TxBLEND Model Extension and Salinity Validation for the Sabine-Neches Estuary: Extending Simulations Through 2013

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Purpose

This technical memo documents the procedure for updating the TxBLEND hydrodynamic and salinity transport model for the Sabine-Neches Estuary which was calibrated and validated for the period 1990 – 2005 to extend to simulate the period 1990 – 2013.

Introduction

The Texas Water Development Board (TWDB) maintains a data collection and analytical study program focused on determining freshwater inflow needs which are supportive of economically important and ecologically characteristic fish and shellfish species and the estuarine life upon which they depend (Senate Bill 137 (1975), House Bill 2 (1985), and Senate Bill 683 (1987)). Additional legislative directives, Senate Bill 1 (1997) and Senate Bill 3 (2007), also direct TWDB to provide technical assistance in support of regional water planning and development of environmental flow regime recommendations. This may include assisting others in evaluating freshwater inflow management approaches and in understanding the effects of dynamic freshwater inflow conditions, including droughts and flood cycles, on salinity patterns in the estuaries. TWDB's principal tools for examining salinity patterns is the TxBLEND hydrodynamic and salinity transport model, a two-dimensional, depth-averaged model that simulates water circulation and salinity condition within the bays (TWDB 1999). Because TxBLEND produces high-resolution, dynamic simulations of estuarine conditions over long-term periods, the model has been used in a variety of projects including freshwater inflow studies, oil spill response, forecasting of bay conditions, oyster reef restoration, salinity mitigation, and environmental impact evaluations.

For assistance to the Sabine-Neches Senate Bill 3 process for environmental flows, TWDB calibrated and validated the TxBLEND model for the Sabine-Neches Estuary (Sabine Lake) in order to simulate the modern period of record 1990 – 2005 (Schoenbaechler *et al*. 2013). However, in order to better understand recent patterns of salinity and drought impacts in this estuarine system, the National Wildlife Federation (NWF) requested TWDB extend TxBLEND's capabilities to simulate conditions during the recent 2011 drought, generally recognized as the worst one-year drought period in Texas' recorded history. This technical memo therefore describes updates to model input data, model changes, and simulated salinity results that now allow for simulating the full period of record from 1990 – 2013. For a comprehensive description of the Sabine Lake TxBLEND model domain, data requirements, calibration, and validation refer to Schoenbaechler *et al*. 2013.

Model Description

TxBLEND is a computer model designed to simulate water levels, water circulation, and salinity condition in estuaries. The model is based on the finite-element method, employs triangular elements with linear basis functions, and simulates movements in two horizontal dimensions (hence vertically averaged). The current version of TxBLEND being used for model applications is Version S8HH-AvDay.f (August 20, 2014). Model output includes time-varying depth and vertically-averaged horizontal velocity components of flow and salinity throughout the model domain. TxBLEND thus provides water velocity and direction, surface elevation, and salinity at each node in the model (Figure 1). The model does not provide information about vertical variation within the water column, but rather provides information about horizontal variation, such as salinity zonation patterns throughout the estuary. The model was run in two minute time-steps with hourly output. The model simulated bay circulation and salinity condition for the period 1990 – 2013.

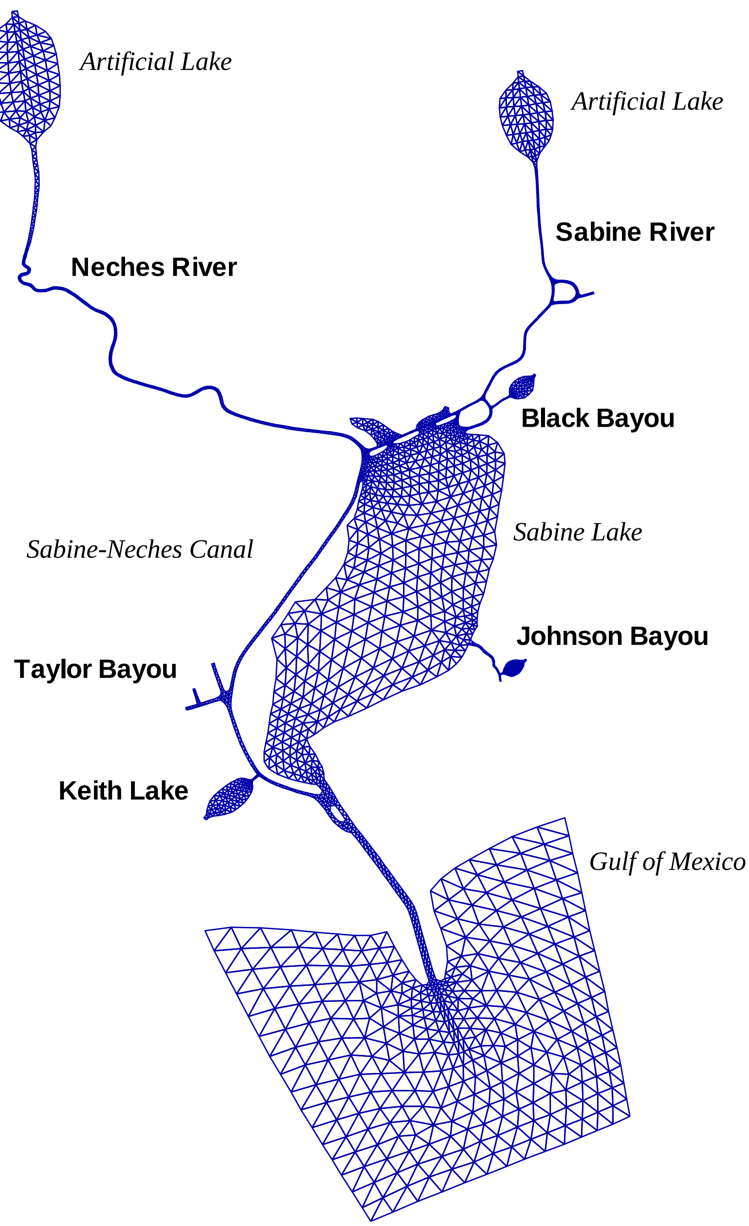

Figure 1. Computational grid and six inflow points (Sabine River, Neches River, Black Bayou, Johnson Bayou, Taylor Bayou, and Keith Lake) for the Sabine-Neches Estuary TxBLEND model.

Model Domain

The TxBLEND model domain remains unchanged from the previous calibration and validation effort described in Schoenbaechler *et al*. (2013). The TxBLEND computational grid for the Sabine-Neches Estuary contains 2,341 nodes and 3,408 elements (Figure 1). The model grid has six inflow points corresponding to the Sabine and Neches Rivers, Black Bayou, Taylor Bayou, Johnson Bayou, and the Keith Lake/Salt Bayou complex. Artificial lakes are utilized as a means for allowing the salinity boundary condition of the freshwater inflow sources to be accurately represented without having to greatly extend the model grid further upriver. Bathymetric information was obtained from the Coastal Relief Model of the National Geophysical Data Center (NGDC) of the National Oceanic and Atmospheric Administration (NOAA) and NOAA navigation charts for Sabine Pass and Sabine Lake.

Surface Inflows

From 1990 – 2009, daily surface inflow values were based on TWDB's coastal hydrology dataset version #TWDB201004 for the Sabine-Neches Estuary (Schoenbaechler *et al*., *in prep.*). From 2010 – 2013, daily surface inflows were based on updated hydrology in which return flow and diversion data have not been finalized and are therefore provisional, version #TWDB201402 (*preliminary*, *unpublished data*). In all cases, daily inflow datasets use measurements from U.S. Geological Survey (USGS) stream gages for gaged watersheds (Table 1) and estimates of rainfall-runoff based on National Weather Service precipitation data as simulated with TWDB's Texas Rainfall-Runoff (TxRR) model for ungaged watersheds. Estimates from ungaged areas are further adjusted for known diversion and return flows obtained from the Texas Commission on Environmental Quality (TCEQ) and TWDB Irrigation Water Use estimates. Figure 2 displays the watershed boundaries, including the ungaged watersheds modeled with TxRR during the period 1990 – 2013. Table 2 lists the distribution of inflows from surrounding gaged and ungaged watersheds that were applied to the inflow control points.

Table 1. USGS stream gages used to develop surface inflow estimates for the Sabine-Neches Estuary.

USGS Gage Station Number	**USGS Gage Location**	**Utilized Period of Record**
8030500	Sabine River near Ruliff	1990 – 2013
8031000	Cow Bayou near Mauriceville	8/28/2002 – 2013
8041000	Neches River at Evadale	1990 – 2013
9041700	Pine Island Bayou near Sour Lake	1990 – 2013
8041500	Village Creek near Kountze	1990 – 2013

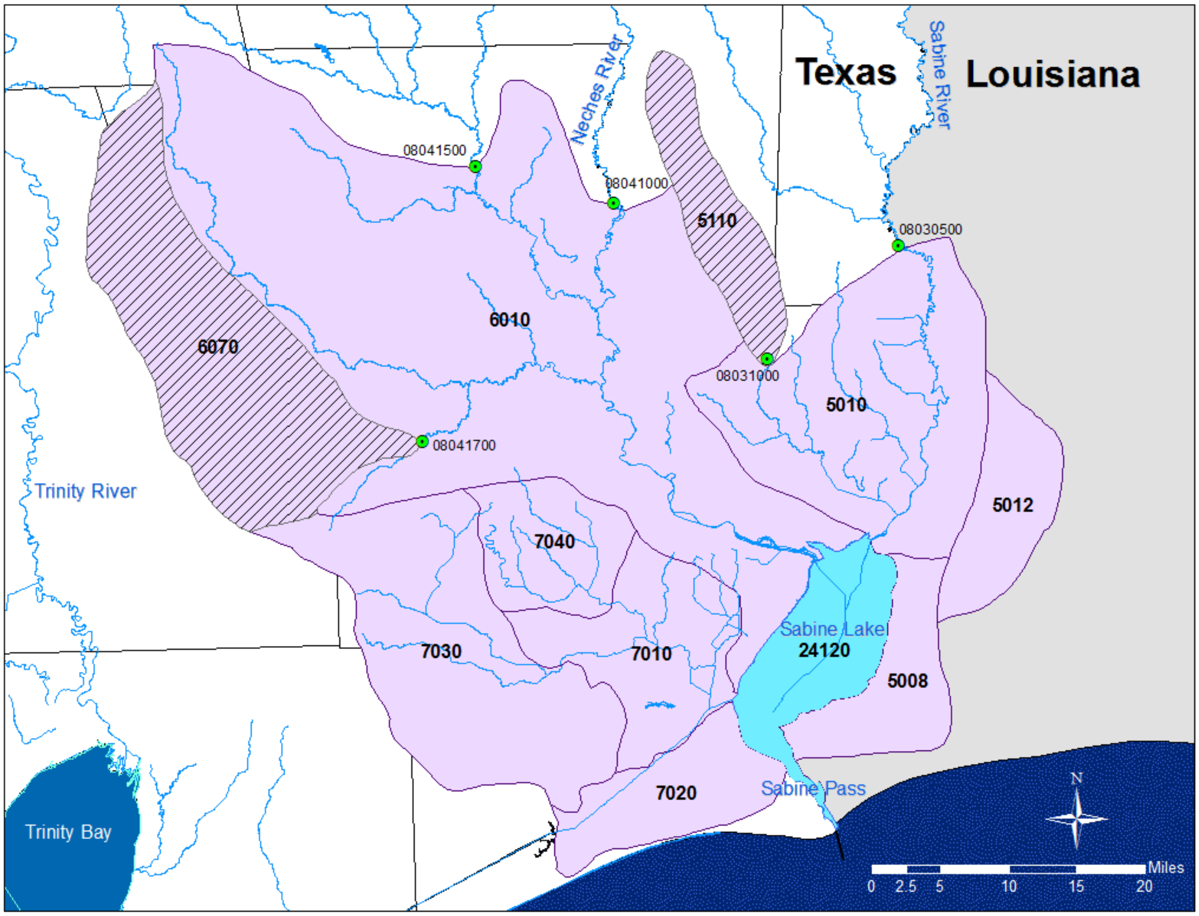

Figure 2. Watershed delineation used to determine ungaged inflows to the Sabine-Neches Estuary. Ungaged watersheds are identified by watershed number and purple shading. USGS stream gage locations, as indicated by green circles, suggest the area upstream is gaged. However, two gaged watersheds, as indicated by cross-hatching, have intermittent periods of record and therefore at times were treated as ungaged watersheds. During the TxBLEND simulation period for 1990 – 2013, only gage #08031000 (Cow Bayou near Mauriceville) was intermittently active thus requiring treatment as an ungaged watershed from 1/1/1990 – 8/27/2002.

Table 2. Distribution of inflows from surrounding river basins and coastal watersheds to the six inflow points of the Sabine-Neches Estuary TxBLEND model.

Inflow Point	**Gaged Watersheds (USGS Gage #)**	**Ungaged Watersheds**	**Returns**	**Diversions**
Sabine River	#08030500 Sabine River near Ruliff #08031000 Cow Bayou near Mauriceville	05010, 05110*	05010	05010
Neches River	#08041000 Neches River at Evade #08041700 Pine Island Bayou near Sour Lake #08041500 Village Creek near Kountze	06010	06010	06010
Black Bayou	*None*	05012	*None*	*None*
Johnson Bayou	*None*	05008	*None*	*None*
Taylor Bayou	*None*	07010, 07030, 07040	07010, 07030, 07040	07010, 07030, 07040
Keith Lake	*None*	07020	*None*	*None*

**Watershed #051100 was ungaged during 1/1/1990 to 8/27/2002. From 8/28/2002 onwards, it was a gaged watershed represented by #08031000*

Tides

Tidal elevations at Sabine Pass were obtained from three sources:

1. Texas Coastal Ocean Observation Network (TCOON): http://lighthouse.tamucc.edu/TCOON/HomePage
2. National Oceanic and Atmospheric Administration's Center for Operational Oceanographic Products and Services (NOAA-COOPS): http://tidesandcurrents.noaa.gov/
3. University of South Carolina: http://tbone.biol.sc.edu/tide/sites_usgulf.html

No measured data was available for the period January 1 to August 31, 1990. Therefore, predicted tide data from the University of South Carolina was used. The earliest, measured data was available from TCOON beginning September 1, 1990. TCOON data was used until January 1, 1992 at which time recorded levels came primarily from NOAA-COOPS, because the data had fewer missing values than TCOON data. Predicted values were used to fill in data gaps in both the TCOON and NOAA-COOPS data by incrementally shifting the predictions according to the measured levels nearest the missing data. Figure 3 shows where the predicted levels were shifted to fill missing measurements in April 2005.

Peter Mantz (1997) correlated the Sabine Pass (SAP) tidal elevation to the Sabine Offshore (SAO) tidal elevation with the following equation: SAO = 0.06 + 1.13 * SAP. This equation was used to generate the offshore tide which was applied at the Gulf open boundary for the model period (1990 – 2013).

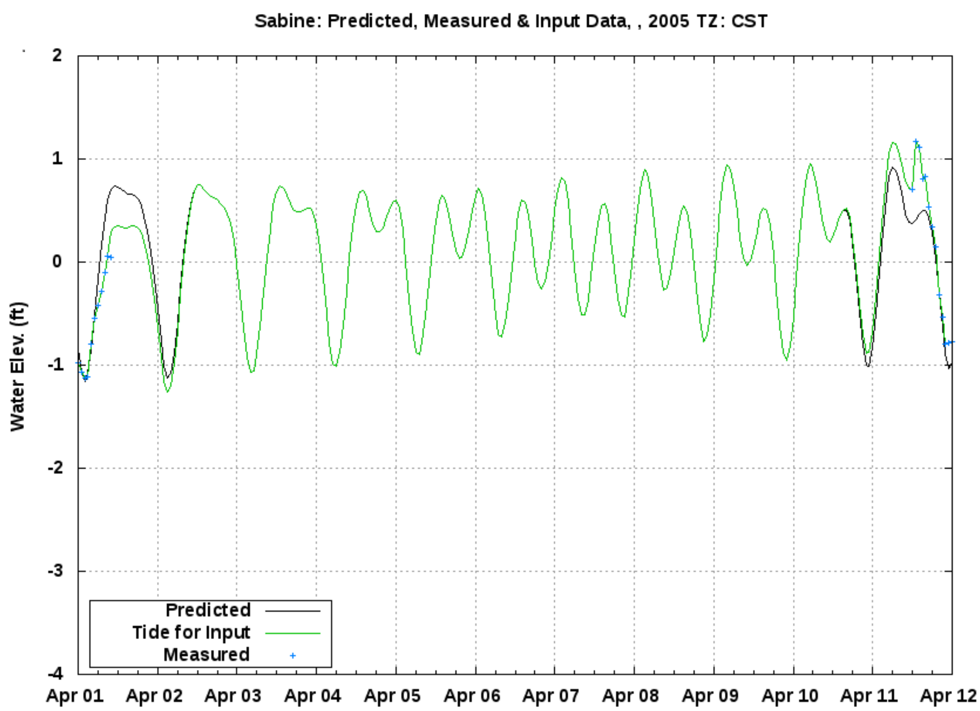

Figure 3. Predicted tides (*black line*) were shifted to match measured levels (*blue points*) nearest to the missing data to generate model input (*green line*) for tidal elevation.

Meteorology

Time-varying and spatially uniform meteorology data was used to drive the model, including wind, precipitation, and evaporation. A large portion of the meteorology data (wind speed, wind direction, air temperature, and precipitation) used to drive the model was obtained from the National Climatic Data Center (NCDC) Port Arthur station for the period 1990 – 2013. Evaporation data for Sabine Lake was calculated based on the Harbeck Equation (Brandes and Masch 1972) using the wind data and temperature data from the NCDC Port Arthur station.

Salinity

In addition to daily inflows, tidal elevations, and meteorological data, the model requires establishing salinity boundary conditions at the river inflow point and at the Gulf boundary. River inflow salinity boundary conditions were set to zero and remained at zero throughout the simulation period. Gulf boundary salinity conditions were based on observed salinity data that is collected by the Texas Parks & Wildlife Department (TPWD) Coastal Fisheries Program. These data include twice monthly offshore salinity measurements at five to eight sites. TWDB uses this salinity database to create bi-hourly salinity data through cubic spline interpolation. For this effort, TWDB extended and applied the gulf boundary salinity data through 12/31/2013.

Salinity data also is used to aid in model calibration and/or validation. For this, TWDB relies on salinity data collected through the TWDB Datasonde Program (in partnership with the Texas Parks and Wildlife Department). Data has been collected at a variety of sites from 1990 through the present day (Table 3; Figure 4). Mid-Sabine Lake and Mesquite Point are the earliest sites with data collection beginning in May 1990. Upper Sabine Lake replaced Mid-Sabine Lake in 1996. Recently, SAB1, located at the intersection of Neches River and Sabine-Neches Cannel at the north-west corner on the lake, replaced Upper Sabine Lake, and SAB2, located a little south of Mesquite Point, replaced the Mesquite Point station.

Table 3. TWDB Datasonde sites and data availability.

Site	Period of Record
SAB1	3/11/2008 - 12/18/2013
Upper Sabine Lake	5/29/1996 - 6/29/2005
Mid-Sabine Lake	5/16/1990 - 8/4/1995
Mesquite Point	5/16/1990 - 11/19/2008
SAB2	2/19/2009 - 12/18/2013

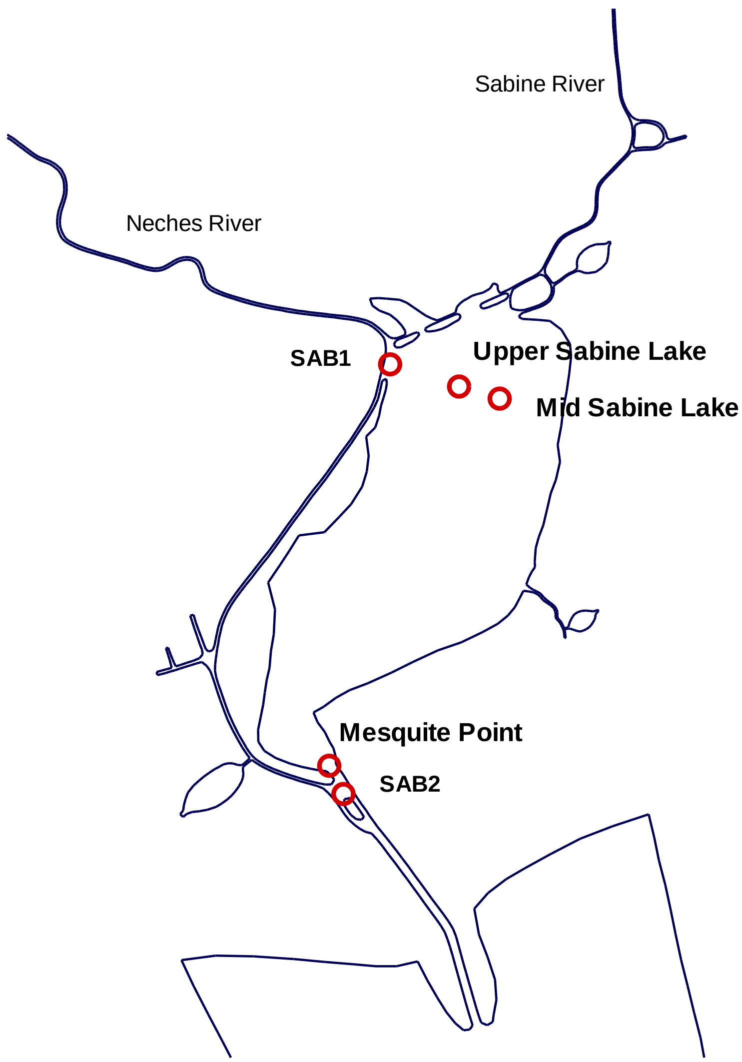

Figure 4. Five long-term monitoring stations that provided time-series salinity data for use in model calibration and validation.

Model Calibration

The TxBLEND model was calibrated for the period 1990 – 1997 and validated for the period 1998 – 2005 for hydrodynamic performance by using water velocity and surface elevation data from intensive field studies and for salinity transport performance by using long-term time-series salinity data (Schoenbaechler *et al*. 2013). Previous model calibration efforts focused on improving model performance by adjusting parameters such as Manning's *n* (Figure 5) and dispersion coefficients. The present extension of the Sabine Lake TxBLEND model to simulate the period of record through 2013 did not include an extensive calibration or validation effort. However, the dispersion coefficients at the entrance channel and in the Gulf (see Figure 6) were modified from the calibrated values previously reported (Schoenbaechler *et al*. 2013). The intent was to improve simulated salinity values at Mesquite Point. The dispersion coefficients were changed as follows and were applied to the entire period of record. The Entrance Channel was changed from 8,000 ft^2/sec to 10,000 ft^2/sec, and the Gulf was changed from 10,000 ft^2/sec to 11,000 ft^2/sec. Salinity simulation results are presented below for all sites include Mesquite Point, but it is worth a note here that, because model performance was generally acceptable with the new dispersion coefficients, an overall model re-calibration was not necessary.

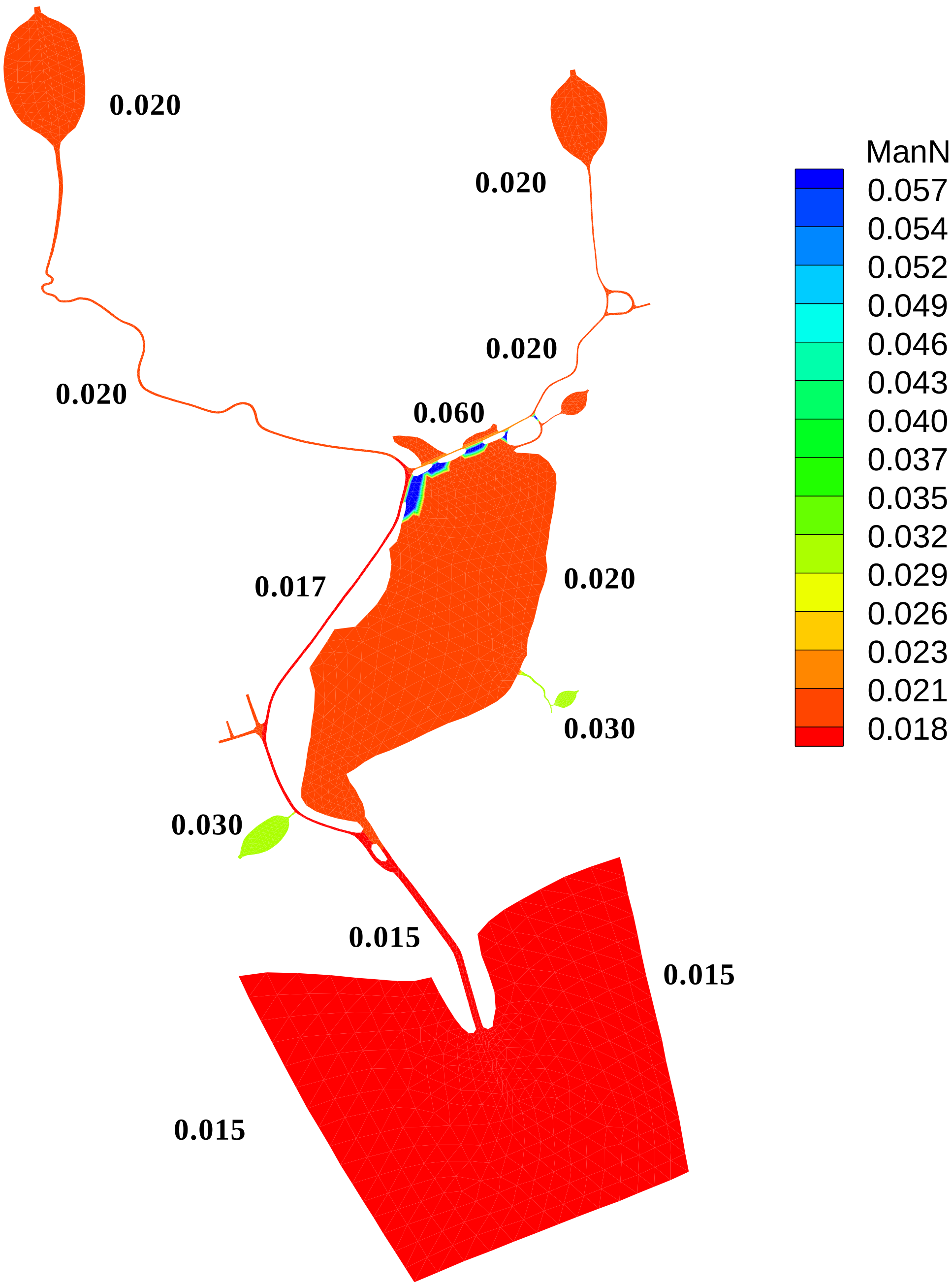

Figure 5. Values of Manning's *n* (bottom roughness coefficient) used in the previously calibrated Sabine Lake TxBLEND model (Schoenbaechler *et al*. 2013) and reapplied in this simulation effort.

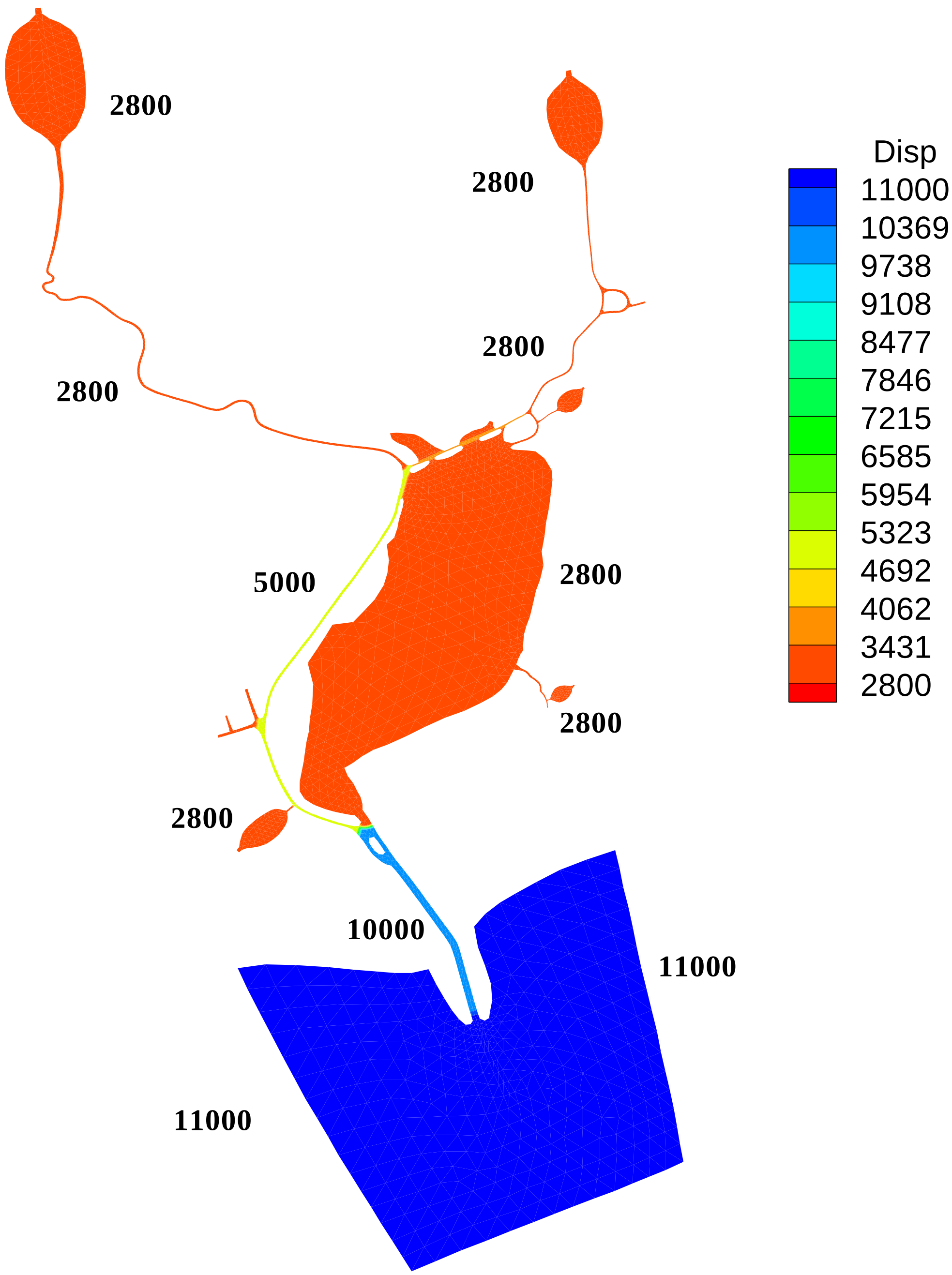

Figure 6. Values of the dispersion coefficient (ft^2/sec) used in the Sabine Lake TxBLEND model. All values, except the entrance channel and the Gulf region, were the same as in the previously calibrated Sabine model (Schoenbaechler *et al*. 2013). Here, the Entrance Channel was changed from 8,000 ft^2/sec to 10,000 ft^2/sec, and the Gulf was changed from 10,000 ft^2/sec to 11,000 ft^2/sec.

Salinity Simulation Results

Salinity simulation results were generated for the entire period of interest, 1990 – 2013, using the updated model inputs for inflow, tides, and meteorology as well as using the modified dispersion coefficients. For analysis of model performance, the simulation period was divided into two sub-periods. The first consisted of 1990 – 2005, the same period as used for model calibration and validation as reported in Schoenbaechler *et al*. 2013. The second was of the new, extended period, 2006 – 2013. For each, simulated and observed salinity was presented in time-series plots and in scatter plots along with the corresponding statistics.

Simulated Salinity 1990 – 2005

TxBLEND salinity simulations for 1990 – 2005 were evaluated for three locations in which measured salinity data was available. These include Upper Sabine Lake (data available for 1996 – 2005), Mid-Sabine Lake (data available for 1990 – 1995), and Mesquite Point (data available for the full simulation period; refer to Table 3 and Figure 4). Table 4 summarizes observed and simulated mean daily salinity at these sites. The difference in mean daily salinity ranged from 0.0 ppt to 1.9 ppt. Good model performance was indicated by reasonably strong r^2 values ranging from 0.66 to 0.73, and high NSEC values ranging from 0.60 to 0.73. These results suggest that TxBLEND more accurately predicted salinity in Upper Sabine Lake (r^2 = 0.73, NSEC = 0.73) than at Mid-Sabine Lake (r^2 = 0.66, NSEC = 0.63) or Mesquite Point (r^2 = 0.67, NSEC = 0.60). Viewing the visual display of the scatter plots in Figure 7 and the value of percent bias, Upper Sabine Lake (3.3 percent bias) and Mid-Sabine Lake (3.9 percent bias) have a low bias and a reasonably even distribution of points as compared to Mesquite Point (16.0 percent bias), which is slightly biased towards under-prediction.

Table 4. Summary statistics for observed and simulated mean daily salinity for the period from 1990 - 2005 for three sites in the Sabine-Neches Estuary.

Site	n	r^2	RMS (ppt)	Observed Mean Salinity (ppt)	Simulated Mean Salinity (ppt)	Difference	NSEC	Percent Bias
Upper Sabine Lake	2072	0.73	3.0	6.1	6.1	0.0	0.73	3.3
Mid Sabine Lake	1179	0.66	2.2	4.9	4.7	0.2	0.63	3.9
Mesquite Point	3741	0.67	4.7	12.2	10.3	1.9	0.60	16.0

RMS is Root Mean Square error.

The Nash-Sutcliffe Efficiency Criterion (NSEC; E) describes model performance, where E = 1.0 represents a match between model output and observed data, and E < 0 suggests the model is a poor predictor.

Percent Bias (Pbias; %) measures the average tendency of simulated values to be larger or smaller than observed values; ± <10% is Excellent, ± 10 – 20% is Very Good, ± 20 – 40% is Good/Satisfactory, and ± >40% is Poor/Unsatisfactory (Marechal 2004, Moriasi *et al*. 2007).

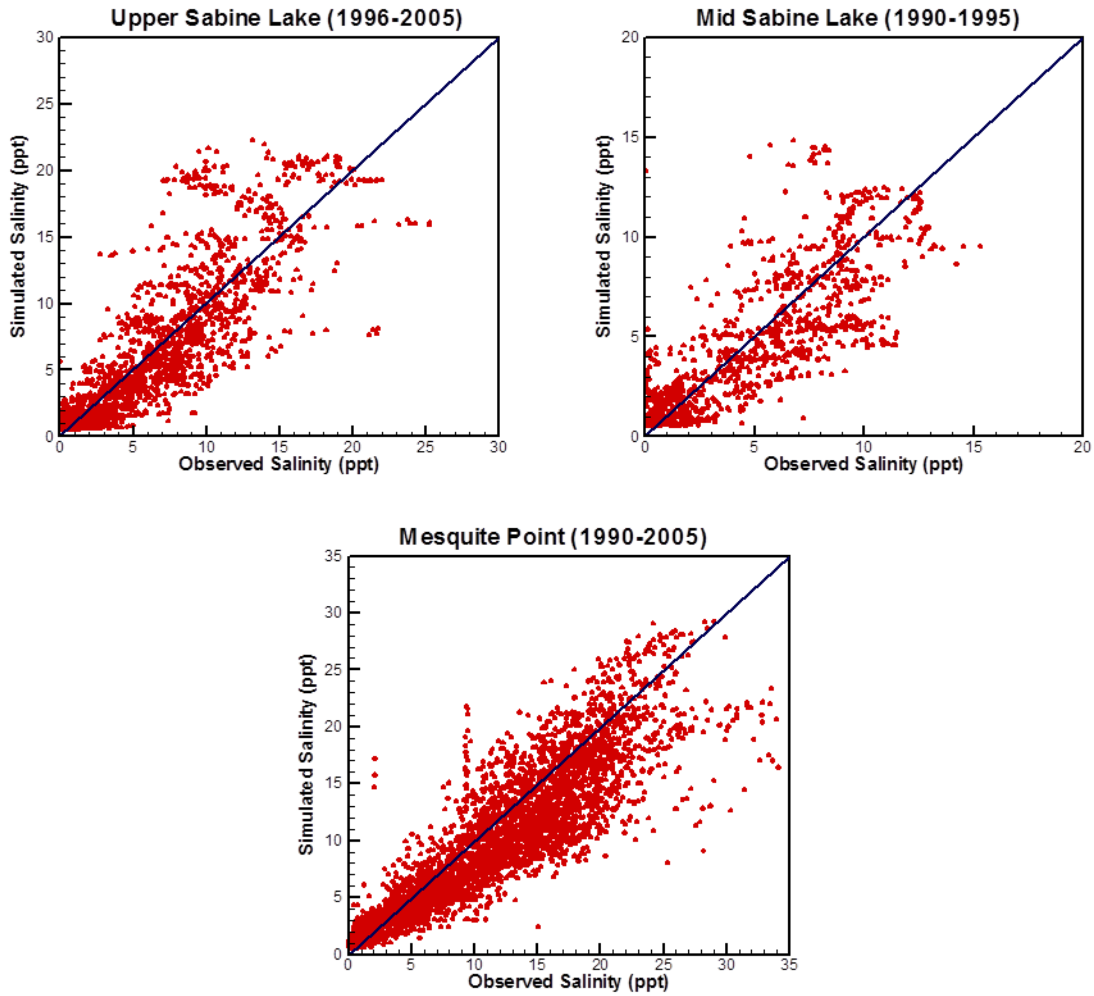

Figure 7. Scatter plots comparing simulated to observed mean daily salinity at Upper Sabine Lake, Mid-Sabine Lake, and Mesquite Point for 1990 – 2005.

Figures 8 through 10 display time-series plots comparing simulated salinity against observed salinity at each of the three locations. Model simulations were conducted for the period 1990 – 2005, but measured data availability does not always cover the entire simulation period. Time-series plots show only the simulation period that is consistent with data availability. The TxBLEND model simulated long-term salinity trends fairly well, but still does not simulate the short-term, high-frequency variation in salinity that is observed throughout the estuary.

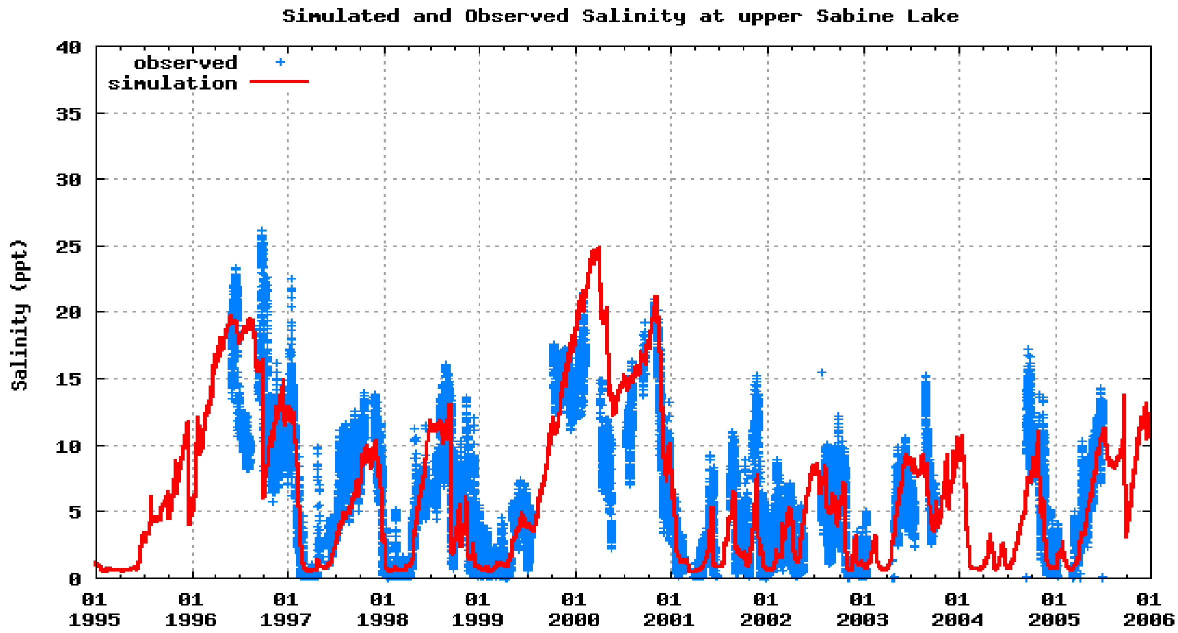

Figure 8. Simulated (*red*) versus observed (*blue*) salinity at Upper Sabine Lake for 1995 – 2005 in the Sabine-Neches Estuary.

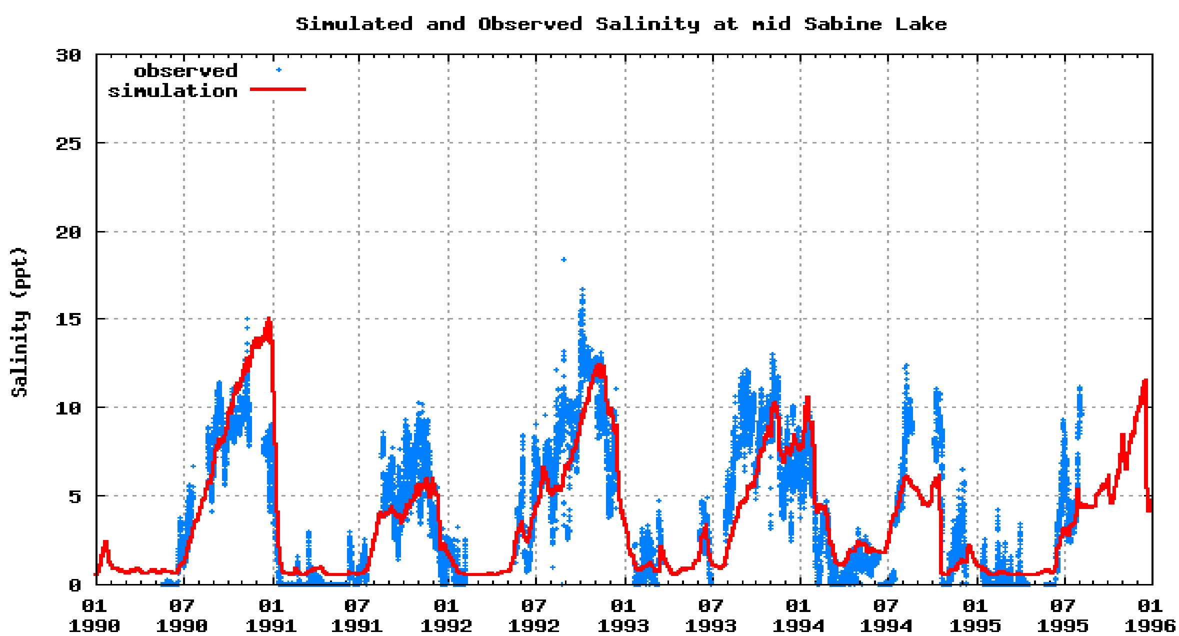

Figure 9. Simulated (*red*) versus observed (*blue*) salinity at Mid-Sabine Lake in the Sabine-Neches Estuary for 1990 – 1995.

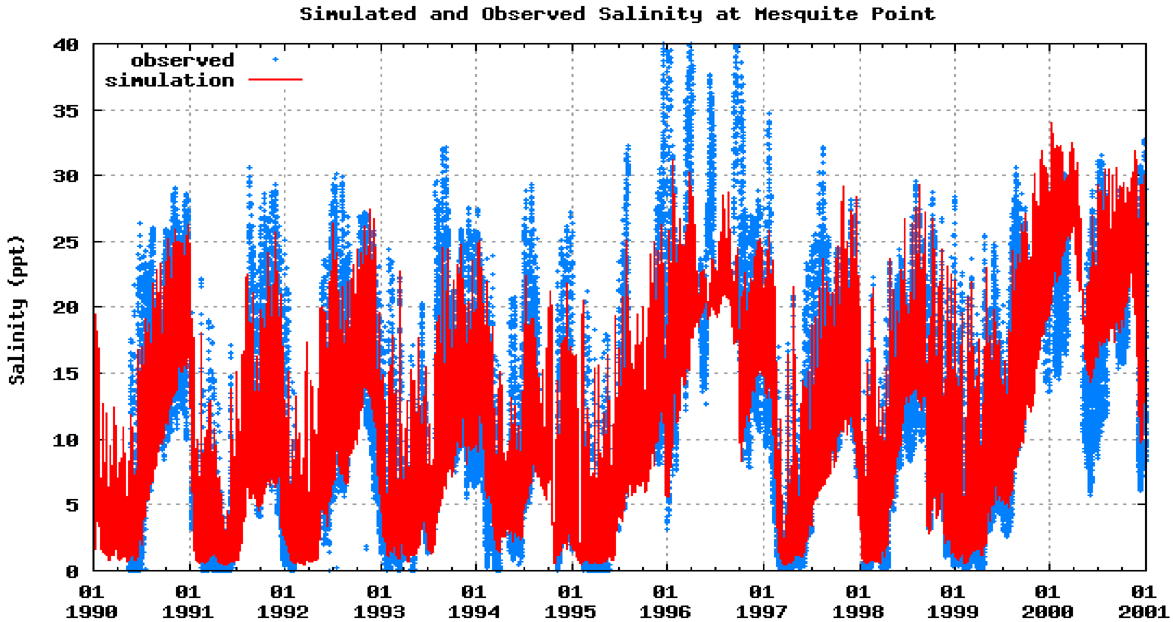

Figure 10. Simulated (*red*) versus observed (*blue*) salinity at Mesquite Point for 1990 – 2000 in the Sabine-Neches Estuary.

Simulated Salinity 2006 – 2013

TxBLEND salinity simulations for 2006 – 2013 were evaluated for three locations in which measured salinity data was available. These include SAB1 (data available for 2008 – 2013), Mesquite Point (data available for 2006 – 2008), and SAB2 (data available for 2009 – 2013; refer to Table 3 and Figure 4). Table 5 summarizes observed and simulated mean daily salinity at these sites. The difference in mean daily salinity ranged from 0.4 ppt to 1.1 ppt. Good model performance was indicated by reasonably strong r^2 values ranging from 0.57 to 0.75, and high NSEC values ranging from 0.53 to 0.74. Results suggest that TxBLEND more accurately predicted salinity at SAB1 (r^2 = 0.75, NSEC = 0.66) and SAB2 (r^2 = 0.70, NSEC = 0.74) than at Mesquite Point (r^2 = 0.57, NSEC = 0.53). Viewing the scatter plots (Figure 11) and comparing percent bias, all three sites had an excellent measure of bias in that all were within ±10 percent (Table 5). Only SAB1 (-9.4 percent bias) and SAB2 (-6.5 percent bias) showed a slight bias toward over-prediction.

Figures 12 – 14 show time-series plots comparing simulated salinity to observed salinity at each of the three locations. Again, model simulations were conducted for the period 2006 – 2013, but time-series plots show simulated data only for the periods consistent with available measured data. These salinity simulations are comparable to the simulations for the period 1990 – 2005, though Mesquite Point appears to better capture salinity variation in the recent period 2006 – 2013. Statistics in Tables 4 and 5 support this observation.

Table 5. Summary statistics for observed and simulated mean daily salinity for the period from 2006 – 2013 for three sites in the Sabine-Neches Estuary.

Site	**n**	r^2	**RMS (ppt)**	**Observed Mean Salinity (ppt)**	**Simulated Mean Salinity (ppt)**	**Difference**	**NSEC**	**Percent Bias**
SAB1	1795	0.75	3.8	11.0	12.1	1.1	0.66	-9.4
Mesquite Point	542	0.57	4.1	12.3	11.9	0.4	0.53	3.5
SAB2	1507	0.70	3.6	17.5	18.6	1.1	0.74	-6.5

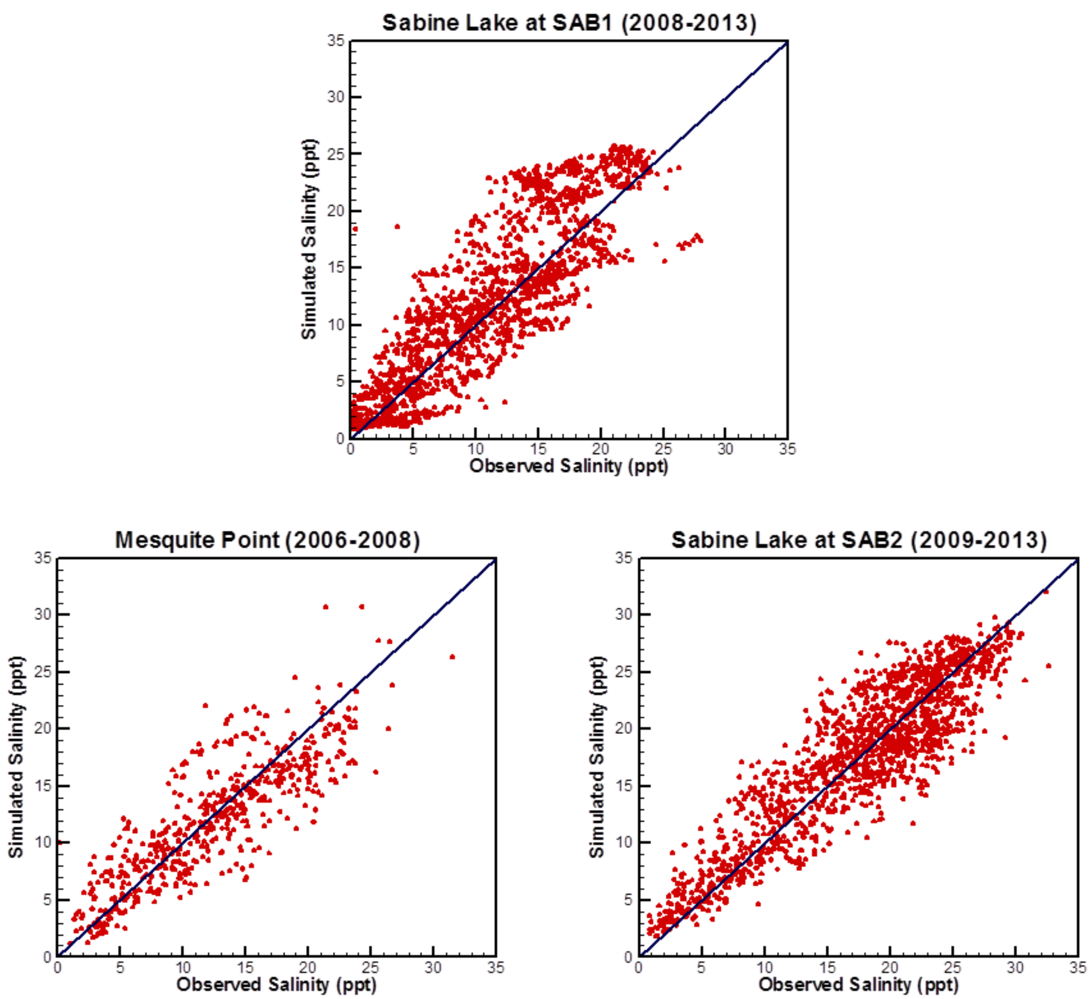

Figure 11. Scatter plots comparing simulated to observed salinity at SAB1, Mesquite Point, and SAB2 for 2006 – 2013.

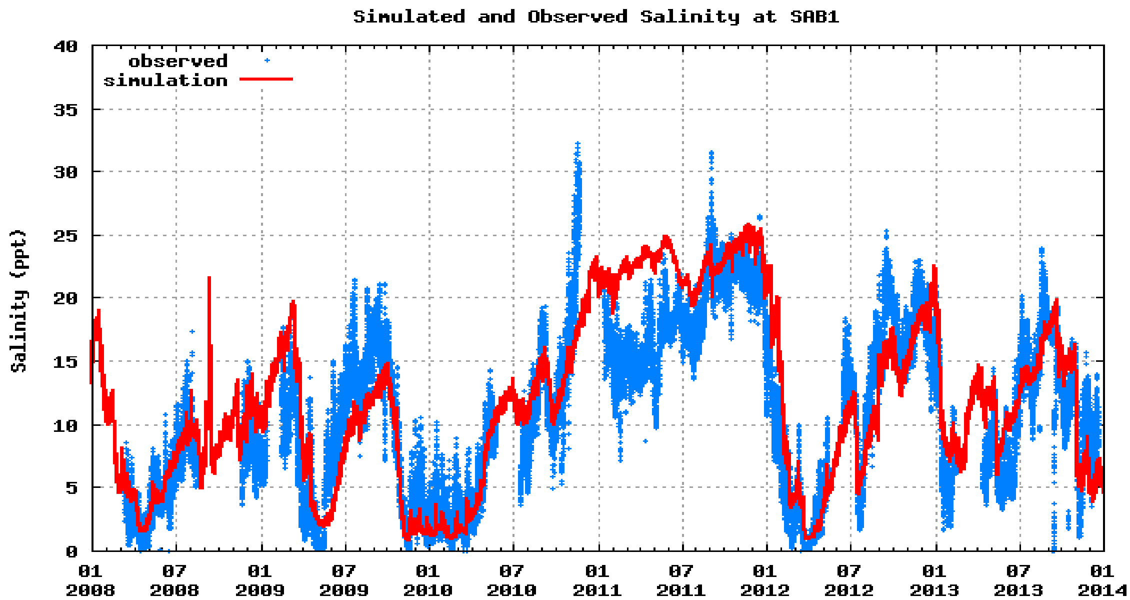

Figure 12. Simulated (*red*) versus observed (*blue*) salinity at SAB1 for 2008 - 2013 in the Sabine-Neches Estuary.

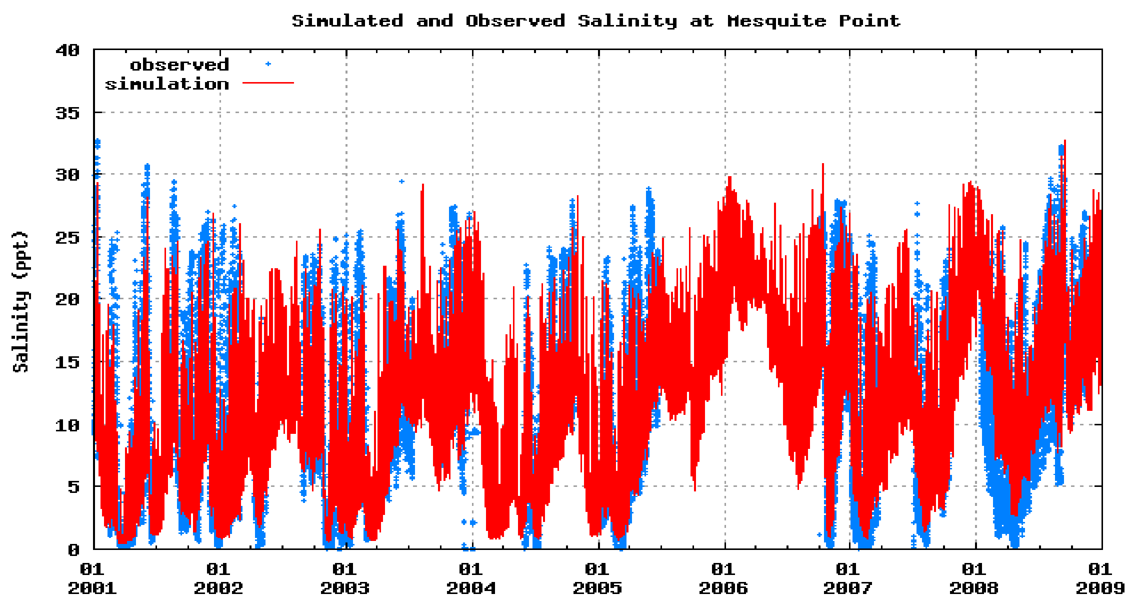

Figure 13. Simulated (*red*) versus observed (*blue*) salinity at Mesquite Point for 2001- 2008 in the Sabine-Neches Estuary.

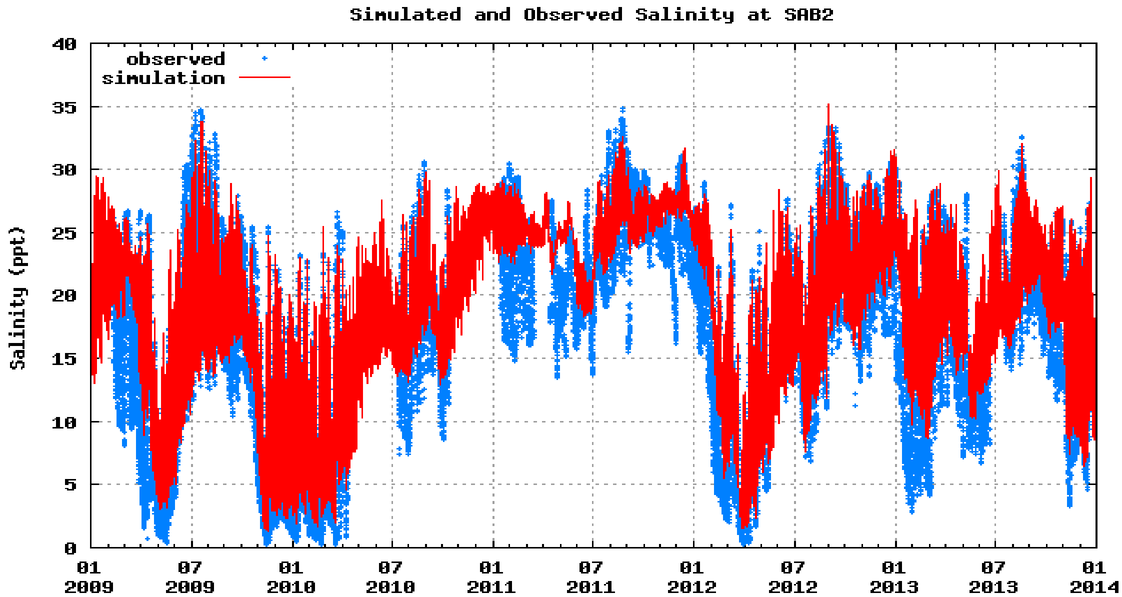

Figure 14. Simulated (*red*) versus observed (*blue*) salinity at SAB2 for 2009 - 2013 in the Sabine-Neches Estuary.

Discussion

The previously calibrated and validated TxBLEND Model for the Sabine-Neches Estuary covered the period from 1990 – 2005. Now with updated input files, the new simulation period extends to include 1990 – 2013. The model was not re-calibrated and all parameters remained the same as previously reported (refer to Schoenbaechler *et al*. 2013) except for a slight modification to the dispersion coefficients applied at the Sabine Lake Entrance Channel and the off-shore Gulf of Mexico region. These parameter modifications were made to improve salinity simulations at Mesquite Point and were applied to the entire 24-year simulation period. It was determined that this change did not require a full recalibration of the model.

To evaluate salinity performance of the extended model, the full simulation period was divided into two periods: 1990 – 2005 (16 years) and 2006 – 2013 (8 years). Scatter plots and time-series plots allowed for a visual comparison of measured data to simulated values, and descriptive statistics quantified model output relative to measured data. Model performance was generally acceptable with low bias towards under- or over-prediction. A visual comparison shows that the model simulates long-term trends in the observed salinity data but is unable to capture the high-frequency variation over short time periods.

Three of the five monitoring locations that were used to compare model results from this effort also were used in the initial calibration/validation effort reported in Schoenbaechler *et al*. (2013). These were Upper Sabine Lake, Mid-Sabine Lake, and Mesquite Point. Tables 6 – 8 allow for a comparison of the previous calibration/validation results to the results generated for the original simulation period (through 2005) – but with different Entrance Channel and off-shore dispersion coefficients. The tables also allow for a comparison of the original period to the extended simulation period. For Upper Sabine Lake, data availability only allows a comparison of the effect of applying old versus new dispersion coefficients during the original simulation period (1990 – 2005; Table 6). At this station, salinity performance is consistent with the previous modeling effort. For Mid-Sabine Lake, data availability allows for comparison of the calibration period (1990 – 1997) to the extended simulation period of 1990 – 2005 (Table 7). Model performance at this site was not as good as reported during the original calibration period though overall performance was acceptable. Mesquite Point is the only site for which all four periods of time (*i.e.*, calibration, validation, original, and extended) can be compared (Table 8). Based on salinity simulations at this site, the model performed better with the original calibration values in use and tended towards under-predicting salinity conditions during the period 1990 – 2005. The extended model period of 2006 – 2013 likewise did not compare well to observed data though the model showed excellent performance with respect to generating unbiased results.

Table 6. Summary statistics for observed and simulated salinity at Upper Sabine Lake for four time periods; 1990 – 1997 model calibration, 1998 – 2005 model validation (Schoenbaechler *et al*. 2013) and 1990 – 2005 and 2006 – 2013 model extension to recent period.

Simulation Period	**n**	**r^2**	**RMS (ppt)**	**Observed Mean Salinity (ppt)**	**Simulated Mean Salinity (ppt)**	**Difference**	**NSEC**	**Percent Bias**
1990 - 1997	457	0.62	4	8.7	8.6	0.1	0.52	nd
1998 - 2005	1622	0.73	2.6	5.4	4.7	0.7	0.69	nd
1990 - 2005	2072	0.73	3.0	6.1	6.1	0.0	0.73	3.3
2006 – 2013	nd	nd	nd	nd	nd	nd	nd	nd

Table 7. Summary statistics for observed and simulated salinity at Mid-Sabine Lake for four time periods; 1990 – 1997 model calibration, 1998 – 2005 model validation (Schoenbaechler *et al*. 2013) and 1990 – 2005 and 2006 – 2013 model extension to recent period.

Simulation Period	**n**	**r^2**	**RMS (ppt)**	**Observed Mean Salinity (ppt)**	**Simulated Mean Salinity (ppt)**	**Difference**	**NSEC**	**Percent Bias**
1990 - 1997	1433	0.71	2.1	4.0	4.1	0.1	0.69	nd
1998 - 2005	nd	nd	nd	nd	nd	nd	nd	nd
1990 - 2005	1179	0.66	2.2	4.9	4.7	0.2	0.63	3.9
2006 – 2013	nd	nd	nd	nd	nd	nd	nd	nd

Table 8. Summary statistics for observed and simulated salinity at Mesquite Point for four time periods; 1990 – 1997 model calibration, 1998 – 2005 model validation (Schoenbaechler *et al*. 2013) and 1990 – 2005 and 2006 – 2013 model extension to recent period.

Simulation Period	n	r^2	RMS (ppt)	Observed Mean Salinity (ppt)	Simulated Mean Salinity (ppt)	Difference	NSEC	Percent Bias
1990 - 1997	1959	0.79	4	12.2	10.4	1.8	0.73	nd
1998 - 2005	1565	0.82	3.6	11.7	9.6	1.1	0.71	nd
1990 - 2005	3741	0.67	4.7	12.2	10.3	1.9	0.6	16
2006 – 2013	542	0.57	4.1	12.3	11.9	0.4	0.53	3.5

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Appendix - Daily Salinity at 44 Locations within the Sabine-Neches Estuary

The National Wildlife Federation requested simulated mean daily salinity at 44 model nodes (sites; Table A1). Table A2 shows a representation of mean daily salinity for the period January 1 – 8, 1990 for 44 selected nodes (sites) as recorded in the file *avesalD.w*. Table A3 shows an example of program output for seven nodes (sites), using the fortan program *rearrange.f* to display mean daily salinity for each site.

Table A1. Forty-four TxBLEND model nodes and their description selected by the National Wildlife Federation for reporting simulated mean daily salinity.

Site Number	Model Node #	Site Name and Description
1	962	NWF-1
2	1094	NWF-2
3	1752	NWF-3
4	916	NWF-4
5	650	NWF-5
6	602	NWF-6
7	643	NWF-7
8	630	NWF-8
9	774	NWF-9
10	756	NWF-10
11	860	NWF-11
12	689	NWF-12
13	585	NWF-13
14	565	NWF-14
15	1033	NWF-15
16	1208	NWF-16
17	1986	NWF-17
18	1013	NWF-18
19	772	NWF-19
20	8	SAO Sabine Offshore
21	404	SPS Sabine Pilot Station
22	425	SAP Sabine Pass(T9)
23	492	MSP Mesquite Point(T8)
24	499	PAC Port Arthur Canal
25	594	KTH Keith Lake Fish Pass
26	979	TLR Taylor Bayou/GIW
27	1393	1321 NRH Neches River rn 87
28	1087	1052 PAN Saine-Neches Canal
29	1322	1290 STI Stewts Island/GIW
30	1420	1495 RBO Rainbow Bridge(T3)

Site Number	Model Node #	Site Name and Description
31	2196	BMT Beaumont(T1)
32	1933	ORG Orange(T2)
33	1902	IWC GIW to Calcasieu
34	1620	1458 SBR Sabine River(T4)
35	1586	1349 BLB Black Bayou(T5)
36	993	1026 1092 USL Upper Sabine Lake : Platform A
37	844	817 JOB Johnson Bayou
38	1390	POA Port Arthur
39	1137	TPWD-1: upper Lake
40	781	TPWD-2: mid Lake
41	537	TPWD-3: lower Lake
42	970	Mid Sabine (Datasonde)
43	476	SAB2: lower Sabine (Datasonde)
44	1082	SAB1: (Datasonde) new upper sabine lake site

Table A2. An example of model output for mean daily salinity for the period January 1 – 8, 1990 for 44 selected nodes. The filename containing this information for the full simulation period is *avesalD.w*.

```
Sabine Lake  1990-2013 24-yr simulation
Average Daily Salinity, year: 1990 month:  1 day:  1
0.53  0.53  0.50  0.53  0.58  0.77  0.72  0.62  0.53  0.54  0.53  0.56  1.32  1.43  0.53  0.53  0.50
4.00  4.10 30.37 16.96 13.49  5.65  8.22  5.86  2.96  0.52  0.56  0.53  0.52  0.50  0.50  0.51  0.57
0.65  0.53  0.57  1.42  0.53  0.54   2.70  0.53  7.90  0.53
Average Daily Salinity, year: 1990 month:  1 day:  2
0.58  0.55  0.51  0.55  0.66  0.89  0.86  0.74  0.58  0.58  0.56  0.63  1.37  1.44  0.54  0.55  0.50
4.78  4.84 30.37  18.50 13.98  5.18  7.50  5.85  3.99  0.56  0.75  0.57  0.55  0.50  0.50  0.51  0.57
0.62  0.56  0.60  2.81  0.54  0.57  2.40  0.55  7.52  0.59
Average Daily Salinity, year: 1990 month:  1 day:  3
0.63  0.58  0.51  0.59  0.73  0.99  0.97  0.83  0.63  0.64  0.60  0.71  1.54  1.62  0.58  0.58  0.50
5.23  5.26 30.33  19.54 14.47  5.63  7.46  5.78  4.63  0.61  0.96  0.62  0.61  0.50  0.50  0.51  0.57
0.61  0.60  0.64  3.78  0.57  0.62  2.71  0.59  7.79  0.66
Average Daily Salinity, year: 1990 month:  1 day:  4
0.67  0.62  0.51  0.64  0.82  1.13  1.10  0.94  0.69  0.70  0.65  0.79  1.70  1.76  0.62  0.62  0.50
5.43  5.44 30.25 17.29 12.37  5.11  6.78  5.58  4.62  0.64  0.83  0.65  0.63  0.50  0.50  0.51  0.58
0.62  0.65  0.70  3.05  0.61  0.68  2.79  0.63  6.88  0.68
Average Daily Salinity, year: 1990 month:  1 day:  5
0.69  0.65  0.51  0.68  0.88  1.19  1.13  0.97  0.73  0.75  0.69  0.83  1.82  1.92  0.65  0.64  0.50
5.38  5.41 30.15 17.82 14.04  6.29  8.27  6.15  4.12  0.64  0.86  0.67  0.63  0.50  0.50  0.50  0.58
0.61  0.67  0.75  2.64  0.64  0.74  3.04  0.66  8.26  0.69
Average Daily Salinity, year: 1990 month:  1 day:  6
0.76  0.69  0.53  0.72  0.96  1.37  1.29  1.08  0.78  0.80  0.74  0.89  2.18  2.30  0.69  0.68  0.50
6.13  6.21 30.02 18.33 15.14  7.14 10.09  7.72  5.02  0.69  1.06  0.74  0.68  0.50  0.50  0.50  0.58
0.61  0.73  0.80  3.12  0.68  0.78  3.72  0.71  9.51  0.78
Average Daily Salinity, year: 1990 month:  1 day:  7
0.85  0.75  0.54  0.78  1.06  1.56  1.47  1.20  0.85  0.87  0.80  0.98  2.54  2.69  0.74  0.73  0.50
7.05  7.13 29.87 18.29 15.48  7.85 11.07  8.75  5.84  0.75  1.24  0.81  0.73  0.50  0.50  0.50  0.58
0.62  0.80  0.86  3.60  0.73  0.85  4.27  0.76 10.22  0.87
Average Daily Salinity, year: 1990 month:  1 day:  8
0.95  0.83  0.57  0.86  1.24  1.99  1.86  1.45  0.96  0.97  0.89  1.13  3.39  3.58  0.82  0.80  0.50
8.13  8.22 29.70 19.07 16.61  9.36 12.72 10.03  6.73  0.84  1.40  0.91  0.82  0.50  0.50  0.50  0.60
0.64  0.89  0.97  4.07  0.80  0.94  5.58  0.84 11.72  0.98
```

Table A3. A re-arrangement of mean daily salinity as reported in *avesalD.w* and provided by the fortran program *rearrange.f*. This table shows model output for the first seven representative sites from January 1 – February 6, 1990, but this information was computed for all 44 selected nodes (sites) for the full simulation period of 1990 – 2013.

Year	Month	Day	site-1	site-2	site-3	site-4	site-5	site-6	site-7
1990	1	1	0.53	0.53	0.5	0.53	0.58	0.77	0.72
1990	1	2	0.58	0.55	0.51	0.55	0.66	0.89	0.86
1990	1	3	0.63	0.58	0.51	0.59	0.73	0.99	0.97
1990	1	4	0.67	0.62	0.51	0.64	0.82	1.13	1.1
1990	1	5	0.69	0.65	0.51	0.68	0.88	1.19	1.13
1990	1	6	0.76	0.69	0.53	0.72	0.96	1.37	1.29
1990	1	7	0.85	0.75	0.54	0.78	1.06	1.56	1.47
1990	1	8	0.95	0.83	0.57	0.86	1.24	1.99	1.86
1990	1	9	1.05	0.91	0.58	0.97	1.53	2.5	2.4
1990	1	10	1.16	1.01	0.6	1.11	1.77	2.72	2.63
1990	1	11	1.3	1.13	0.65	1.25	1.97	2.95	2.85
1990	1	12	1.41	1.26	0.69	1.4	2.13	3.01	2.92
1990	1	13	1.6	1.4	0.77	1.53	2.16	2.84	2.74
1990	1	14	1.74	1.54	0.79	1.67	2.22	2.88	2.83
1990	1	15	1.84	1.68	0.76	1.8	2.29	2.86	2.85
1990	1	16	1.92	1.79	0.75	1.92	2.35	2.85	2.85
1990	1	17	2.02	1.9	0.77	2.02	2.45	3.01	2.98
1990	1	18	2.12	2.01	0.88	2.14	2.69	3.43	3.4
1990	1	19	2.23	2.1	0.96	2.27	2.9	3.73	3.71
1990	1	20	2.33	2.2	0.89	2.39	3.08	3.83	3.84
1990	1	21	2.39	2.24	0.77	2.46	3.04	3.55	3.49
1990	1	22	2.44	2.27	0.7	2.48	2.99	3.5	3.43
1990	1	23	2.4	2.23	0.63	2.49	3	3.55	3.5
1990	1	24	2.3	2.11	0.6	2.45	2.98	3.46	3.43
1990	1	25	2.08	1.82	0.57	2.26	2.81	3.12	3.09
1990	1	26	1.83	1.5	0.59	1.99	2.56	2.75	2.74
1990	1	27	1.65	1.34	0.51	1.8	2.33	2.51	2.53
1990	1	28	1.47	1.23	0.5	1.65	2.11	2.26	2.27
1990	1	29	1.3	1.13	0.5	1.46	1.88	1.99	1.99
1990	1	30	1.19	1.05	0.5	1.32	1.67	1.76	1.76
1990	1	31	1.13	1.01	0.5	1.24	1.52	1.61	1.61
1990	2	1	1.1	0.99	0.5	1.19	1.42	1.52	1.52
1990	2	2	1.08	0.98	0.5	1.15	1.36	1.48	1.48
1990	2	3	1.05	0.97	0.5	1.12	1.33	1.45	1.46
1990	2	4	0.99	0.93	0.51	1.07	1.26	1.36	1.34
1990	2	5	0.96	0.9	0.52	1.02	1.21	1.38	1.34
1990	2	6	0.94	0.88	0.52	0.99	1.2	1.45	1.42