Appendix N
Model Configuration, Calibration and Validation

Basin: Illinois River (Illin)

Contents

Watershed Background **N-4**
Water Body Characteristics N-4
Soil Characteristics N-7
Land Use Representation N-7
Point Sources N-11
Meteorological Data N-14
Watershed Segmentation N-16
Calibration Data and Locations N-18
SWAT Modeling **N-19**
Assumptions N-19
Hydrology Calibration N-19
Hydrology Validation N-23
Hydrology Results for Larger Watershed N-26
Water Quality Calibration and Validation N-28
Water Quality Results for Larger Watershed N-31
References **N-33**

Tables

Table 1. Aggregation of NLCD land cover classes N-9
Table 2. Land use distribution for the Illinois River basin (2001 NLCD) (mi^2) N-10
Table 3. Major point source discharges in the Illinois River basin N-11
Table 4. Precipitation stations for the Illinois River basin model N-15
Table 5. Calibration and validation locations in the Illinois River basin N-18
Table 6. Summary statistics at USGS 05526000 Iroquois River near Chebanse, IL - calibration period N-23
Table 7. Summary statistics at USGS 05526000 Iroquois River near Chebanse, IL - validation period N-26
Table 8. Summary statistics (percent error): all stations - calibration period N-27
Table 9. Summary statistics: all stations - validation period N-28
Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 05526000 Iroquois River near Chebanse, IL N-30
Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 05526000 Iroquois River near Chebanse, IL N-31
Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 05526000 Iroquois River near Chebanse, IL N-31
Table 13. Summary statistics for water quality at all stations – calibration period 1985-2001 (unless otherwise noted) N-32
Table 14. Summary statistics for water quality at all stations – validation period 1978-1984 (unless otherwise noted) N-32

Figures

Figure 1. Location of the Illinois River basin. N-6
Figure 2. Land use in the Illinois River basin. N-8
Figure 3. Model segmentation and USGS stations utilized for the Illinois River basin. N-17
Figure 4. Mean monthly flow at USGS 05526000 Iroquois River near Chebanse, IL– calibration period. N-21
Figure 5. Seasonal regression and temporal aggregate at USGS 05526000 Iroquois River near Chebanse, IL - calibration period. N-21
Figure 6. Seasonal medians and ranges at USGS 05526000 Iroquois River near Chebanse, IL – calibration period. N-22
Figure 7. Flow exceedance at USGS 05526000 Iroquois River near Chebanse - calibration period. N-22
Figure 8. Mean monthly flow at USGS 05526000 Iroquois River near Chebanse, IL – validation period. N-24
Figure 9. Seasonal regression and temporal aggregate at USGS 05526000 Iroquois River near Chebanse, IL - validation period. N-24
Figure 10. Seasonal medians and ranges at USGS 05526000 Iroquois River near Chebanse, IL – validation period. N-25
Figure 11. Flow exceedance at USGS 05526000 Iroquois River near Chebanse, IL - validation period... N-25
Figure 12. Fit for monthly load of TSS at USGS 05526000 Iroquois River near Chebanse, IL. N-29
Figure 13. Fit for monthly load of total phosphorus at USGS 05526000 Iroquois River near Chebanse, IL. N-30
Figure 14. Fit for monthly load of total nitrogen at USGS 05526000 Iroquois River near Chebanse, IL.. N-31

Watershed Background

The Illinois River basin study area 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. The majority of the Illinois River basin lies in the state of Illinois except small portions extending into Wisconsin and Indiana. The Illinois River basin is comprised of 12 HUC8 cataloging units.

Water Body Characteristics

The Illinois River is approximately 273 miles in length and is one of the major tributaries to the Mississippi River. The Illinois River joins the Mississippi River near Grafton, IL, about 20 miles upstream from the confluence of the Missouri and the Mississippi rivers. This study addresses the upper portion of the basin (Figure 1), which has a drainage area of 17,004 mi^2 (44,040 km^2) and includes eleven HUC8s within HUC 0712 and HUC 0713 (Figure 1).

Within the upper portion of the basin (HUC 0712), over 80 percent of the land area is classified as part of the Central Corn Belt Plains ecoregion. With the exception of the Chicago metropolitan area, land use in the Central Corn Belt Plains is mostly corn and soybean cultivation for livestock feed crops and some livestock production. The flat topography of the lower portion of the basin (HUC 0713) is in the Till Plains Section of the Central Lowland physiographic province. The altitude of the land surface ranges from 600 to 800 ft above sea level. The area of greatest topographic relief is along the river valley, where topographic relief can range from 200 to 400 ft. The majority of the basin is extremely flat with less than 20 ft of relief.

Agriculture accounts for about 66 percent of the land use in the study area. Most of the recent urbanization is the result of development of new suburban and residential areas. Urban areas account for about 18 percent of the land use in the basin and are mainly concentrated in the metropolitan areas in and around Chicago. Forests cover about 10 percent of the study area and are concentrated along large-stream riparian areas.

Wetlands now make up a relatively small amount (1 percent) of land cover, but were once a major feature of the basin. The majority of wetlands in the basin were drained prior to the 1850's for the development of farmland. Remaining wetlands in the basin are mainly in riparian areas.

The climate of the Illinois River basin is classified as humid continental because of the cool, dry winters and warm, humid summers. The average annual temperature for the Illinois River basin ranges from 46° F in the north of the basin to 55° F in the south of the study area. Lake Michigan has a moderating effect on temperature near the shoreline. Average annual precipitation, including snowfall, ranges from less than 32 inches in the northern Wisconsin part of the basin to more than 38 inches near the southern and eastern Lake Michigan shoreline in the Indiana part of the basin.

Streamflow in the study area consists of overland flow, groundwater discharge, agricultural drainage, and point-source return flow. Local flooding generally is caused by isolated thunderstorms, whereas widespread flooding is caused by more extensive thunderstorms that cover a wide area, by rapid snowmelt in the spring, or by a combination of these factors. Flooding is common in the basin, in some years resulting in significant loss of life and property.

The Illinois River connects Great Lakes at Chicago to the Mississippi River via the Illinois Waterway System. It is also an important part of the Great Loop (the circumnavigation of Eastern North America by water). Originally the Illinois and Michigan canal, opened in 1849, connected the Illinois River to the Chicago River. Later, the Sanitary District of Chicago replaced the canal with the Chicago Sanitary and Shipping Canal and also reversed

the flow of the Chicago River, originally flowing into Lake Michigan. Now, the Chicago Sanitary and Shipping Canal is part of the Illinois Waterway. The Illinois Waterway System is a system of rivers, lakes, and canals that provides shipping connection from the Great Lakes to the Gulf of Mexico via the Mississippi River. It consists of 336 miles (541 km) of water from the mouth of the Calumet River to the mouth of the Illinois River at Grafton, IL. River traffic and flood control is managed by eight locks and dams operated by the Army Corps of Engineers. The upper lock, T.J. O'Brien, is 7 miles from Lake Michigan on the Calumet River and the last lock is 90 miles (140 km) upstream of the Mississippi River at the LaGrange lock and dam.

The watershed does not contain major reservoirs. However, there are a number of smaller lakes and reservoirs that influence flow in this low gradient terrain. The river system in the Illinois River basin is highly manipulated by human intervention including the reversal of the Chicago River and the massive Illinois Waterway. The river flow and barge traffic is controlled by a series of lock and dams. Additional flow from Lake Michigan was not considered in the model. Irrigation and groundwater pumping in the watershed are generally small and, therefore, not included for the purposes of the 20 Watershed model.

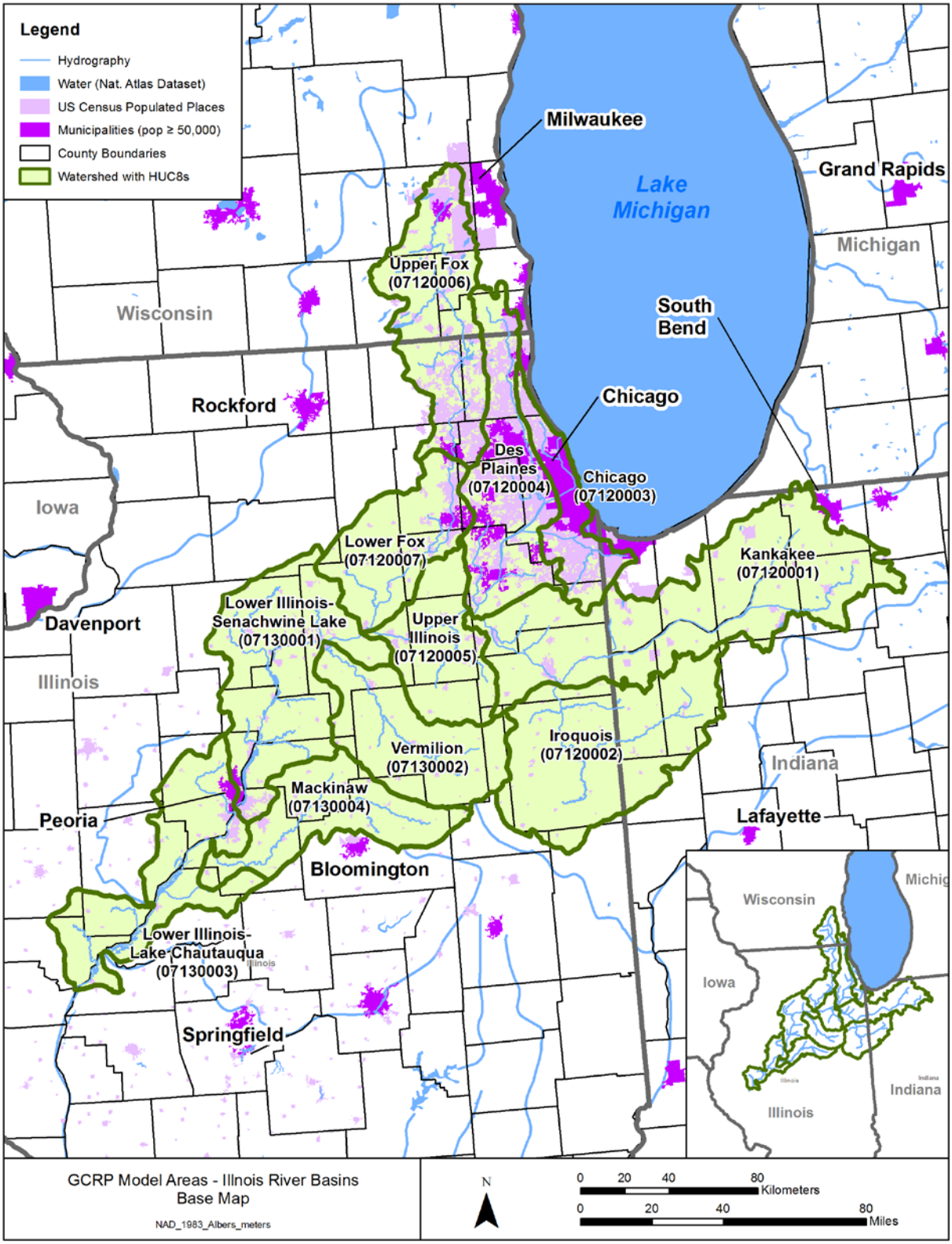

Figure 1. Location of the Illinois River basin.

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 C (moderately high runoff potential). 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 row crop agriculture (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 STATSGO soils. The distribution of land use in the watershed is summarized in Table 2.

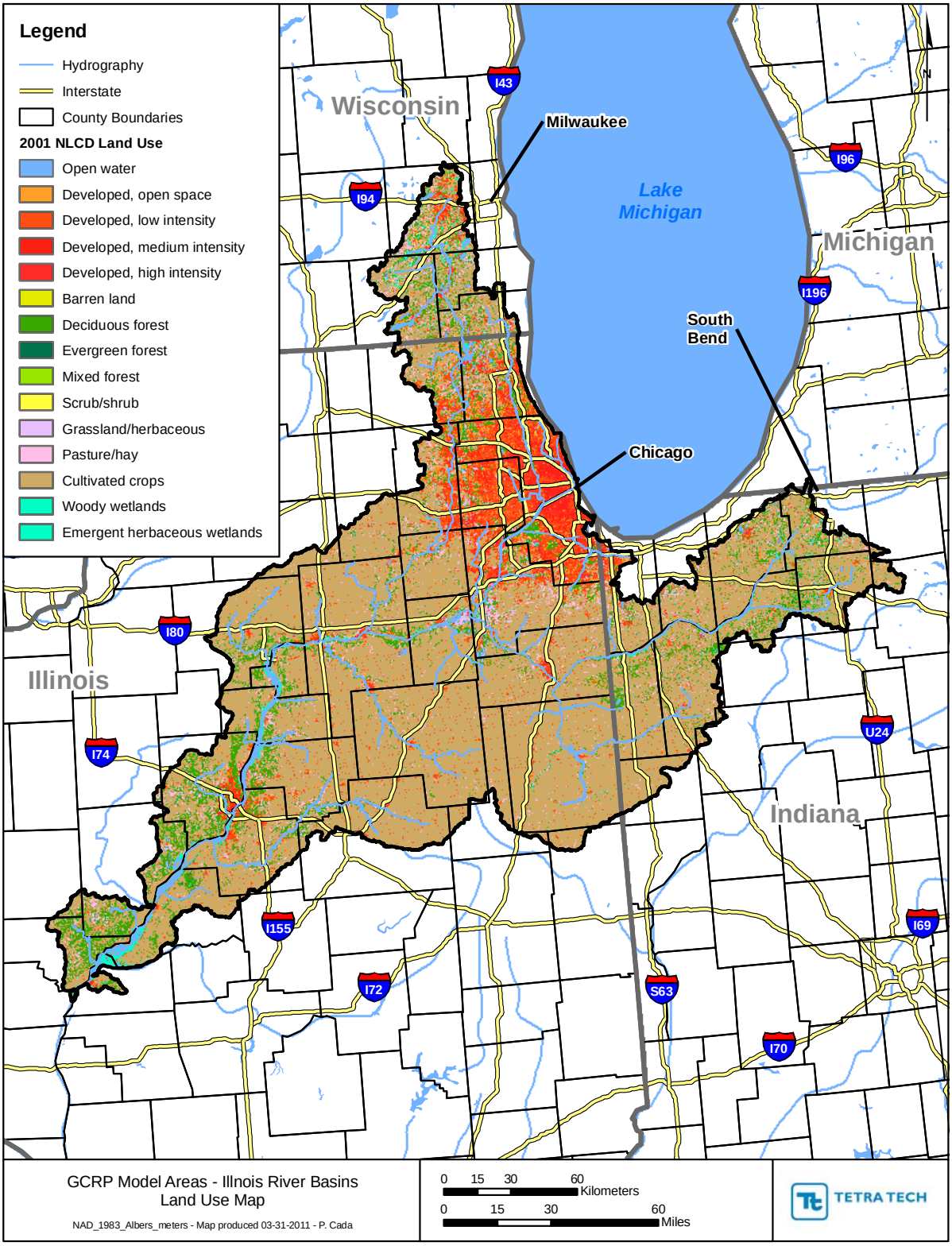

Figure 2. Land use in the Illinois River basin.

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 Illinois River basin (2001 NLCD) (mi^2)

HUC 8 watershed	Open water	Developed[a]				Barren land	Forest	Shrubland/ Grassland	Pasture/ Hay	Cultivated	Wetland	Total
		Open space	Low density	Medium density	High density							
Kankakee **07120001**	28.6	114.1	133.0	21.7	7.7	1.1	329.9	95.8	108.3	2,013.6	46.6	**2,900.4**
Iroquois **07120002**	6.7	76.2	60.1	4.9	1.4	0.8	86.9	7.8	42.6	1,837.2	12.4	**2,136.9**
Chicago **07120003**	8.7	67.7	238.1	175.2	87.3	1.2	60.9	29.4	4.1	32.2	0.9	**705.9**
Des Plaines **07120004**	27.1	166.8	414.4	174.0	81.2	2.0	145.2	76.4	26.0	258.3	9.9	**1,381.3**
Upper Illinois **07120005**	23.7	43.8	42.5	6.7	2.5	1.1	66.3	27.6	14.2	900.3	6.0	**1,134.8**
Upper Fox **07120006**	73.3	150.2	187.8	49.1	14.9	4.3	285.5	63.9	135.4	536.0	43.7	**1,544.1**
Lower Fox **07120007**	9.7	70.3	103.9	30.2	8.9	1.7	69.9	30.2	38.5	739.1	0.8	**1,103.1**
Lower Illinois-Senachwine Lake **07130001**	65.9	84.1	76.3	20.8	7.9	2.4	228.2	15.5	70.3	1,353.6	41.0	**1,966.0**
Vermilion **07130002**	4.4	42.8	47.9	6.2	1.5	1.6	29.5	6.6	20.4	1,171.0	1.3	**1,333.1**
Lower Illinois-Lake Chautauqua **07130003**	64.3	63.4	70.9	21.5	4.5	0.7	376.2	4.7	97.8	866.0	79.4	**1,649.4**
Mackinaw **07130004**	4.6	44.7	41.5	7.5	1.8	0.2	66.4	2.2	47.7	929.5	3.0	**1,149.1**
Total	**317.0**	**924.1**	**1,416.3**	**517.9**	**219.5**	**17.1**	**1,745.1**	**360.1**	**605.2**	**10,636.9**	**245.0**	**17,004.1**

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (8.83%), low density (32.36%), medium density (61.24%), and high density (88.70%).

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 Illinois River basin

NPDES ID	Name	Design flow (MGD)	Observed flow (MGD) (1991-2006 average)
IL0025135	BEARDSTOWN SD STP	1.13	1.31
IL0001830	CATERPILLAR INC.-MAPLETON	14.15	0.89
IL0027839	CANTON WEST STP	3.43	2.5284
IL0001953	AVENTINE RENEWABLE ENERGY	34.09	0.54
IL0001970	AMEREN ENERGY RESOURCES-EDWARD	357.90	5.06
IL0002232	MIDWEST GENERATION-POWERTON	530.10	11.13
IL0002526	KEYSTONE STEEL AND WIRE	10.12	5.06
IL0034495	PEKIN STP #1	4.50	3.43
IL0001414	CATERPILLAR INC-MOSSVILLE	1.44	0.86
IL0002291	CATERPILLAR INC.-EAST PEORIA	3.10	2.18
IL0021288	PEORIA SD STP	37.00	22.97
IL0028576	EAST PEORIA STP #1	4.22	3.85
IL0042412	WASHINGTON STP #2	1.50	2.02
IL0046213	EAST PEORIA STP #3	1.20	0.18
IL0001392	EMERALD PERFORMANCE MATERIALS	0.95	0.78
IL0002631	ARCELORMITTAL HENNEPIN INC	7.25	3.05
IL0029424	LASALLE STP	3.33	1.40
IL0030660	PERU STP #1	3.00	5.68
IL0031216	SPRING VALLEY STP	1.10	0.86
IL0030384	OTTAWA STP	4.00	2.84
IL0023221	MENDOTA STP	2.40	0.98
IL0022004	STREATOR STP	3.30	3.44
IL0030457	PONTIAC STP	3.50	2.97
IL0021059	MARSEILLES WWTP	1.23	1.04
IL0048151	EXELON GENERATION CO, LLC	35.02	0.04
IL0048321	EXELON GENERATION-BRAIDWOOD	22.85	0.15
IL0002917	EQUISTAR CHEMICALS, LP	6.47	2.38
IL0021113	MORRIS STP	2.50	2.13
IL0002224	EXELON GENERATION CO.,LLC	481.10	0.15
IL0021130	BLOOMINGDALE-REEVES WRF	3.45	2.20
IL0021547	GLENBARD WASTEWATER AUTH-MAIN	16.02	14.16
IL0023469	WEST CHICAGO REGIONAL STP	7.64	4.55
IL0026352	CAROL STREAM WRC	6.50	4.61

NPDES ID	Name	Design flow (MGD)	Observed flow (MGD) (1991-2006 average)
IL0027618	BARTLETT WWTP	3.68	2.30
IL0028967	GLENDALE HEIGHTS STP	5.26	3.31
IL0031739	WHEATON SD WWTF	8.90	5.99
IL0032735	BOLINGBROOK WRF #2	3.00	2.85
IL0034061	NAPERVILLE SPRINGBROOK WRC	26.25	16.03
IL0034479	HANOVER PARK STP #1	2.42	1.15
IL0036137	MWRDGC HANOVER PARK WRP	12.00	9.22
IL0048721	ROSELLE-J BOTTERMAN STP	1.22	0.78
IL0055913	MINOOKA STP	1.09	0.42
IL0074373	PLAINFIELD NORTH STP	3.50	2.28
IL0001619	INEOS NOVA LLC	0.12	0.08
IL0001643	BP AMOCO CHEMICAL-JOLIET	2.32	1.15
IL0001732	CATERPILLAR, INC.-JOLIET	2.12	0.36
IL0002216	MIDWEST GENERATION,LLC-JOLIET9	398.70	8.55
IL0002453	STEPAN COMPANY-ELWOOD	0.88	0.67
IL0002861	EXXONMOBIL OIL-JOLIET REFINERY	15.50	2.84
IL0033553	JOLIET WEST STP	14.00	10.91
IL0020532	FRANKFORT WEST WWTP	1.30	1.04
IL0020559	NEW LENOX STP #1	2.52	1.70
IL0024201	MOKENA STP	2.50	1.47
IL0045403	FRANKFORT NORTH STP	1.35	0.92
IL0001589	CITGO PETROLEUM CORPORATION	5.82	4.18
IL0022519	JOLIET EAST STP	18.20	18.02
IL0022586	FLAGG CREEK WRD MCELWAIN STP	12.00	12.11
IL0029611	LOCKPORT STP	3.40	3.64
IL0032760	IL AMERICAN WATER-SANTA FE	1.00	0.32
IL0025089	MANTENO WPCC	1.15	1.37
IL0021784	KANKAKEE RIVER METRO AGENCY	25.00	12.50
IL0022179	MOMENCE STP	1.60	1.04
IL0022161	WATSEKA STP	1.60	0.84
IN0023621	LOWELL MUNICIPAL STP	4.00	259.50
IN0037176	TWIN LAKES UTILITIES, INC WWTP	1.10	0.86
IN0030651	SOUTH HAVEN SEWER WORKS, INC.	2.00	1.03
IN0020991	PLYMOUTH MUNICIPAL STP	3.50	2.15
IN0025577	LAPORTE MUNICIPAL STP	7.00	5.40
IN0038172	ROLL COATER, INC.	0.14	0.07
IN0024520	SOUTH BEND MUNICIPAL STP	37.70	40.13
IN0020427	BREMEN MUNICIPAL WWTP	1.30	0.91
IN0021466	NAPPANEE MUNICIPAL STP	1.9	1.55

NPDES ID	Name	Design flow (MGD)	Observed flow (MGD) (1991-2006 average)
IL0030970	SANDWICH STP	1.50	0.64
IL0036412	YORKVILLE-BRISTOL SD STP	3.62	1.26
IL0062260	ELBURN STP	1.27	0.55
IL0020087	GENEVA STP	5.00	3.18
IL0022543	BATAVIA STP	4.20	2.98
IL0022705	ST. CHARLES EASTSIDE STP	9.00	4.41
IL0035891	FOX RIVER WRD WEST STP	5.00	1.20
IL0020583	FOX RIVER GROVE STP	1.25	0.80
IL0021733	LAKE IN THE HILLS SD STP	4.20	2.21
IL0023329	ALGONQUIN STP	3.00	2.31
IL0027944	CARPENTERSVILLE STP	4.50	2.50
IL0028282	CRYSTAL LAKE STP #2	5.80	4.01
IL0028541	EAST DUNDEE WWTP	2.30	0.37
IL0028657	FOX RIVER WRD SOUTH STP	25.00	15.62
IL0028665	FOX RIVER WRD NORTH STP	7.75	5.10
IL0001716	ROHM & HAAS CHEMICAL LLC	2.00	1.62
IL0020109	WAUCONDA STP	1.40	1.48
IL0020516	CARY STP	2.80	1.58
IL0021067	MCHENRY CENTRAL STP	3.00	2.06
IL0031933	NORTHERN MORAINE WW REC DIST	2.00	0.93
IL0053457	CRYSTAL LAKE STP #3	1.70	0.56
IL0066257	MCHENRY SOUTH WWTP	1.50	0.65
IL0031861	WOODSTOCK NORTH STP	3.50	2.20
IL0034282	WOODSTOCK SOUTH STP	1.75	1.02
IL0020354	ANTIOCH STP	1.60	1.46
IL0020958	FOX LAKE NW REGIONAL WRF	9.00	6.32
WI0022926	BURLINGTON WATER POLLUTION CON	2.50	3.01
WI0031496	SALEM UTILITY DISTRICT NO 2	1.57	0.89
WI0028291	UNION GROVE VILLAGE	1.00	0.91
WI0028754	WESTERN RACINE COUNTY SEWERAGE	0.92	0.95
WI0038938	TRENT TUBE DIV OF CRUCIBLE PLA	0.00	0.20
WI0020559	SUSSEX WASTEWATER TREATMENT FA	1.00	1.42
WI0023469	BROOKFIELD, CITY OF	10.00	7.52
WI0029971	WAUKESHA CITY	16.00	6.49
IL0020575	PRINCETON STP	2.15	1.82
IL0020061	WOOD DALE NORTH STP	1.97	1.83
IL0026280	ITASCA STP	2.60	2.01
IL0027367	ADDISON SOUTH-A.J. LAROCCA STP	3.20	1.95
IL0030953	SALT CREEK SD STP	3.30	3.01

NPDES ID	Name	Design flow (MGD)	Observed flow (MGD) (1991-2006 average)
IL0033812	ADDISON NORTH STP	5.30	3.58
IL0034274	WOOD DALE SOUTH STP	1.13	0.68
IL0036340	MWRDGC EGAN WRP	30.00	24.76
IL0022055	LCDPW-DES PLAINES STP	16.00	10.32
IL0022071	LCDPW-NEW CENTURY TOWN STP	6.00	2.48
IL0022501	MUNDELEIN STP	4.95	4.26
IL0020796	LINDENHURST SD STP	2.00	1.11
IL0035092	NSSD GURNEE STP	23.60	15.32
IL0071366	LAKE COUNTY DPW-MILL CREEK WRF	1.00	0.59
IL0002178	MIDWEST GENERATION,LLC-FISK	241.20	0.75
IL0002186	MIDWEST GENERATION,LLC-CRAWFRD	356.80	1.07
IL0002208	MIDWEST GENERATION,LLC-WILL CO	715.70	0.93
IL0028347	DEERFIELD WRF	3.50	3.02
IL0030171	NSSD CLAVEY ROAD STP	17.80	14.11
IL0028088	MWRDGC NORTHSIDE WRP	333.00	262.75
IL0028061	MWRDGC CALUMET WRP	354.00	266.94
IN0023060	HAMMOND MUNICIPAL STP	37.80	39.92
IN0024457	SCHERERVILLE MUNICIPAL STP	8.75	4.57
IN0039331	DYER MUNICIPAL WWTP	2.60	1.36
IL0024473	AQUA ILLINOIS-UNIV PARK	2.17	2.05
IL0027723	THORN CREEK BASIN SD STP	15.94	15.83

Most of these point sources have reasonably good monitoring for total phosphorus and total suspended solids (TSS), but not for total nitrogen. In many cases, only ammonia nitrogen is monitored. The point sources were initially represented in the model with the median of reported values for the constituents (total phosphorus, total nitrogen, and 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). However, in cases where point source contribution was deemed unusually high, average concentration of the available data was assumed for the missing ones.

Meteorological Data

The required meteorological time series 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 72 precipitation stations were identified for use in the Illinois River basin model with a common period of record of 10/1/1971-9/30/2001 (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 Illinois River basin model

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (ft)
471205	WI471205	42.6508	-88.2544	X	751
473058	WI473058	43.2390	-88.1222	X	850
474174	WI474174	42.5609	-87.8156	X	600
474457	WI474457	42.5937	-88.4347	X	846
475474	WI475474	43.0719	-88.0293	X	725
475479	WI475479	42.9550	-87.9043	X	669
478723	WI478723	42.6904	-88.0336		732
478937	WI478937	43.0064	-88.2492	X	830
479190	WI479190	42.8508	-88.7246	X	876
110203	IL110203	42.4811	-88.0994	X	751
110338	IL110338	41.7806	-88.3092	X	659
110442	IL110442	42.1153	-88.1638		876
110492	IL110492	40.0179	-90.4381		449
110583	IL110583	42.2551	-88.8644		738
110761	IL110761	40.4957	-89.0006		774
111250	IL111250	40.5447	-90.0211		650
111420	IL111420	41.3978	-88.2818		505
111475	IL111475	40.7407	-88.7128	X	709
111549	IL111549	41.9950	-87.9335	X	659
111577	IL111577	41.7373	-87.7775	X	620
111627	IL111627	40.9156	-89.5031		535
112011	IL112011	41.4492	-87.6222		663
112223	IL112223	41.9342	-88.7755	X	873
112736	IL112736	42.0629	-88.2861		764
112923	IL112923	40.7512	-88.4983		689
113413	IL113413	40.4732	-88.3653		751
113940	IL113940	40.3431	-90.0164	X	459
114013	IL114013	41.3017	-89.3157	X	459
114198	IL114198	40.4745	-87.6557	X	709
114530	IL114530	41.5034	-88.1028		545
114603	IL114603	41.1382	-87.8855		640
114710	IL114710	41.2484	-89.8991	X	781
114805	IL114805	41.0415	-89.4060	X	459
115272	IL115272	40.5526	-89.3336		709
115326	IL115326	42.2928	-88.6469	X	814
115334	IL115334	40.5019	-90.3892		640
115372	IL115372	41.3287	-88.7532		489
115413	IL115413	40.2018	-89.6949	X	574
115493	IL115493	42.3103	-88.2524		741
115712	IL115712	40.9126	-89.0339	X	751

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (ft)
116526	IL116526	41.3283	-88.9106	X	525
116616	IL116616	41.4933	-87.6800	X	709
116661	IL116661	41.7123	-88.9989	X	951
116711	IL116711	40.6675	-89.6838	X	650
116725	IL116725	41.3270	-87.7857		719
116753	IL116753	41.3503	-89.1072	X	620
116819	IL116819	40.7570	-88.1828	X	669
116910	IL116910	40.8854	-88.6389	X	650
117004	IL117004	40.9314	-89.7800	X	100000
117150	IL117150	40.3131	-88.1594	X	741
117551	IL117551	40.1159	-90.5608	X	659
118353	IL118353	41.0909	-88.8157		610
118756	IL118756	41.3242	-88.9857		459
118870	IL118870	39.9451	-90.2099		620
118916	IL118916	41.5520	-89.5989	X	689
119021	IL119021	40.7928	-87.7556	X	620
119029	IL119029	42.3493	-87.8828	X	699
119221	IL119221	41.8129	-88.0728	X	679
119816	IL119816	40.7765	-90.0203		676
123418	IN123418	41.5575	-85.8824	X	876
124527	IN124527	40.7592	-87.4352	X	696
124782	IN124782	41.5269	-86.2691		840
125174	IN125174	41.2647	-87.4177	X	666
125535	IN125535	41.1590	-86.9013		696
127298	IN127298	40.9357	-87.1564	X	650
127482	IN127482	41.0659	-86.2094	X	771
128187	IN128187	41.7073	-86.3331	X	774
128999	IN128999	41.5115	-87.0378	X	801
129222	IN129222	41.4437	-86.9300	X	735
129240	IN129240	41.2390	-85.8700	X	810
129511	IN129511	41.1947	-87.0578	X	666
129670	IN129670	41.0265	-86.5871	X	689

Watershed Segmentation

The Illinois River basin was divided into 100 subwatersheds for the purposes of modeling (Figure 3). The model encompasses the complete watershed without any external area draining into it and, therefore, does not require specification of any upstream boundary conditions for application. It should be noted, however, the Calumet River (subbasin 98) discharging to the Chicago Sanitary and Shipping Canal (CSSC) and the CSSC itself (subbasin 95) were disconnected from contributing to the downstream flow and the flow from CSSC was simulated as a point source.

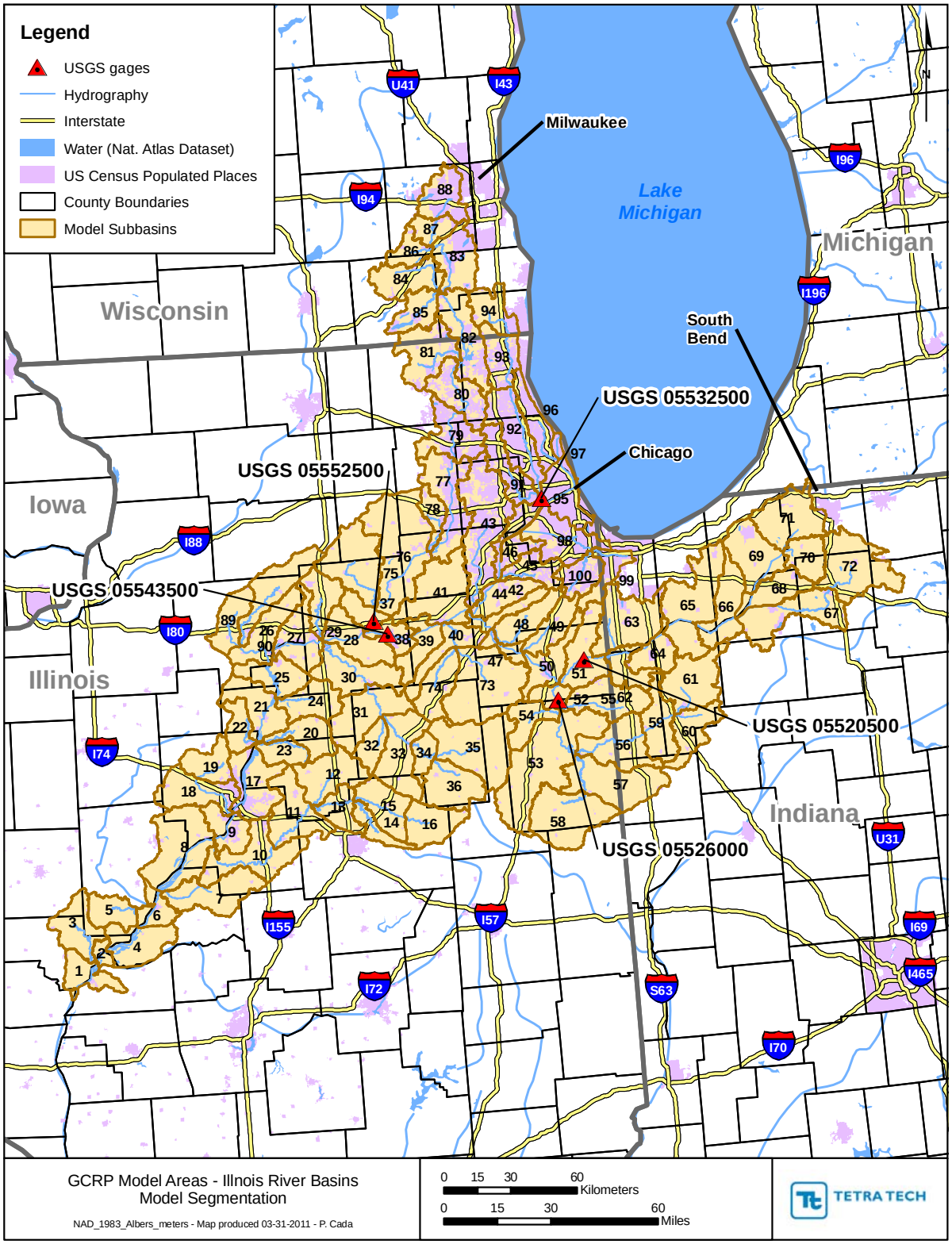

Figure 3. Model segmentation and USGS stations utilized for the Illinois River basin.

Calibration Data and Locations

The specific site chosen for initial calibration was the Iroquois River (HUC8: 07120002) near Chebanse, IL, a flow and water quality monitoring location that approximately coincides with the mouth of an 8-digit HUC just before Iroquois River joins Kankakee River. The Iroquois watershed was selected because there is a good set of flow and water quality data available and the watershed has no major point sources or impoundments. Parameters derived on the Iroquois River were not fully transferable to other portions of the Illinois River watershed and additional calibration and validation was conducted at multiple gage locations (Table 5).

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

Station name	USGS ID	Drainage area (mi^2)	Hydrology calibration	Water quality calibration
Iroquois River at Chebanse, IL	05526000	2,091	X	X
Kankakee River at Momence, IL	05520500	2,294	X	X
Des Plaines River at Riverside, IL	05532500	630	X	X
Fox River at Dayton, IL	05552500	2,642	X	X
Illinois river at Marseilles, IL	05543500	8,259	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 1982-1992. Water quality calibration used calendar years 1985-2001, while validation used 1978-1984. However, there was some variation to this time period across the monitoring stations depending on the availability of monitored data.

SWAT Modeling

Assumptions

McHenry Lock and Dam on the Fox River and Peoria Lock and Dam on the Illinois River were represented as reservoirs in the model. 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.

Another important characteristic of the watershed is the widespread presence of subsurface tile drainage. Installation of tile drainage has converted what were predominantly glacial plain outwash depressional wetlands into productive farmland. The presence of tile drains, which include both surface and subsurface inlets, has radically altered the natural hydrology of the area. Surface inlet tile drains, in particular, may also play a significant role in the transport of sediment and pollutants from agricultural land to the river. It is not feasible to simulate individual tile drain systems at the large watershed scale. Further, neither the location nor the total density of tile drainage is known throughout the watershed. In most areas, only the public tile drains and ditches are documented in spatial coverage, and the extent of private tile drains is known only for limited areas. The SWAT model allows for some representation of tile drains in the form of three parameters: depth to the tile drains, time to drain soil to field capacity, and tile drain lag time. Tile drains were applied on poorly drained soils (identified from STATSGO data) under cultivation with slopes less than one percent.

Hydrology Calibration

Although, a spatial calibration approach was adopted for GCRP-SWAT modeling for the Illinois River basin, adjustments to specific subwatesheds were kept as minimal as possible. However, a systematic adjustment of parameters was been adopted and some adjustments were applied throughout the watershed. Most of the calibration efforts were geared toward getting a closer match between simulated and observed flows at the outlet of the calibration focus area.

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. The cropland HRUs were split into corn and soybean in the ratio 1:1. Urban land use classes were exempted from the HRU overlay thresholds.

The calibration focus area (Iroquois River) includes 10 subwatersheds and is representative of the general land use characteristics of the overall Illinois River basin. The parameters were adjusted within the practical range 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 overall water balance of the whole Illinois River basin predicted by the SWAT 20 Watershed model over the 30-year simulation period is as follows:

```
PRECIP =    958.1 MM
SNOW FALL =  127.74 MM
```

```
SNOW MELT =   122.18 MM
SUBLIMATION =     6.13 MM
SURFACE RUNOFF Q =   264.25 MM
LATERAL SOIL Q =    2.29 MM
TILE Q =    21.22 MM
GROUNDWATER (SHAL AQ) Q =    33.99 MM
REVAP (SHAL AQ => SOIL/PLANTS) =   78.22 MM
DEEP AQ RECHARGE =     4.71 MM
TOTAL AQ RECHARGE =   94.18 MM
TOTAL WATER YLD =   319.41 MM
PERCOLATION OUT OF SOIL =   91.80 MM
ET =    579.0 MM
PET =   1106.2MM
TRANSMISSION LOSSES =     2.35 MM
```

Hydrologic calibration adjustments focused on the following parameters:

- Curve numbers (all landuse except forest)
- CN (curve number) coefficient
- FFCB (fraction of field capacity)
- SURLAG (surface runoff lag coefficient)
- Baseflow factor
- GW_DELAY (groundwater delay time)
- GWQMN (threshold depth of water in the shallow aquifer required for return flow to occur)
- SHALLST (Initial depth of water in the shallow aquifer)
- CANMAX (maximum canopy storage)
- RevapMN (threshold depth of water in the shallow aquifer required for “revap” or percolation to the deep aquifer to occur
- CH_K2 (channel hydraulic conductivity)
- CH_N2 (channel Mannings’ coefficient)
- Sol_AWC (available water capacity of the soil layer, mm water/mm of soil)
- Depth to impervious surface
- Snow parameters SMTMP, SMFMX, SMFMN, TIMP
- Tile drain parameters (DDRAIN, TDRAIN and GDRAIN)
- Average wind speed in the weather database

Calibration results for the Iroquois River are summarized in Figures 4 through 7 and Table 6. In general, the model captured the timing of the peaks well but tends to underestimate the high flows resulting in overall underestimation by 17%.

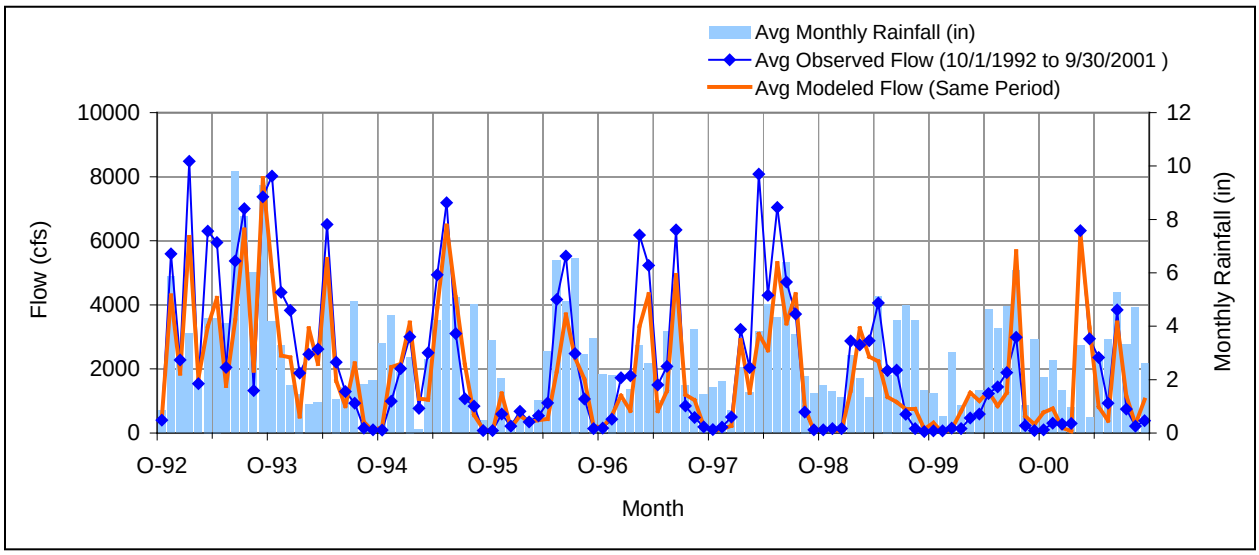

Figure 4. Mean monthly flow at USGS 05526000 Iroquois River near Chebanse, IL– calibration period.

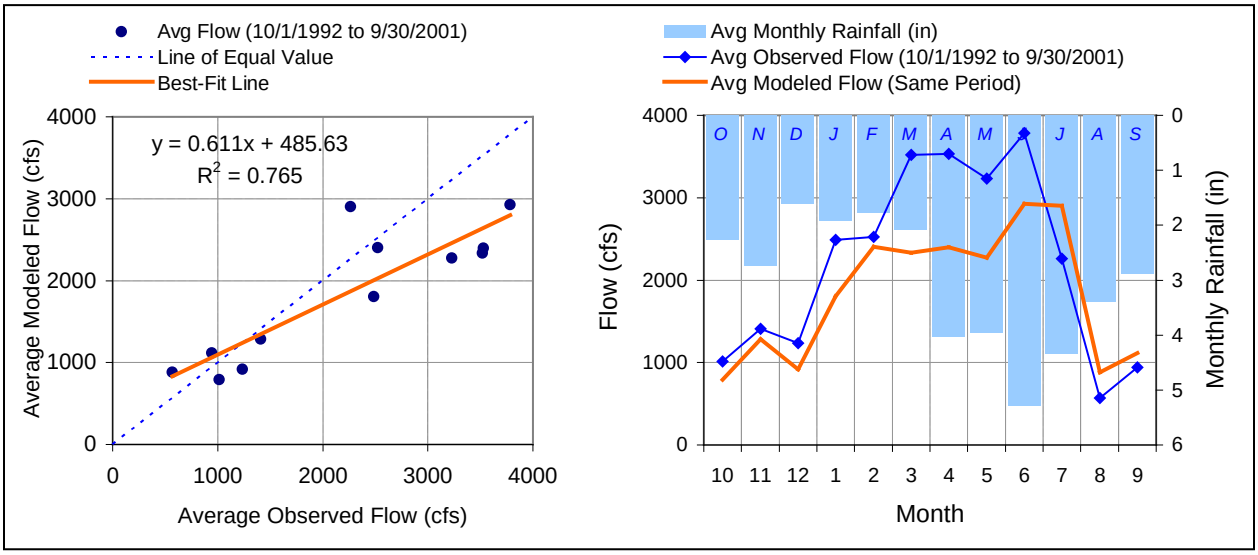

Figure 5. Seasonal regression and temporal aggregate at USGS 05526000 Iroquois River near Chebanse, IL - calibration period.

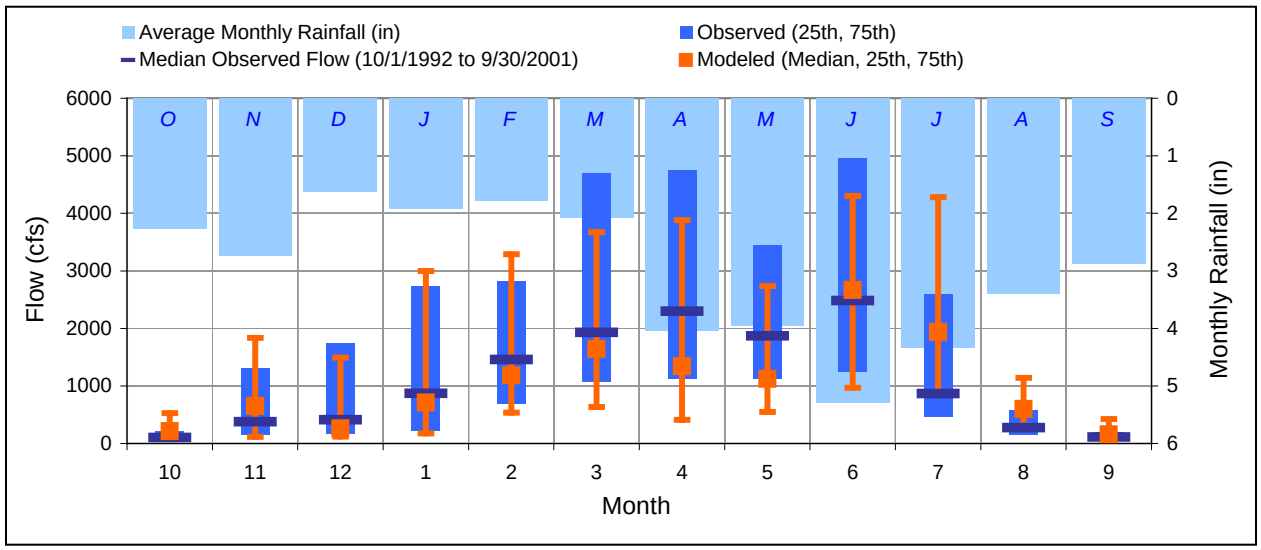

Figure 6. Seasonal medians and ranges at USGS 05526000 Iroquois River near Chebanse, IL – calibration period.

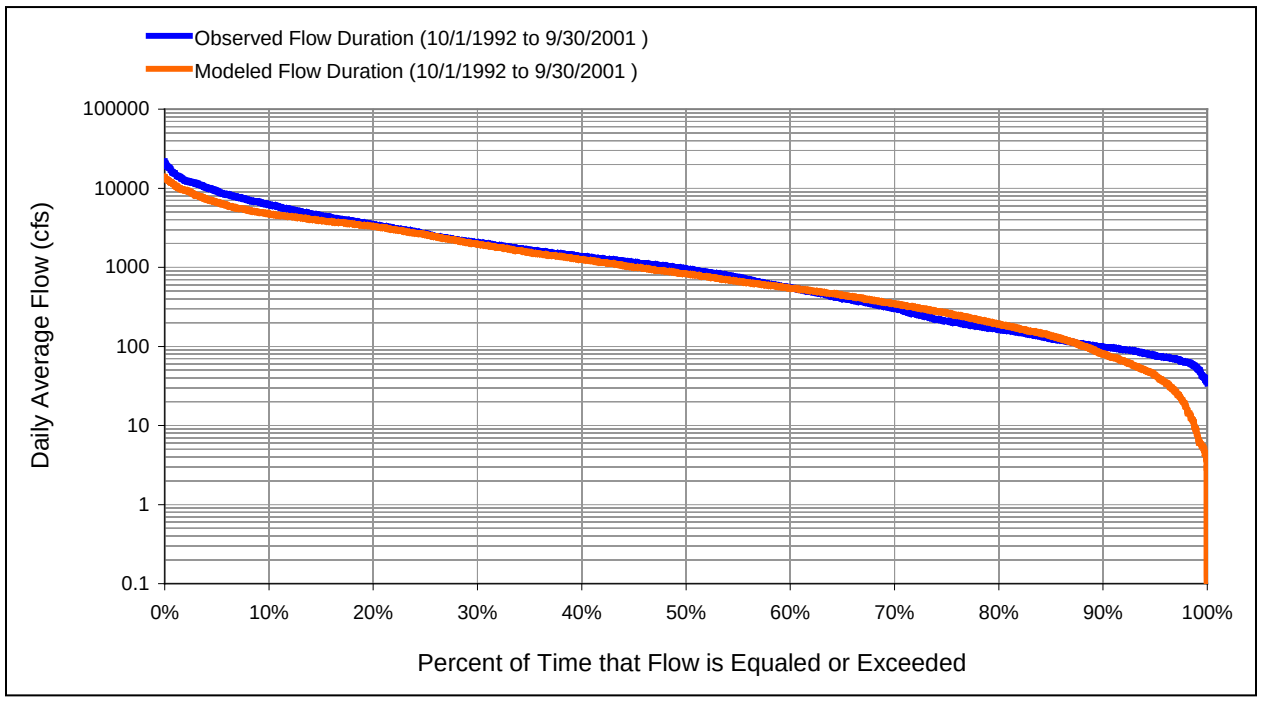

Figure 7. Flow exceedance at USGS 05526000 Iroquois River near Chebanse - calibration period.

Table 6. Summary statistics at USGS 05526000 Iroquois River near Chebanse, IL - calibration period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 52 9-Year Analysis Period: 10/1/1992 - 9/30/2001 Flow volumes are (inches/year) for upstream drainage area		USGS 05526000 IROQUOIS RIVER NEAR CHEBANSE, IL Hydrologic Unit Code: 7120002 Latitude: 41.0089215 Longitude: -87.8233719 Drainage Area (sq-mi): 2091	
Total Simulated In-stream Flow:	**11.89**	Total Observed In-stream Flow:	**14.32**
Total of simulated highest 10% flows:	**4.85**	Total of Observed highest 10% flows:	**6.67**
Total of Simulated lowest 50% flows:	**1.03**	Total of Observed Lowest 50% flows:	**1.03**
Simulated Summer Flow Volume (months 7-9):	**2.68**	Observed Summer Flow Volume (7-9):	**2.07**
Simulated Fall Flow Volume (months 10-12):	**1.63**	Observed Fall Flow Volume (10-12):	**1.99**
Simulated Winter Flow Volume (months 1-3):	**3.49**	Observed Winter Flow Volume (1-3):	**4.58**
Simulated Spring Flow Volume (months 4-6):	**4.09**	Observed Spring Flow Volume (4-6):	**5.68**
Total Simulated Storm Volume:	**4.06**	Total Observed Storm Volume:	**6.30**
Simulated Summer Storm Volume (7-9):	**0.85**	Observed Summer Storm Volume (7-9):	**1.00**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	**-16.99**	**10**	
Error in 50% lowest flows:	-0.58	10	
Error in 10% highest flows:	**-27.20**	**15**	
Seasonal volume error - Summer:	29.82	30	
Seasonal volume error - Fall:	-18.41	30	
Seasonal volume error - Winter:	-23.84	30	
Seasonal volume error - Spring:	-27.98	30	
Error in storm volumes:	**-35.59**	**20**	
Error in summer storm volumes:	-14.89	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.699	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.563	as E or E' approaches 1.0	
Monthly NSE	0.768		

Hydrology Validation

Hydrology validation for the Iroquois River was performed for the period 10/1/1982 through 9/30/1992. Results are presented in Figures 8 through 11 and Table 7. The validation achieved a high Nash-Sutcliffe model efficiency, but is under on 50 percent low volume and over on summer volume (Figure 8, Figure 9, Figure 10, Figure 11, and Table 7). Although, the validation period is from 1982 to 1992 and the landuse data used in the model was obtained from 2001 NLCD, the model performance was very much comparable for both calibration and validation periods. This could be due to no major changes in the landuse/land management in the watershed and a somewhat consistent weather pattern.

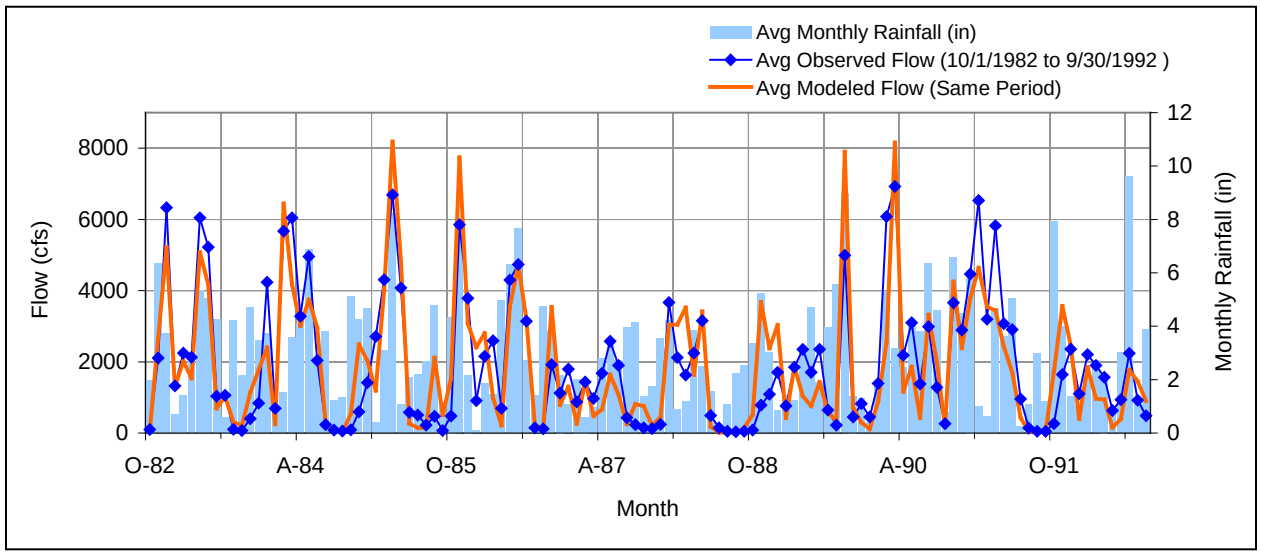

Figure 8. Mean monthly flow at USGS 05526000 Iroquois River near Chebanse, IL – validation period.

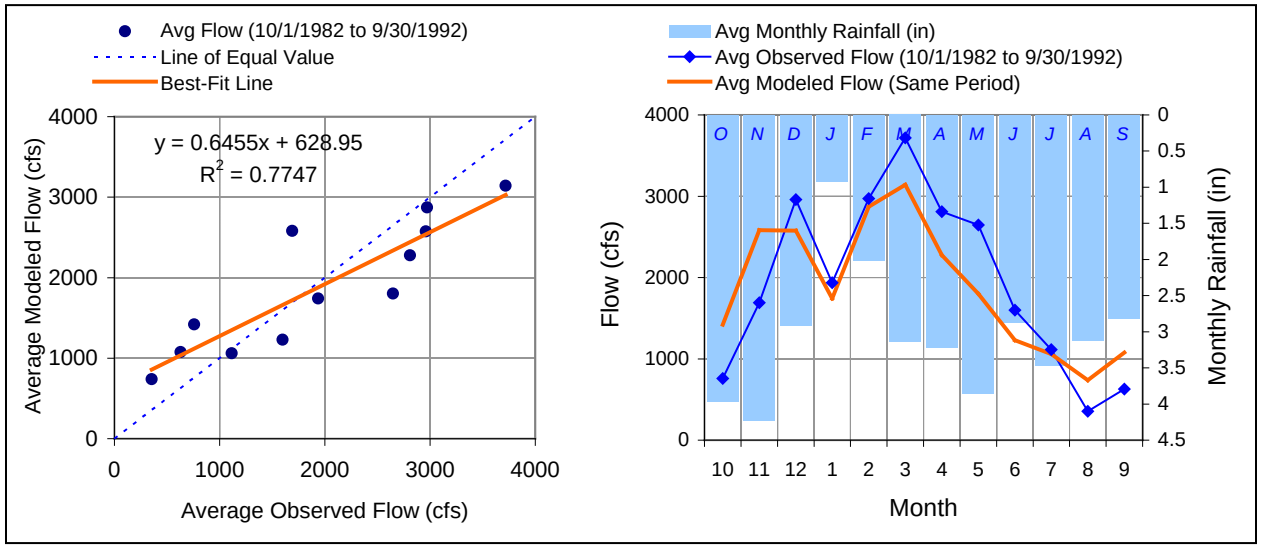

Figure 9. Seasonal regression and temporal aggregate at USGS 05526000 Iroquois River near Chebanse, IL - validation period.

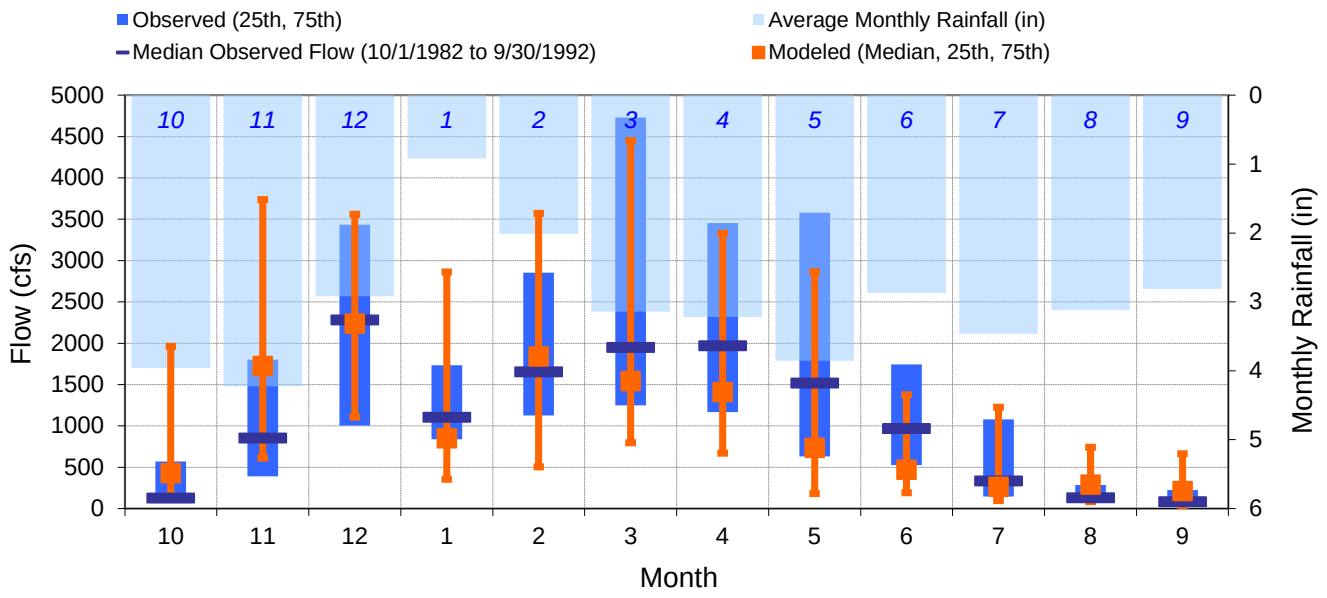

Figure 10. Seasonal medians and ranges at USGS 05526000 Iroquois River near Chebanse, IL – validation period.

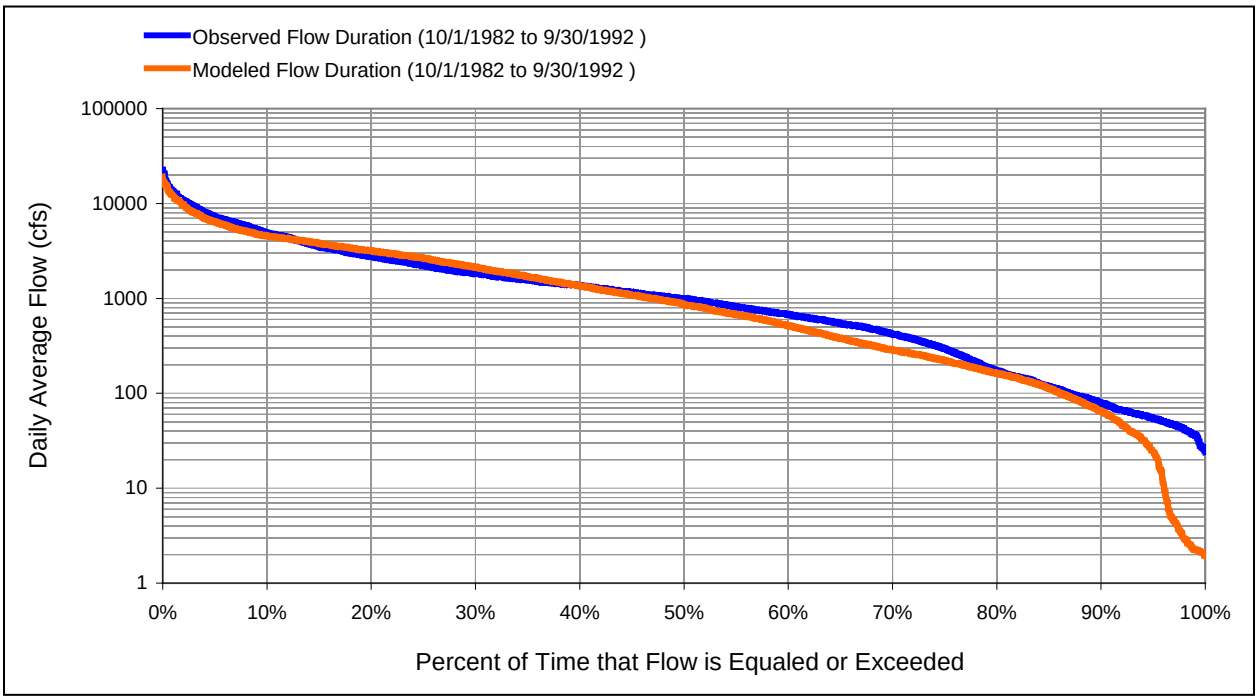

Figure 11. Flow exceedance at USGS 05526000 Iroquois River near Chebanse, IL - validation period.

Table 7. Summary statistics at USGS 05526000 Iroquois River near Chebanse, IL - validation period.

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 52 10-Year Analysis Period: 10/1/1982 - 9/30/1992 Flow volumes are (inches/year) for upstream drainage area		USGS 05526000 IROQUOIS RIVER NEAR CHEBANSE, IL Hydrologic Unit Code: 7120002 Latitude: 41.0089215 Longitude: -87.8233719 Drainage Area (sq-mi): 2091	
Total Simulated In-stream Flow:	**12.15**	Total Observed In-stream Flow:	**12.52**
Total of simulated highest 10% flows:	**5.02**	Total of Observed highest 10% flows:	**5.64**
Total of Simulated lowest 50% flows:	**0.95**	Total of Observed Lowest 50% flows:	**1.21**
Simulated Summer Flow Volume (months 7-9):	**1.57**	Observed Summer Flow Volume (7-9):	**1.15**
Simulated Fall Flow Volume (months 10-12):	**3.58**	Observed Fall Flow Volume (10-12):	**2.95**
Simulated Winter Flow Volume (months 1-3):	**4.14**	Observed Winter Flow Volume (1-3):	**4.61**
Simulated Spring Flow Volume (months 4-6):	**2.86**	Observed Spring Flow Volume (4-6):	**3.81**
Total Simulated Storm Volume:	**4.28**	Total Observed Storm Volume:	**5.19**
Simulated Summer Storm Volume (7-9):	**0.54**	Observed Summer Storm Volume (7-9):	**0.57**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	-2.98	10	
Error in 50% lowest flows:	**-21.27**	**10**	
Error in 10% highest flows:	-11.00	15	
Seasonal volume error - Summer:	**36.69**	**30**	
Seasonal volume error - Fall:	21.34	30	
Seasonal volume error - Winter:	-10.30	30	
Seasonal volume error - Spring:	-24.88	30	
Error in storm volumes:	-17.48	20	
Error in summer storm volumes:	-4.76	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.674	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.457	as E or E' approaches 1.0	
Monthly NSE	0.712		

Hydrology Results for Larger Watershed

Parameters determined for the Iroquois River monitoring station were not fully transferable to all other areas in the watershed, especially the Kankakee and Fox gages. Kankakee River originally drained one of the largest wetlands in North America and has since been significantly altered. The river now flows through primarily rural lands of reclaimed croplands. During the calibration, Channel Mannings' N had to be reduced for the Kankakee drainage area to reduce the peak flow rates in the channel. Higher upland erosion rates simulated by SWAT were controlled by reducing the P-factor for cropland HRUs for both Kankakee and Fox drainage areas. In general, calibration results were acceptable at most gages, as summarized in Table 8. Model performance was relatively poor at the Kankakee and Fox stations.

Results of the validation exercise are summarized in Table 9. Summer season flows were overestimated both during the calibration and validation periods at all stations except Kankakee. Unlike the calibration period, fall season flows were overestimated during the validation period. Overall, hydrology was simulated well at all gages, except the Kankakee station where low flows were underpredicted and high flows were over predicted, resulting in an overprediction of total storm volumes.

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

Station	05526000 Iroquois River at Chebanse, IL	05520500 Kankakee River at Momence, IL	05532500 Des Plaines River at Riverside, IL	05552500 Fox River at Dayton, IL	05543500 Illinois River at Marseilles, IL
Error in total volume:	-16.99	-16.74	-7.97	-2.94	-6.75
Error in 50% lowest flows:	-0.58	-37.19	-6.98	-5.58	-8.18
Error in 10% highest flows:	-27.20	32.90	-14.69	1.14	-5.35
Seasonal volume error - Summer:	29.82	-5.31	29.05	47.39	11.96
Seasonal volume error - Fall:	-18.41	-24.23	-7.60	-8.61	-4.52
Seasonal volume error - Winter:	-23.84	-15.45	-18.09	-24.48	-12.03
Seasonal volume error - Spring:	-27.98	-20.05	-16.18	-6.00	-14.21
Error in storm volumes:	-35.59	44.06	-32.00	16.17	-5.03
Error in summer storm volumes:	-14.89	5.27	-21.41	57.63	3.30
Daily Nash-Sutcliffe Coefficient of Efficiency, E:	0.699	0.241	0.561	0.367	0.787
Monthly Nash-Sutcliffe Coefficient of Efficiency, E:	0.768	0.540	0.622	0.530	0.883

Table 9. Summary statistics: all stations - validation period

Station	05526000 Iroquois River at Chebanse, IL	05520500 Kankakee River at Momence, IL	05532500 Des Plaines River at Riverside, IL	05552500 Fox River at Dayton, IL	05543500 Illinois River at Marseilles, IL
Error in total volume:	-2.98	-9.24	12.69	9.52	5.78
Error in 50% lowest flows:	-21.27	-33.25	13.77	9.19	-3.45
Error in 10% highest flows:	-11.00	37.98	12.33	23.25	17.49
Seasonal volume error - Summer:	36.69	-5.79	42.17	52.54	18.46
Seasonal volume error - Fall:	21.34	9.77	12.41	2.17	21.78
Seasonal volume error - Winter:	-10.30	-11.44	1.08	-5.13	-2.24
Seasonal volume error - Spring:	-24.88	-23.42	4.55	10.02	-9.45
Error in storm volumes:	-17.48	68.38	-13.72	37.25	19.98
Error in summer storm volumes:	-4.76	13.56	-12.01	67.69	21.93
Daily Nash-Sutcliffe Coefficient of Efficiency, E:	0.674	0.036	0.586	0.418	0.571
Monthly Nash-Sutcliffe Coefficient of Efficiency, E:	0.712	0.473	0.635	0.702	0.635

Water Quality Calibration and Validation

Initial calibration and validation of water quality was done on the Iroquois River (USGS 05526000), using time period 1985-2001 for calibration and 1978-1984 for validation. As with hydrology, calibration was performed on the later period as this better reflects the land use included in the model. The validation period at stations 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)
- PRF (Peak rate adjustment factor for sediment routing in the main channel)
- USLE-K (USLE erodibility factor)
- CH_COV (Channel cover factor)
- CH_EROD (Channel erodibility factor)
- USLE-P (USLE support practice factor)
- DIRTMX and curb length density in urban database

Simulated and estimated sediment loads at the Iroquois River 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.

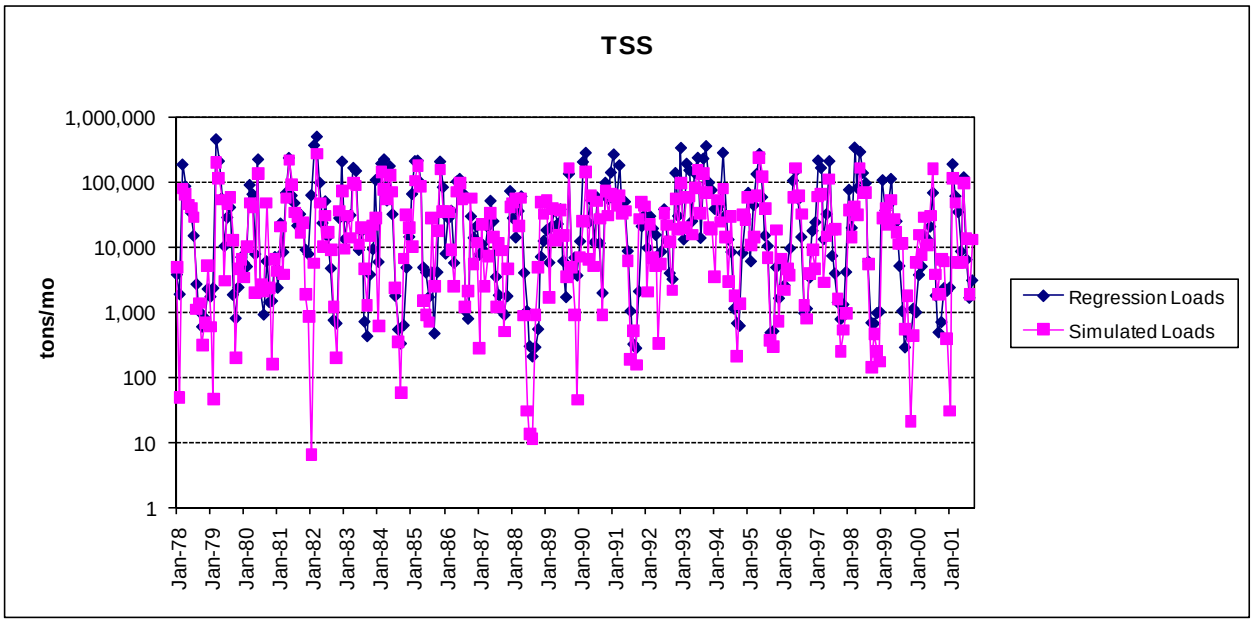

Figure 12. Fit for monthly load of TSS at USGS 05526000 Iroquois River near Chebanse, IL.

Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 05526000 Iroquois River near Chebanse, IL

Statistic	Calibration period (1985-2001)	Validation period (1978-1984)
Relative Percent Error	38%	39%
Relative Average Absolute Error	56%	51%
Relative Median Absolute Error	19.8%	9.9%

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

- Initial soil organic N and P
- PPERCO (phosphorus percolation coefficient)
- NPERCO (nitrogen percolation coefficient)
- PHOSKD (phosphorus soil partitioning coefficient)
- SOL_CBN1 (Organic carbon in the first soil layer)
- MUMAX
- QUAL2E parameters such as algal, organic nitrogen, and organic phosphorus settling rate in the reach, benthic source rate for dissolved phosphorus and NH4-N in the reach, fraction of algal biomass that is nitrogen and phosphorus, Michaelis-Menton half-saturation constant for nitrogen and phosphorus

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 good for phosphorus and nitrogen was underpredicted.

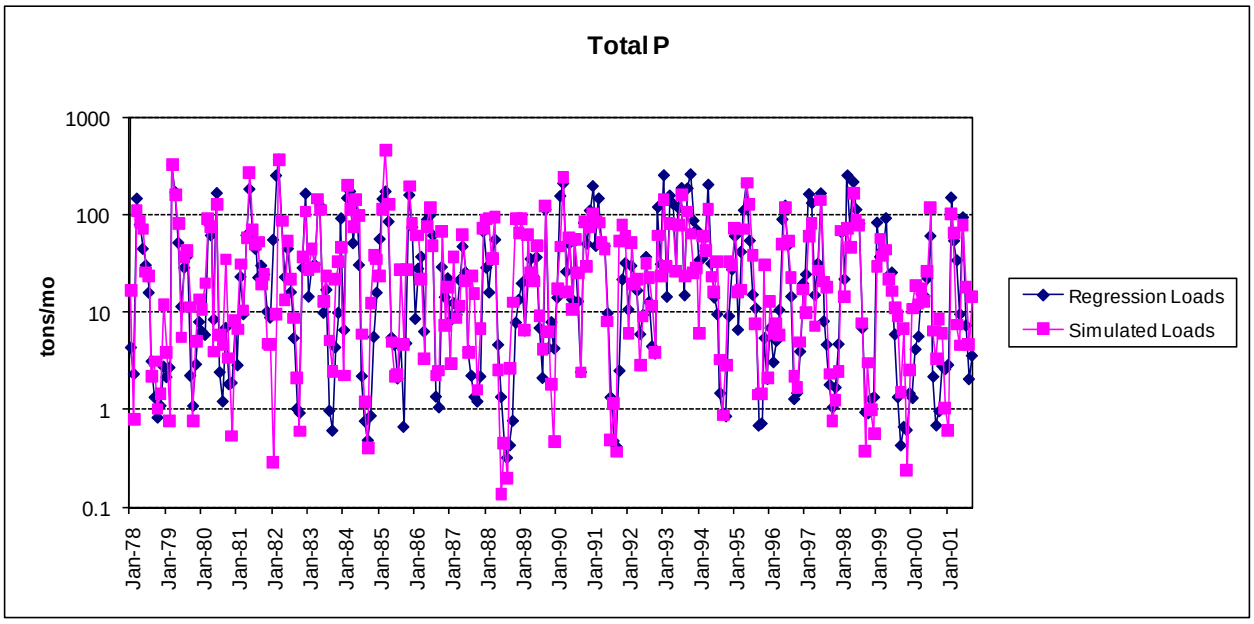

Figure 13. Fit for monthly load of total phosphorus at USGS 05526000 Iroquois River near Chebanse, IL.

Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 05526000 Iroquois River near Chebanse, IL

Statistic	Calibration period (1985-2001)	Validation period (1978-1984)
Relative Percent Error	5%	-1
Average Absolute Error	49%	33%
Median Absolute Error	16.9%	11.9%

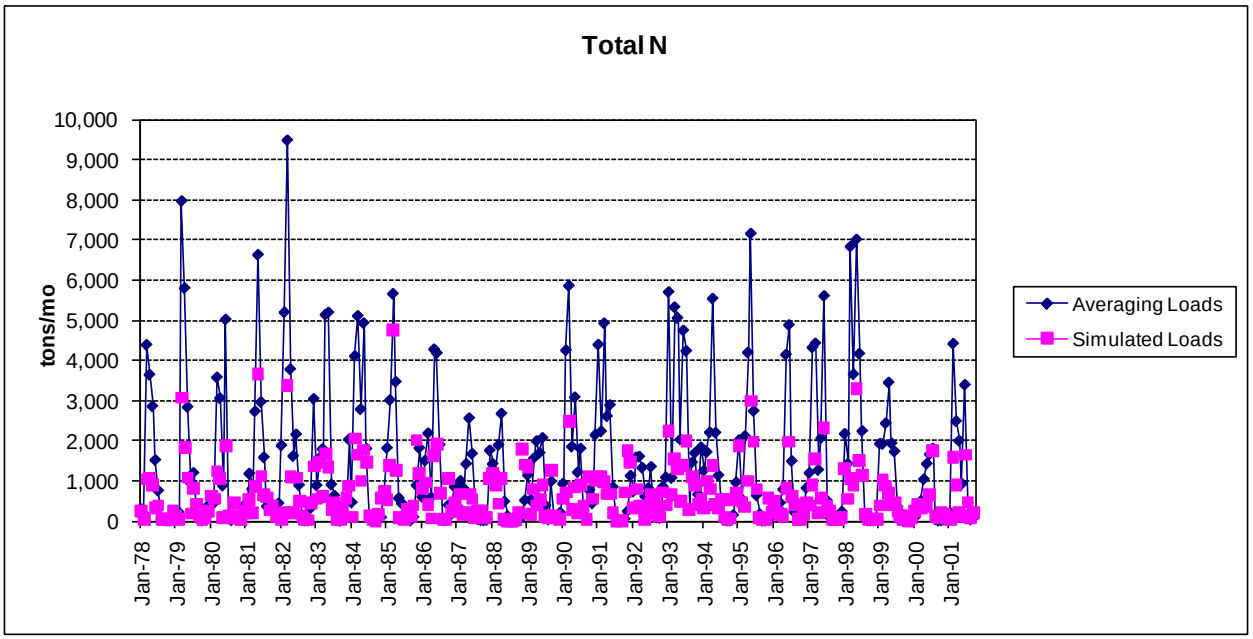

Figure 14. Fit for monthly load of total nitrogen at USGS 05526000 Iroquois River near Chebanse, IL.

Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 05526000 Iroquois River near Chebanse, IL

Statistic	Calibration period (1985-2001)	Validation period (1978-1984)
Relative Percent Error	56%	60%
Average Absolute Error	64%	64%
Median Absolute Error	29.8%	20.5%

Water Quality Results for Larger Watershed

Only the USLE P-factor was spatially adjusted to account for high upland erosion for the Kankakee and Fox watersheds. Summary statistics for the SWAT water quality calibration and validation at other stations in the watershed are provided in Table 13 and Table 14. There were unexplained high simulated sediment loads at the Fox stations that were not reflected in the measured sediment data at this station.

Table 13. Summary statistics for water quality at all stations – calibration period 1985-2001 (unless otherwise noted)

Station	05526000 Iroquois River at Chebanse, IL	05520500 Kankakee River at Momence, IL	05532500 Des Plaines River at Riverside, IL	05552500 Fox River at Dayton, IL (1990-2001)	05543500 Illinois River at Marseilles, IL
Relative Percent Error TSS Load	38	-7	-3	-234	-97
Relative Percent Error TP Load	5	-71	-54	-51	14
Relative Percent Error TN Load	56	-5	-46	-3	26

Table 14. Summary statistics for water quality at all stations – validation period 1978-1984 (unless otherwise noted)

Station	05526000 Iroquois River at Chebanse, IL	05520500 Kankakee River at Momence, IL	05532500 Des Plaines River at Riverside, IL	05552500 Fox River at Dayton, IL (1978-1989)	05543500 Illinois River at Marseilles, IL (1974-1984)
Relative Percent Error TSS Load	39	-1	-23	-267	-107
Relative Percent Error TP Load	-1	-100	-68	-71	9
Relative Percent Error TN Load	60	-13	-58	-14	24

References

Tetra Tech. 1999. Improving Point Source Loadings Data for Reporting National Water Quality Indicators. Final Technical Report prepared for U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, DC, by Tetra Tech, Inc., Fairfax, VA.

USGS (United States Geological Survey). 1994. NAWQA Fact Sheet. Available at: http://il.water.usgs.gov/proj/lirb/pubs/pdfs/fctsheet.pdf

USEPA (United States Environmental Protection Agency). 2008. Using the BASINS Meteorological Database (Version 2006). BASINS Technical Note 10. Office of Water, U.S. Environmental Protection Agency, Washington, DC. http://water.epa.gov/scitech/datait/models/basins/upload/2009_04_13_BASINSs_tecnote10.pdf (Accessed June, 2009).