Comparison of Two Hydrology Datasets, as Applied to the TxBLEND Model, on Salinity Condition in Nueces Bay

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Introduction

A recent Texas Water Development Board (TWDB) technical memo documented the calibration and validation of the Nueces Estuary TxBLEND hydrodynamic and salinity transport model in which inflows to Nueces Bay, via the Nueces River Inflow Point, were based on the USGS stream gage on the Nueces River at Calallen plus return flows from the Allison Wastewater Treatment Plant (WWTP, Schoenbaechler *et al.* 2011a). As such, the inflows captured only a portion of the total inflows entering Nueces Bay, though it closely represented inflows entering the bay via the Nueces River. At the request of the Senate Bill 3 Nueces Basin and Bay Expert Science Team (BBEST), TWDB prepared an alternate hydrology dataset to better represent *total* inflows entering Nueces Bay. Specifically, the alternate hydrology was based on the USGS stream gage on the Nueces River at Calallen plus inflows from a portion of watersheds #20005 and #21010 and all of watershed #22012, as well as the Allison WWTP return flows and any other appropriate diversion and returns for these watersheds. Under this alternate hydrology, total inflows to Nueces Bay are better represented, though due to constraints on the model design, the inflows are applied solely to the Nueces River Inflow Point, which may slightly over-represent inflows entering the system at this location. This technical memo documents salinity output from the TxBLEND model using this alternate hydrology dataset as applied to the Nueces River Inflow Point. Additionally, this memo documents the comparison between TxBLEND model output using two different hydrology datasets (1) that which was used in the calibration and validation of the TxBLEND model and also (2) the proposed alternate hydrology described herein.

Methodology

Model Domain and Inputs

The model domain, parameters, and model inputs (except for inflows) are consistent with that used for calibration and validation of the Nueces Estuary TxBLEND model (Schoenbaechler *et al.* 2011a). However in the *Alternate Hydrology* simulation presented here, results are focused on salinity in Nueces Bay for the period 2000 – 2009.

Inflows

As described in the calibration and validation report for the Nueces Estuary TxBLEND model (Schoenbaechler *et al.* 2011a):

> "Daily inflow values for Nueces Bay were modified from those prepared for TWDB coastal hydrology dataset version #TWDB201004 for the Nueces Estuary, which is based on gaged inflows from the U.S. Geological Survey (USGS) stream gage on the Nueces River at Mathis (Station no. 08211000, Schoenbaechler *et al.*, 2011b), to better reflect inflows entering Nueces Bay via the Nueces River inflow point. However, the modified hydrology was used only after 1989, when the Nueces River at Calallen gage (Station no. 08211500) became operational. Before then, daily inflows prepared for hydrology version #TWDB201004 (for only the portion of flows that drain to Nueces Bay) were applied to the Nueces River inflow point. Specifically, those flows were based on gaged inflows from the USGS gage at Mathis,

and ungaged inflows from watersheds #20005, #21010, #22012, and #22013. Diversions and return flows also were accounted for in those ungaged watersheds."

After 1989, daily inflow values were modified by using the USGS stream gage at Calallen due to its close proximity to the bay and by applying return flows from the Allison WWTP (as a constant 10.5 acre-feet per day based on the daily average discharge from 2003 – 2009; Table 1). This modification slightly under-represents total inflows entering Nueces Bay but more accurately reflect total inflows entering the bay via the Nueces River Inflow Point. However, other hydrology data sets can be developed and applied to the TxBLEND model.

Table 1 describes three hydrology data sets that are relevant to consider when conducting freshwater inflow analyses of Nueces Bay. The dataset referred to as *TxBLEND Nueces River Inflow Point (Calibration Hydrology)* is that which was applied to the calibration and validation of the model, as described above. The dataset referred to as *TxBLEND Nueces River Inflow Point (Alternate Hydrology)* is that which was requested by the Nueces BBEST and better represents total inflows entering Nueces Bay, but with a slight over-representation of inflows passing through the Nueces River Inflow Point. Both of these hydrology datasets were modified from an earlier version of hydrology, #TWDB201004, which lacked some diversion and return flow data (refer to Schoenbaechler *et al*. 2011b for specific information about each version of hydrology and refer to Figures 6 and 11 in Schoenbaechler *et al*. 2011a for plots comparing the *Calibration Hydrology* to total inflows to the estuary). After 1989, both of these datasets are based on using the USGS stream gage for the Nueces River at Calallen. Also presented, for comparison purposes only, is a description of the most recent version of hydrology developed for the entire Nueces Estuary, #TWDB201101-*Full Hydrology*, which includes updated diversion and return flow data, as well as a description of the subset of inflows which drain into Nueces Bay (referred to as *TWDB201101-Nueces Bay Hydrology*). These last two descriptions are based on using the USGS stream gage for the Nueces River near Mathis and ungaged flows from the watershed below that gage. Figure 1, below, is provided to serve as an aid for understanding the various hydrology datasets described in Table 1.

Table 1. Comparison of components used to estimate inflows for four hydrology datasets. *TWDB201101-Full Hydrology* represents the most recent TWDB estimate of freshwater inflow to the Nueces Estuary. *TWDB201101-Nueces Bay Hydrology* represents only the inflows entering Nueces Bay, a subset of the full hydrology. The two *TxBLEND Nueces River Inflow Point* hydrology datasets represent those inflows applied to the Nueces Bay Inflow Point in the TxBLEND model for the Nueces Estuary. The *Calibration Hydrology* was used to calibrate and validate the model from 1987- 2009 and represents inflows passing from the Nueces River watershed into Nueces Bay; whereas, the *Alternate Hydrology* was applied to better represent total inflows entering Nueces Bay for all surrounding watersheds. Refer to Figure 1 for gage, watershed, diversion, and return flow locations.

Inflow Component	**TWDB201101 (Full Hydrology) 1941 - 2009**	**TWDB201101 (Nueces Bay Hydrology) 1977 - 2009**	**TxBLEND Nueces River Inflow Point (Calibration Hydrology)**		**TxBLEND Nueces River Inflow Point (Alternate Hydrology) 1990 - 2009**
			1987 - 1989	**1990 - 2009**	
Gaged Watersheds	#08211000 - Nueces R. nr Mathis (1941 – 2009) #08211520 - Oso Creek @ Corpus Christi (1977 – 2009)	#08211000 - Nueces R. nr Mathis	#08211000 - Nueces R. nr Mathis	#08211500 – Nueces R. @ Calallen	#08211500 – Nueces R. @ Calallen
Ungaged Watersheds	100% of all watersheds: #21010, #20005, #22012, #22013, #22011, #22014, #22015, and before 1977, #22010 (which has since been gaged by Oso Crk gage)	100% of area of #21010, 50% of area of #20005, 100% of area of #22012, 0% of area of #22013 (not included as drains to Corpus Christi Ship Channel)	100% of all watersheds: #21010, #20005, #22012, #22013	None included	20% of area of #21010, 50% of area of #20005, 100% of #22012, 0% of #22013 (not included as drains to Corpus Christi Ship Channel)
Returns	All return flow data available	100% of #21010, 13% of #20005, 100% of #22012	100% of #21010, #20005, #22012, #22013	Return flows from Alison Wastewater Treatment Plant only	100% of #21010, 13% of #20005, 100% of #22012
Diversions	All diversion data available	100% of #21010	100% of #21010, #20005	n/a	n/a

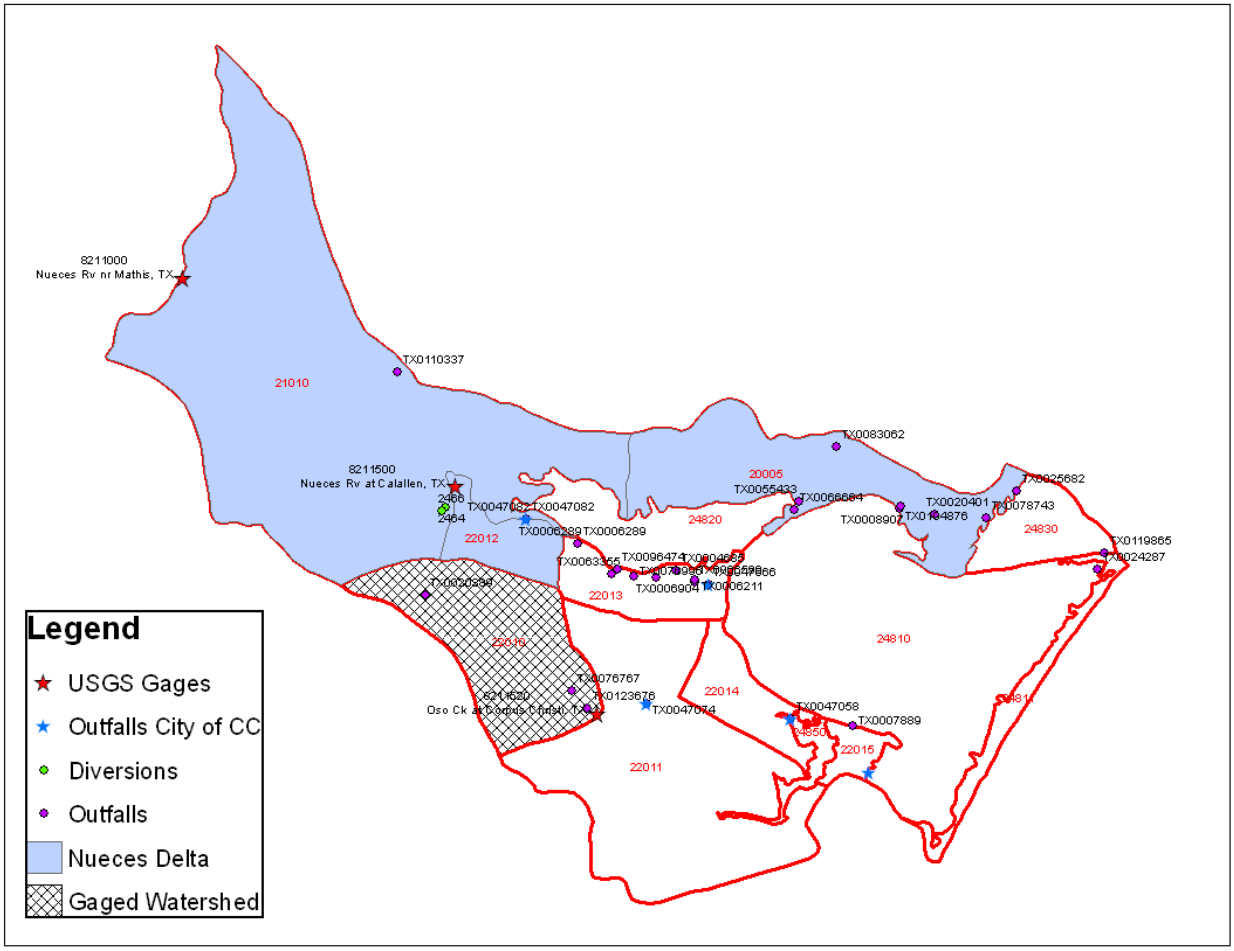

Figure 1. Location of USGS stream gages (red stars), permitted diversion points (green circles), wastewater outfalls (purple circles) and City of Corpus Christi outfalls (blue stars) in the Nueces Estuary watershed. Watersheds #21010, #22012, and a portion of #20005 drain to the Nueces Delta and are highlighted in blue.

While all three Nueces Bay inflow hydrology datasets are comparable in terms of average annual inflow (Table 2), there are annual and intra-annual differences such that none of the hydrology datasets yield consistently more or less inflows (Figures 2 and 3). However, a comparison of the two TxBLEND hydrology datasets shows that the *Alternate Hydrology* captures more inflows than the *Calibration Hydrology*. This is consistent with having included those inflows contributed from the watersheds surrounding Nueces Bay in the *Alternate Hydrology*. The effect of including these additional watersheds and applying all Nueces Bay inflows to the Nueces River Inflow Point in the TxBLEND model is described in the following sections. Though not applied to the TxBLEND model at this time, inflow estimates for *TWDB201101-Nueces Hydrology* (based on the USGS stream gage on the Nueces River near Mathis) includes higher inflow events, which are not captured by either of the TxBLEND hydrology datasets (Figure 4). Figure 5 focuses specifically on the 2000 – 2009 period, which was simulated for this technical memo, and shows flows ranging from 0 – 200,000 acre-feet per month to allow for a better visual comparison of differences among the hydrology datasets.

Table 2. Annual total freshwater inflow (in acre-feet) to Nueces Bay, as estimated by three hydrology datasets: *TWDB201101-Nueces Bay Hydrology*, *TxBLEND Calibration Hydrology*, and *TxBLEND Alternate Hydrology*, for the period 1990 – 2009.

Year	TWDB201101 Nueces Hydrology	TxBLEND Nueces Calibration Hydrology	TxBLEND Nueces Alternate Hydrology
1990	247,789	195,324	202,311
1991	114,446	97,035	114,330
1992	959,322	479,915	530,274
1993	146,305	79,845	102,473
1994	144,310	55,430	69,233
1995	103,377	52,098	71,419
1996	32,173	10,036	11,478
1997	236,346	126,910	150,699
1998	272,042	198,978	209,347
1999	158,846	111,901	126,500
2000	68,066	51,671	61,490
2001	244,006	277,886	296,372
2002	2,263,878	2,483,278	2,528,243
2003	493,223	554,650	573,029
2004	899,765	923,845	956,209
2005	189,078	184,193	198,628
2006	66,066	38,150	65,681
2007	1,118,550	1,160,271	1,209,915
2008	43,822	32,265	47,665
2009	27,407	19,228	30,903
Average Inflow	372,369	346,241	364,661

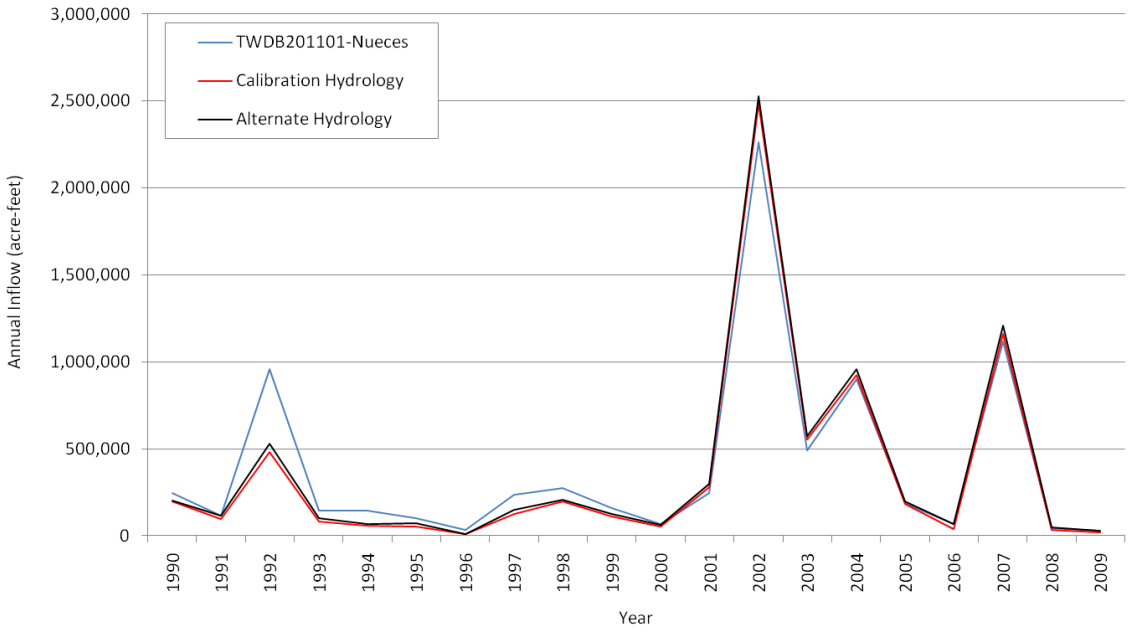

Figure 2. Annual freshwater inflow estimates (in acre-feet) to Nueces Bay between three hydrology datasets for 1987 – 2009; *TWDB201101-Nueces Bay Hydrology* (*blue*), *TxBLEND Calibration Hydrology* (*red*), and *TxBLEND Alternate Hydrology* (*black*).

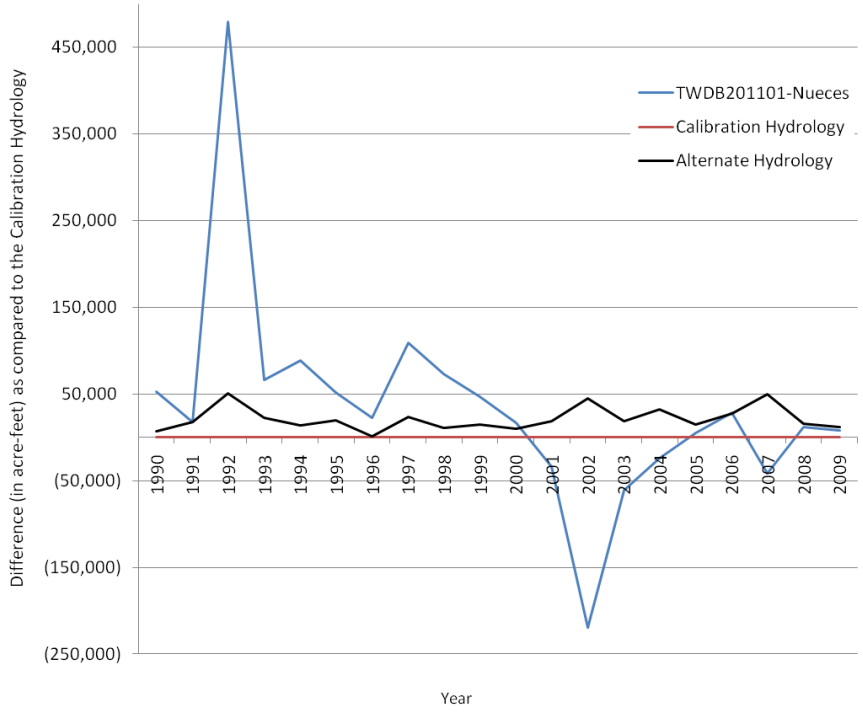

Figure 3. Difference in annual inflow estimates (in acre-feet) to Nueces Bay for three hydrology datasets from 1987 – 2009; *TWDB201101-Nueces Bay Hydrology* (*blue*), *TxBLEND Calibration Hydrology* (*red*), and *TxBLEND Alternate Hydrology* (*black*). Differences are compared to the *TxBLEND Calibration Hydrology*.

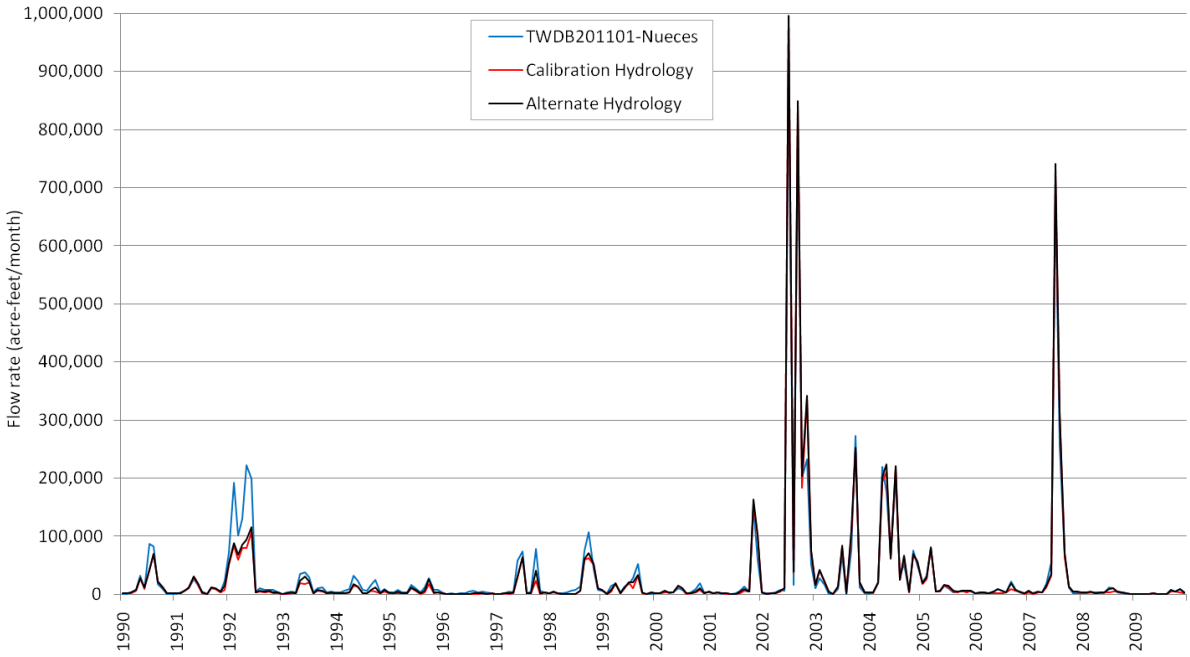

Figure 4. Freshwater inflow (in acre-feet per month) to Nueces Bay as estimated by three hydrology datasets: *TWDB201101-Nueces Bay Hydrology* (*blue*), *TxBLEND Calibration Hydrology* (*red*), and *TxBLEND Alternate Hydrology* (*black*), for the period 1987 – 2009.

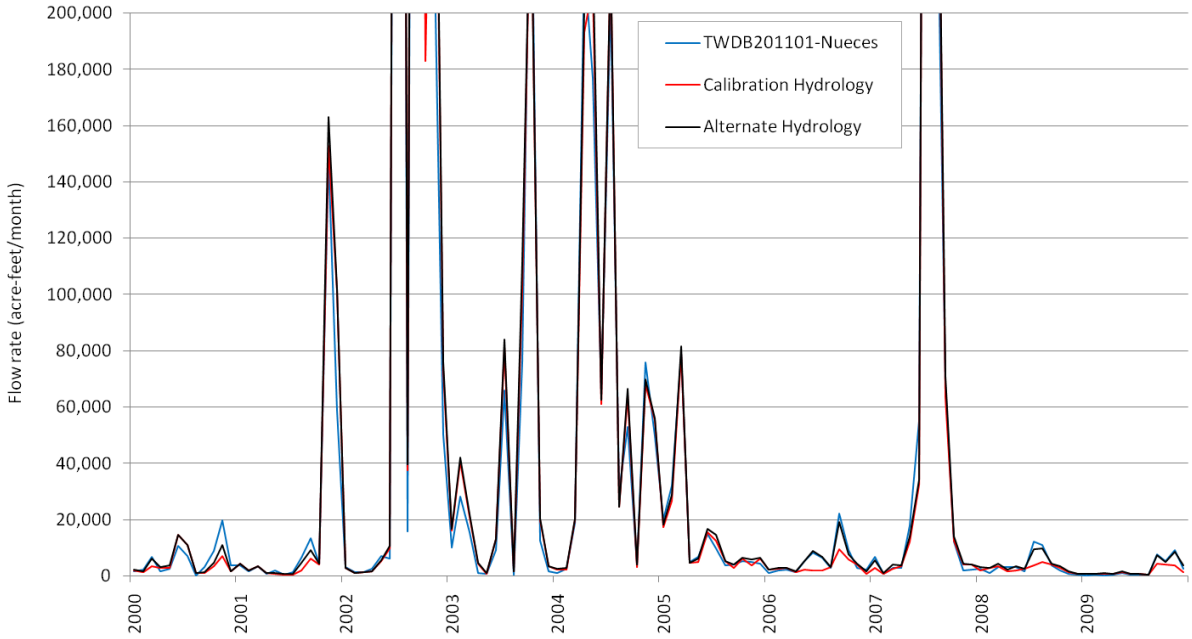

Figure 5. Freshwater inflow to Nueces Bay (in acre-feet per month, up to 200,000 acre-feet) as estimated by three hydrology datasets: *TWDB201101-Nueces Bay Hydrology* (*blue*), *TxBLEND Calibration Hydrology* (*red*), and *TxBLEND Alternate Hydrology* (*black*), for the period 2000 – 2009.

Results

TxBLEND Salinity Results Based on the Alternate Hydrology

TxBLEND daily salinity output at the mid-Nueces Bay site for the period 2000 – 2009 was compared to observed measurements of salinity obtained from the SALT01 station maintained by the Division of Nearshore Research (DNR; http://lighthouse.tamucc.edu/Salinity/HomePage; Figures 6 – 9). For this site under the *Alternate Hydrology*, the difference between mean simulated and observed salinity for the two time periods was less than 2 ppt (Table 3), and the results were similar to those observed under the *Calibration Hydrology*. For both hydrology data sets, r^2 values and Nash-Sutcliffe Efficiency Criterion (E) were high, indicating good model performance in representing salinity conditions during both periods. Additionally, Root Mean Square Error (RMS) for observed versus simulated salinity was similar between the two hydrology datasets, indicating that the model's response to inflows is consistent for both scenarios. *Note*: Because the *Calibration Hydrology* was used to both calibrate (2000 – 2004) and validate (2005 – 2009) the TxBLEND model, salinity results for the *Alternate Hydrology* are presented for the same two time periods to allow for direct comparison of model performance between the two hydrology datasets.

Time-series plots of observed versus simulated salinity at mid-Nueces Bay under the *Alternate Hydrology* (Figures 6 – 9) show that the model captures long-term trends in salinity, generally rising and falling with the patterns observed in measured data. For the 2000 – 2004 simulation period, the model tends to under-predict salinity values more often than over-predicting salinity. For the 2005 – 2009 simulation period, the model tends to over-predict salinity more often but still captures long-term trends in changing salinity. These plots also may be compared to those developed to show observed salinities at the mid-Nueces Bay site versus simulated salinities using the *Calibration Hydrology* (Figures 47 – 48, 59 – 60 in Schoenbaechler *et al*. 2011a). Again, both hydrology datasets yield similar model predictions.

Table 3. Summary statistics for comparisons of simulated to observed daily salinity for the Nueces Bay site for various periods from 2000 - 2009 under two hydrology datasets. The *Calibration Hydrology* dataset was used to calibrate the model for the period 2000 – 2004 and validate the model from 2005 – 2009. (Data and plots are available in Schoenbaechler *et al.* 2011a.) The *Alternate Hydrology* was applied to the calibrated model for the full period, but statistics were calculated separately for each time period to aid in comparing the effect of each hydrology dataset.

Nueces Bay Hydrology Dataset	Period	Days	r^2	RMS (ppt)	NSEC (E)	Average Salinity (ppt)		
						Simulated Salinity	Observed Salinity	Difference (Sim-Obs)
Calibration Hydrology	2000 - 2004	1,413	0.91	3.8	0.90	19.4	20.2	-0.8
	2005 - 2009	1,328	0.84	4.3	0.79	26.8	25.0	1.8
Alternate Hydrology	2000 - 2004	1,413	0.91	3.8	0.89	19.1	20.2	-1.1
	2005 - 2009	1,328	0.84	4.1	0.81	26.3	25.0	1.3

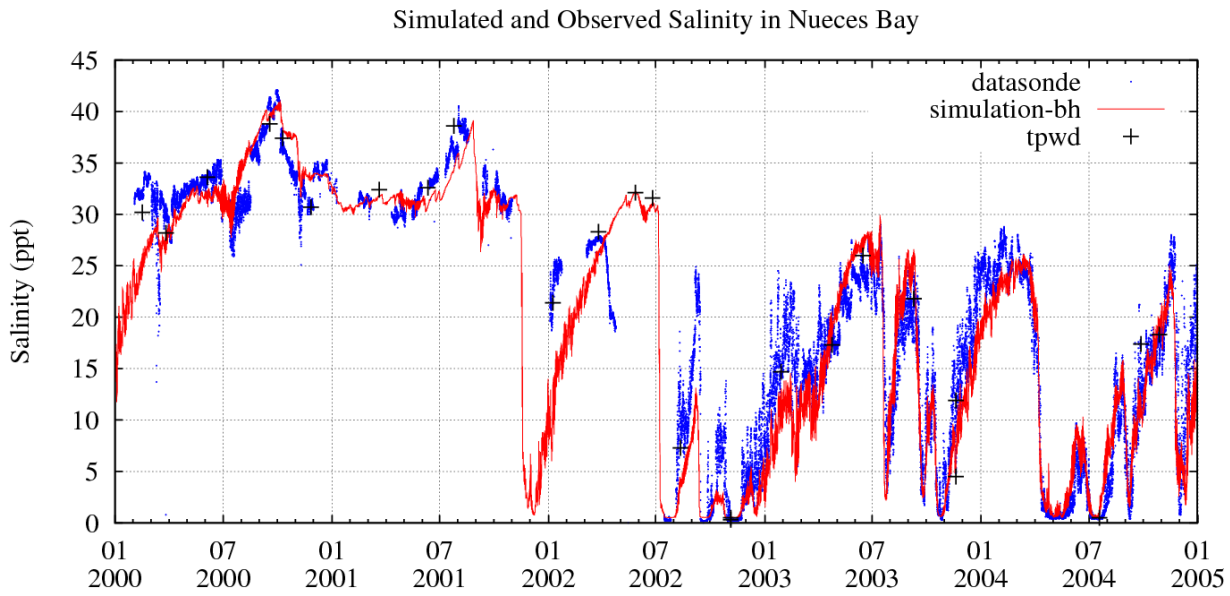

Figure 6. Observed (*blue*) versus simulated (*red*) salinities at the Nueces Bay site in the Nueces Estuary for 2000 – 2004, using the *Alternate Hydrology* dataset. Point measurement data collected by TPWD (+) near this site also was included for comparison.

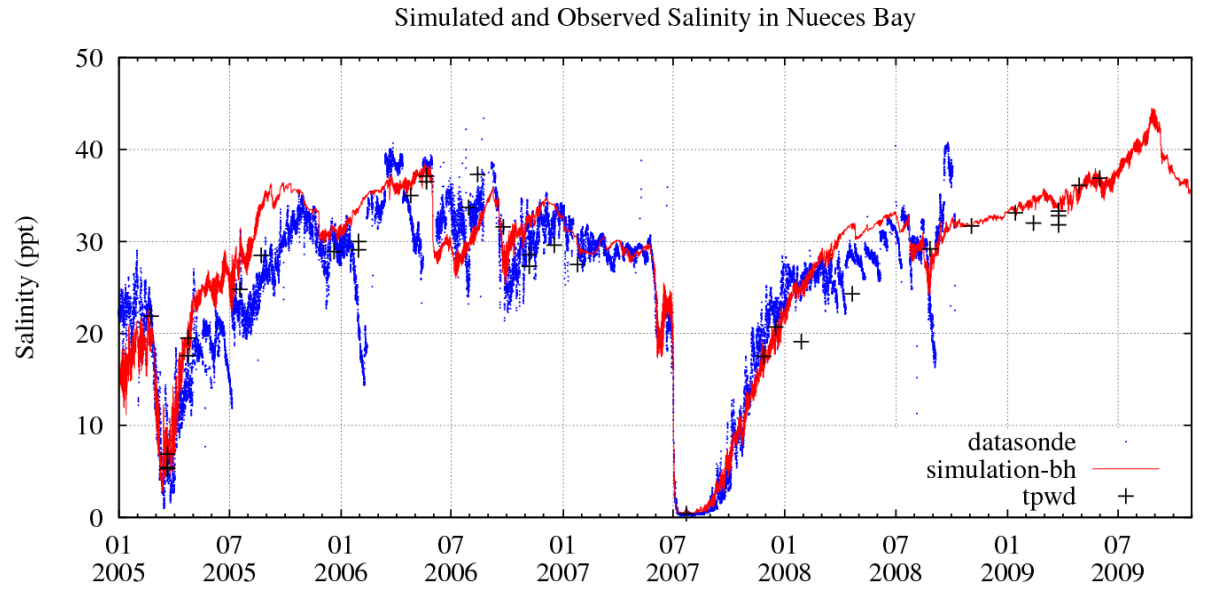

Figure 7. Observed (*blue*) versus simulated (*red*) salinities at the Nueces Bay site in the Nueces Estuary for a period from 2005 – 2009, using the *Alternate Hydrology* dataset. Point measurement data collected by TPWD (+) near this site also was included for comparison.

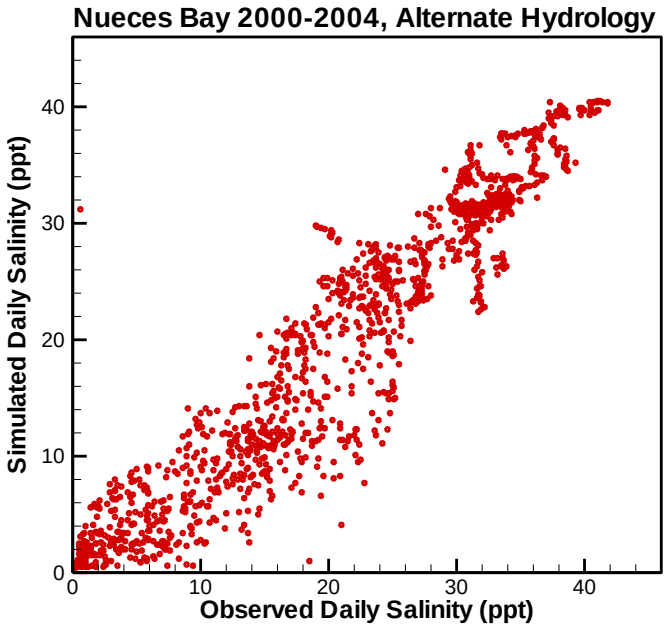

Figure 8. Scatter plot comparing simulated to observed salinities at the Nueces Bay site for the period from 2000 – 2004 ($r^2 = 0.91$).

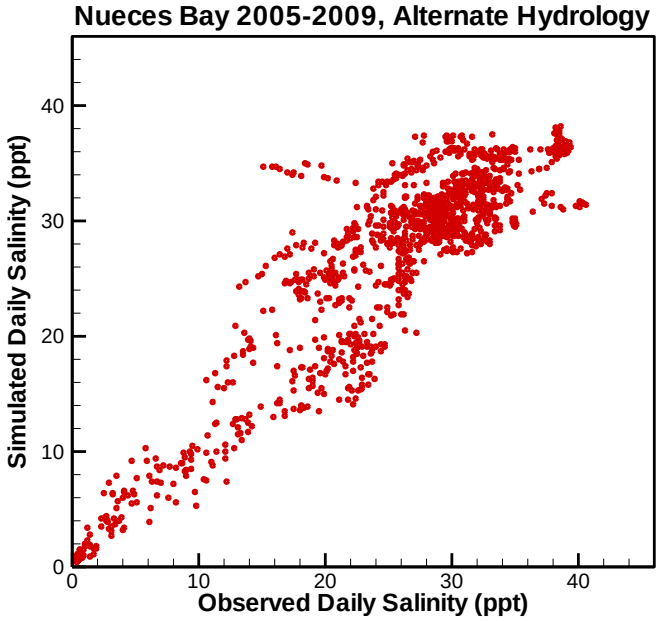

Figure 9. Scatter plot comparing simulated to observed salinities at the Nueces Bay site for the period from 2005 – 2009 ($r^2 = 0.84$).

Comparison of Salinity Simulations for the Calibration Hydrology and Alternate Hydrology

To directly compare each model scenario to one another, Figures 10 and 11 plot the time-series of simulated daily salinity for both hydrology scenarios. From these plots, it is evident that there is little difference in simulated salinities between these two hydrology scenarios. This is due primarily to there being little difference between the two hydrology datasets. In late 2001 (Figure 10), the *Alternate Hydrology* yields higher inflows than the *Calibration Hydrology*, which results in lower simulated salinities than predicted by the *Calibration Hydrology*. This situation occurs again from 2006 to early 2007, in mid-2008, and in late 2009 (Figure 11).

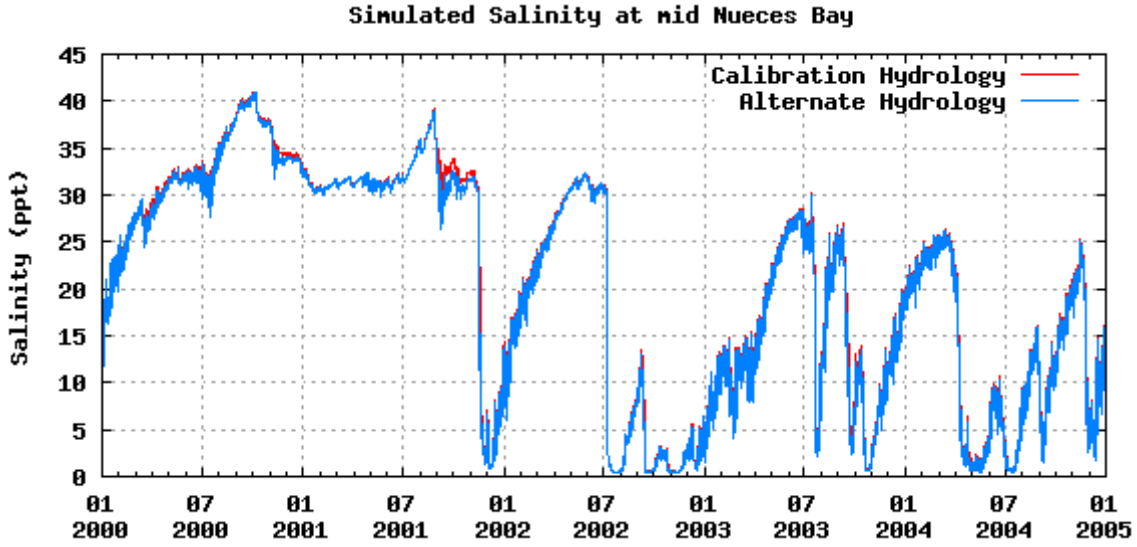

Figure 10. Comparison of simulated salinities between the Calibration Hydrology (red) and Alternate Hydrology (blue) at the mid-Nueces Bay site for 2000 – 2004.

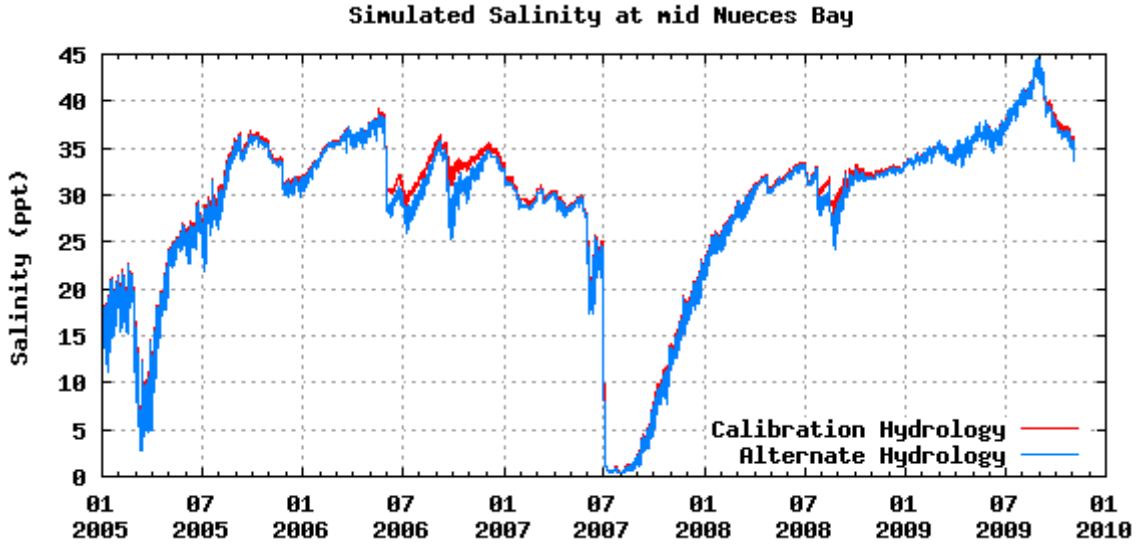

Figure 11. Comparison of simulated salinities between the Calibration Hydrology (red) and Alternate Hydrology (blue) at the mid-Nueces Bay site for 2005 – 2009.

Discussion

This technical memo describes three estimates of total freshwater inflow for Nueces Bay which were developed using a distinct combination of stream gages, watersheds, diversion, and return flow data. Each of these three hydrology versions provide reasonable estimates of flows entering Nueces Bay. For studies which are aimed at evaluating estuarine responses to total inflows to Nueces Bay or for studies where the geographic distribution of inflows is not important, the more appropriate hydrology may be *TWDB201101-Nueces Bay Hydrology* as it represents all inflows entering from the Nueces Basin as well as the surrounding coastal watersheds. For studies where the geographic distribution of inflows is important, such as the TxBLEND hydrodynamic and salinity transport model where only a single inflow point exists by which to input all representative inflows, it then becomes necessary to carefully consider which hydrology best captures the question of interest or it becomes necessary to model more than one scenario. The latter option was demonstrated in this technical memo by comparing an *Alternate Hydrology* to a previously modeled *Calibration Hydrology* (see Schoenbaechler *et al*. 2011a).

For the scenarios presented herein, the *Alternate Hydrology* differed from the *Calibration Hydrology* by an average of 21,165 acre-feet or 17%, with a minimum difference of 1,442 acre-feet in 1996 and a maximum difference of 50,359 acre-feet in 1992. Overall, these differences were not sufficient to dramatically alter the salinity predictions modeled by TxBLEND in Nueces Bay. Although at times, the higher inflows captured by the *Alternate Hydrology*, such as in 2001, 2006, early 2007, mid-2009 and late 2009, were large enough to result in lower salinity predictions by a few parts per thousand, in mid-Nueces Bay as compared to those simulated by the *Calibration Hydrology*.

Literature Cited

Schoenbaechler, C., C.G. Guthrie, J. Matsumoto, Q. Lu, and S. Negusse. 2011a. *TxBLEND Model Calibration and Validation for the Nueces Estuary.* Texas Water Development Board, Austin, Texas. 61pp.

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