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HSPF Modeling of Nonpoint Sources in Tickfaw River Watershed

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Table of Contents

List of Figures

List of Tables

Abstract

The Tickfaw watershed is located in southeastern Louisiana with the Tickfaw River originating in Southern Mississippi, flowing through St. Helena and Livingston Parishes, and eventually emptying into Lake Maurepas. The total drainage area is 1,896 km^2. Forests cover 66% of the watershed and agriculture is the second predominant land use type. The elevation of the watershed changes from 0 m above sea level in the south to 130 m in the north.

According to the 2004 Louisiana Water Quality Inventory report section 303(d), outstanding natural resource and secondary contact recreation designated uses are fully supported, but fish and wildlife propagation and primary contact recreation are not supported. According to the 303(d) list, the impairments in Tickfaw River are mercury, total dissolved solids, fecal coliform, phosphorus and dissolved oxygen. There are many suspected sources of impairment, including agriculture, construction, forest management, and industrial sources.

The goal of this study is to make use of a Geographic Information System (GIS), the EPA's BASINS tools, and the HSPF water quantity and quality modeling program to quantify and differentiate the sources of pollution that arise from storm water runoff coming from agriculture, forestry, and other sources. This will allow the Louisiana Department of Environmental Quality (LADEQ) personnel to better focus implementation efforts on those areas and practices that appear most critical to water quality problems.

In the process, a water quality model has been calibrated and validated for annual flows; seasonal flows and for water quality parameters like dissolved oxygen, nitrogen and phosphorus. An assessment analysis was performed to determine the loading of nitrogen and phosphorus coming from each land use. Various land use scenarios were created in Tickfaw watershed and total loading resulting from these landuses were integrated with the watershed's subbasins in the

GIS for graphical presentation. These landuse scenarios were also ranked based on its resultant total loading. Based on these loading rates, total loading of nitrogen and phosphorus resulting from these land use scenarios were significantly higher when current landuse was converted to cropland and pasture, thereby adversely affecting the water quality in rivers.

1. INTRODUCTION

1.1 Overview

Water quality resulting from nonpoint source pollution, is still a great challenge, even though it is gradually improving locally (Stanners and Bourdeau 1995; USEPA, 2002). Because of the growth in human population, land use is being changed substantially and it is estimated that approximately one acre of land has been lost due to urbanization and highway construction for every person added to the U.S. population (Alig et al., 2004; Pimentel and Giampietro, 1994).

1.2 Site Description

The Tickfaw Watershed is located in Southeastern Louisiana with Tickfaw River flowing from the Mississippi state line to Springville at Louisiana Highway 42 then to Lake Maurepas with a total drainage area of 1,896 km^2. Figure 1.1 shows the location of Tickfaw Watershed in Louisiana. This watershed is a typical drainage basin as the elevation of the watershed changes from 0 m above sea level in the south to 130 m in the north; forests cover 69% of the watershed with agriculture as the second predominant landuse type. Detailed landuse types in the watershed are shown in Table 1.1.

Tickfaw River flows into Lake Maurepas, which circulates water into Lake Pontchartrain through two tidal channels, Pass Manchac and North Pass. The Lake Pontchartrain Basin is in a shallow depression lying between the alluvial ridge of the Mississippi River to the west, sloping uplands to the north, the Pearl River Basin to the

east, and the Mississippi Sound to the south (US Army Corps of Engineers (USACE), 1982). Lake Pontchartrain and its surrounding lakes are among the most important estuary systems along the Gulf Coast of the United States (Penland et al., 2002).

Figure 1.1: Map of Tickfaw Watershed in South Eastern Louisiana

Table 1.1: Percentage of land uses in the Tickfaw River watershed (USDA, 1994)

	Land use type	Area (acres)	Percentage
1	EVERGREEN FOREST LAND	67275	42.29%
2	CROPLAND AND PASTURE	46309	29.11%
3	MIXED FOREST LAND	41032	25.79%
4	RESIDENTIAL	1917	1.21%
5	FORESTED WETLAND	1002	0.63%
6	TRANSITIONAL AREAS	659	0.41%
7	TRANS, COMM, UTIL	362	0.23%
8	COMMERCIAL AND SERVI	193	0.12%
9	NONFORESTED WETLAND	93	0.06%
10	RESERVOIRS	77	0.05%
11	OTHER AGRICULTURAL L	69	0.04%
12	INDUSTRIAL	57	0.04%
13	MXD URBAN OR BUILT-U	35	0.02%
	Total	**159080**	100.00%

Tickfaw watershed overlaps area in four counties (parish) in Louisiana; Amite, Livingston, Tangipahoa and St. Helena. Figure 1.2 shows the Tickfaw watershed with the county boundaries.

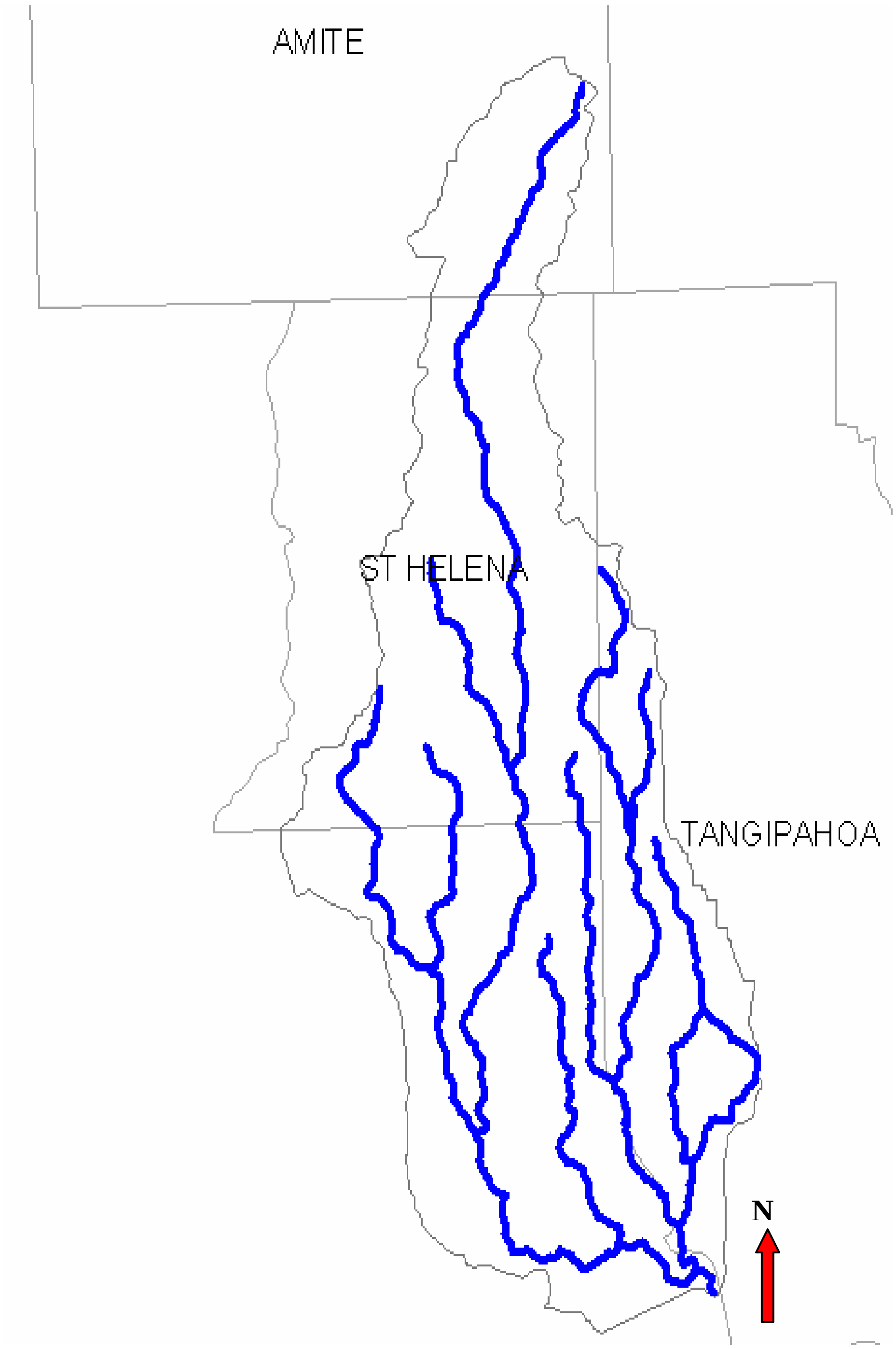

Figure 1.2: Tickfaw Watershed with County boundaries

1.3 Climatic Conditions

According to the long-term annual average air temperature (1948-2000) is about 19^0C, with the lowest monthly average of 12^0C in January and the highest monthly average of 28^0C in July. The long-term annual average precipitation is about 1600 mm, varying from 1108 mm to 2178 mm. The highest monthly average precipitation in the area occurs in July (159 mm), while the lowest is in October (86 mm) (Rohli et al, 1995).

1.4 Land Cover and Vegetation

Forests and agricultural lands are the two major landuse types in the watershed. Tickfaw River watershed is predominantly covered by forests. Approximately 66% of the watershed has forest cover (Table 1.1). Agricultural land covers 33% with the remaining 1% by urban land (USDA ARS, 1994).

1.5 Water Quality

According to 2004 Louisiana Water Quality Inventory report section 305(b), Tickfaw river is suitable for activities such as swimming and other direct water contact sports and also for activities such as boating and fishing where there is less bodily contact with the waters. Outstanding natural resources and secondary contact recreation designated uses are fully supported, but fish and wildlife propagation and primary contact recreation are not supported. There are many suspected sources of impairment, including agriculture, construction, forest management, and industrial sources. At this point, a good hydrologic and water quality model for Tickfaw River watershed is necessary to analyze stream concentrations, calculate the loading from the current land use and to develop a TMDL.

1.6 Objectives

- Delineate the Tickfaw River Basins based on the existing land use patterns.
- Calibrate the hydrologic modeling component of the model using the USGS stream flow database.
- Conduct a sensitivity analysis to adjust the hydrologic parameters of the study area to accurately estimate the stream flow based on the different land use patterns.
- Calibrate the water quality modeling components of the model using LDEQ water quality measurement database.
- Determine the rates of nitrogen and phosphorous loading from the existing land use patterns within the Tickfaw Basin.
- Create various landuse scenarios, analyze their impacts on the water quality and rank them according to its effect on water quality within the Tickfaw River Basin.

This dissertation is organized in six chapters. Chapter 2, following this introduction, provides intensive literature review on various software's which are used to develop the model, introduces some of the research concepts, and modeling software which can be used for this study. Chapter 3 focuses on the methodology adopted for this study. It also provides information on various kinds of data which were needed and collected for this study. In Chapter 4, development of hydrology and water quality model is discussed. Chapter 5 summarizes the findings of this study. Chapter 6 identifies the methods in which this study could be used in future.

2. Literature Review and Background Information

The Louisiana Department of Environmental Quality (LADEQ) will be able to use the model developed to focus their effort on areas and practices that have the greatest impact on the Tickfaw watershed's water quality. The model developed can also be used to analyze stream water quality concentrations, calculate load differences due to landuse changes, and to calculate Total Maximum Daily Load (TMDL).

2.1 BASINS

A sophisticated and widely used assessment tool, the Better Assessment Science Integrating Point and Nonpoint Sources, BASINS, (US Environmental Protection Agency, 1998) was utilized in this study. It provides a framework for integrating spatial data e.g.; land use, vegetation, climate, elevation, and spatial data. BASINS was developed by the US Environmental Protection Agency (USEPA) as an assessment tool for watershed and water quality based studies.

BASINS was developed as a system for supporting the development of Total Maximum Daily Loads (TMDLs). Each state shall assemble and evaluate all existing and readily available water quality data and information to develop the Section 303(d) list of waters. Section 303(d) of the Clean Water Act requires states to develop TMDLs for water bodies that are not meeting applicable water quality standards by using technology-based controls. Developing TMDLs requires a watershed-based approach that integrates both point and nonpoint sources. BASINS can support this type of watershed-based point and nonpoint source analysis for a variety of pollutants.

Previously watershed based assessment studies were performed by traditional approaches which involved many steps like preparing data, summarizing the information, developing maps and tables, and applying and interpreting models. Each individual step was performed using a variety of tools and computer systems. This resulted in lack of integration, limited coordination and time intensive execution.

BASINS was developed with an emphasis on watershed and water quality based assessment and integrated analysis of point and nonpoint sources of environmental pollution. BASINS makes watershed and water quality studies easier by bringing key data and analytical components in one framework, and eliminating the numerous problems that are encountered in the approaches in which watershed is broken down into several separate tasks involving the application of several different models and analytical tools.

BASINS uses a Geographic Information System (GIS) as the integrating framework to provide the user with a fully comprehensive watershed management tool. ArcView 3.1 of GIS is used in BASINS which was developed by Environmental System Research Institute, Inc. GIS organizes spatial information so it can be displayed as maps, tables, or graphics. BASINS include a data extractor, projector, project builder, GIS interface, various GIS-based tools, a series of models, and custom databases. These data are available entirely through a web data extraction tool.

BASINS address three objectives: 1) to facilitate examination of environmental information, 2) to provide an integrated watershed and modeling framework, and 3) to support analysis of point and nonpoint source management alternatives. Overcoming the lack of integration, limited coordination, and time-intensive execution, BASINS makes watershed and water quality studies easier by bringing key data and analytical components together.

Version of BASINS 3.0 was used in this study to characterize the flow and water quality conditions in the watershed. The significant changes between BASINS Versions include 1) Addition of grid data sets including USGS DEM elevations grids (1:250,000 scale) 2) New utility to perform automatic watershed delineations based on DEM data 3) A new interface to the Hydrological Simulation Program - Fortran (HSPF), called *WinHSPF*, 4) A postprocessor known as *GenScn*, 5) A utility program for managing WDM files known as *WDMUtil*.

There are numerous numbers of hydrologic models in use today. They differ in capability, complexity, scale and resolution. The main criteria for choosing the model were: model accuracy, capabilities, data requirements, and flexibility. Simulation models are integrated into the GIS environment through a dynamic link in which the data required to build the input files are generated in the ArcView environment and then passed directly to the models. The models can run individually either in a Windows or a DOS environment. The results of the simulation models can also be displayed visually and can be used to perform further analysis and interpretation. BASINS includes In-Stream models, Loading models, and Watershed models.

2.2 In-Stream Models

2.2.1 QUAL2E - It is a steady-state, one-dimensional receiving water quality model supported by EPA. It can simulate dissolved oxygen, Biochemical Oxygen demand, Temperature, Ammonia as N, Nitrate as N, Nitrite as N, Organic phosphorus as P, Dissolved Phosphorus as P, and Coliform. The model includes the effects of advection, dispersion, dilution and pollutant reactions, interactions, sources and sinks.

QULA2E assumes that the major transport mechanisms, advection and dispersion, are significant only along the main direction of flow. It allows for multiple waste discharges, withdrawals, tributary flows, and incremental inflow and outflow. The capability to compute

required dilution flows for flow augmentation to meet any prespecified dissolved oxygen level is a major characteristic of the model. The model has built-in options to depict the major reactions of nutrient cycles, algal production, benthic and carbonaceous oxygen demand and atmospheric reaeration. QUAL2E is generally used where there is a major concern for DO in effluent dominated system and the use of low flow steady state conditions can be justified.

2.2.2 QUAL2K - A modernized version of QUAL2E known as QUAL2K was released by EPA in December 2003, and QUAL2E is no longer supported by EPA. QUAL2K, also known as Q2K is a river and stream water quality model.

2.3 Loading model

2.3.1 PLOAD - It is a simple watershed model that computes nonpoint source loads from different sub watersheds and land uses based on annual precipitation, land uses and Best Management Practices (BMP's). Successful linking of the model to existing BASINS data and user supplied data makes the model useful in estimating nonpoint source loads, relative contributions and load reduction by BMP's. PLOAD is generally used to estimate seasonal or annual loading to feed simple eutrophication models and also used where there is great uncertainty in effectiveness of controls and adjustments to the TMDL may be expected after post-implementation monitoring.

2.4 Watershed Models

2.4.1 SWAT – SWAT, developed at the USDA-ARS (Arnold et al., 1998) is a physically based distributed parameter continuous simulation model. It is used to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long period of time. It

simulates hydrology, pesticide and nutrient cycling, bacteria transport, erosion and sediment transport.

SWAT2000 is the underlying model that is run from the BASINS ArcView interface. It is a continuous model not deigned to simulate detailed, single-event flood routing. SWAT uses a daily time step for simulations running from 1 to 100 years. SWAT is generally used when there is no nearby meteorological station with hourly data and / or when there is no nearby gaged watershed.

2.4.2 WinHSPF – It is an interface to the Hydrologic Simulation Program FORTRAN (HSPF). HSPF is a comprehensive, conceptual, continuous watershed simulation model designed to simulate all the water quantity and water quality processes that occur in a watershed and in-stream including sediment transport and movement of contaminants for extended periods of time.

HSPF originated from the watershed and field-scale models Agricultural Runoff Model (ARM) and Non Point Source (NPS). A strong force behind the development of HSPF was to provide a data management structure which could support many different modeling algorithms developed to simulate different hydrologic and water quality processes. HSPF is generally used where hourly meteorological data from a location on or near the watershed is available. The Watershed Data Management (WDM) was developed to hold tabular information. WDM supports HSPF and other models, as well as several large standardized government database sources for water resources data.

HSPF is a very robust, high resolution, flexible, reliable, and comprehensive hydrologic model for simulation of watershed hydrology and water quality (Bicknell et al., 1996). HSPF is derived from the Stanford Watershed Model (SWM). It uses input data to describe hydrological

conditions in a watershed. It can simulate continuously hydrologic and associated water quality processes on pervious and impervious land surfaces as well as in streams.

HSPF considers all stream flow components (runoff, interflow, and base flow) and their pollutant contributions. It has incorporated many non-point source models, such as ARM and NPS. By integrating the chemical, biological, and contaminant runoff processes on land surfaces and in the soil profiles with in-stream hydraulic, water temperature, sediment transport, and nutrient and sediment-chemical interactions, it simulates hydrolysis, oxidation, photolysis, biodegradation, Volatilization and sorption (Tong et al., 2002).

Based on a continuous record of precipitation and evaporation data, it computes a continuous hydrograph of stream flow at the basin outlet and produces a time history of the runoff, sediment load, and nutrient and pesticide concentrations (Donigian and Huber, 1991). It has been widely used for simulating watershed hydrology and water quality, and has been applied to support various watershed and water quality modeling studies.

The HSPF model performs all calculations in S.I. metric units. The most input data is provided in either English or metric units. Concentration values in the detailed process are provided in customary metric units i.e., mg/l. Most of the water quality parameters are derived values, to a large extent, developed during the model calibration/verification process.

The HSPF model supports a number of different simulation algorithms at different levels of detail and sophistication, providing the user a choice of approaches. The simulation algorithms available within HSPF are a mixture of physically-based and empirical approaches. Although some portions of the model employ algorithms and parameters which are not directly based on quantifiable physical and chemical phenomena, relationships can often be derived to develop those model parameters based on measurable quantities or characteristics of the

watershed. In some cases, model algorithms and parameters remain strictly in the realm of mathematical constructs and may be used primarily for calibration purposes to adjust the response of the mode. It is important to understand and accommodate both the limitations of the available data and the simplifying assumptions incorporated in the simulation algorithms to best apply the model to the problems at hand. Careful selection of parameters to be used for model calibration purposes will generally allow a simulation to be developed which can reasonably mimic the performance of the watershed under study.

Successful simulation of the model depends on development of reliable, representative time series inputs. Time series data include precipitation, air temperature, dewpoint temperature, wind movement, solar radiation, evaporation/evapotranspiration and upstream inflows, upstream or tributary inflows.

HSPF is a continuous simulation program. It requires continuous records of rainfall, evapotranspiration, temperature, and solar intensity to drive the simulations. Moreover, for calibration purposes, the watershed has to have USGS gauge stations that have historical discharge, flow and water quality information.

Meteorological data such as precipitation, evaporation/evapotranspiration, dewpoint temperature, solar radiation and air temperature are usually available in most areas. Sometimes monitoring stations may not be directly located within the basin being modeled and data for the desired simulation time step may not be available. During such scenarios, statistical analysis of the available data may be performed to derive characteristics of the local area. Pseudo-stations may also be developed using statistical methods to interpolate additional stations and provide added spatial variability to the inputs driving the simulation. This is particularly applicable to precipitation records when the watershed is large.

WDMUtil tool can be used to develop user's own file of hourly meteorological data for a more appropriate meteorological station that is included in the BASINS watershed. If an USGS gage station is not available in the watershed which is to be calibrated for hydrology, paired watershed approach can be used for calibrating HSPF on a nearby watershed of similar characteristics and then applying the calibrated model to the watershed required. HSPF uses an hourly time step.

HSPF also contains tabular input parameters, such as monthly varying inputs, program control flags, constants for model algorithms, and state variables. Program control flags are generally used to specify model sections which will be activated, which algorithms will be used when choices are available, and what data sources will be used. A number of algorithms will allow use of a single constant, monthly-varying values or an input time series.

HSPF and SWAT are very similar but have some major differences. The hydrologic and sediment estimations are slightly different but the chemical transport mechanisms are similar. The major advantage of HSPF is that it can include many non-conservative parameters and can simulate time periods less than 1 day. The main disadvantage is the intensive data requirements, and the large amount of time needed to calibrate the model.

HSPF was selected over SWAT as the appropriate model, to model the quantity and quality of the runoff from different types of land use and also as an hourly time step is required to model DO.

3. Methodology and Data Collection

3.1 Overview

An Overview of the methodology followed to accomplish the objectives is outlined below:

- Data Collection
- Delineation of Watershed
- Hydrology Calibration
- Water Quality Calibration
- Land use Scenarios
- Ranking of Land use Scenarios

3.2 Data Collection

3.2.1 Geographic Data

Using the Pontchartrain Basin GIS, the Tickfaw river watershed was identified as USGS cataloging unit 8070203 and the relevant topographic maps were obtained. Figure 3.1 shows the Tickfaw River watershed with Tickfaw river highlighted in yellow in BASINS. Projects were created in Basins for Tickfaw after studying the watershed characteristics from the topographic maps. The required data for creating a project in BASINS were obtained from the BASINS online source files and the spatial data sets of Hydrologic Unit Code (HUC), Digital Elevation Model (DEM) data, land use land cover, soil classification, USGS gaging stations, water quality observation stations, weather stations, permit compliance system sites, industrial discharge sites, perennial streams, reach files and various boundaries were compiled.

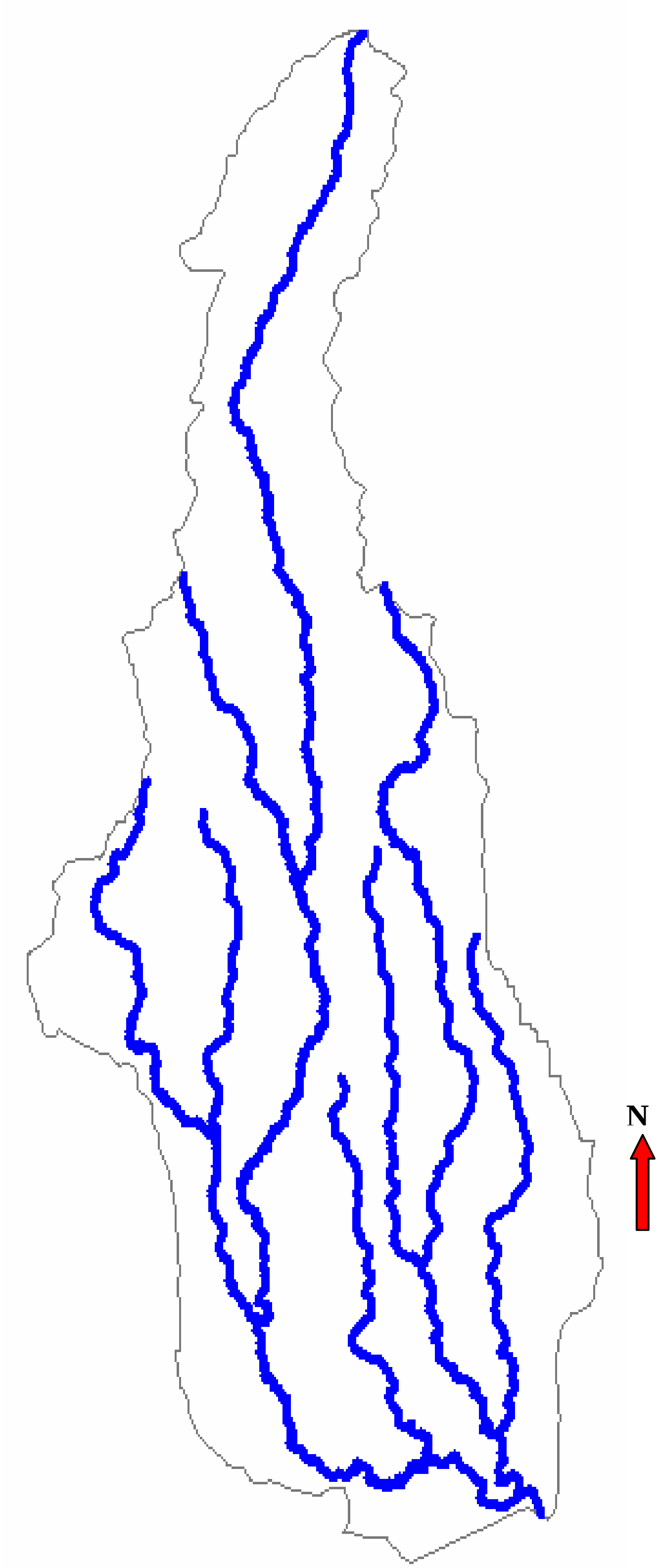

Figure 3.1: Tickfaw River watershed

3.2.2 Meteorological Data

The data required for model execution involves the weather and the flow data. In order to successfully calibrate hydrology, meteorological data local to the watershed is required. The National Climatic Data Center (NCDC) was extensively searched using the county filter for all the meteorological stations available within the watershed. Baton Rouge meteorological station was selected as the station local to the watershed. Data at this station was available for the period of 01/01/1970 to 12/31/2005. Meteorological constituents like hourly precipitation, hourly evaporation, hourly temperature, hourly wind speed, hourly solar radiation, hourly potential evapotranspiration, hourly dew point temperature, hourly cloud cover were extracted for Baton Rouge meteorological station. Daily precipitation data at Hammond, LA was collected from 1941 to 1986.

These data are stored in the Watershed Data Management (WDM) format, which is used by both BASINS and HSPF. WDM files and the code library that manages them provide a powerful tool for managing and manipulating time-series data. The current version of BASINS can contain 10 meteorological stations per state. The WDMUtil program provides operational capabilities to allow users to import available meteorological data into WDM files and perform operations necessary (e.g., editing, aggregation/disaggregation, filling missing data, etc.) in order to create the input time-series data for WinHSPF. WDMUtil will allow the user to add available local meteorological data to their study, thus removing the existing reliance on the limited set of meteorological data stored in BASINS (USEPA, 1999).

HSPF requires a unique data set for each meteorological parameter that will be imported. In the BASINS Met WDM files, 20 data set fields relating to specific meteorological parameters are allocated for each WDM station. Using WDMUtil, data sets in WDM files are designated by

a unique number and other relevant information relating to the time series data fields into which the data are imported. The table displays data sets and a brief description of the information contained in each data set for a template WDM file used to import both hourly and daily data sets for 10 WDM stations. Data sets are numbered from 11 to 210. All hourly information is listed in data fields 1 through 8. HSPF algorithms use these hourly values. The remaining data fields (9 - 16) contain daily time series data, as well as intermediate time series data used in the conversion of HSPF parameters (USEPA, 1998). A Weather Data Management (WDM) file was created using the meteorological data from the Baton Rogue weather station, the Hammond station daily precipitation data, and the flow data at Holden.

A powerful function of WDMUtil is the ability to disaggregate daily precipitation into hourly values based on hourly time series from nearby stations. WDMUtil uses values from the secondary hourly station with daily total closest to the daily value of the station in question. If there is not a daily total from a secondary station within a user-specified tolerance of the daily value, hourly values are obtained from a triangular distribution of the daily value with a peak at the middle of the day. (Hummel et al, 2001). WDMUtil uses a triangular distribution to disaggregate values outside of the data tolerance. Because triangular distribution is quite inaccurate, the data tolerance is set high in order to increase the acceptable range of daily totals and to minimize use of triangular distribution. Daily precipitation data of Hammond, LA was disaggregated into hourly precipitation using the Baton Rogue, LA hourly precipitation data for the period from 1970 to 1986.

3.2.3 Stream Flow Data

An extensive search was carried out to identify the gage stations in the watershed. Daily stream flow data was available only at USGS gage station Holden (Station ID 07376000) for the

period of 09/1940 to 09/1988. The data were extracted from United States Geological Survey website (www.usgs.gov). The downloaded data which were in word data format was then exported to Microsoft Excel. Quality Assurance and Quality Control (QAQC) was carried out to check for any erroneous and missing data.

In order to calibrate hydrology manually, we need to compare observed flow volumes to simulated flow volumes. Annual and seasonal flow volumes can be calculated in a spreadsheet from the observed flow time series. Stream flow data available from USGS is in cubic feet per second. In order to compute total volumes from average daily flows, we need to: (1) convert the flow values from cubic feet per second to acre-feet per day, (2) sum the flow rates for a desired time period. A factor of 1.983 was multiplied for each record of stream flow data in cubic feet per second to convert it into acre-feet per day. The conversion from ft^3/sec to acre-feet/day is:

$$\frac{ft^3}{1\sec} * \frac{60\sec}{1\min} * \frac{60\min}{1hour} * \frac{24hour}{1day} * \frac{1acre}{43560\,ft^2} = \frac{acre \cdot feet}{day}$$ Or 1 cfs = 1.983 acre-feet/day

Yearly flow volumes were then calculated by summing the stream flow in acre-feet per day from 1^{st} of January to 31^{st} of December for the period of 1970 to 1986. Rainfall patterns for the Tickfaw watershed were examined and compiled for annual, seasonal, and monthly analyses. For seasonal calibration, each year was divided into two seasons; May – October and November – April. Seasonal flow volumes were then compiled by adding the flow volumes from the beginning day to the end day of the season. Seasonal flow volumes were compiled for all seasons for the period of 1970 to 1986.

3.2.4 Water Quality Data

An extensive search was carried out to identify the water quality stations in the Tickfaw watershed. In Appendix A, Figure 3.2 displays the location of water quality monitoring stations

in the watershed. A water quality observation station along the Tickfaw River was identified in Springville, LA. Data for Nitrogen, Phosphorus, Dissolved Oxygen and Temperature of water were available at this station for the period of 1978 to 2004. Data available at this station were in irregular intervals varying from one observation in one month to one observation in four-month periods. A Quality Assurance/Quality Control (QA/QC) analysis of these data was carried out to detect if any erroneous data was recorded at the station. The temperature which was recorded in degrees Celsius was converted into Fahrenheit and formatted for the WDM. A new script file was created to read and write the data into a water quality WDM file.

3.3 Watershed Delineation

The Digital Elevation Model (DEM) data set was overlaid on the Tickfaw watershed to delineate the watershed into smaller hydrologically connected watersheds. Figure 3.2 shows the DEM of the Tickfaw watershed. This watershed is a typical drainage basin as the elevation of the watershed changes from 0 m above sea level in the south to 130 m in the north. The predominant portion of the southern watershed elevation is around 0m.

Using the DEM data sets, the Tickfaw River Watershed was delineated using the auto delineation tool within BASINS. Peculiar results were obtained as the automatic delineation did not work for the southern part of the Tickfaw River Watershed. The automatic delineation of BASINS resulted in delineating the southern part of the watershed as one sub basin. Figure 3.3 shows the sub basins resulted due to the automatic delineation along with streams and outlets.

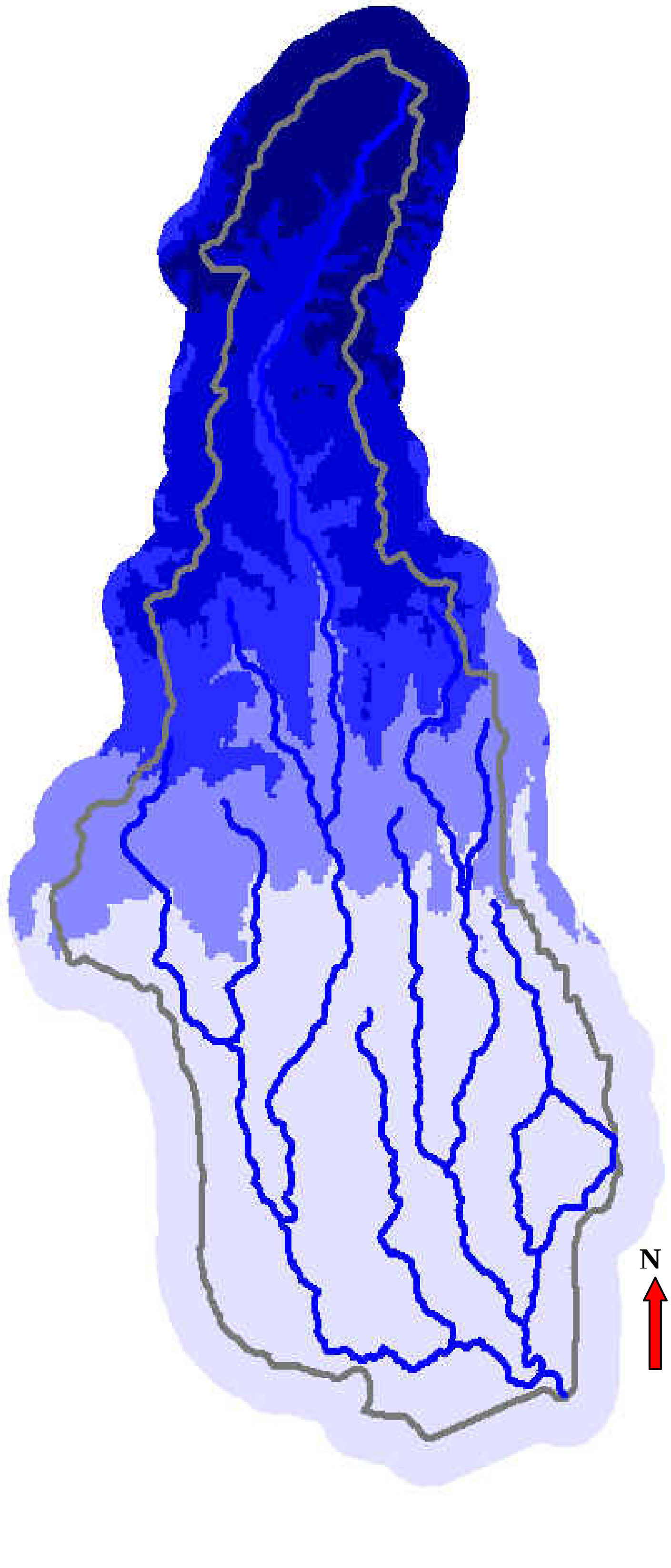

Figure 3.2: Digital Elevation Model of Tickfaw Watershed

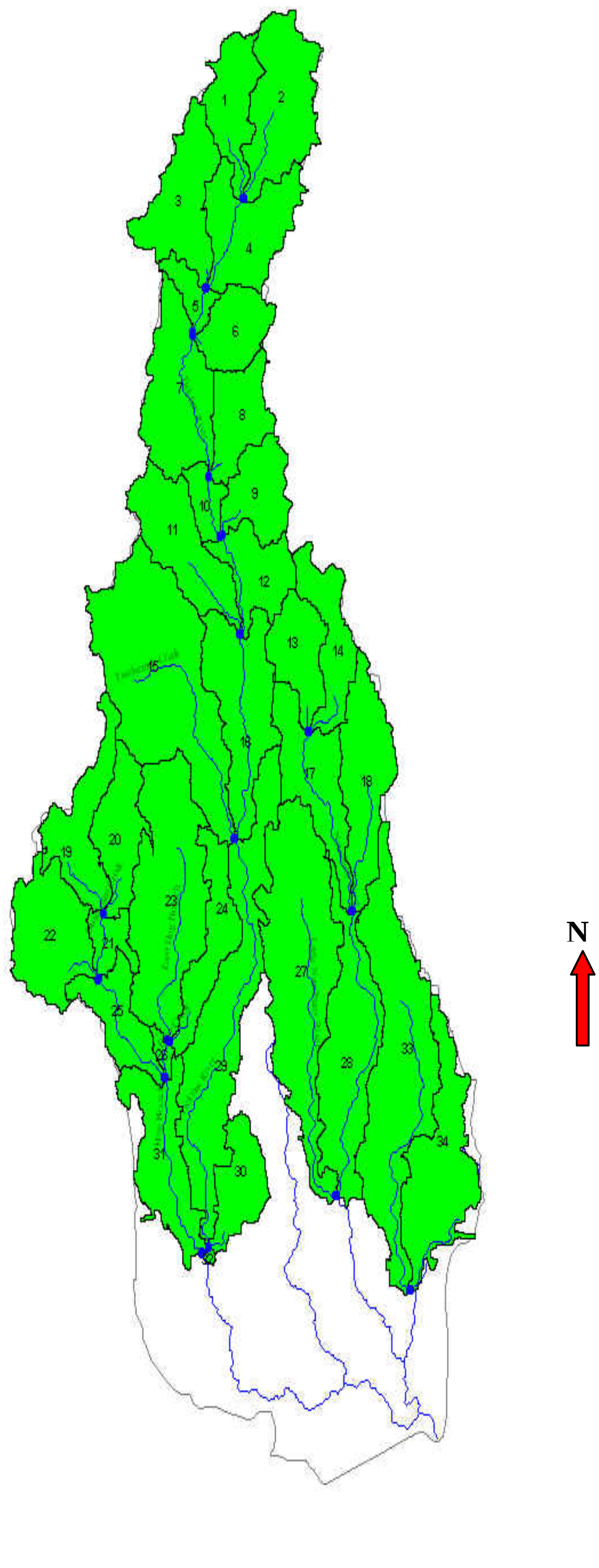

Figure 3.3: Automatic Delineation of Tickfaw Watershed

After extensive investigation, it was found that since a major portion of the southern part of the watershed had an elevation of 0m, BASINS was considering this whole area as one sub basin. It was then decided that a higher resolution data set such as LIDAR data would be necessary. The corresponding LIDAR data for Tickfaw River Watershed was downloaded from LSU Atlas website.

The data which was in raster format for individual quadrangles was converted to grid format using Arc Toolbox, then, using the ArcView 3.2, the grid data was converted to shape files for merging and clipping to the project area. Since the data was downloaded separately for each quarter quadrangle, the shape files were merged and then clipped from the boundaries of the corresponding watersheds to cover the whole watershed area.

It was then noted that the LIDAR data format that had been downloaded, included the buildings and trees which would interfere with the automatic delineation process. Thus, edited LIDAR xyz data (without buildings and trees) was also obtained. The edited LIDAR data is in point format which can not be used directly by the auto delineation tool in BASINS. Conversion of this data is currently being worked out to arrive at a usable format for delineation.

Delineation of Tickfaw River watershed was ultimately performed manually. Since the manual delineation requires utmost care and accuracy and since it is dependent on engineer's judgment, many layers of data required for delineation were obtained. Delineation mainly depends on the elevation data, hence, besides the LIDAR and DEM data, the USGS's 1:24,000 Scanned Topographic Maps, and Digital Orthophoto Quarter Quadrangles (DOQQ) images were obtained. With those data, a better understanding of the watershed topography was provided. Figure 3.4 shows the LIDAR layer which was hill shaded in order to have a better idea about the ridges and slopes, which are important parameters in delineation. The delineation uses National

Hydrograph Dataset (NHD) data for completing the manual delineation and burning in the stream network.

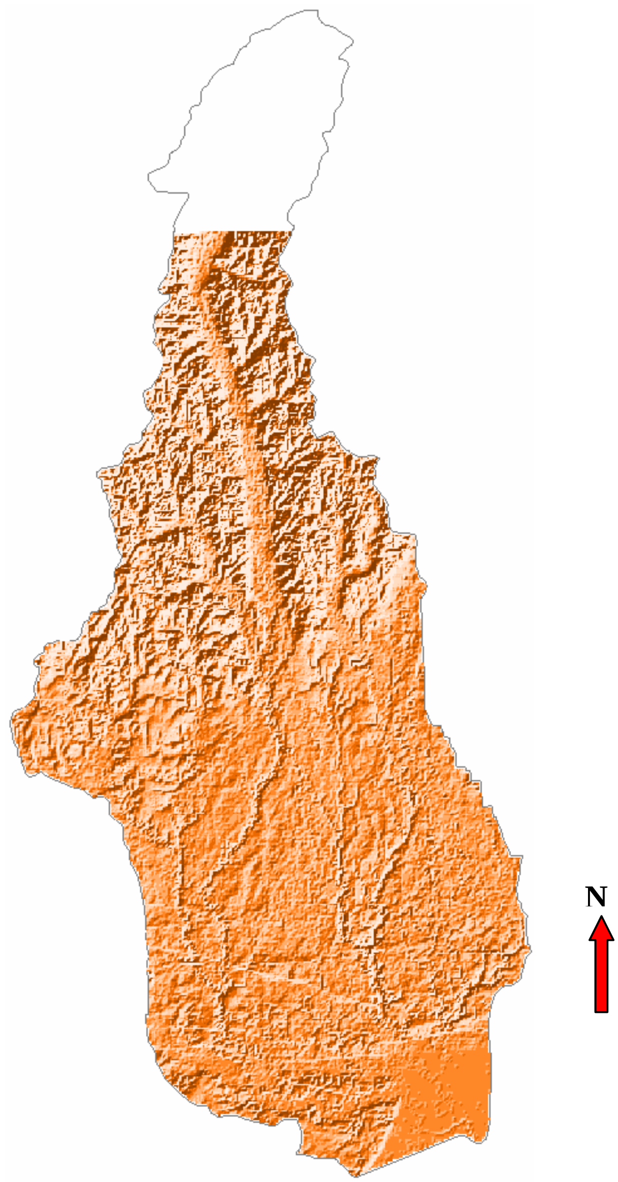

Figure 3.4: Hill shade of LIDAR data of Tickfaw Watershed

In the Tickfaw river watershed, it was found that there was no connectivity of streams in many of the sub basins after burning in the outlets, sub basins, and stream network, during the process of manual delineation. Figure 3.5 shows the disconnectivity in streams with outlets and sub basins in Tickfaw watershed.

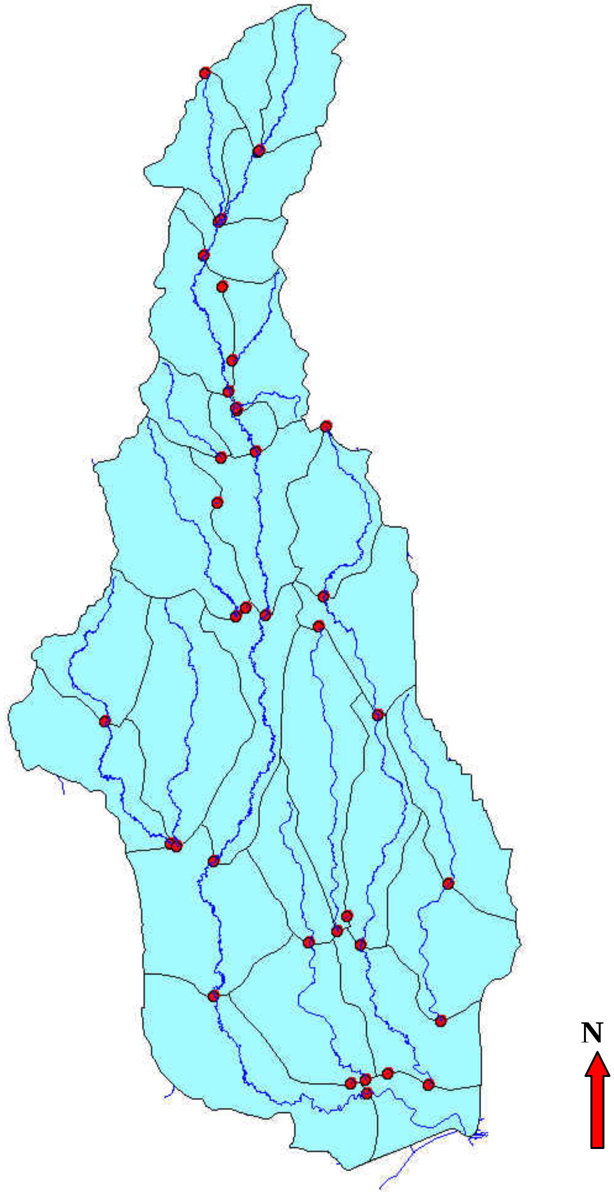

Figure 3.5: Dis-connectivity of streams in Tickfaw River Watershed from manual delineation

Several attempts were made in delineating the watershed using the NHD to attain proper connectivity in the streams in all the sub-watersheds. Finally, the Tickfaw River watershed was manually delineated into 12 sub watersheds that can be used for flow calibration. The area around the Natalbany River, Little Natalbany River and Ponchatoula Creek were delineated into one single sub watershed that has its pour point outlet below the last flow gage on the Tickfaw

River. This area is not considered in the model. Figure 3.6 shows the final delineated Tickfaw watershed.

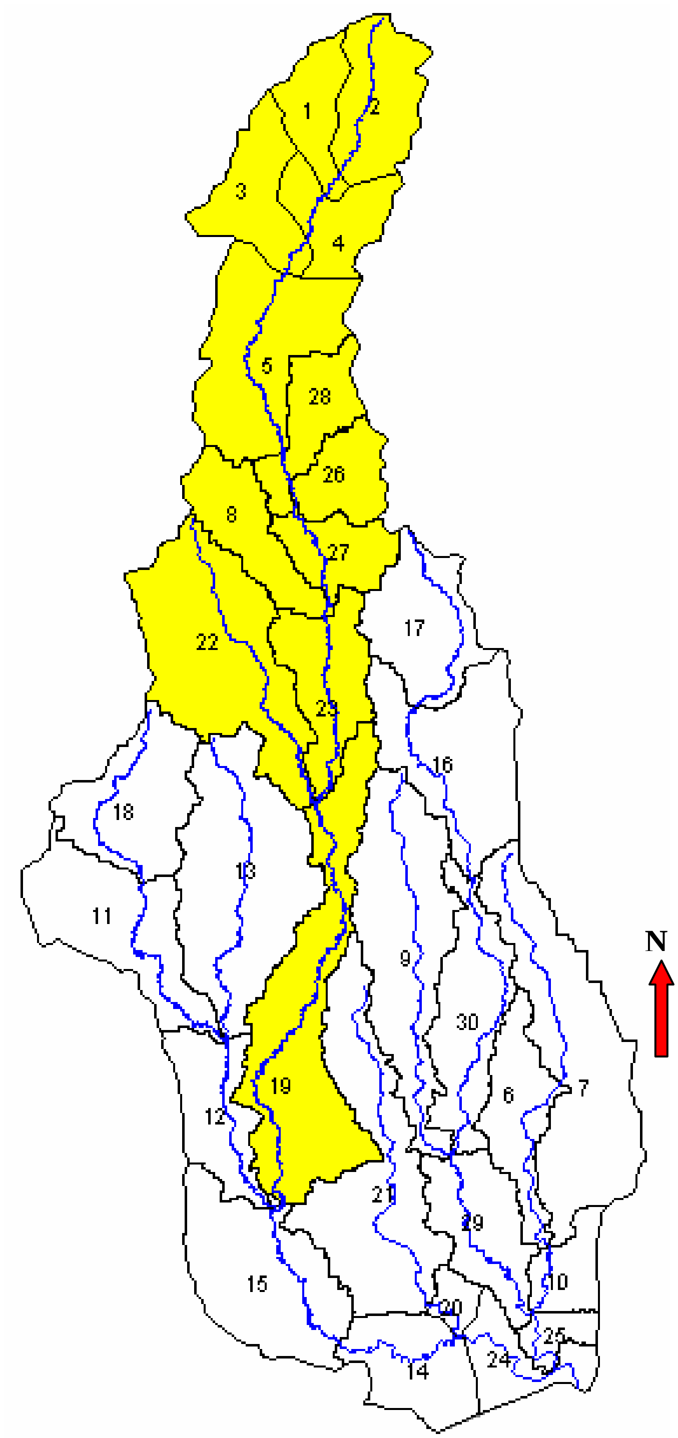

Figure 3.6: Manually delineated Tickfaw Watershed

4. Model Development

4.1 Hydrology Modeling

One of the most important aspects of modeling watersheds is hydrology calibration. In order to ascertain how well our model is simulating conditions in our watershed, we need to compare the model's output to observed data. The WinHSPF interface includes many useful tools and user-input windows, many of which allow user-specified parameter adjustments. The *Streams*, *Subbasins*, and *Outlets* themes are required in order to launch WinHSPF from the BASINS interface. These files are generally created using the manual delineation tool or the automatic delineation tool. The Predefined Data tool allows users to import previously delineated watersheds where the S*treams*, S*ubbasins*, and O*utlets* themes have already been created. The *Streams*, *Subbasins*, and *Outlets* files which were created during manual delineation of Tickfaw watershed were used to launch WinHSPF. Figure 4.1 shows the HSPF model schematic of Tickfaw river watershed.

WinHSPF was launched from BASINS interface using *Streams*, *Subbasins*, and *Outlets* themes, and the WDM file which was prepared using all the meteorological and hydrology data. When WinHSPF is launched from BASINS, an input file (*.uci*) is created. WinHSPF estimates the depth and width of individual reaches using variables such as the area and slope of a subbasin. These estimates are generally accurate, and as no additional data was available for the Tickfaw watershed, these values were retained.

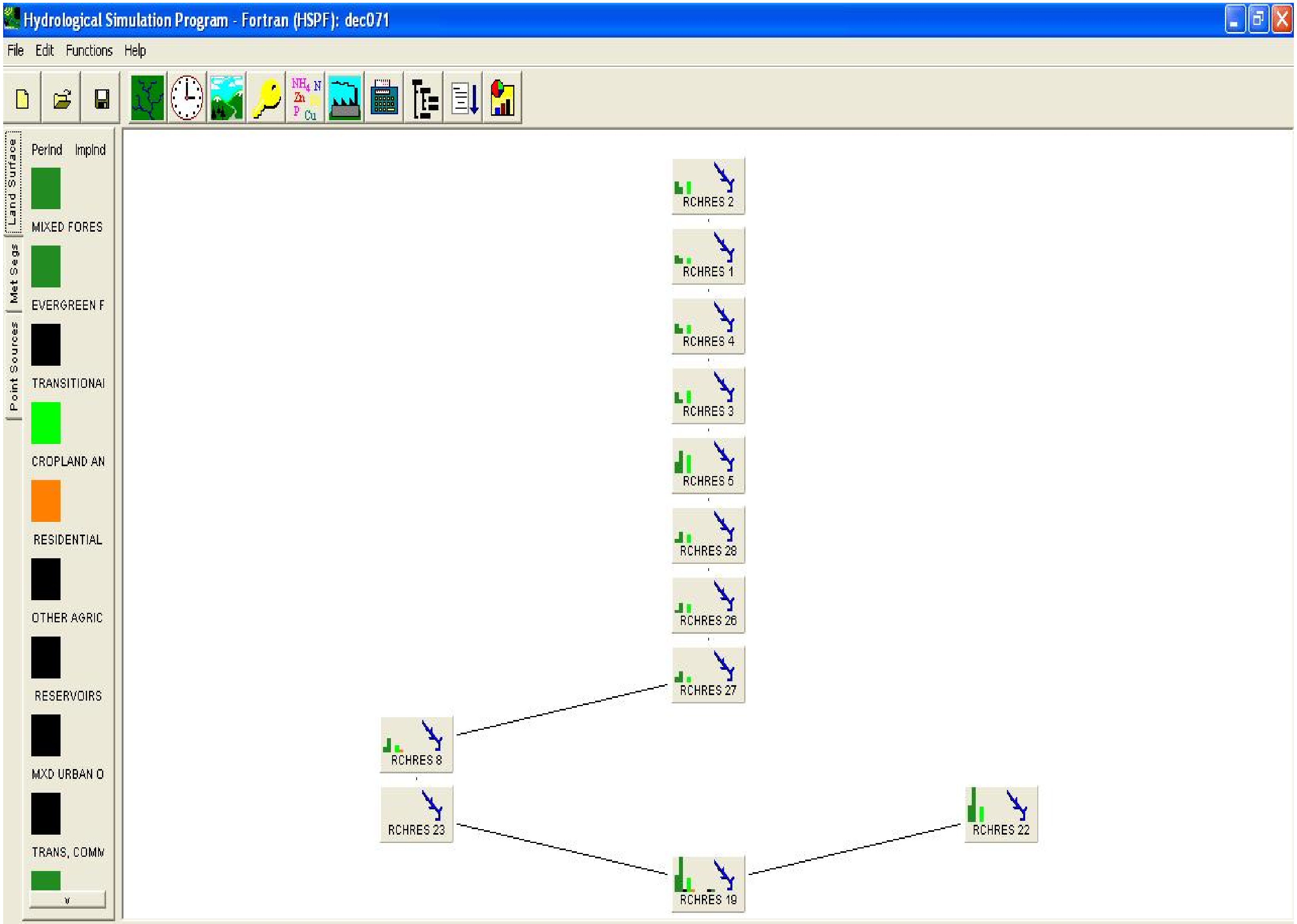

Figure 4.1: Tickfaw River HSPF Model Schematic

The goal of calibration is to "tune" the model so that the simulated flow resembles the observed flow data as closely as possible. This is accomplished by adjusting various input parameters within WinHSPF. The best way was to begin the calibration process is to look at the annual total runoff volume error. This type of analysis should be performed for annual and seasonal periods. The total runoff volume error for a specific time period was computed by estimating the total volume of water passing through a reach according to the gage data (observed flow) and comparing it to the output volume simulated by the WinHSPF model (simulated flow). Once the simulated and observed volumes have been calculated and compared, the values of calibration parameters were adjusted until the total annual simulated volumes are very close to the total annual observed volumes. Losses in the watershed are generally accounted for by quantifying flow diversions, evapotranspiration losses, and losses due to deep percolation. For the Tickfaw River watershed model, it was assumed that all flow diversions were accounted and that losses due to deep percolation are negligible. It was assumed that all losses are due to evapotranspiration and parameters that are associated with evapotranspiration were adjusted.

4.2 Hydrology Calibration

4.2.1 Simulation with default parameters:

Initially, the model was run with the default parameters for the period of 1981 to 1984 and the total annual simulated flow volumes were compared with the observed annual flow volumes to determine whether calibration efforts should be focused on increasing or decreasing the total annual simulated flow volumes. Annual simulated flow volumes at reach 19 were

compared with the observed flow volumes at Holden as shown in Table 4.1. It was observed that the model was over simulating by 37 %.

Output results were plotted in GenScn (GENeration and analysis of model simulation SCeNarios). GenScn is a postprocessor used to create scenarios, analyze results of the scenarios, and compare scenarios. Graphical comparison of the simulated flow volumes with observed flow volumes was performed.

Table 4.1: Comparison between Annual Simulated flow volumes and Observed flow volumes at Holden with default parameters.

Date	Simulated Flow (acre-feet)	Observed Flow (acre-feet)	Percentage Difference
1981	2.41E+05	139313	42.29
1982	3.18E+05	256185	19.49
1983	7.52E+05	479176	36.28
1984	3.89E+05	200556	48.50
		Average	36.64

The simulated flows and the observed flows during calibration are given in **Figure 4.2**. **Figure 4.3** shows the flow duration graph. The model as expected showed that the simulated flows over predicted the observed flow at Holden (Figure 4.2). HSPF uses the information found in BASINS to estimate values for many parameter inputs. These values can be highly inaccurate and should be modified if more accurate information is available.

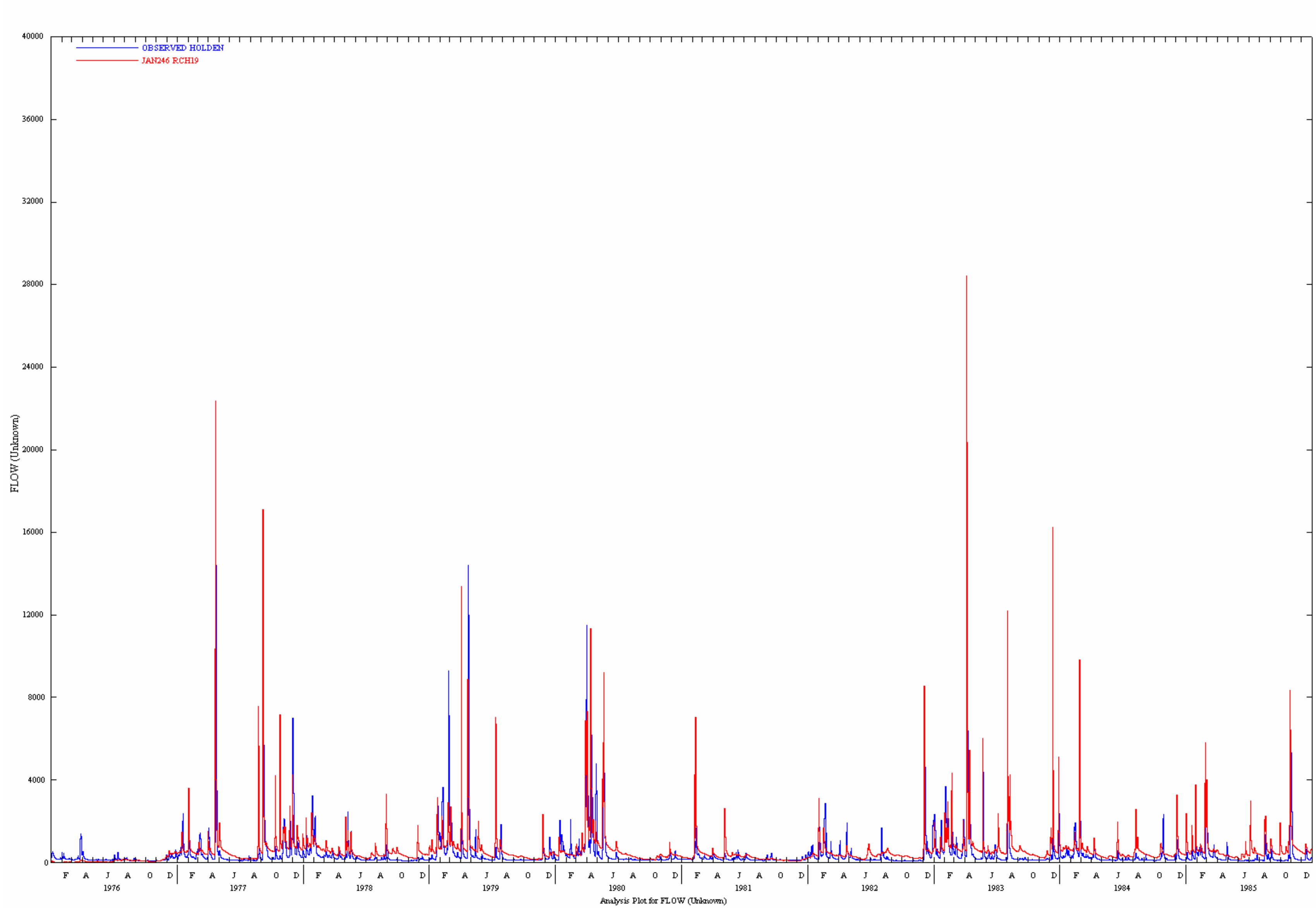

Figure 4.2: Simulated and Observed Flows at Holden with default parameters

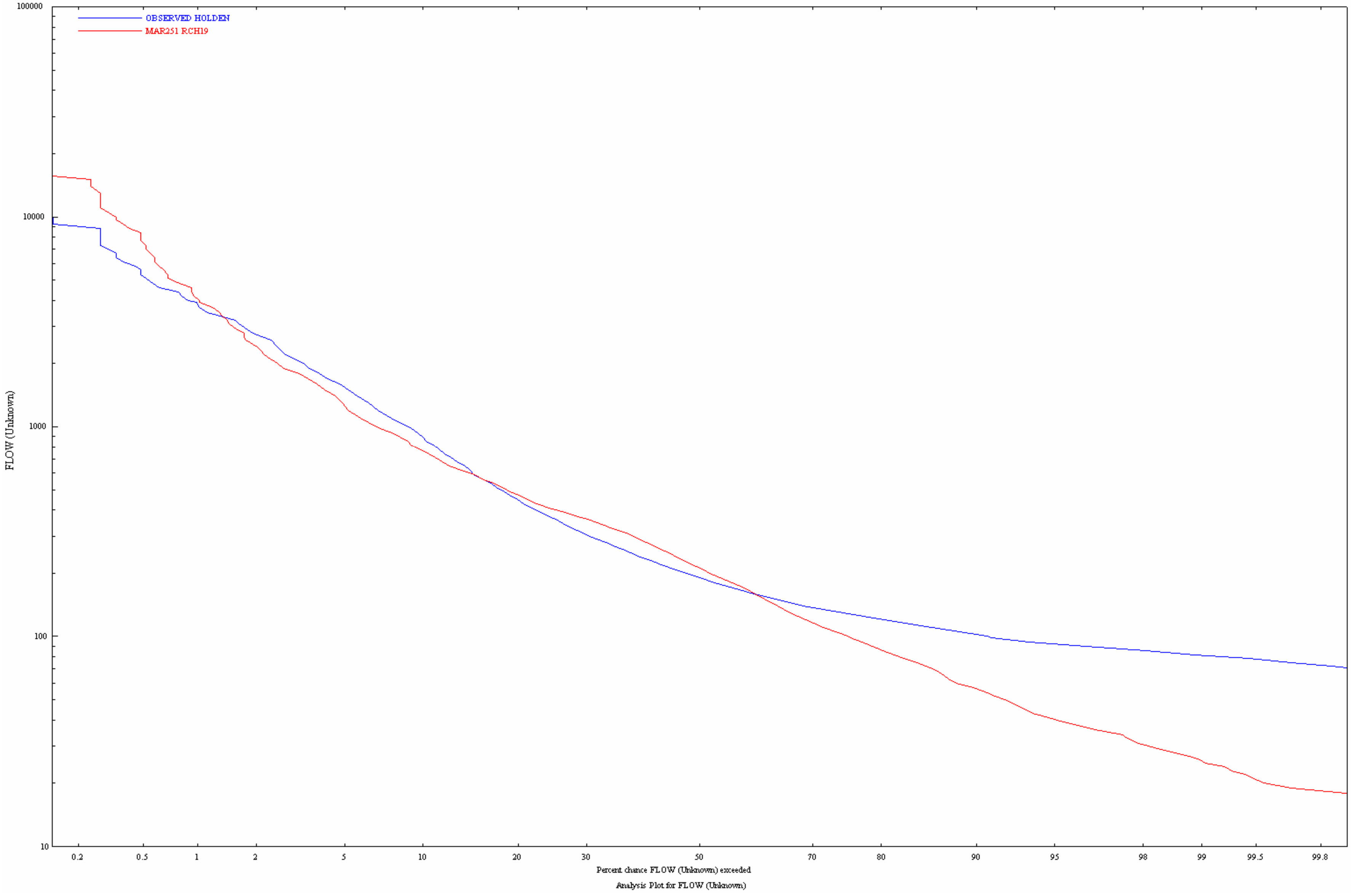

Figure 4.3: Flow Duration Diagram of Simulated and Observed Flows at Holden

The HSPF Model created was modified for hydrologic and hydraulic parameters. All the initial input parameters in ATEMP, SNOW, PWATER, and HYDR tables were determined or estimated with guidance from EPA/BASINS Technical Note 6 – Estimating Hydrology and Hydraulic Parameters for HSPF. This technical note provides BASINS users with guidance in how to estimate the input parameters in the ATEMP, SNOW, PWATER, IWATER, HYDR, and ADCALC sections of the Hydrological Simulation Program Fortran (HSPF) watershed model.

For each input parameter, this guidance includes a parameter definition, the units used in HSPF, and how the input value may be determined (e.g. initialize with reported values, estimate, measure, and/or calibrate). The outcome of the literature survey pointed to the importance of **LZSN** (**L**ower **Z**one **S**torage **N**ominal), **UZSN** (**U**pper **Z**one **S**torage **N**ominal) and **DEEPFR** (the fraction of infiltrating water which is lost to deep aquifers) as the key parameters for annual flow calibration.

4.2.2 Key Parameters for Annual Calibration:

4.2.2.1 Lower Zone Storage Nominal (LZSN)

LZSN is related to both precipitation patterns and soil characteristics in the region. The ARM Model User Manual (Donigian and Davis, 1978, p. 56, LZSN variable) includes a mapping of calibrated LZSN values across the country based on almost 60 applications of earlier models derived from the Stanford-based hydrology algorithms. LaRoche et al (1996) shows values of 5 inches to 14 inches, which is consistent with the ‘possible’ range of 2 inches to 15 inches. Viessman, et al, 1989, provide initial estimates for LZSN in the Stanford Watershed Model (SWM-IV, predecessor model to HSPF) as one-quarter of the mean annual rainfall plus four inches for arid and semiarid regions, or one-eighth annual mean rainfall plus 4 inches for coastal, humid, or sub humid climates. These formulae tend to give values

somewhat higher than are typically seen as final calibrated values; since LZSN will be adjusted through calibration, initial estimates obtained through these formulae may be reasonable starting values.

The LZSN (lower zone storage nominal) is related to precipitation and soil characteristics in the watershed. Increasing the value of LZSN increases the amount of water stored in the lower zone and therefore, increases the opportunity for evapotranspiration from the upper zone. This decreases flow rates by providing greater opportunity for evapotranspiration. Decreasing the value of LZSN increases flow rates in the reach.

4.2.2.2 Upper Zone Storage Nominal (UZSN)

UZSN is related to land surface characteristics, topography, and LZSN. For agricultural conditions, tillage and other practices, UZSN may change over the course of the growing season. Increasing UZSN value increases the amount of water retained in the upper zone and available for ET, and thereby decreases the dynamic behavior of the surface and reduces direct overland flow; decreasing UZSN has the opposite effect. Donigian and Davis (1978, p. 54) provide initial estimates for UZSN as 0.06 of LZSN, for steep slopes, limited vegetation, low depression storage; 0.08 LZSN for moderate slopes, moderate vegetation, and moderate depression storage; 0.14 LZSN for heavy vegetal or forest cover, soils subject to cracking, high depression storage, very mild slopes. Donigian et al., (1983) include detailed guidance for UZSN for agricultural conditions. LaRoche shows values ranging from 0.016 in to 0.75 in. Fontaine and Jacomino showed average daily stream flow was relatively insensitive to this value but sediment and sediment associated contaminant outflow was sensitive; this is consistent with experience with UZSN having an impact on direct overland flow, but little impact on the annual water balance (except for extremely small watersheds with no base flow).

The UZSN (upper zone storage nominal) is related to land surface characteristics, topography, and LZSN. This parameter can change over the course of a growing season. Increasing UZSN increases the amount of water retained in the upper zone and available for evapotranspiration, allowing less overland flow.

4.2.3 Model Sensitivity for annual calibration parameters

Using the above key annual calibration parameters, model was checked for its sensitivity for a period of four years from 1981 to 1984. Suggestions for UZSN from literature are

- 0.06*LZSN – steep slopes and limited vegetation
- 0.08*LZSN – moderate slopes and vegetation
- 0.14*LZSN – mild slopes and heavy forest cover

As 0.14*LZSN goes beyond the suggested maximum value of 1.0, the maximum UZSN value of 1.0 was used as a starting point. The results showed that Annual simulated flow volumes were greater than observed flow volumes at Holden by 30.41 % as shown in Table 4.2.

UZSN was then increased to 1.5, LZSN was increased to 4, and the model was re-executed to check the simulated flow volumes. It was observed that the total percentage difference between simulated flow volumes and observed flow volumes decreased to 25.4%. UZSN was again increased to 1.7 and LZSN, was further decreased to 8.0 and the model was re-executed. The simulated flow volumes decreased and the percentage difference between simulated and observed flow volumes decreased from 25.4% to 16.38%. Also, DEEPFR was then decreased to 0.2 which resulted in the increase in total percentage difference for the same period to 18%. With this, it was concluded that with the increase in these three parameters, the simulated flow volumes decrease. Table 4.3 shows the simulated and observed flow volumes when UZSN is 1.6, LZSN is 14 and DEEPFR is 0.2.

Table 4.2: Comparison between Annual Simulated flow volumes and Observed flow volumes at Holden when LZSN is 14, UZSN is1.

Date	Simulated Flow (acre-feet)	Observed Flow (acre-feet)	Percentage Difference
1981	2.18E+05	139313.682	36.18
1982	2.83E+05	256185.753	9.44
1983	6.91E+05	479176.086	30.64
1984	3.53E+05	200556.654	43.20
		Average	30.41

Table 4.3: Comparison between Annual Simulated flow volumes and Observed flow volumes at Holden when LZSN is 8, UZSN is1.6 and DEEPFR is 0.2

Date	Simulated Flow (acre-feet)	Observed Flow (acre-feet)	Percentage Difference
1981	1.75E+05	139313.682	20.39
1982	2.25E+05	256185.753	-14.06
1983	6.01E+05	479176.086	20.28
1984	2.85E+05	200556.654	29.68
		Average	16.38

4.2.4 Annual Calibration

As the hourly precipitation data at Hammond is available for the period of 1970 to 1986, it was decided to use the data from 1970 to 1978 for calibration and the data from 1979 to 1986 for validation. As discussed in the model sensitivity section, the key annual calibration parameters were adjusted accordingly to bring down the percentage difference between

simulated flow volumes and observed flow volumes below 15% during annual calibration. These parameters were adjusted within the permissible range suggested by Technical Note 6 of WinHSPF Manual. Table 4.4 shows the comparison between annual simulated flow volumes and observed flow volumes at Holden during the Calibration period. Figure 4.4 shows the annual simulated and observed flows at Holden during the calibration period and Figure 4.5 shows the flow duration graph for the same period.

Table 4.4: Comparison between Annual Simulated flow volumes and Observed flow volumes at Holden during calibration

Year	Simulated (acre-feet)	Observed (acre-feet)	% Difference
1971	260866	241016	7.61
1972	299124	265377	11.28
1973	476765	435082	8.74
1974	411985	361473	12.26
1975	296859	356575	-20.12
1976	121695	130424	-7.17
1977	480723	449300	6.54
1978	223505	225239	-0.78
Sum	**2571522**	**2464486**	**4.34**

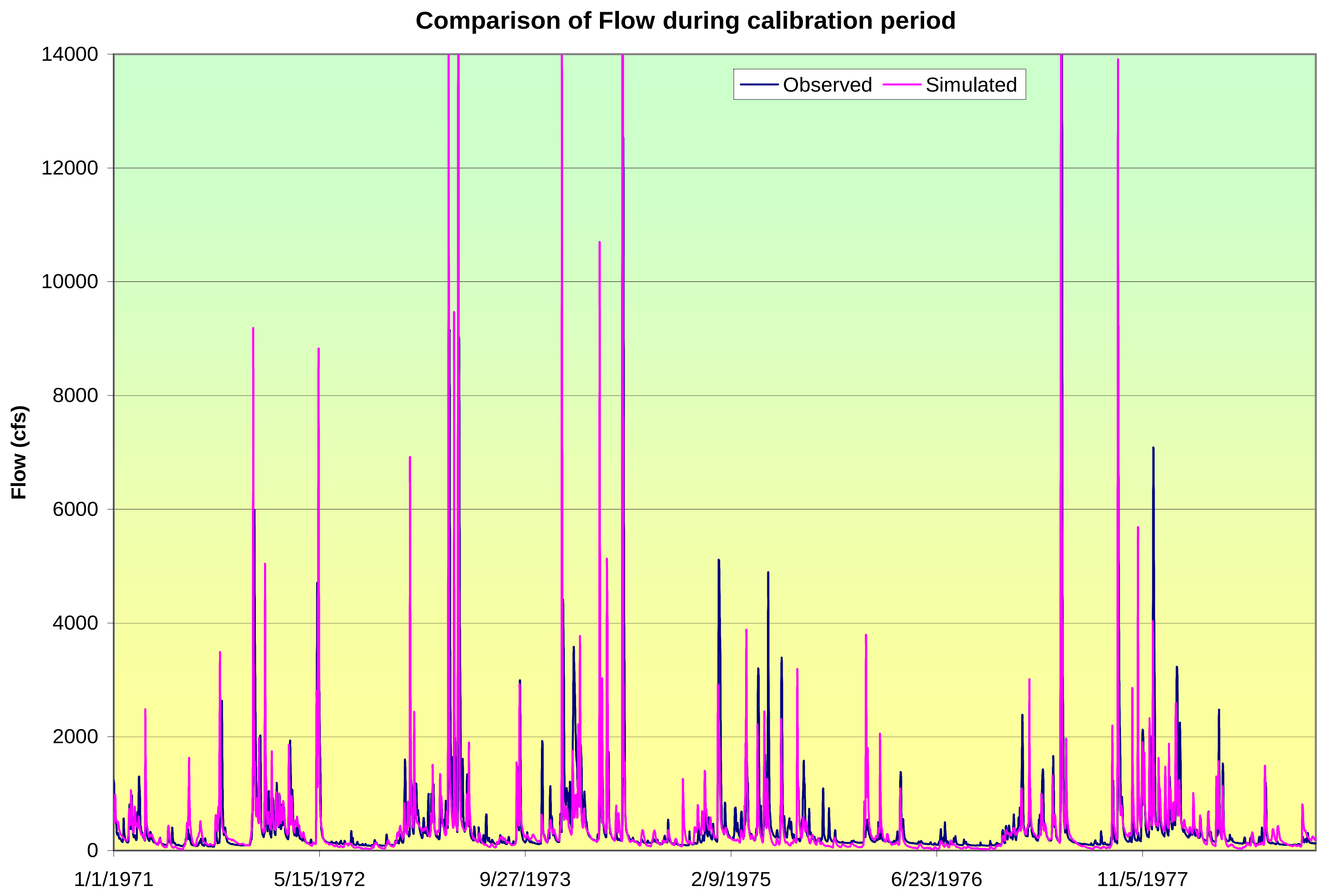

Figure 4.4: Annual Flow Diagram of Simulated and Observed Flows for the Tickfaw River watershed for calibration

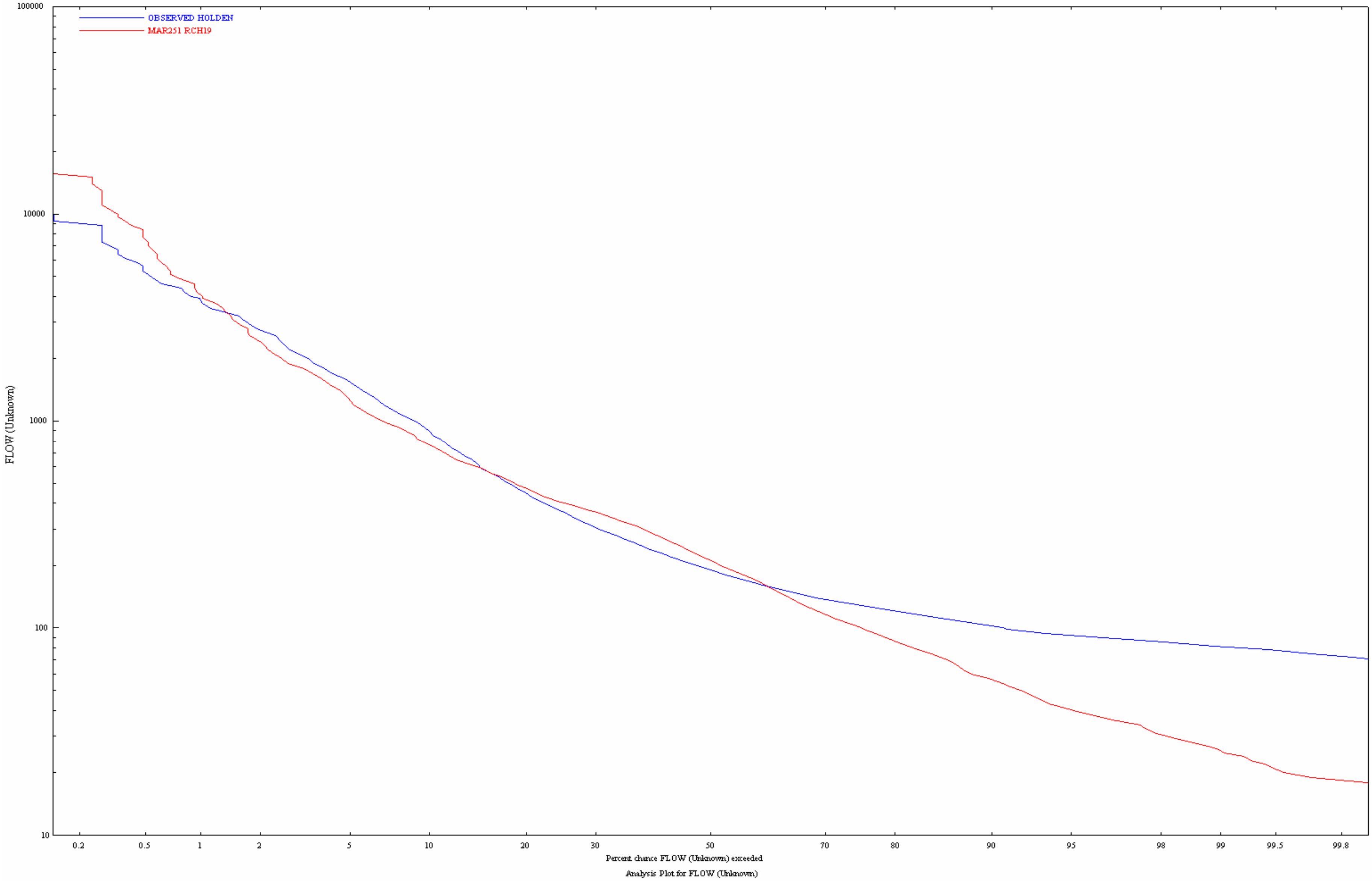

Figure 4.5: Flow duration graph for the Tickfaw River watershed during calibration

In southeastern Louisiana, during the summer season the prevailing winds are predominantly from the south providing abundant moisture from the Gulf of Mexico resulting in numerous, locally intense, thunderstorms. During the winter, the southward movement of polar air meeting warm air from the Gulf of Mexico produces significant precipitation events. Two periods of the year are used in the study: May through October, which is referred to as the summer season; and November through April, which is referred to as the winter season. This division of seasons is based on the climatic mechanism study done by Barbe and Francis (1995) during the analysis of seasonal fecal coliform levels in the Tchefuncte River. Cruise and Arora (1990) who studied flood data collected on 18 watersheds in south Louisiana also successfully used this division for seasons in southeast Louisiana.

The main parameters for seasonal and monthly calibration were **UZSN** and **INFILT** (an index to mean soil infiltration rate) and **BASETP** (Evapotranspiration by riparian vegetation). These parameters were tuned until the seasonal flow difference was less than 10%.

4.2.4.1 Key Parameters for Seasonal Calibration

The BASETP is the evapotranspiration of riparian vegetation as active groundwater enters the streambed and is a fraction of the potential evapotranspiration. If significant riparian vegetation is present in the watershed, then non-zero values of BASETP should be used. Adjustments to this parameter will be visible in changes in low flow simulation and will affect the annual water balance.

4.2.3 Infiltration (INFILT)

In HSPF, INFILT is the parameter that effectively controls the overall division of the available moisture from precipitation (after interception) into surface and subsurface flow and storage components. Thus, high values of INFILT will produce more water in the lower zone and groundwater, and result in higher base flow to the stream; low values of INFILT will produce

more upper zone and interflow storage water, and thus result in greater direct overland flow and interflow. LaRoche et al (1996) shows a range of INFILT values used from 0.004 in/hr to 0.23 in/hr, consistent with the ‘typical’ range of 0.01 to 0.25 in/hr in the Summary Table. Fontaine and Jacomino (1997) show sediment and sediment associated transport to be sensitive to the INFILT parameter since it controls the amount of direct overland flow transporting the sediment. Since INFILT is not a maximum rate nor an infiltration capacity term, it’s values are normally much less than published infiltration rates, percolation rates (from soil percolation tests), or permeability rates from the literature. In any case, initial values are adjusted in the calibration process.

The INFILT is an index to mean soil infiltration rate. It is a function of soil characteristics and controls how much of the water from precipitation will become surface flow, subsurface flow, and a portion of the storage components. Increasing the value of INFILT produces more water in the lower zone and therefore, generally results in higher base flow in the streams. Low values of INFILT will produce more upper zone and interflow storage water, resulting in greater direct overland flow (if the upper zone is saturated) and interflow (*BASINS Technical Note 6*).

4.2.5 Model Sensitivity for seasonal calibration parameters

During seasonal calibration, the model was also checked to see the changes in annual simulated flow volumes. When INFILT was decreased from 0.5 to 0.1, it was observed that the simulated flow volumes decreased and the percentage difference between simulated and observed flow volumes decreased from 32.4% to 18.02% for the period 1971 to 1978. Hence, it was concluded that INFILT values would be in the range of 0.1 to 0.5 for the total percentage

difference to be within 15% and with the increase in INFILT values, the simulated flow volumes decrease.

Table 4.5: Comparison between Annual Simulated flow volumes and Observed flow volumes at Holden when INFILT is 0.1.

Year	Simulated (acre-feet)	Observed (acre-feet)	% Difference
1971	3.55E+05	241016	32.11
1972	3.63E+05	265377	26.95
1973	5.36E+05	435082	18.84
1974	4.31E+05	361473	16.05
1975	4.21E+05	356575	15.30
1976	1.48E+05	130424	11.76
1977	4.69E+05	449300	4.12
1978	2.84E+05	225239	20.63
Sum	**301E+06**	**2464486**	**18.02**

4.2.6 Seasonal Calibration

The model was calibrated using these parameters for the time period **1971 to 1978**. The final calibration parameters were set to a UZSN value of 2.0, LZSN of 6.0, INFILT of 0.16, DEEPFR of 0.3, and a BASETP value of 0.1, which are all within the suggested range based on literature review. The model is calibrated for annual flow at an average difference of 4.34% (Table 4.5) and seasonal flows with differences ranging from 0.23% to 3% (Table 4.6) between simulated and observed flows.

Table 4.6: Comparison between Seasonal Simulated flow volumes and Observed flow volumes at Holden during calibration

Season	Simulated (acre-feet)	Observed (acre-feet)	% Difference
May – Oct	842957	844912	**-0.23**
Nov – Apr	1670738	1619573	**3.06**

4.3 Water Quality Calibration

Water quality data for the Tickfaw River watershed were obtained from the Springville water quality observation station. Quality Assurance/Quality Control (QA/QC) was carried out to detect if any erroneous data were recorded at the station.

Temperature recorded at this station was in Celsius. This data was converted into Fahrenheit and then into WDM recognizable formats. A new script file was then created to read and write the data into a Water Quality WDM file for the Tickfaw River watershed. As mentioned earlier, water quality data was available for a period of 9 years from 1978 to 1986. Hence, it was decided that the data for the period from 1978 to 1986 which overlaps validation period would be used for water quality calibration and data for the period 1983 to 1986 will be used for water quality validation.

4.3.1 Temperature

For the successful calibration of water quality, prior calibration of temperature is required. Average land use elevation was calculated in ArcGIS to obtain the difference in elevations between each land use in the watershed and the corresponding weather station to

prepare the Air Temperature Data (ATEMP-DAT) table in the Tickfaw River watershed, which plays a major role in calibration of temperature.

In general, the amount of surface flow is small relative to that within the stream channel. This means that the temperature of the overland flow will generally and quickly come into a dynamic equilibrium with the in stream flow (without drastically changing the in stream temperatures) due to the heat capacity within the stream being much larger than that in the surface flow.

Elevation data of each reach and the mean difference between the reach and the temperature gage station were obtained from BASINS and edited in the Reach Data editor. The Reaches (RCHRES) parameter; correction factor for solar radiation (CFSAEX) is a key parameter as it attempts to capture the large variability in the amount of solar radiation actually reaching the stream. The default value of this parameter was resulting in an under simulation of temperature of water. It was found that a high correction factor resulted in over simulation; therefore, CFSAEX was adjusted accordingly to calibrate for temperature of water in the Tickfaw River watershed (Figure 4.6). The final CFSAEX value at calibration is 1.2.

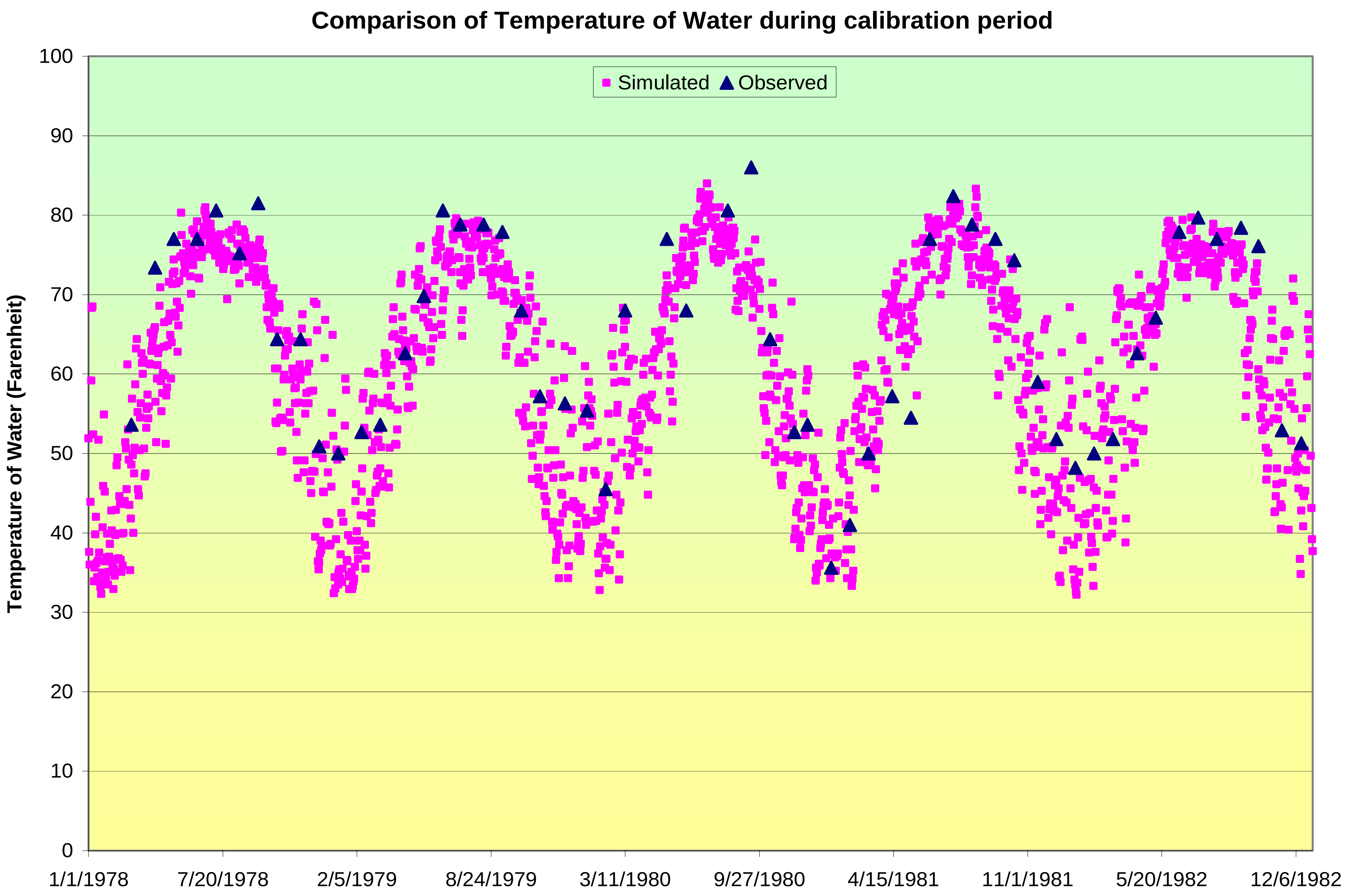

Figure 4.6: Temperature Calibration in the Tickfaw River watershed

4.3.2 Dissolved Oxygen

Initial simulation of Dissolved Oxygen (DO) in the Tickfaw River watershed resulted in over simulation based on the default values. Average temperatures during the October – March season for the 1978 to 1986 time period was calculated and saturation DO was obtained using this average temperature. Saturation DO was found to be 10.29 for October – March season and DO was calibrated accordingly.

After extensive examination regarding the channel reaeration contribution to the DO modeling, it was found that the use of a user specified power function of velocity and depth to calculate reaeration coefficient was the most appropriate choice. Parameters like escape coefficient in reaeration equation (REAK), temperature correction coefficient for reaeration (TCGINV), and exponent to velocity in user-specified reaeration equation (EXPREV), exponent to depth in user-specified reaeration equation (EXPRED) were identified as the key calibration parameters for DO in the stream. REAK, EXPREV, and EXPRED were adjusted accordingly to bring down DO. The final REAK, EXPREV, and EXPRED values were 0.2, -1.673 and 0.969 respectively.

For the Tickfaw River watershed, these calibration parameters were adjusted accordingly to match the observed DO. The simulated DO in the Tickfaw River watershed for the calibration period 1978 to 1982 is shown in Figures 4.7.

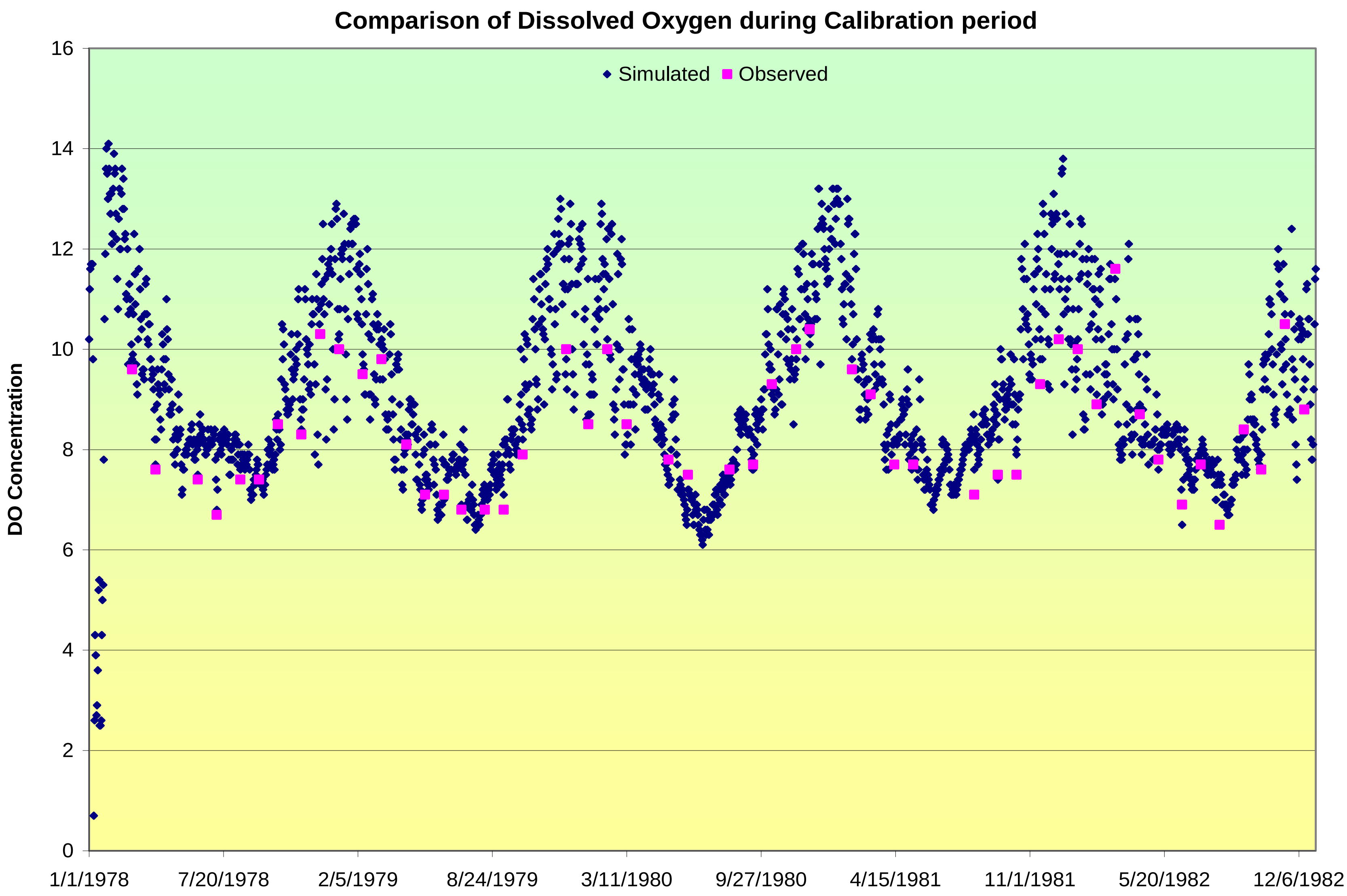

Figure 4.7: Dissolved Oxygen Calibration in the Tickfaw River watershed

4.3.3 Nitrogen

After calibrating the model for temperature and DO, NO_3 was added to the Tickfaw River model from the pollution selection tool. An extensive literature review was carried out to find out the key calibration parameters for modeling nitrogen. It was observed that monthly values of accumulation rate of overland flow (MON-ACCUM), monthly values of limiting storage of overland flow (MON-SQOLIM), monthly values of concentration of interflow (MON-IFLW), and monthly values of concentration of ground water (MON-GRND) were the key calibration parameters.

Initially the Tickfaw River model was run with the default parameters. It was observed that the model was over predicting NO_3 throughout. It was decided to decrease the monthly accumulation rates (MON-ACCUM). Default values of MON-INFLW and MON-GRND values were imported to excel and the difference between MON-INFLW and MON-GRND values were calculated for all the months. In addition, monthly average values were calculated from the observed records of NO_3. These values were used for MON-GRND concentrations and MON-INFLW values were calculated using the difference calculated previously from the default values. Finally, MON-ACCUM, MON-INFLW and MON-GRND concentrations were adjusted accordingly to calibrate nitrogen. Simulation of NO_3 in the Tickfaw River watershed during the calibration period is shown in Figure 4.8.

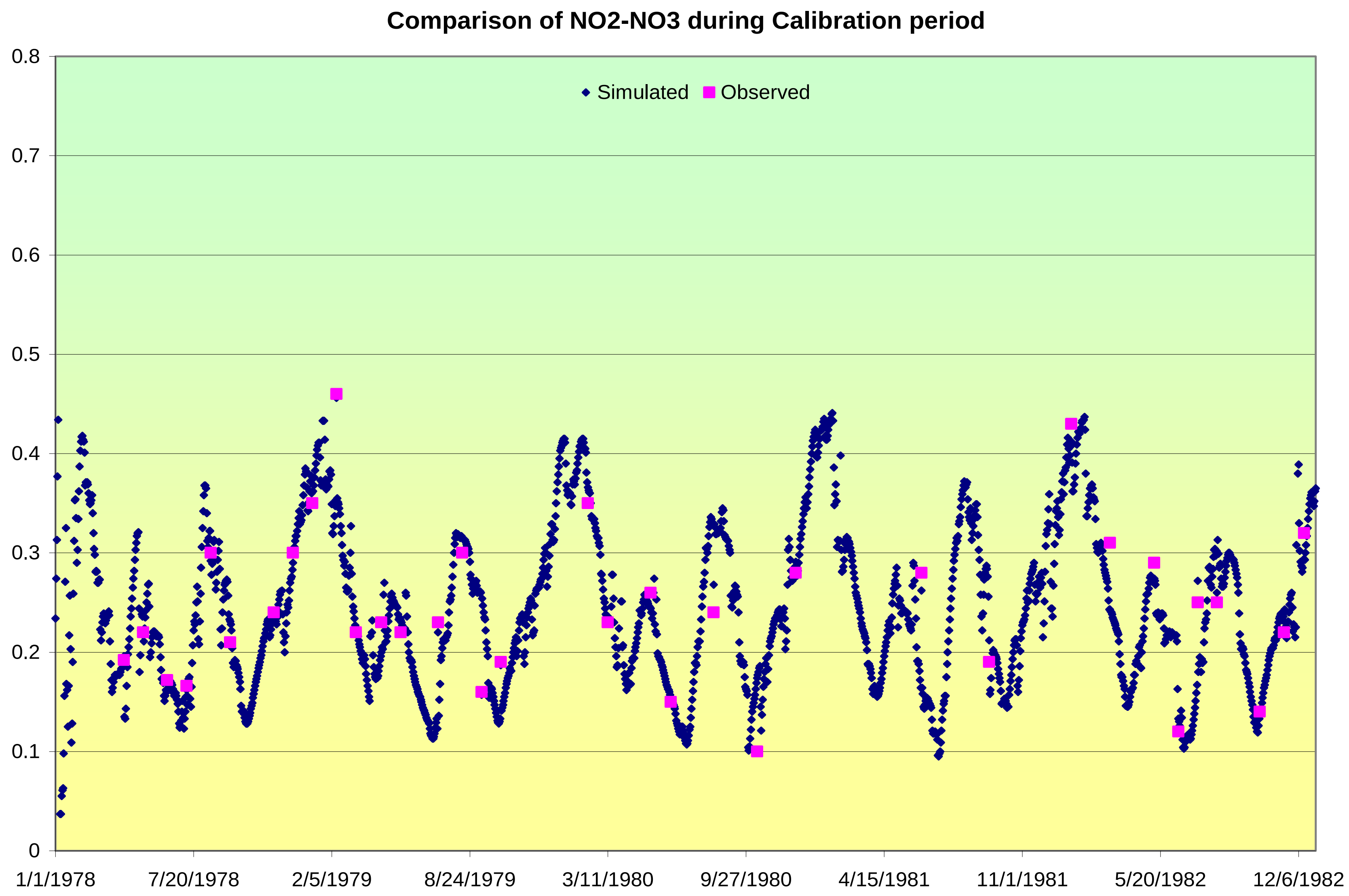

Figure 4.8: NO_2-NO_3 Calibration in the Tickfaw River watershed

4.3.4 Ortho Phosphorus

OrthoP was then added to the Tickfaw River models to predict the simulation of phosphorus. From the literature review, it was observed that for phosphorus calibration, that monthly values of accumulation rate of overland flow (MON-ACCUM), monthly values of limiting storage of overland flow (MON-SQOLIM), monthly values of concentration of interflow (MON-IFLW), and monthly values of concentration of ground water (MON-GRND) were the key calibration parameters. The model was initially run with the default parameters. It was observed that the model was over predicting phosphorus throughout the calibration period.

Default values of MON-INFLW and MON-GRND values of OrthoP in the Tickfaw River model were imported to excel and the difference between MON-INFLW and MON-GRND values were calculated for all the months. Monthly average values were calculated from the observed records of phosphorus. These values were used for MON-GRND concentrations of OrthoP and MON-INFLW values of OrthoP were calculated using the difference calculated previously from the default values. Finally, MON-ACCUM, MON-INFLW and MON-GRND concentrations of OrthoP were adjusted accordingly to calibrate phosphorus (Figure 4.9).

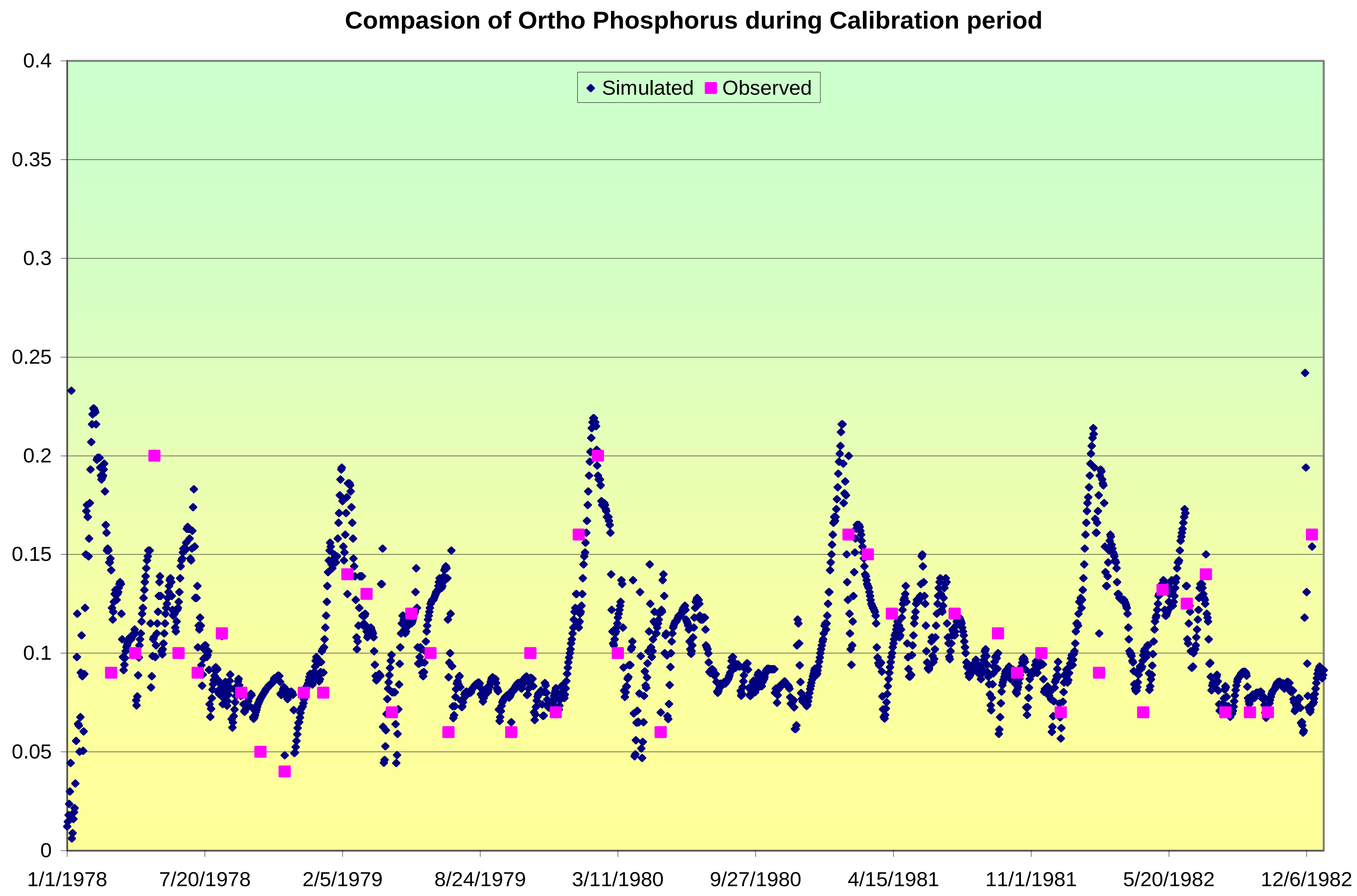

Figure 4.9: Ortho Phosphorus Calibration in the Tickfaw River watershed

5. Results and Discussion

The results and analysis of the model developed are presented in this chapter. This report has so far described the Modeling and Monitoring of nonpoint source pollutants in the Tickfaw River in Southeast Louisiana. In the process, a calibrated HSPF water quantity and quality model of the Tickfaw River watershed have been developed.

5.1 Hydrology Calibration and Validation

As explained in the previous chapter, the model has been calibrated to 4.5% difference between simulated and observed flow for annual and 0.23% difference during May – October and 3.06% difference during November – April seasonal flows. Statistical Analysis using regression was performed using the annual simulated and observed flow volumes. The results indicate a very good correlation with R^2 value of 0.92 (Table 5.1). . The key parameters, which were adjusted during the calibration process, are shown in Table 5.2.

Model verification was performed for the January 1 1979 through December 31 1985 period and the simulated flow was found to be within 1.40% (Table 5.3) of annual flows and 11.06% during May – October and 9.25% difference during November – April seasonal flows (Table 5.4). Figure 5.1 shows the simulated and observed flows during validation. Figure 5.2 shows the flow duration graph during validation time period.

Statistical analysis of the annual flow values observed at Holden, LA and simulated values from HSPF model illustrates that the model does a good job of predicting flows that fall within the 1%-60% frequency according to the flow duration curve in Figure 5.2. This curve shows that there is a 3% probability of the flow going below the 10% and the difference between

the percentage chances of the flow exceeding 50% is around 5%, which are within the allowed 15% range.

Table 5.1: Regression Analysis of annual simulated and observed flows

	R Square	Intercept	X Variable
Calibration Period	0.926	-16905.29	1.908
Validation Period	0.934	-3325.65	0.996

Table 5.2: Key Parameters for hydrology calibration and its values

Parameter	Value
Lower Zone Storage Nominal (LZSN)	6
Infiltration (INFILT)	0.4
DEEPFR	0.3
Base Evapotranspiration (BASETP)	0.12
Upper Zone Storage Nominal (UZSN)	2
Interflow (INTFW)	0.75
IRC	0.5
Lower Zone Evapotranspiration (LZETP)	0.1

Table 5.3: Comparison between Annual Simulated flow volumes and Observed flow volumes at Holden during validation

Year	Simulated	Observed	% Difference
1979	368256	414863	-12.66
1980	399452	429803	-7.60
1981	128947	139314	-8.04
1982	225874	256186	-13.42
1983	526983	479176	9.07
1984	214638	200120	6.76
1985	268723	243608	9.35
Sum	2132873	2163070	**-1.40**

Table 5.4: Comparison between Seasonal Simulated flow volumes and Observed flow volumes at Holden during validation

Season	Simulated	Observed	% Difference
May – Oct	675866	601086	**11.06**
Nov – Apr	1429787	1561983	**-9.25**

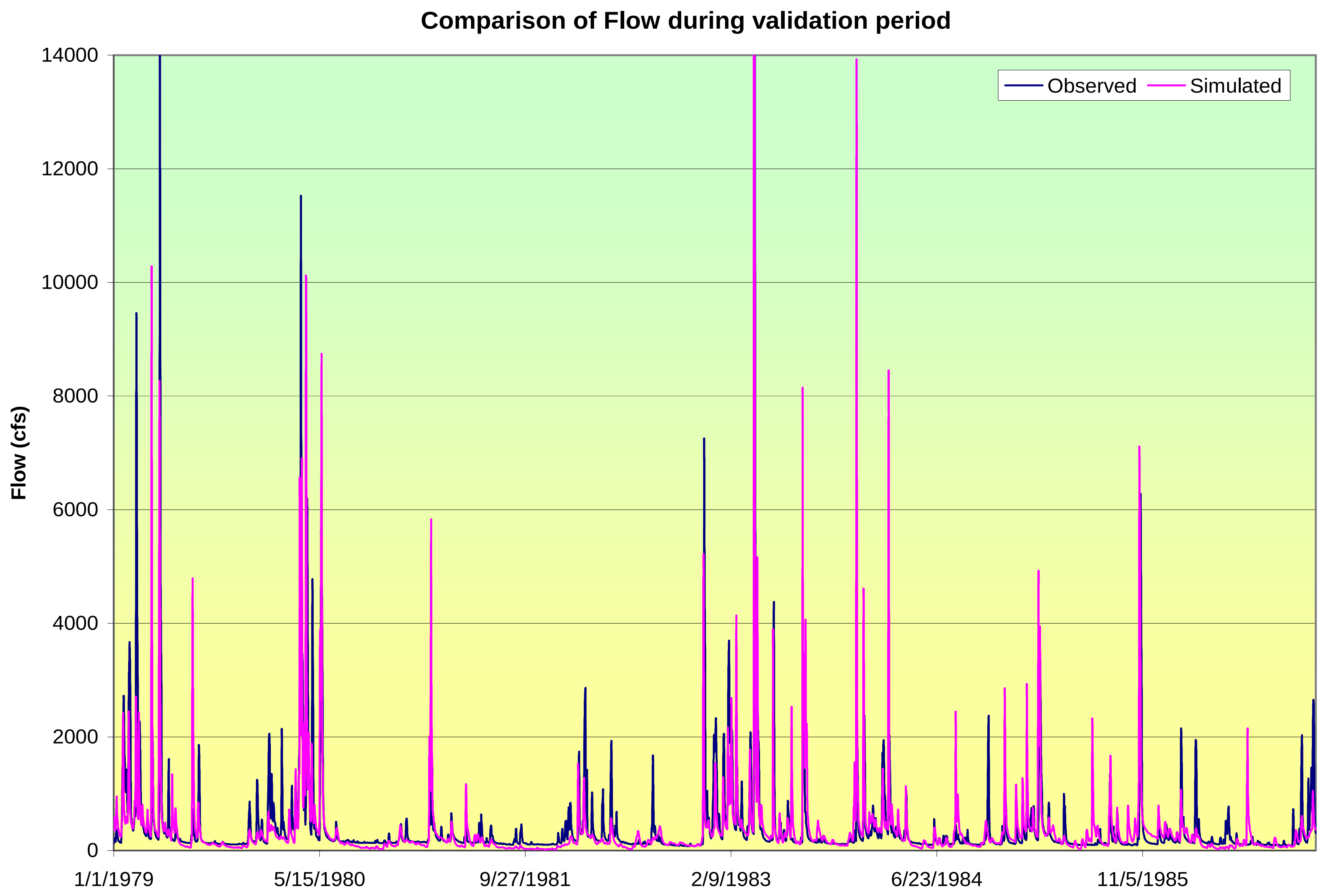

Figure 5.1: Annual Flow Diagram of Simulated and Observed Flows for Tickfaw River Watershed for validation

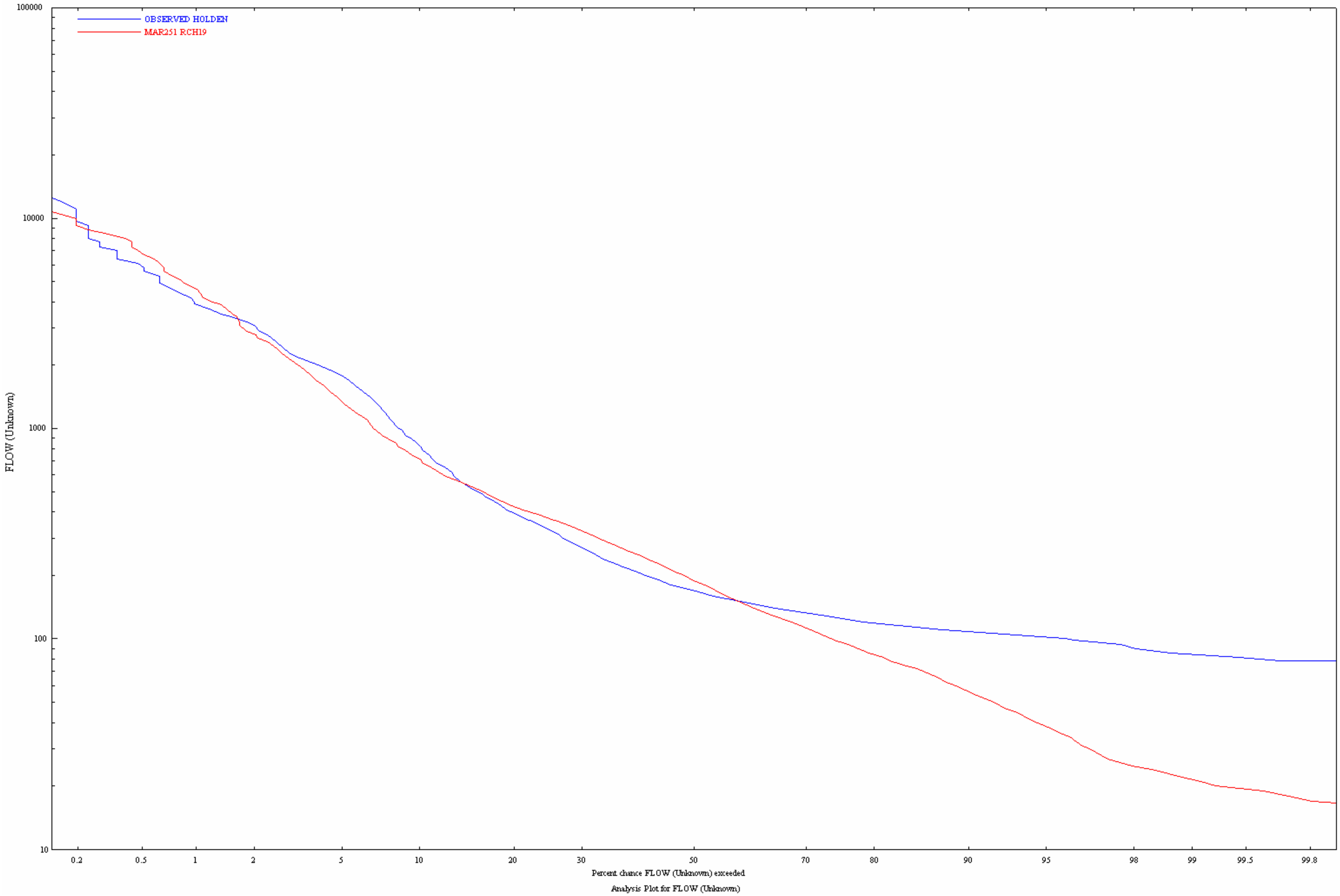

Figure 5.2: Flow duration graph for Tickfaw watershed during validation

5.2 Water Quality Validation

Temperature of water, dissolved oxygen, nitrogen, and phosphorus were calibrated as explained in the previous chapter for the period 1978 to 1982. Model verification for these parameters was performed for the period 1983 to 1986. Simulated temperature of water, dissolved oxygen, nitrogen, and phosphorus for the validation period are shown in figure 5.3, 5.4, 5.5 and 5.6 respectively.

Observed temperature of water and Concentrations of DO, NO_2-NO_3 and Ortho Phosphorus were obtained in irregular intervals. Simulated concentrations for the dates on which observed values are available were extracted from the model. Comparisons between simulated and observed values are shown in Figures 5.7, 5.8, 5.9 and 5.10 for temperature of water, DO, NO_2-NO_3 and Ortho Phosphorus respectively.

A Statistical Analysis using regression was performed for all the water quality parameters. The results indicate a very good correlation with R2 value of 0.829 (Table 5.5) during calibration period and R2 value of 0.811 (Table 5.5) during validation period for temperature of water; R2 value of 0.909 (Table 5.6) during calibration period and R2 value of 0.953 (Table 5.6) during validation period for DO; R2 value of 0.943 (Table 5.7) during calibration period and R2 value of 0.918 (Table 5.7) during validation period for NO2-NO3, R2 value of 0.840 (Table 5.8) during calibration period and R2 value of 0.859 (Table 5.8) during validation period for Ortho Phosphorus.

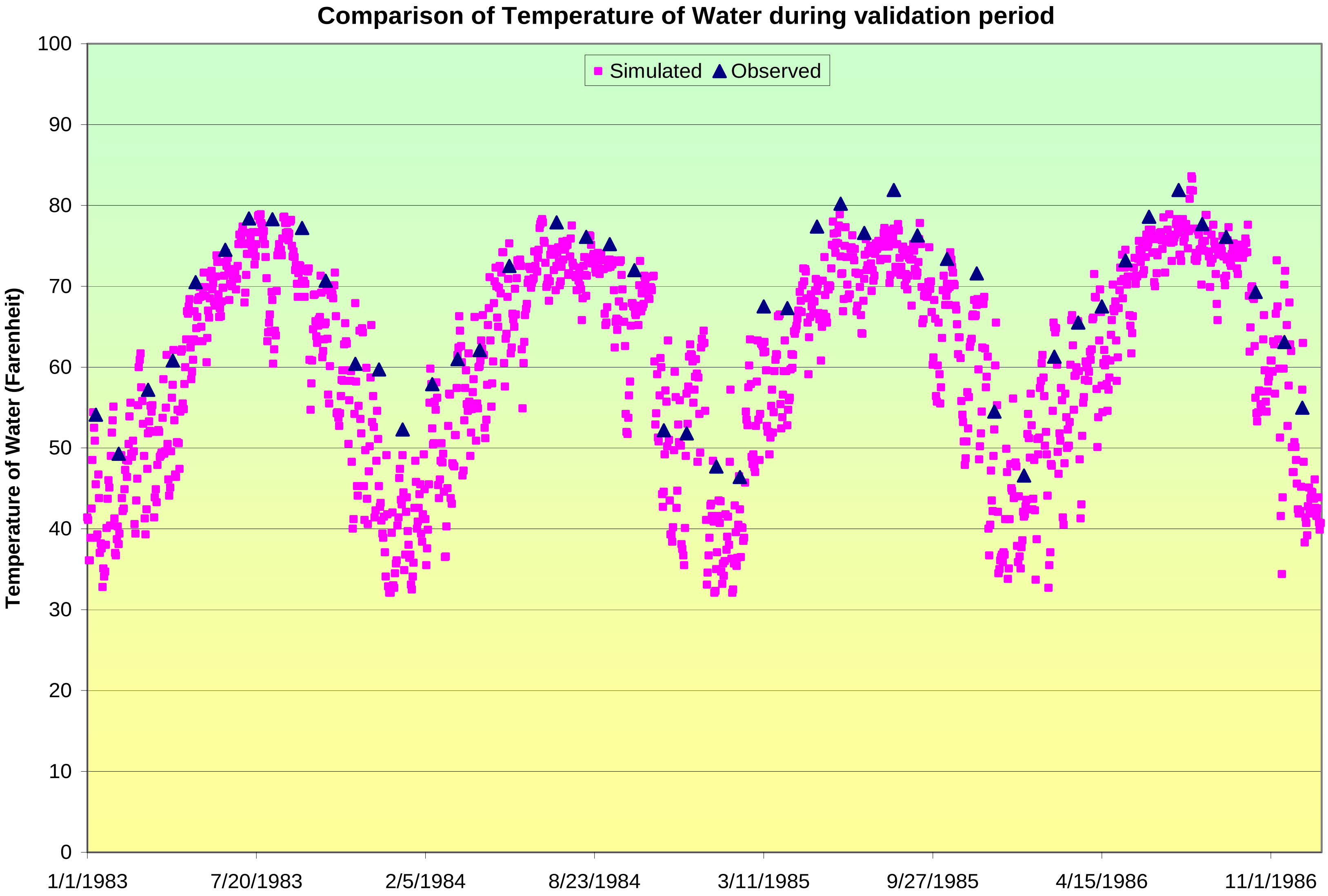

Figure 5.3: Temperature Validation in the Tickfaw River watershed

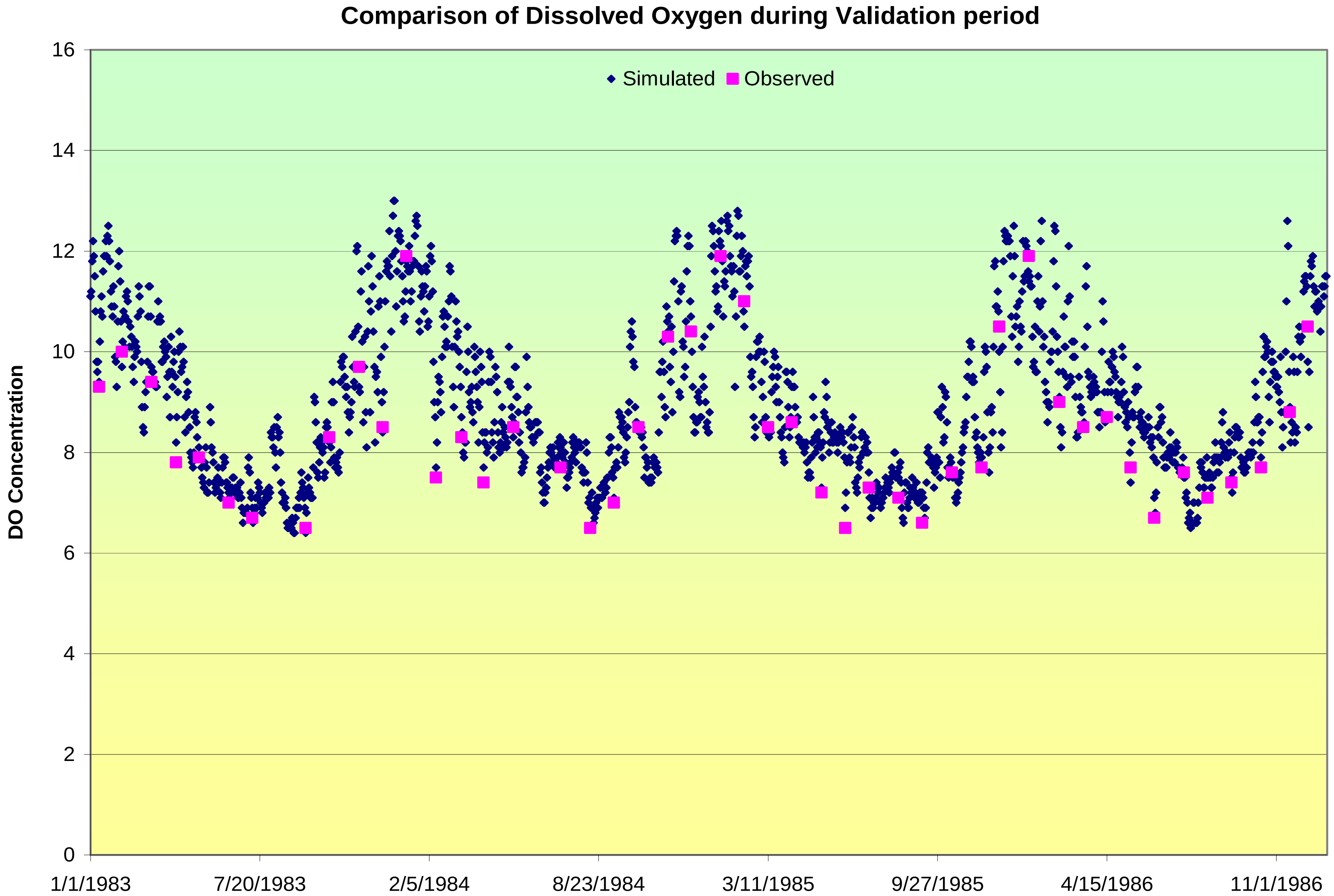

Figure 5.4: Dissolved Oxygen simulation in the Tickfaw River watershed for Validation period

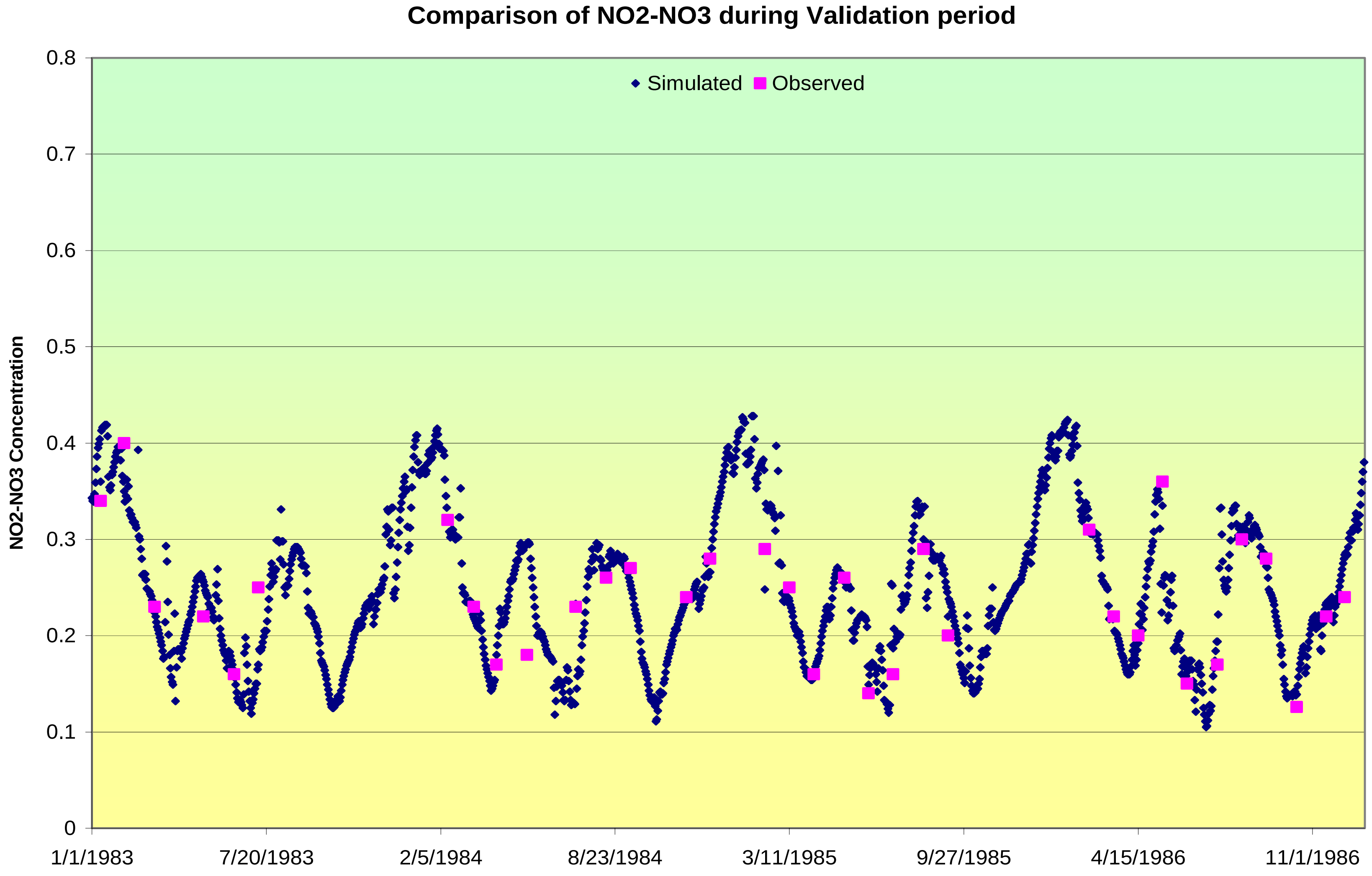

Figure 5.5: NO2-NO3 simulation in the Tickfaw River watershed for Validation period

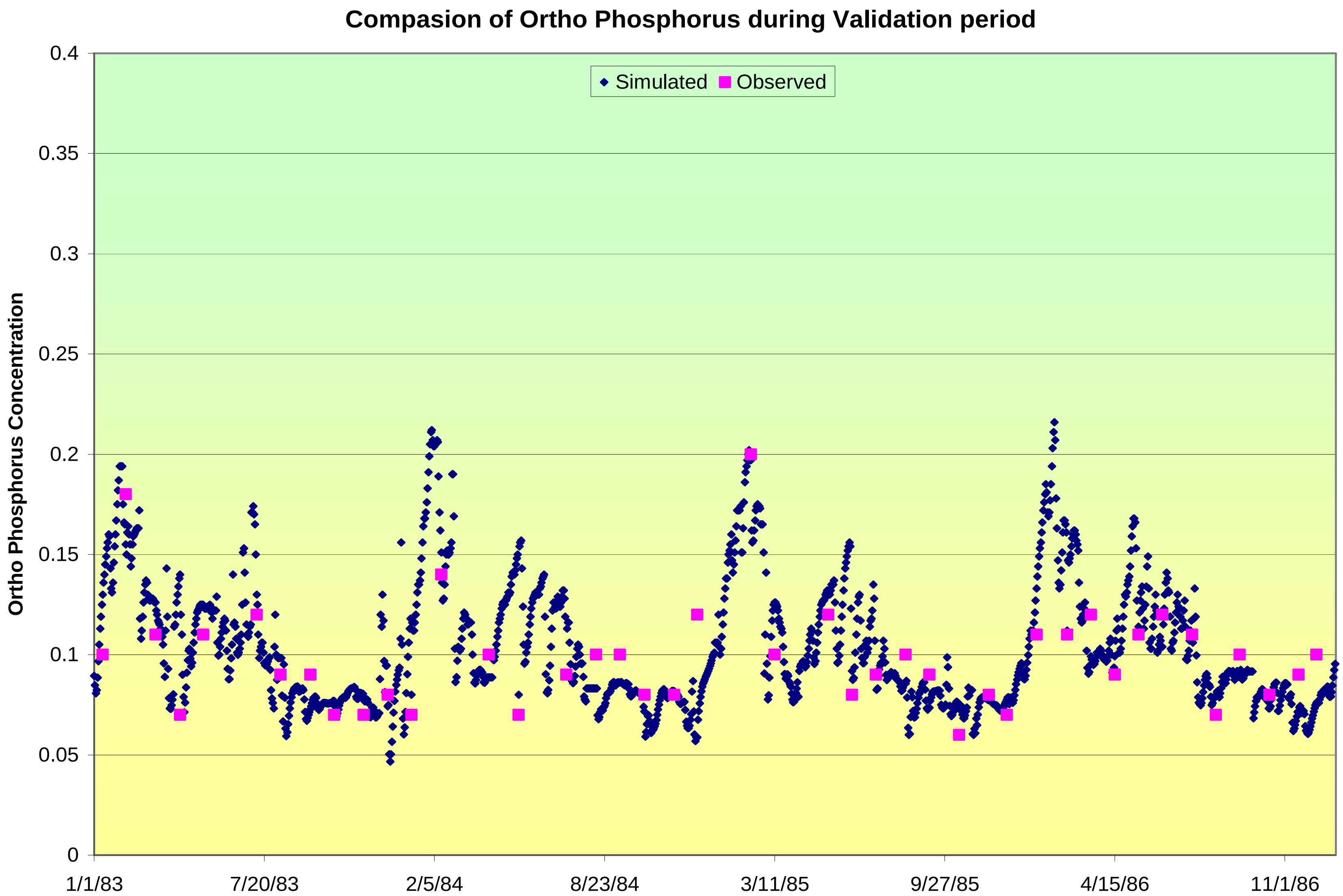

Figure 5.6: OrthoP simulation in the Tickfaw River watershed for Validation

Table 5.5: Regression Analysis of simulated and observed Temperature of Water

	R Square	Intercept	X Variable
Calibration Period	0.821	-3.093	0.982
Validation Period	0.811	-3.273	0.984

Table 5.6: Regression Analysis of simulated and observed Dissolved Oxygen

	R Square	Intercept	X Variable
Calibration Period	0.909	0.387	0.965
Validation Period	0.953	1.251	0.857

Table 5.7: Regression Analysis of simulated and observed NO_2-NO_3

	R Square	Intercept	X Variable
Calibration Period	0.943	0.014	0.939
Validation Period	0.918	0.026	0.909

Table 5.8: Regression Analysis of simulated and observed Ortho Phosphorus

	R Square	Intercept	X Variable
Calibration Period	0.840	0.022	0.808
Validation Period	0.859	0.005	0.972

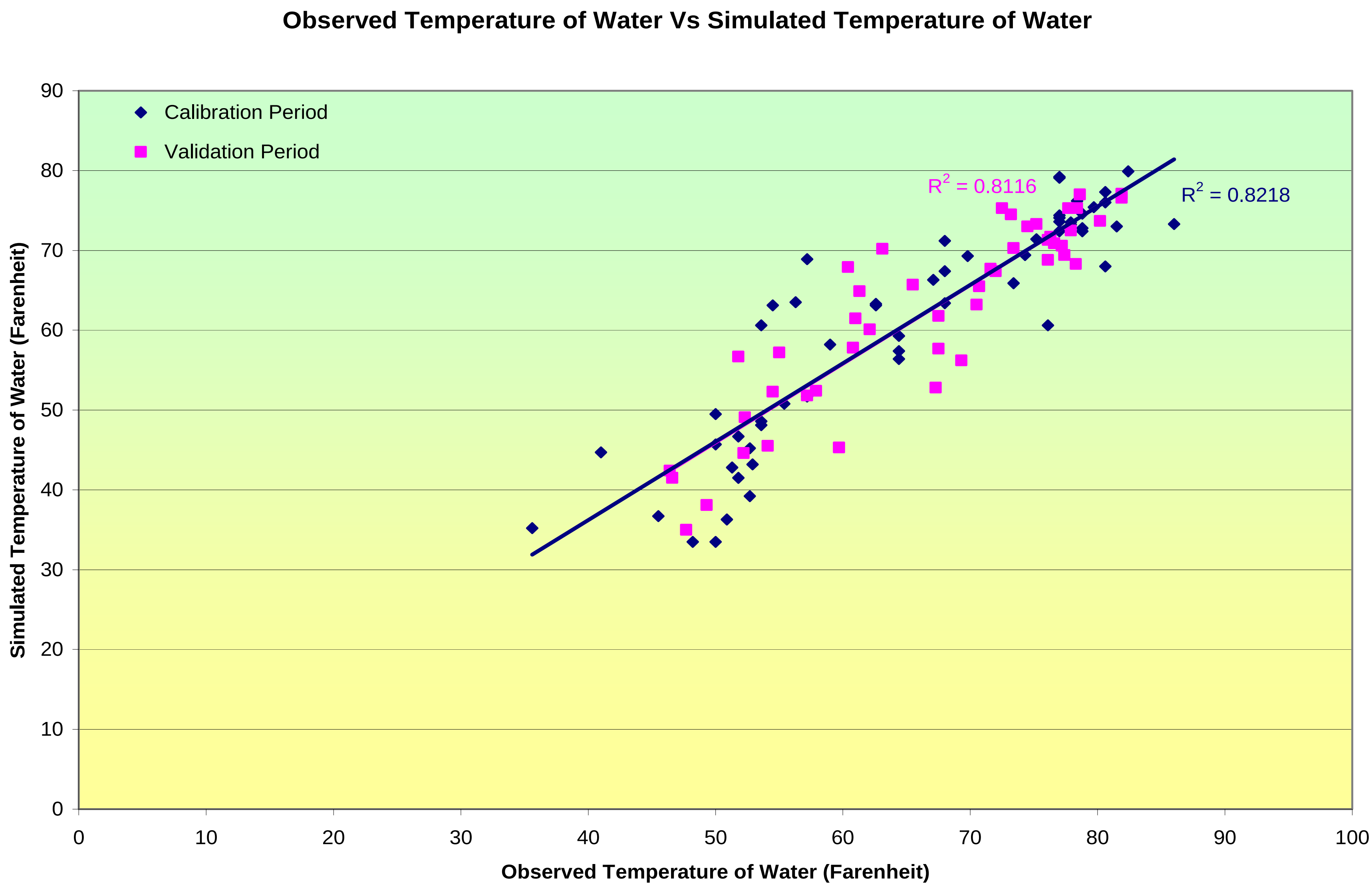

Figure 5.7: Comparison of Observed and Simulated Temperature of Water

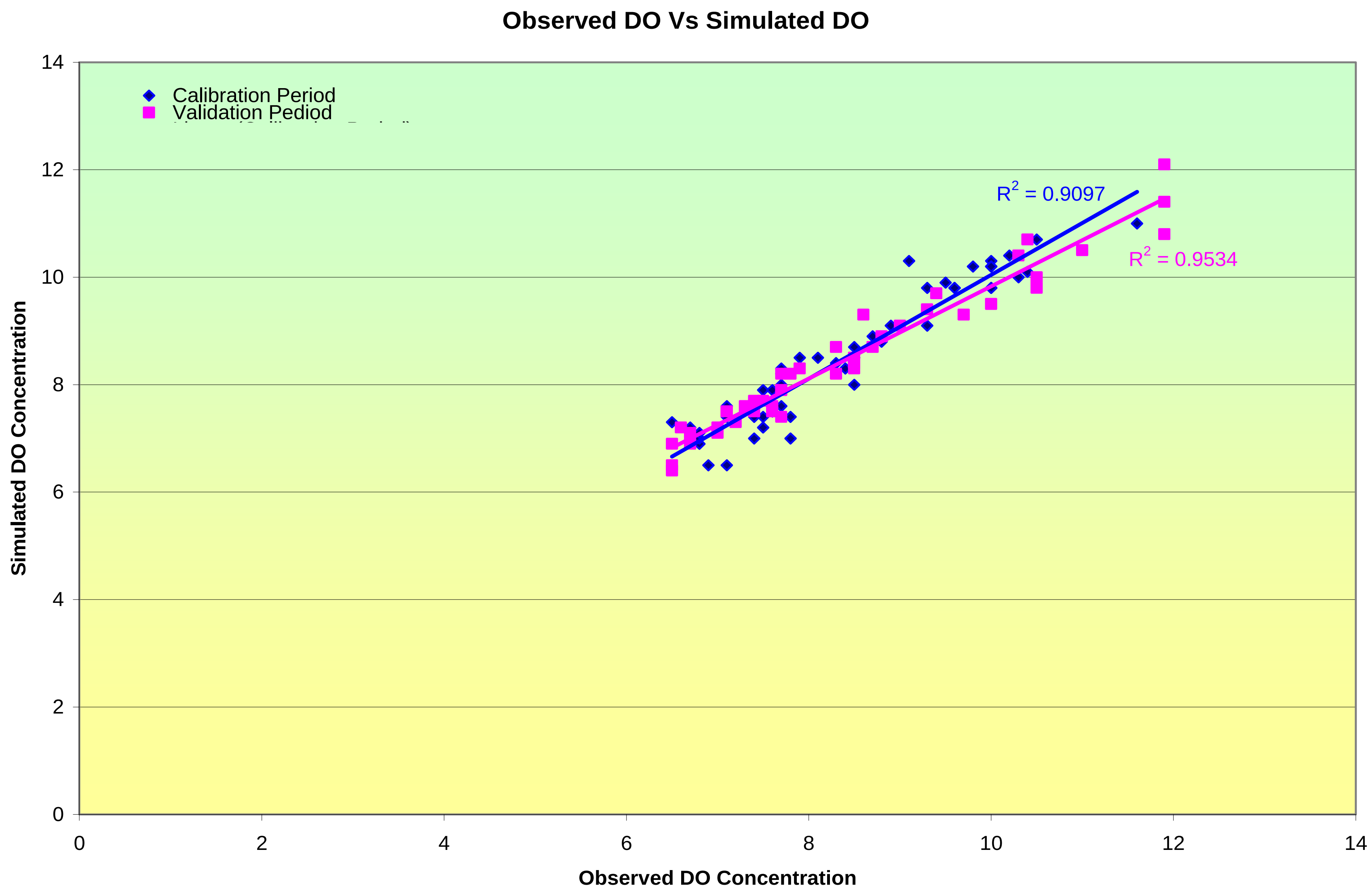

Figure 5.8: Comparison of Observed and Simulated Dissolved Oxygen

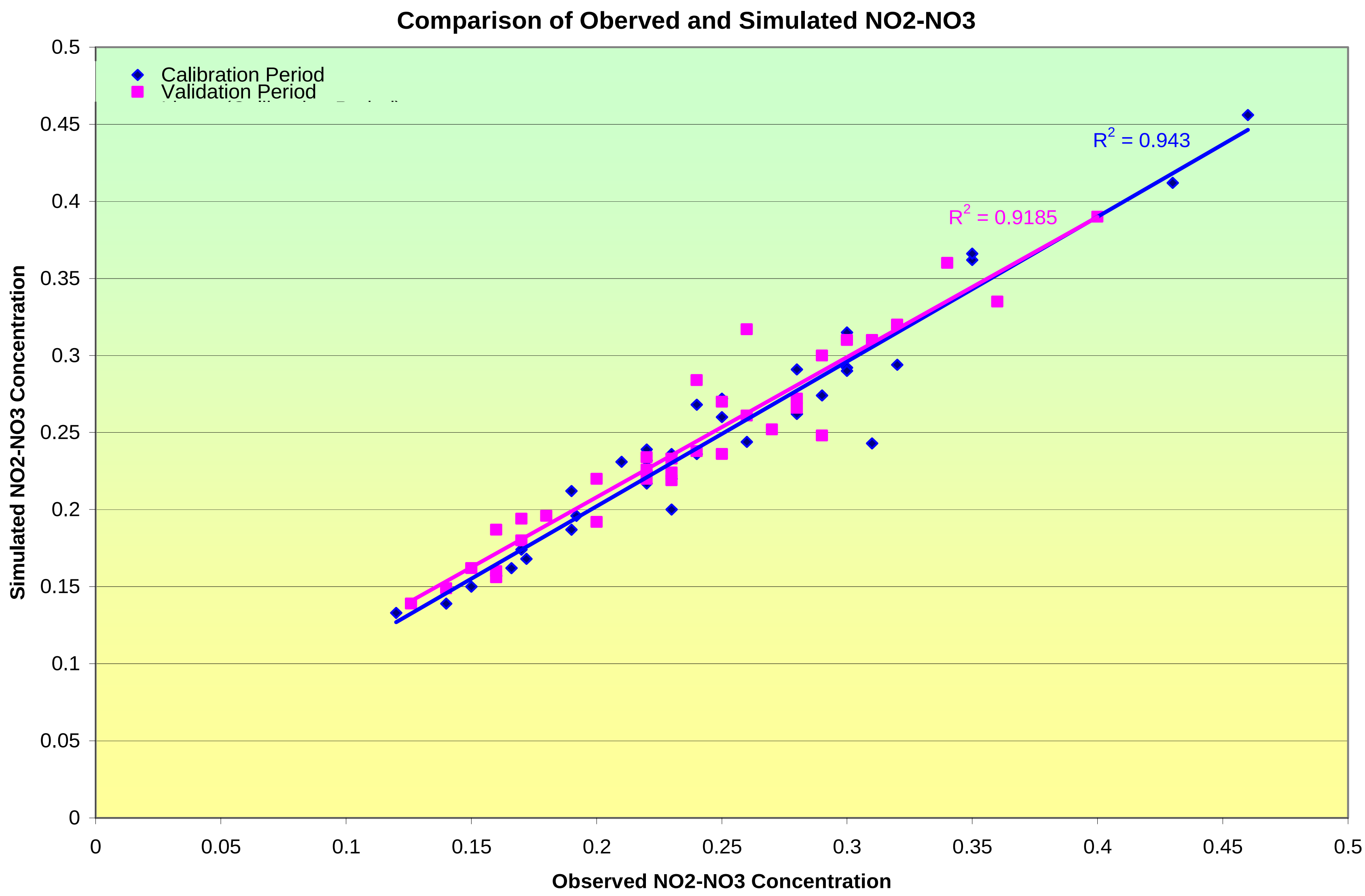

Figure 5.9: Comparison of Observed and Simulated NO2-NO3

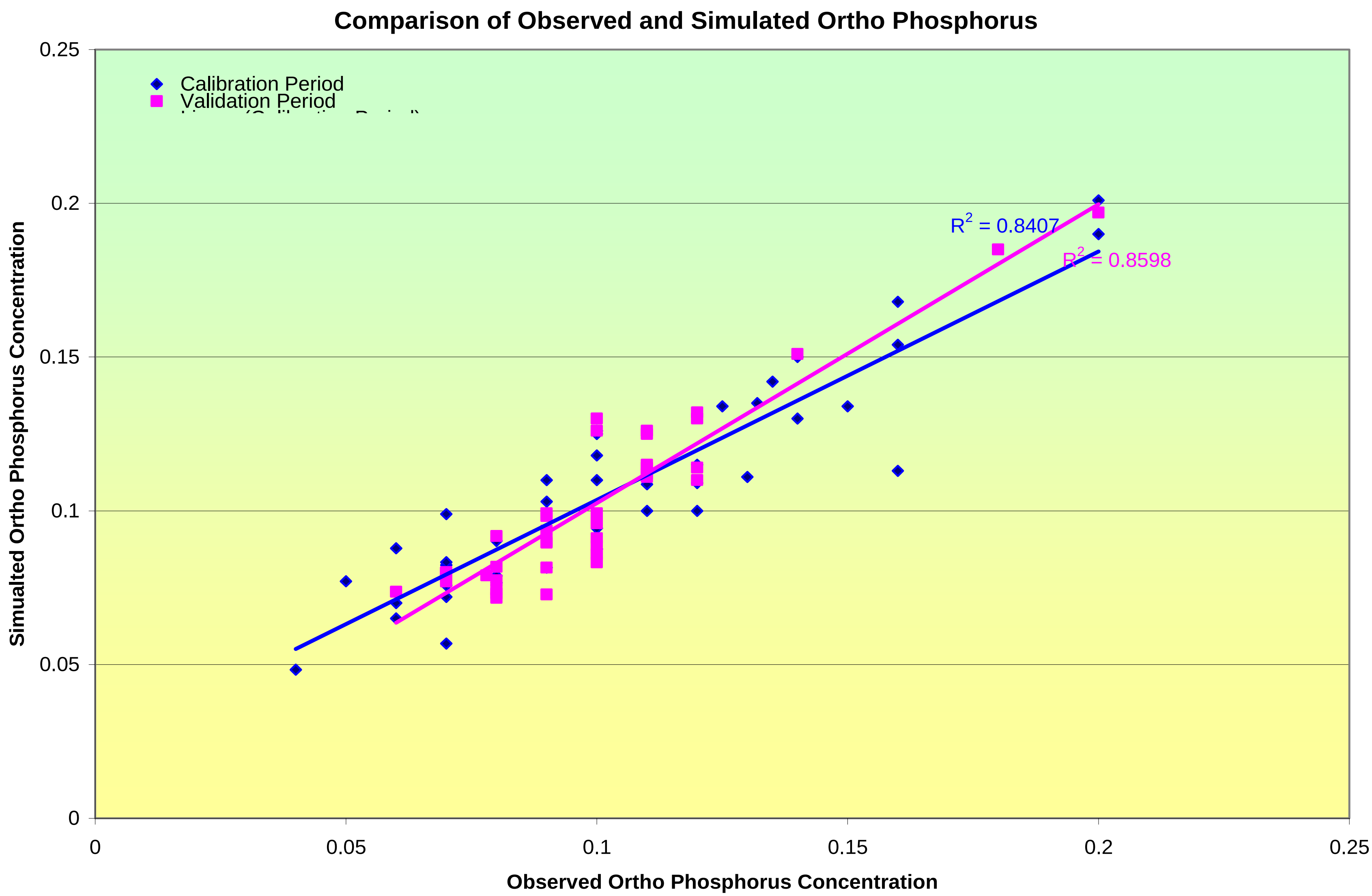

Figure 5.10: Comparison of Observed and Simulated Ortho Phosphorus

5.3 Loading Operations

The Report operation in WinHSPF is used to produce a series of standard output reports, which generate the loading for each land use for each constituent. The REPORT function is not supported in the current version of WinHSPF, which is being used. An application of request was sent to EPA to grant Aqua Terra Consultants, the consulting company that developed WinHSPF, permission to provide support through a special grant of user support in WinHSPF. with a positive reply from EPA, Aqua Terra Consulting specified the changes to be made to the General Information (GEN-INFO) in Input Data Editor to simulate the rates of nitrogen and phosphorus loading from the existing land use patterns.

The PUNIT1 in general info of pervious land was changed to 91 in the data editor, which enabled the model to print the loading of nitrogen and phosphorus coming from each land use in the output file. These loading were extracted from huge data files and pasted in Excel as opposed to Report files, which were being generated previously using REPORT function.

Table 5.9 shows the loading of nitrogen and Table 5.10 shows the loading of phosphorus in pounds (lbs) coming from each individual land use during the period 1978 to 1986.

Table 5.9: Loading of Nitrogen from each land use for the period of 1978 to 1985

Land Use Code	Land Use	1978	1979	1980	1981	1982	1983	1984	1985
		lbs							
PERLND 101	MIXED FOREST LAND	69.34236	1.373964	5.54E-05	2.53E-05	1.81E-05	5.03E-15	1.03E-16	1.14E-17
PERLND 201	MIXED FOREST LAND	319.3538	6.327742	0.000255	0.000117	8.35E-05	2.32E-14	4.73E-16	5.25E-17
PERLND 102	EVERGREEN FOREST LAN	152.3732	3.019155	0.000122	5.56E-05	3.98E-05	1.11E-14	2.26E-16	2.5E-17
PERLND 202	EVERGREEN FOREST LAN	484.9229	9.608363	0.000387	0.000177	0.000127	3.52E-14	7.18E-16	7.97E-17
PERLND 103	TRANSITIONAL AREAS	3.201874	0.063443	2.56E-06	1.17E-06	8.37E-07	2.32E-16	4.74E-18	5.26E-19
PERLND 203	TRANSITIONAL AREAS	3.040833	0.060252	2.43E-06	1.11E-06	7.95E-07	2.21E-16	4.5E-18	4.99E-19
PERLND 104	CROPLAND AND PASTURE	54.53606	1.080589	4.35E-05	1.99E-05	1.43E-05	3.96E-15	8.07E-17	8.96E-18
PERLND 204	CROPLAND AND PASTURE	384.1491	7.61161	0.000307	0.00014	0.0001	2.79E-14	5.69E-16	6.31E-17
PERLND 105	RESIDENTIAL	8.686741	0.172121	6.94E-06	3.17E-06	2.27E-06	6.3E-16	1.29E-17	1.43E-18
PERLND 205	RESIDENTIAL	9.473	0.1877	7.56E-06	3.46E-06	2.48E-06	6.88E-16	1.4E-17	1.56E-18
PERLND 106	OTHER AGRICULTURAL L	0.265244	0.005256	2.12E-07	9.68E-08	6.93E-08	1.93E-17	3.93E-19	4.36E-20
PERLND 206	OTHER AGRICULTURAL L	0.388393	0.007696	3.1E-07	1.42E-07	1.02E-07	2.82E-17	5.75E-19	6.38E-20
PERLND 107	RESERVOIRS	0.492596	0.00976	3.93E-07	1.8E-07	1.29E-07	3.58E-17	7.29E-19	8.09E-20
PERLND 207	RESERVOIRS	0.236825	0.004693	1.89E-07	8.64E-08	6.19E-08	1.72E-17	3.51E-19	3.89E-20
PERLND 208	MXD URBAN OR BUILT-U	0.331555	0.00657	2.65E-07	1.21E-07	8.67E-08	2.41E-17	4.91E-19	5.45E-20
PERLND 109	TRANS, COMM, UTIL	3.296604	0.06532	2.63E-06	1.2E-06	8.62E-07	2.39E-16	4.88E-18	5.41E-19
PERLND 209	TRANS, COMM, UTIL	0.132622	0.002628	1.06E-07	4.84E-08	3.47E-08	9.63E-18	1.96E-19	2.18E-20
PERLND 110	FORESTED WETLAND	8.923566	0.176813	7.13E-06	3.26E-06	2.33E-06	6.48E-16	1.32E-17	1.47E-18
PERLND 210	FORESTED WETLAND	0.56838	0.011262	4.54E-07	2.07E-07	1.49E-07	4.13E-17	8.41E-19	9.34E-20
PERLND 111	INDUSTRIAL	0.539961	0.010699	4.31E-07	1.97E-07	1.41E-07	3.92E-17	7.99E-19	8.87E-20
PERLND 112	NONFORESTED WETLAND	0.880989	0.017456	7.03E-07	3.22E-07	2.3E-07	6.39E-17	1.3E-18	1.45E-19
PERLND 213	COMMERCIAL AND SERVI	1.828289	0.036226	1.46E-06	6.67E-07	4.78E-07	1.33E-16	2.71E-18	3E-19

Table 5.10: Loading of Phosphorus from each land use for the period of 1978 to 1985

Land Use Code	Land Use	1978	1979	1980	1981	1982	1983	1984	1985
		lbs							
PERLND 101	MIXED FOREST LAND	727.8276	730.6092	731.3412	730.2432	710.6256	493.1484	635.742	728.4132
PERLND 201	MIXED FOREST LAND	3351.984	3364.795	3368.166	3363.109	3272.761	2271.177	2927.887	3354.681
PERLND 102	EVERGREEN FOREST LAN	1599.332	1605.444	1607.052	1604.64	1561.532	1083.646	1396.982	1600.618
PERLND 202	EVERGREEN FOREST LAN	5089.822	5109.274	5114.393	5106.714	4969.525	3448.67	4445.852	5093.917
PERLND 103	TRANSITIONAL AREAS	33.60734	33.73578	33.76958	33.71888	32.81304	22.77106	29.3553	33.63438
PERLND 203	TRANSITIONAL AREAS	31.91703	32.03901	32.07111	32.02296	31.16268	21.62577	27.87885	31.94271
PERLND 104	CROPLAND AND PASTURE	572.4185	574.6062	575.1819	574.3183	558.8896	387.8491	499.9955	572.8791
PERLND 204	CROPLAND AND PASTURE	4032.085	4047.495	4051.55	4045.468	3936.788	2731.988	3521.941	4035.33
PERLND 105	RESIDENTIAL	91.17731	91.52577	91.61747	91.47992	89.02236	61.77829	79.64145	91.25067
PERLND 205	RESIDENTIAL	99.43	99.81	99.91	99.76	97.08	67.37	86.85	99.51
PERLND 106	OTHER AGRICULTURAL L	2.78404	2.79468	2.79748	2.79328	2.71824	1.88636	2.4318	2.78628
PERLND 206	OTHER AGRICULTURAL L	4.07663	4.09221	4.09631	4.09016	3.98028	2.76217	3.56085	4.07991
PERLND 107	RESERVOIRS	5.17036	5.19012	5.19532	5.18752	5.04816	3.50324	4.5162	5.17452
PERLND 207	RESERVOIRS	2.48575	2.49525	2.49775	2.494	2.427	1.68425	2.17125	2.48775
PERLND 208	MXD URBAN OR BUILT-U	3.48005	3.49335	3.49685	3.4916	3.3978	2.35795	3.03975	3.48285
PERLND 109	TRANS, COMM, UTIL	34.60164	34.73388	34.76868	34.71648	33.78384	23.44476	30.2238	34.62948
PERLND 209	TRANS, COMM, UTIL	1.39202	1.39734	1.39874	1.39664	1.35912	0.94318	1.2159	1.39314
PERLND 110	FORESTED WETLAND	93.66306	94.02102	94.11522	93.97392	91.44936	63.46254	81.8127	93.73842
PERLND 210	FORESTED WETLAND	5.9658	5.9886	5.9946	5.9856	5.8248	4.0422	5.211	5.9706
PERLND 111	INDUSTRIAL	5.66751	5.68917	5.69487	5.68632	5.53356	3.84009	4.95045	5.67207
PERLND 112	NONFORESTED WETLAND	9.24699	9.28233	9.29163	9.27768	9.02844	6.26541	8.07705	9.25443
PERLND 213	COMMERCIAL AND SERVI	19.18999	19.26333	19.28263	19.25368	18.73644	13.00241	16.76205	19.20543

5.4 Landuse Scenarios

According to USGS, in the last 200 years world population has increased six times and the urban population has increased 100 times (USGS Fact Sheet 188-89). This indicated that there is a high probability of forestland being converted to residential. If Tickfaw River watershed experiences similar landuse changes, unacceptable water quality levels may be reached which could result in making the river not acceptable for secondary contact recreation.

As mentioned previously, the Tickfaw River watershed consists of 68.8% forestland, 29.2% agricultural land and 1.2% residential land (Table 1.1). After discussion with LADEQ personnel, two major landuse scenarios were created. In order to incorporate these scenarios in WinHSPF, two spreadsheet models were developed to calculate area of various landuses for different landuse scenarios. The first spreadsheet model gives the area of different landuses contributing to each reach with a percentage incremental conversion of forests to residential. Care has been taken to make sure that the total area contributing to each reach has not changed. Using spreadsheet model 1, three hypothetical scenarios were created when the forestland is converted into residential with 25%, 50% and 75% change.

Similarly, Spreadsheet Model 2 gives the area of different landuses contributing to each reach with incremental conversion of forest to cropland and pasture. Again, care has been taken to make sure that the total area contributing to each reach has not changed. Using spreadsheet model 2, three hypothetical scenarios were created when the forestland is converted into cropland and pasture with 25%, 50% and 75% change.

Spreadsheet models were developed in such a way that if a user enters the percentage of forestland being converted to residential (Management Scheme 1) or cropland and pasture

(Management Scheme 2) for the watershed, the model calculates the area of individual landuse contributing to each reach without changing the total area contributing to each reach.

These land use areas were then multiplied by the loading rates of nitrogen and phosphorus, which are simulated by the WinHSPF model. Loading of nitrogen contributing to each reach for both management schemes are shown in Tables 5.11 and 5.12 with the subbasins in order from the upstream to downstream point calibration was performed and are also presented graphically in Figures 5.11 and 5.12. Loading of phosphorus contributing to each reach for all the landuse scenarios are shown in Tables 5.13 and 5.14 and are presented graphically in Figures 5.13 and 5.14.

Table 5.11: Average Loading of Nitrogen for 25%, 50% and 75% of forestland converted into residential

	25%	**50%**	**75%**
Reach	**Average Loading (lbs)**	**Average Loading (lbs)**	**Average Loading (lbs)**
2	2323.64	2323.64	2323.64
1	1136.16	1136.16	1136.16
4	1522.17	1522.17	1522.17
3	2235.56	2235.56	2235.56
5	4177.94	4436.69	4661.75
28	1689.80	1786.95	1867.88
22	4806.67	5212.60	5565.90
26	1412.95	1412.95	1412.95
27	1134.28	1134.28	1134.28
8	1771.32	1902.11	2012.25
19	5084.20	5507.48	5875.36

Table 5.12: Average Loading of Nitrogen for 25%, 50% and 75% of forestland converted into cropland and pasture

	25%	50%	75%
Reach	**Average Loading (lbs)**	**Average Loading (lbs)**	**Average Loading (lbs)**
2	2718.39	3113.14	3507.89
1	1418.99	1701.83	1984.67
4	1817.44	2112.70	2407.97
3	2543.74	2851.91	3160.08
5	4543.00	5301.53	6060.07
28	1840.11	2152.42	2464.74
22	5378.63	6567.08	7755.53
26	1640.71	1868.47	2096.22
27	1464.44	1794.60	2124.76
8	1969.27	2380.59	2791.92
19	5682.49	6925.65	8168.81

Table 5.13: Average Loading of Phosphorus for 25%, 50% and 75% of forestland converted into residential

	SCN-11	SC-12	SC-13
Reach	**Average Loading (lbs)**	**Average Loading (lbs)**	**Average Loading (lbs)**
2	1236.94	1236.94	1236.94
1	714.12	714.12	714.12
4	855.20	855.20	855.20
3	1104.25	1104.25	1104.25
5	2178.10	2187.38	2195.45
28	888.37	891.85	894.75
22	2846.80	2861.36	2874.03
26	745.56	745.56	745.56
27	771.21	771.21	771.21
8	1039.13	1043.82	1047.77
19	3106.67	3121.85	3135.04

Table 5.14: Average Loading of Phosphorus for 25%, 50% and 75% of forestland converted into cropland and pasture

	SCN-21	SC-22	SC-23
Reach	**Average Loading (lbs)**	**Average Loading (lbs)**	**Average Loading (lbs)**
2	1244.94	1252.95	1260.95
1	719.86	725.59	731.32
4	1110.50	867.17	873.16
3	1110.50	1116.75	1123.00
5	2179.36	2194.74	2210.12
28	888.89	895.22	901.55
22	2848.79	2872.88	2896.98
26	750.18	754.80	759.41
27	777.90	784.59	791.29
8	1039.82	1048.16	1056.50
19	3108.74	3133.95	3159.15

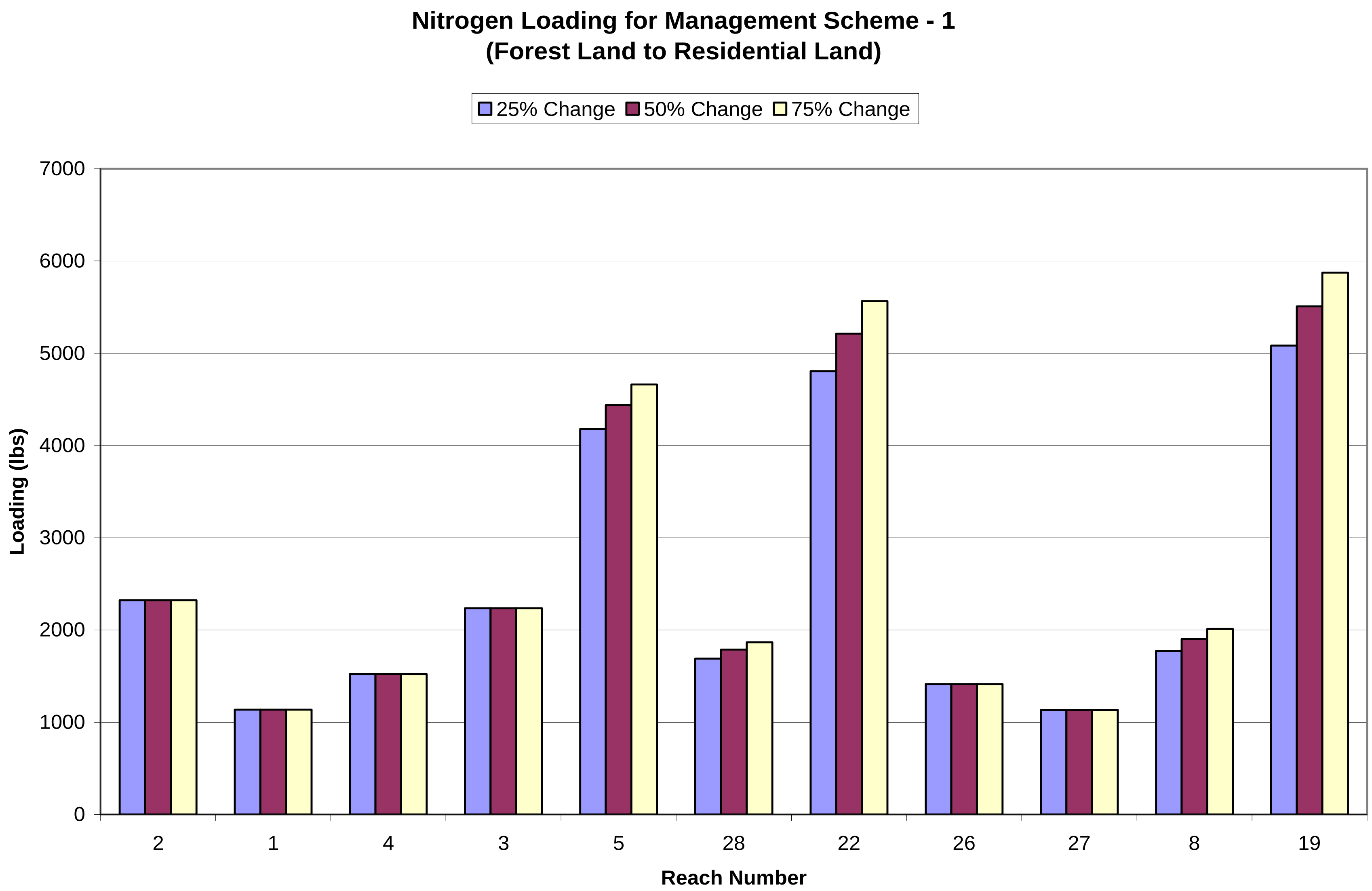

Figure 5.11: Nitrogen Loading for Management Scheme 1 of the Tickfaw River watershed

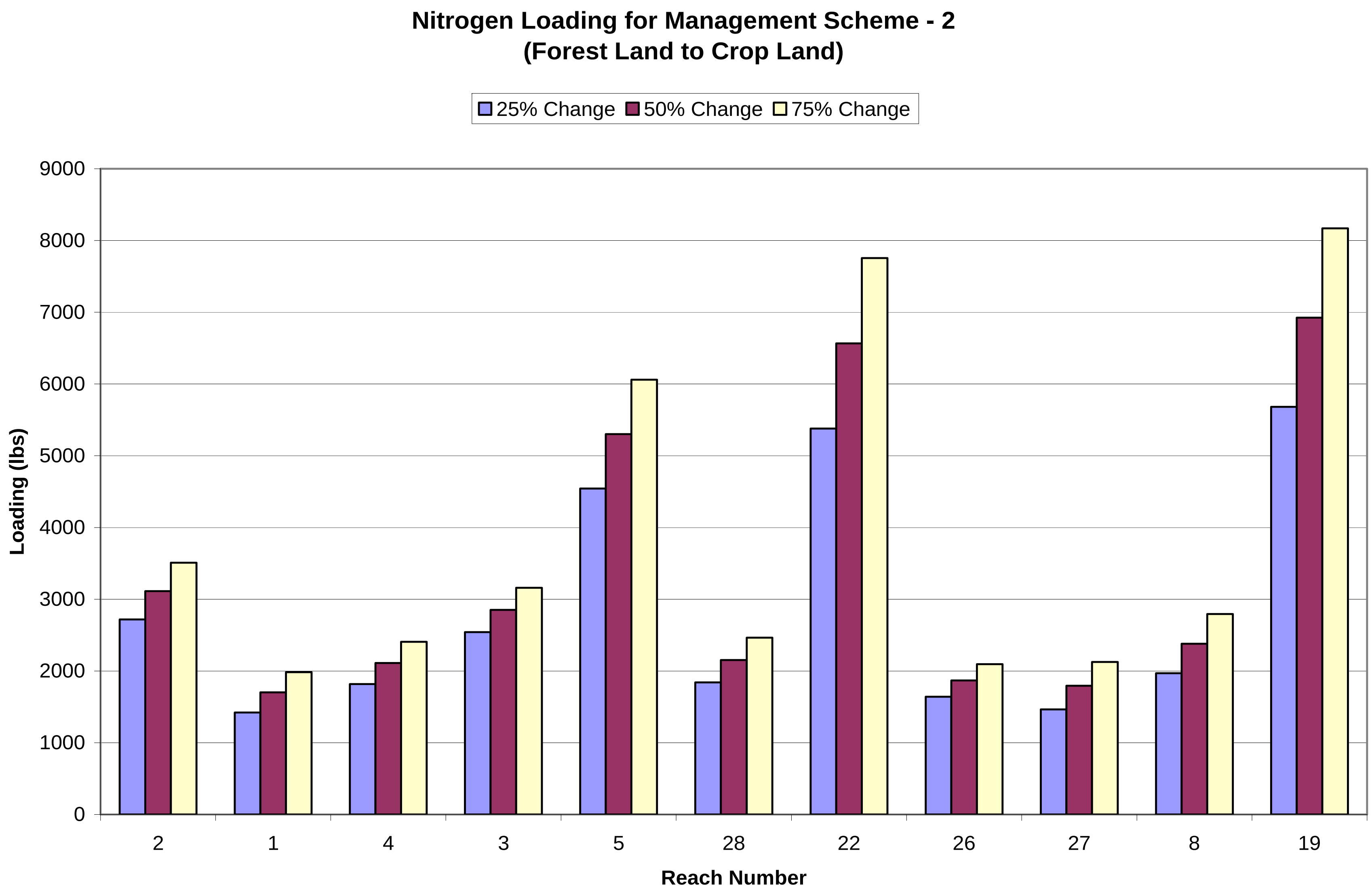

Figure 5.12: Nitrogen Loading for Management Scheme 2 of the Tickfaw River watershed

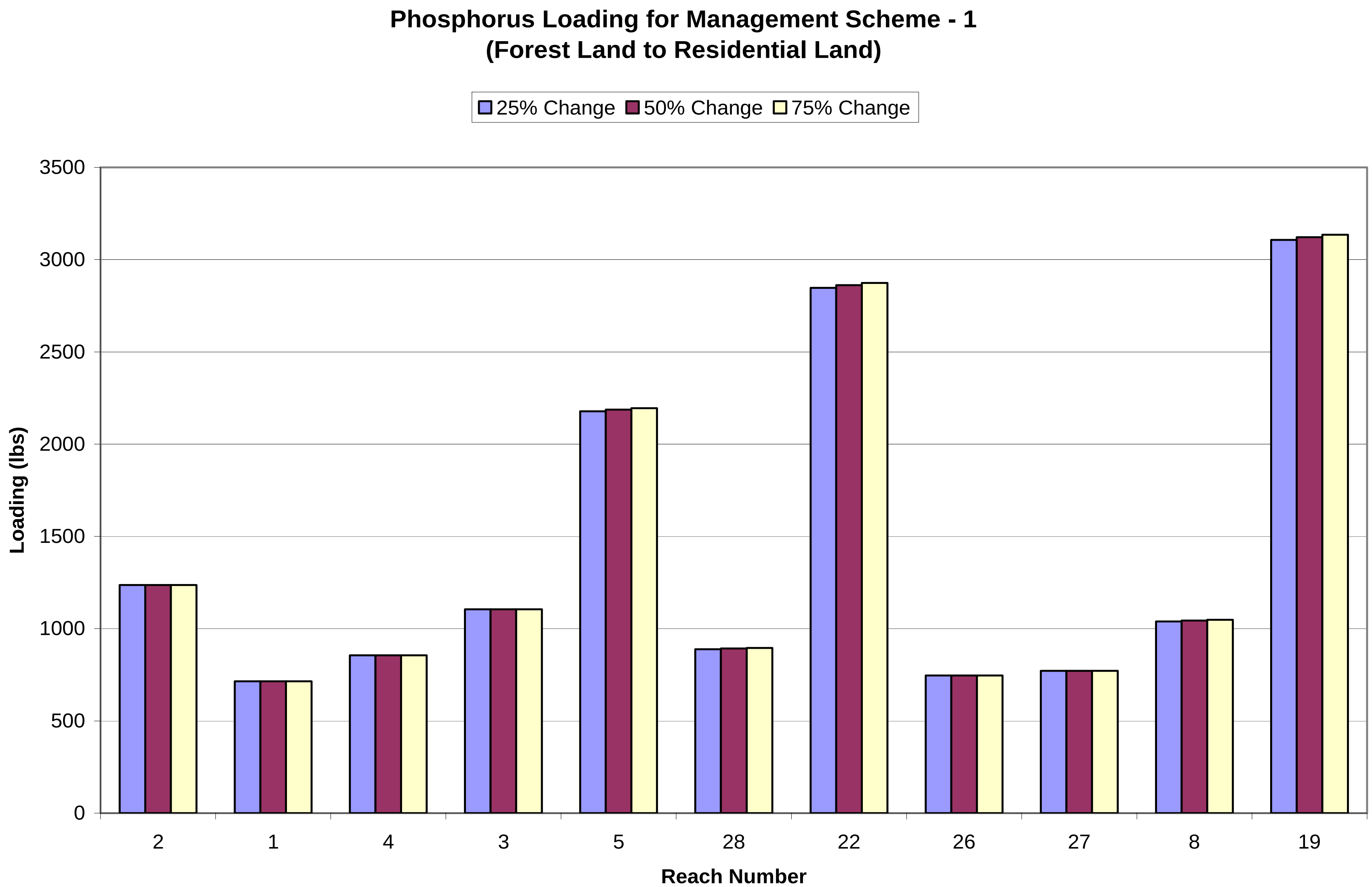

Figure 5.13: Phosphorus Loading for Management Scheme 1 of the Tickfaw River watershed

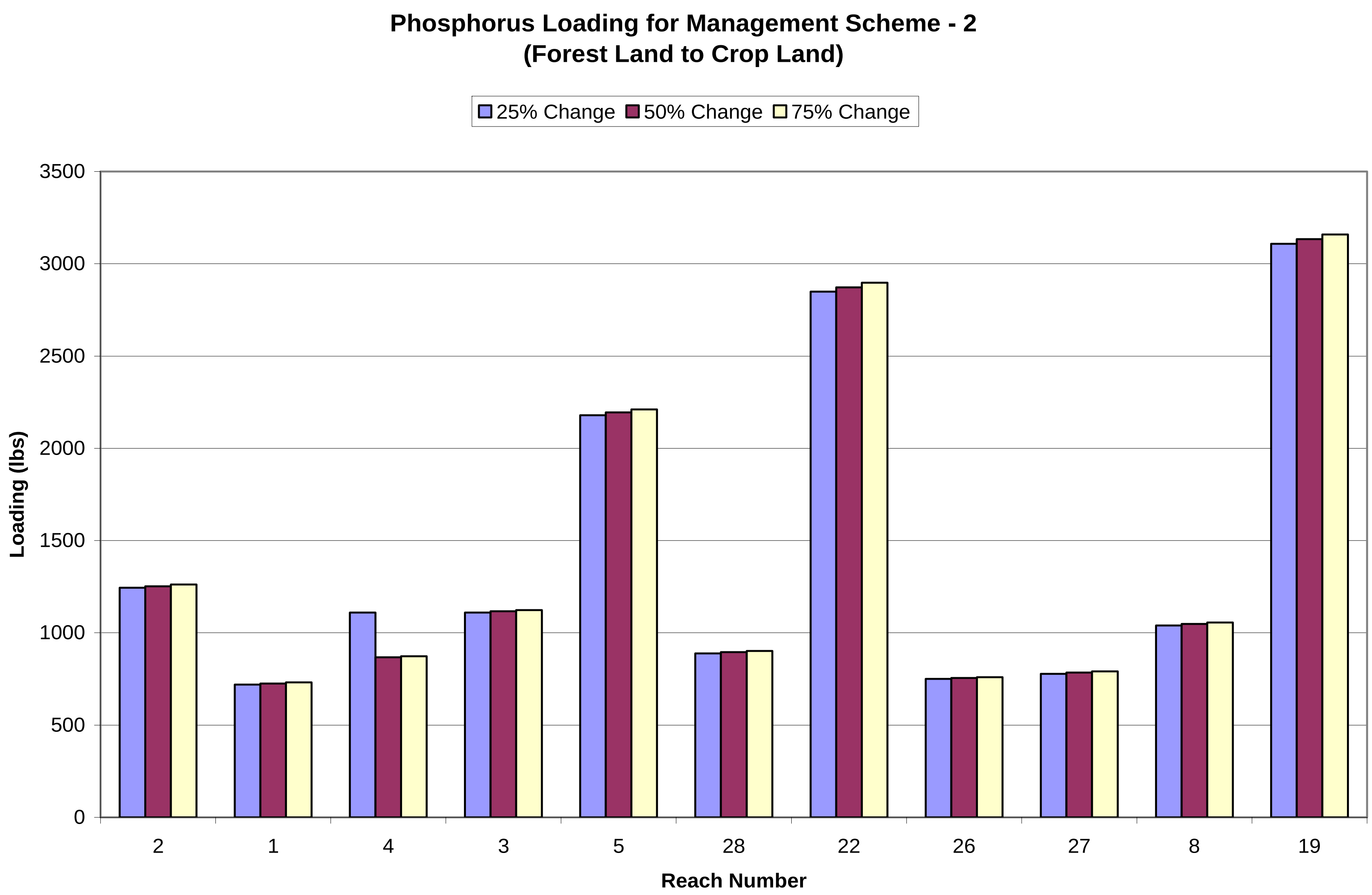

Figure 5.14: Phosphorus Loading for Management Scheme 2 of the Tickfaw River watershed

5.5 Sensitivity of loading due to landuse change

In the delineated Tickfaw Watershed, subbasin 19 has the largest forestland along with residential land followed by subbasin 22 and subbasin 5. Hence, any change in landuse from forestland to residential would have a significant impact on the resultant loading of nitrogen and phosphorus in these subbasins. This could be observed in Figure 5.11 where the resultant nitrogen loading is maximum in subbasin 19 followed by subbasin 22 and 5. Similarly, Figure 5.13 shows that the phosphorus loading is maximum in subbasin 19. For example in subbasin 19, a 50% conversion to residential adds approximately 420 lbs of nitrogen to the river. This 50% conversion to residential land also results in approximately 15 lbs increase in Phosphorus to the river. Increase in phosphorus loads is visually smaller than those of nitrogen because the loading rates of phosphorus are so much lower than the rates of nitrogen.

In Tickfaw Watershed, Cropland is present in all the subbasins where forestland is present. As mentioned earlier, as subbasin 19 has the largest forestland followed by subbasin 22 and 5. Maximum loading of nitrogen and phosphorus is observed in subbasin 19 when forestland is converted to cropland. Thus at subbasin 19, a 50% conversion from forest land to cropland results in an additional 1240 lbs of Nitrogen and 25 lbs of Phosphorus to the river.

5.6 Ranking

It was observed that the loading rates of nitrogen for residential, cropland and pasture were higher than forestland. This resulted in increase in loading of nitrogen when the area of residential, cropland and pasture are increased in the hypothetical scenarios created. An average loading of nitrogen contributing to each reach was calculated for the years 1978 to 1982. Using

these average loading values of nitrogen, scenarios were ranked as shown in Table 5.15 with 1 having the least effect on water quality and 6 having the maximum effect.

It was also observed that the loading rates of phosphorus for residential, cropland and pasture were higher than forestland. This resulted in increase in loading of phosphorus when the area of residential, cropland and pasture are increased in the hypothetical scenarios created. An average loading of phosphorus contributing to each reach was calculated for the years 1978 to 1982. Using these average loading values of phosphorus, scenarios were ranked as shown in Table 5.16 with 1 having the least effect on water quality and 6 having the maximum effect.

Table 5.15: Ranking of Nitrogen Loading Scenarios in the Tickfaw River watershed

Rank	Scenarios	Loading (lbs)
1	SC-11	2481
2	SC-12	2600
3	SC-13	2704
4	SC-21	2819
5	SC-22	3342
6	SC-23	3865

Table 5.16: Ranking of Phosphorus Loading Scenarios in the Tickfaw River watershed

Rank	Scenarios	Loading (lbs)
1	SC-11	1407
2	SC-12	1412
3	SC-13	1415
4	SC-21	1411
5	SC-22	1422
6	SC-23	1433

5.7 Visualization of Landuse Scenarios

Total loading of nitrogen and phosphorus coming from each landuse to reaches in the Tickfaw River watershed was calculated as explained earlier. The sub segment layer, sub basins in BASINS was converted into a new shape file and named as "N-SCN11" using the "convert to shape file" tool in BASINS. A new column for "loading" was created in the "N-SCN11" table using the "start editing" tool. Total loading of nitrogen during the scenario of 25% change of forestland to residential were entered in the "loading" column under the corresponding subbasin. This layer was then color-coded using the values in the loading column. This procedure was repeated for nitrogen and phosphorus loading for all the scenarios created. Details of the acronyms used for the shape file scenarios created are shown in Table 5.17.

Table 5.17: Acronyms used for the shape file scenarios created in BASINS

N-scn11.shp	Nitrogen loading scenario in the sub basins when 25% of the forestland is converted to residential land.
N-scn12.shp	Nitrogen loading scenario in the sub basins when 50% of the forestland is converted to residential land.
N-scn13.shp	Nitrogen loading scenario in the sub basins when 75% of the forestland is converted to residential land.
N-scn21.shp	Nitrogen loading scenario in the sub basins when 25% of the forestland is cropland.
N-scn21.shp	Nitrogen loading scenario in the sub basins when 50% of the forestland is converted to cropland.
N-scn13.shp	Nitrogen loading scenario in the sub basins when 75% of the forestland is converted to cropland.
P-scn11.shp	Phosphorus loading scenario in the sub basins when 25% of the forestland is converted to residential land.
P-scn12.shp	Phosphorus loading scenario in the sub basins when 50% of the forestland is converted to residential land.
P-scn13.shp	Phosphorus loading scenario in the sub basins when 75% of the forestland is converted to residential land.
P-scn21.shp	Phosphorus loading scenario in the sub basins when 25% of the forestland is converted to cropland.
P-scn22.shp	Phosphorus loading scenario in the sub basins when 50% of the forestland is converted to cropland.
P-scn23.shp	Phosphorus loading scenario in the sub basins when 75% of the forestland is converted to cropland.

Figure 5.15 shows the resultant nitrogen loading in each subbasin when 25% of the forestland in each subbasin is converted to residential. It could be observed that only subbasins 2, 3, 5, 8, 19, 22 and 28 have both forest land and residential. Hence, forestland was converted to residential only in these sub basins. Figure 5.15 graphically represents that the Total Nitrogen from these subbasins to the Tickfaw River increases by 1400 lbs following the 25% change in landuse from forestland to residential.

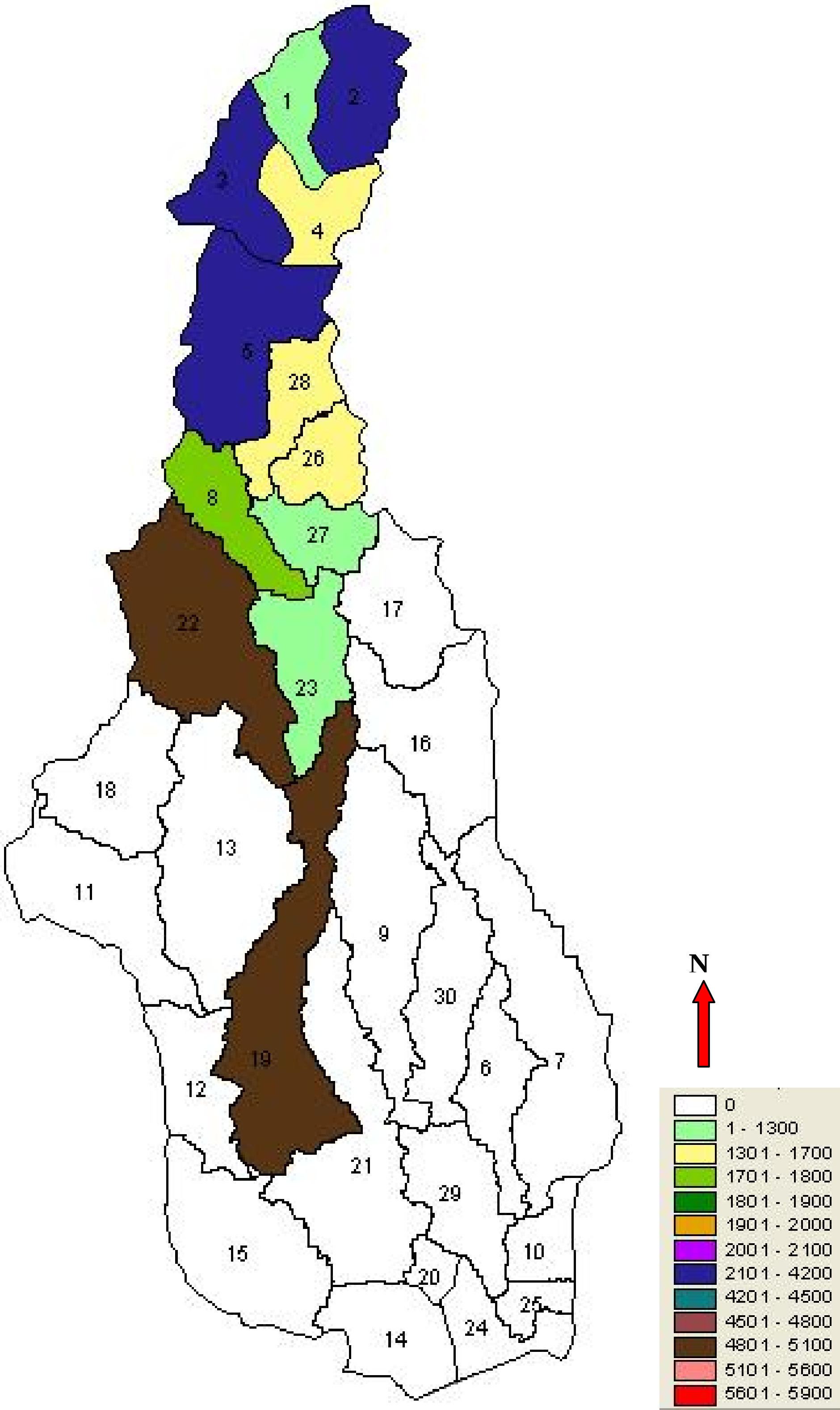

Figure 5.15: Resultant Nitrogen loading from land uses during Scenario 11

Figure 5.16 shows the resultant phosphorus loading in each subbasin when 25% of the forestland in each subbasin is converted to residential. As mentioned earlier, as only subbasins 2, 3 5, 8, 19, 22 and 28 have both forestland and residential land. Hence, forestland was converted to residential only in these sub basins. Figure 5.16 graphically represents that the Phosphorus from these subbasins to the Tickfaw River increases by 54 lbs following the 25% change in landuse from forestland to residential.

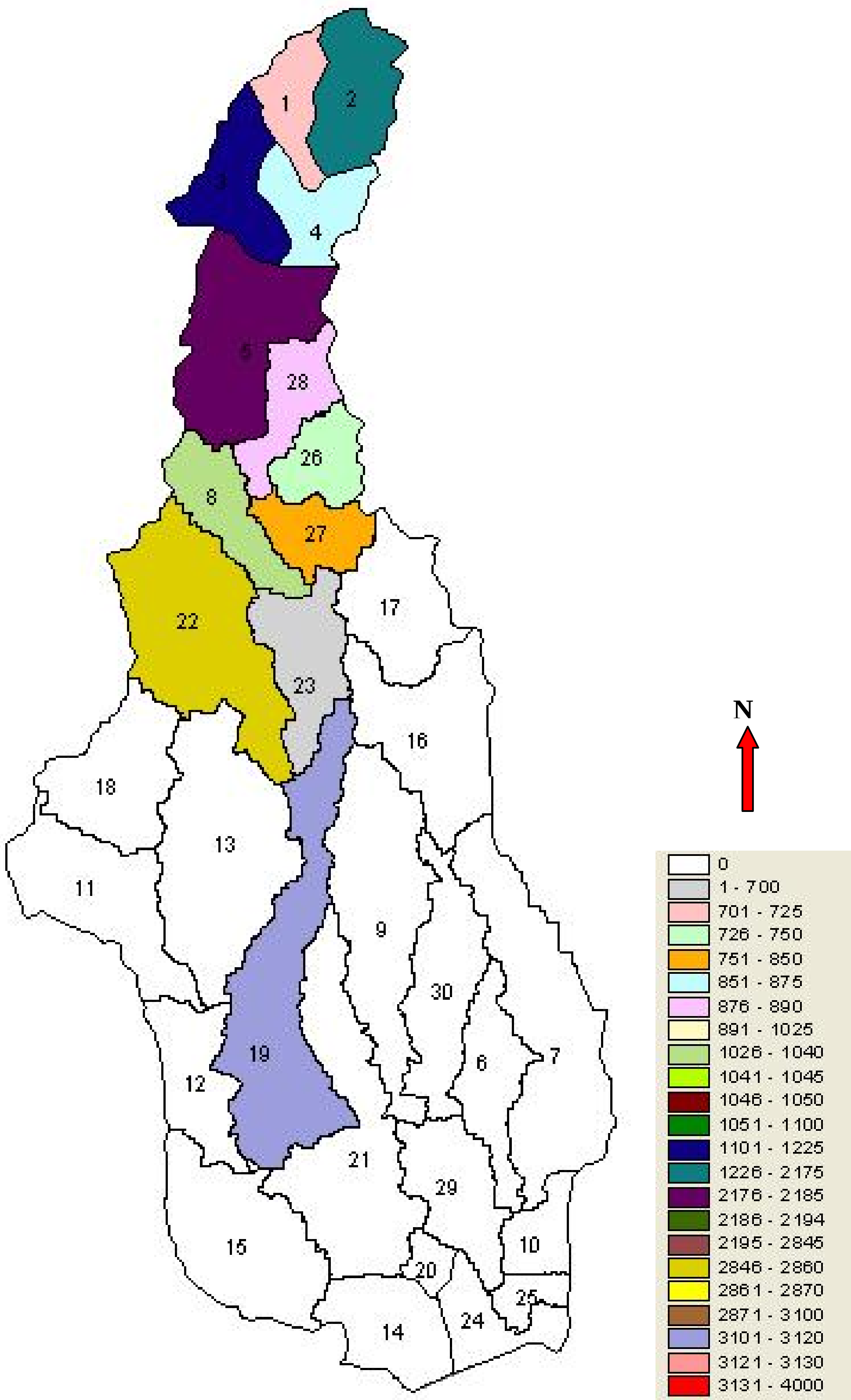

Figure 5.16: Resultant Phosphorus loading from land uses during Scenario 11

Figure 5.17 shows the resultant nitrogen loading in all the subbasins when 50% of the forest land in each subbasin is changed to residential. The change in color which represents the change in loading could be observed only in subbasins 2, 3 5, 8, 19, 22 and 28. Figure 5.17 graphically represents that the Total Nitrogen from these subbasins to the Tickfaw River increases by 2700 lbs following the 50% change in landuse from forest land to residential.

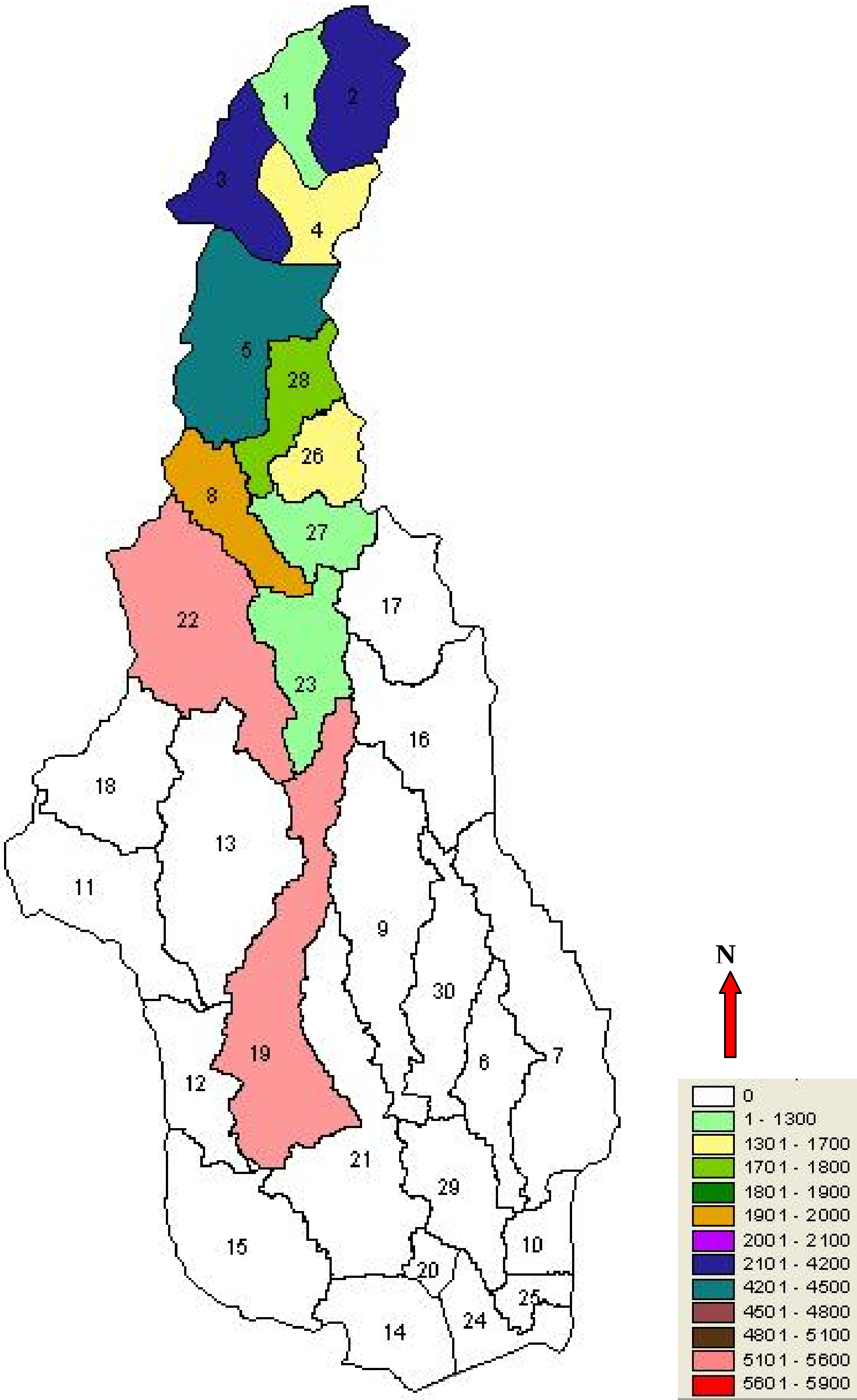

Figure 5.17: Resultant Nitrogen loading from land uses during Scenario 12

Figure 5.18 shows the resultant phosphorus loading in all the subbasins when 50% of the forest land in each subbasin is changed to residential. The change in color which represents the change in loading could be observed only in subbasins 2, 3 5, 8, 19, 22 and 28. Figure 5.18 graphically represents that the Phosphorus from these subbasins to the Tickfaw River increases by 104 lbs following the 50% change in landuse from forest land to residential.

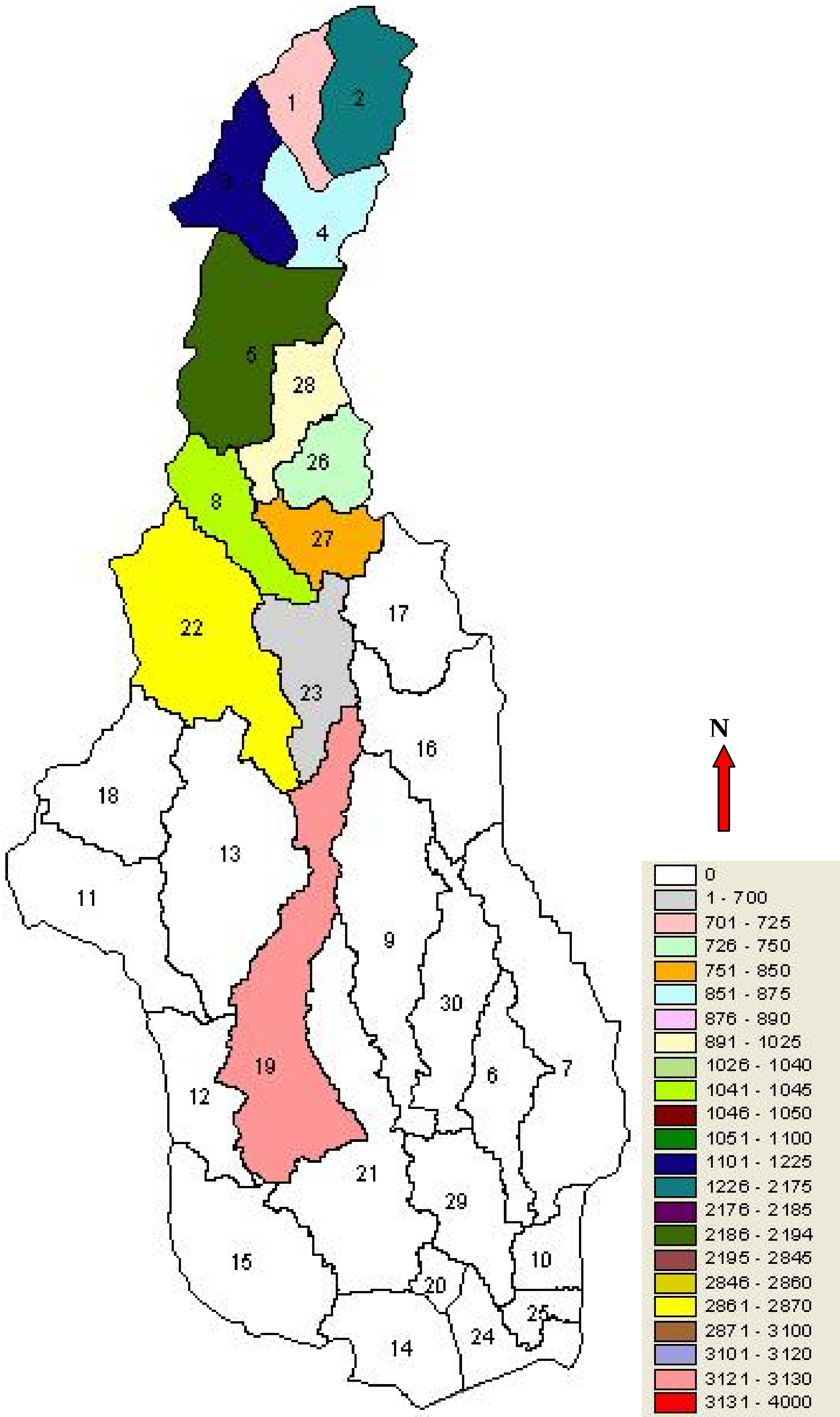

Figure 5.18: Resultant Phosphorus loading from land uses during Scenario 12

Figure 5.19 shows the resultant nitrogen loading in all the subbasins when 75% of the forest land in each subbasin is changed to residential. The change in color which represents the change in loading could be observed only in subbasins 2, 3 5, 8, 19, 22 and 28. Figure 5.19 graphically represents that the Total Nitrogen from these subbasins to the Tickfaw River increases by 3800 lbs following the 75% change in landuse from forest land to residential.

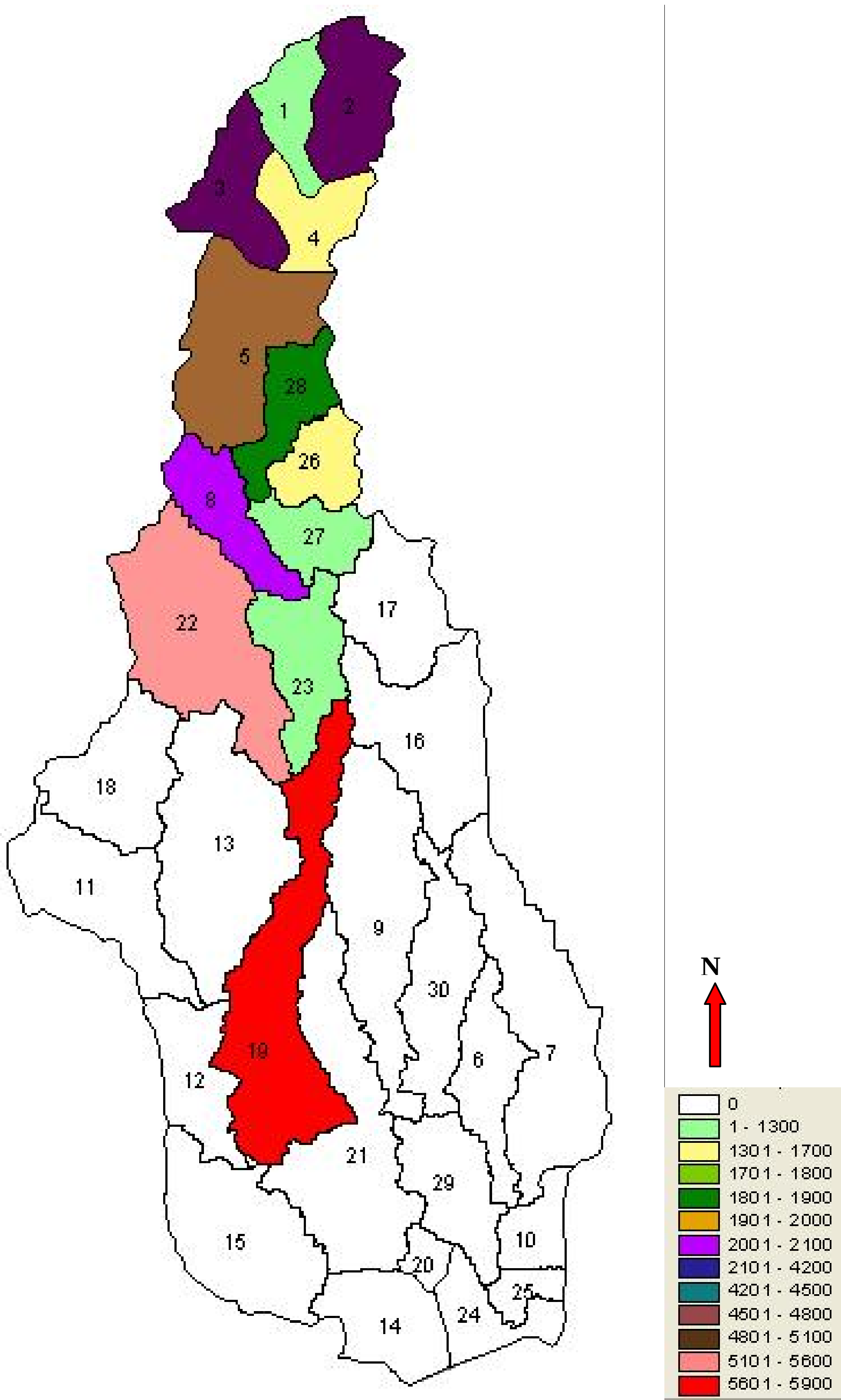

Figure 5.19: Resultant Nitrogen loading from land uses during Scenario 13

Figure 5.20 shows the resultant phosphorus loading in all the subbasins when 75% of the forestland in each subbasin is changed to residential. The change in color which represents the change in loading could be observed only in subbasins 2, 3 5, 8, 19, 22 and 28. Figure 5.20 graphically represents that the Phosphorus from these subbasins to the Tickfaw River increases by 142 lbs following the 75% change in landuse from forestland to residential.

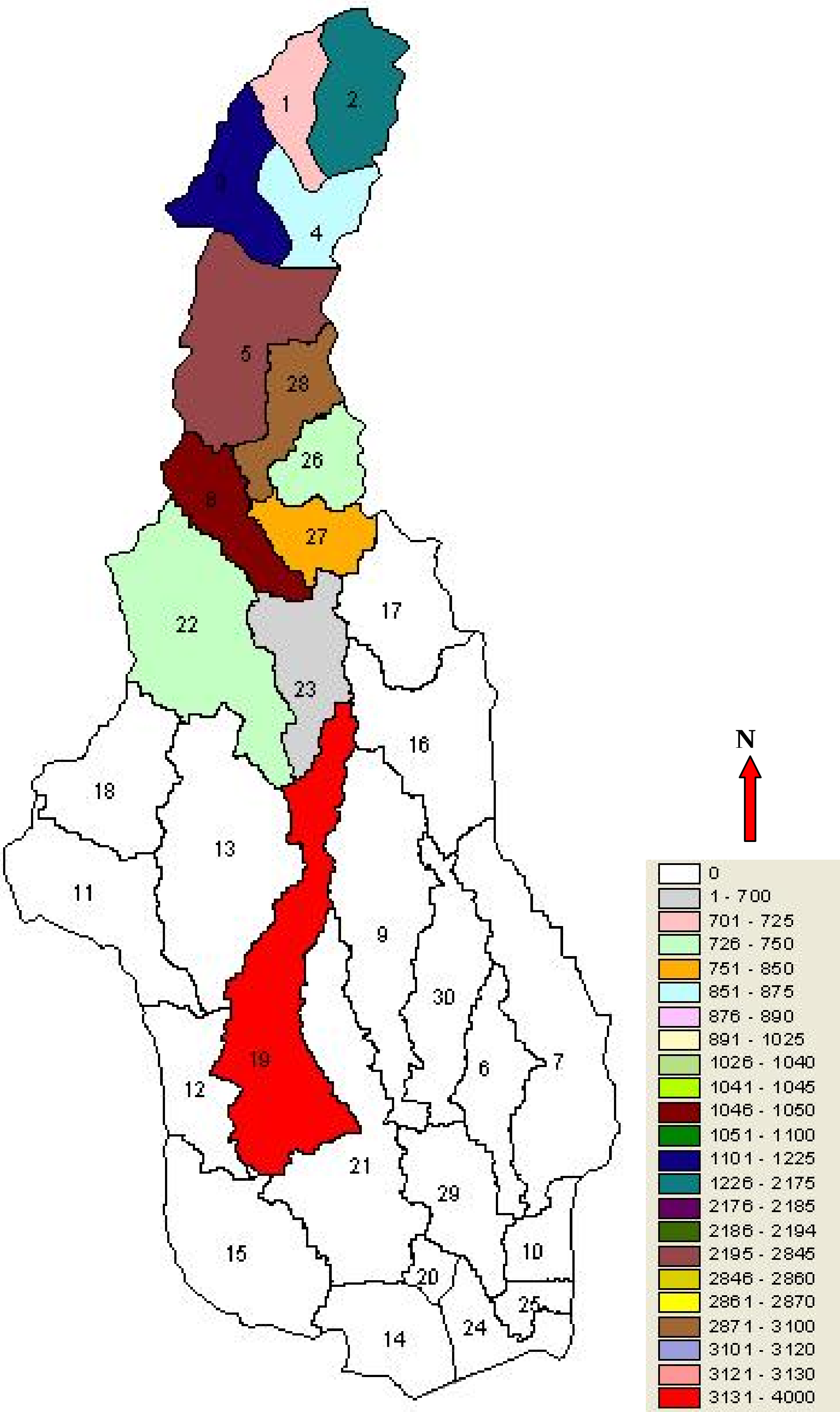

Figure 5.20: Resultant Phosphorus loading from land uses during Scenario 13

As cropland was present in all the subbasins where forestland was present, 25% of the forestland was converted to cropland. Figure 5.21 graphically represents that the Total Nitrogen from these subbasins to the Tickfaw River increases by 7000 lbs following the 25% change in landuse from forestland to cropland.

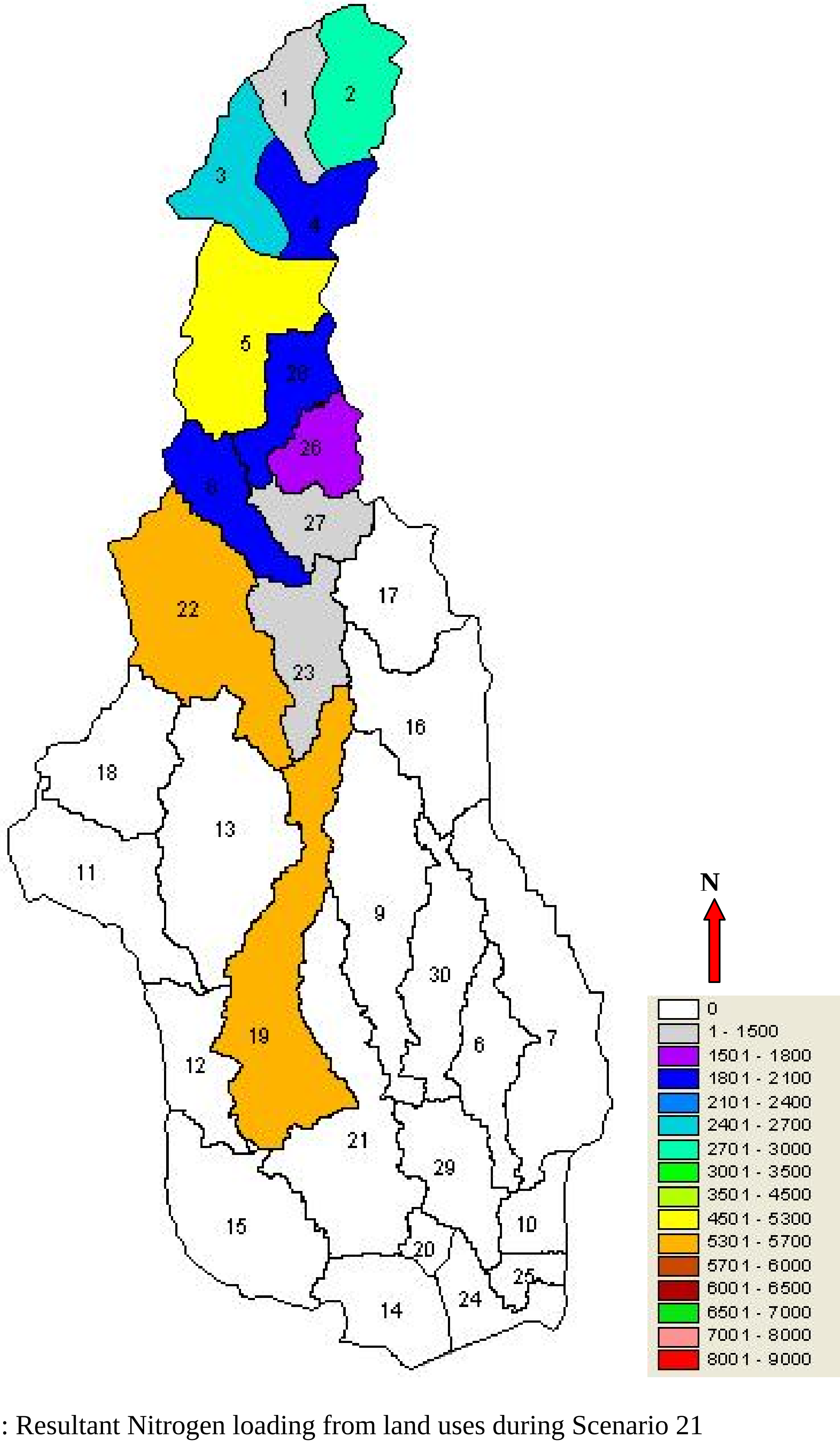

Figure 5.21: Resultant Nitrogen loading from land uses during Scenario 21

Similarly, Figure 5.22 graphically represents that the Phosphorus from these subbasins to the Tickfaw River increases by 110 lbs following the 25% change in landuse from forestland to cropland.

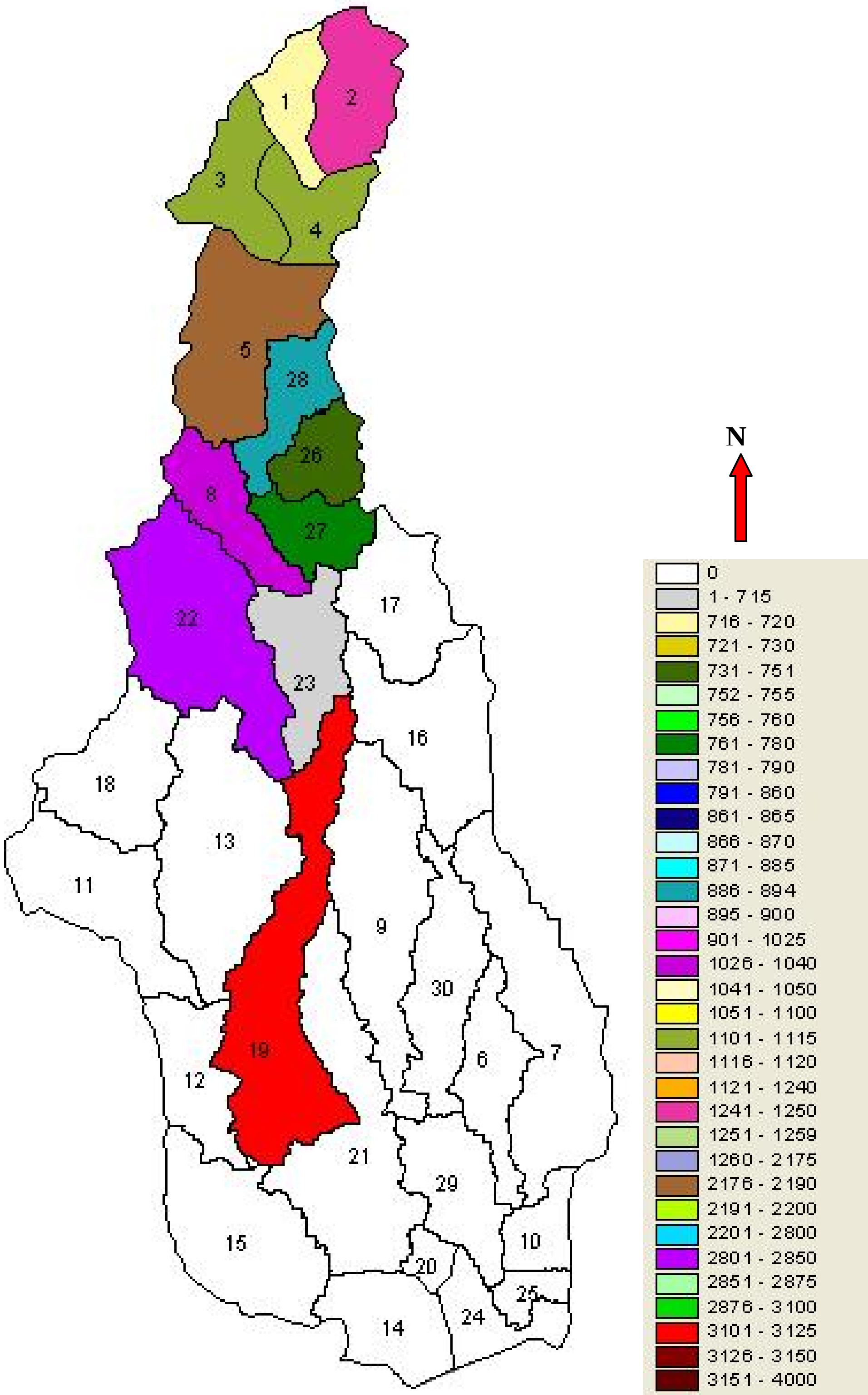

Figure 5.22: Resultant Phosphorus loading from land uses during Scenario 21

As all the subbasins had forestland and cropland, 50% of the forestland was converted to cropland. Figure 5.23 graphically represents that the Total Nitrogen from these subbasins to the Tickfaw River increases by 12,700 lbs following the 50% change in landuse from forestland to cropland.

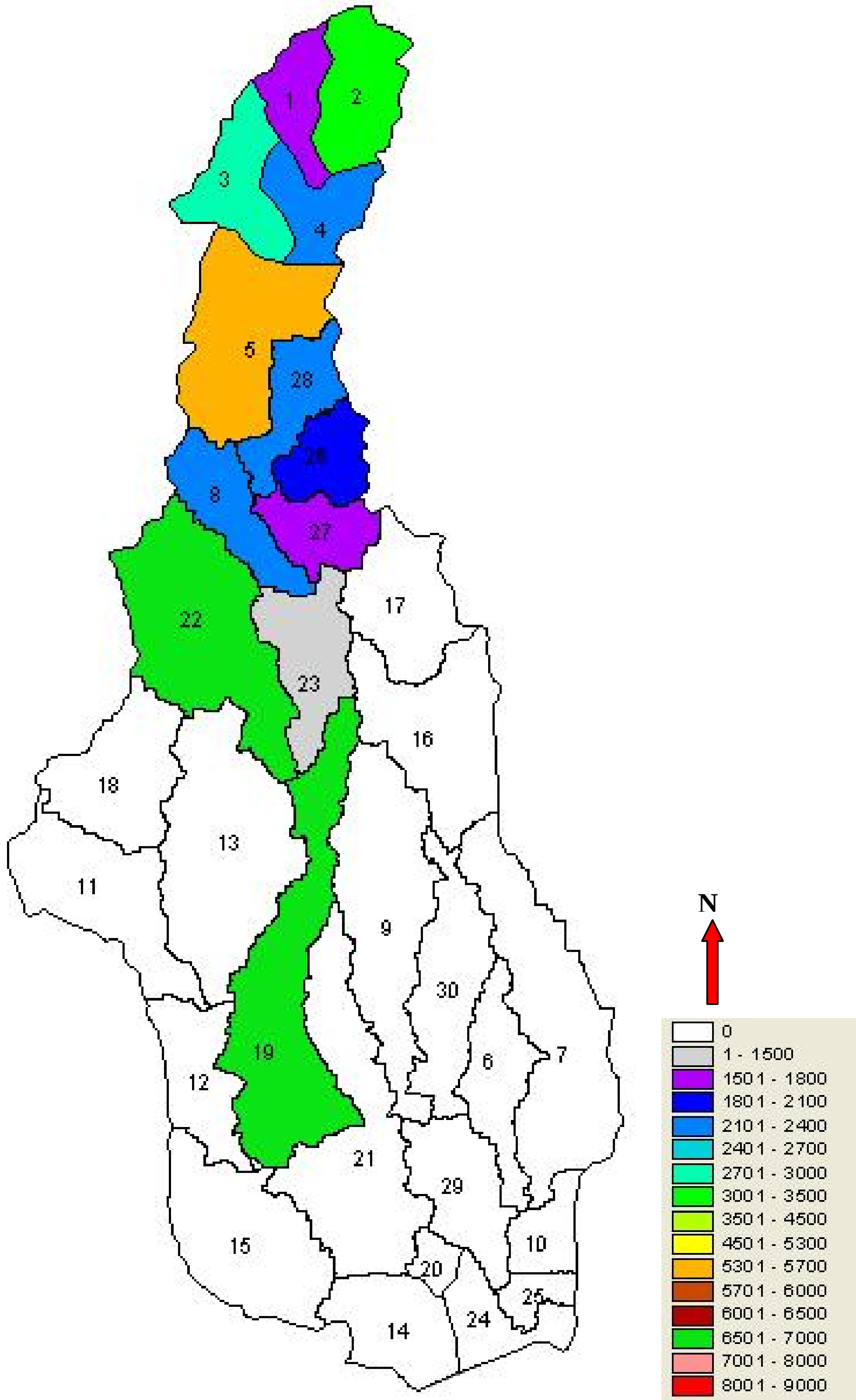

Figure 5.23: Resultant Nitrogen loading from land uses during Scenario 22

Similarly, Figure 5.24 graphically represents that the Phosphorus from these subbasins to the Tickfaw River increases by 220 lbs following the 50% change in landuse from forestland to cropland.

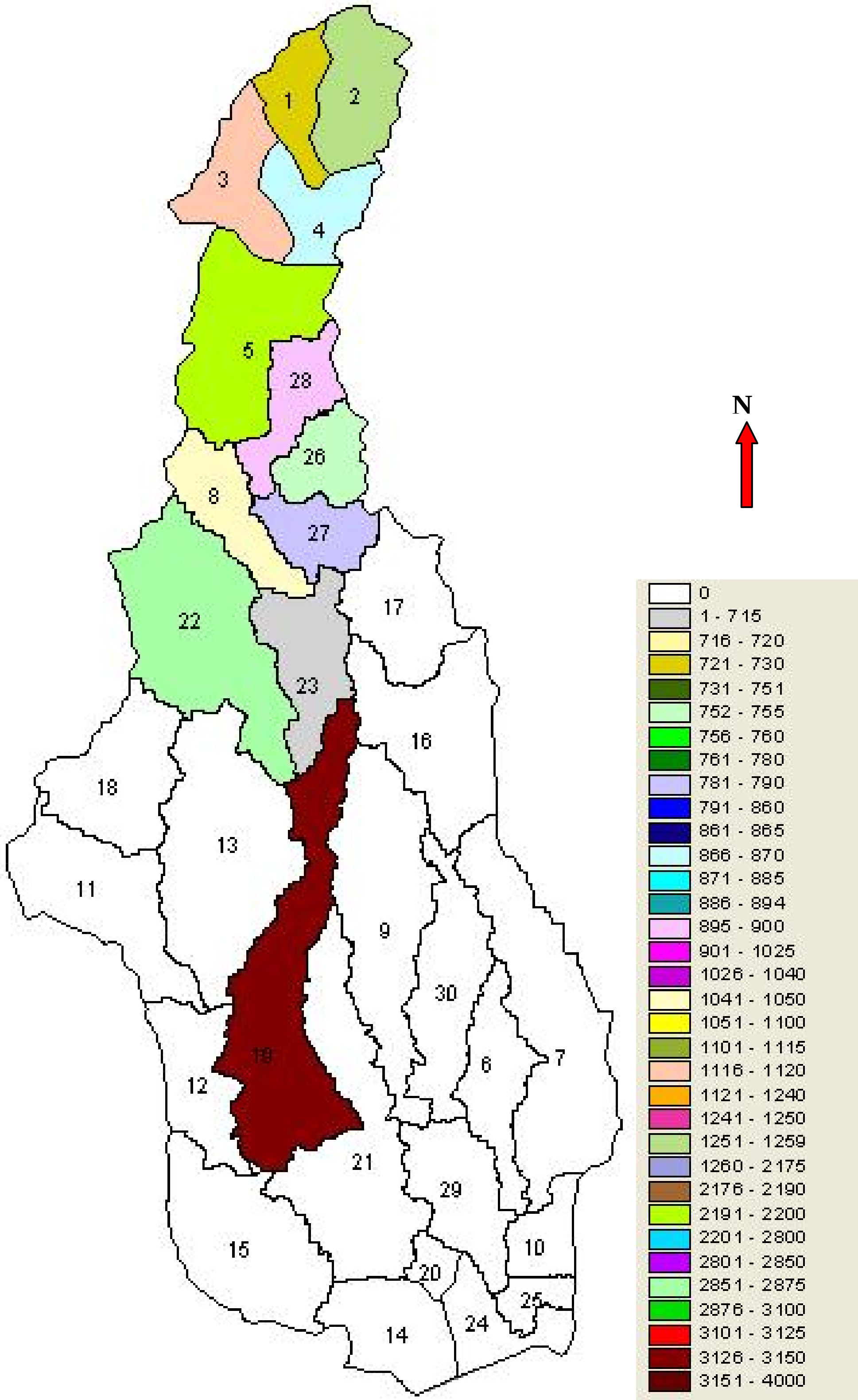

Figure 5.24: Resultant Phosphorus loading from land uses during Scenario 22

As all the subbasins had forestland and cropland, 75% of the forestland was converted to cropland. Figure 5.25 graphically represents that the Total Nitrogen from these subbasins to the Tickfaw River increases by 17,200 lbs following the 75% change in landuse from forestland to cropland.

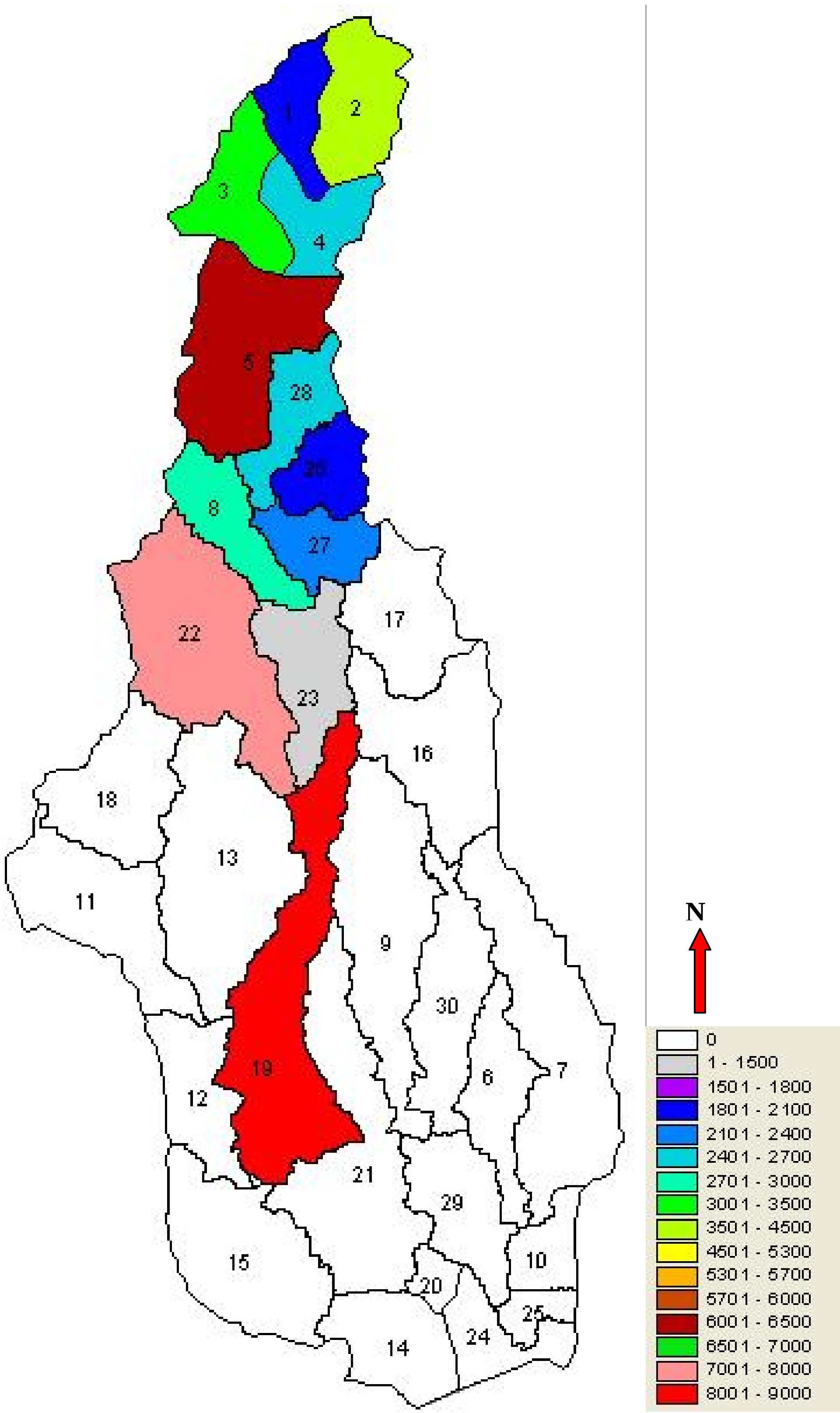

Figure 5.25: Resultant Nitrogen loading from land uses during Scenario 23

Similarly, Figure 5.26 graphically represents that the Phosphorus from these subbasins to the Tickfaw River increases by 330 lbs following the 75% change in landuse from forestland to cropland.

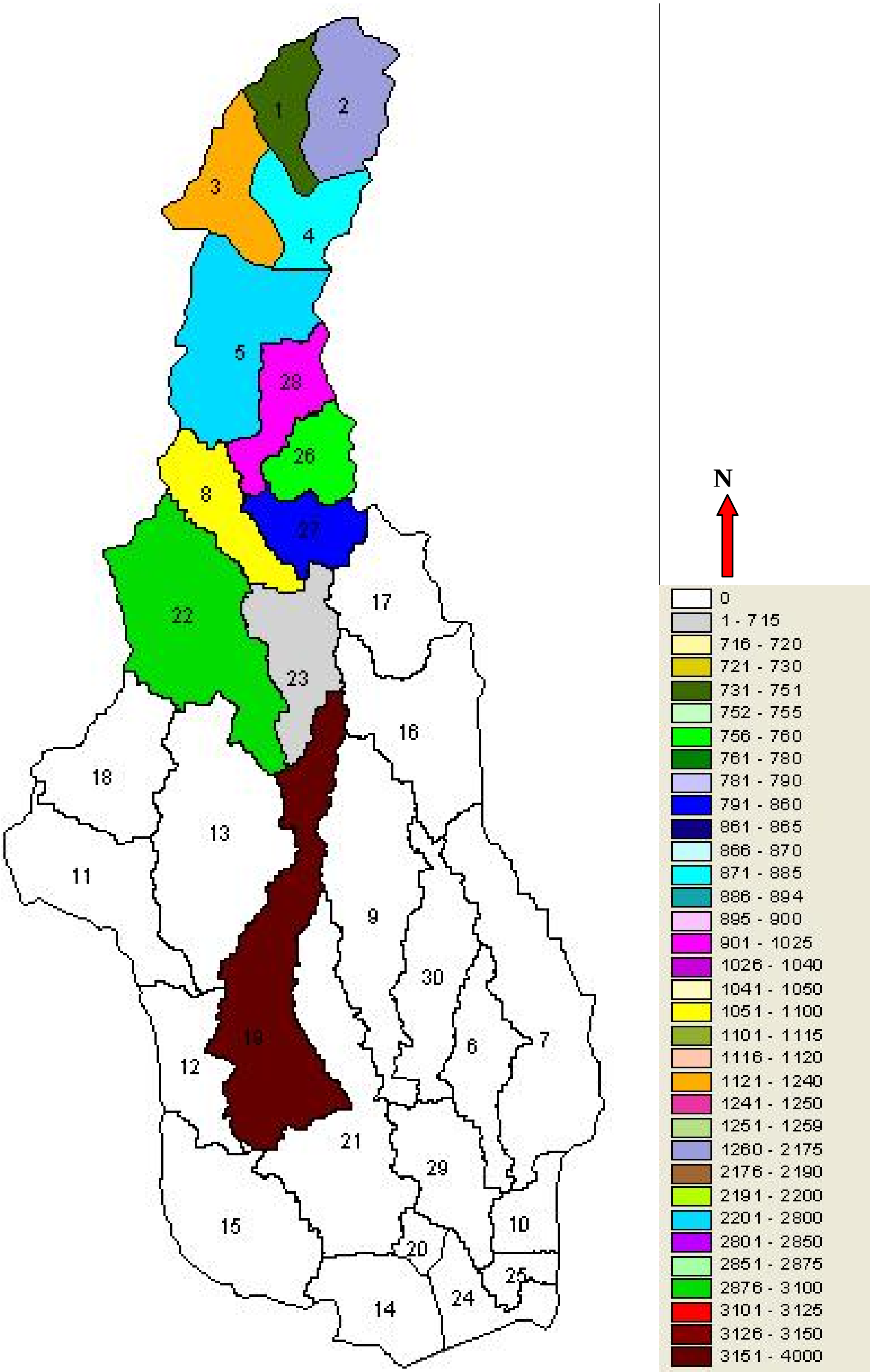

Figure 5.26: Resultant Phosphorus loading from land uses during Scenario 23

6. Conclusions and Recommendations

This report has described the Modeling of nonpoint sources in the Tickfaw River watershed in Southeast Louisiana. In the process, a calibrated HSPF water quantity and quality model of the Tickfaw River watershed have been developed. For the Tickfaw River watershed, the simulated flow has been calibrated to within 4% and 3% of the annual and seasonal flows. Model verification was performed for the January 1st 1979 through December 31st 1985 period and the simulated flow was found to be within 1.4% and 11% of the annual and seasonal flows.

Simulated temperature, dissolved oxygen, nitrogen, and phosphorus were calibrated and validated graphically and stastically comparing with the observed values. The model, which is calibrated for hydrology and water quality, is used to calculate the loading of nitrogen and phosphorus as a result of various land uses.

The Tickfaw River watershed consists of 68.8% forestland, 29.2% agricultural land and 1.2% residential land. As the watershed was predominant with forestland, hypothetical scenarios of forestland converted to residential and forestland converted to cropland and pasture were created. Care has been taken to make sure that the total area contributing to each reach has not changed.

In the Tickfaw River watershed, various land use scenarios such as loading resulting from conversion of forestland to residential land and forestland to agricultural land were created. An assessment analysis was performed to determine the loading coming from each land use. Loading rates of nitrogen and phosphorus were extracted for all these landuse scenarios and the total loading resulting from each landuse to the stream was calculated.

In the Tickfaw River watershed the loading rates of nitrogen and phosphorus for cropland and pasture are higher than residential which in turn is higher than forestland. Hypothetical

scenarios created resulted in an increase in total loading of both nitrogen and phosphorus when current landuse is converted to cropland and pasture with 25%, 50% and 75% change. The total loading generated due to these landuse scenarios are shown in Table 5.18 to 5.20.

Based on these results, it was observed that conversion of current land use to residential had less effect on nitrogen and phosphorus water quality than conversion of current landuse to cropland and pasture in Tickfaw watershed. The model was resulting in high loading of nitrogen and phosphorus for cropland, which is adversely affecting the water quality in the river. The results indicate a smaller water quality impact due to conversion of forestland to residential than that of forestland to cropland. Therefore, if conversion of current landuse is inevitable, then in general low density residential is recommended over cropland with respect to nitrogen and phosphorus. Using the model developed, specific recommendations can be made using model results of landuse changes on specific parcels of land in the watershed. The model can be edited to reflect landuse projections and give total loading results on a sub basin area basis.

The model can be used by LADEQ to analyze stream Water Quality (WQ) concentration, calculate load differences due to land use changes, and to calculate Total Maximum Daily Load (TMDL). At this point, the results of the hypothetical landuse area changes are used to show relative impact compared to historical landuse. Best Management Practices (BMP) such as stream buffers, filter strips, retention ponds etc. can be applied to various land segments until the highest daily-simulated concentration is just below the standard. The TMDL is found by identifying the day on witch the WQ parameter lies just below the standard. The TMDL is the corresponding daily load at that point. The TMDL can be recalculated to determine how the TMDL is impacted for projected future conditions.

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Vita

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