Appendix U
Model Configuration, Calibration and Validation

Basin: Trinity River (Trin)

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Watershed Background

The Trinity River basin was selected as one of the 15 non-pilot application watersheds for the 20 Watershed study. Watershed modeling for the non-pilot areas is accomplished using the SWAT model only, and model calibration and validation results are presented in abbreviated form.

Water Body Characteristics

The Trinity River basin is located in east central Texas. It extends on a southeast diagonal, from immediately south of the Oklahoma-Texas border to the Trinity Bay at the Gulf of Mexico. The model study area encompasses almost 18,000 mi^2 in 12 HUC8s in HUC 1203 (Figure 1). The watershed is dissected by alternate bands of rolling, treeless prairies, smooth to slightly rolling prairies, rolling timbered hills, and a relatively flat coastal plain. The watershed slopes gradually from about 1,200 ft above sea level in the northwest, to about 600 ft mid-basin, and on to sea level in the southeastern section of the area, at Trinity Bay (Land et al., 1998; Ulery et al., 1993).

Past and current human activities, including construction of reservoirs, urbanization, farming, ranching, and oil and gas production, have greatly altered the natural environment in the Trinity River basin. Approximately 37 percent of the watershed is cropland or pasture. Major crops include corn, cotton, peanuts, sorghum, soybeans, rice, and wheat. Wheat and cotton are dry cropland crops, while rice is an irrigated crop. Forest and wetlands represent about 33 percent of the watershed and developed land makes up about 19 percent of the watershed. The population in the watershed is mainly clustered in the Dallas-Fort Worth metropolitan area, with a few secondary population clusters (Denton, McKinney, Corsicana, and Waxahachie).

The climate of the basin is described as modified-marine, subtropical-humid, having warm summers and a predominant onshore flow of tropical maritime air from the Gulf of Mexico. Precipitation varies considerably across the watershed. Average annual precipitation ranges from less than 27 inches in the northwest part of the watershed to greater than 52 inches in the southeast. On average, the watershed experiences a winter surplus and a summer deficiency of precipitation. Average annual temperature is fairly uniform throughout the basin, ranging from about 69° F in the southeastern area of the watershed to about 65° F in the northwest.

There are 22 large reservoirs in the Trinity River basin and hundreds of smaller reservoirs, mostly flood control structures. Reservoirs have been built to retain runoff on all major tributaries and the mainstem of the Trinity River. Diversions move water within the basin and to and from adjacent river basins. The largest interbasin diversion is out of the basin, from the Trinity River below Livingston Reservoir to the Houston metropolitan area. There are numerous other inter- and intrabasin diversions.

The largest consumptive use in the watershed is domestic with the majority being used in Dallas and Tarrant counties because of their large populations. Surface water, almost entirely from reservoirs, supplies more than 90 percent of the water used in the basin. Groundwater is used for municipal and domestic supply in some of the smaller towns and in rural areas. Transfers of water, from the adjoining basins and from reservoirs below Dallas and Fort Worth, are required to meet the needs of the Dallas-Fort Worth area. Relatively little water is used for irrigating crops.

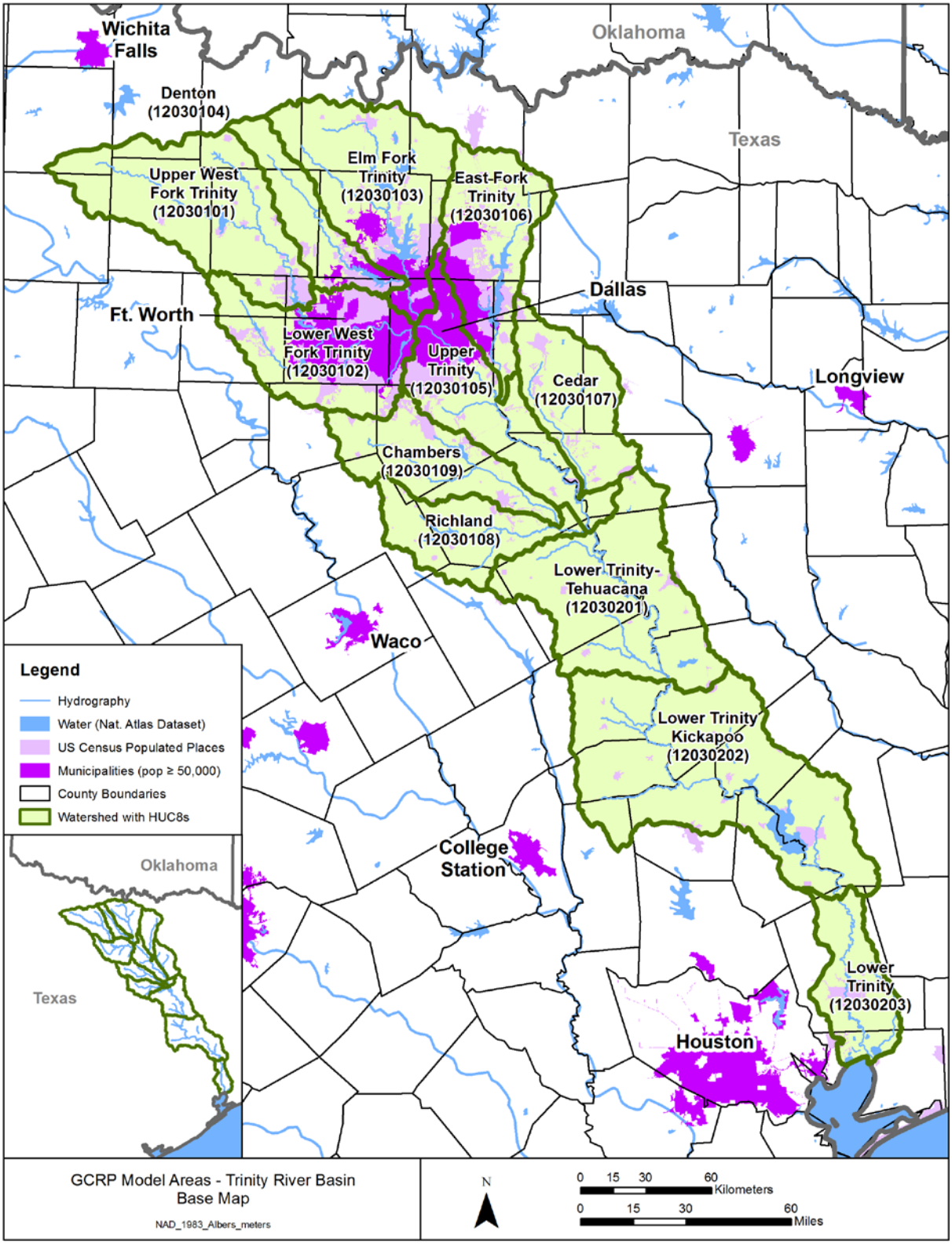

Figure 1. Location of the Trinity River basin.

Soil Characteristics

Soils in the watershed, as described in STATSGO soil surveys, fall primarily into hydrologic soil groups (HSGs) C (moderately low infiltration capacity) and D (low infiltration capacity). Soils range from course textured loamy sands to fine textured montmorillonitic clays. Soil depths vary from very shallow to deep. SWAT uses information drawn directly from the soils data layer to populate the model.

Land Use Representation

Land use/cover in the watershed is based on the 2001 National Land Cover Database (NLCD) coverage and is predominantly rangeland (Figure 2). NLCD land cover classes were aggregated according to the scheme shown in Table 1 for representation in the 20 Waterhsed model. SWAT uses the built-in hydrologic response unit (HRU) overlay mechanism in the ArcSWAT interface. SWAT HRUs are formed from an intersection of land use and SSURGO major soils. The distribution of land use in the watershed is summarized in Table 2.

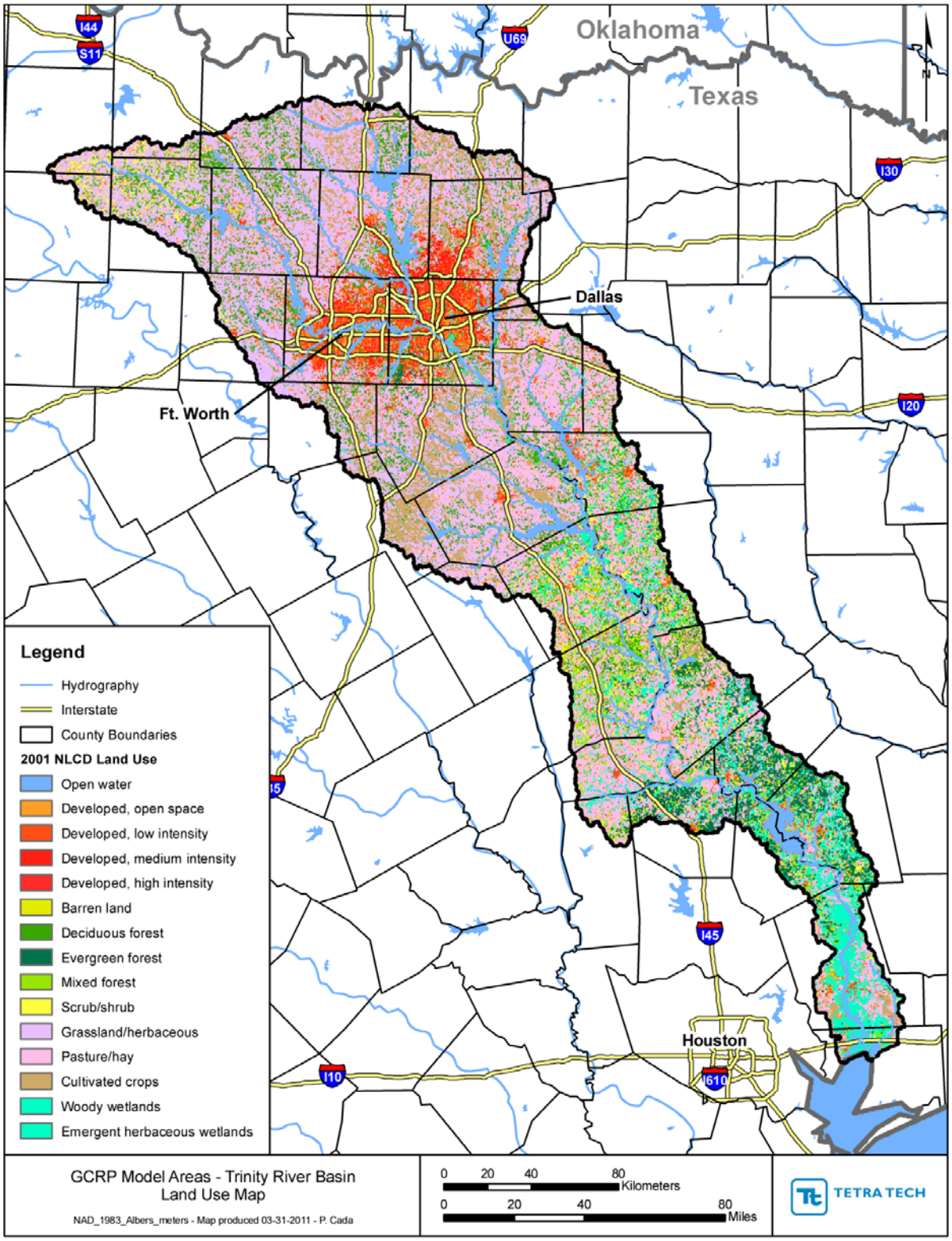

Figure 2. Land use in the Trinity River basin.

Table 1. Aggregation of NLCD land cover classes

NLCD Class	Comments	SWAT class
11 Water	Water surface area usually accounted for as reach area	WATR
12 Perennial ice/snow		WATR
21 Developed open space		URLD
22 Dev. Low Intensity		URMD
23 Dev. Med. Intensity		URHD
24 Dev. High Intensity		UIDU
31 Barren Land		SWRN
41 Forest	Deciduous	FRSD
42 Forest	Evergreen	FRSE
43 Forest	Mixed	FRST
51-52 Shrubland		RNGB
71-74 Herbaceous Upland		RNGE
81 Pasture/Hay		HAY
82 Cultivated		AGRR
91-97 Wetland	Emergent & woody wetlands	WETF, WETL, WETN
98-99 Wetland	Aquatic bed wetlands (not emergent)	WATR

Table 2. Land use distribution for the Trinity River basin (2001 NLCD) (mi^2)

HUC 8 watershed	Open water	Developed[a]				Barren land	Forest	Shrubland	Pasture/Hay	Cultivated	Wetland	Total
		Open space	Low density	Medium density	High density							
12030101	45.0	116.5	31.3	7.1	2.0	8.0	321.0	1,283.3	88.1	52.9	1.4	1,956.7
12030102	40.4	159.9	232.1	107.0	62.0	2.8	183.9	557.2	108.4	49.4	10.9	1,514.1
12030103	103.6	116.8	98.2	71.1	35.7	1.9	188.2	746.1	256.0	228.9	11.5	1,858.1
12030104	15.0	37.6	25.9	13.7	5.2	0.9	100.5	389.5	83.1	45.8	2.3	719.4
12030105	25.2	112.4	121.2	67.4	49.0	2.2	182.1	300.6	299.2	152.2	58.3	1,369.7
12030106	74.2	94.3	110.6	82.4	25.0	0.7	152.3	414.6	160.5	167.7	21.1	1,303.2
12030107	61.6	40.0	46.9	5.8	2.6	0.7	136.8	185.1	479.1	55.5	51.7	1,065.8
12030108	56.8	42.7	4.9	1.1	0.3	0.4	100.3	354.0	200.7	145.2	10.4	916.7
12030109	39.6	59.3	21.9	6.7	3.6	1.6	124.5	416.7	182.3	208.0	10.9	1,075.0
12030201	31.6	74.2	64.3	6.1	2.4	32.2	515.8	315.1	705.5	63.8	295.1	2,106.0
12030202	140.5	123.5	75.4	6.9	2.2	4.3	880.3	479.3	956.9	41.3	547.1	3,257.7
12030203	35.2	40.9	18.0	2.6	1.2	4.4	58.7	53.1	169.0	45.8	377.5	806.6
Total	668.6	1,018.2	850.6	378.1	191.2	59.9	2,944.2	5,494.6	3,688.9	1,256.5	1,398.2	17,949.1

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (7.74%), low density (31.65%), medium density (60.78%), and high density (89.15%).

Point Sources

There are numerous point source discharges in the watershed. Only the major dischargers, with a design flow greater than 1 MGD are included in the simulation (Table 3). The major dischargers are represented at long-term average flows, without accounting for changes over time or seasonal variations.

Table 3. Major point source discharges in the Trinity River basin

ID	Name	Design flow (MGD)	Observed flow (MGD)
TX0001007	EXTEX LAPORTE LIMITED PARTNERS	927	1.24
TX0001023	LUMINANT GENEATION COMPANY LLC	870	0.58
TX0001198	EXTEX LAPORTE LIMITED PARTNERS	1280	10.67
TX0020354	UPPER TRINITY REGIONAL WATER D	5	2.15
TX0020711	FLOWER MOUND, TOWN OF	10	3.49
TX0022241	NORTH TEXAS MWD	1.2	0.72
TX0022357	GAINESVILLE, CITY OF	4.14	1.74
TX0022527	TERRELL, CITY OF - KINGS CREEK	3	2.45
TX0022802	TRINITY RIVER AUTHORITY OF TEX	162	133.25
TX0023116	AZLE, CITY OF	0.941	0.69
TX0023931	NORTH TEXAS MWD	4.75	2.025
TX0024163	LIVINGSTON, CITY OF	2.25	1.029
TX0024678	GARLAND, CITY OF (DUCK CREEK)	30	21.15
TX0024686	GARLAND, CITY OF (ROWLETT CREE	24	14.67
TX0024911	DECATUR, CITY OF	1.2	0.92
TX0025011	TRINITY RIVER AUTHORITY OF TEX	0.9	11.54
TX0025364	ATHENS, CITY OF	1.367	0.81
TX0025372	ATHENS, CITY OF	1.027	54.76
TX0025453	PALESTINE CITY OF-TOWN CREEK	2.05	2.88
TX0025950	NORTH TEXAS MWD	2	3.00
TX0030180	BIG BROWN POWER COMPANY LLC	1015	1.15
TX0031577	TEXAS DEPARTMENT OF CRIMINAL J	2.85	1.77
TX0032018	GRAPEVINE, CITY OF	5.75	2.51
TX0047180	DENTON, CITY OF (PECAN CREEK)	12	10.28
TX0047261	ENNIS, CITY OF	3.1	1.64
TX0047295	FORT WORTH, CITY OF	166	106.75
TX0047431	NORTH TEXAS MWD	25	12.17
TX0047724	WEATHERFORD, CITY OF	4.5	2.046
TX0047830	DALLAS, CITY OF (CENTRAL)	150	130.29
TX0047848	DALLAS, CITY OF (SOUTHSIDE)	110	67.85
TX0047911	NORTH TEXAS MWD	16	18.08
TX0052892	LEWISVILLE, CITY OF	12	7.63
TX0052990	MEXIA, CITY OF	2	0.55
TX0053112	THE COLONY, CITY OF	3.39	1.68

ID	Name	Design flow (MGD)	Observed flow (MGD)
TX0055735	TROPHY CLUB MUD NO. 1	1.4	0.58
TX0056731	CORSICANA, CITY OF	4.95	3.05
TX0062189	BRAZOS ELECTRIC POWER COOPERAT	85	1.78
TX0070831	CROCKETT, CITY OF	2	0.68
TX0072974	HUNTSVILLE, CITY OF	4.15	2.97
TX0074284	LIBERTY,CITY OF	2.5	1.38
TX0075388	TEXAS DEPARTMENT OF CRIMINAL J	1.44	0.73
TX0078565	NORTH TEXAS MUNICIPAL WATER DI	2.25	0.90
TX0079391	KAUFMAN, CITY OF	1.2	0.57
TX0088633	NORTH TEXAS MWD	24	26.1
TX0092789	TEXAS DEPARTMENT OF CRIMINAL J	1.5	0.76
TX0100170	DAYTON, CITY OF	2	1.47
TX0103501	NORTH TEXAS MUNICIPAL WATER DI	5	3.98
TX0104345	TRINITY RIVER AUTHORITY OF TEX	3.5	1.95
TX0104957	TRINITY RIVER AUTHORITY OF TEX	5	1.31

Most of these point sources have reasonably good monitoring for total suspended solids (TSS), but not for total nitrogen and total phosphorus. The point sources were initially represented in the model with the median of reported values for TSS and an assumed total nitrogen concentration of 11.2 mg/L and assumed total phosphorus concentration of 7.0 mg/L for secondary treatment facilities (Tetra Tech 1999).

Meteorological Data

The required meteorological time series for the 20 Waterhsed SWAT simulations are precipitation and air temperature. The 20 Waterhsed simulations do not include water temperature simulation and use a degree-day method for snowmelt. SWAT estimates Penman-Monteith potential evapotranspiration using a statistical weather generator for inputs other than temperature and precipitation. These meteorological time series are drawn from the BASINS4 Meteorological Database (USEPA 2008), which provides a consistent, quality-assured set of nationwide data with gaps filled and records disaggregated. Scenario application requires simulation over 30 years, so the available stations are those with a common 30-year period of record (or one that can be filled from an approximately co-located station) that covers the year 2001. A total of 64 precipitation stations were identified for use in the Trinity River model with a common period of record of 10/1/1972-9/30/2002 (Table 4). Temperature records are sparser; where these are absent, temperature is taken from nearby stations with an elevation correction.

Table 4. Precipitation stations for the Trinity River watershed model

ID	Name	Latitude	Longitude	Elevation	Temperature
410129	TX410129	32.6444	-97.5617	241	No
410206	TX410206	33.3867	-97.7163	308	No
410235	TX410235	29.7879	-94.6342	7	Yes
410271	TX410271	33.4407	-98.3708	317	No
410337	TX410337	32.7395	-97.1277	200	No
410440	TX410440	32.2067	-96.7957	162	No
410518	TX410518	32.2636	-96.6375	141	Yes

ID	Name	Latitude	Longitude	Elevation	Temperature
410691	TX410691	32.6476	-97.4438	241	Yes
410984	TX410984	33.5511	-97.8472	329	Yes
411063	TX411063	33.2067	-97.7716	227	Yes
411596	TX411596	31.2581	-95.9744	98	Yes
411800	TX411800	32.3139	-97.4064	239	Yes
411810	TX411810	30.3637	-95.0838	60	Yes
411870	TX411870	30.5334	-95.1500	108	Yes
412019	TX412019	32.1078	-96.4746	126	Yes
412096	TX412096	32.5562	-97.6697	346	No
412114	TX412114	31.3073	-95.4508	106	No
412244	TX412244	32.8525	-96.8555	134	No
412404	TX412404	33.1990	-97.1050	192	Yes
412772	TX412772	32.3657	-95.6085	155	No
413047	TX413047	31.7322	-96.2078	132	Yes
413080	TX413080	33.1397	-96.3974	179	No
413133	TX413133	32.5340	-96.6607	143	Yes
413284	TX413284	32.8193	-97.3614	209	No
413285	TX413285	32.8339	-97.2974	196	No
413370	TX413370	33.1519	-96.8122	226	No
413415	TX413415	33.6359	-97.1444	238	No
413642	TX413642	33.7970	-96.8568	221	No
413668	TX413668	33.1025	-98.5849	320	Yes
413691	TX413691	32.9507	-97.0553	178	No
414182	TX414182	32.0162	-97.1093	168	Yes
414315	TX414315	29.7284	-95.1306	11	No
414382	TX414382	30.7064	-95.5421	151	Yes
414517	TX414517	33.2384	-98.1453	314	Yes
414679	TX414679	33.0798	-97.2967	195	No
414705	TX414705	32.5590	-96.2724	128	Yes
414972	TX414972	33.2251	-97.8316	265	No
415094	TX415094	33.0353	-96.4860	155	Yes
415192	TX415192	33.0689	-97.0100	169	No
415196	TX415196	30.0593	-94.7950	11	Yes
415271	TX415271	30.7394	-94.9256	54	Yes
415477	TX415477	30.9392	-95.9202	77	Yes
415766	TX415766	33.2365	-96.6419	190	Yes
415869	TX415869	31.6833	-96.4832	163	Yes
416130	TX416130	33.6536	-97.3752	306	No
416210	TX416210	31.9611	-96.6881	138	Yes
416331	TX416331	33.4561	-98.0253	323	No

ID	Name	Latitude	Longitude	Elevation	Temperature
416636	TX416636	33.3737	-98.7657	364	Yes
416641	TX416641	33.4372	-98.7806	361	No
416757	TX416757	31.7832	-95.6038	142	Yes
417028	TX417028	33.3659	-97.0122	210	Yes
417556	TX417556	32.9537	-97.5738	235	No
417586	TX417586	30.5382	-95.8457	96	No
417588	TX417588	32.9522	-96.7664	190	No
417659	TX417659	33.0068	-97.2246	190	No
417707	TX417707	32.9334	-96.4667	166	No
417773	TX417773	32.4612	-96.4493	111	No
418274	TX418274	33.7033	-96.6419	232	Yes
418929	TX418929	32.7668	-96.2831	157	No
419125	TX419125	33.4254	-96.3393	232	No
419286	TX419286	33.4869	-97.1572	221	No
419522	TX419522	32.4287	-96.8432	192	Yes
419532	TX419532	32.7484	-97.7699	291	Yes
419800	TX419800	32.7018	-96.0150	158	Yes

Watershed Segmentation

The Trinity River basin was divided into 73 subwatersheds for the purposes of modeling (Figure 3). The model encompasses the complete watershed and does not require specification of any upstream boundary conditions for application.

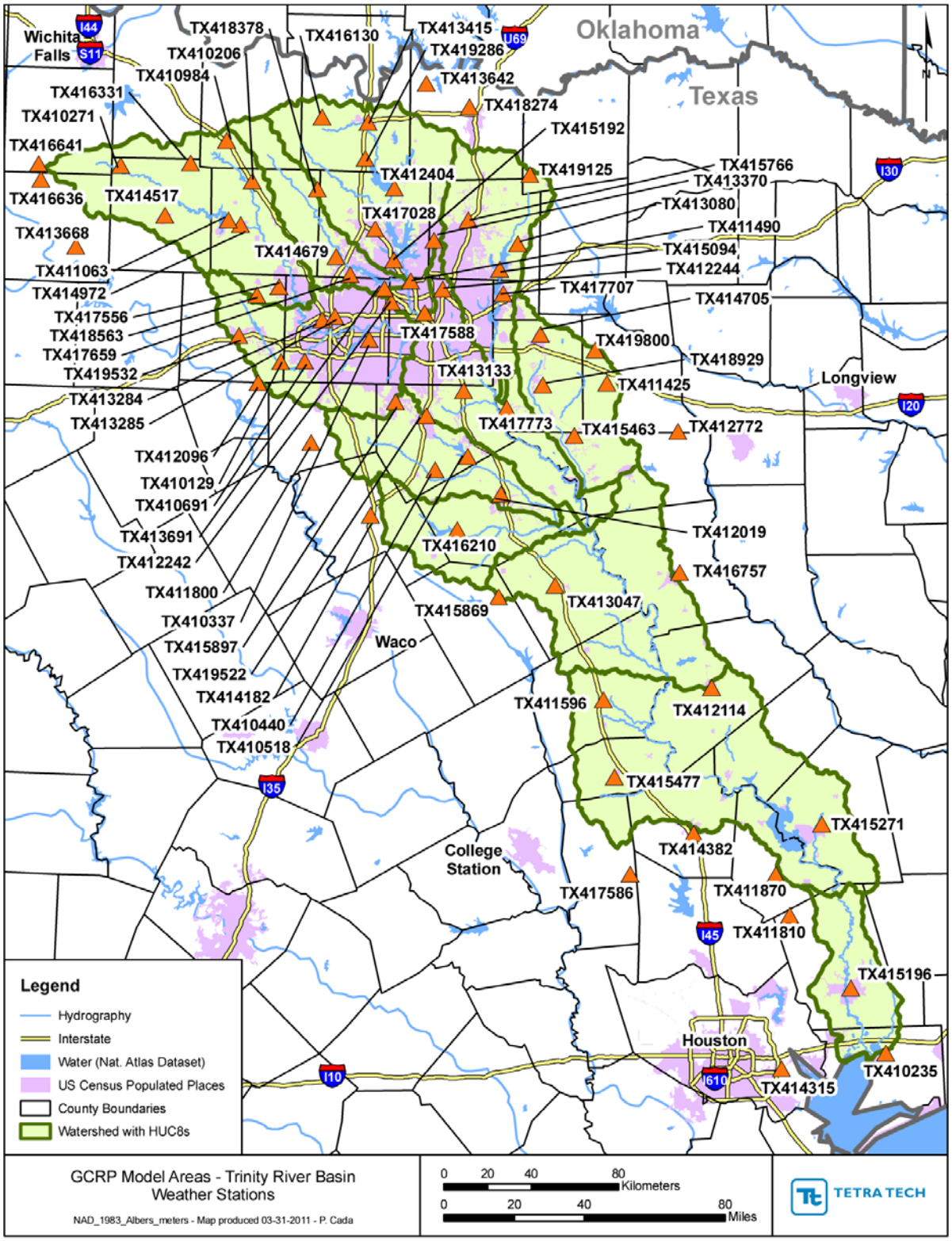

Figure 3. Model segmentation and USGS stations utilized for the trinity river watershed

Calibration Data and Locations

The specific site chosen for initial calibration was the Trinity River at Romayor, which is the most downstream gaging station in the basin. Calibration and validation were pursued at multiple locations (Table 5). Parameters derived on the Trinity River at Romayor were transferred to other portions of the Trinity River basin.

Table 5. Calibration and validation locations in the Trinity River basin

Station name	USGS ID	Drainage area (mi^2)	Hydrology calibration	Water quality calibration
East Fork Trinity River at Grand Prairie, TX	08062000	629	X	X
Clear Creek at Sanger, TX	08051500	1,300	X	X
East Fork Trinity near Crandall, TX	08062000	851	X	X
Trinity River at Rosser, TX	08062500	2,410	X	X
Trinity River at Trinidad, TX	08062700	1,110	X	X
Trinity River near Crockett, Tx	08065350	14,900	X	X
Trinity River at Romayor, Tx	08066500	16,200	X	X

The model hydrology calibration period was set to Water Years 1992-2001 (within the 30-year period of record for modeling). Hydrologic validation was then performed on Water Years 1982-1991. Water quality calibration used calendar years 1985-2001, while validation used 1972-1984. However, there was some variation to this time period across the monitoring stations depending on the availability of monitored data.

SWAT Modeling

Assumptions

Eighteen major reservoirs occur in the upper portion of the Trinity River basin. Pertinent reservoir information including surface area and storage at principal (normal) and emergency spillway levels for the reservoirs modeled were obtained from the National Inventory of Dams (NID) database. The SWAT model provides four options to simulate reservoir outflow: measured daily outflow, measured monthly outflow, average annual release rate for uncontrolled reservoir, and controlled outflow with target release. Keeping in view the 20 Waterhsed climate change impact evaluation application, it was assumed that the best representation of the reservoirs was to simulate them without supplying time series of outflow records. Therefore, the target release approach was used in the GCRP-SWAT model.

Hydrology Calibration

A spatial calibration approach was not adopted for GCRP-SWAT modeling for Trinity River basin; however, a systematic adjustment of parameters was adopted and some adjustments were applied throughout the basin. Most of the calibration efforts were geared toward getting a closer match between simulated and observed flows at the outlet closest to the most downstream USGS gaging station of the basin.

Land Use / Soil / Slope Definition

A 5/10/5 percent threshold was used for land use/soil/slope in the SWAT model while defining the HRUs. Urban land use classes were exempted from the HRU overlay thresholds.

The parameters were adjusted within the practical range at the calibration focus area to obtain reasonable fit between the simulated and measured flows in terms of Nash-Sutcliffe modeling efficiency and the high flow and low flow components as well as the seasonal flows.

The water balance of the whole Trinity River basin predicted by the SWAT model over the 30-year simulation period is as follows:

```
PRECIP =   1046.9 MM
SNOW FALL =   16.34 MM
SNOW MELT =    16.21 MM
SUBLIMATION =     0.13 MM
SURFACE RUNOFF Q =   167.49 MM
LATERAL SOIL Q =   10.66 MM
TILE Q =     0.00 MM
GROUNDWATER (SHAL AQ) Q =    16.31 MM
REVAP (SHAL AQ => SOIL/PLANTS) =  151.18 MM
DEEP AQ RECHARGE =     8.86 MM
TOTAL AQ RECHARGE =  177.28 MM
TOTAL WATER YLD =   192.80 MM
PERCOLATION OUT OF SOIL =  175.92 MM
ET =    703.4 MM
PET =   1937.8MM
TRANSMISSION LOSSES =     1.66 MM
```

Hydrologic calibration adjustments focused on the following parameters:

- SURLAG (surface runoff lag coefficient)
- CNCOEFF (plant ET curve number coefficient)
- Baseflow factor
- GWQMn (threshold depth of water in the shallow aquifer for return flow to occur [mmH2O])
- NDTarg (number of days needed to reach target storage from current pond storage)
- CN2 (initial SCS runoff curve number for moisture condition II)
- ESCO (soil evaporation compensation factor)
- Revap coeff

Calibration results for the Trinity River at Romayor are summarized in Figures 4 through 7 and Table 6. The calibration results show a good match (both in volume and timing) between the observed and the simulated flows (Figure 4, Figure 5, Figure 6, Figure 7, and Table 6).

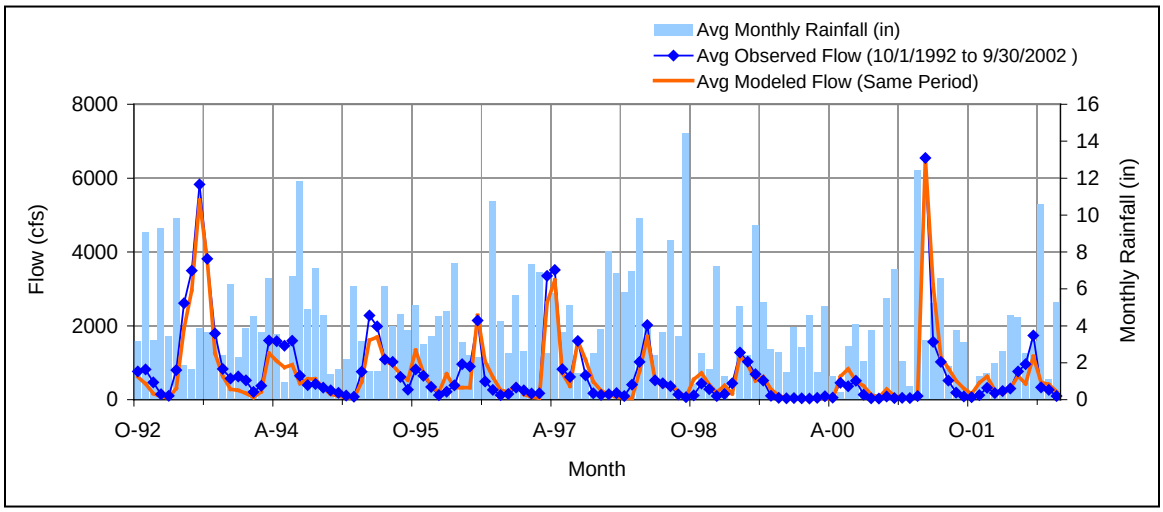

Figure 4. Mean monthly flow at USGS 08066500 Trinity River at Romayor, TX – calibration period.

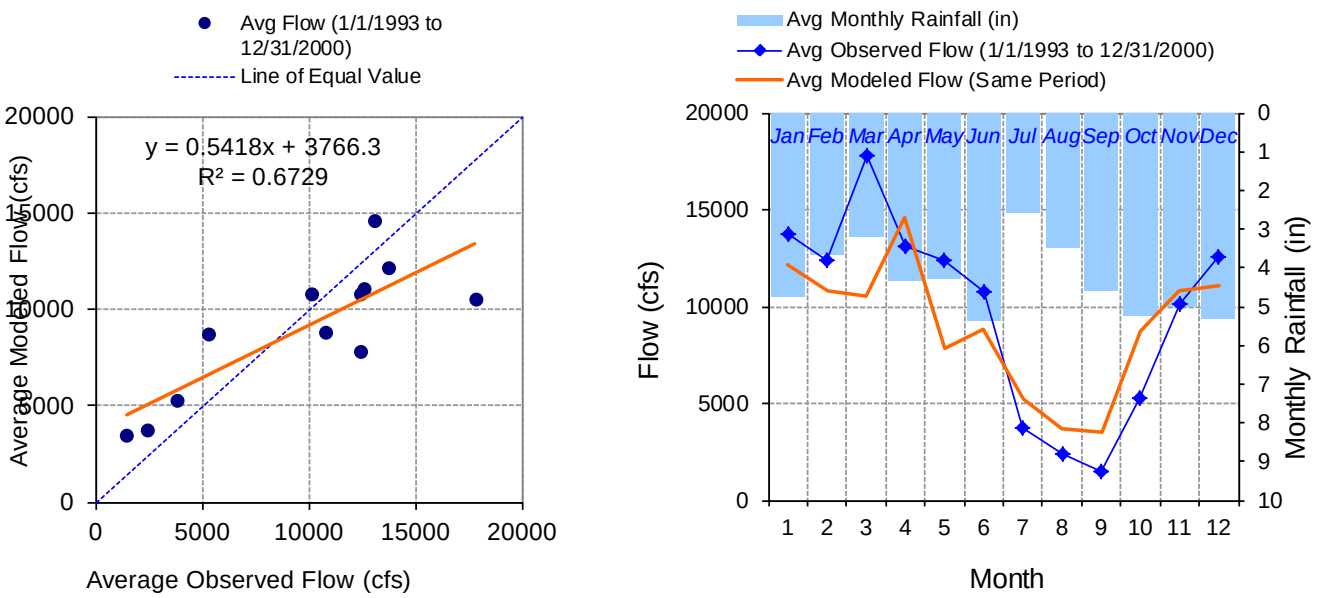

Figure 5. Seasonal regression and temporal aggregate at USGS 08066500 Trinity River at Romayor, TX - calibration period.

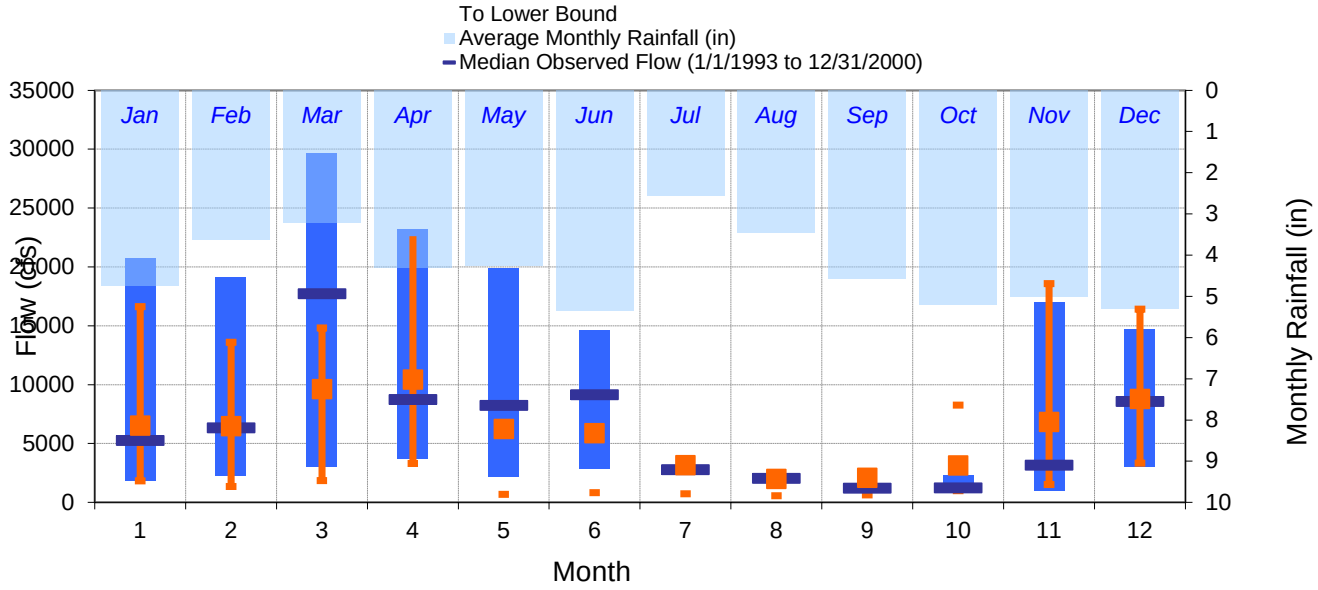

Figure 6. Seasonal medians and ranges at USGS 08066500 Trinity River at Romayor, TX – calibration period.

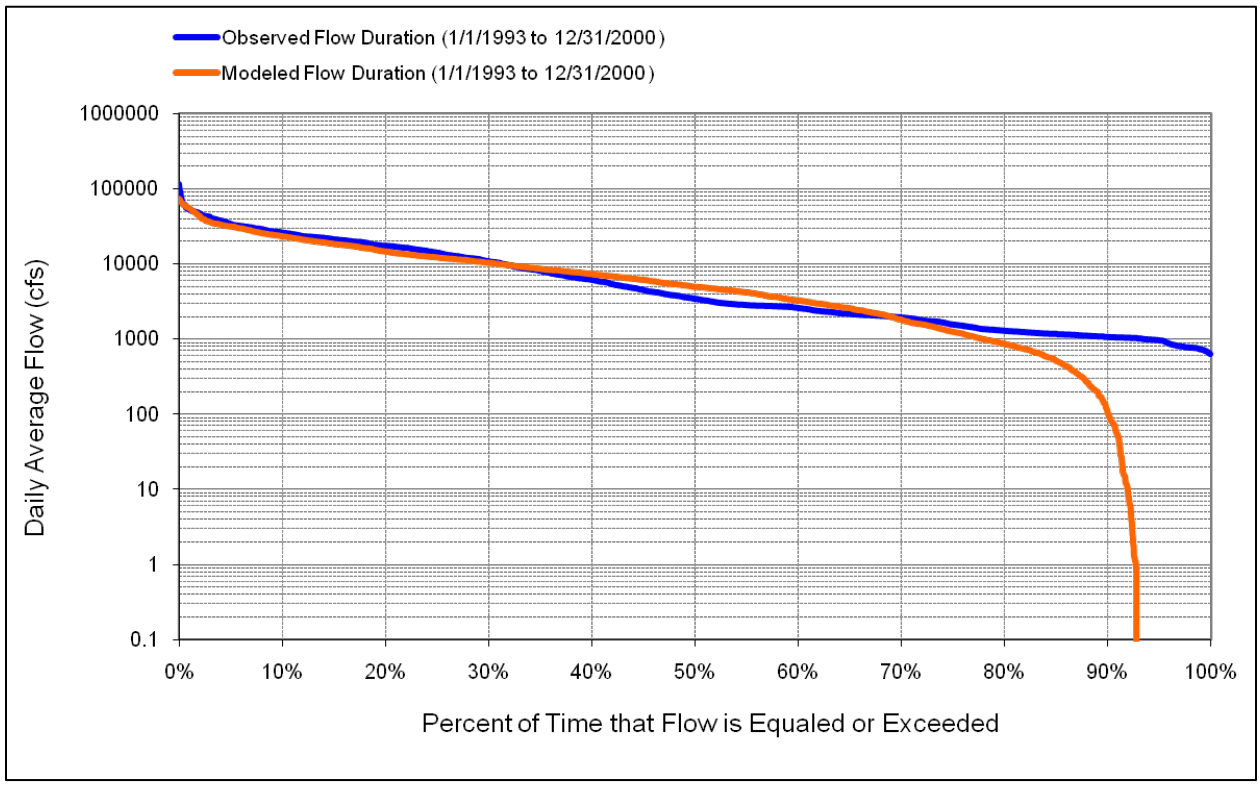

Figure 7. Flow exceedance at USGS 08066500 Trinity River at Romayor, TX - calibration period.

Table 6. Summary statistics at USGS 08066500 Trinity River at Romayor, TX - calibration period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 3 8-Year Analysis Period: 1/1/1993 - 12/31/2000 Flow volumes are (inches/year) for upstream drainage area		USGS 08066500 Trinity Rv at Romayor, TX Hydrologic Unit Code: 12030202 Latitude: 30.4252067 Longitude: -94.8507622 Drainage Area (sq-mi): 17186	
Total Simulated In-stream Flow:	**7.10**	Total Observed In-stream Flow:	**7.62**
Total of simulated highest 10% flows:	**2.80**	Total of Observed highest 10% flows:	**3.09**
Total of Simulated lowest 50% flows:	**0.67**	Total of Observed Lowest 50% flows:	**0.69**
Simulated Summer Flow Volume (months 7-9):	**0.83**	Observed Summer Flow Volume (7-9):	**0.51**
Simulated Fall Flow Volume (months 10-12):	**2.04**	Observed Fall Flow Volume (10-12):	**1.85**
Simulated Winter Flow Volume (months 1-3):	**2.18**	Observed Winter Flow Volume (1-3):	**2.88**
Simulated Spring Flow Volume (months 4-6):	**2.04**	Observed Spring Flow Volume (4-6):	**2.38**
Total Simulated Storm Volume:	**2.85**	Total Observed Storm Volume:	**2.41**
Simulated Summer Storm Volume (7-9):	**0.39**	Observed Summer Storm Volume (7-9):	**0.13**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	-6.88	10	
Error in 50% lowest flows:	-2.33	10	
Error in 10% highest flows:	-9.48	15	
Seasonal volume error - Summer:	**63.58**	**30**	
Seasonal volume error - Fall:	9.93 >>	30	Clear
Seasonal volume error - Winter:	-24.04	30	
Seasonal volume error - Spring:	-14.28	30	
Error in storm volumes:	18.68	20	
Error in summer storm volumes:	**210.14**	**50**	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.623	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.482	as E or E' approaches 1.0	
Monthly NSE	0.740		

Hydrology Validation

Hydrology validation for the Trinity River was performed for the period 10/1/1983 through 9/30/1992. The results are presented in Figures 8 through 11 and Table 7. The validation achieves a reasonable coefficient of model fit efficiency, but is under on 50 percent low volume and over on seasonal volumes for summer and fall (Figure 8 through Figure 11 and Table 7).

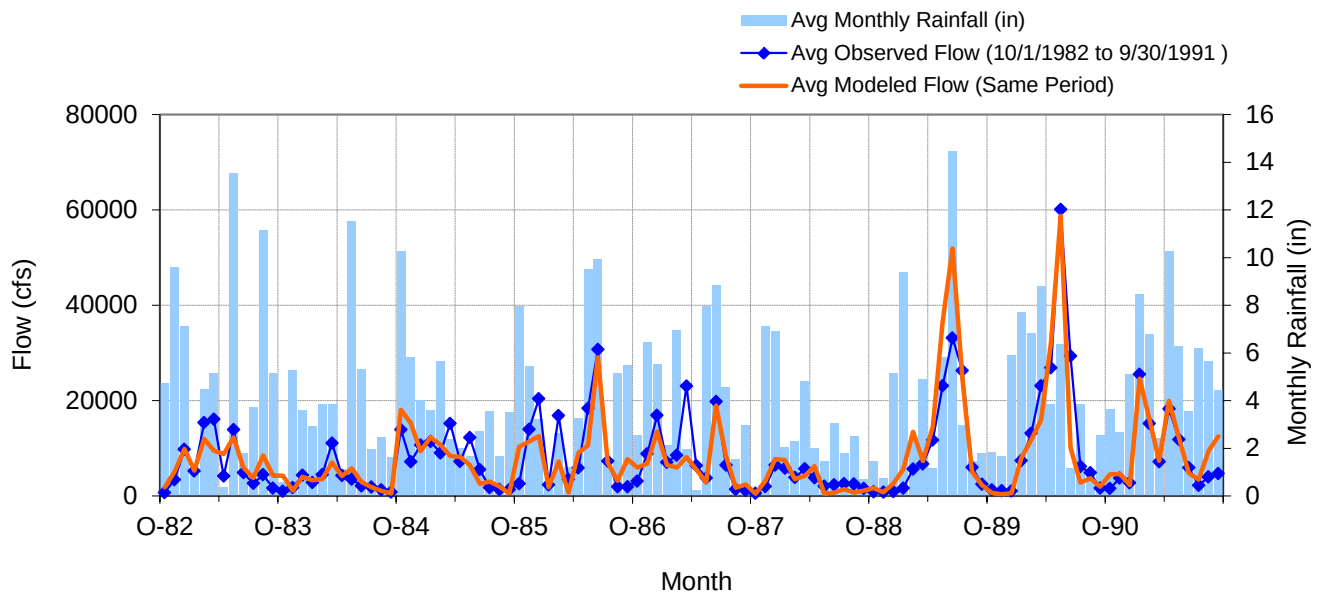

Figure 8. Mean monthly flow at USGS 08066500 Trinity River at Romayor, TX- validation period.

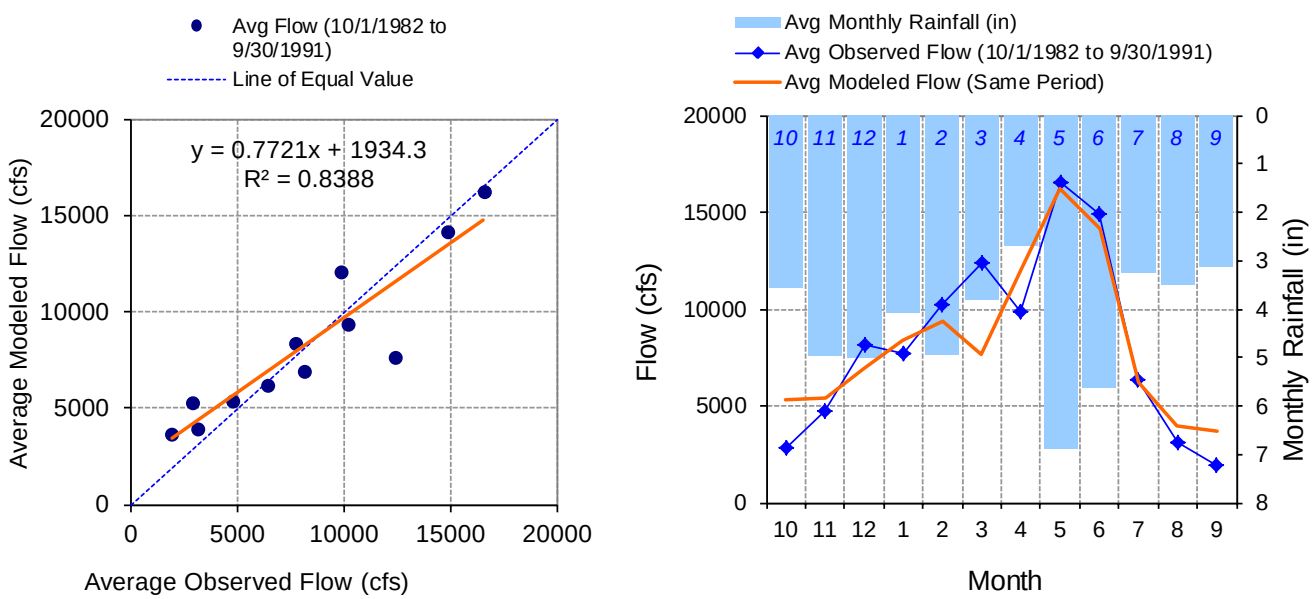

Figure 9. Seasonal regression and temporal aggregate at USGS 08066500 Trinity River at Romayor, TX – validation period.

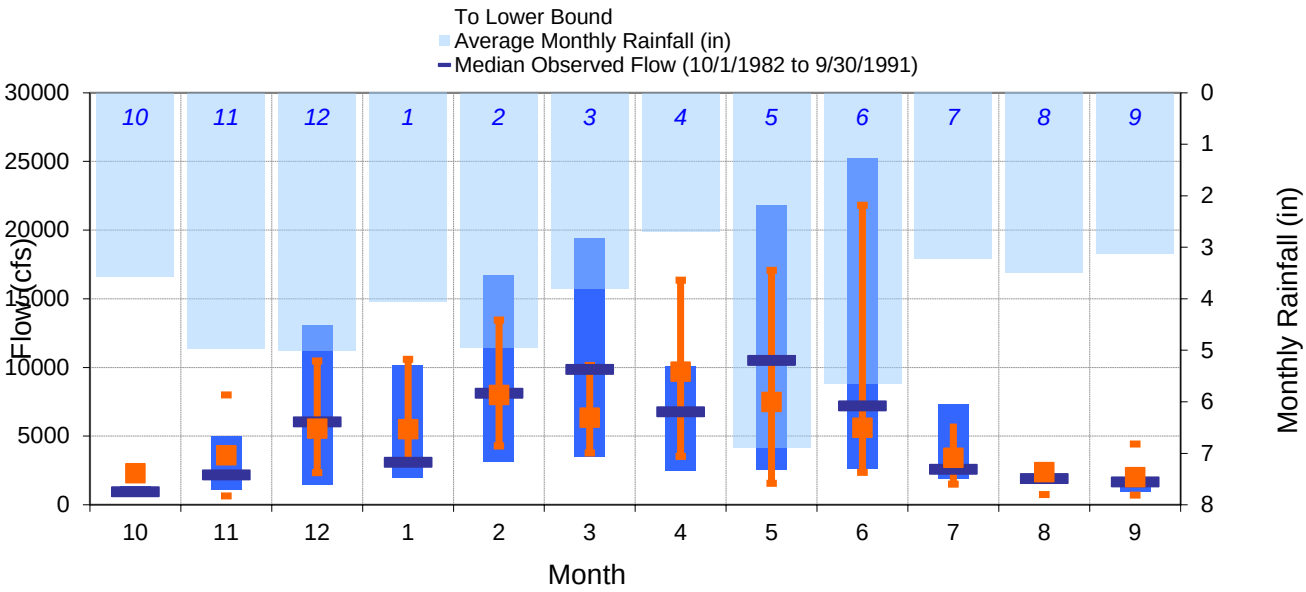

Figure 10. Seasonal medians and ranges at USGS 08066500 Trinity River at Romayor, TX – validation period.

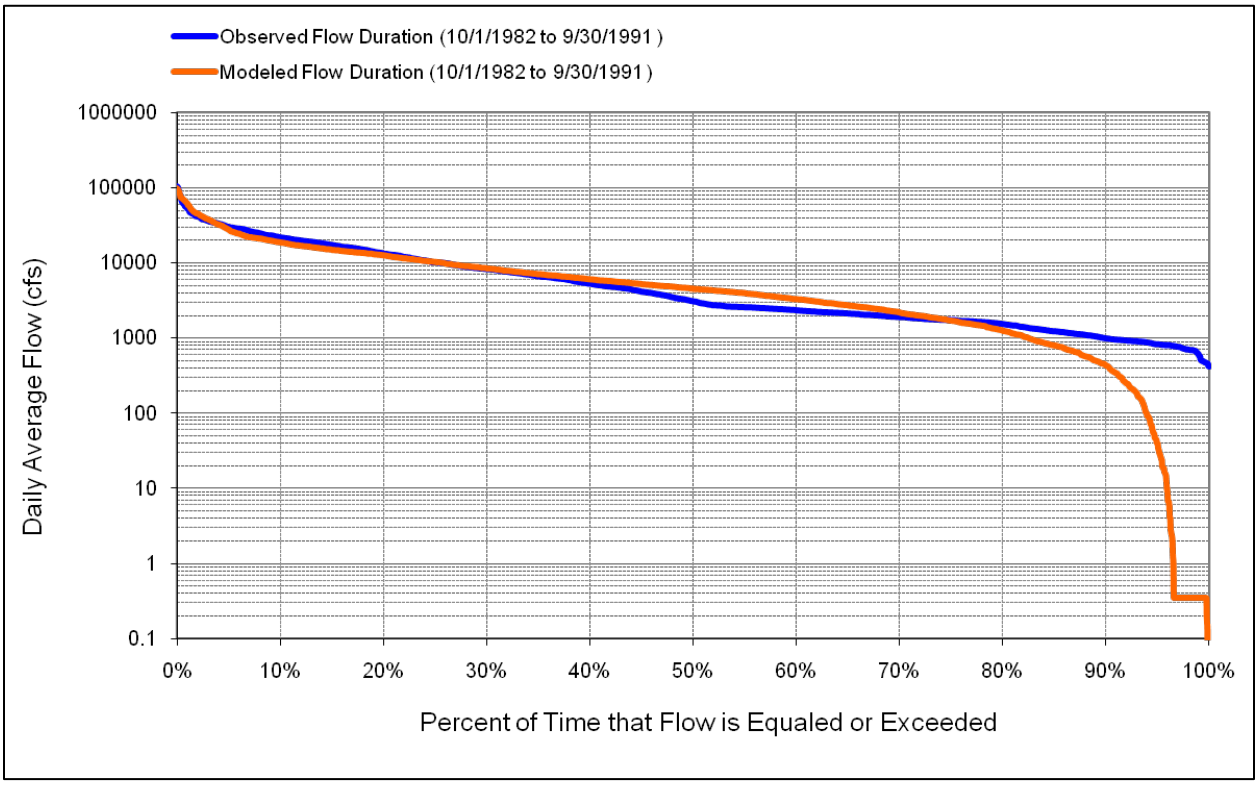

Figure 11. Flow exceedance at USGS 08066500 Trinity River at Romayor, TX - validation period.

Table 7. Summary statistics at USGS 08066500 Trinity River at Romayor, TX - validation period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 3 9-Year Analysis Period: 10/1/1982 - 9/30/1991 Flow volumes are (inches/year) for upstream drainage area		USGS 08066500 Trinity Rv at Romayor, TX Hydrologic Unit Code: 12030202 Latitude: 30.4252067 Longitude: -94.8507622 Drainage Area (sq-mi): 17186	
Total Simulated In-stream Flow:	**6.54**	Total Observed In-stream Flow:	**6.49**
Total of simulated highest 10% flows:	**2.76**	Total of Observed highest 10% flows:	**2.78**
Total of Simulated lowest 50% flows:	**0.74**	Total of Observed Lowest 50% flows:	**0.67**
Simulated Summer Flow Volume (months 7-9):	**0.92**	Observed Summer Flow Volume (7-9):	**0.76**
Simulated Fall Flow Volume (months 10-12):	**1.18**	Observed Fall Flow Volume (10-12):	**1.05**
Simulated Winter Flow Volume (months 1-3):	**1.64**	Observed Winter Flow Volume (1-3):	**1.97**
Simulated Spring Flow Volume (months 4-6):	**2.79**	Observed Spring Flow Volume (4-6):	**2.71**
Total Simulated Storm Volume:	**2.48**	Total Observed Storm Volume:	**2.39**
Simulated Summer Storm Volume (7-9):	**0.41**	Observed Summer Storm Volume (7-9):	**0.23**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	0.70	10	
Error in 50% lowest flows:	**11.67**	**10**	
Error in 10% highest flows:	-0.63	15	
Seasonal volume error - Summer:	21.78	30	
Seasonal volume error - Fall:	12.35	30	
Seasonal volume error - Winter:	-16.62	30	
Seasonal volume error - Spring:	2.88	30	
Error in storm volumes:	3.66	20	
Error in summer storm volumes:	**77.98**	**50**	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.471	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.431	as E or E' approaches 1.0	
Monthly NSE	0.760		

Hydrology Results for Larger Watershed

As described above, parameters determined for the Romayor gage were fully transferable to other gages in the watershed. In addition, calibration and validation was pursued at a total of seven gages throughout the watershed. Calibration results were acceptable at most gages (Table 8).

Results of the validation exercise are summarized in Table 9**.** Problems similar to those experienced on the Romayor gage were seen at most of the tributary gages, with over-prediction of seasonal flows in summer and under-prediction in winter and spring. However, as noted above, this is likely due to the use of land use and model parameters that are more reflective of current conditions and is not believed to present a bar to application of the model.

Table 8. Summary statistics (percent error): all Stations - calibration period

Station	08049500 West Fork Trinity River at Grand Prairie	08051500 Clear Creek near Sanger	08062000 East Fork Trinity near Crandall	08062500 Trinity River near Rosser	08062700 Trinity River near Trinidad	08065350 Trinity River near Crockett	08066500 Trinity River at Romayor
Error in total volume:	-21.5	-1.45	-4.33	-36.72	-28.22	-13.76	-6.88
Error in 50% lowest flows:	-22.96	-68.43	-12.98	-22.65	-15.64	-20.30	-2.33
Error in 10% highest flows:	-22.09	4.2	-2.26	-30.65	-25.85	1.63	-9.48
Seasonal volume error - Summer:	27.87	169.54	110.48	44.47	58.55	47.56	63.58
Seasonal volume error - Fall:	-2.90	20.8	28.55	-22.01	-15.66	2.84	9.93
Seasonal volume error - Winter:	-28.82	-15.79	-30.22	-45.18	-38.74	-30.16	-24.04
Seasonal volume error - Spring:	-42.02	-16.05	-6.16	-61.25	-46.16	-17.33	-14.28
Error in storm volumes:	-32.74	3.55	-6.33	-27.19	-21.96	29.75	18.68
Error in summer storm volumes:	55.10	192.89	159.69	116.13	149.46	155.46	210.14
Daily Nash-Sutcliffe Coefficient of Efficiency, E:	0.556	0.3	0.258	0.388	0.496	0.265	0.623
Baseline adjusted coefficient (Garrick), E':	0.424	0.380	0.323	0.358	0.427	0.368	0.482
Monthly Nash-Sutcliffe Coefficient of Efficiency, E:	0.541	0.584	0.595	0.388	0.605	0.651	0.740

Table 9. Summary statistics: all stations - validation period

Station	08049500 West Fork Trinity River at Grand Prairie	08051500 Clear Creek near Sanger	08062000 East Fork Trinity near Crandall	08062500 Trinity River near Rosser	08062700 Trinity River near Trinidad	08065350 Trinity River near Crockett	08066500 Trinity River at Romayor
Error in total volume:	6.38	-2.4	12.95	-25.22	-12.94	-11.10	0.7
Error in 50% lowest flows:	10.4	-86.16	22.86	-8.38	1.87	-17.16	11.67
Error in 10% highest flows:	-4.43	1.86	13.16	-20.01	-9.75	4.38	-0.63
Seasonal volume error - Summer:	104.35	8.88	55.60	15.41	29.18	11.0	21.78
Seasonal volume error - Fall:	29.01	41.28	82.61	-11.38	-1.31	-1.24	12.35
Seasonal volume error - Winter:	-29.5	-35.41	-36.32	-47.22	-41.84	-41.97	-16.62
Seasonal volume error - Spring:	-2.74	5.30	15.48	-30.13	-12.50	0.66	2.88
Error in storm volumes:	-19.03	1.84	-2.03	-22.33	-11.06	18.61	3.66
Error in summer storm volumes:	97.08	42.3	160.45	103.72	142.79	59.70	81.05
Daily Nash-Sutcliffe Coefficient of Efficiency, E:	0.820	0.605	0.367	0.705	0.626	0.128	0.471
Baseline adjusted coefficient (Garrick), E':	0.550	0.540	0.268	0.462	0.455	0.32	0.431
Monthly Nash-Sutcliffe Coefficient of Efficiency, E:	0.932	0.864	0.732	0.807	0.833	0.730	0.760

Water Quality Calibration and Validation

Initial calibration and validation of water quality was done on Trinity River at Romayor (USGS 08066500), using 1985-2001 for calibration and 1972-1984 for validation. As with hydrology, water quality calibration was performed on the later period as this better reflects the land use included in the model. The start of the validation period is constrained by data availability.

Calibration adjustments for sediment focused on the following parameters:

- SPCON (linear parameters for estimating maximum amount of sediment that can be re-entrained during channel sediment routing)
- CH_COV (channel cover factor)
- CH_EROD (channel erodibility factor)

Simulated and estimated sediment loads at the Romayor station for both the calibration and validation periods are shown in Figure 12 and statistics for the two periods are provided separately in Table 10. The key statistic in Table 10 is the relative percent error, which shows the error in the prediction of monthly load normalized to the estimated load. Table 10 also shows the relative average absolute error, which is the average of the relative magnitude of errors in individual monthly load predictions. This number is inflated by outlier months in which the simulated and estimated loads differ by large amounts (which may be as easily due to uncertainty in the estimated load due to limited data as to problems with the model) and the third statistic, the relative median absolute error, is likely more relevant and shows better agreement.

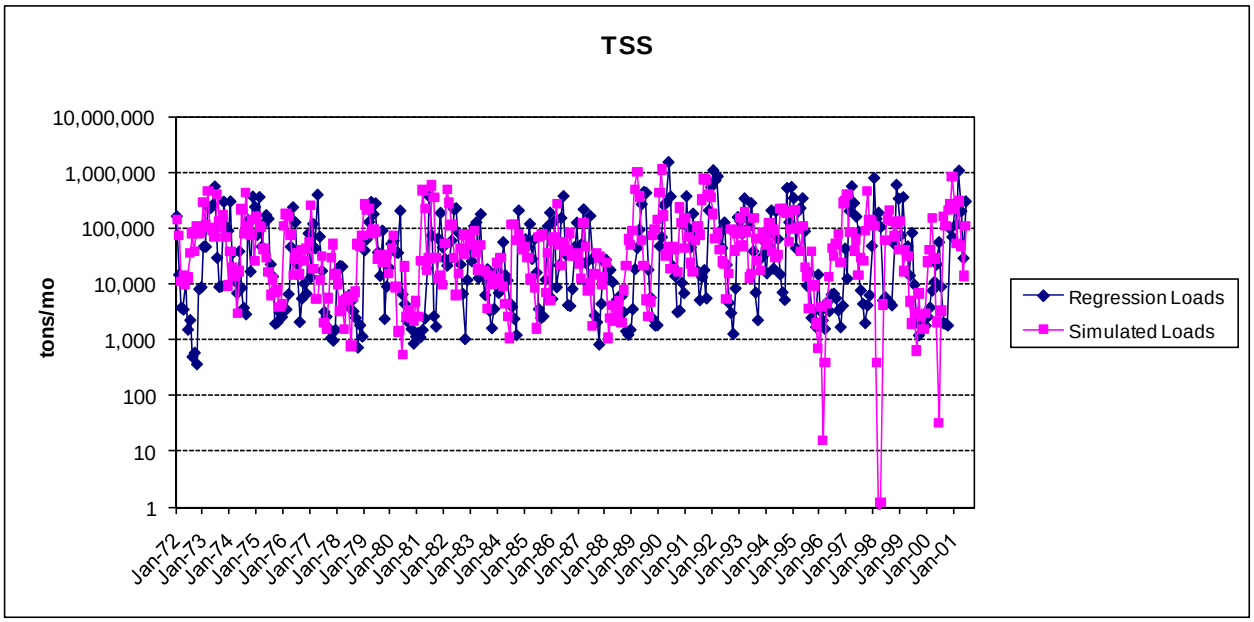

Figure 12. Fit for monthly load of TSS at USGS 08066500 Trinity River at Romayor, TX.

Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 08066500 Trinity River at Romayor, TX

Statistic	Calibration period (1985-2001)	Validation period (1972-1984)
Relative Percent Error	9.2%	-17.4%
Relative Average Absolute Error	129%	137%
Relative Median Absolute Error	58.8%	56.4%

Calibration adjustments for total phosphorus and total nitrogen focused on the following parameters:

- PHOSKD (Phosphorus soil partitioning coefficient)
- RS2(benthic source rate for dissolved phosphorus in the reach [mg P/m2*day])
- RS3 (benthic source rate for NH4-N in the reach [mg N/m2*day])
- RS4 (rate coefficient for organic N settling in the reach [day-1])

- RS5 (organic phosphorus settling rate in the reach [day-1])
- BC1 (rate constant for biological oxidation of NH4 to NO2 in the reach [day-1])
- BC2 (rate constant for biological oxidation of NO2 to NO3 in the reach [day-1])
- BC4 (rate constant for mineralization of organic P to dissolved P in the reach [day-1])
- MUMAX (maximum specific algal growth rate [day-1])

Results for the phosphorus simulation are shown in Figure 13 and Table 11. Results for the nitrogen simulation are shown in Figure 14 and Table 12. The model fit is generally good.

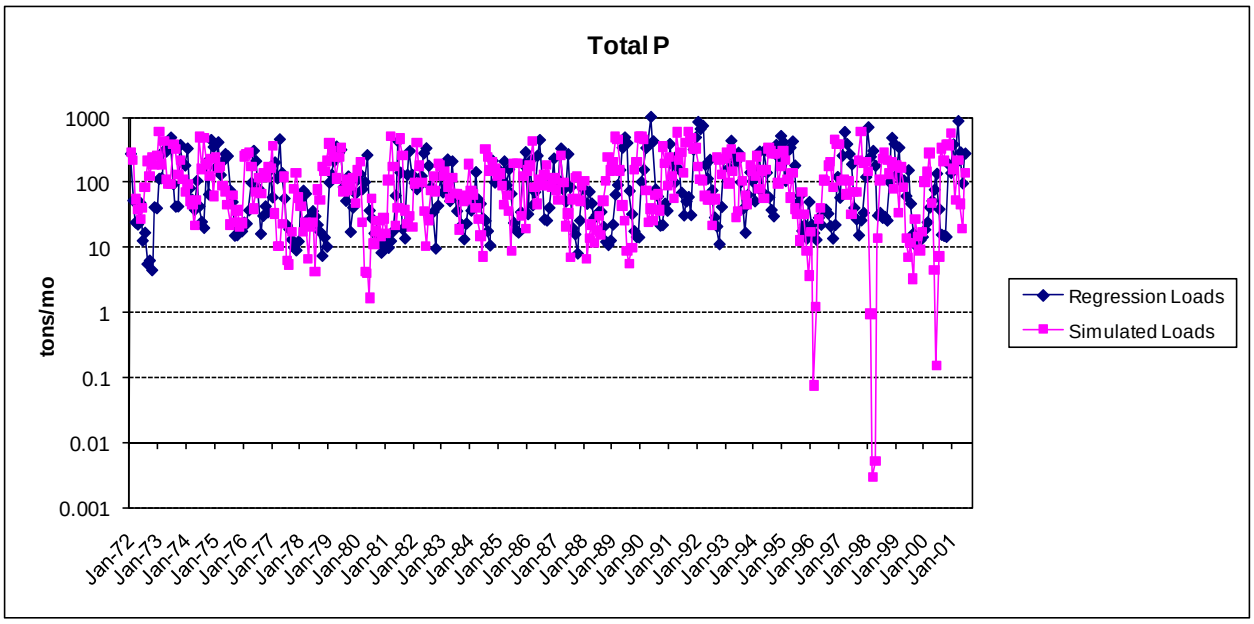

Figure 13. Fit for monthly load of total phosphorus at USGS 08066500 Trinity River at Romayor, TX.

Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 08066500 Trinity River at Romayor, TX

Statistic	Calibration period (1985-2001)	Validation period (1972-1984)
Relative Percent Error	3.0%	-21.58
Average Absolute Error	108%	110%
Median Absolute Error	75.7%	68.6%

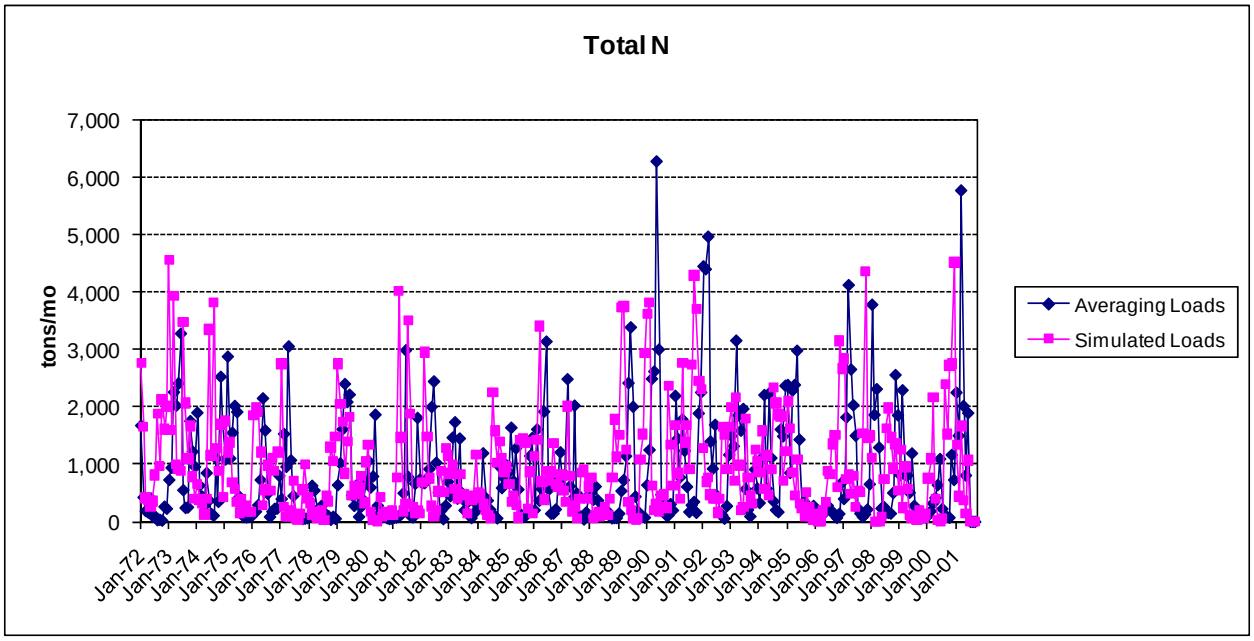

Figure 14. Fit for monthly load of total nitrogen at USGS 08066500 Trinity River at Romayor, TX.

Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 08066500 Trinity River at Romayor, TX

Statistic	Calibration period (1985-2001)	Validation period (1972-1984)
Relative Percent Error	-3.8%	-31.9%
Average Absolute Error	107%	113%
Median Absolute Error	78.4%	66.7%

Water Quality Results for Larger Watershed

As with hydrology, the SWAT model parameters used to calibrate at the USGS 08066500 Trinity River at Romayor, TX station for water quality were directly transferred to other portions of the watershed. Application of the SWAT model without spatial adjustments resulted in relatively large errors in predicting loads and concentrations at some stations. Summary statistics for the SWAT water quality calibration and validation at other stations in the watershed are provided in Table 13 and Table 14.

Table 13. Summary statistics for water quality at all stations – calibration period 1985-2001

Station	08049500 West Fork Trinity River at Grand Prairie	08051500 Clear Creek near Sanger	08062000 East Fork Trinity near Crandall	08062500 Trinity River near Rosser	08062700 Trinity River near Trinidad	08065350 Trinity River near Crockett	08066500 Trinity River at Romayor
Relative Percent Error TSS Load	62.9%	98.3%	-26.4%	44.9%	58.1%	53.4%	9.2%
Relative Percent Error TP Load	38.9%	77%	-186.9%	12.4%	9%	15.8%	3.0%
Relative Percent Error TN Load	77.3%	83.9%	41.2%	63.0%	60.7%	50.5%	-3.8%

Table 14. Summary statistics for water quality at all stations – validation period 1972-1984

Station	08049500 West Fork Trinity River at Grand Prairie	08051500 Clear Creek near Sanger	08062000 East Fork Trinity near Crandall	08062500 Trinity River near Rosser	08062700 Trinity River near Trinidad	08065350 Trinity River near Crockett	08066500 Trinity River at Romayor
Relative Percent Error TSS Load	58.1%	97.4%	-43.3%	36.4%	55.8%	54.0%	-17.4%
Relative Percent Error TP Load	36.58%	50.06%	-192.45%	14.42%	9.48%	17.04%	-21.58%
Relative Percent Error TN Load	60.0%	64.2%	18.8%	45.7%	42.4%	36.9%	-31.9%

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