged watershed, but is not reflected as such in this Figure.

Diversion and Return Points

Rainfall-runoff estimates from the TxRR model are adjusted for known diversion and return flows. The major water rights and holders and the major discharge permits and dischargers providing return flows to the Nueces Estuary are listed in Table 3, with locations of those permits shown in Figure 3.

Table 3. Major water rights and discharge permits in the Nueces River basin below the USGS stream gages on the Nueces River at Mathis and on Oso Creek at Corpus Christi.

	Water Right Number	Owner
DIVERSION	2464	City of Corpus Christi*
	2466	Nueces County WCID 3*
	unknown	Flint Hills*
	unknown	Hoechst Celanese*
	unknown	San Patricio Municipal Water District*
	NPDES Number†	**Owner**
RETURNS	TX0004685	American Chrome and Chemicals LP
	TX0006599	Flint Hills Resources LP
	TX0006904	Valero Refining – Texas LP
	TX0006211	CITGO Refining and Chemicals Co LP
	TX0006289	Flint Hills Resources LP
	TX0008907	E I DuPont De Nemours & Co
	TX0063355	Valero Refining – Texas LP
	TX0076996	Equistar Chemicals LP
	TX0007889	US Dept of the Navy
	TX0096474	Trigeant LTD
	TX0104876	Occidental Chemical Corporation, Oxymar and Ingleside Center LLC
	TX0119865	Texas A&M University System
	TX0083062	City of Gregory
	TX0020389	City of Robstown
	TX0047074	City of Corpus Christi
	TX0047058	City of Corpus Christi
	TX0047066	City of Corpus Christi
	TX0047082	City of Corpus Christi
	TX0020401	City of Ingleside
	TX0055433	City of Portland
	TX0025682	City of Aransas Pass
	TX0024287	Nueces County WCID 4
	TX0066664	Sublight Enterprises INC
	TX0076767	Corpus Christi Peoples Baptist Church
	TX0078743	GM Fabricators LP dba Gulf Marine Fabricators
	TX0110337	San Patricio County MUD 1*
	TX0123676	Tennessee Pipeline Construction CO

*Diversions and returns denoted with asterisk are above the USGS stream gage on the Nueces River at Calallen.

†National Pollutant Discharge Elimination System (NPDES)

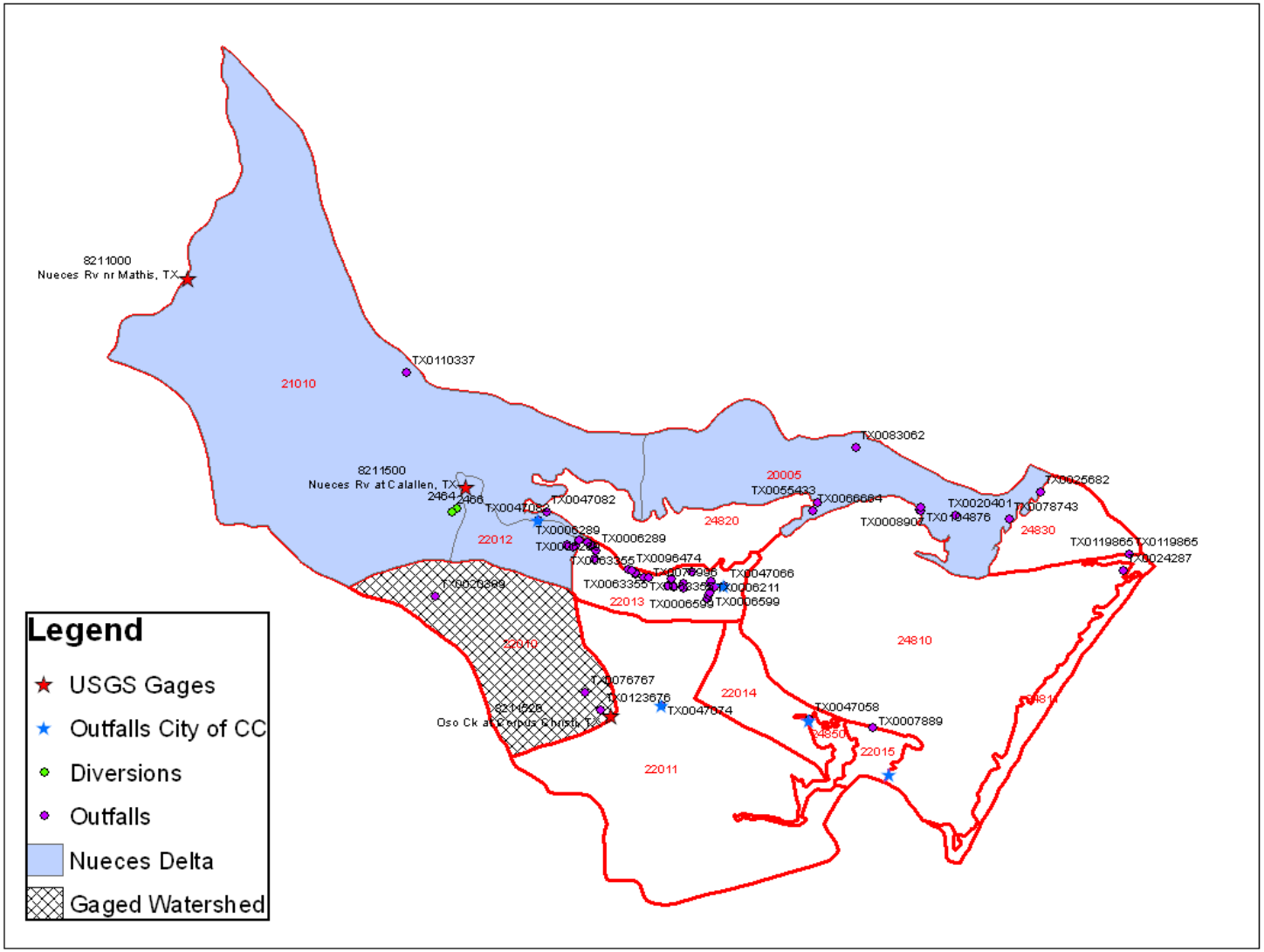

Figure 3. Location of USGS stream gages (red stars), permitted diversion points (green circles), wastewater outfalls (purple circles) and City of Corpus Christi outfalls (blue stars) in the Nueces Estuary watershed. Watersheds #21010, #22012, and the western portion of #20005 drain to the Nueces Delta and are highlighted in blue.

An interbasin transfer of water from Lake Texana is consumed by the City of Corpus Christi and the San Patricio Municipal Water District, with any unconsumed water being returned to the Nueces River basin. Thus, water that drains to the Nueces Estuary from the interbasin transfer is accounted for in return flow from the City of Corpus Christi and San Patricio Municipal Water District. However, since the interbasin transfer is not accounted for in the diversions, but rather only in return flows, the net diversion curve (Figure 4) shows a steep decline (a function of the increase in return flow) after 1998.

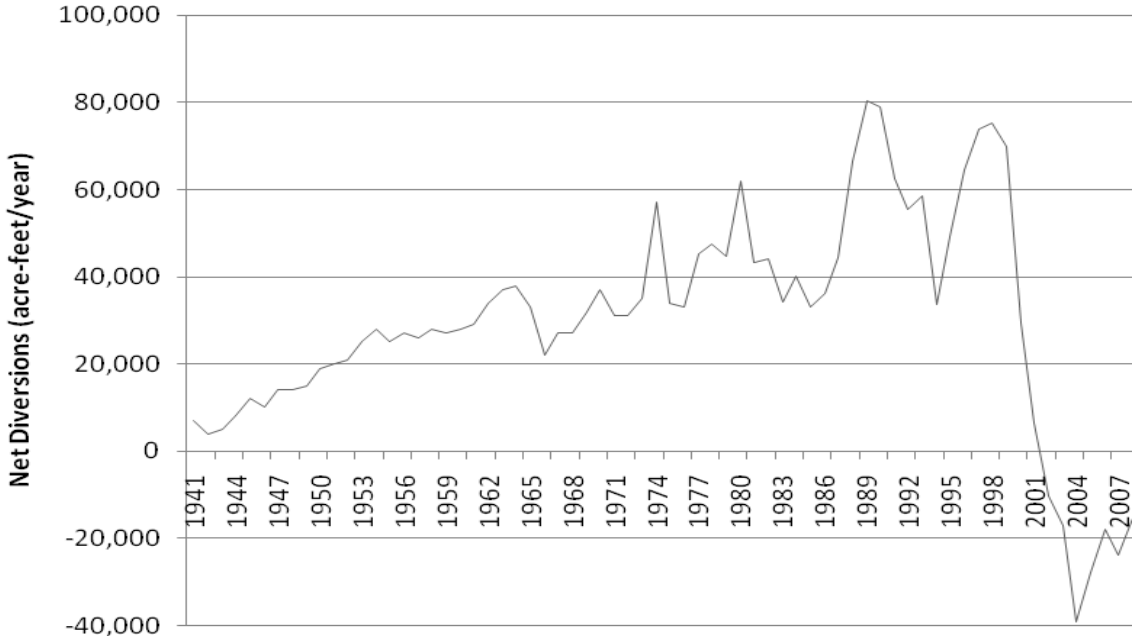

Figure 4. Net diversions (diversions-returns) in acre-feet per year in the Nueces River basin. The steep decline in net diversion after 1998 is due to an increase in return flows from the City of Corpus Christi and San Patricio Municipal Water District resulting from water obtained via an interbasin transfer from Lake Texana.

Estimates of Freshwater Inflow Balance

Total Freshwater Inflow to the estuary 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. Due to limitations on estimates of evaporation throughout the period of record, estimates of the freshwater inflow balance are available in monthly intervals.

The bay surface area which was used to calculate precipitation onto and evaporation from the estuary has changed over time. Prior to 1977, the bay surface area was estimated to be 171.55 square miles (109,795 acres); whereas, after 1977, the surface area was estimated to be 245.31 square miles (157,440 acres; Table 4). Using a larger bay surface area then, results in an increase in the annual estimates for precipitation and evaporation from the estuary after 1977. Note however that these annual estimates are rarely used in freshwater inflow analyses. They are presented for descriptive purposes only, but when applied to modeling analyses (such as in the TxBLEND hydrodynamic and salinity transport model) a rate of evaporation or precipitation is used.

Table 4. Comparison of bay segment areas used to estimate evaporation from and precipitation onto the surface of the Nueces Estuary between LP-108 (TDWR 1981) and current estimates.

Bay Segment ID Number	LP-108 (Square Miles) 1941 - 1976	Current Area (Square Miles) 1977 - 2009
24810	Not Specified	177.78
24820	Not Specified	37.87
24830	Not Specified	23.04
24850	Not Specified	6.62
Total Bay	171.55	245.31

Precipitation

Direct precipitation onto the surface of the Nueces Estuary was calculated using Thiessen-weighted precipitation techniques as described in LP-108 (TDWR 1981). Station based rainfall data were obtained from the National Weather Service (NWS) and processed using Arc/Info Macro Language (AML). Bay segments #24810, #24820, #24830, and #24850 were used to calculate precipitation on the bay by summing the area-weighted rainfall of the Thiessen polygon fragments over the bay. Figure 5 shows the Thiessen polygons that are coincident with the rainfall stations and used to calculate watershed rainfall.

Figure 6 shows annual estimates of precipitation onto the surface of the bay as prepared for hydrology version #TWDB201101 for the Nueces Estuary. However, since precipitation estimates were affected by the increase in bay segments, Figure 7 shows annual estimates of precipitation on the surface of the bay adjusted for the change in bay area. Precipitation values in the earlier period of record, from 1941 - 1976, were adjusted with a ratio of 245.31/171.55 to provide for comparable precipitation estimates between the two time periods. Hydrology version #TWDB201101 for the Nueces Estuary does not reflect these adjustments.

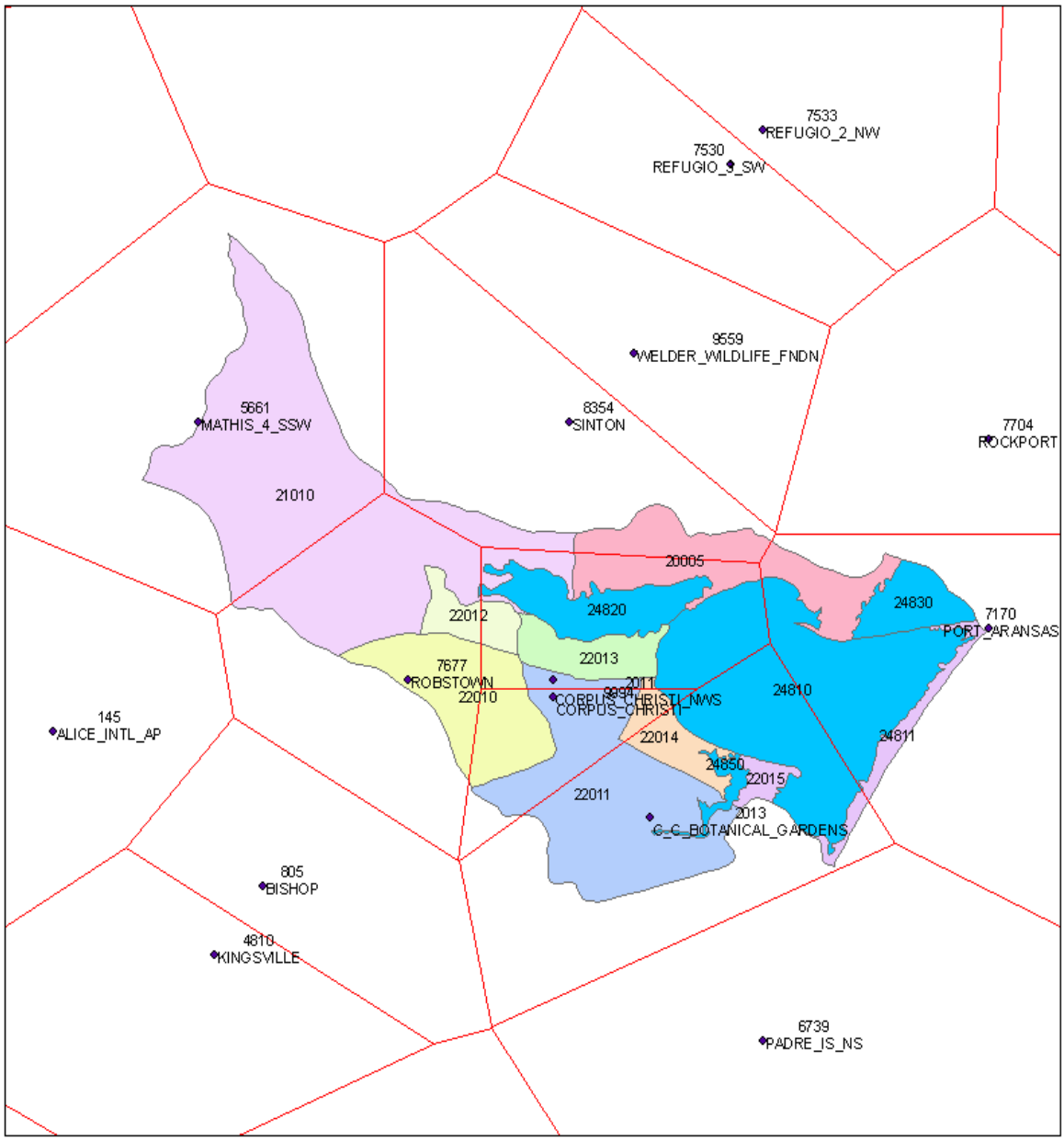

Figure 5. Rainfall stations (♦) and Thiessen polygons (red lines) used to estimate direct precipitation onto the Nueces Estuary and associated ungaged watersheds.

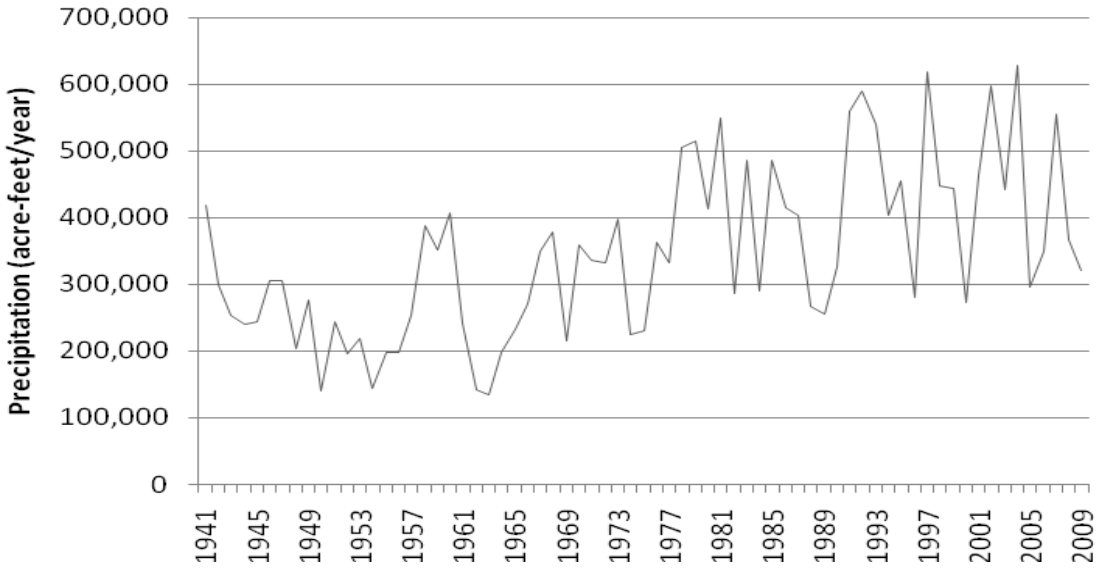

Figure 6. Annual estimates of precipitation on the estuary (in acre-feet per year) over the period from 1941 - 2009. Precipitation estimates prior to 1977 are based on a smaller bay surface area, 172 $mi.^2$ versus the current estimate of 245 $mi.^2$.

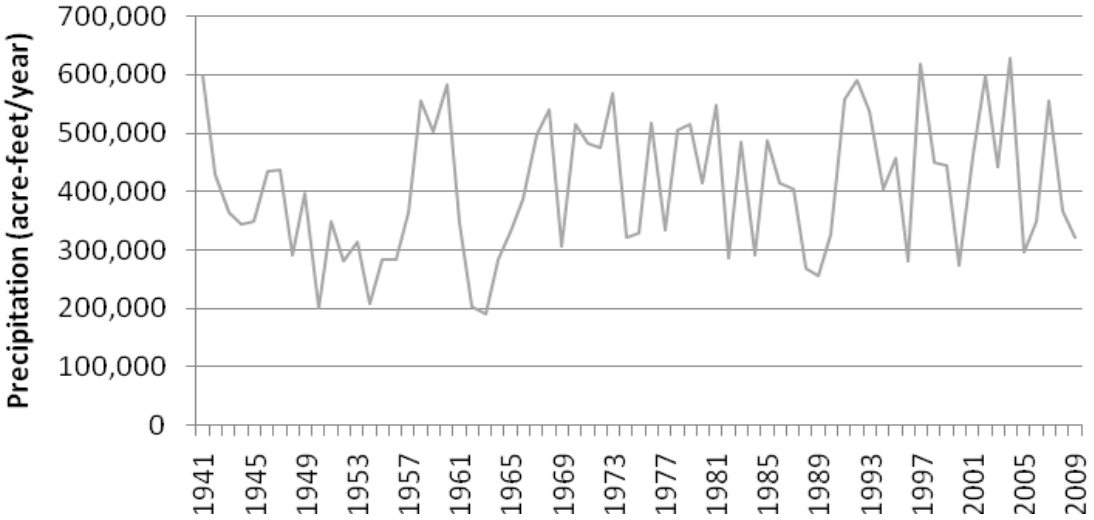

Figure 7. Area-adjusted annual precipitation estimates on the estuary (in acre-feet/year) over the period from 1941 - 2009. Values in the period of 1941 - 1976 were adjusted with the ratio of 245.31/171.55.

Evaporation

Evaporation was calculated for the surface of the bay using TWDB and NWS pan evaporation data to estimate evaporation rates. Bay segments used to calculate evaporation include segments #24810, #24820, #24830, and #24850 which are located within TWDB quadrangle #1010 (Figure 8). Total water evaporated from bay segments is calculated by multiplying a segment's area by observed evaporation rates. Evaporation rates were determined with a GIS-based program, *ThEvap*, using TWDB and NWS pan evaporation data. The *ThEvap* program replaced an older program, *WD0300*, previously run by the Texas Department of Water Resources (TDWR) (http://midgewater.twdb.state.tx.us/Evaporation/evap.html).

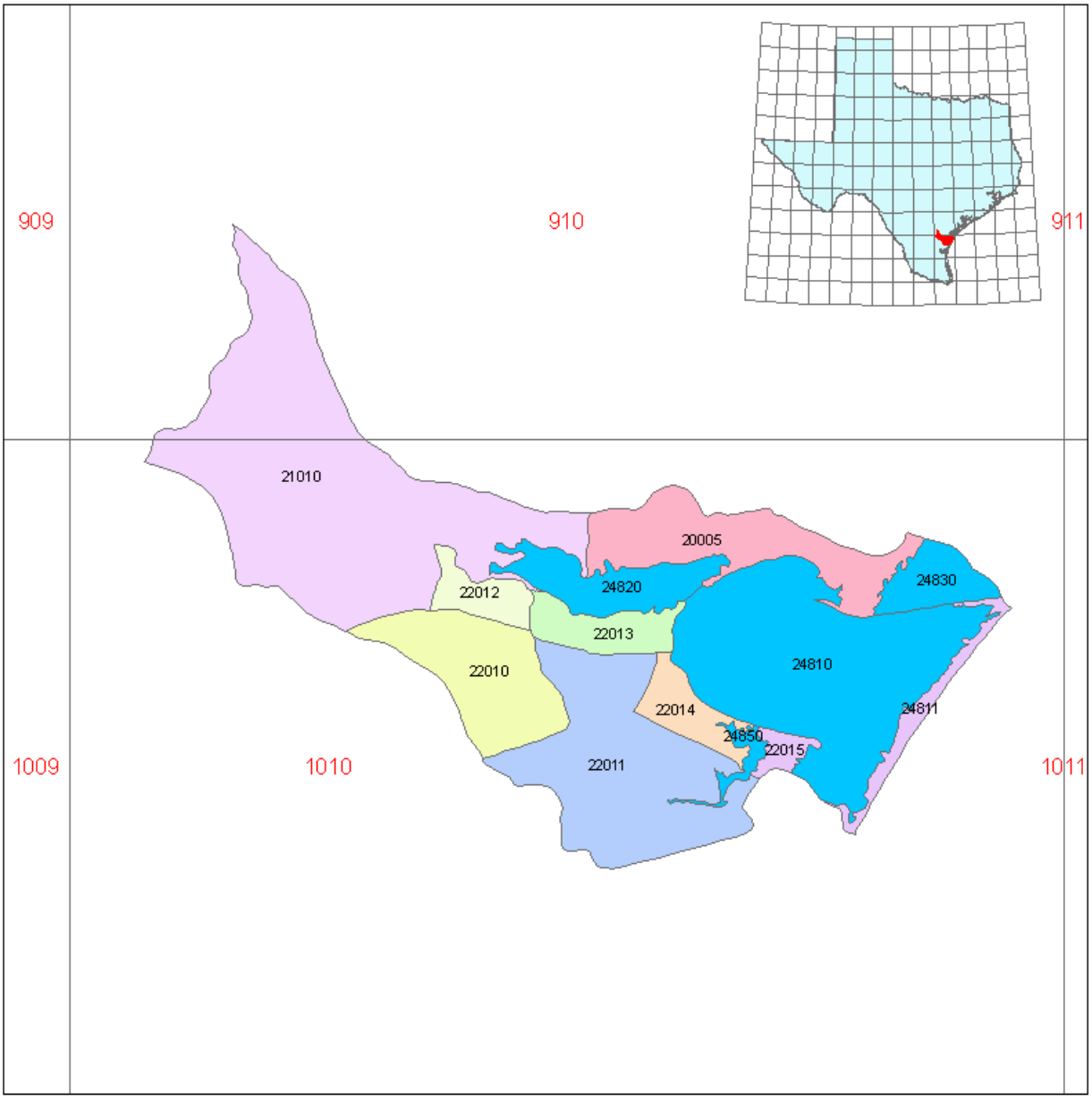

Figure 8. TWDB evaporation quadrangles used to estimate evaporation for the Nueces Estuary. TWDB quadrangle #1010 is used to estimate evaporation from Nueces Estuary segments #24810, #24820, #24830, and #24850.

Annual estimates of evaporation from the surface of the estuary are shown in Figure 9. The increase in evaporation estimates after 1976 is due to the use of increased bay surface area estimates. Figure 10 shows the pre-1977 evaporation estimates adjusted for the more recent approximation of bay surface area by using a ratio of 245.31/171.55; however, hydrology version #TWDB201101 for the Nueces Estuary, as presented in Appendix B, does not reflect these adjustments.

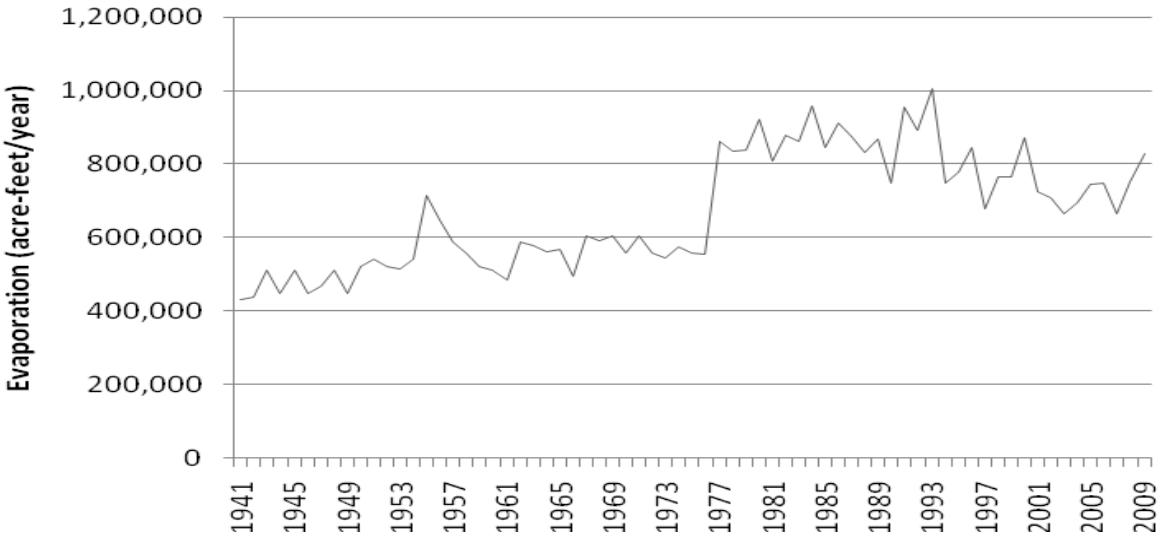

Figure 9. Annual estimates of evaporation (in acre-feet per year) from the estuary over the study period from 1941 - 2009. Note the change in evaporation estimates after 1976. Evaporation estimates prior to 1977 are based on a smaller bay surface area, 172 mi.^{2} versus the current estimate of 245 mi.^{2}

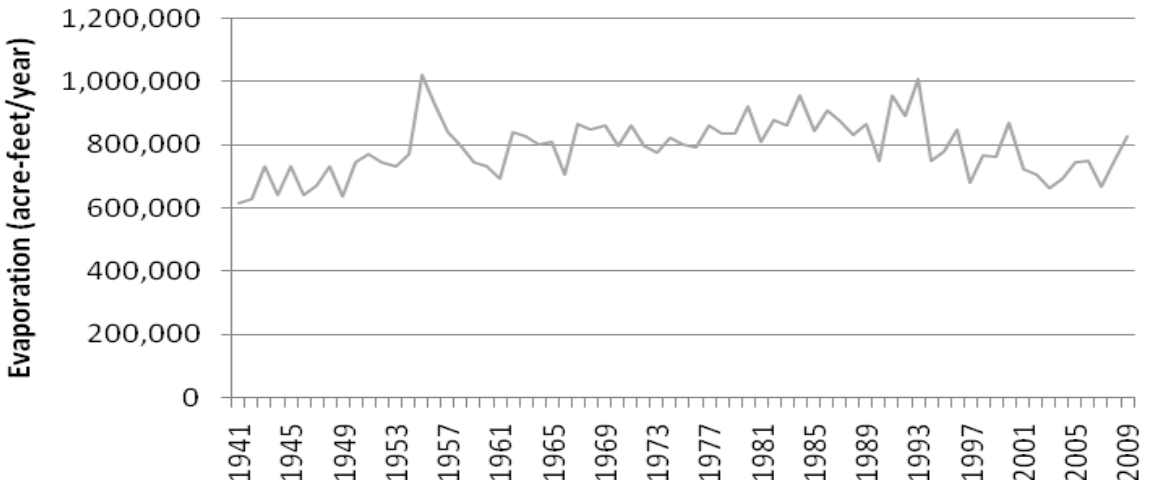

Figure 10. Area-adjusted annual evaporation (in acre-feet per year) from the estuary over the period from 1941 - 2009. Values in the period of 1941 - 1976 were adjusted with the ratio of 245.31/171.55.

Hydrology: Version #TWDB201001

TWDB coastal hydrology version #TWDB201001 for the Nueces Estuary included gaged and ungaged inflows through December 2008. Raw diversion data were obtained from the Texas Department of Water Resources (TDWR) Water Usage System for the period from 1941 through 1988 and from the South Texas Water Master (STWM) for the period from 1989 through October 2005. Industrial and municipal return flow data were obtained from the TDWR self-reporting system from 1941 through 1976 and from TCEQ for the period from 1977 to 2007. Additional return flow data were obtained from TWDB's agricultural return flow estimates through December 2005.

Hydrology: Version #TWDB201004

TWDB coastal hydrology version #TWDB201004 for the Nueces Estuary extends the previous version by updating gaged, ungaged, diversion, and return flow data to provide inflow estimates through 2009. Gaged data were extended using approved data through November 2009 and provisional data for December 2009. Ungaged inflows were updated using approved daily precipitation data from the National Weather Service through November 2009, with provisional data for December 2009. Diversions were the same as in version #TWDB201001 through October 2005 and returns were the same as in #TWDB201001 through 2007, but both of the STWM and TCEQ datasets were extended to 2009. However, there are missing diversion data for November – December 2005 and throughout 2006. Agricultural return flow data obtained from TWDB were extended through December 2007.

Hydrology: Version #TWDB201101

TWDB coastal hydrology version #TWDB201101 for the Nueces Estuary extends the previous version by updating diversion and return flow data obtained from the Nueces River Authority (provided to TWDB by HDR, Inc). Diversions and returns were the same as in version #TWDB201004 through 1999, but the additional data obtained from the Nueces River Authority were used for the period between 2000 - 2009. Figure 10 displays the combined annual surface inflow to the Nueces Estuary as calculated by version #TWDB201101. This dataset and a watershed map can be obtained on the TWDB website: http://midgewater.twdb.state.tx.us/bays_estuaries/hydrologypage.html.

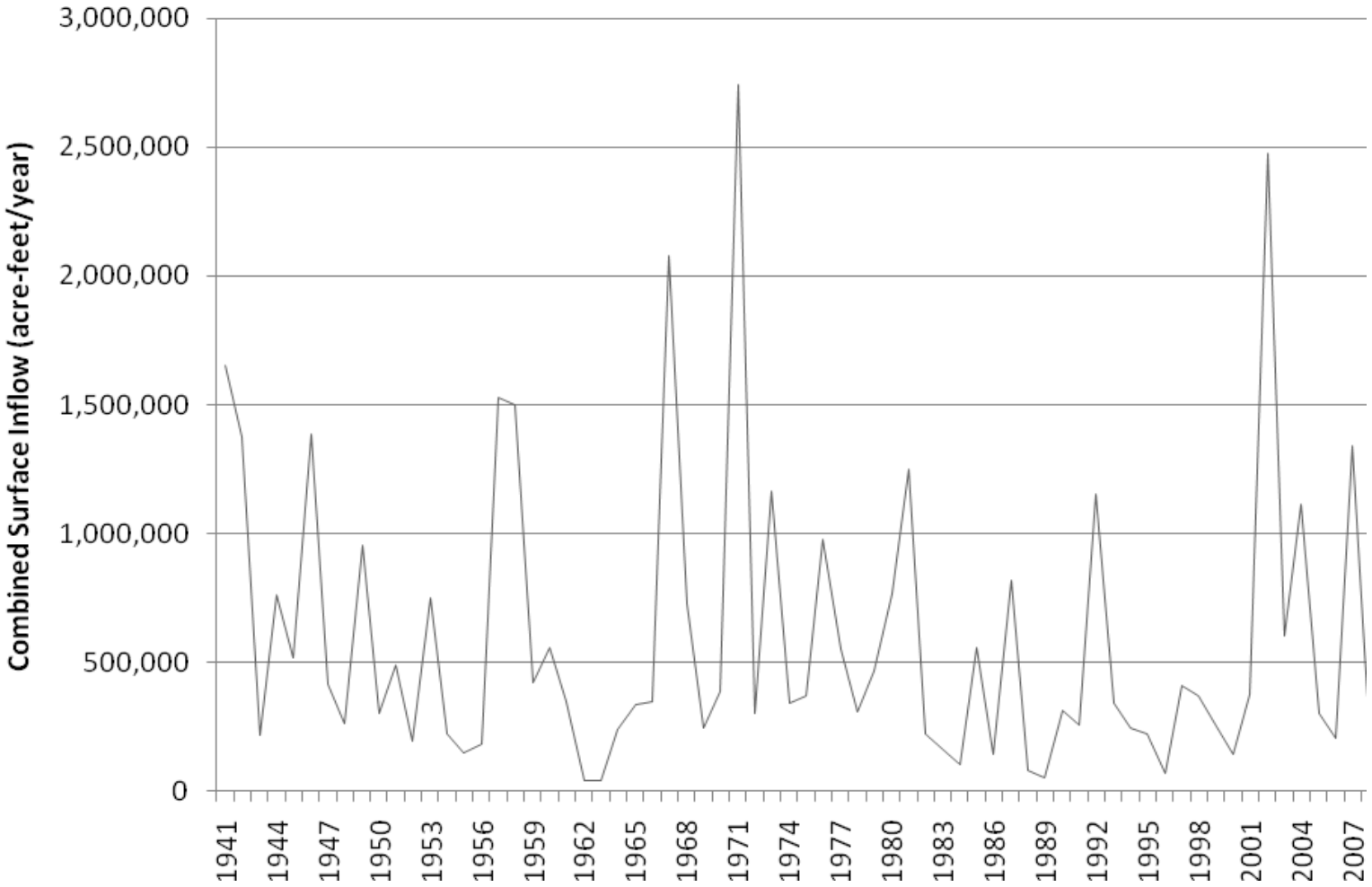

Figure 10. Combined annual surface inflow to the Nueces Estuary (version #TWDB201101) for the period from 1941 - 2009, including updated diversion and return data obtained from the Nueces River Authority via HDR, Inc.

Discussion

Version #TWDB201101 of coastal hydrology for the Nueces 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 recent updates, by version, to hydrology for the Nueces Estuary. Appendix B lists the annual combined freshwater inflow along with the four components, as well as estimates for evaporation and precipitation on the estuary and the total freshwater inflow balance of the Nueces Estuary as calculated by version #TWDB201101. Appendix C lists summary statistics for the inflow components during the 1941 through 2009 period.

During the period from 1941 to 2009, gaged inflow from the Nueces River accounted for approximately 90 percent of combined inflow, while ungaged flows accounted for about 15 percent of combined inflow. Since diversions exceed return flows in this basin, net diversions total -5 percent of combined inflows. In the Nueces River basin, average annual diversions were about 13 percent of combined freshwater inflows, and average annual return flows were about eight percent of inflows. Average combined surface inflow to the Nueces Estuary over the study period was 586,854 acre-feet per year, and ranged from a minimum of 42,551 acre-feet in 1962 to a maximum of 2,744,260 acre-feet in 1971.

Finally, when considering the total freshwater inflow balance, evaporation from and precipitation onto the surface of the estuary also must be considered. In 31 out of 69 years, there was a negative freshwater inflow balance, which indicates that evaporation exceeded precipitation and combined inflow to the estuary during periods of drought and reduced freshwater inflow. During this period of record, annual average evaporation was 670,984 acre-feet, while annual average precipitation was 345,737 acre-feet over the surface of the Nueces Estuary. Thus, the average freshwater inflow balance for the Nueces Estuary was approximately 261,606 acre-feet per year. However, as Appendix B shows, wide variations from the mean freshwater inflow balance occur, ranging from a minimum of -563,830 acre-feet in 1984 to a maximum of 2,476,966 acre-feet in 1971.

Literature Cited

TDWR. 1981. *Nueces and Mission-Aransas Estuaries: A study of the influence of freshwater inflows*. LP-108. Texas Department of Water Resources, Austin, Texas.

Appendix A. Record of Coastal Hydrology Versions Developed by the TWDB Bays & Estuaries Program for the Nueces Estuary

Estuary	Version	Date Range	Gaged Flows	Ungaged Flows	Diversions	Return Flows	Creation Date
Nueces	TWDB201001	1941-2008	1941-2008	1941-2008	1941-10/2005, TDWR 1941-1988 STWM 1989 – 10/2005	1941-2007, TDWR 1941-1976 TCEQ 1977-2007 TWDB 1977-2005 (Agricultural)	01/2010
	TWDB201002	Dataset does not exist.					
	TWDB201003	Dataset does not exist.					
	TWDB201004	1941-2009	1941-2009, provisional for 12/09	1941-2009, Precipitation data provisional for 12/09	1941-2009, TDWR 1941-1988 STWM 1989 – 2009 *Missing data for 11/2005 – 12/2006	1941-2009, TDWR 1941-1976 TCEQ 1977-2009 TWDB 1977-2007 (Agricultural)	05/2011
	TWDB201101	1941-2009	1941-2009, provisional for 12/09	1941-2009, Precipitation data provisional for 12/09	1941-2009, TDWR 1941-1988 STWM 1989 – 1999 NRA/HDR 2000-2009	1941-2009, TDWR 1941-1976 TCEQ 1977-1999 TWDB 1977-2007 (Agricultural) NRA/HDR 2000-2009	05/2011

Appendix B. Annual hydrology for the Nueces Estuary, version #TWDB201101, with updated diversion and return data obtained from the Nueces River Authority via HDR, Inc. Included are estimates of gaged and ungaged (modeled) inflows, diversions and return flows, combined surface inflow to the estuary, as well as evaporation and direct precipitation on the estuary and the 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**
1941	1,337,280	322,292	16,000	9,000	1,652,572	431,000	419,053	1,640,625
1942	1,276,040	100,460	14,000	10,000	1,372,500	438,000	300,107	1,234,607
1943	204,540	20,068	15,000	10,000	219,608	512,000	254,358	-38,034
1944	742,940	29,007	20,000	12,000	763,947	448,000	240,634	556,581
1945	488,860	40,141	26,000	14,000	517,001	512,000	244,295	249,296
1946	1,306,320	87,052	24,000	14,000	1,383,372	449,000	304,682	1,239,054
1947	323,590	104,747	29,000	15,000	414,337	469,000	305,596	250,933
1948	137,790	140,323	28,000	14,000	264,113	512,000	204,036	-43,851
1949	907,490	59,679	30,000	15,000	952,169	447,000	277,232	782,401
1950	204,470	115,055	36,000	17,000	300,525	521,000	140,903	-79,572
1951	428,250	80,375	38,000	18,000	488,625	540,000	244,295	192,920
1952	160,270	52,824	40,000	19,000	192,094	521,000	195,803	-133,103
1953	636,940	140,378	47,000	22,000	752,318	513,000	219,591	458,909
1954	242,730	10,818	51,000	23,000	225,548	540,000	144,565	-169,887
1955	129,470	43,730	50,000	25,000	148,200	714,000	198,546	-367,254
1956	136,720	73,662	54,000	27,000	183,382	649,000	197,634	-267,984
1957	1,546,500	8,993	53,000	27,000	1,529,493	587,000	254,359	1,196,852
1958	1,413,150	115,928	54,000	26,000	1,501,078	557,000	387,943	1,332,021
1959	416,620	29,159	53,000	26,000	418,779	521,000	351,344	249,123
1960	455,140	128,773	55,000	27,000	555,913	512,000	407,156	451,069
1961	320,750	53,697	56,000	27,000	345,447	484,000	241,550	102,997
1962	76,390	161	66,000	32,000	42,551	588,000	141,821	-403,628
1963	79,910	n/a	70,000	33,000	42,910	577,000	133,585	-400,505
1964	276,630	749	70,000	32,000	239,379	560,000	197,631	-122,990
1965	369,190	1,275	66,000	33,000	337,465	567,000	231,485	1,950
1966	331,070	40,875	66,000	44,000	349,945	495,000	270,829	125,774
1967	1,799,910	304,648	73,000	46,000	2,077,558	605,000	348,601	1,821,159
1968	672,990	82,190	70,000	43,000	728,180	593,000	378,792	513,972
1969	250,010	25,133	83,000	51,000	243,143	604,000	214,101	-146,756
1970	358,310	63,851	84,000	47,000	385,161	557,000	359,578	187,739
1971	2,537,410	237,850	82,000	51,000	2,744,260	604,000	336,706	2,476,966
1972	298,938	34,410	83,000	52,000	302,348	558,000	332,131	76,479
1973	1,096,618	102,485	85,000	50,000	1,164,103	543,000	397,092	1,018,195
1974	397,379	967	89,000	32,000	341,346	574,000	225,080	-7,574
1975	385,402	19,490	87,000	53,000	370,892	559,000	230,569	42,461
1976	968,060	40,786	85,000	52,000	975,846	553,000	362,324	785,170
1977	540,959	58,301	94,391	49,241	554,110	861,966	332,691	24,835
1978	249,410	104,743	96,626	49,247	306,774	836,515	504,249	-25,492
1979	396,628	112,216	96,040	51,381	464,185	837,431	514,150	140,904
1980	599,321	229,823	109,753	47,935	767,326	922,189	413,298	258,435
1981	1,085,814	207,888	102,571	59,402	1,250,533	809,878	548,564	989,219

Year	Gage	Ungaged	Diversion	Return	Combined Surface Inflow*	Evaporation	Precipitation	Freshwater Balance**
1982	226,932	42,119	107,340	63,127	224,838	877,843	286,456	-366,549
1983	121,934	73,794	101,114	66,888	161,502	861,048	485,135	-214,411
1984	116,953	26,618	98,791	58,691	103,471	958,135	290,834	-563,830
1985	491,027	99,382	94,036	60,957	557,330	846,355	486,561	197,536
1986	139,852	40,691	94,801	58,689	144,431	910,115	414,198	-351,486
1987	779,421	82,916	100,850	56,534	818,021	876,268	403,462	345,215
1988	118,138	26,683	125,621	59,135	78,335	832,445	267,180	-486,930
1989	122,328	9,142	139,988	59,630	51,112	867,608	254,690	-561,806
1990	365,532	28,196	131,842	52,849	314,735	749,133	326,307	-108,091
1991	204,236	114,838	119,988	57,539	256,625	956,428	559,298	-140,505
1992	953,522	255,737	112,075	56,664	1,153,848	893,323	590,011	850,536
1993	239,249	162,162	114,712	56,086	342,785	1,006,419	538,896	-124,738
1994	198,902	77,723	82,838	49,138	242,925	748,277	403,469	-101,883
1995	176,523	98,358	90,928	41,614	225,567	779,835	456,125	-98,143
1996	120,284	14,614	94,448	29,968	70,418	846,613	281,087	-495,108
1997	291,567	191,323	103,147	29,218	408,961	678,672	619,062	349,351
1998	355,778	89,716	107,481	32,118	370,131	765,646	448,480	52,965
1999	214,955	108,047	101,180	31,338	253,160	763,379	444,434	-65,785
2000	123,883	46,780	87,627	58,269	141,305	870,770	272,218	-457,247
2001	279,472	104,202	67,724	61,226	377,176	723,326	462,966	116,816
2002	2,276,890	188,831	66,109	76,482	2,476,094	707,759	598,098	2,366,433
2003	512,915	74,506	62,106	79,191	604,506	663,145	441,571	382,932
2004	930,384	146,309	59,571	98,772	1,115,894	694,284	629,074	1,050,684
2005	234,394	38,860	67,968	95,657	300,943	745,569	296,426	-148,200
2006	106,919	82,000	67,632	85,417	206,704	748,318	349,870	-191,744
2007	1,126,762	188,998	61,597	85,393	1,339,556	665,240	555,598	1,229,914
2008	88,422	59,341	62,624	78,040	163,179	750,800	367,304	-220,317
2009	84,386	38,434	76,388	73,878	120,310	829,170	320,082	-388,778

*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 1941 - 2009 period for the Nueces Estuary, version #TWDB201101.

	Gage	Ungaged	Diversion	Return	Combined Surface Inflow	Evaporation	Precipitation	Freshwater Balance
MIN	76,390	161	14,000	9,000	42,551	431,000	133,585	-563,830
5th%ile	95,821	3,976	21,600	12,800	73,585	448,400	165,060	-475,057
10th%ile	119,855	13,475	28,800	14,800	137,106	492,800	198,364	-391,123
25th%ile	198,902	37,428	54,000	27,000	225,548	540,000	244,295	-146,756
MEDIAN	331,070	74,150	70,000	47,000	349,945	649,000	332,131	52,965
MEAN	530,258	87,284	73,158	43,735	586,854	670,984	345,737	261,606
75th%ile	672,990	112,872	94,801	58,269	763,947	829,170	419,053	458,909
90th%ile	1,282,096	189,696	107,935	74,399	1,374,674	876,583	540,830	1,230,853
95th%ile	1,493,160	235,041	117,878	82,912	1,603,340	917,359	577,726	1,517,183
MAX	2,537,410	322,292	139,988	98,772	2,744,260	1,006,419	629,074	2,476,966
TOTAL	36,587,769	5,935,322	5,047,907	3,017,714	40,492,898	46,297,902	23,855,851	18,050,847