Appendix Q
Model Configuration, Calibration and Validation

Basin: Rio Grande

Contents

Watershed Background **1**

Water Body Characteristics 1

Soil Characteristics 3

Land Use Representation 3

Point Sources 7

Meteorological Data 7

Watershed Segmentation 9

Calibration Data and Locations 11

SWAT Modeling **12**

Assumptions 12

Hydrology Calibration 12

Hydrology Validation 16

Hydrology Results for Larger Watershed 19

Water Quality Calibration and Validation 21

Water Quality Results for Larger Watershed 24

References **26**

Tables

Table 1. Aggregation of NLCD land cover classes 5
Table 2. Land use distribution for the Rio Grande basin (2001 NLCD) (mi^2) 6
Table 3. Major point source discharges in the Rio Grande basin 7
Table 4. Precipitation stations for the Rio Grande watershed model 7
Table 5. Calibration and validation locations in the Rio Grande basin 11
Table 6. Summary statistics USGS 08227000 Saguache Creek near Saguache, CO - calibration period....16
Table 7. Summary statistics at USGS 08227000 Saguache Creek near Saguache, CO – validation period 19
Table 8. Summary statistics (percent error): all stations - calibration period 20
Table 9. Summary statistics: all stations - validation period 21
Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 08276500 Rio Grande near Taos, NM 22
Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 08276500 Rio Grande near Taos, NM 23
Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 08276500 Rio Grande near Taos, NM....24
Table 13. Summary statistics for water quality at all stations – calibration period 1985-2003....25
Table 14. Summary statistics for water quality at all stations – validation period 1973-1984....25

Figures

Figure 1. Location of the Rio Grande basin....2
Figure 2. Land use in the Rio Grande basin....4
Figure 3. Model segmentation and USGS stations utilized for the Rio Grande basin....10
Figure 4. Mean monthly flow at USGS 08227000 Saguache Creek near Saguache, CO - calibration period. 13
Figure 5. Seasonal regression and temporal aggregate at USGS 08227000 Saguache Creek near Saguache, CO - calibration period....14
Figure 6. Seasonal medians and ranges at USGS 08227000 Saguache Creek near Saguache, CO - calibration period....14
Figure 7. Flow exceedance at USGS 08227000 Saguache Creek near Saguache, CO - calibration period. .15
Figure 8. Mean monthly flow at USGS 08227000 Saguache Creek near Saguache, CO - validation period. 17
Figure 9. Seasonal regression and temporal aggregate at USGS 08227000 Saguache Creek near Saguache, CO - validation period....17
Figure 10. Seasonal medians and ranges at USGS 08227000 Saguache Creek near Saguache, CO - validation period....18
Figure 11. Flow exceedence at USGS 08227000 Saguache Creek near Saguache, CO - validation period. ..18
Figure 12. Fit for monthly load of TSS at USGS 08276500 Rio Grande near Taos, NM....22
Figure 13. Fit for monthly load of total phosphorus at USGS 08276500 Rio Grande near Taos, NM. 23
Figure 14. Fit for monthly load of total nitrogen at USGS 08276500 Rio Grande near Taos, NM. 24

Watershed Background

The Rio Grande 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 Rio Grande is a river that flows from southwestern Colorado to the Gulf of Mexico. Its length varies as its course changes. It serves as a natural border between Texas and the Mexican states of Chihuahua, Coahuila, Nuevo León, and Tamaulipas. The Rio Grande's watershed is 182,200 square miles (472,000 km^2). The study area for the 20 Watershed project is the portion of the Rio Grande basin toward the northern and central part of the basin spanning across parts of Colorado and New Mexico (Figure 1).

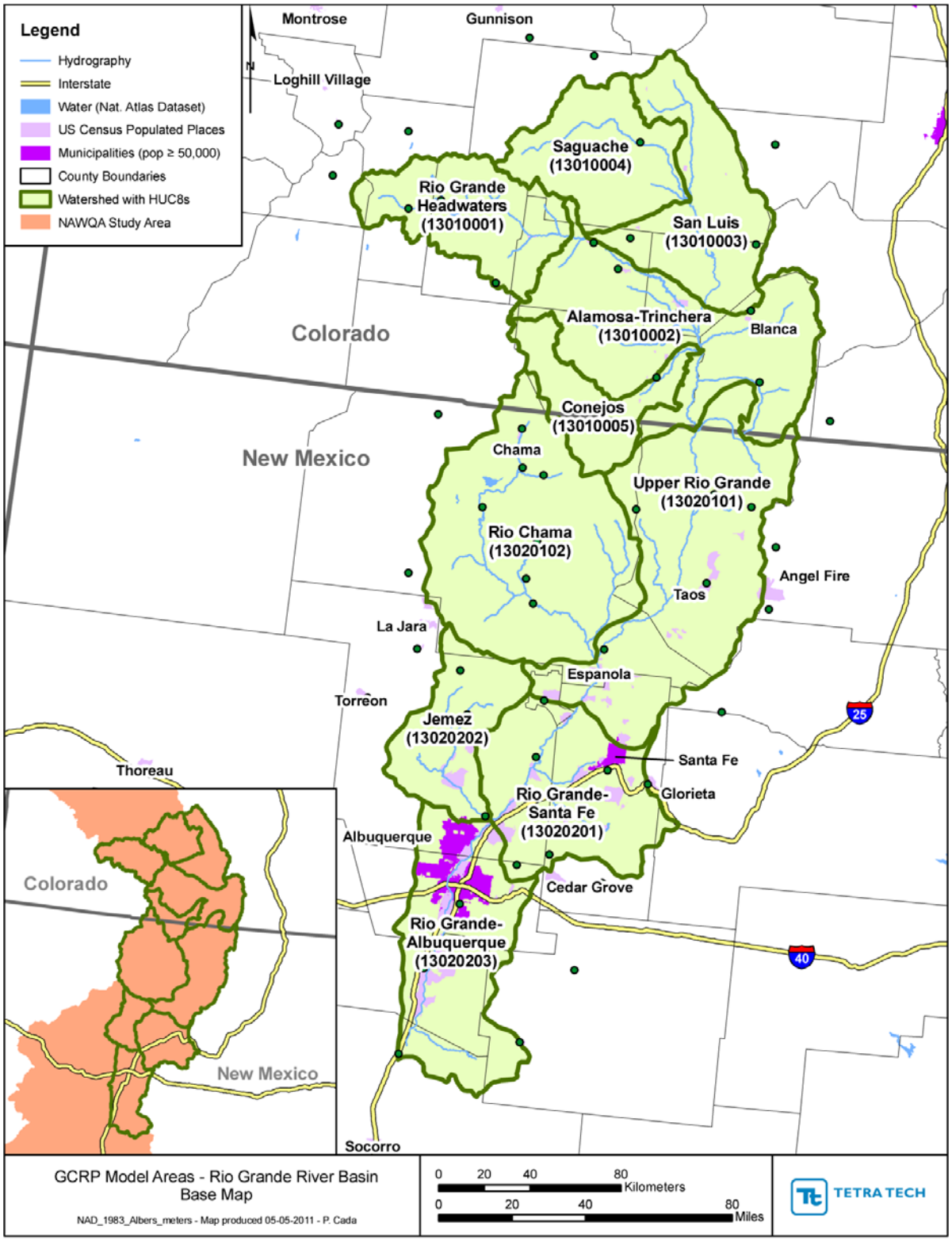

Figure 1. Location of the Rio Grande basin.

Soil Characteristics

Soils in the watershed, as described in STATSGO soil surveys, fall primarily into hydrologic soil groups (HSGs) B (moderately high infiltration capacity) and D (low infiltration capacity). 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 in the south, and forest in the Southern Rocky Mountains and Colorado Plateaus Provinces in the north. (Figure 2). NLCD land cover classes were aggregated according to the scheme shown in Table 1 for representation in the 20 Watershed 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.

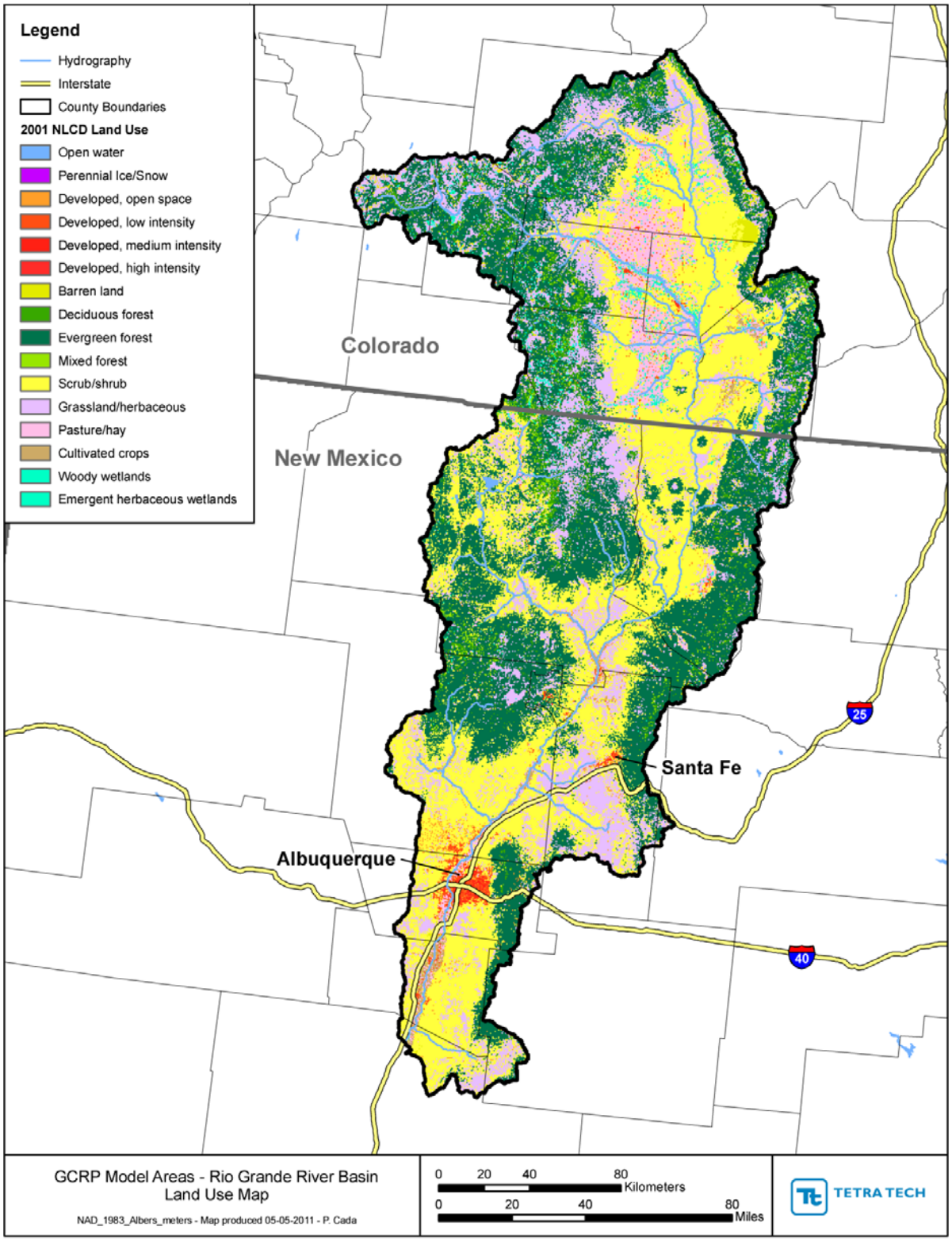

Figure 2. Land use in the Rio Grande basin.

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 Rio Grande 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							
13010001	4.81	4.74	1.41	0.15	0.00	48.41	770.84	37.25	8.84	0.73	59.03	936.20
13010002	7.19	28.23	17.89	3.27	0.23	24.48	648.74	938.39	276.16	15.52	124.15	2,084.26
13010003	3.94	8.44	13.47	1.21	0.00	69.09	292.24	666.65	253.94	0.64	39.08	1,348.69
13010004	0.84	8.57	6.99	0.18	0.00	10.34	464.47	334.13	89.74	0.27	48.73	964.27
13010005	1.51	6.45	1.87	0.27	0.00	5.14	300.24	120.75	41.18	0.37	51.59	529.37
13020101	3.67	29.88	13.09	1.37	0.19	20.31	1,457.63	1,200.68	20.80	33.46	13.54	2,794.63
13020102	22.72	18.02	2.14	0.07	0.00	5.14	1,546.58	1,007.69	22.76	12.00	41.18	2,678.28
13020201	4.26	26.55	12.87	2.56	0.28	0.29	470.66	807.99	1.18	13.08	2.22	1,341.96
13020202	1.91	5.03	0.96	0.03	0.00	2.88	464.23	408.48	3.72	4.37	6.21	897.82
13020203	8.21	81.87	94.44	33.65	5.65	10.83	273.65	1,117.01	56.29	46.57	12.14	1,740.32
Total	59.05	217.79	165.13	42.75	6.37	196.93	6,689.28	6,639.03	774.61	127.00	397.87	15,315.79

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (8.76%), low density (32.36%), medium density (60.49%), and high density (84.32%).

Point Sources

There are several 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 Rio Grande basin

ID	Name	Design glow (mgd)	Observed flow (mgd)
NM0020150	Belen, City of	1.2	0.79
NM0022250	Albuquerque, City of (WWTP#2)	60	58.57
NM0027987	Rancho, City of	2.4	3.02
NM0022292	Santa Fe, City of (Airport Rd)	6.5	5.79
NM0028355	Los Alamos National Laboratory		0.62
NM0029351	Espanola, City of	1.01	0.91
NM0024066	Taos, Town of	1.25	0.98
NM0022101	Village of Taos Ski Valley	0.13	0.04
NM0022306	Molycorp Inc - Questa		0.49
NM0024899	Red River AWWT, Town of	2.5	0.47
NM0020141	Los Alamos County (Bayo Canyon)	1.37	12.22
CO0044458	Alamosa, City of	2.6	1.53

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 data for the 20 Watershed SWAT simulations are precipitation and air temperature. The 20 Watershed 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 54 precipitation stations were identified for use in the Rio Grande 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 Rio Grande watershed model

ID	Name	Latitude	Longitude	Elevation	Temperature
50130	CO050130	37.4389	-105.8610	2296	Yes
50776	CO050776	37.4723	-105.5040	2390	Yes
51458	CO051458	37.7067	-106.1440	2339	Yes
51713	CO051713	38.4462	-106.7610	2438	Yes
52184	CO052184	37.6742	-106.3240	2397	Yes
53541	CO053541	37.7333	-105.5110	2494	Yes

ID	Name	Latitude	Longitude	Elevation	Temperature
53951	CO053951	37.7718	-107.1090	2758	Yes
54734	CO054734	38.0248	-107.3140	2643	Yes
55322	CO055322	37.1742	-105.9390	2344	Yes
55706	CO055706	37.5811	-106.1870	2345	Yes
56203	CO056203	38.0207	-107.6680	2390	Yes
57337	CO057337	38.0858	-106.1440	2347	Yes
57428	CO057428	37.1954	-107.6650	2421	No
57460	CO057460	38.4040	-105.4660	2579	No
57656	CO057656	37.8193	-106.4270	2828	Yes
58220	CO058220	37.0708	-106.6210	2521	No
58931	CO058931	38.1312	-106.0560	2396	Yes
290041	NM290041	36.2403	-106.8320	1945	Yes
290234	NM290234	35.0357	-105.5950	1618	Yes
290245	NM290245	36.0909	-106.5780	1731	Yes
290915	NM290915	34.4220	-106.9680	1443	Yes
291000	NM291000	36.3120	-107.0000	2635	No
291180	NM291180	36.7444	-105.2620	2440	No
291389	NM291389	36.4820	-106.7300	2386	No
291630	NM291630	36.7409	-106.0810	2332	yes
291664	NM291664	36.9178	-106.0340	2393	yes
291982	NM291982	35.6414	-105.4480	1695	No
292241	NM292241	36.0106	-106.6870	2147	yes
292608	NM292608	36.9359	-107.0540	2071	yes
292700	NM292700	36.5575	-106.3210	2524	yes
292837	NM292837	36.5928	-106.7610	2054	yes
293031	NM293031	35.9882	-106.2600	1702	yes
293060	NM293060	34.8242	-105.6880	1871	yes
293488	NM293488	35.8918	-105.4030	2515	yes
293511	NM293511	36.3336	-106.3650	1981	No
293586	NM293586	35.5817	-105.9750	2292	No
293592	NM293592	35.2656	-105.9430	2042	No
294366	NM294366	35.3886	-105.5860	1642	No
294369	NM294369	35.7784	-106.5530	1909	Yes
294960	NM294960	36.3043	-107.1810	2201	Yes
295084	NM295084	35.8645	-106.7460	2263	Yes
295150	NM295150	34.7675	-105.8610	1475	Yes
295965	NM295965	34.5209	-105.5040	1987	Yes
296676	NM296676	35.5490	-106.1440	2096	Yes
297323	NM297323	36.7059	-106.7610	2644	Yes
298015	NM298015	35.2106	-106.3240	2143	Yes

ID	Name	Latitude	Longitude	Elevation	Temperature
298085	NM298085	35.6194	-105.5110	2059	Yes
298518	NM298518	35.1767	-107.1090	1943	Yes
298668	NM298668	36.3906	-107.3140	2123	Yes
298845	NM298845	36.7664	-105.9390	2275	Yes
299031	NM299031	35.7992	-106.1870	2042	Yes
299085	NM299085	36.6511	-107.6680	2481	No
299820	NM299820	35.9479	-106.1440	2505	Yes

Watershed Segmentation

The Rio Grande basin was divided into 74 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.

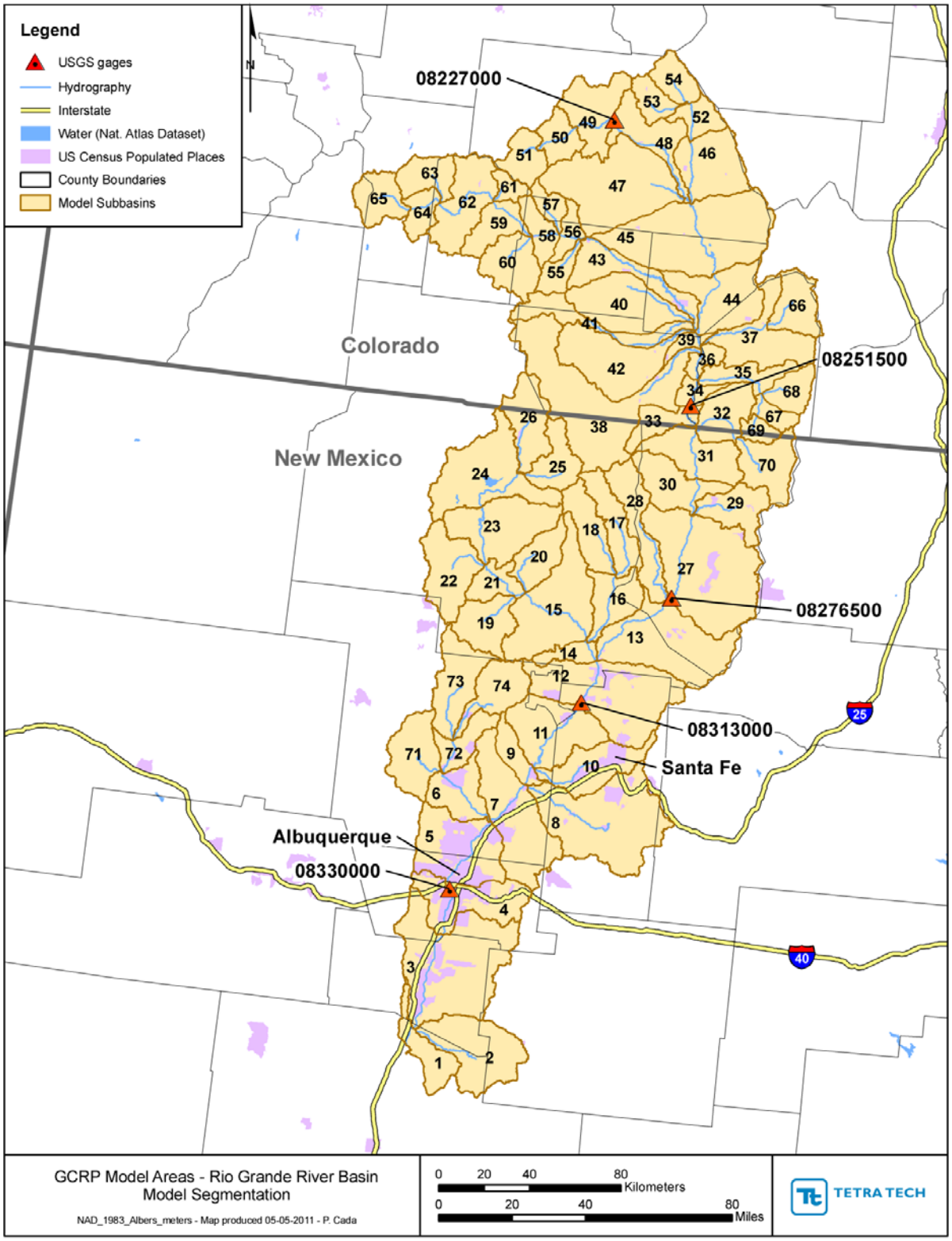

Figure 3. Model segmentation and USGS stations utilized for the Rio Grande basin.

Calibration Data and Locations

The specific site chosen for initial calibration was Saguache Creek near Saguache, CO (USGS 08227000), which is the only gaging station in the basin without any reservoirs. Calibration and validation were pursued at multiple locations (Table 5). Parameters derived at the Saguache Creek station were transferred to other portions of the Rio Grande basin.

Table 5. Calibration and validation locations in the Rio Grande basin

Station Name	USGS ID	Drainage area (mi^2)	Hydrology calibration	Water quality calibration
Saguache Creek near Saguache, CO	08227000	595	X	X
Rio Grande near Lobatos, NM	08251500	7700	X	X
RioGrande near Taos, NM	08276500	9730	X	X
RioGrande at Otowi Bridge, NM	08313000	14300	X	X
RioGrande at Albuquerque	08330000	17440	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 1985-2003, while validation used 1973-1984. However, there was some variation to this time period across the monitoring stations depending on the availability of monitored data.

SWAT Modeling

Assumptions

Ten major reservoirs occur in the Rio Grande 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 Watershed 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.

Elevation bands were also created in the subwatersheds where elevation was above 3,000 m to account for the impact of higher elevation. Moreover, since the northern and southern part of the Rio Grande basin are geographically different, certain parameters have different values for the Colorado part of Rio Grande and for the New Mexico part of the Rio Grande basin, respectively.

Hydrology Calibration

A spatial calibration approach was not adopted for GCRP-SWAT modeling for the Rio Grande basin; howover, 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 one of the USGS gaging stations in 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 Rio Grande basin predicted by the SWAT model over the 30-year simulation period is as follows:

```
PRECIP =    307.4 MM
SNOW FALL =   38.57 MM
SNOW MELT =    34.39 MM
SUBLIMATION =     4.58 MM
SURFACE RUNOFF Q =     5.73 MM
LATERAL SOIL Q =   15.40 MM
TILE Q =     0.00 MM
GROUNDWATER (SHAL AQ) Q =     6.51 MM
REVAP (SHAL AQ => SOIL/PLANTS) =    7.47 MM
DEEP AQ RECHARGE =     1.22 MM
TOTAL AQ RECHARGE =   15.21 MM
TOTAL WATER YLD =    24.24 MM
PERCOLATION OUT OF SOIL =   12.18 MM
ET =    274.8 MM
```

```
PET =   1946.4MM
TRANSMISSION LOSSES =     3.41 MM
```

Hydrologic calibration adjustments focused on the following parameters:

- Snow parameters SMTMP, SMFMX, SMFMN, TIMP
- Baseflow factor
- GW_DELAY (groundwater delay time)
- GWQMN (threshold depth of water in the shallow aquifer required for return flow to occur)
- Rchrg_DP
- CH_K2 (channel hydraulic conductivity)
- NDTarg
- Curve Number
- Temperature Lapse Rate
- SURLAG (surface runoff lag time [days])
- ESCO (soil evaporation compensation factor)
- FFCB (fraction of field capacity)

Calibration results for the Rio Grande basin at Saguache Creek near Saguache, CO are summarized in Figures 4 through 7 and Table 6. In general, the model represents the observed flow well, both in terms of volume and timing of the peaks (Figure 4, Figure 5, Figure 6, Figure 7, and Table 6).

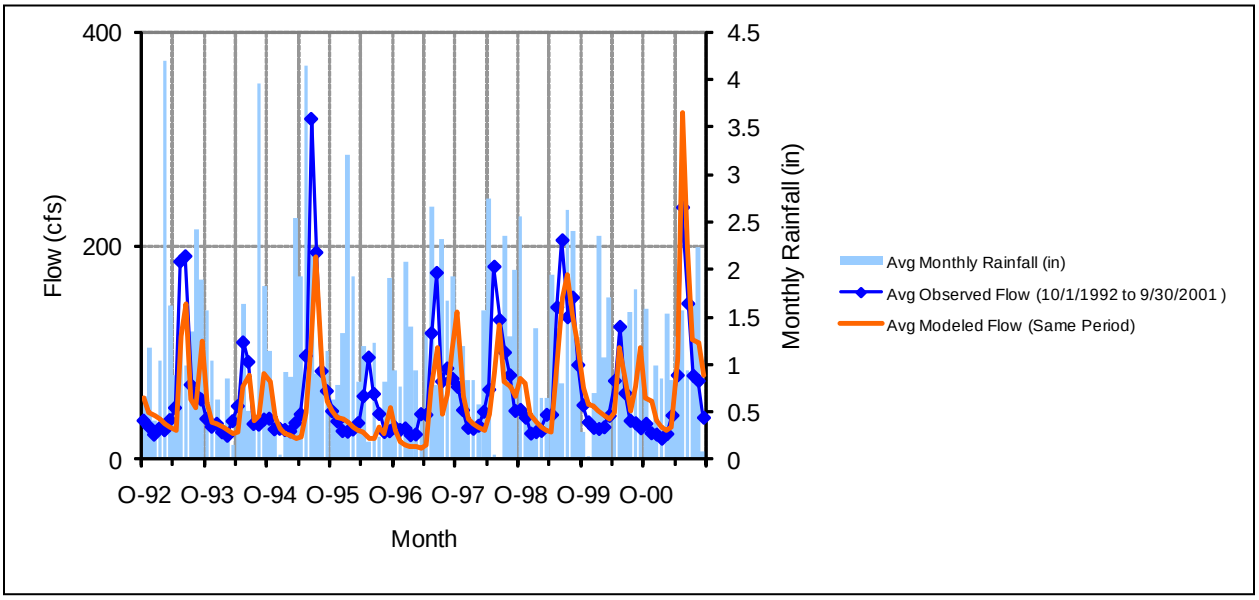

Figure 4. Mean monthly flow at USGS 08227000 Saguache Creek near Saguache, CO - calibration period.

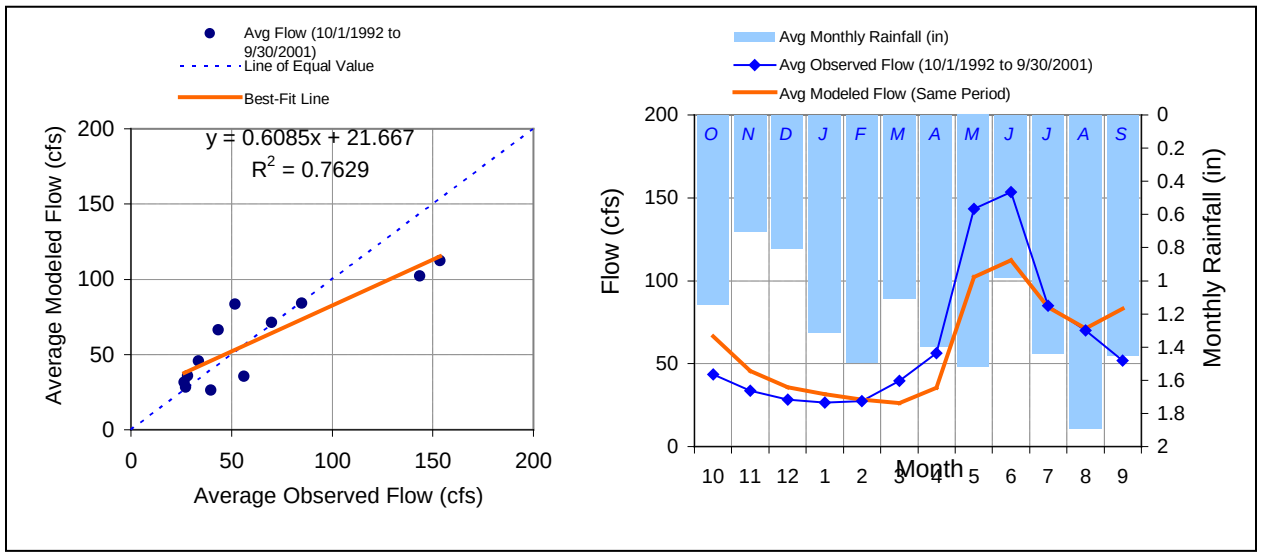

Figure 5. Seasonal regression and temporal aggregate at USGS 08227000 Saguache Creek near Saguache, CO - calibration period

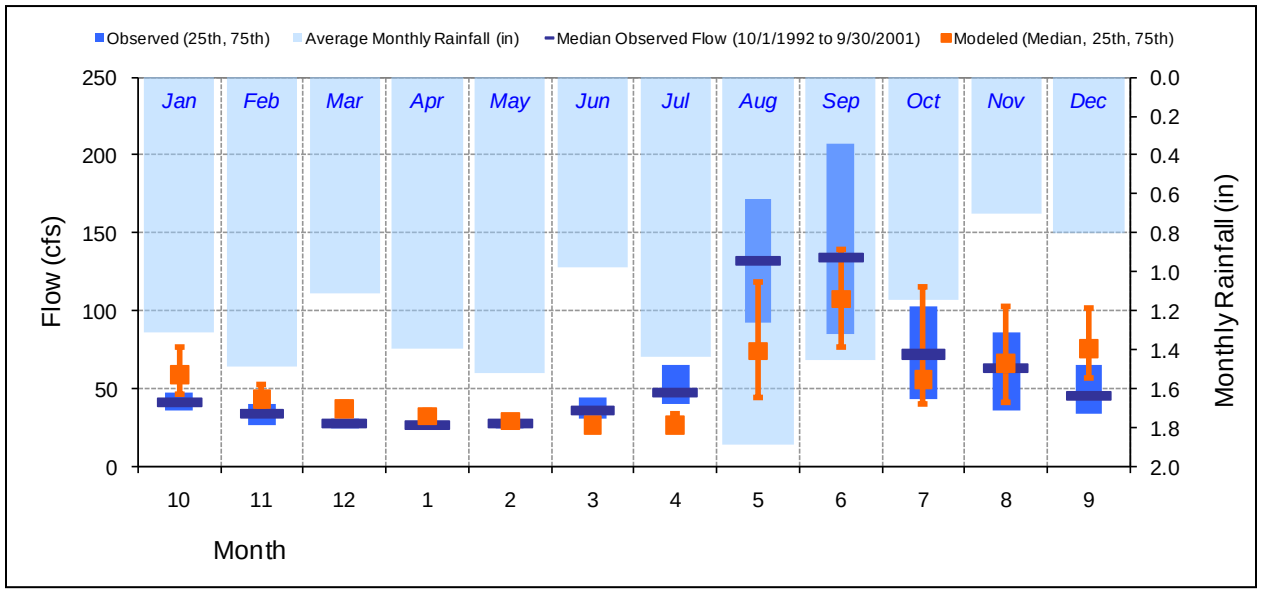

Figure 6. Seasonal medians and ranges at USGS 08227000 Saguache Creek near Saguache, CO - calibration period

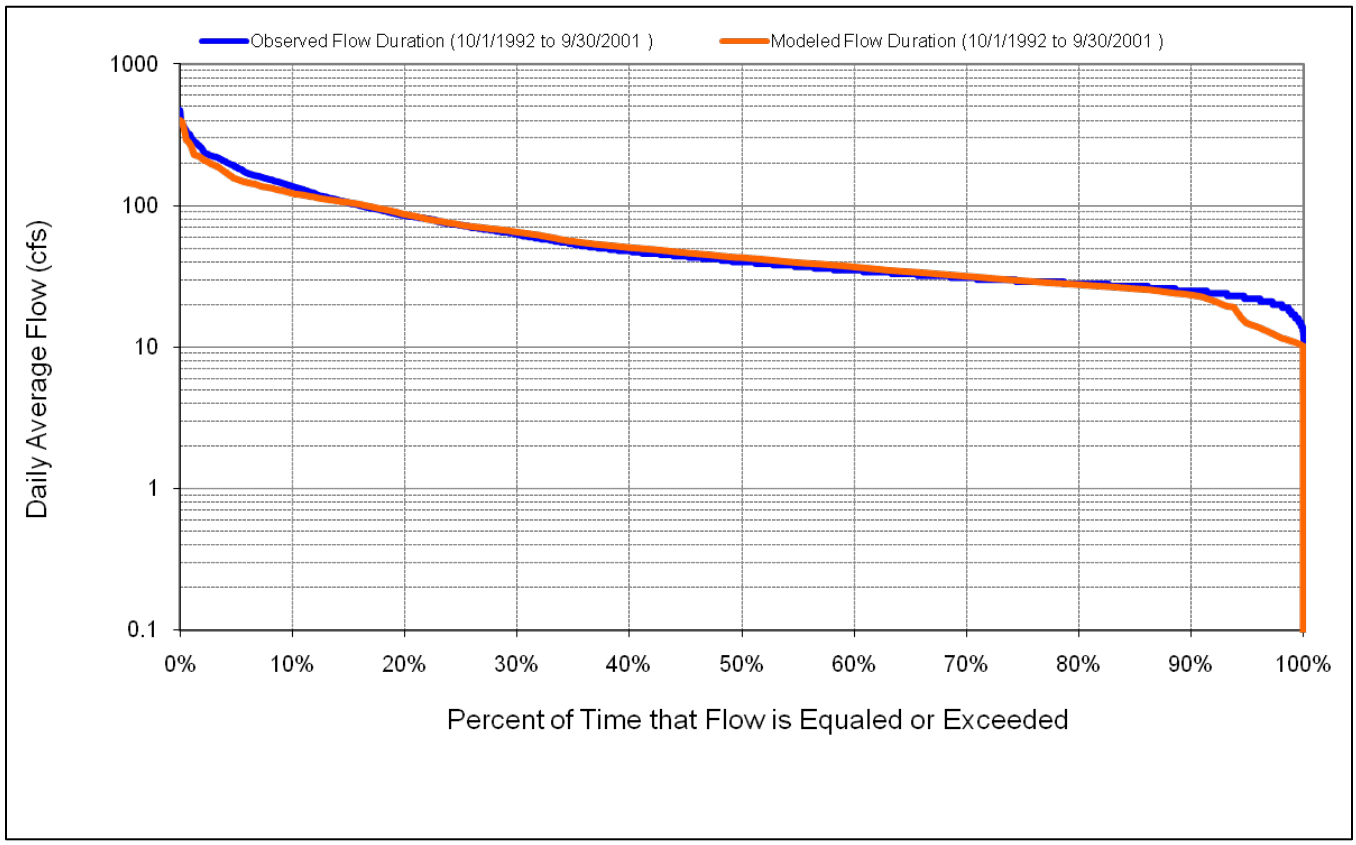

Figure 7. Flow exceedance at USGS 08227000 Saguache Creek near Saguache, CO - calibration period.

Table 6. Summary statistics USGS 08227000 Saguache Creek near Saguache, CO - calibration period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 49 9-Year Analysis Period: 10/1/1992 - 9/30/2001 Flow volumes are (inches/year) for upstream drainage area		USGS 08227000 SAGUACHE CREEK NEAR SAGUACHE, CO Hydrologic Unit Code: 13010004 Latitude: 38.16333294 Longitude: -106.2838 Drainage Area (sq-mi): 595	
Total Simulated In-stream Flow:	**1.38**	Total Observed In-stream Flow:	**1.45**
Total of simulated highest 10% flows:	**0.41**	Total of Observed highest 10% flows:	**0.48**
Total of Simulated lowest 50% flows:	**0.33**	Total of Observed Lowest 50% flows:	**0.34**
Simulated Summer Flow Volume (months 7-9):	**0.46**	Observed Summer Flow Volume (7-9):	**0.40**
Simulated Fall Flow Volume (months 10-12):	**0.28**	Observed Fall Flow Volume (10-12):	**0.20**
Simulated Winter Flow Volume (months 1-3):	**0.16**	Observed Winter Flow Volume (1-3):	**0.18**
Simulated Spring Flow Volume (months 4-6):	**0.48**	Observed Spring Flow Volume (4-6):	**0.67**
Total Simulated Storm Volume:	**0.08**	Total Observed Storm Volume:	**0.20**
Simulated Summer Storm Volume (7-9):	**0.03**	Observed Summer Storm Volume (7-9):	**0.06**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	-4.92	10	
Error in 50% lowest flows:	-2.42	10	
Error in 10% highest flows:	-14.20	15	
Seasonal volume error - Summer:	14.91	30	
Seasonal volume error - Fall:	**39.93** >>	**30**	Clear
Seasonal volume error - Winter:	-8.39	30	
Seasonal volume error - Spring:	-29.24	30	
Error in storm volumes:	**-60.14**	**20**	
Error in summer storm volumes:	-47.15	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.467	Model accuracy increases as E or E' approaches 1.0	
Baseline adjusted coefficient (Garrick), E':	0.336		
Monthly NSE	0.944		

Hydrology Validation

Hydrology validation for the Rio Grande basin was performed for the period 10/1/1973 through 9/30/1982 at the Saguache Creek USGS station due to unavailability of data for 1983-1992. The validation period for the other stations was 1983-1992. Results are presented in Figure 8, Figure 9, Figure 10, Figure 11, and Table 7.

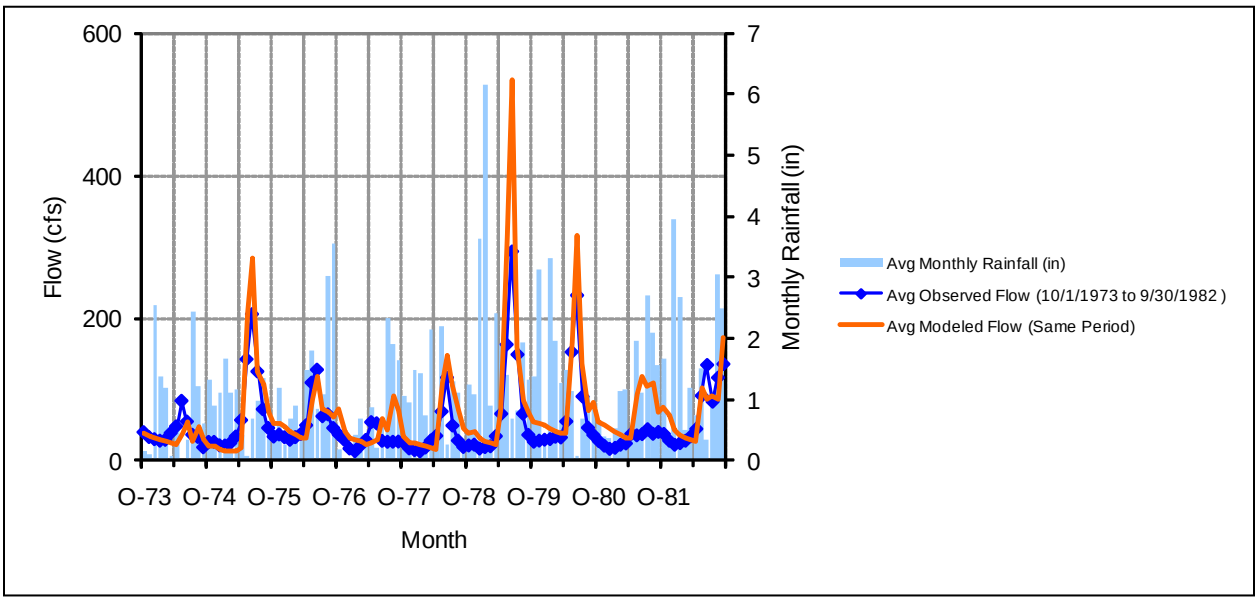

Figure 8. Mean monthly flow at USGS 08227000 Saguache Creek near Saguache, CO - validation period.

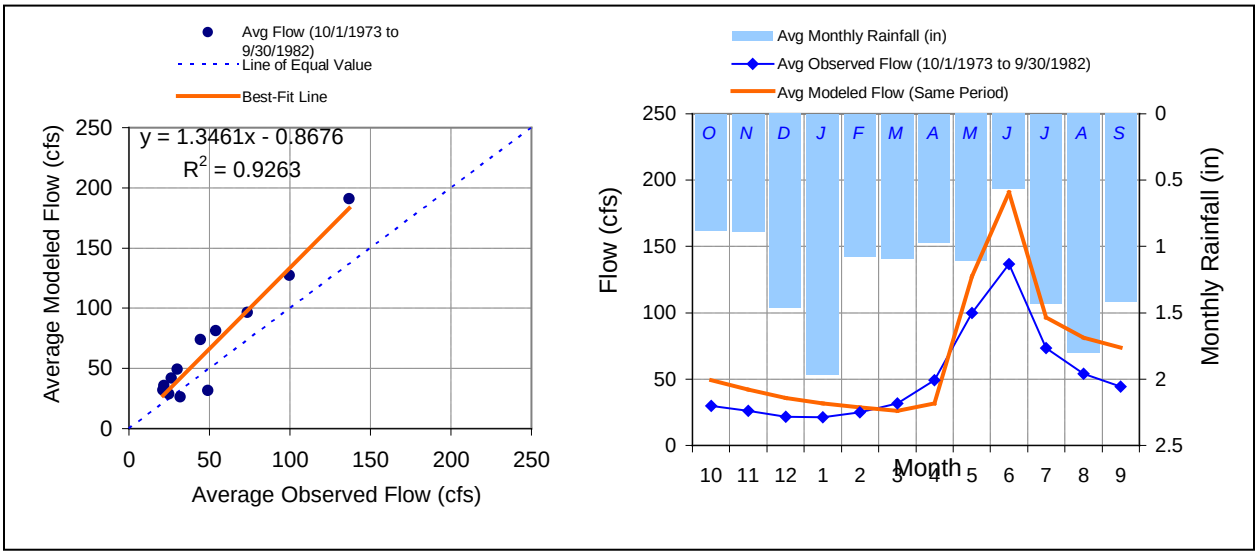

Figure 9. Seasonal regression and temporal aggregate at USGS 08227000 Saguache Creek near Saguache, CO - validation period.

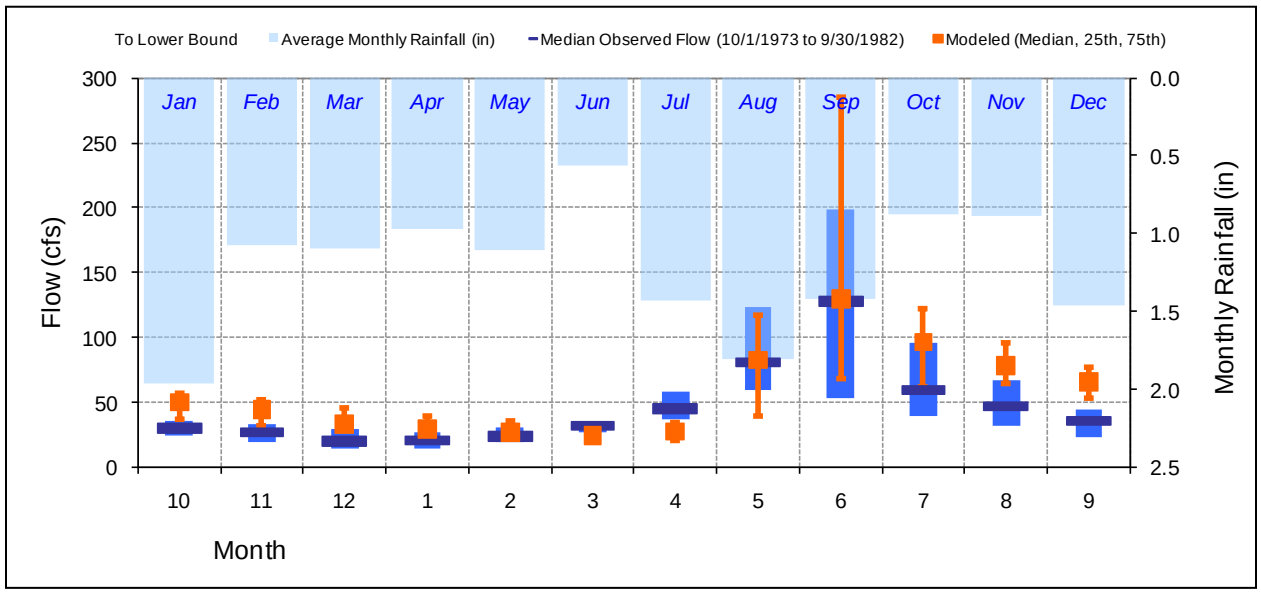

Figure 10. Seasonal medians and ranges at USGS 08227000 Saguache Creek near Saguache, CO - validation period.

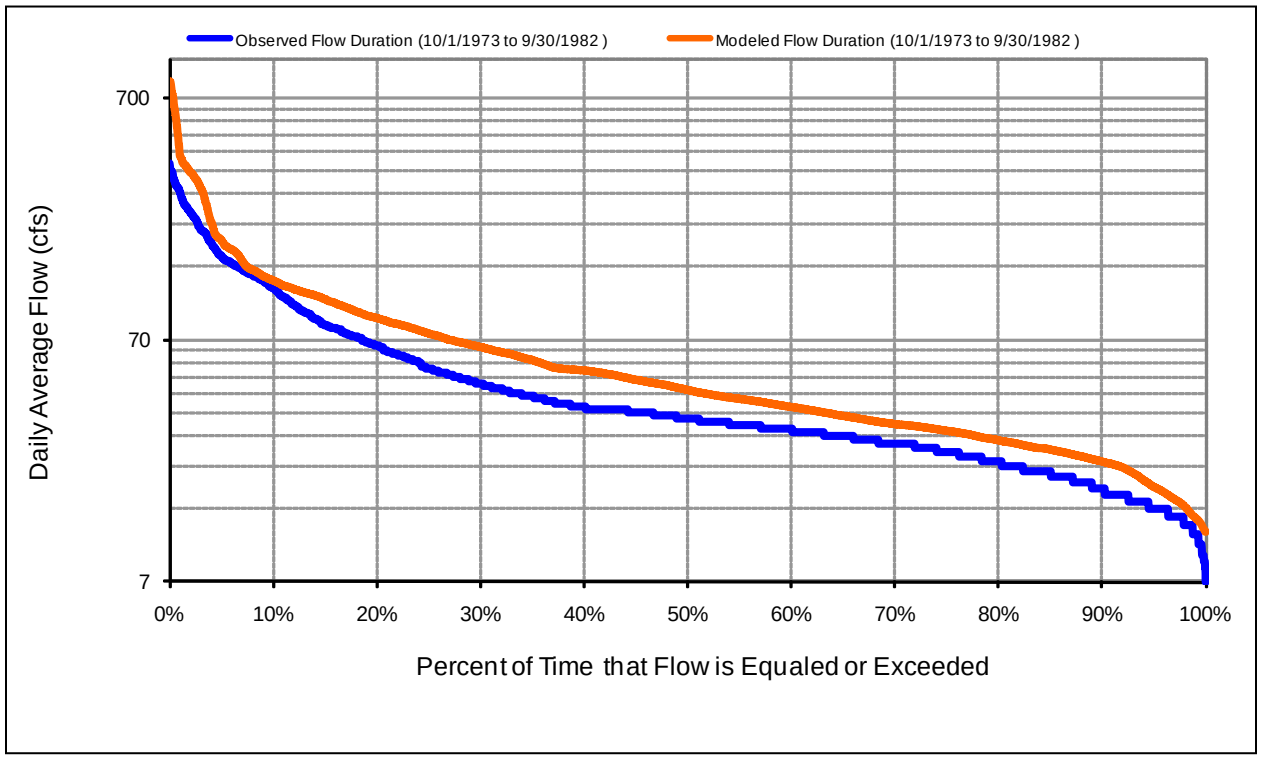

Figure 11. Flow exceedence at USGS 08227000 Saguache Creek near Saguache, CO - validation period.

Table 7. Summary statistics at USGS 08227000 Saguache Creek near Saguache, CO – validation period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 49 9-Year Analysis Period: 10/1/1973 - 9/30/1982 Flow volumes are (inches/year) for upstream drainage area		USGS 08227000 SAGUACHE CREEK NEAR SAGUACHE, CO Hydrologic Unit Code: 13010004 Latitude: 38.16333294 Longitude: -106.2838 Drainage Area (sq-mi): 595	
Total Simulated In-stream Flow:	**1.55**	Total Observed In-stream Flow:	**1.17**
Total of simulated highest 10% flows:	**0.57**	Total of Observed highest 10% flows:	**0.41**
Total of Simulated lowest 50% flows:	**0.33**	Total of Observed Lowest 50% flows:	**0.27**
Simulated Summer Flow Volume (months 7-9):	**0.48**	Observed Summer Flow Volume (7-9):	**0.33**
Simulated Fall Flow Volume (months 10-12):	**0.24**	Observed Fall Flow Volume (10-12):	**0.15**
Simulated Winter Flow Volume (months 1-3):	**0.16**	Observed Winter Flow Volume (1-3):	**0.15**
Simulated Spring Flow Volume (months 4-6):	**0.66**	Observed Spring Flow Volume (4-6):	**0.54**
Total Simulated Storm Volume:	**0.10**	Total Observed Storm Volume:	**0.15**
Simulated Summer Storm Volume (7-9):	**0.03**	Observed Summer Storm Volume (7-9):	**0.05**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	**32.99**	**10**	
Error in 50% lowest flows:	**25.16**	**10**	
Error in 10% highest flows:	**38.45**	**15**	
Seasonal volume error - Summer:	**46.11**	**30**	
Seasonal volume error - Fall:	**63.28**	**30**	
Seasonal volume error - Winter:	11.01	30	
Seasonal volume error - Spring:	22.61	30	
Error in storm volumes:	**-34.14**	**20**	
Error in summer storm volumes:	-46.45	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.071	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.159	as E or E' approaches 1.0	
Monthly NSE	0.943918282		

Hydrology Results for Larger Watershed

As described above, parameters determined for the Saguache Creek gage were fully transferable to other gages in the watershed. In addition, calibration and validation was pursued at a total of 5 gages throughout the watershed. Calibration results acceptable at most gages with decent monthly Nash Sutcliffe efficiency (NSE) (Table 8). The daily NSE for most of the stations was not good due to the presence of major reservoirs on the main stem and also due to the complex interaction between surface water and groundwater in this region. Results of the validation exercise are summarized in Table 9.

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

Station	Saguache Creek near Saguache CO 08227000	Rio Grande near Lobatos, NM 08251500	Rio Grande near Taos, NM 08276500	Rio Grande at Otowi Bridge, NM 08313000	Rio Grande at Albuquerque 08330000
Error in total volume:	-4.92	26.41	0.58	-32.08	-6.06
Error in 50% lowest flows:	-2.42	121.00	36.50	-12.26	38.00
Error in 10% highest flows:	-14.20	-27.38	-44.58	-61.45	-55.65
Seasonal volume error - Summer:	14.91	140.32	59.47	-12.41	40.71
Seasonal volume error - Fall:	39.93	137.69	91.40	56.44	89.73
Seasonal volume error - Winter:	-8.39	-20.45	-20.57	-18.20	9.78
Seasonal volume error - Spring:	-29.24	-41.03	-50.51	-74.12	-62.19
Error in storm volumes:	-60.14	-76.95	-80.60	-85.08	-73.33
Error in summer storm volumes:	-47.15	-60.47	-73.62	-81.09	-60.36
Nash-Sutcliffe Coefficient of Efficiency, E:	0.47	-0.29	-0.08	-0.29	-0.11
Baseline adjusted coefficient (Garrick), E':	0.34	-0.26	-0.09	-0.04	-0.07
Monthly NSE	0.94	0.43	0.42	0.25	0.34

Table 9. Summary statistics: all stations - validation period

Station	Saguache Creek near Saguache, CO 08227000	Rio Grande near Lobatos, NM 08251500	Rio Grande near Taos, NM 08276500	Rio Grande at Otowi Bridge, NM 08313000	Rio Grande at Albuquerque 08330000
Error in total volume:	32.99	20.30	1.51	-30.04	-2.77
Error in 50% lowest flows:	25.16	160.26	62.77	7.42	93.64
Error in 10% highest flows:	38.45	-53.82	-57.80	-64.33	-47.39
Seasonal volume error - Summer:	46.11	354.31	140.26	29.36	50.54
Seasonal volume error - Fall:	63.28	150.71	112.77	69.62	132.95
Seasonal volume error - Winter:	11.01	-11.36	-13.42	-27.66	-7.73
Seasonal volume error - Spring:	22.61	-57.22	-58.06	-75.28	-61.01
Error in storm volumes:	-34.14	-80.42	-80.47	-85.28	-76.43
Error in summer storm volumes:	-46.45	-69.42	-73.25	-85.39	-76.27
Nash-Sutcliffe Coefficient of Efficiency, E:	0.07	-0.17	-0.12	-0.29	-0.23
Baseline adjusted coefficient (Garrick), E':	0.16	-0.25	-0.13	0.00	-0.09
Monthly NSE	0.94	0.18	0.23	0.18	0.25

Water Quality Calibration and Validation

Initial calibration and validation of water quality was done at the Rio Grande near Taos, NM (USGS 08276500) using 1985-2003 for calibration and 1973-1984 for validation. As with hydrology, 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)
- SPEXP (exponent parameter for calculating sediment reentrained during channel sediment routing)

Simulated and estimated sediment loads at the Rio Grande near Taos (USGS 08276500) 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 the table is the relative percent error, which shows the error in the prediction of monthly load normalized to the estimated load. The table 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.

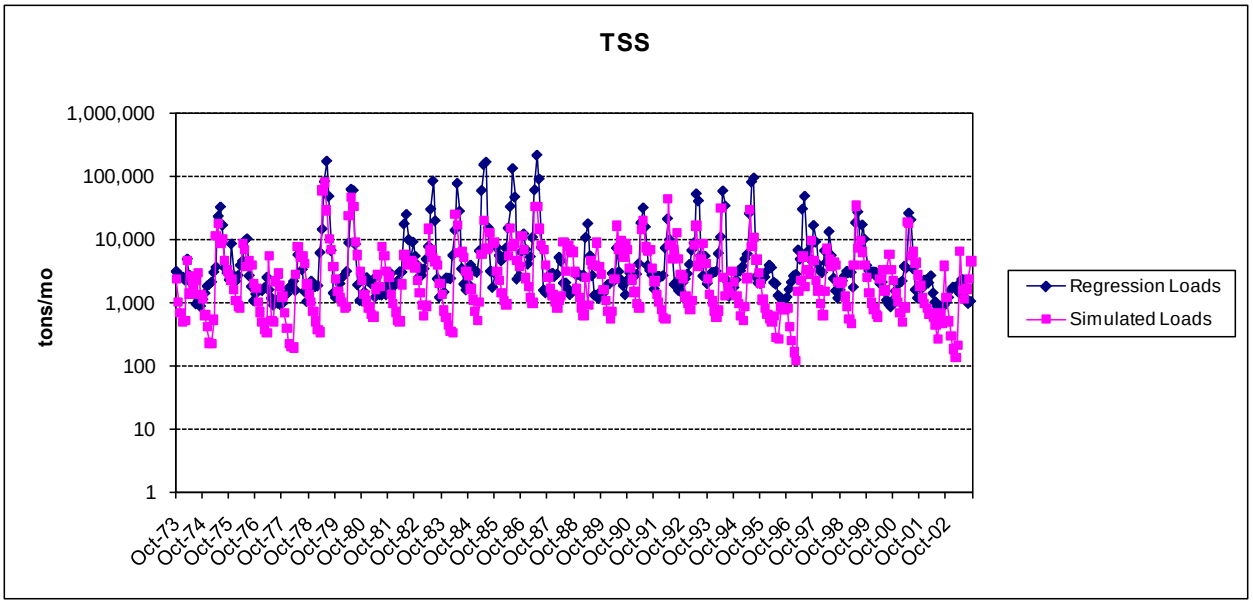

Figure 12. Fit for monthly load of TSS at USGS 08276500 Rio Grande near Taos, NM.

Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 08276500 Rio Grande near Taos, NM

Statistic	Calibration period (1985-2001)	Validation period (1972-1984)
Relative Percent Error	57.3%	41%
Relative Average Absolute Error	82%	69%
Relative Median Absolute Error	22.1%	19.7%

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.

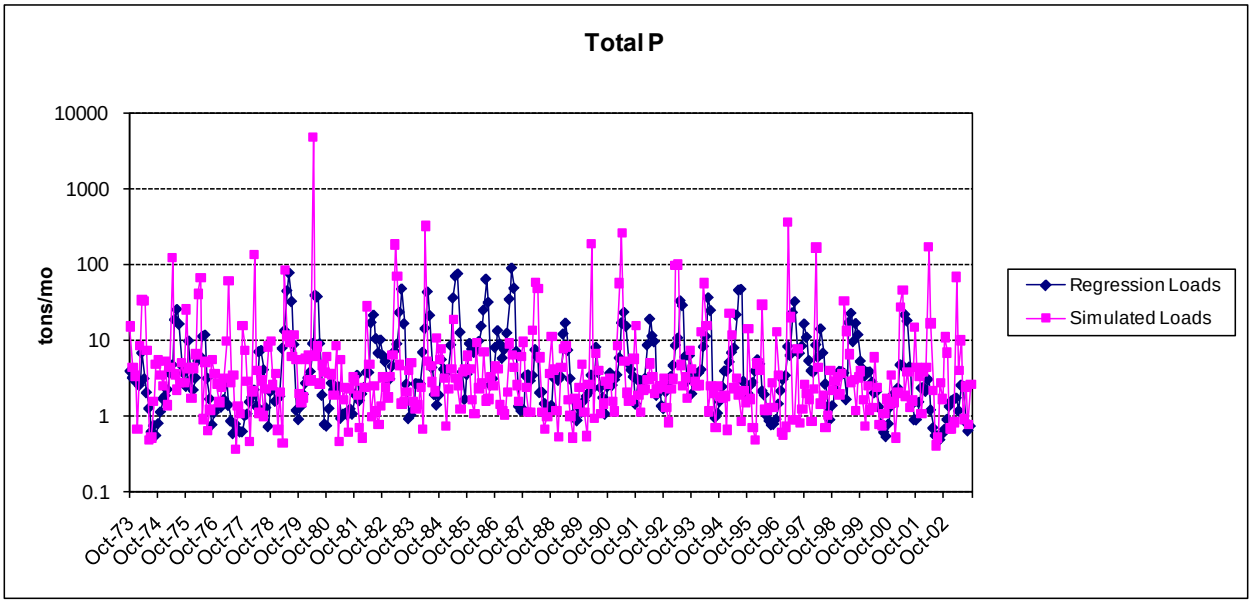

Figure 13. Fit for monthly load of total phosphorus at USGS 08276500 Rio Grande near Taos, NM.

Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 08276500 Rio Grande near Taos, NM

Statistic	Calibration period (1985-2003)	Validation period (1973-1984)
Relative Percent Error	-46.9%	-653.98%
Average Absolute Error	180%	773%
Median Absolute Error	32.1%	45%

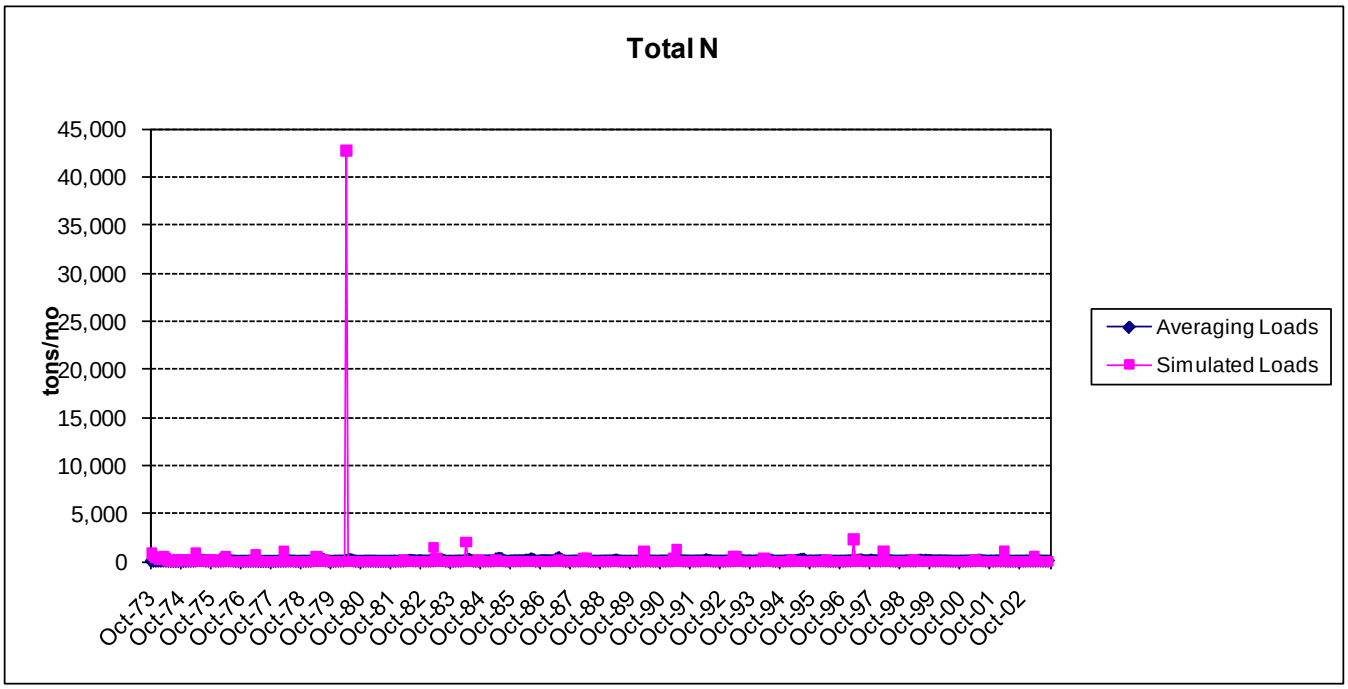

Figure 14. Fit for monthly load of total nitrogen at USGS 08276500 Rio Grande near Taos, NM.

Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 08276500 Rio Grande near Taos, NM

Statistic	Calibration period (1985-2003)	Validation period (1973-1984)
Relative Percent Error	-28.3%	-909.1%
Average Absolute Error	155%	996%
Median Absolute Error	46.6%	58.5%

Water Quality Results for Larger Watershed

As with hydrology, the SWAT model parameters used to calibrate at the USGS 08276500 Rio Grande near Taos, NM 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 1985-2003

Station	Saguache Creek near Saguache, CO 08227000	Rio Grande near Lobatos, NM 08251500	Rio Grande near Taos, NM 08276500	Rio Grande at Otowi Bridge, NM 08313000	Rio Grande at Albuquerque 08330000
Relative Percent Error TSS Load	20.2%	55.0%	57.3%	98.1%	95.6%
Relative Percent Error TP Load	93.0%	-198.0%	-46.9%	42.2%	-85.1%
Relative Percent Error TN Load	77.8%	-193.6%	-28.3%	30.4%	-41.3%

Table 14. Summary statistics for water quality at all stations – validation period 1973-1984

Station	Saguache Creek near Saguache, CO 08227000	RioGrande near Lobatos, NM 08251500	RioGrande near Taos, NM 08276500	RioGrande at Otowi Bridge, NM 08313000	RioGrande at Albuquerque 08330000
Relative Percent Error TSS Load	-63.9%	55.6%	41.0%	97.6%	94.1%
Relative Percent Error TP Load	86.80%	-708.19%	-653.98%	-151.77%	9.41%
Relative Percent Error TN Load	44.1%	-1093.7%	-909.1%	-411.8%	-26.7%

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