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MEMORANDUM

DATE:	June 1, 2007
FROM:	Todd Redder
PROJECT:	PLATTE3
TO:	Ray Canale
CC:	Dave Dilks, Penelope Moskus
SUBJECT:	Platte River Watershed Model Calibration & Application (final draft)

Summary

The purpose of this memorandum is to document the Phase II calibration and application of the Platte River watershed model. The watershed simulation tool, which is based on the *Hydrologic Simulation Program – FORTRAN* (HSPF) model found within the overall EPA BASINS framework, includes simulation of hydrology and flow, as well as instream total phosphorus (TP) and total suspended solids (TSS) concentrations derived from watershed sources (Bicknell, et al.; http://www.epa.gov/ceampubl/swater/hspf/).

The watershed model was originally configured and a baseline calibration was conducted during Phase I of the project (LimnoTech, 2004). The Phase II effort built on the earlier effort by updating and extending input datasets (e.g., daily precipitation) and calibrating the watershed model to robust datasets collected by the Platte Lake Improvement Association (PLIA) for flow, TP, and TSS during the 2003-05 period. The results of the calibrated model for the 1990-2005 period compare favorably to daily observed USGS flows at Honor, data-based estimates of annual TP load at key locations, and peak TP concentrations for most wet weather events. In addition to direct model-data comparisons for system locations, the unit area loads (UALs) associated with each land use type were compared against literature values and values used for other LimnoTech projects to confirm that the values obtained via calibration were reasonable.

The calibrated model simulations 1990-2005 period were used to identify "high load" (i.e., wet), "low load" (dry), and "typical" (average load) years. Year 1992 was selected as the "High" period because it has the highest annual TP load during the 1990-2005 period. Year 2000 was selected as the "Low" year because it has the lowest annual TP load during the 16-year period. Year 2004 was selected as the "typical" year because its TP load to Big Platte Lake (4,662 lb/yr) was most similar to the 1990-2005 average annual TP load (4,634 lb/yr).

The watershed model GUI (Graphical User Interface) application involved running HSPF single year simulations for years 1992, 2000, and 2004 to generate a set of baseline "High", "Low", and "typical" TP loadings, respectively. Unit area loads (UAL) for all land uses were extracted from the model for these years. The UAL values and hatchery point source loading data were used to develop a spreadsheet-based graphical user interface (GUI) tool that allows the user to modify land use distribution and point source loadings on a subwatershed basis. This tool can be used in the future to investigate the impact of any such proposed land use changes or point source discharges on annual TP loading to Big Platte Lake under "High", "Low", and "typical" watershed loading conditions. The GUI tool also permits the user to investigate the potential benefits of watershed best management practices (BMPs) in specific subwatersheds.

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Background

The Platte River watershed is located in the northwest region of Michigan's Lower Peninsula. The Platte River flows westward from numerous natural headwater lakes and through Big Platte Lake before finally emptying into Lake Michigan. The watershed area is approximately 495 km^2 in size and is currently very rural and largely forested. The predominant land use is forest (57%), followed by permanent pasture/open lands (16%). Developed lands comprise approximately 6% of the watershed area. A coho and chinook salmon hatchery is the sole point source that discharges to the Platte River upstream of Big Platte Lake.

"Since the 1920's, the State of Michigan has operated a fish hatchery on the Platte River, approximately 14 km upstream of the lake. In the early 1970's the hatchery was expanded and production shifted from rainbow trout to salmon and other anadromous fish (Walker, 1998)." The water quality of Big Platte Lake declined noticeably in response to this expansion in fish production and the increased phosphorus loading from the hatchery. As a consequence, the Michigan Department of Natural Resources (MDNR) and the Platte Lake Improvement Association (PLIA) agreed on a program to reduce the hatchery phosphorus discharge to 175 lbs/year. The agreement on hatchery discharges was completed in 2000. As a result, the hatchery loadings have declined and water quality in Big Platte Lake has improved.

In order to maintain high water quality in the lake in the future, the MDNR and the PLIA are working together to evaluate and determine the impact of non-point phosphorus loading to the lake. A watershed-scale modeling study was initiated as part of Phase I of the project and now has been completed in Phase II. The ultimate goal of the study and the model application is to control non-point sources of phosphorus through comprehensive watershed management, including anticipated future loadings resulting from increased land development within the watershed. This summary memorandum presents the final model calibration for flow, phosphorus, and suspended solids in the Platte River watershed upstream of Big Platte Lake.

Review of Data Sources

The Phase II watershed model calibration took advantage of input datasets utilized in the previous modeling effort whenever possible. Model inputs used previously for current land use, soil characteristics, and stream network characteristics were not modified in any way. Details regarding these datasets are available in a previous project report (LimnoTech, 2004). The primary modifications to the Phase II watershed model involved extending the simulation period to cover the entire 1990-2005 period where newly available comprehensive hydraulic and water quality data are available.

Climate Datasets

Climate datasets that were updated and extended for the 2001-2005 period included:

- Daily precipitation and minimum/maximum air temperature data at the National Climactic Data Center (NCDC) station in Frankfort, MI (COOP ID: 202984);
- Hourly precipitation at various Traverse City NCDC stations (used to disaggregate (i.e., apportion) daily Frankfort data into hourly values);
- Daily estimates of evaporation rates for surface water;
- Daily estimates of potential evapotranspiration (PET) rates; and
- Radar maps of daily rainfall available from the National Weather Service.

Table 1 provides a summary of annual precipitation at Frankfort for the 1990-2005 period as well as annual mean daily streamflow observed at the USGS gage location in Honor, MI. Daily precipitation data were disaggregated into hourly values using hourly precipitation distribution data available for several Traverse City NCDC stations. Daily datasets for minimum/maximum air temperature, evaporation, and potential evapotranspiration were input directly to the watershed model.

Table 1. Platte River Watershed Annual Precipitation and Streamflow

Year	Total Precipitation[1] (inches)	Mean Daily Streamflow[2] (cfs)
1990	39.6	136[3]
1991	39.3	140
1992	41.6	142
1993	38.5	147
1994	34.9	138
1995	38.3	120
1996	37.5	125
1997	29.3	131
1998	38.2	112
1999	32.2	105
2000	30.3	101
2001	42.0	113
2002	29.4	132
2003	31.3	125
2004	39.7	134
2005	27.2	121
Average	***35.6***	***126***

Notes:
[1]Data compiled from daily NCDC data available online for Frankfort (supplemented with data available for Beulah and Traverse City).
[2]Computed based on daily observed flow records for the USGS gage at Honor, MI.
[3]Based on an incomplete record; data collection for 1990 began on March 27th.

The selection of the Frankfort NCDC daily precipitation dataset was based on an analysis that compared all available local precipitation datasets to USGS streamflow data available for the Platte River. In addition to the Frankfort NCDC dataset, precipitation datasets available for Beulah (daily total), Traverse City (hourly and daily) were evaluated. The hatchery precipitation dataset was not included in the final analysis because there were significant inconsistencies between this dataset and the before mentioned precipitation datasets that could not be resolved. The USGS flow data was analyzed using hydrograph separation techniques, which yielded estimates of monthly runoff and baseflow quantities.

The key conclusion of precipitation and flow analysis was that the Frankfort precipitation dataset provided the most consistent match to annual and monthly runoff quantities for the Platte River watershed. National Weather Service radar maps were used in a qualitative manner to analyze specific cases where significant deviations occurred between the Frankfort rainfall data and the River response at the Honor gauging station. Based on preliminary flow calibration results from the watershed model, it was determined that the Frankfort dataset was sufficiently accurate to support model calibration. The complete precipitation and flow analysis, including a discussion of radar rainfall data, is documented in a previous memorandum (LimnoTech, 2006) that is provided as Appendix D to this memorandum.

Flow Calibration Datasets

The model flow simulation was calibrated using the following data sources:

- Continuous USGS mean daily flow data for Honor, MI (1990-2005);
- Periodic stage data and flow estimates available for various locations from recent PLIA monitoring (2003-05); and
- Daily average snow pack depth data available for the Frankfort NCDC station (1990-2005).

The USGS daily flow dataset served as the primary target for the overall watershed flow calibration, and the Frankfort NCDC snow depth dataset was specifically used to parameterize and calibrate the snow accumulation and melt calculations in the watershed model. The annual mean daily streamflow for the USGS gage station is provided in Table 1.

The PLIA stage/flow datasets were used to establish the upstream boundary inflow for tributary reaches, including Brundage Creek, North Branch Platte River, Carter Creek, and Collison Creek. Estimates of point-in-time flows were developed for each monitoring location using raw water stage measurement and stage-discharge curves provided by PLIA (Ray Canale, personal communications).

Water Quality Calibration Datasets

Recent instream measurements of total phosphorus (TP) and turbidity available from the PLIA monitoring program were used as the basis for calibrating the model water quality simulation for TSS and TP. The PLIA datasets characterize a variety of dry and wet weather events at key locations for 2003-05 within the mainstem of the Platte River and several major tributaries. Monitoring locations for which TP and turbidity data were used to support model calibration include:

- Platte River at Fewins Road;
- Platte River at Stone bridge;
- Platte River at Veteran's Park;
- Platte River at Pioneer Road;
- Platte River at the USGS gage location;
- Stanley Creek;
- Brundage Creek at Old Residence;
- Carter Creek;
- Collison Creek; and
- North Branch Platte River at Deadstream Road.

Raw TP and turbidity data were provided in the form of a Microsoft Access database. Turbidity (NTU) measurements were converted to estimates of TSS using regressions provided by PLIA (Ray Canale, personal communications).

Watershed Model Calibration

The watershed model calibration effort consisted of two major steps, including calibration of simulated runoff and subsurface (groundwater) flows followed by calibration of simulated water quality (i.e., TP and TSS concentrations) at key locations within the main stem Platte River and its tributaries.

General Approach

Model calibration involves the process of comparing model predictions for parameters of interest to site-specific measurements and iteratively adjusting model coefficients to achieve an acceptable fit between predicted and observed values. The process of model calibration is important not only in terms of optimizing the model fit to available field data, but also in terms of developing a better conceptual understanding of how the physical system behaves and responds under different environmental conditions.

For the Platte River watershed model, the parameters of interest include flow/hydrology and total phosphorus (TP). Total suspended solids (TSS) is a parameter of secondary interest that should be calibrated for the purpose of supporting the TP calibration. Calibration of the model flow simulation was conducted first in order to provide the necessary information to the water quality simulation. A rough TSS calibration was conducted next to establish reasonable scour and washoff rates for watershed soils. The TP calibration was conducted as a final step in the process, although some additional calibration of the TSS parameter was necessary to achieve the best fit for both water quality parameters.

The watershed model calibration encompasses the 1990-2005 period because 1) USGS daily flow data are available for nearly this entire period, and 2) substantial TP and TSS data are available from the PLIA monitoring program for the 2003-05 period. Although PLIA monitoring data are also available for year 2006, sufficient climate data were not available at the time of model development and calibration.

The model calibration was limited to the portion of the watershed extending from Fewins Road to Big Platte Lake. The rationale for representing the upstream lake system using a boundary condition at Fewins Road is discussed in the "Data Gaps Identified" section below. A detailed discussion of the upstream boundary condition development for flow and TP and TSS concentrations is provided in the "Upstream Boundary Condition Development" section.

Data Gaps Identified

The original (baseline) watershed model calibration conducted by LimnoTech identified several data gaps that limited how well the model could simulate observed flows and TP concentrations in the Platte River. Key data gaps identified in the final report (LimnoTech, 2004) and associated recommendations are summarized below:

1. Wet and dry weather TSS data are needed to further refine the TP calibration. Additional sampling was recommended.
2. Additional TP wet weather data are needed to refine the TP calibration. Additional sampling was recommended.
3. Significant uncertainty exists in the watershed and flow calibration for North Branch Platte River and Little Platte Lake. It was recommended that a flow gage be installed on North Branch upstream of Little Platte Lake and a field visit be conducted to better understand the influence of Little Platte Lake inflow/outflow on North Branch outflows to the mainstem Platte River.
4. Limited information is available regarding the morphometry and hydraulic behavior of numerous lakes located upstream of Fewins Road in the eastern portion of the watershed. Lakes that likely have a significant influence on flows and TP loads to Fewins Road include Bronson Lake, Lake

Ann, Bellows Lake, Lake Dubonnet, and Long Lake. It was recommended that information on the volume, depth, surface area, and outflow characteristics of these lakes be collected to improve model predictions of total outflow and TP load to the mainstem Platte River below Bronson Lake.

Data gaps #1 and #2 were addressed by the PLIA monitoring conducted during the 2003-05 period, and this monitoring effort continues. Data gaps #3 and #4 have not been addressed; therefore, there continues to be uncertainty in how to characterize the watershed model for 1) North Branch Platte River and its interaction with Little Platte Lake, and 2) the upstream system of lakes that supply the background flow and TP load at Fewins Road. These data gaps were taken into consideration when configuring and calibrating the watershed model, as discussed in the below sections.

Upstream Boundary Condition Development

The upstream system of lakes that contribute flow and TP load to Fewins Road were not simulated directly in the model. Instead, PLIA monitoring data available for Fewins Road and the nearby Stone bridge location were used to develop upstream boundary conditions TP and TSS concentrations. The daily inflow at Fewins Road (Q_{Fewins}, in cfs) was calculated from observed flows at the USGS gage (Q_{USGS}, also in cfs) using the following regression: $Q_{Fewins} = 0.49*Q_{USGS} – 4.98$ (Canale, et.al., 2006).

For dry/wet weather days where data were available, observed concentrations were used to specify the TP/TSS boundary concentrations. Concentrations during wet weather events were specified on an hourly basis to capture trends of observed TP concentrations during the course of the event. For days where data were not available, TP and TSS concentrations were specified as follows:

- Concentrations for dry weather days (rainfall at Frankfort < 0.20”) were specified on a monthly basis per the values provided in Table 2. These values were based on TP/TSS PLIA measurements available for the USGS sampling location for the 2004-05 period.

Table 2. Monthly Dry Weather TP/TSS Concentrations at Upstream Boundary

Month	TP Concentration (ug/L)	TSS Concentration (mg/L)
1	22.6	15.5
2	19.7	14.8
3	14.9	11.1
4	15.4	11.8
5	12.9	10.4
6	13.6	9.8
7	13.7	7.6
8	10.1	5.9
9	8.6	4.9
10	8.2	4.8
11	11.1	8.0
12	13.6	10.0

- TP and TSS boundary concentrations for wet weather days (rainfall at Frankfort > 0.20”) were specified based on correlations between daily rainfall and average daily wet weather concentrations for individual rainfall amounts. As for the dry weather analysis, the PLIA TP/TSS datasets for the USGS location were used to support the development of the rainfall-concentration correlations.

Data for the USGS location were used in place of the Stone bridge TP/TSS datasets because: 1) the USGS and Stone bridge concentration data demonstrate good consistency, and 2) the USGS dataset is more comprehensive in terms of number of dry/wet events sampled and frequency of sampling during wet weather events. The approach described above was applied to develop daily flow and hourly TP and TSS concentration time series covering the 1990-2005 calibration period. Table 3 summarizes the annual average flow and the total annual TP loading by year.

Table 3. Annual Flow and TP Load at Upstream Boundary (Fewins Road)

Year	Annual Average Flow (cfs)	Annual TP Load (lb/yr)
1990	63.7	2,196
1991	64.0	2,165
1992	65.0	2,237
1993	67.4	2,302
1994	63.3	2,091
1995	54.1	1,834
1996	56.8	1,893
1997	59.8	1,857
1998	50.2	1,730
1999	46.9	1,525
2000	44.7	1,451
2001	50.9	1,812
2002	60.1	1,997
2003	56.6	1,845
2004	61.3	2,033
2005	54.8	1,826
Average:	***57.5***	***1,925***

Flow Calibration

General performance targets have been established by researchers and engineers for streamflow calibrations using the BASINS/HSPF model. These performance targets allow model users such as planners to evaluate the success of a BASINS calibration for a particular watershed compared to results from other watersheds. The established calibration criteria are shown in Table 4 (Donigian, 2002). These targets are applicable when comparing annual and monthly model predictions of streamflow to mean annual and monthly data-based flows.

Table 4. General Calibration/Validation Targets or Tolerances for BASINS Hydrology/Flow (Donigian, 2002)

% Difference Between Simulated and Recorded Values		
Very Good	Good	Fair
< 10	10 - 15	15 - 25

Annual and monthly results of the Platte River watershed model flow calibration at the USGS gage location are summarized in Figure 1. The annual and monthly comparisons of predicted and observed flows are provided in Figure 2 and Figure 3, respectively. (It should be noted that year 1990 is not included in Figures 2-3 because that year has an incomplete flow record.) The summary in Figure 1 indicates that the mean absolute percent difference between simulated and observed stream flows is 4.3% on an annual basis and 5.7% on a monthly basis for the full calibration period (1990-2005). These results compare very favorably with the calibration performance targets generally associated with the BASINS/HSPF model (Table 4). The 2003-05 daily time series comparison of BASINS-predicted flow and USGS observed flow at the Honor, MI gage location is provided in Figure 4, and additional flow calibration figures for the Platte River and North Branch are provided in Appendix A to this memorandum.

As an additional test of the flow calibration, LimnoTech also used the USGS's HYSEP and PART software programs to estimate the base flow contribution to the daily flow time series simulated by the BASINS model. Based on this analysis, the monthly base flow component predicted by the BASINS model ranged between 84-99%, which compares very well with data-based estimates of monthly base flow that fall in the range 88-99%. This data-based range for baseflow contribution was also confirmed by an independent PART analysis conducted by the USGS (Ray Canale, personal communication).

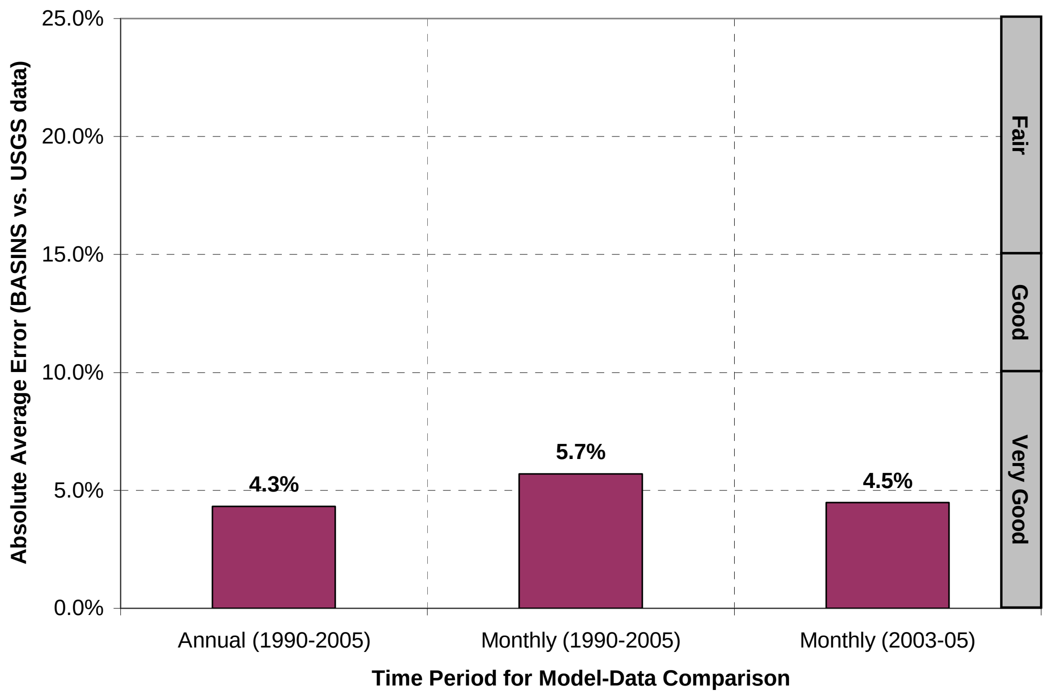

Figure 1. Annual and Monthly Mean Errors for Model-Predicted Flow Relative to USGS Data

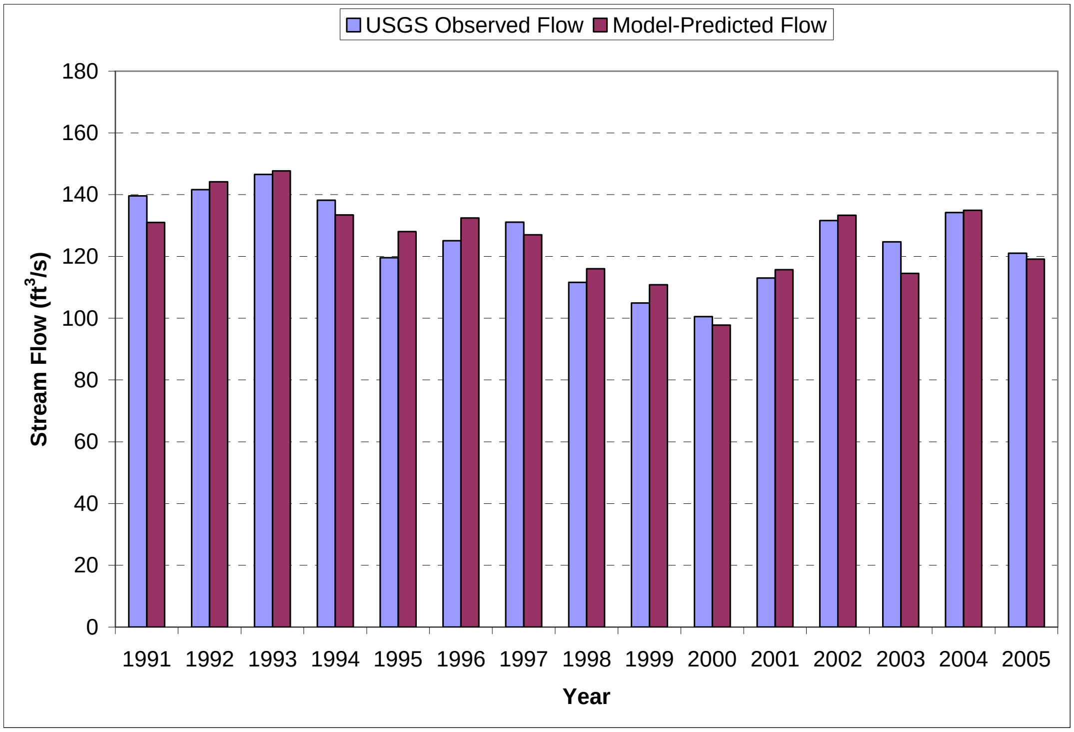

Figure 2. Annual Average Model-Predicted and Observed Flow at USGS Gaging Station

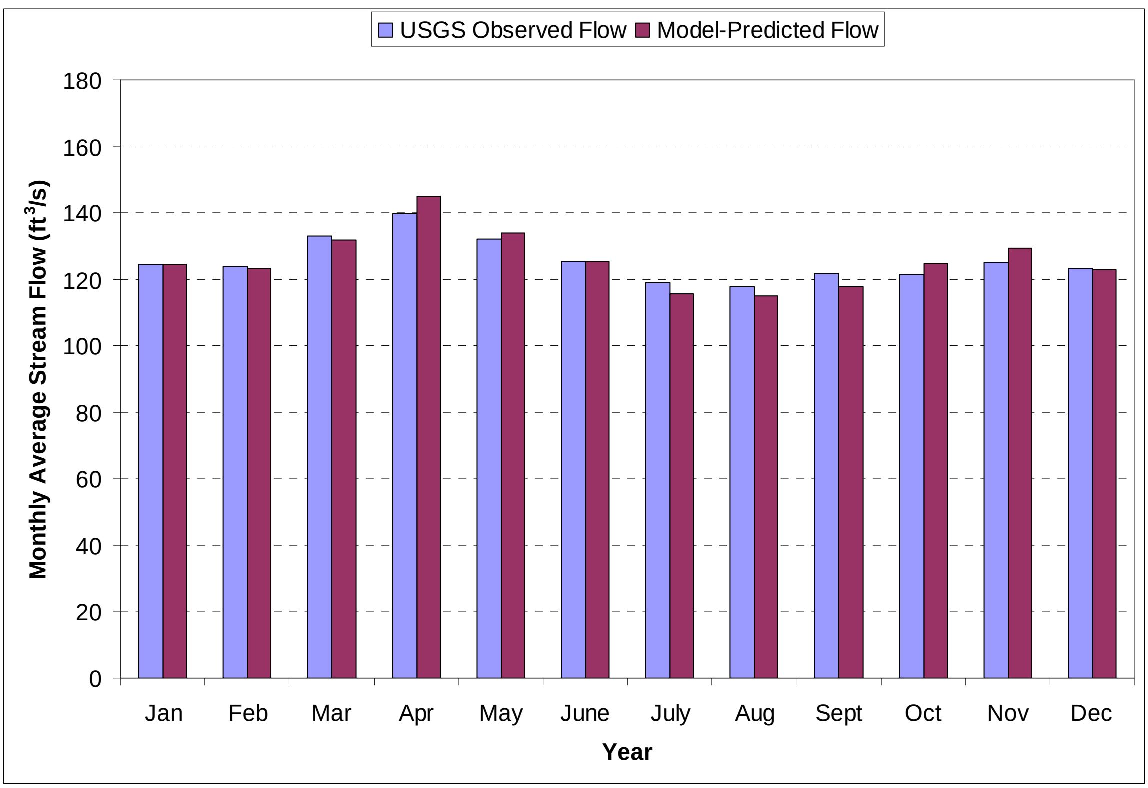

Figure 3. Monthly Average Model-Predicted and Observed Flow at USGS Gaging Station (1991-2005)

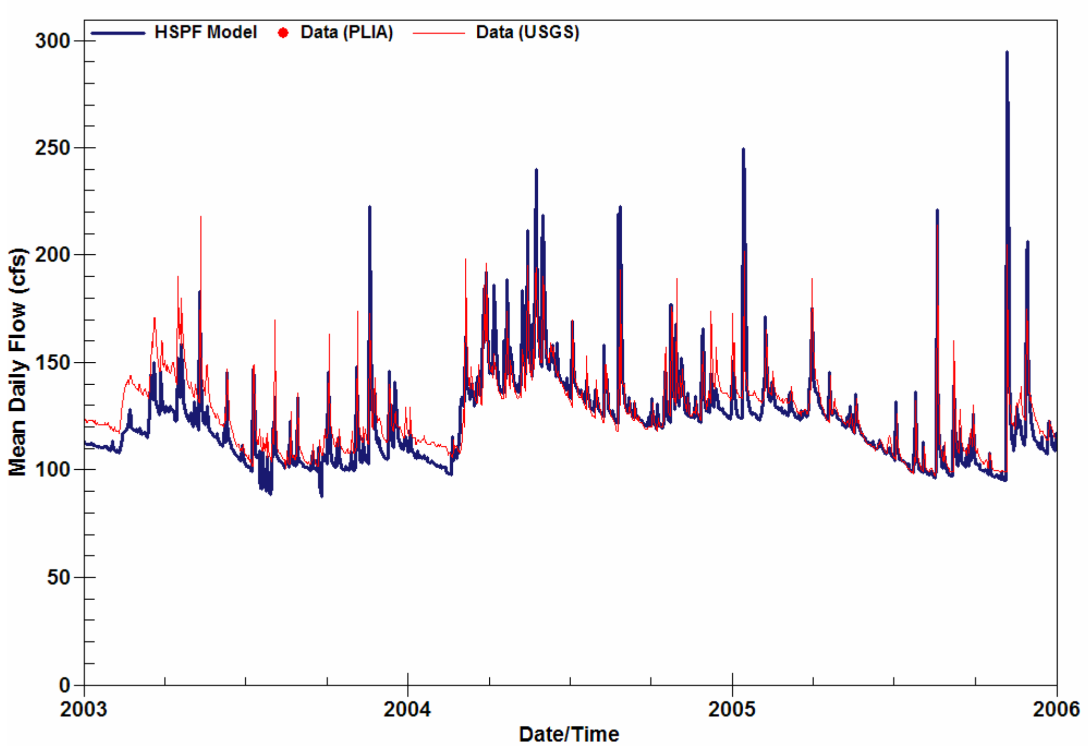

Figure 4. Model-Predicted and Observed Daily Flow Time Series at the USGS Gaging Station

Total Phosphorus Calibration

The watershed model was calibrated to total phosphorus (TP) data collected by the PLIA during the 2003-05 period. The calibration focused on achieving a good fit between model and data at key watershed locations in terms of 1) TP loading estimates for year 2005, and 2) individual dry and wet datasets for various locations. Total suspended solids (TSS) data were available for many of the wet weather events and locations where TP was sampled; therefore, it was possible to use TSS data as an additional constraint on the TP calibration. As discussed previously, TP and TSS concentrations were input to the model on an hourly basis at the Fewins Road location to represent the load/concentration contribution from the upstream lake systems. The bar chart in Figure 5 compares model results and data-based estimates for annual TP loading for locations where sufficient (wet and dry) weather TP data were available to develop a reasonable estimate.

The data-based TP loading estimates are not 100% accurate because the TP concentration was not sampled on an hourly or daily basis for direct comparison to the model load predictions. The 2005 TP dataset for the four locations in Figure 5 includes a reasonable distribution of dry weather and wet weather event samples; however, there remain uncertainties in the data-based estimates because not every day or event is precisely represented. The comparison in Figure 5 illustrates that the model predictions are within approximately 20% of the data-based estimates at each location, which indicates a very good overall fit considering the inherent uncertainties in the data-based estimates.

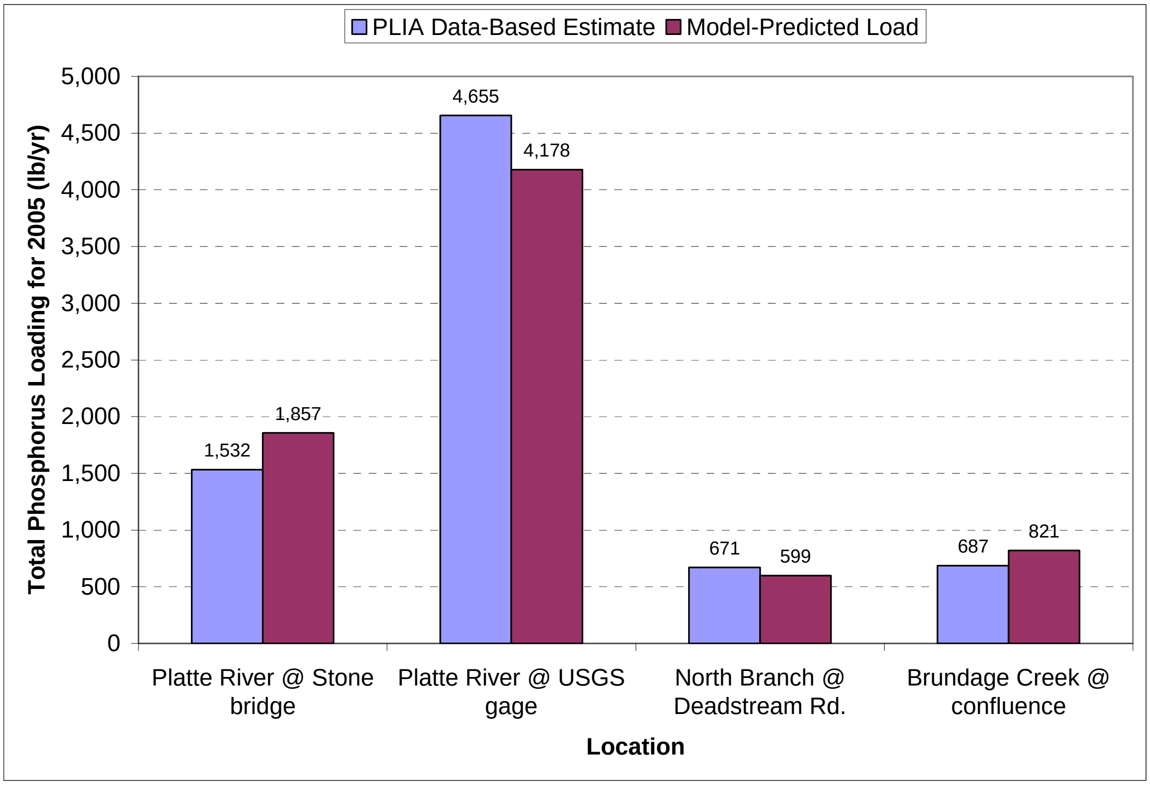

Figure 5. Annual TP Load Comparison for Model-Based and Data-Based Estimates

In addition to accurately simulating the data-based TP loadings at key locations, the model calibration also reproduces the dry and wet weather TP concentrations at those locations. Figures 6a and 6b show the model-data comparison at the USGS gage location for the 2003-05 period and the June 20 – July 22, 2005 period, respectively. Figure 6a illustrates the model simulation captures the overall behavior of TP concentrations at the USGS gage during the PLIA sampling period. The model closely reproduces the observed dry weather concentration patterns and also accurately reflects TP concentrations for most sampled wet weather events. In particular, Figure 6b shows that the model closely reproduces the observed TP concentration profile for the July 4, 2005 wet weather pattern.

The TP simulation results for Brundage Creek provide a similarly good fit to available TP concentration data. Figures 7a and 7b show the simulated and observed TP concentrations at Old Residence for the 2003-05 period and the June 20 – July 20, 2005 period, respectively. Figure 7a illustrates that the model predictions reproduce the observed TP dry and wet weather concentrations quite well at this location. Similar to the USGS gage location, Figure 7b illustrates that the model closely reproduces the observed TP concentrations at Old Residence for the July 4, 2005 wet weather event (and surrounding days).

The North Branch Platte River is the major tributary that enters the mainstem Platte River between the USGS gage location and the entrance to Big Platte Lake. Therefore, it is important that TP loading and concentration data for this tributary be accurately simulated as well. Figure 8 compares model-predicted and observed TP concentrations for the North Branch Platte at Deadstream Road for 2003-05. A review of the data suggests that seasonal patterns exist at this location, most likely due to the influence of Little Platte Lake. It should also be noted that the relatively smooth concentration profile evident for the North Branch Platte is the result of the attenuation of peak TP concentrations that enter Little Platte Lake during wet weather events. As the result of this attenuation effect, peaks in TP concentration are only evident for the largest watershed runoff events.

Initial simulation results for the North Platte under-predicted the (annual) average TP concentration at Deadstream Road (13.8 ug/L) by approximately 4 ug/L. It was hypothesized that this under-prediction is due to natural and/or human activities in Little Platte Lake. The observed seasonal patterns in TP concentration suggest that increased breakdown of organic matter and the subsequent release of phosphorus from wetland areas may occur during the summer months. Human activities that might contribute additional phosphorus to Little Platte Lake include loadings from septic systems and general stormwater runoff from private residences located along the lake. Because hydraulic and TP concentration information for Little Platte Lake are very limited, a constant TP load (139 lb/year, or 0.38 lb/day) was introduced to Little Platte Lake to increase the model-predicted concentrations to the average observed concentrations. It is recommended that a sampling program be designed and implemented to revolve the apparent discrepancy between the model and the data for the North Branch watershed including Little Platte Lake.

The complete set of model-data TP calibration figures is provided in Appendix B to this memorandum, including time series graphics for mainstem Platte River locations, Brundage Creek (at Old Residence), and North Branch Platte River (at Deadstream Road). Total suspended solids (TSS) model-data comparisons are not shown or discussed here for brevity; however, a set of TSS calibration graphics can be found in Appendix C.

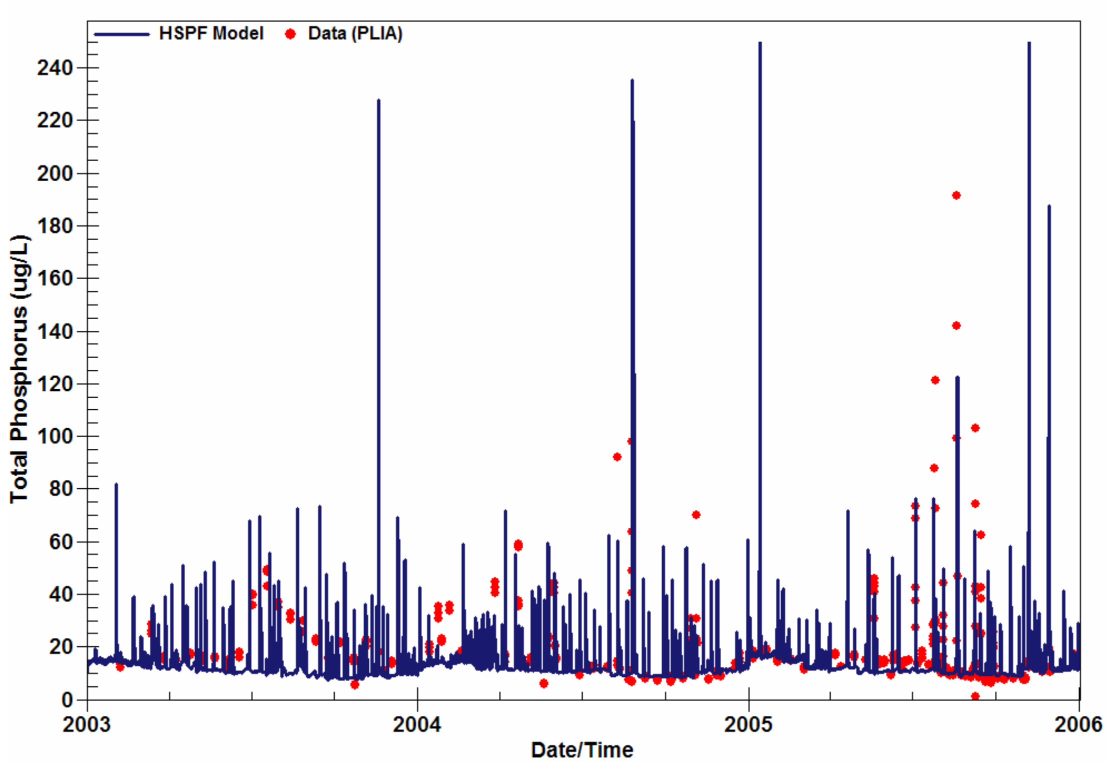

Figure 6a. Simulated and Observed TP Concentrations for the Platte River at the USGS Station

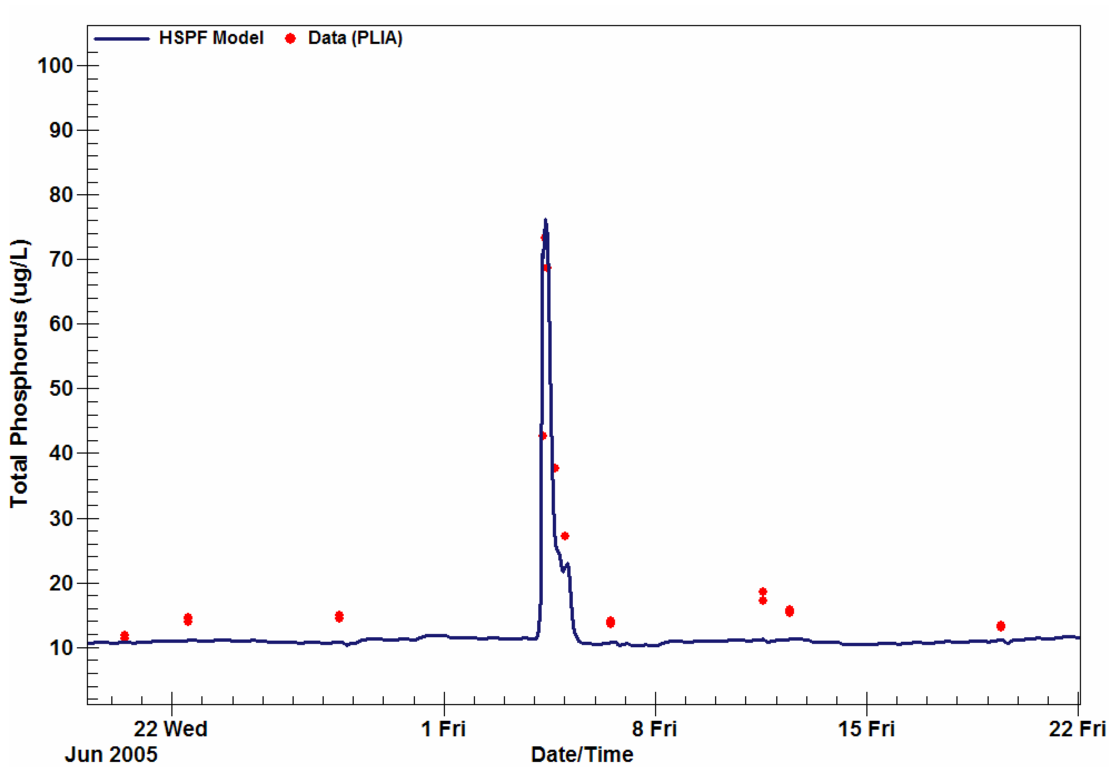

Figure 6b. Simulated and Observed TP Concentrations for the Platte River at the USGS Station (June 20 – July 22, 2005)

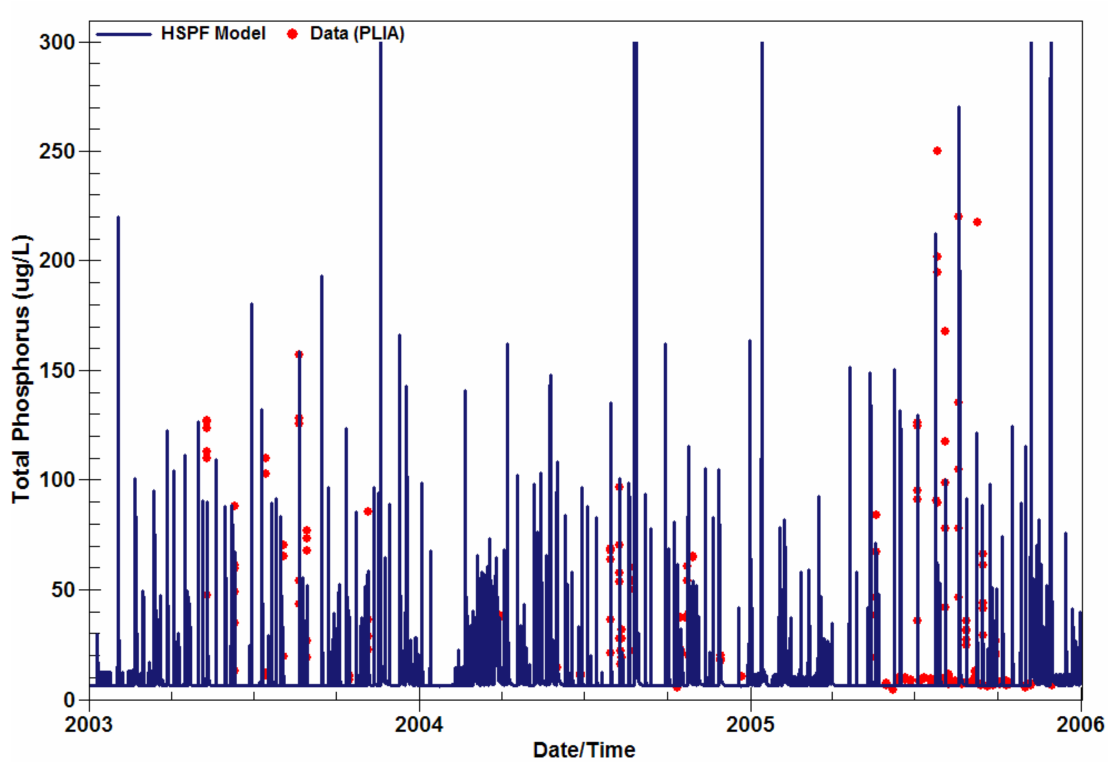

Figure 7a. Simulated and Observed TP Concentrations for Brundage Creek at Old Residence

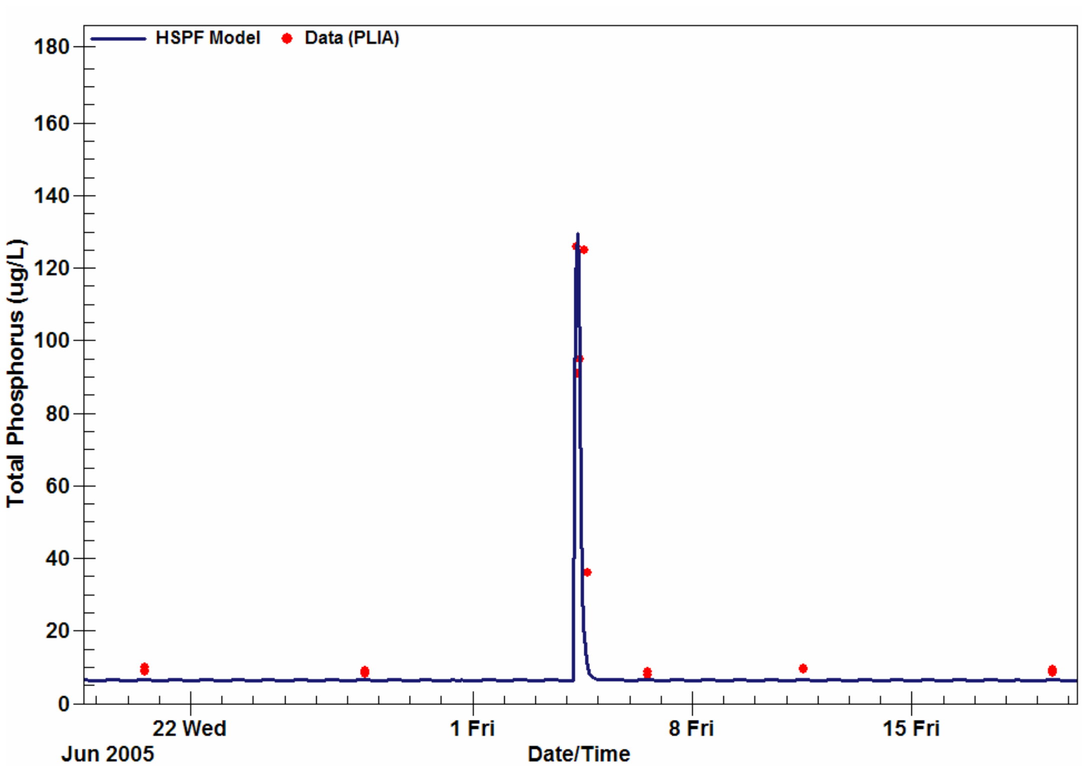

Figure 7b. Simulated and Observed TP Concentrations for Brundage Creek at Old Residence (June 20 – July 20, 2005)

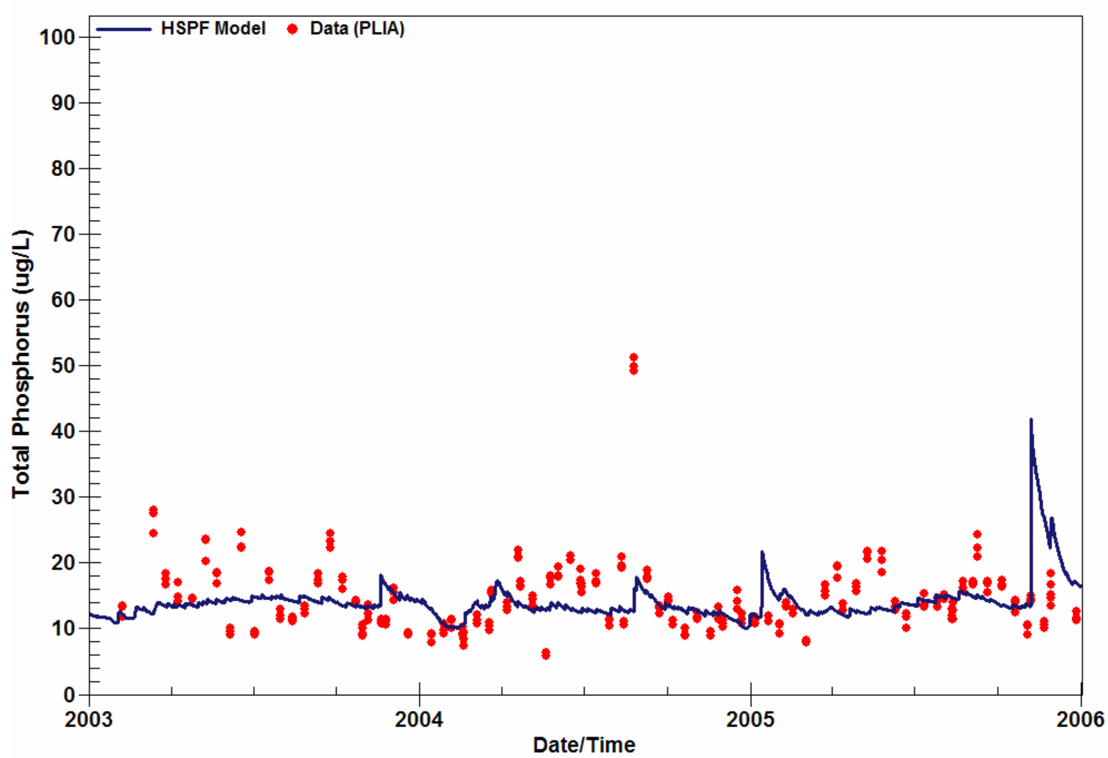

Figure 8. Simulated and Observed TP Concentrations for North Branch Platte River at Deadstream Road

An important additional check on the model calibration for total phosphorus is to ensure that the calibrated unit area load (UAL) rates are generally consistent with literature ranges available for individual land use types. Table 5 presents the average UAL rate (lb/acre/year) for each of the nine land use types included in the BASINS model for the Platte River watershed, as well as the range of annual UALs for the entire 1990-2005 period. Literature ranges are provided in the rightmost column of the table.

Although many of the data-based ranges are quite large, a review of the values in Table 5 suggests that the calibrated model UALs generally fall within, or very close to, the data-based ranges. It is also worth noting that the *relative* magnitude of UALs across land use types is similar between the model and data ranges. This comparison provides added confidence that the model simulation of watershed runoff flow, TP, and TSS is reasonable and provides results consistent with previous studies of watershed TP loading.

It should be noted that the UALs in Table 5 include TP loads delivered via groundwater flow in addition to TP loads delivered via direct watershed runoff. The groundwater TP loading rate is generally consistent across the various land use types. The hatchery TP contribution is not included as part of the UAL values, but is considered separately within the model as a true point source. As part of the calibration, it was assumed that interactions with the sediment bed do not result in any net gain or loss of TP from the river water. Therefore, the UAL values in Table 5, combined with the net hatchery point source loading, translate directly into the actual TP loadings from the watershed between the boundary at Fewins Road and Big Platte Lake. This correspondence is important because it allows the direct use of the UALs, subwatershed / land use areas, and the hatchery point source loads to predict potential changes in TP loading within the graphical user interface (GUI) tool.

Table 5. Total Phosphorus Calibrated Unit Area Loads & Literature Ranges

Land Use Type	Unit Area Loads (lb/ac/yr)		
	Average	Range	Literature Ranges
Forest	0.03	0.02-0.05	0.02-0.74 [a]
Barren	0.08	0.04-0.15	n/a
Orchards	0.05	0.03-0.10	n/a
Permanent Pasture / Open Land	0.07	0.04-0.16	0.04-0.09 [b]
Cropland	0.11	0.03-0.24	0.22-0.76 [a]
Low-Density Residential	0.25	0.16-0.39	0.41-0.57 [c]
Commercial	0.70	0.61-0.87	0.17-5.56 [a]
Wetland	0.03	0.02-0.04	n/a
Feeding Operation	2.61	2.02-4.17	19-709 [a]

[a] Reckhow, et al., 1980.
[b] Sonzogni, 1980.
[c] EPA, 1999.

Watershed Model Application

Application of the watershed model involved 1) the selection of representative “High”, “Low”, and “typical” years based on rainfall and flow information, 2) simulation of those representative years with the calibrated model, and 3) integration of the model results for each year into a graphical user interface (GUI) to facilitate evaluation of TP load scenarios. The following sections discuss the selection process for the High, Low, and typical years, the results of the model simulations for the selected years, and the GUI tool development.

Selection of High, Low, and Typical Years

For the Platte River watershed, the selection of a “High”, “Low”, and “typical” year can potentially be based on one or a combination of three different criteria:

- Model-predicted TP load to Big Platte Lake;
- Total annual rainfall at Frankfort; and/or
- Mean annual flow for the USGS gage at Honor.

Because TP loads to Big Platte Lake and at other points within the system represent the outcome of greatest interest from the model simulations, TP load was the primary consideration when selecting High, Low, and typical years. Annual rainfall and streamflow statistics were used to support the selection process. Table 6 provides a summary of the TP loads to Big Platte Lake, total rainfall, and mean daily streamflow for all years during the 1990-2005 period, with the years rank-ordered from largest to smallest annual TP load. The TP loads represented in this table are based on the watershed (including upstream) loads from the calibration period and use a constant hatchery net loading of 175 lb/yr for all years in place of the historical hatchery net loadings used for model calibration (Ray Canale, personal communication).

Table 6. Rank-Ordered Annual TP Loads to Big Platte Lake

Load Rank[1]	Year	TP Load (lb/yr)	Rainfall (inches)	Streamflow (cfs)[2]	Notes
1	1992	6,193	41.6	170	Selected as “High” year
2	2002	5,733	29.4	159	
3	1990	5,279	39.6	147	
4	1996	4,993	37.5	157	
5	2001	4,948	42.0	138	
6	1993	4,869	38.5	175	
7	1995	4,835	38.3	150	
8	2005	4,834	27.2	142	
9	1991	4,822	39.3	152	
10	2004	4,662	39.7	162	Selected as “typical” year
11	1994	4,423	34.9	157	
12	1998	3,991	38.2	137	
13	1997	3,932	29.3	150	
14	2003	3,883	31.3	135	
15	1999	3,481	32.2	131	
16	2000	3,273	30.3	116	Selected as “Low” year

Notes:
[1]Each year in the 1990-2005 period is rank-ordered based on largest to smallest model-predicted TP load to the lake. Loads assume a constant hatchery net TP load of 175 lb/yr.
[2]Represents model-simulated average annual flow from the Platte River to Big Platte Lake.

The final selections for the "High", "Low", and "typical" years are noted and highlighted in blue in Table 6. The rationale for the three selections is provided below:

- "High" Year: Year 1992 was selected as the High year because it has the highest TP load of any year within the 1990-2005 period. This year is also characterized by the second-highest rainfall totals and the second-highest streamflow to Big Platte Lake.

- "Low" Year: Year 2000 was selected as the representative Low year because it has the lowest TP load of any year. In addition, this year has the lowest streamflow to Big Platte Lake and the third-lowest rainfall total of any year.

- "Typical" Year: Year 2004 was selected as the representative typical year because the total TP load (4,662 lb/yr) was most similar to the average annual load across the entire 1990-2005 period (4,634 lb/yr).

The relative contributions of the upstream (i.e., above Fewins Road), watershed (between Fewins Road and Big Platte Lake), and the hatchery components to the overall TP load for each year are summarized in Table 7. The upstream and hatchery contributions comprise the highest fraction of the total TP load for the Low year and lowest fraction for the High year.

Table 7. Rank-Ordered Annual TP Loads to Big Platte Lake

Hydrologic Condition	TP Load (lb/yr)	Upstream Contribution	Watershed Contribution	Hatchery Contribution
High Year (1992)	6,194	36.1%	61.1%	2.8%
Typical Year (2004)	4,661	43.6%	52.6%	3.8%
Low Year (2000)	3,275	44.3%	50.4%	5.3%

Of the three selected years, it is anticipated that the "High" year (1992) would have a larger fraction of its total annual TP load delivered during watershed runoff events relative to the Low year (2000). An analysis of the daily rainfall and model-predicted TP load was conducted to confirm this hypothesis. To support this analysis, each day within each of the three years was classified as a "runoff" day if the total precipitation for that day exceeded 0.10-inch and the average air temperature was greater than or equal to 32 degrees Fahrenheit (i.e., snowfall was assumed to occur for temperatures less than 32 degrees). All days that did not meet these criteria were classified as "non-runoff" days. In general, the daily TP load to Big Platte Lake will be dominated by local runoff conditions on "runoff" days, while loads from the upstream lake systems and local baseflow will dominate the TP load on "non-runoff" days.

Table 8 provides the results of the runoff vs. non-runoff TP load analysis. The results in Table 8 confirm that the "High" year has a higher fraction of runoff load (45%) than the "typical" year (32%) and the "Low" year (28%).

Table 8. Runoff vs. Non-Runoff TP Load Contributions for Selected Years

Hydrologic Condition	TP Load (lb/yr)	"Runoff" Days		"Non-Runoff" Days	
		# of days	% TP Load	# of days	% TP Load
High Year (1992)	6,194	68	45%	298	54%
Typical Year (2004)	4,661	63	32%	303	68%
Low Year (2000)	3,275	54	28%	312	72%

Scenario Results & Discussion

The typical, High, and Low years were simulated using the calibrated Platte River watershed model. Land use and meteorological inputs (e.g., rainfall, air temperature) used for these simulations were identical to those used for the calibration. The only modification to the original simulation for the three years of interest was the use of a simplified net hatchery load to replace the time-variable TP intake and loading rates used in the calibration simulation. As indicated above, a constant daily net TP loading rate of 175 lb/yr (0.479 lb/day) was used for each of the scenario years (Ray Canale, personal communication). The TP loads at key points within the system are shown schematically in Figures 9a, 9b, and 9c for the High, typical, and Low years, respectively. It should be noted that because only the net hatchery load to the Platte River is considered in the scenarios, the Brundage Creek load represents its entire watershed load without any load "lost" to the hatchery intakes from the creek or Brundage Spring.

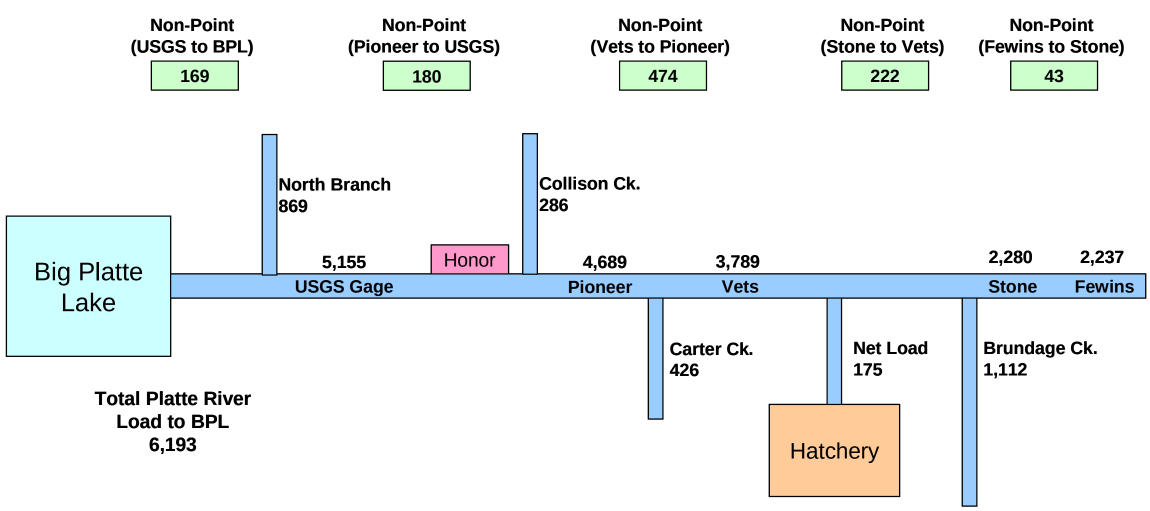

Figure 9a. TP Load Schematic for "High" Year (1992)

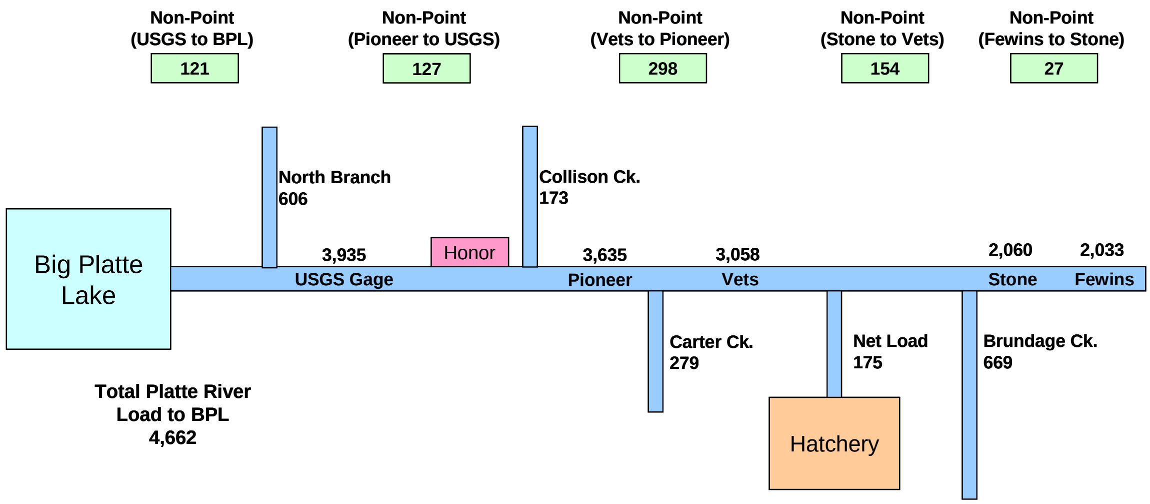

Figure 9b. TP Load Schematic for "Typical" Year (2004)

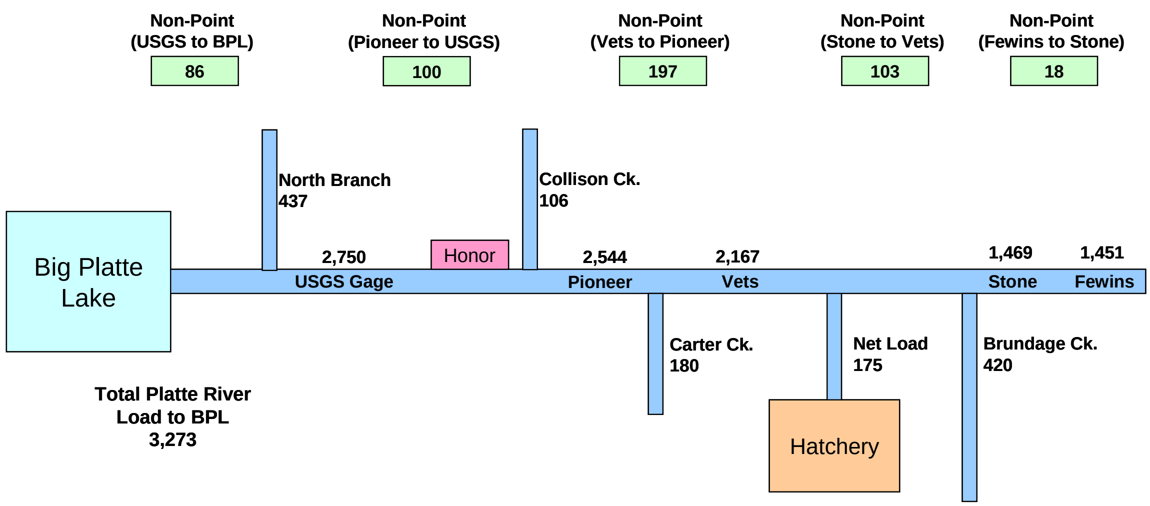

Figure 9c. TP Load Schematic for "Low" Year (2000)

Table 8 summarizes the UALs (lb/acre/year) by land use type for the typical, High, and Low years. As could be expected, the High year has the largest UALs and the Low year has the smallest UALs for each of the land uses.

Table 8. TP Unit Area Loads for the Selected High, Typical, and Low Years

Land Use Type	Area (acres)	Percent of Total Area	Unit Area Load (lb/ac/yr)		
			Low Year (2000)	High Year (1992)	Typical Year (2004)
Forest	23,858	65%	0.023	0.046	0.036
Barren	33	0%	0.038	0.139	0.071
Orchards	702	2%	0.027	0.101	0.054
Pasture	7,833	21%	0.036	0.120	0.071
Cropland	1,660	4%	0.033	0.236	0.079
Low-Density Residential	2,230	6%	0.164	0.388	0.219
Commercial	345	1%	0.654	0.773	0.688
Wetland	310	1%	0.018	0.039	0.039
Feeding Operation	0	0%	2.138	3.242	2.686

Platte River TP Load Scenario Analysis Tool

A graphical user interface (GUI) tool was developed in Microsoft Excel to allow the user to review and modify TP loads for each of the simulated subwatersheds for the "High", "typical", and "Low" years. The unit area loads presented in Table 8 above and the land use areas used for model calibration are used to drive the GUI calculations of TP load for each subwatershed. A screenshot of the GUI tool is provided in Figure 10.

The left pane within the GUI is a "Summary" window that shows the base and scenario (i.e., modified) TP load (lb/yr) contribution for each of the 18 subwatersheds between Fewins Road and Big Platte Lake, as well as the upstream contribution at Fewins Road for a selected hydrologic condition (i.e., typical, High, or Low). The subwatersheds are organized by major tributary or mainstem, including:

- Platte River (upstream and direct drainage);
- Brundage Creek;
- Carter Creek;
- Collison Creek; and
- North Branch Platte River.

TP load subtotals are provided for each of these tributary/mainstem reaches, and the grand total of all loadings to Big Platte Lake is also provided for the base and scenario conditions. The total TP load to Big Platte Lake and the contributions from individual tributaries and direct drainage areas closely match the values shown in Figures 9a, 9b, and 9c. It is important to keep in mind that a constant annual "point source" load of 139 lb/yr is applied to the "NB02: North Branch Platte River (LPL)" subwatershed, consistent with the TP load added as part of calibration for this tributary. The annual hatchery load (175 lb/yr) is included as a point source for the "PR03: Vets Park to Carter Ck" subwatershed.

Positioned to the right of the "Summary" window is the "Editor" window, which allows the user to select one of the three hydrologic conditions (typical, High, or Low) and modify the land use distribution, point source loading, and/or upstream loading for any of the subwatersheds. When a particular subwatershed is selected using the drop-down menu near the top of the window, the map in the lower right-hand corner is updated to highlight the selected area. The "Editor" window also allows the user to specify "best management practice" (BMP) areas for any subwatershed and the associated TP removal efficiency for those areas. Any user-defined scenario (with a maximum of 20 scenarios) can be saved within the GUI using the buttons and descriptions provided in the lower left-hand corner of the "Editor" window. The "Export Daily TP Loads" button allows the user to export a daily time series of flow and TP loads to Big Platte Lake for the three hydrologic conditions. The flows and phosphorus loads generated by the Editor and summarized on the Summary sheet are transferred to a water quality model for the lake by selecting the "Go to Lake Model" button. The model predicts the total phosphorus concentration in the lake and compares the results with water quality goals. This model was developed through an independent project and is described in detail in another report (Canale, et al., 2006).

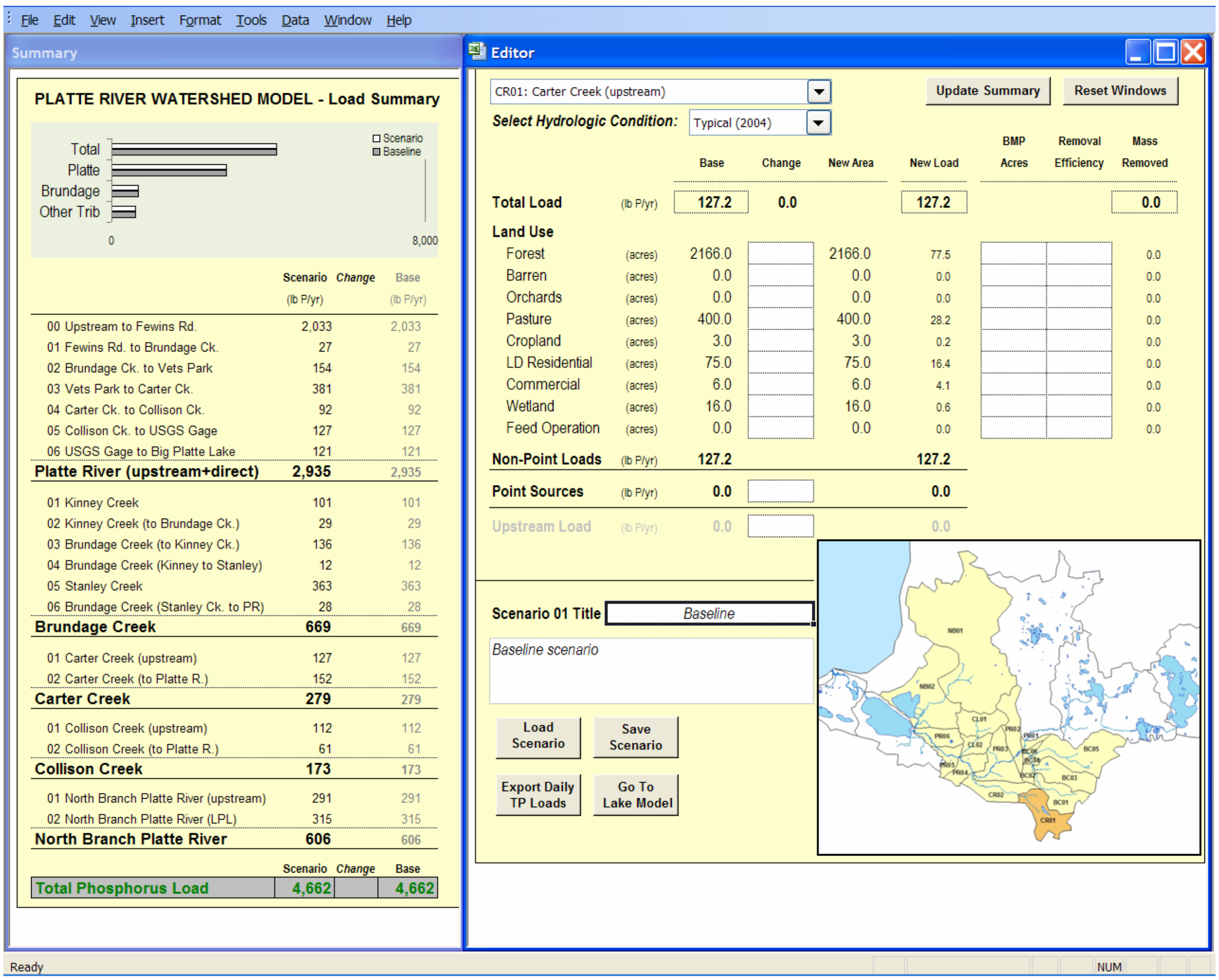

Figure 10. Platte River Watershed TP Load Analysis Tool

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List of Appendices

Appendix A – Watershed Model Flow Calibration Graphics

Appendix B – Watershed Model Total Phosphorus (TP) Calibration Graphics

Appendix C – Watershed Model Total Suspended Solids (TSS) Calibration Graphics

Appendix D – Memorandum: “Comparison of Platte River Watershed Precipitation and Streamflow Datasets”

Appendix A

Watershed Model Flow Calibration Graphics

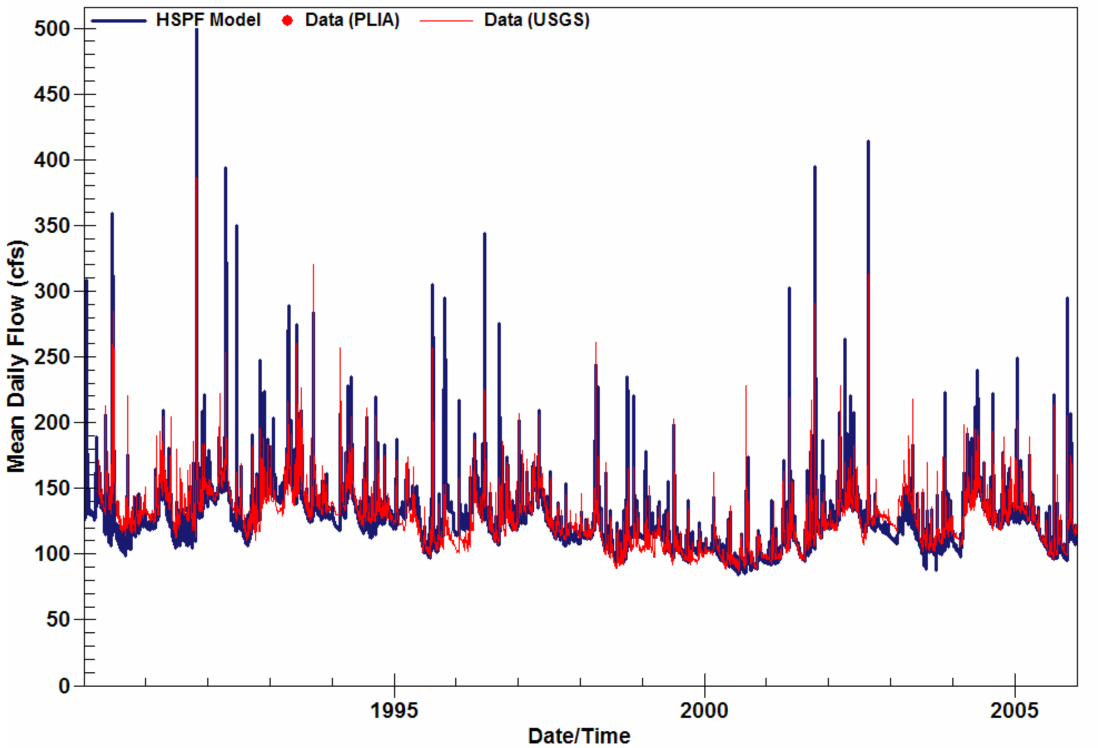

Figure A-1. Model-Predicted vs. Observed Flow for Platte River at USGS Station (1990-2005)

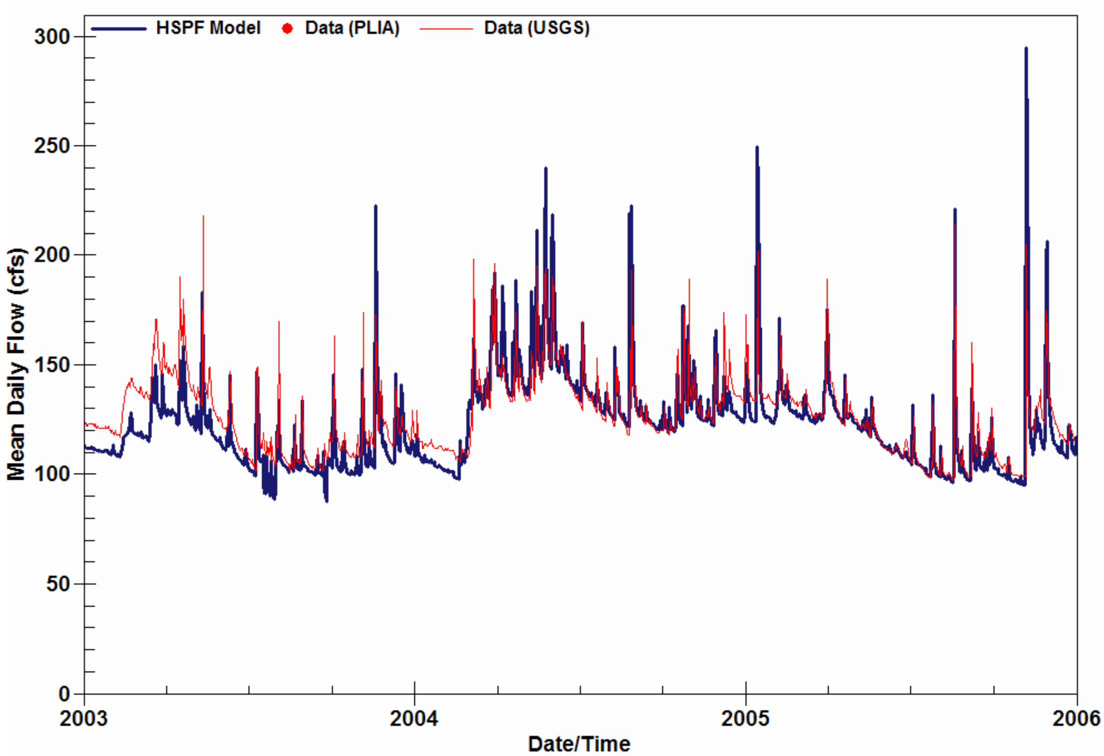

Figure A-2. Model-Predicted vs. Observed Flow for Platte River at USGS Station (2003-05)

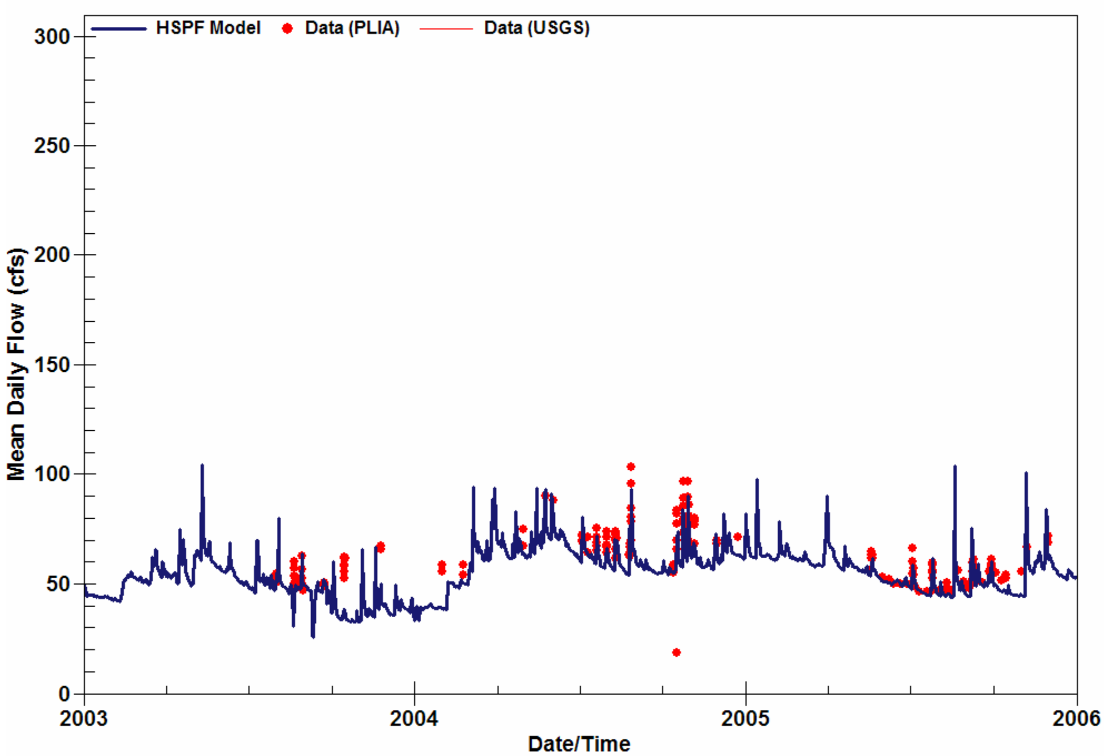

Figure A-3. Model-Predicted vs. Observed Flow for Platte River at Stone Bridge

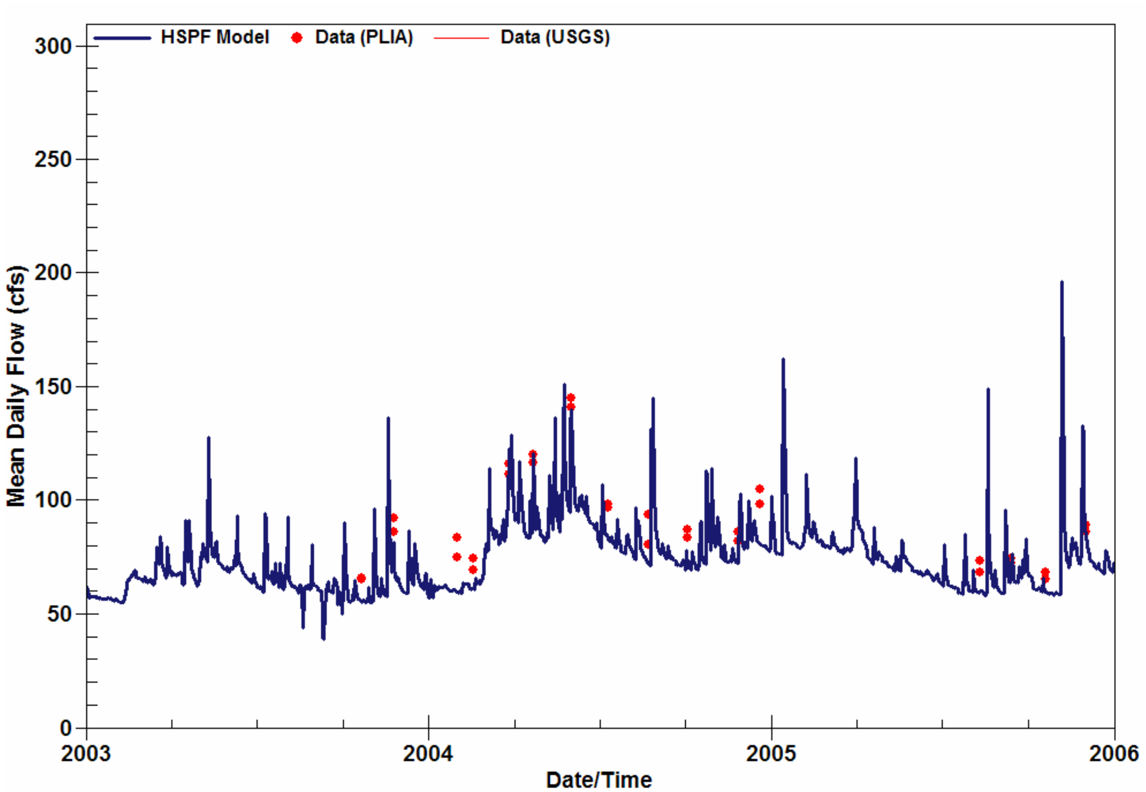

Figure A-4. Model-Predicted vs. Observed Flow for Platte River at Veteran's Park

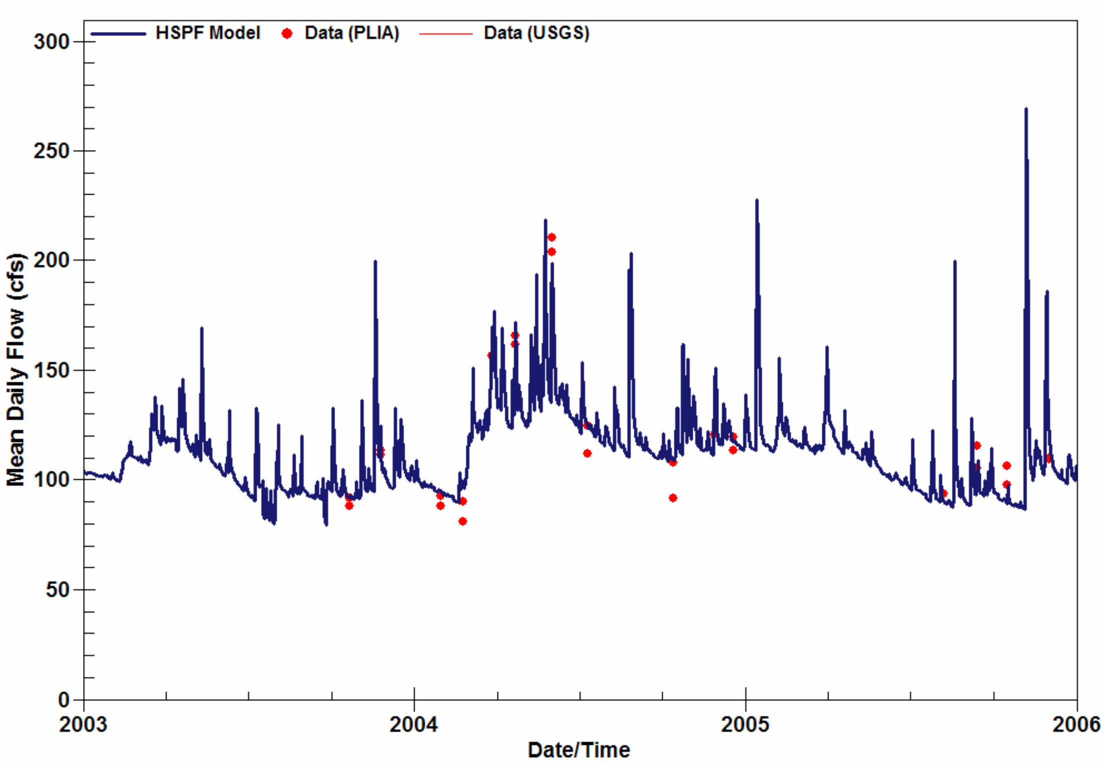

Figure A-5. Model-Predicted vs. Observed Flow for Platte River at Pioneer Road

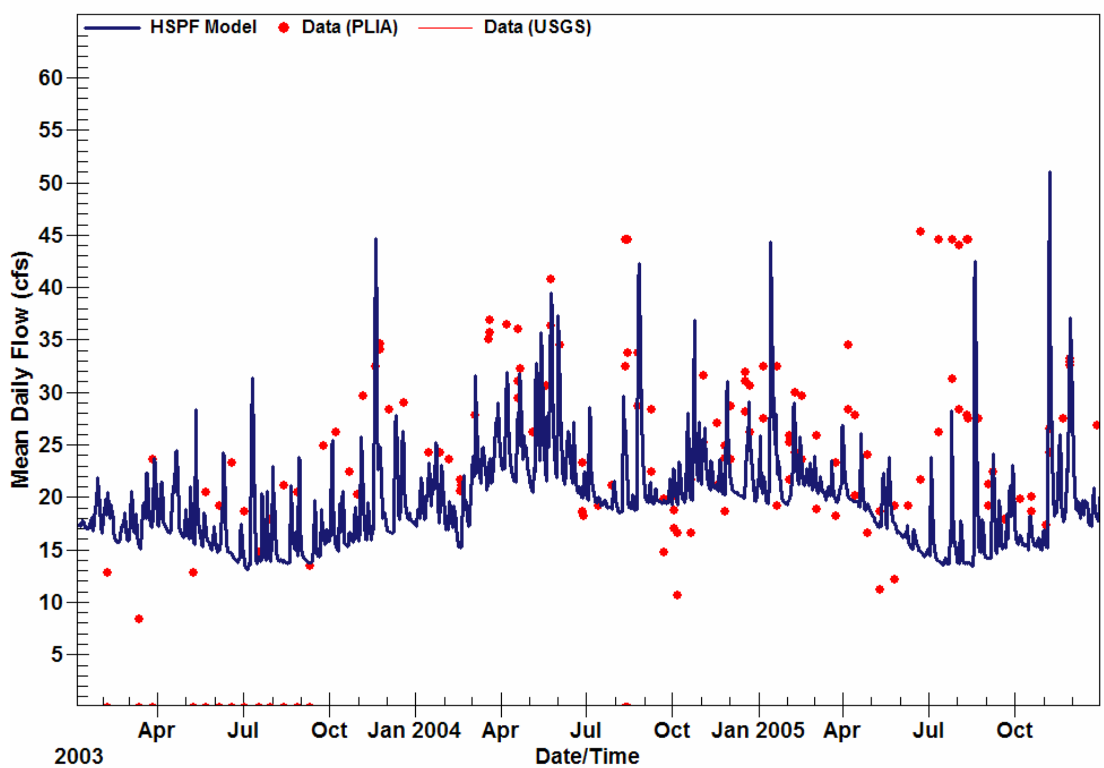

Figure A-6. Model-Predicted vs. Observed Flow for North Branch Platte River at Deadstream Road

Appendix B

Watershed Model Total Phosphorus (TP) Calibration Graphics

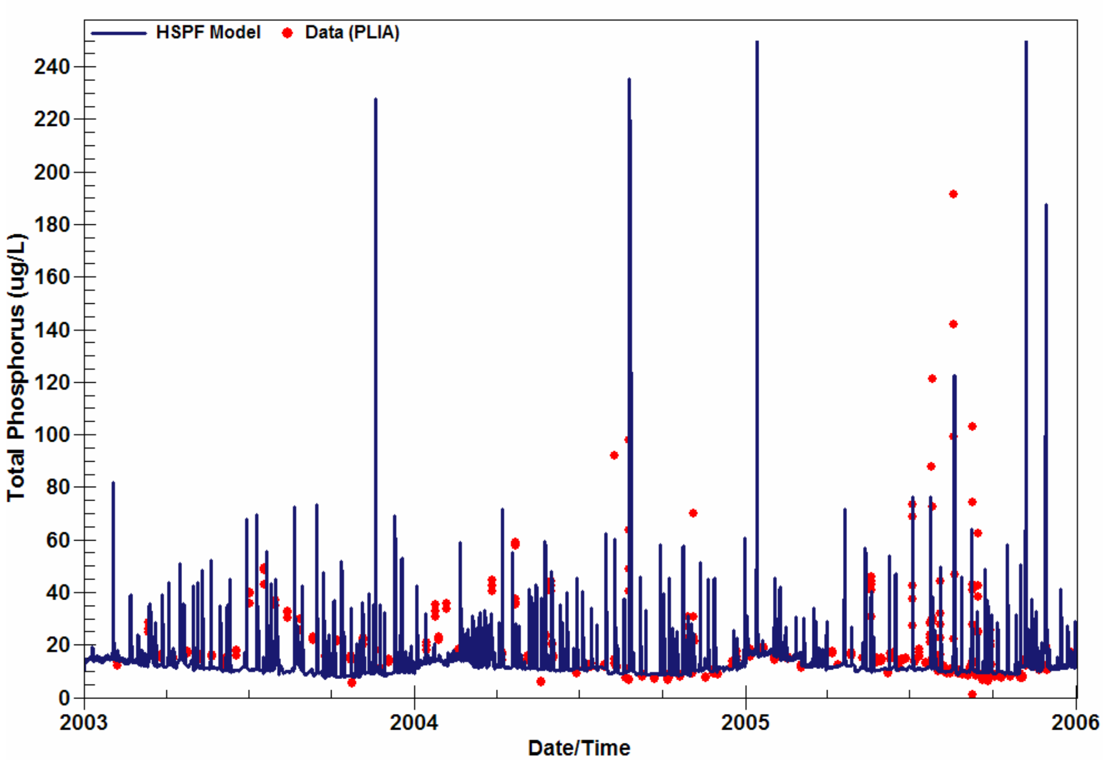

Figure B-1. Model-Predicted vs. Observed TP for Platte River at USGS Station

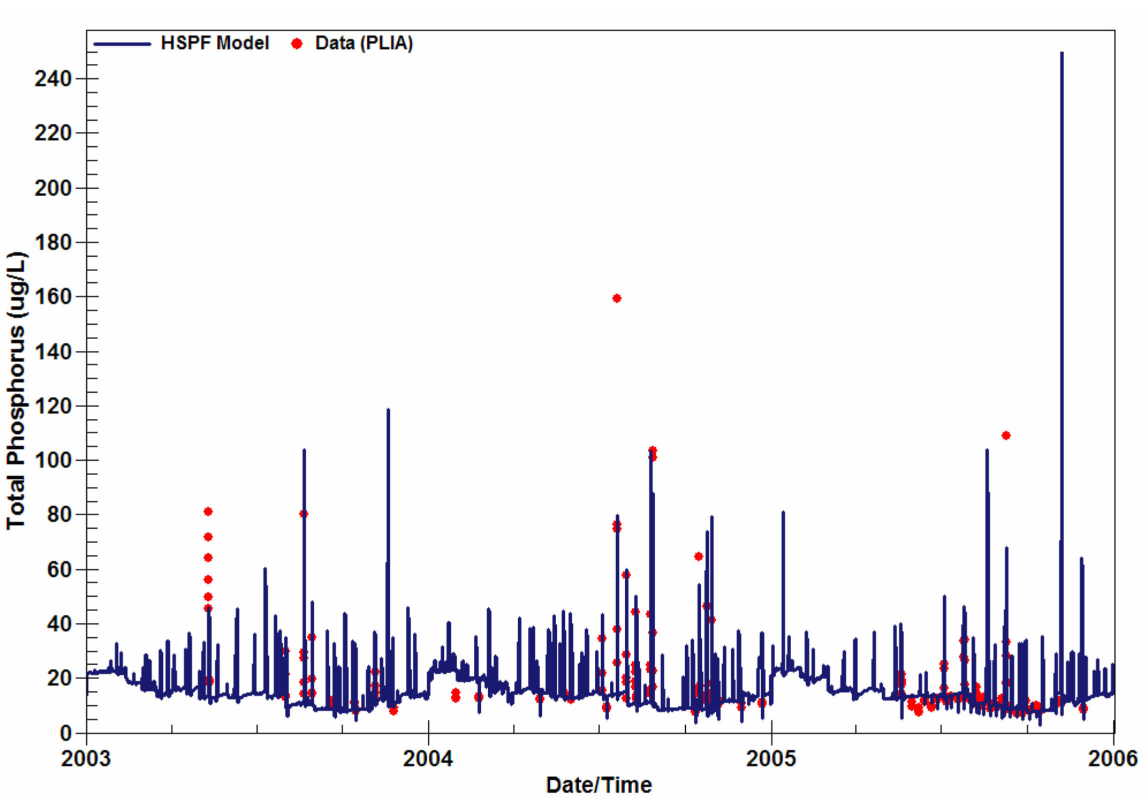

Figure B-2. Model-Predicted vs. Observed Flow for Platte River at Stone Bridge

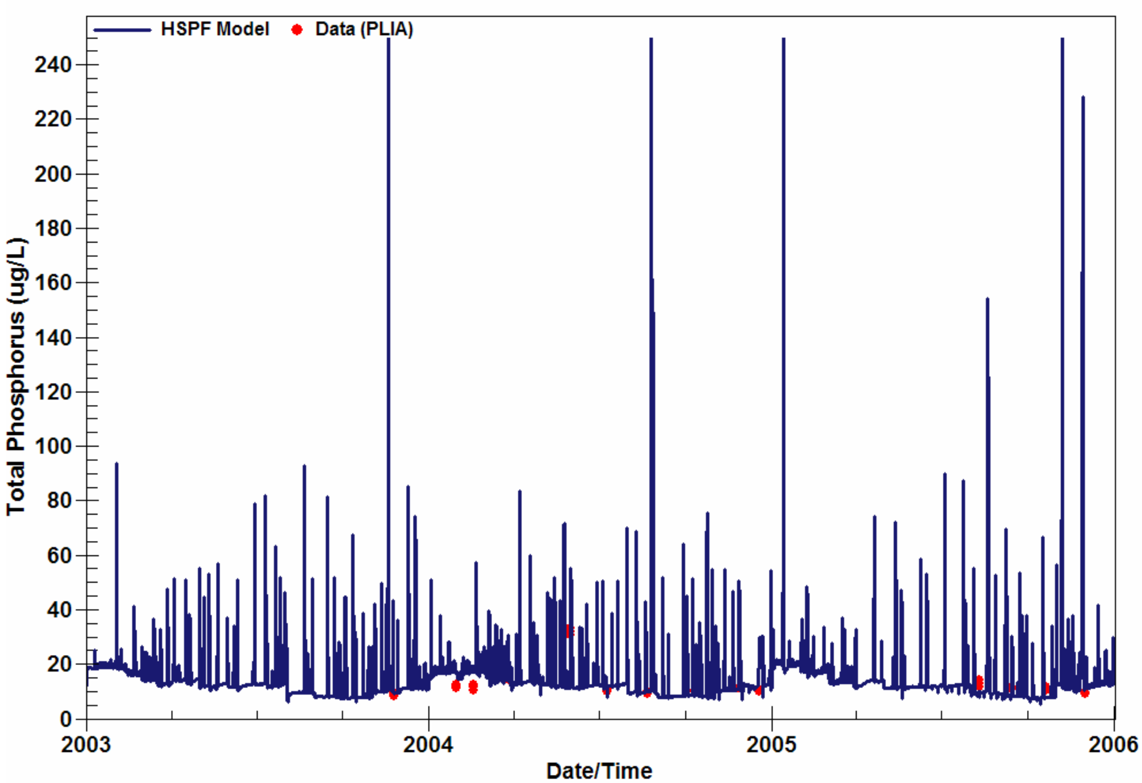

Figure B-3. Model-Predicted vs. Observed Flow for Platte River at Veteran's Park

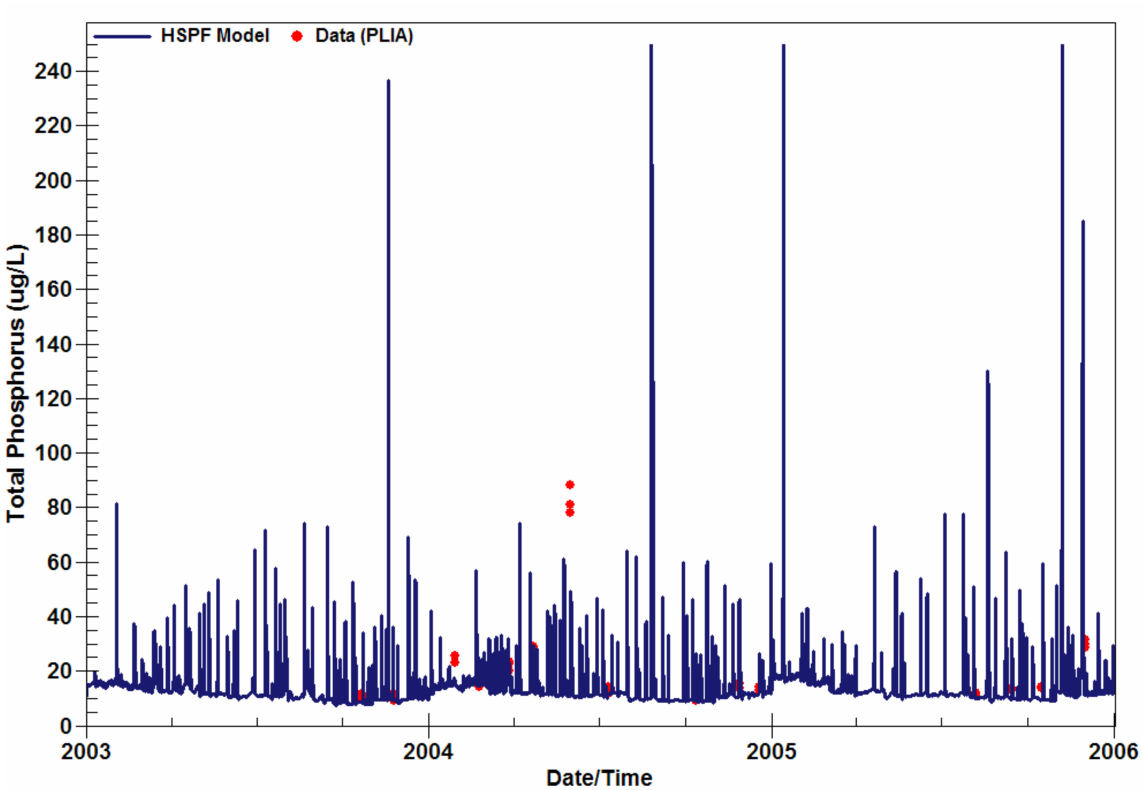

Figure B-4. Model-Predicted vs. Observed Flow for Platte River at Pioneer Road

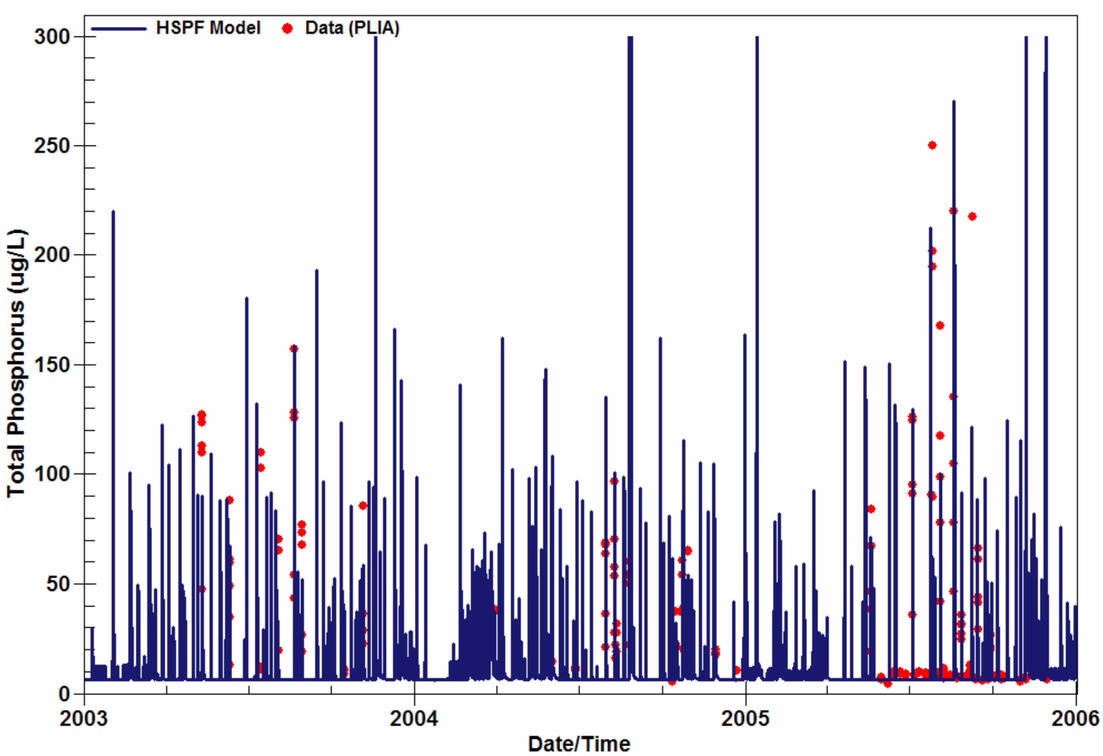

Figure B-5. Model-Predicted vs. Observed Flow for Brundage Creek at Old Residence

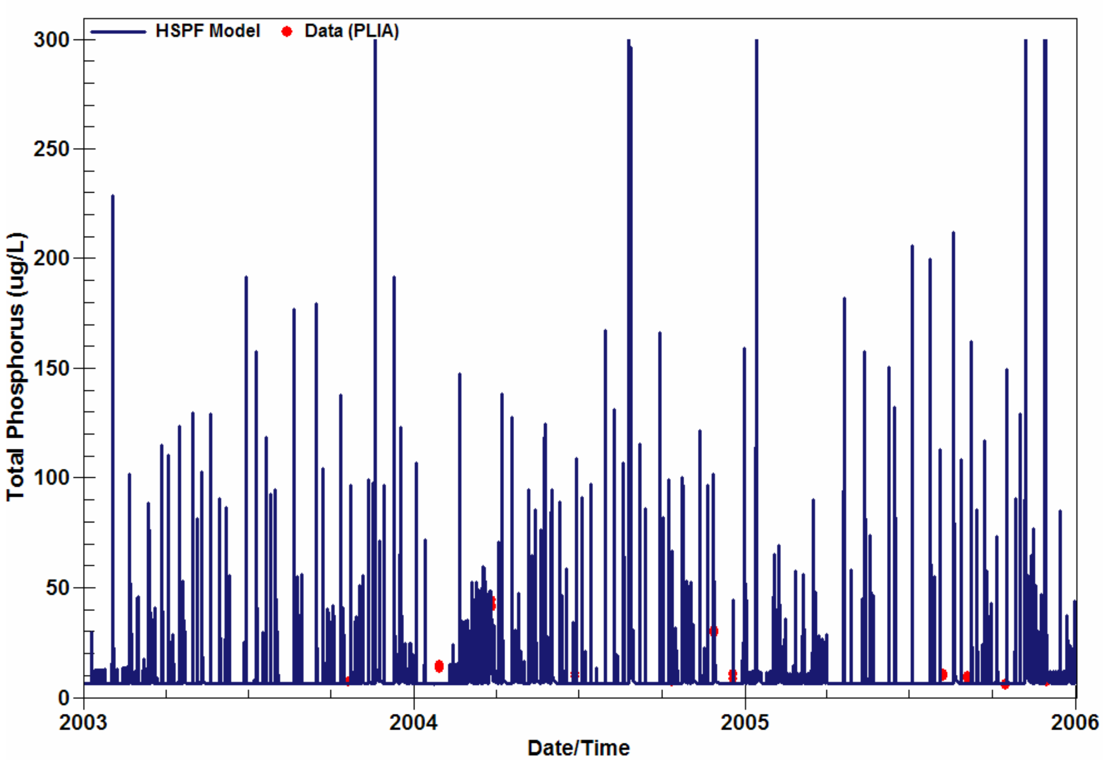

Figure B-6. Model-Predicted vs. Observed Flow for Carter Creek

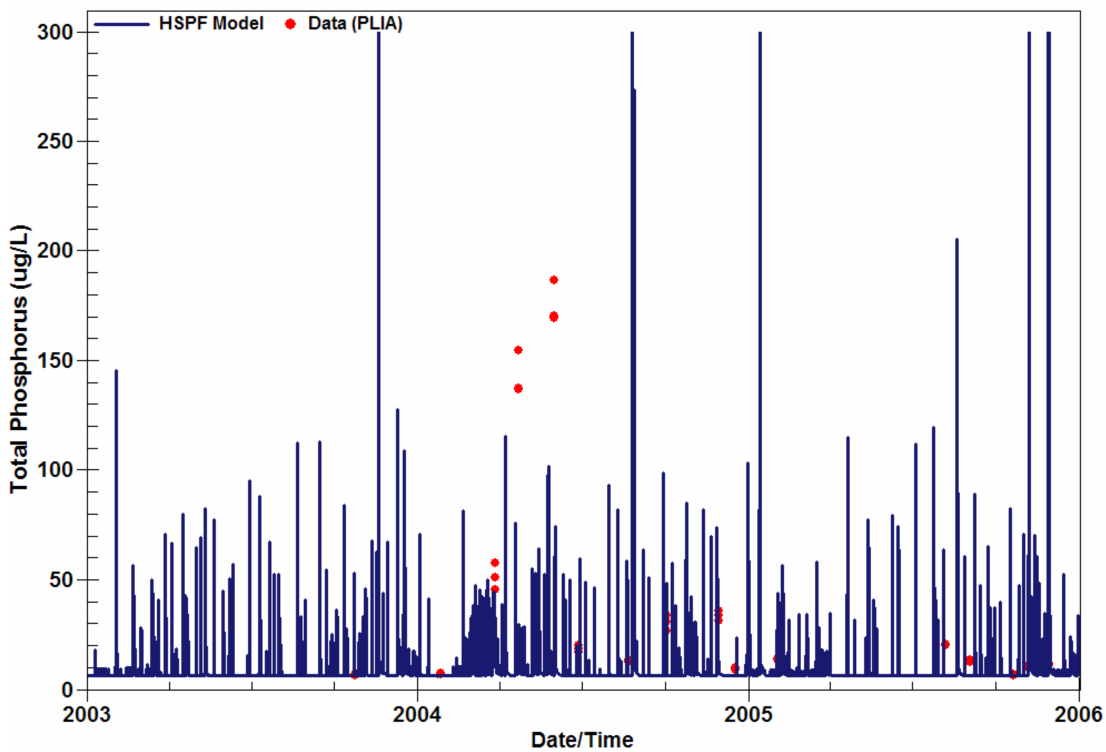

Figure B-7. Model-Predicted vs. Observed Flow for Collison Creek

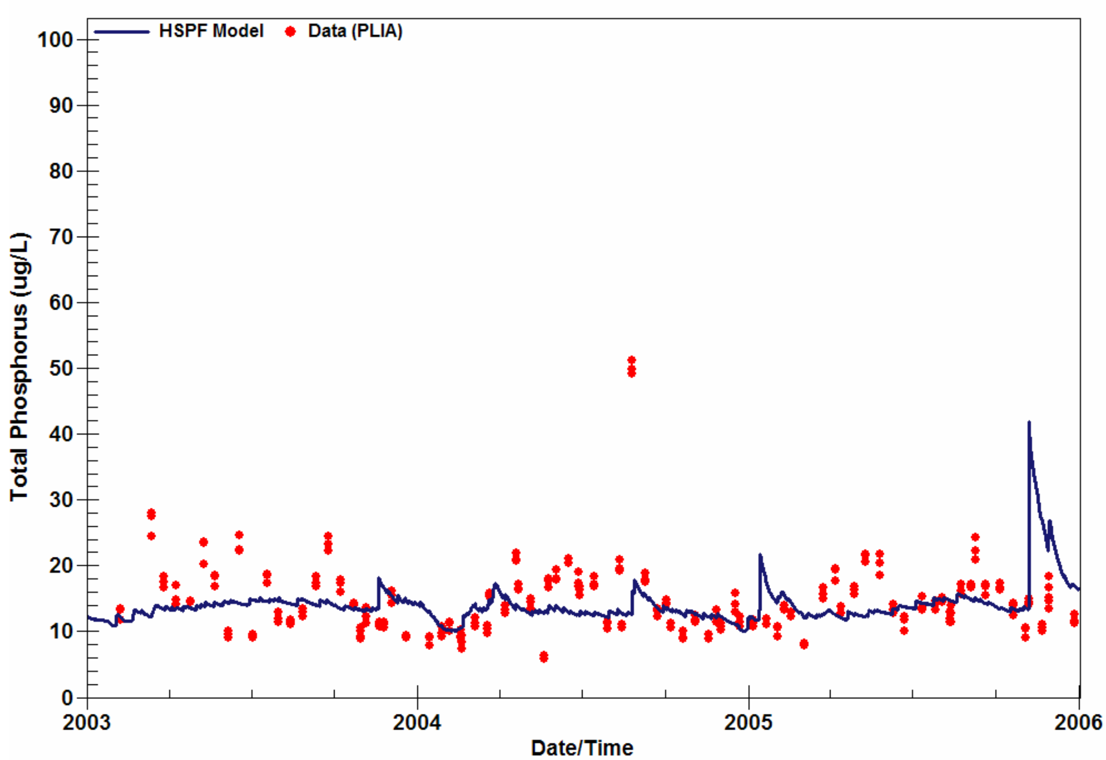

Figure B-8. Model-Predicted vs. Observed Flow for North Branch Platte River at Deadstream Road

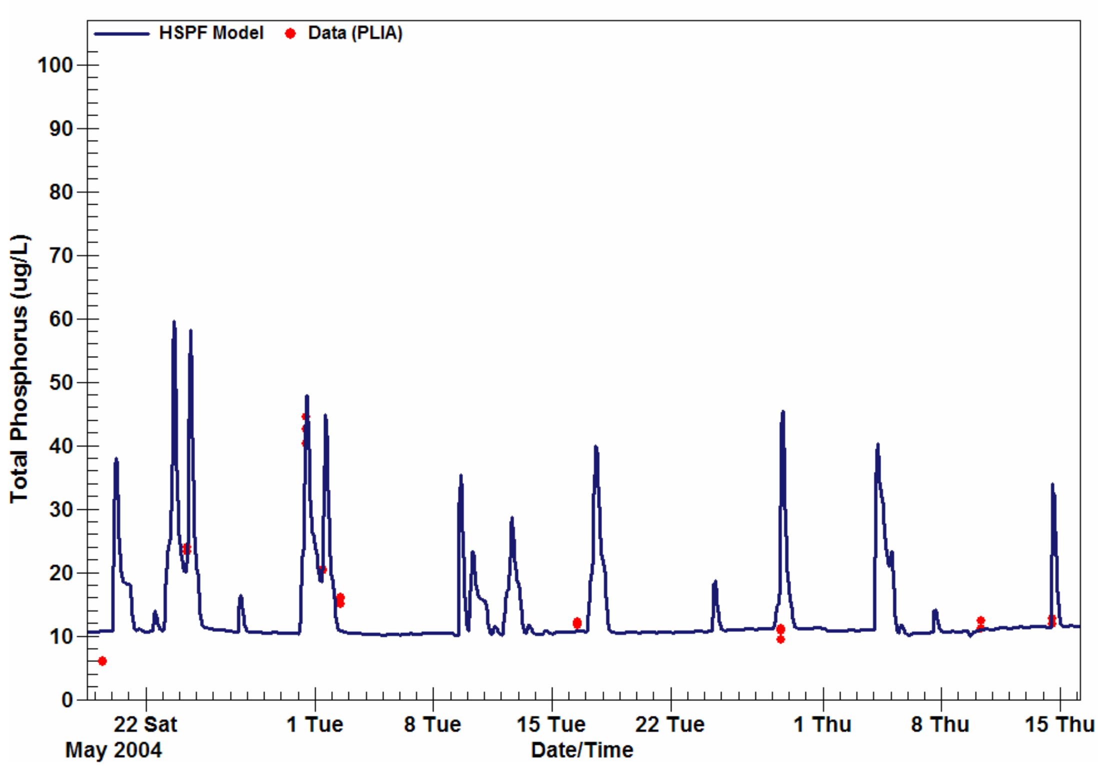

Figure B-9. Model-Predicted vs. Observed TP for Platte River at USGS Station (May 18 – July 15, 2004)

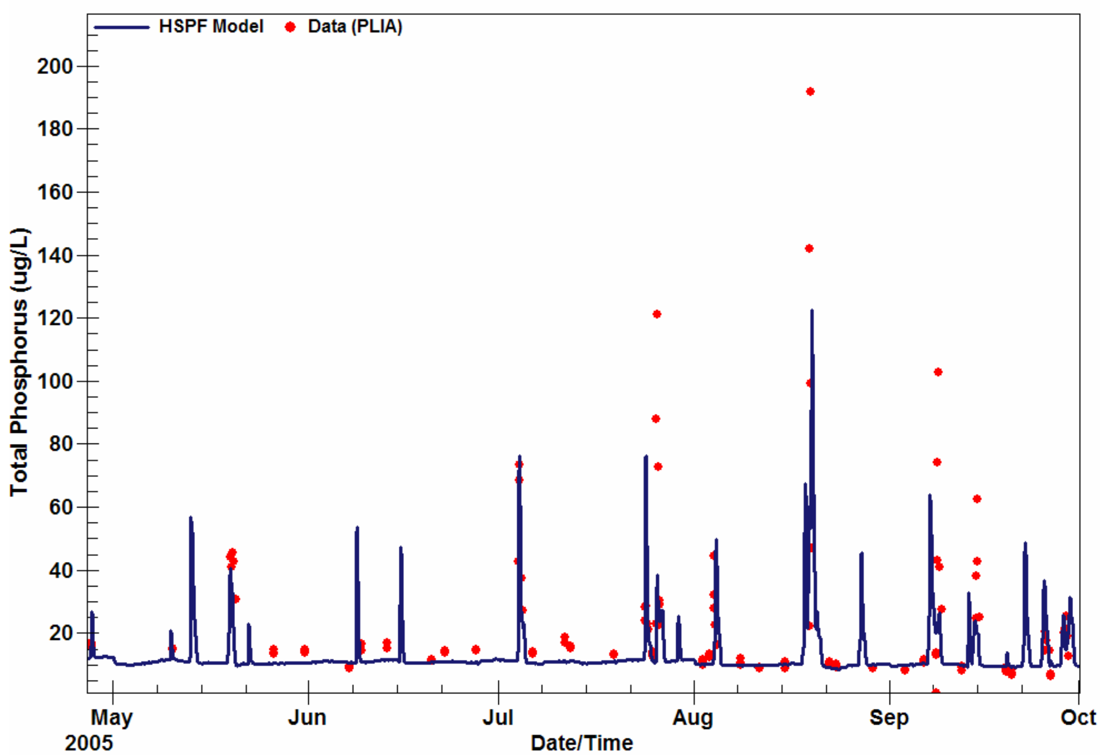

Figure B-10. Model-Predicted vs. Observed TP for Platte River at USGS Station (May-September, 2005)

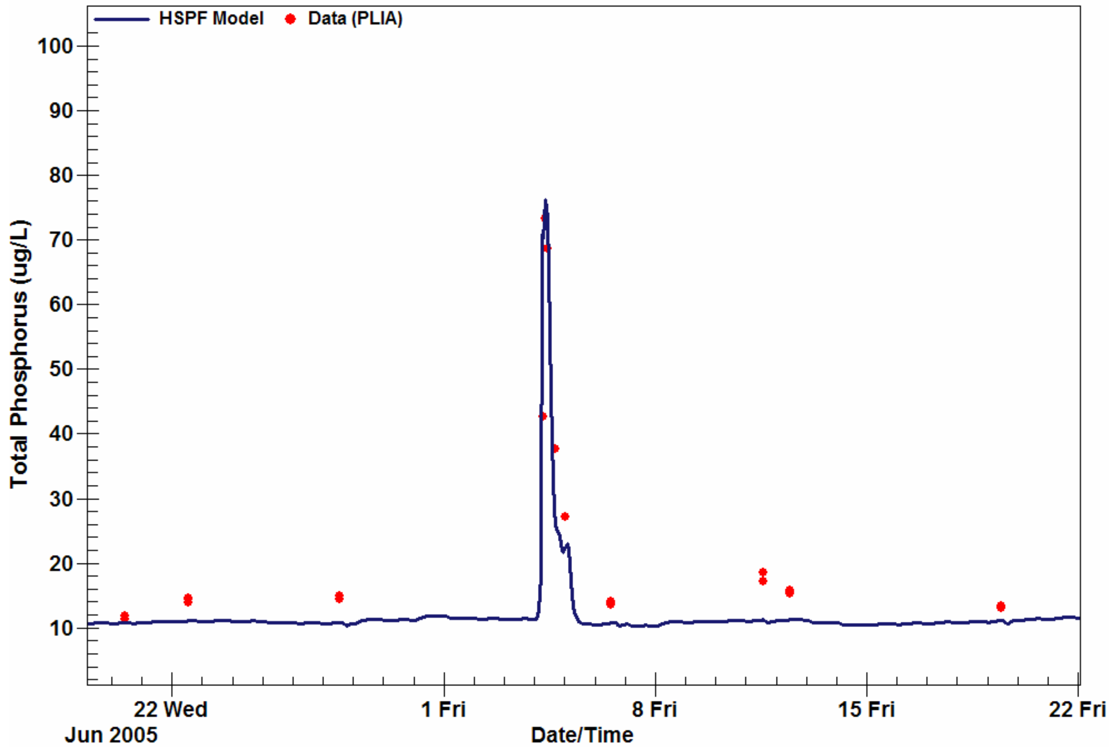

Figure B-11. Model-Predicted vs. Observed TP for Platte River at USGS Station (June 19 – July 22, 2005)

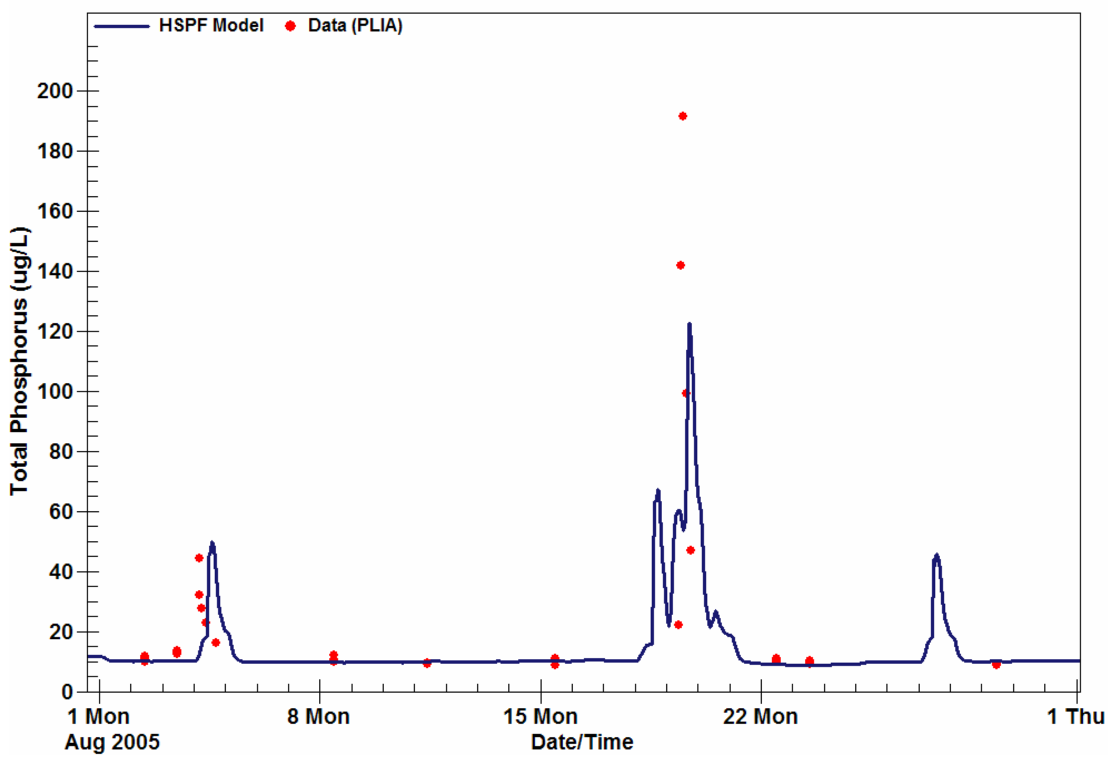

Figure B-12. Model-Predicted vs. Observed TP for Platte River at USGS Station (August, 2005)

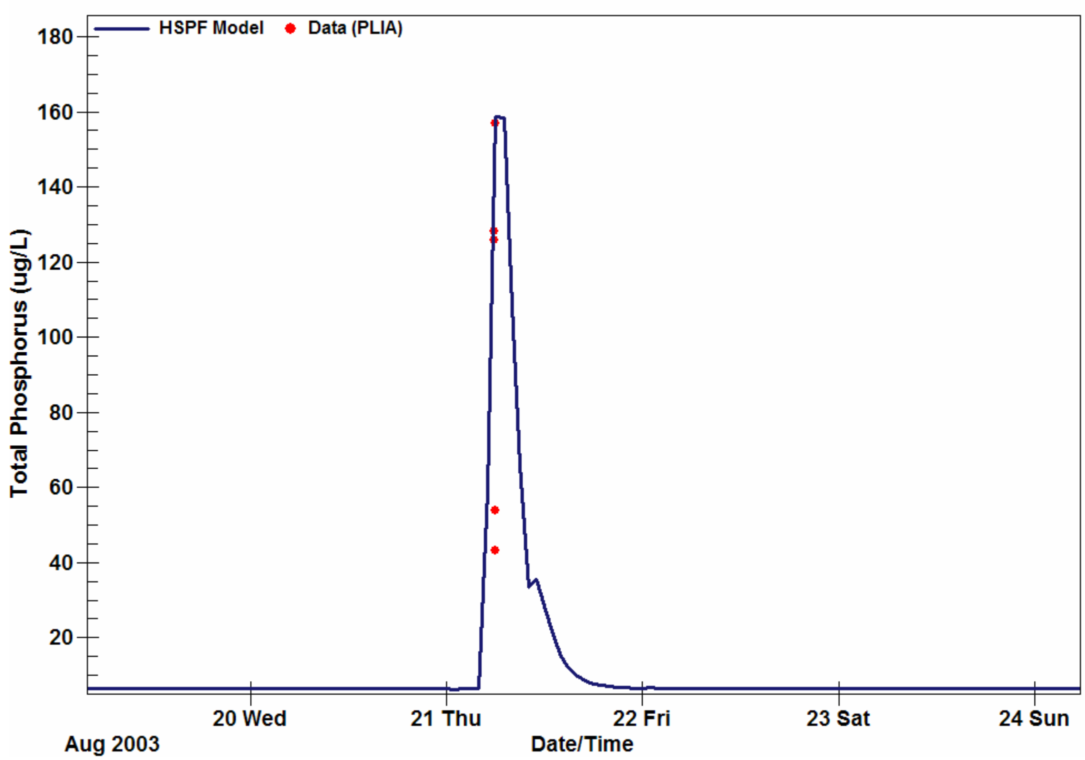

Figure B-13. Model-Predicted vs. Observed TP for Brundage Creek at Old Residence (August 20-24, 2003)

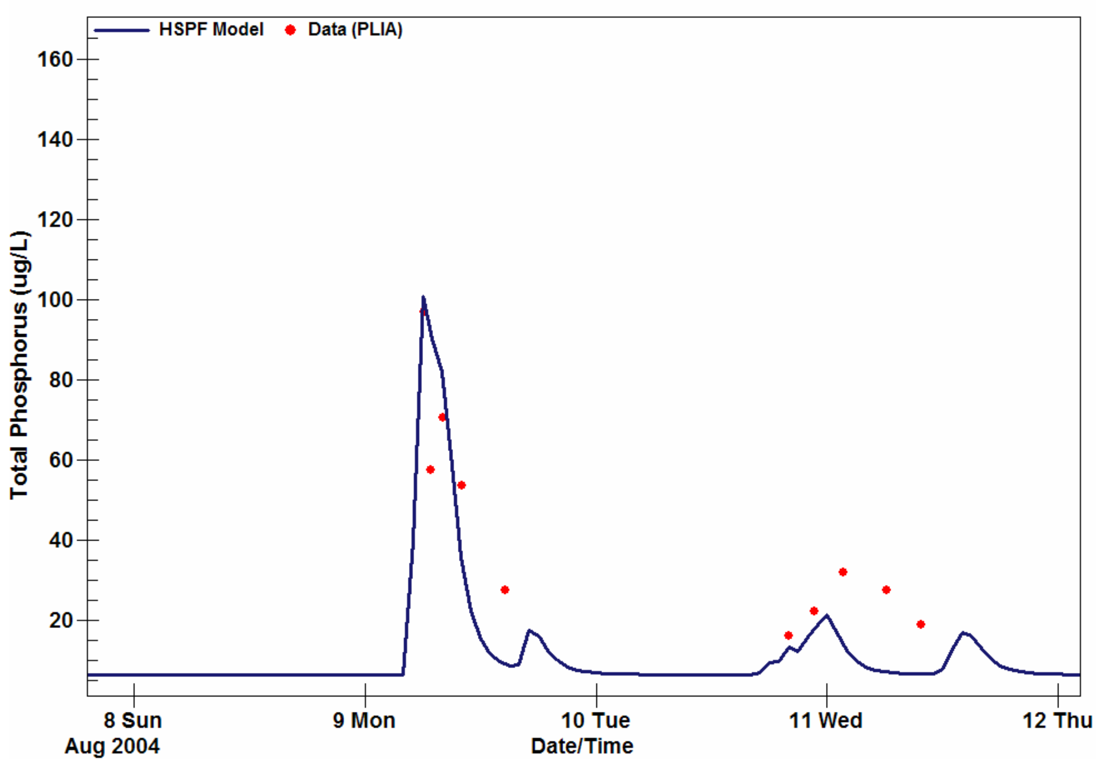

Figure B-14. Model-Predicted vs. Observed TP for Brundage Creek at Old Residence (August 8-12, 2004)

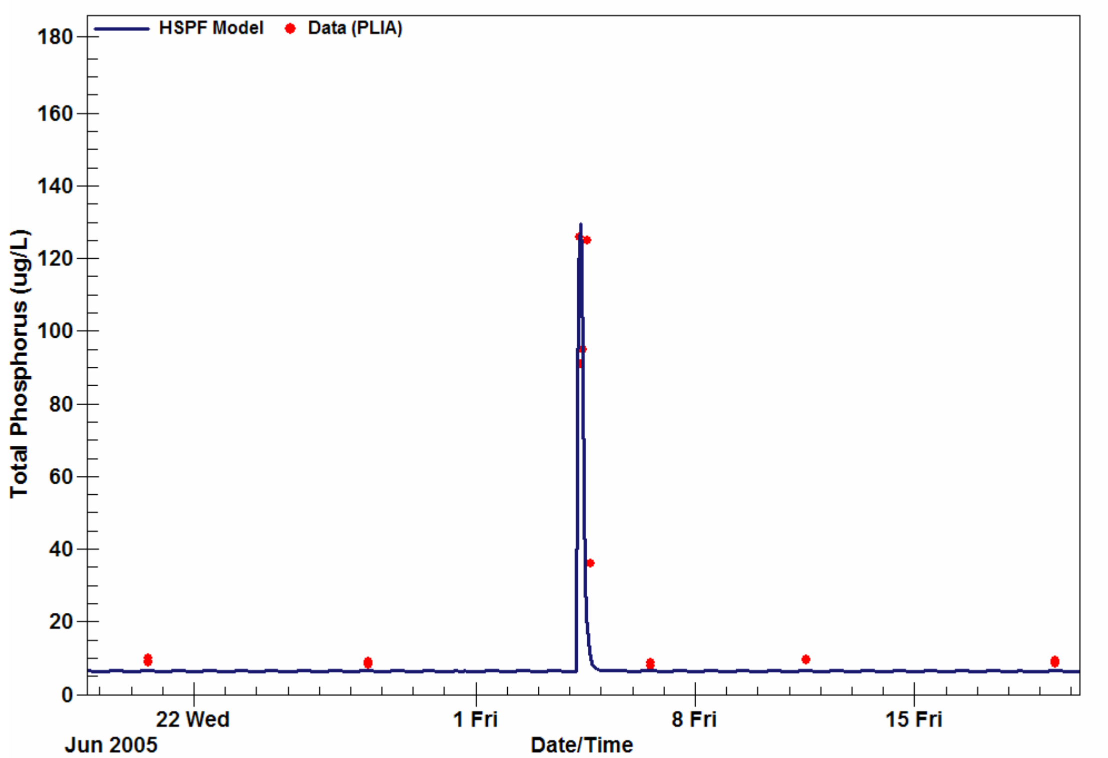

Figure B-15. Model-Predicted vs. Observed TP for Brundage Creek at Old Residence (June 17 – July 20, 2005)

Appendix C

Watershed Model Total Suspended Solids (TSS) Calibration Graphics

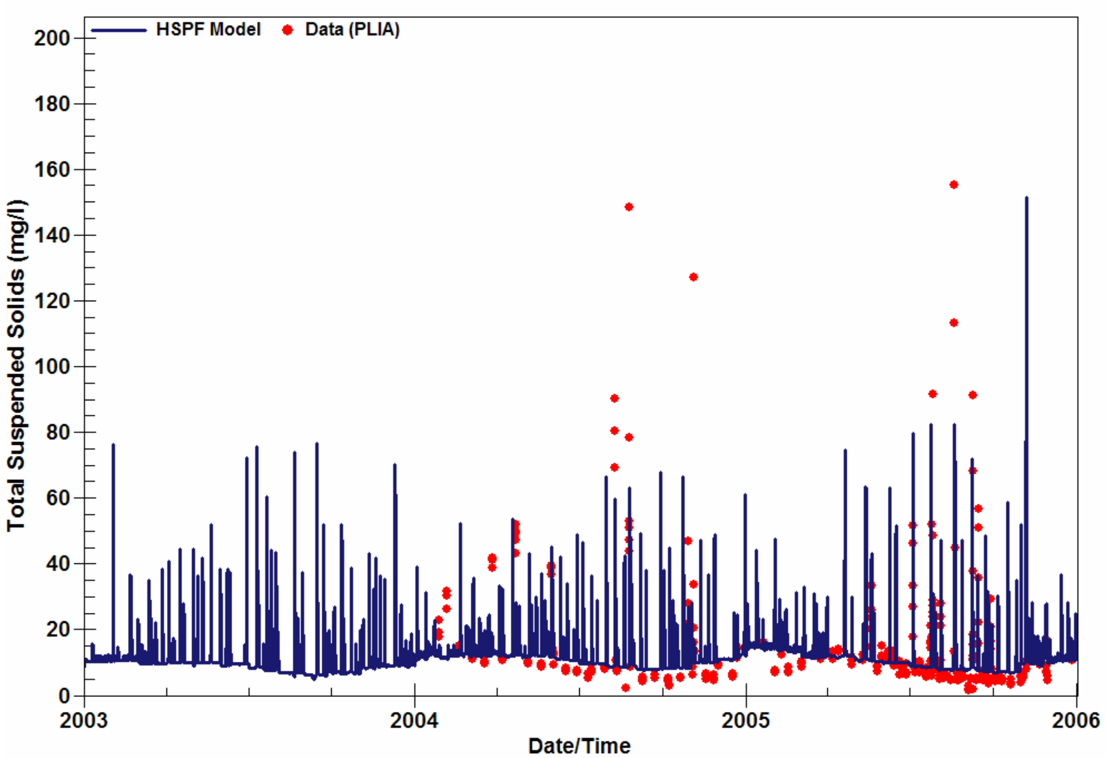

Figure C-1. Model-Predicted vs. Observed TP for Platte River at USGS Station (2003-05)

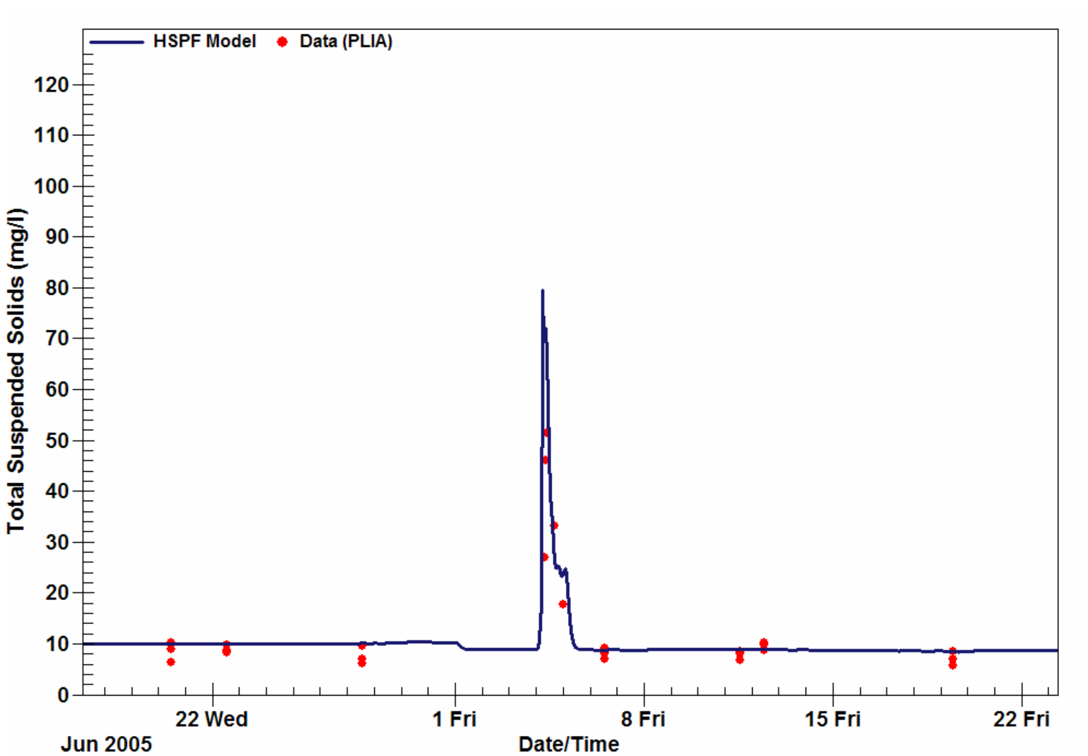

Figure C-2. Model-Predicted vs. Observed TP for Platte River at USGS Station (June 17 – July 23, 2005)

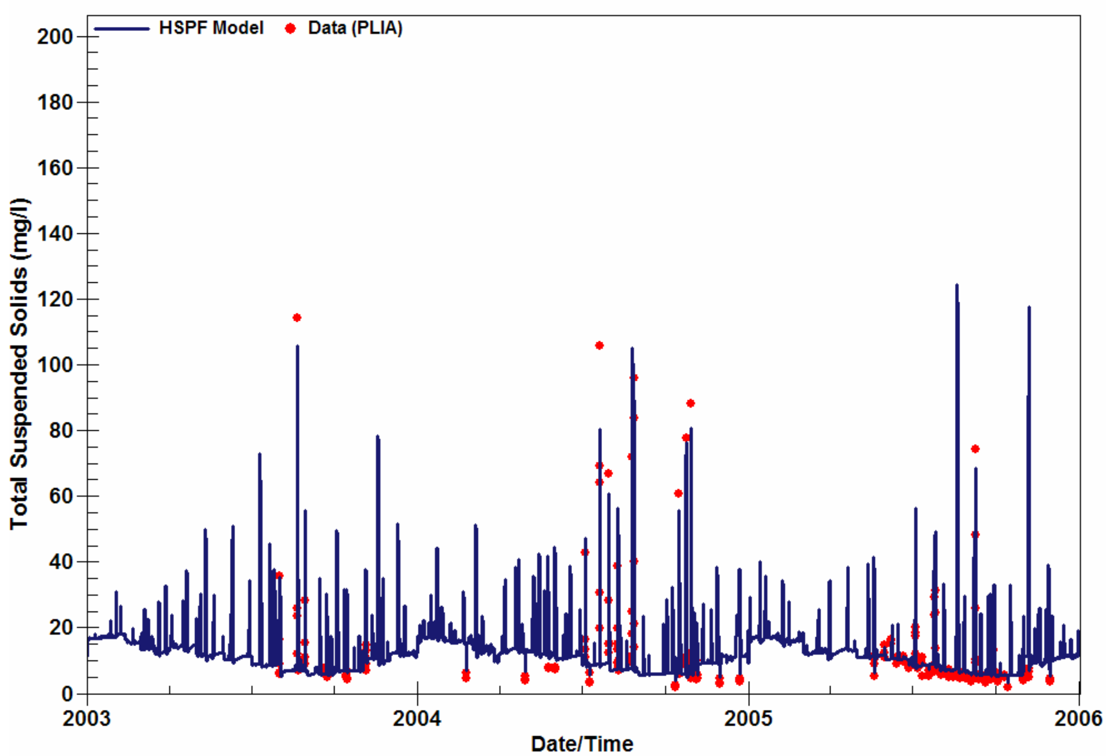

Figure C-3. Model-Predicted vs. Observed Flow for Platte River at Stone Bridge

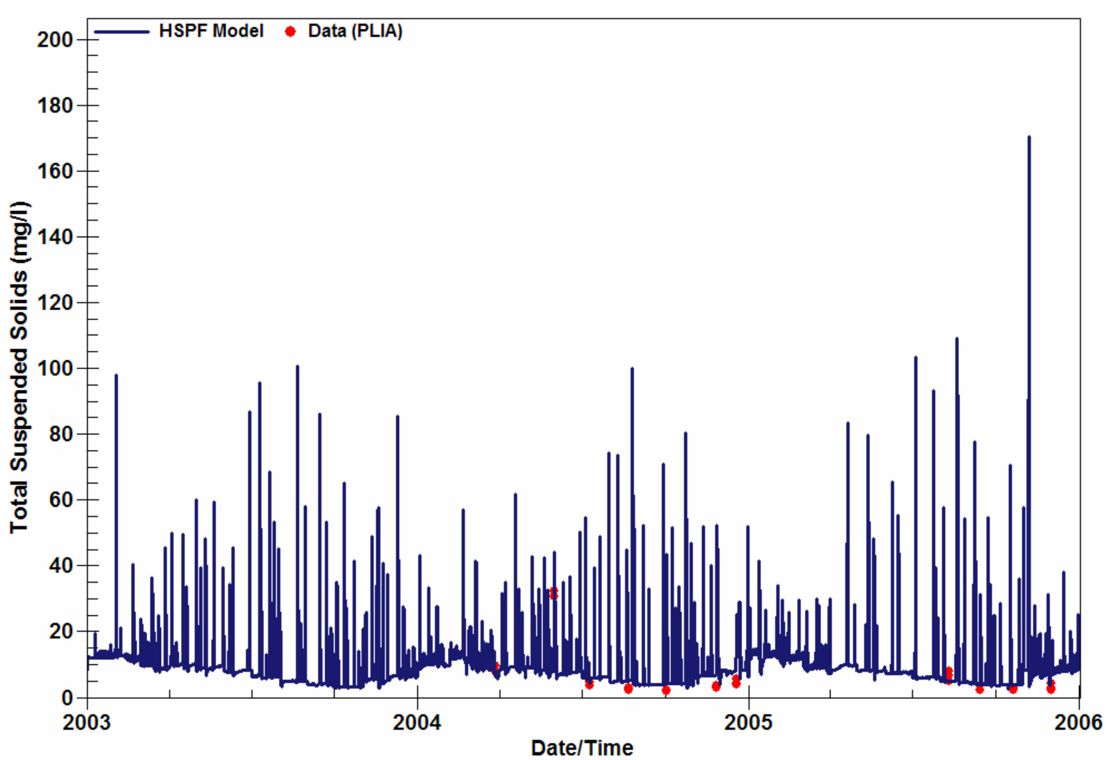

Figure C-4. Model-Predicted vs. Observed Flow for Platte River at Veteran's Park

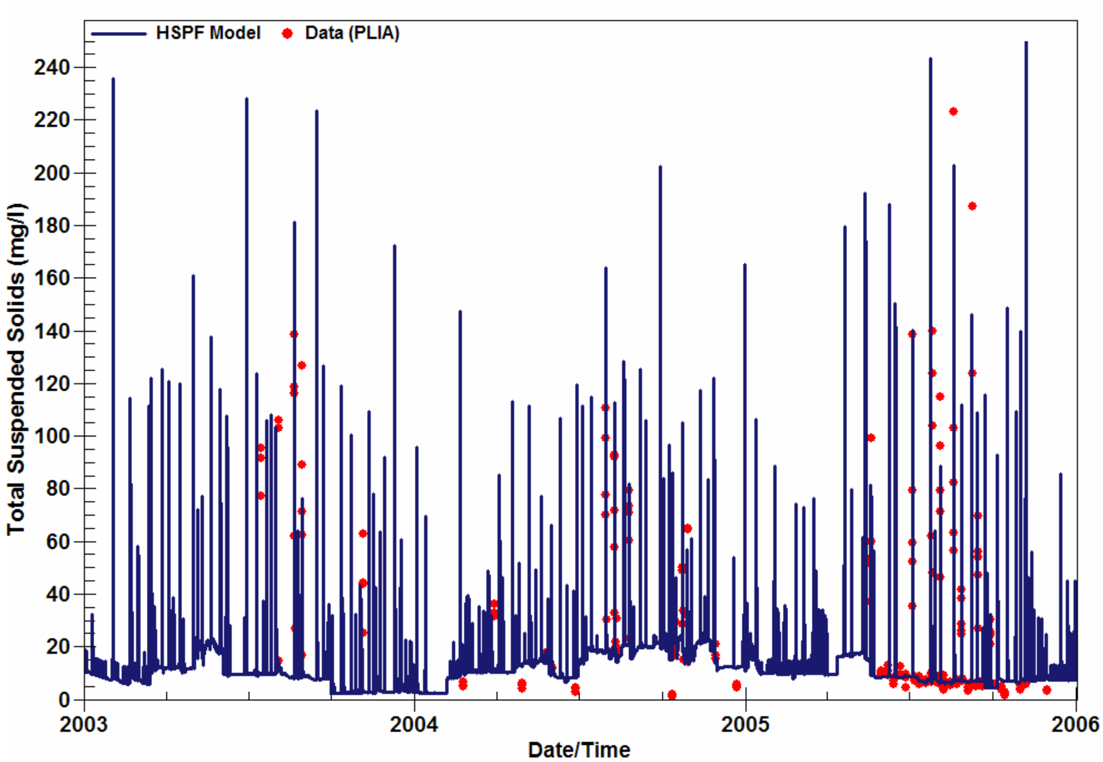

Figure C-5. Model-Predicted vs. Observed Flow for Brundage Creek at Old Residence

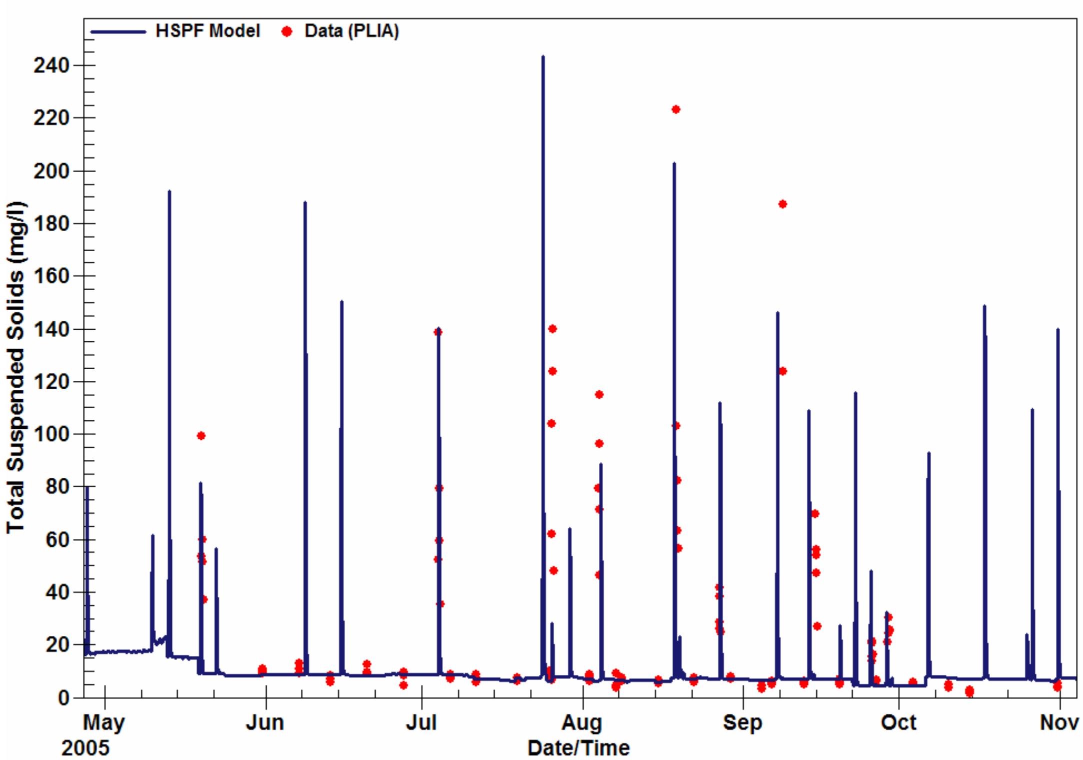

Figure C-6. Model-Predicted vs. Observed Flow for Brundage Creek at Old Residence (May-October, 2005)

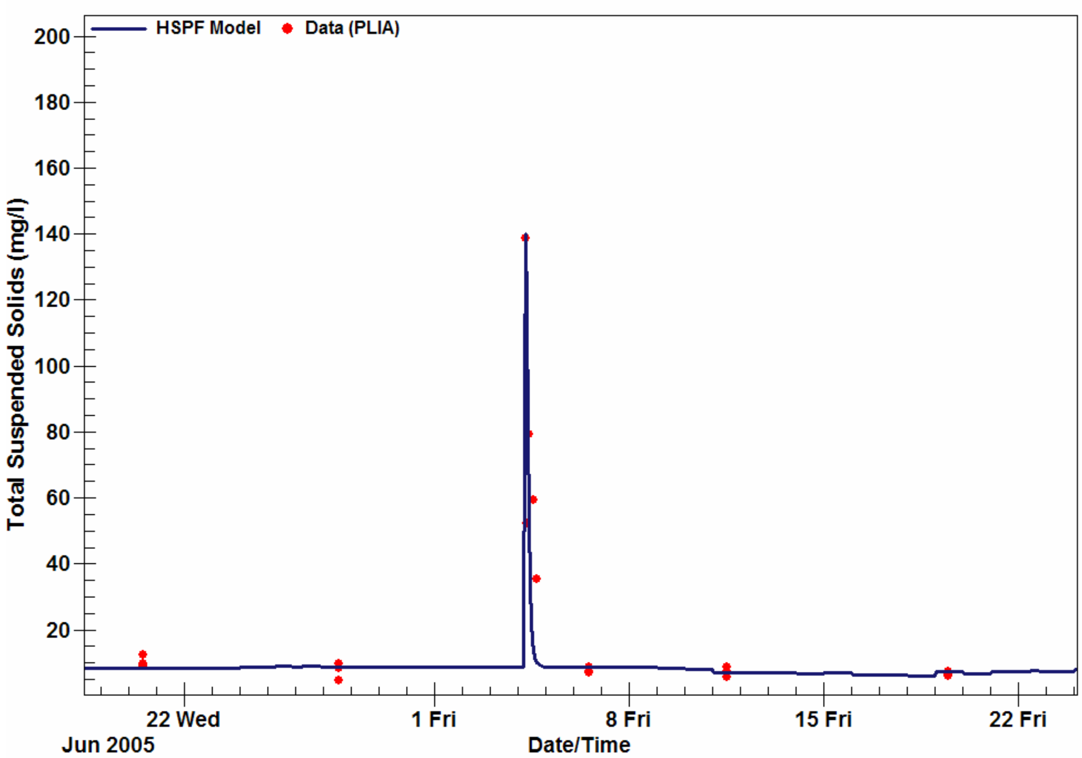

Figure C-7. Model-Predicted vs. Observed Flow for Brundage Creek at Old Residence (June 17 – July 23, 2005)

Limno-Tech, Inc.

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Memorandum

DATE:	December 11, 2006
PROJECT:	**PLATTE3**

TO:	**Wil Swiecki, Ray Canale, Gary Whelan**	**FROM:**	**Todd Redder, Dave Dilks**
SUBJECT:	**Comparison of Platte River Watershed Precipitation and Streamflow Datasets (final draft)**	**COPY:**	

Summary

LTI assessed the suitability of the available precipitation data to support watershed modeling efforts by analyzing available rainfall and streamflow data for the Platte River watershed. Major findings are:

- Observed Platte River runoff flows correlate very well with precipitation data from the Frankfort weather station.
- Preliminary calibration results for the BASINS flow model using Frankfort precipitation data show an extremely good comparison to observed stream flow data.
- For the above reasons, the Frankfort rainfall data are considered by LTI to be sufficient to support BASINS model application.

Introduction

Observed precipitation data are an essential input to watershed models. Several precipitation monitoring stations exist in the vicinity of the Platte River watershed that are potentially suitable for supporting model calibration and application. The purpose of this memorandum is to assess the suitability of the various precipitation data sources to support watershed modeling efforts. The assessment is made by conducting a comparative analysis of the precipitation and streamflow datasets available for use in calibrating the BASINS model for the Platte River watershed for the 1990-2005 period. This assessment was conducted through the following steps:

- Review of data availability;
- Conducting hydrograph separation to differentiate between base flow and runoff flow;
- Analysis of the relationship between precipitation and runoff flow using linear regression techniques;
- Assessment of preliminary calibration of BASINS model; and
- Analysis of weather radar images.

Each step is discussed in detail below.

Data Availability

Two principal data types are required to calibrate and apply a watershed hydrology model: 1) daily/hourly precipitation and 2) daily average streamflow at one or more points within, or in the vicinity of, the subject watershed. Table 1 summarizes the precipitation datasets available for the Platte River watershed, including period of record and data frequency.

Table 1. Summary of Platte River Watershed Precipitation Datasets

Station ID	Station Description	Data Frequency	Period of Record
202984	Frankfort	Daily	11/1/1948 – 12/31/2005
200758	Beulah[1]	Daily	4/1/1999 - 12/31/2005[1]
208246	Traverse City	Hourly	3/1/1971 – 12/31/2005
208251 208252 208249	TC Cherry Capital TC Airport #2 TC Munson	Daily[2]	1/1/1897 – 1/31/1998 3/1/1999 – 8/31/2001 11/1/2001 – 12/31/2005

[1]The Beulah station is missing more than 50% of the days for 1999-2001 and ~30% of days for 2002.
[2]The three daily Traverse City datasets can be merged into a single dataset covering the majority of the 1990-2005 period.

In addition to actual rainfall measurements, weather radar data can also be processed to provide a more spatially detailed estimate of precipitation. The potential application of radar data will be discussed in another section of this report.

Streamflow data are collected by the United States Geological Survey (USGS) at the US-31 highway bridge near Honor, MI. Final approved estimates of mean daily streamflow for this gauge are published on the USGS website (http://waterdata.usgs.gov/nwis/dv/?site_no=04126740) for the period 3/27/1990 – 9/30/2006. Provisional data are also available beginning on 10/1/2006.

Hydrograph Separation

Stream flow consists of two major components, including direct runoff from rainfall and snowmelt events and “base flow”, which is derived from direct and indirect shallow groundwater and inland lake flow contributions to a stream. Hydrograph separation refers to a common approach in which a software program is used to analyze the daily stream flow recession patterns for a given gauge location and estimate the fraction of total flow resulting from the distinct runoff and base flow components. The USGS distributes two software packages that can be used to conduct hydrograph separation – HYSEP (http://water.usgs.gov/software/hysep.html) and PART (USGS, 1998; http://water.usgs.gov/ogw/part/). LTI has applied both of these packages to other watersheds and has found that they generate comparable results. In general, the runoff and base flow estimates generated by these tools are very reliable on a monthly and annual scale. In addition to monthly estimates, HYSEP and PART also provide daily estimates of runoff and base flow, although there is greater uncertainty associated with the day-to-day estimates.

It is important to note that hydrograph separation techniques rely solely on observed streamflow data and do not consider precipitation data. For instance, the PART program scans the flows in a USGS daily record and identifies time periods where the flow patterns are consistent with typical groundwater recession behavior. The baseflow is assumed to be equal to the total flow for those periods, and linear interpolation is used to estimate the baseflow for days that do not exhibit recession behavior (e.g., during a runoff event). Similar techniques are used by HYSEP to estimate baseflow and runoff for each day in the period of record.

Both HYSEP and PART were used to conduct hydrograph separation for the Platte River USGS stream flow gauge operated at Honor. The purpose of the hydrograph separation was two-fold in this case:

1. To provide a quantitative breakdown of the base flow and runoff components to improve general conceptual understanding of watershed behavior; and

2. To allow correlations to be developed between the runoff component estimates and precipitation datasets.

The results of the two applications were very similar and confirm that base flow from groundwater and inland lake sources is the dominant contributor to total streamflow on a monthly and annual basis. Figure 1 summarizes the monthly results for 1990-2005 generated by the PART software package. These results indicate that base flow on average for the 16-year period contributes approximately 97% of the total Platte River flow at the gauge location. On a monthly basis, the contribution of base flow rarely falls below 90% and is typically in the 92-98% range. This range is similar to base flow estimates reported for other streams in northern lower Michigan of similar watershed size, including the Manistee River and the Little Manistee River (USGS, 1998), as shown in Table 2.

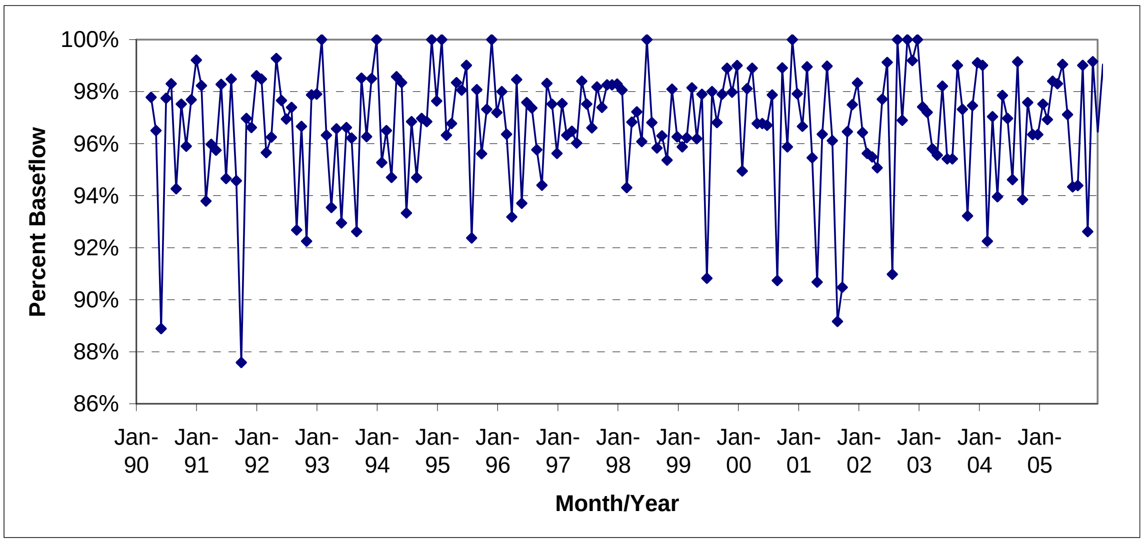

Figure 1. PART-Estimated Monthly Base Flow Percentages for the Platte River at Honor

Table 2. Monthly Flow Contributed by Base Flow for Selected Northern Michigan Streams

Station ID	Station Name	Drainage Area (mi^2)	% of Total Monthly Flow	Source
04126740	Platte River at Honor, MI	118	90-98	USGS and LTI analyses using the PART program.
04135500	Au Sable River at Grayling, MI	110	94.3	USGS, 1998
04123000	Big Sable River near Freesoil, MI	127	95.5	USGS, 1998
04123500	Manistee River near Grayling, MI	159	97.0	USGS, 1998
04126200	Little Manistee River near Freesoil, MI	200	94.5	USGS, 1998

An example of the daily base flow and runoff component time series estimated by HYSEP is provided in Figure 2. It should be noted that the runoff and base flow components always equal the total stream flow (in units of cubic feet per second) when added together. It is evident from Figure 2 that base flow is an important component of the flow even during and following rainfall / snowmelt events. Peak base flow "events" often occur following major runoff events because the soils in the Platte River watershed are predominantly sandy and are characterized by very high infiltration rates. As a result, a runoff event in the watershed will produce not only direct runoff flow, but measurable increases in base flow contributions to the stream network as well. A short (two to three day) lag time is often observed between precipitation and the subsequent increases in base flow, indicating the role of shallow groundwater.

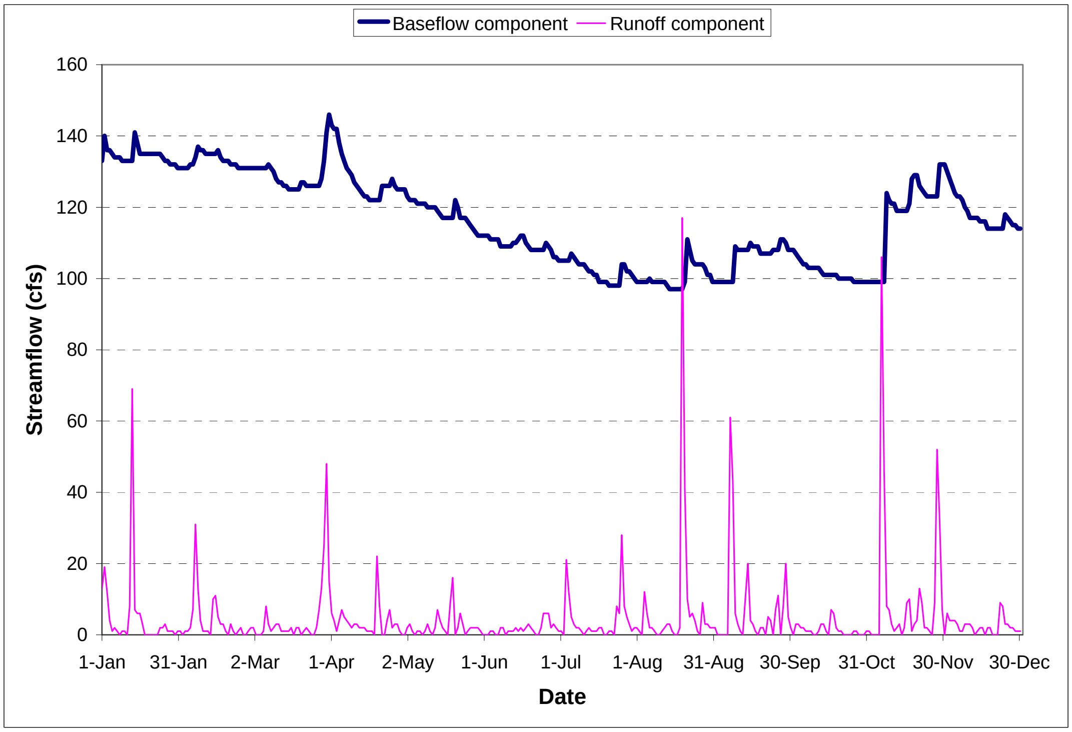

Figure 2. HYSEP Daily Hydrograph Separation Results for Year 2005

The United States Geological Survey (USGS) conducted an independent stream flow partitioning assessment and reached the virtually identical conclusion as LTI that 97% of the stream flow is due to base flow (Ray Canale, personal communication). A very minor discrepancy (96.6% vs. 96.7%) exists between the LTI and USGS results due to the fact that the LTI analysis considered only the final approved data up to 9/30/06 while the USGS analysis included additional data up to 11/7/06.

Comparison of Precipitation and Stream Flow Datasets

A comparative analysis of the available precipitation and stream flow datasets was conducted to explore and quantify the relationship between these variables in the context of BASINS model development, calibration, and eventual application. Specific stream flow-precipitation comparisons that are discussed in this section include:

- The relationship between annual stream runoff flow and annual precipitation; and
- The relationship between monthly stream runoff flow and monthly precipitation, including accounting for the effects of snow accumulation and melt dynamics.

Because surface runoff occurs in direct response to local precipitation / snowmelt, it is expected that it will be possible to directly correlate annual runoff flow quantities to observed precipitation for a representative station(s). This comparison was performed for available precipitation data for two different recent time periods, 2001-05 and 2003-05. A separate analysis for 2003-05 was conducted because the Beulah station only has data available for this period, and because the majority of the sampling data for total phosphorus and suspended solids falls within this period. Table 3 shows the correlation coefficient (R^2) generated by a least squares regression for runoff flow versus annual precipitation for the available precipitation stations. The R^2 value represents the fraction of the total variation in runoff flow that can be explained by the regression. An R^2 value of 1.00 would suggest a perfect linear relationship between annual runoff flow and precipitation.

Table 3. Linear Correlation Results (R^2) for Annual Runoff Flow Versus Precipitation

Station ID	2001-2005	2003-2005
Frankfort	0.98	0.99
Traverse City	0.65	0.77
Hatchery	0.16	0.50
Beulah	n/a[1]	0.51

[1] Data not available for Beulah from 2001-02.

The results in Table 3 show that the runoff flow at the USGS gauging station strongly correlates to the Frankfort precipitation dataset on an annual basis. Figure 3 illustrates this relationship and the linear regression fit for the 2001-05 period. This strong correlation does not mean that every precipitation event measured at Frankfort will also occur over the watershed (or vice versa); however, it does indicate that precipitation measured at Frankfort is representative of the actual event conditions experienced within the watershed during the 2001-05 period. The Traverse City station(s) has a reasonable correlation with runoff flow for the two time periods (i.e., R^2 = 0.65, 0.77); however, the correlations for the hatchery and Beulah stations are generally not as good. It is not immediately apparent why the correlations for the hatchery and Beulah precipitation stations are not as good; potential explanations include station locations not being representative of the entire watershed, monitoring equipment/staffing less rigorous than at the other stations, and/or missing data. Based on the results in Table 3, the Frankfort station was selected for the additional, more detailed analysis described below.

To build on the annual comparison presented in Figure 3, a monthly comparison of runoff flow and precipitation at Frankfort was conducted. Figure 4 shows the monthly runoff-precipitation relationship for all months during the period 2001-2005.

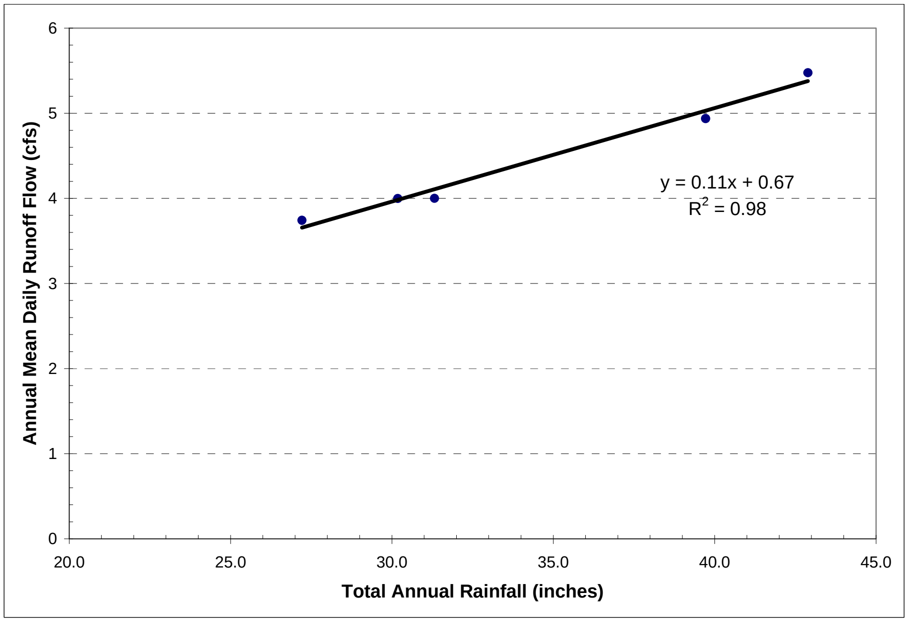

Figure 3. Comparison Annual Mean Daily Runoff Flow to Annual Precipitation at Frankfort (2001-2005)

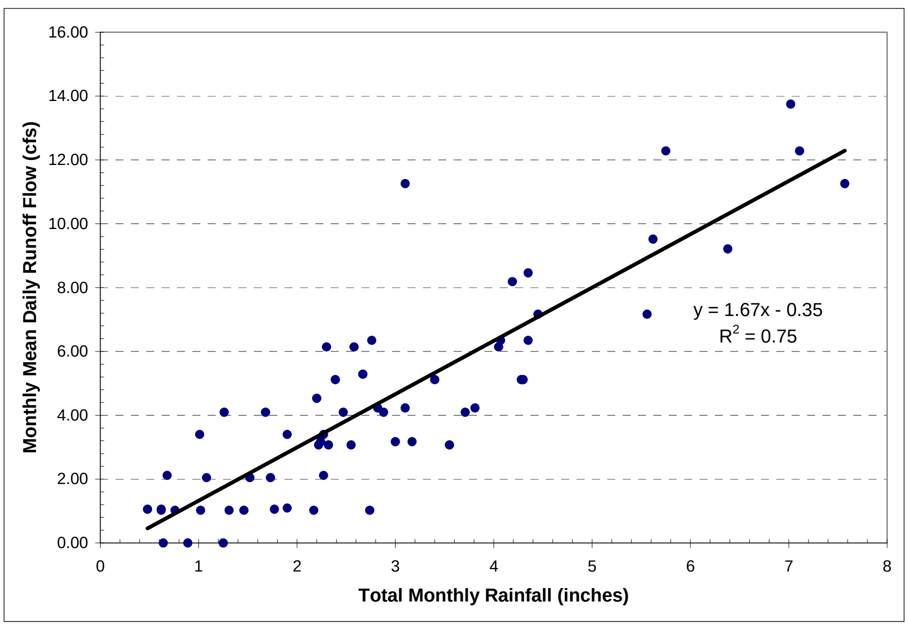

Figure 4. Linear Relationship for Monthly Runoff Flow versus Precipitation at Frankfort (January-December, 2001-2005)

Although the relationship between runoff flow and precipitation in Figure 4 is reasonably good (R^2 = 0.75), it is important to recognize that this relationship is affected by the periodic accumulation and subsequent melting of the snow pack that occurs during the winter months. In northern lower Michigan, snow accumulation and melt dynamics have the potential to significantly impact streamflow during November through April, with the final spring melt typically occurring in late March to mid-April. It is typical for snow that accumulates in January, for example, to melt sometime in February, March, or April. In that case, the effects of January precipitation on total streamflow and runoff will not be realized until later in the winter when the next significant snowmelt event occurs.

If the plot shown in Figure 4 is modified to only include the late spring, summer, and early fall months (i.e., May-October) when snow is not a factor, it is reasonable to expect that the correlation will improve. Figure 5 demonstrates that this is indeed the case; several of the outliers from Figure 4 are absent in Figure 5, and the R^2 correlation coefficient increases to 0.86.

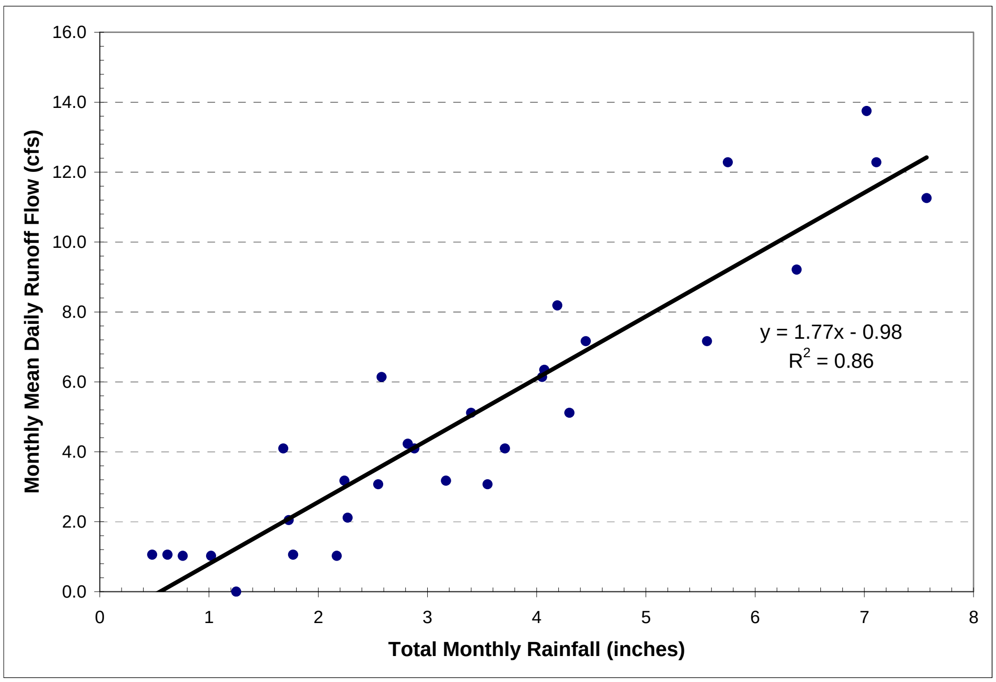

Figure 5. Linear Relationship for Monthly Runoff Flow versus Precipitation at Frankfort (May-October, 2001-2005)

Preliminary Hydrologic Calibration of BASINS Model

LTI further investigated the suitability of the Frankfort precipitation data via its ability to predict observed stream flows in the Platte River when used as input to the BASINS model. General performance targets have been established for streamflow calibrations conducted using the BASINS/HSPF model. These performance targets allow researchers to evaluate the success of a BASINS calibration for a particular watershed compared to results from other watersheds. The established calibration criteria are shown in Table 4 (Donigian, 2002). These targets are applicable when comparing annual and monthly model predictions of streamflow to mean annual and monthly data-based flows.

Table 4. General Calibration/Validation Targets or Tolerances for BASINS/HSPF Hydrology/Flow (Donigian, 2002)

% Difference Between Simulated and Recorded Values		
Very Good	Good	Fair
< 10	10 - 15	15 - 25

Annual and monthly results of the preliminary calibration at the USGS gage location are summarized in Figure 6. This comparison indicates that the mean absolute percent difference between simulated and observed stream flows is 4.3% on an annual basis and 5.7% on a monthly basis for the full calibration period (1990-2005). These results compare very favorably with the calibration performance targets generally associated with the BASINS/HSPF model (Table 4).

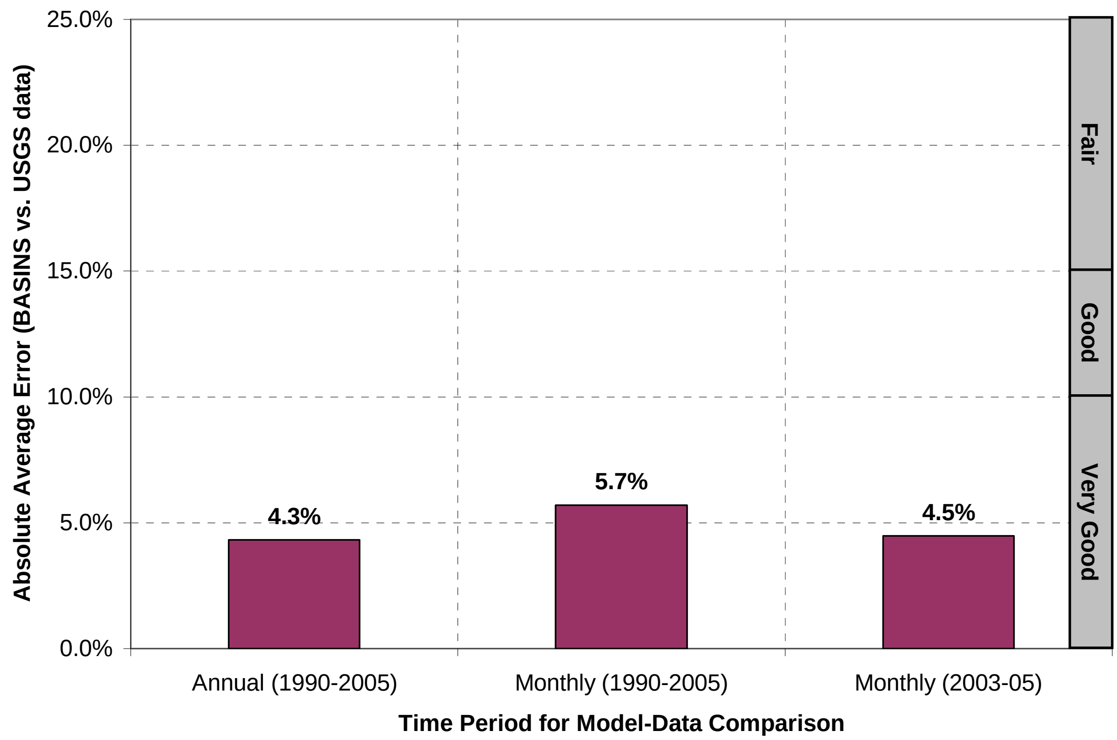

Figure 6. Annual and Monthly Mean Errors for BASINS-Predicted Flow Relative to USGS Data

LTI also used the USGS HYSEP program described previously to compute the base flow contribution to the daily flow time series simulated by the BASINS model. Based on this analysis, the monthly base flow component predicted by the BASINS model is 84-99%, which compares very well with the data-based estimates of monthly base flow shown in Figure 1 (88-99%).

Analysis of Weather Radar Data

The above section demonstrated that the Frankfort precipitation data and the BASINS model do a very good job of simulating flows in the Platte watershed. However, it is obvious that the Frankfort data cannot be used to develop 100% accurate flow predictions. Two possible indications that the precipitation data are the source of these deviations are:

1. A storm runoff event could be indicated by the stream flow data, but not reflected in the Frankfort precipitation data.
2. A rainfall event could be observed at Frankfort without a corresponding increase in stream flow.

A comparison of the BASINS-predicted daily flow using Frankfort precipitation data to USGS daily flow data is provided in Figure 7 for March-December, 2005. Overall, the model-data fit for this time period is excellent. Based on a review of the model-data daily flow comparison, no days were identified as matching case #1 (i.e., lack of rainfall at Frankfort during elevated streamflow). However, events occurring November 6 and November 29 in 2005 are similar to case #2 in that rainfall amounts observed at Frankfort result in model over prediction of streamflow at the USGS gage. It should be noted that the timing of response to the rainfall events is consistent with the streamflow data even though the absolute magnitudes of the model predictions do not exactly match the data.

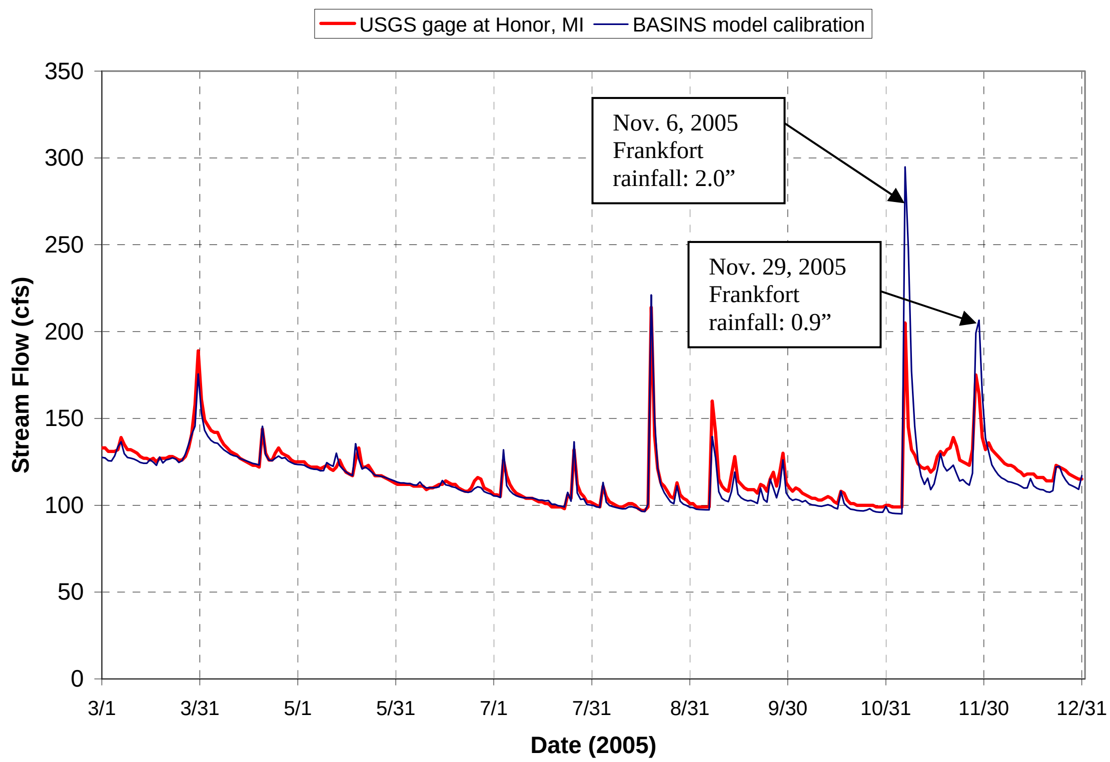

Figure 7. Comparison of BASINS Model-Predicted Flow and USGS Observed Streamflow at Honor, MI for March-December 2005

Therefore, LTI investigated daily weather radar images to determine whether the use of weather radar data has the potential to significantly improve the BASINS calibration for these days.

Daily rainfall radar images are available online from the National Weather Service. Figures 8a and 8b show the spatial regional distribution of rainfall on the November 6 and 29, 2005. These maps show that the rainfall in the far eastern part of the Platte watershed received less rainfall than the western part of the watershed. It is seen that Frankfort precipitation data therefore overestimates the average precipitation over the entire watershed on these days because the Frankfort weather station is located near the western part of the watershed. This results in BASINS over-estimating flow in the Platte River on these days as shown above in Figure 7.

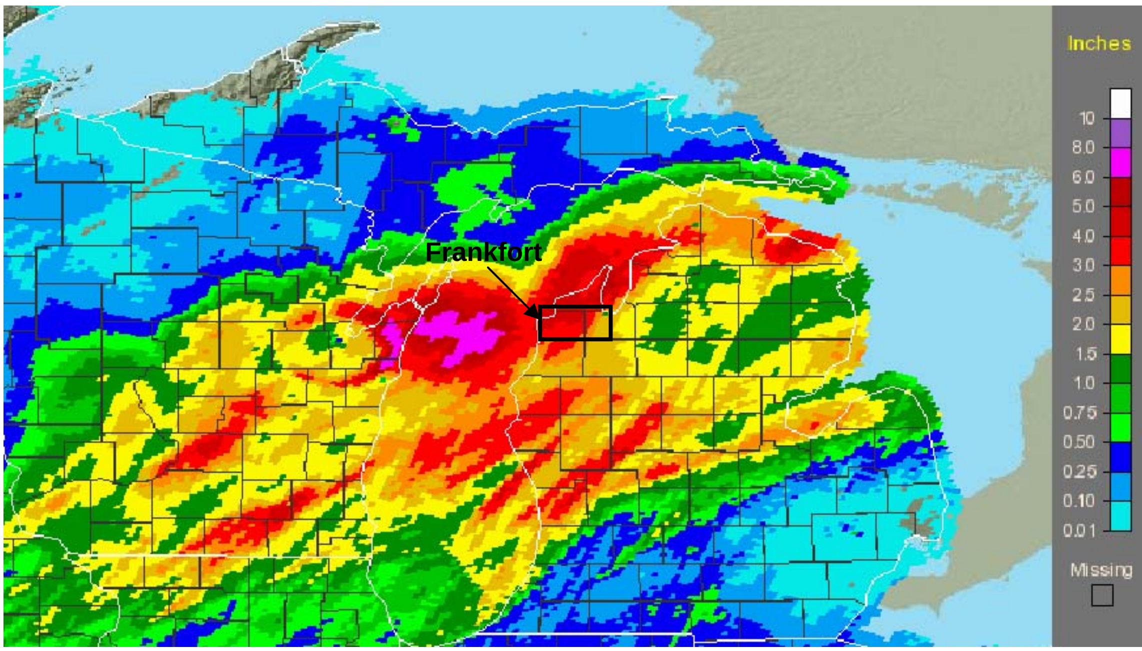

Figure 8a. Radar Map Illustrating Spatial Patterns for Rainfall on November 6, 2005

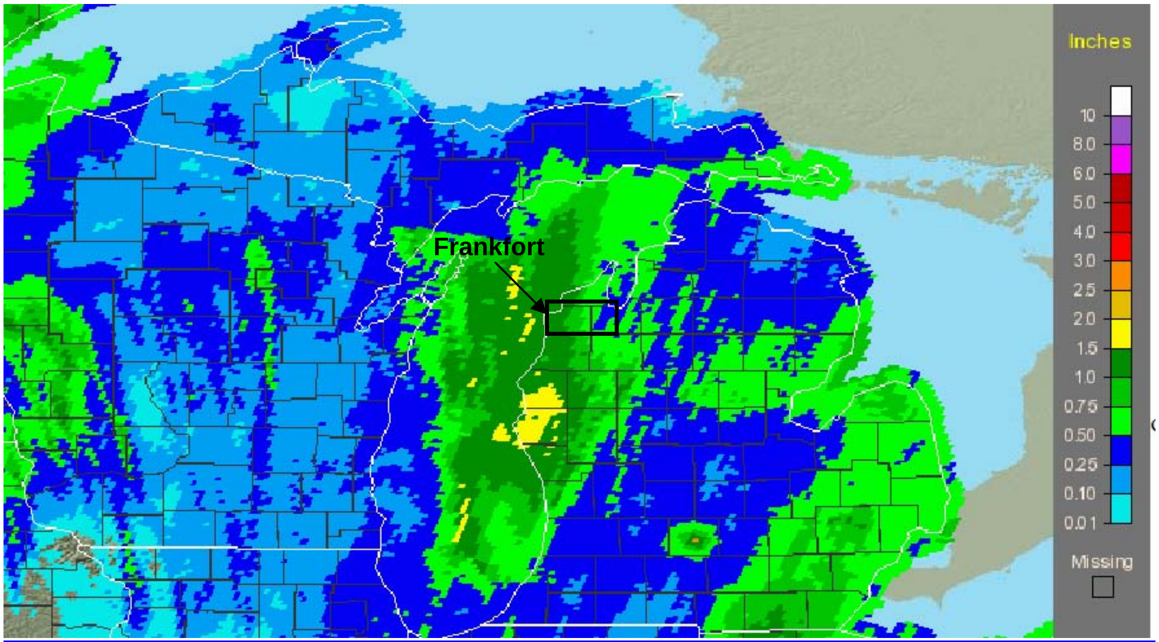

Figure 8b. Radar Map Illustrating Spatial Patterns for Rainfall on November 29, 2005

Suppose it were possible to spatially analyze the data from the local radar and determine the average amount of rainfall over the entire Platte River watershed as opposed to characterizing the watershed with Frankfort data alone. This might reduce the rainfall forcing function to 1.25 inches compared to the 2.0 inches measured at Frankfort and potentially improve the BASINS model flow prediction on November 6, 2005. A similar calculation could be made for November 29, 2005.

Conversion of the radar graphic images into such precipitation inputs for the model is not trivial and would therefore require significant effort and third-party costs. Discussions with a representative from "OneRain", a company that specializes in processing of radar data, indicated that the costs would be $2,000 per storm event to convert the radar data into precipitation estimates for the watershed (L. Torrence, OneRain, personal communication, 10/20/06). Significant additional effort would be required to process this information into a form that could be used by the BASINS model.

Radar data are generally available for the northern Michigan area for the calibration period (1990-2005); however, these data would need to be calibrated against multiple local hourly rainfall gages, including the gage at Traverse City and other northern Michigan locations. The relative scarcity of hourly precipitation stations in the vicinity of the Platte River would likely limit the accuracy of radar-based hourly rainfall estimates for the watershed (L. Torrence, OneRain, personal communication, 10/20/06). Therefore, it is obvious that even local radar data cannot be used to develop 100% accurate flow predictions. The difficulties associated with use of local radar for driving stream flow models is further discussed by Stellman, et al. (2006).

The question becomes: is the extra effort required to incorporate the radar data to calibrate the BASINS model in a quantitative manner as described above worth the potential gain in accuracy and reliability? To address this question, return to the original purpose of the BASINS modeling project. The purpose is to simulate future phosphorus loading from the watershed as a function of <u>changes</u> in land use given existing soil and topographic conditions. The simulations will be performed for different hypothetical weather conditions, such as selected wet and dry years.

Is this goal and use of the model compromised if Frankfort weather data alone are used for model calibration as compared to incorporating local radar data? The answer depends on whether or not the radar data fundamentally improves our understanding of the basic mechanisms that define the connection between rainfall and stream response. The BASINS calibration using Frankfort precipitation data alone has been shown to far exceed the "very good" threshold (i.e., 10% relative error) described in the peer reviewed literature. Therefore, in our judgment the calibrated model using Frankfort data alone is sufficiently accurate and the basic mechanisms are sufficiently understood to be used for its intended application. Thus, it is recommended that Frankfort data be used to calibrate the model. Local radar data should be used in a qualitative manner to help explain deviations between model predictions of stream flow and USGS flow measurements.

Conclusions

The comparative analysis of the NCDC precipitation and USGS streamflow demonstrates that a strong relationship exists between Frankfort daily precipitation and USGS runoff flow at the Honor gauging station, both on a monthly and on an annual basis.

Overall, the BASINS-predicted daily flow at the USGS gage location compares very favorably to the USGS daily data across the variety of rainfall events observed at Frankfort during March-December, 2005. This comparison illustrates that although radar data has the potential to provide a more precise estimate of rainfall for a particular day(s), the Frankfort daily precipitation observations are sufficiently representative to support BASINS model calibration and application.

Preliminary model calibration efforts demonstrate that the Frankfort precipitation data, when used as input to BASINS, results in an extremely strong model calibration. The relationships between Frankfort precipitation and Platte River flow are considered by LTI to be sufficient to support a accurate, reliable, and legally defensible BASINS model development, calibration, and application.

References

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