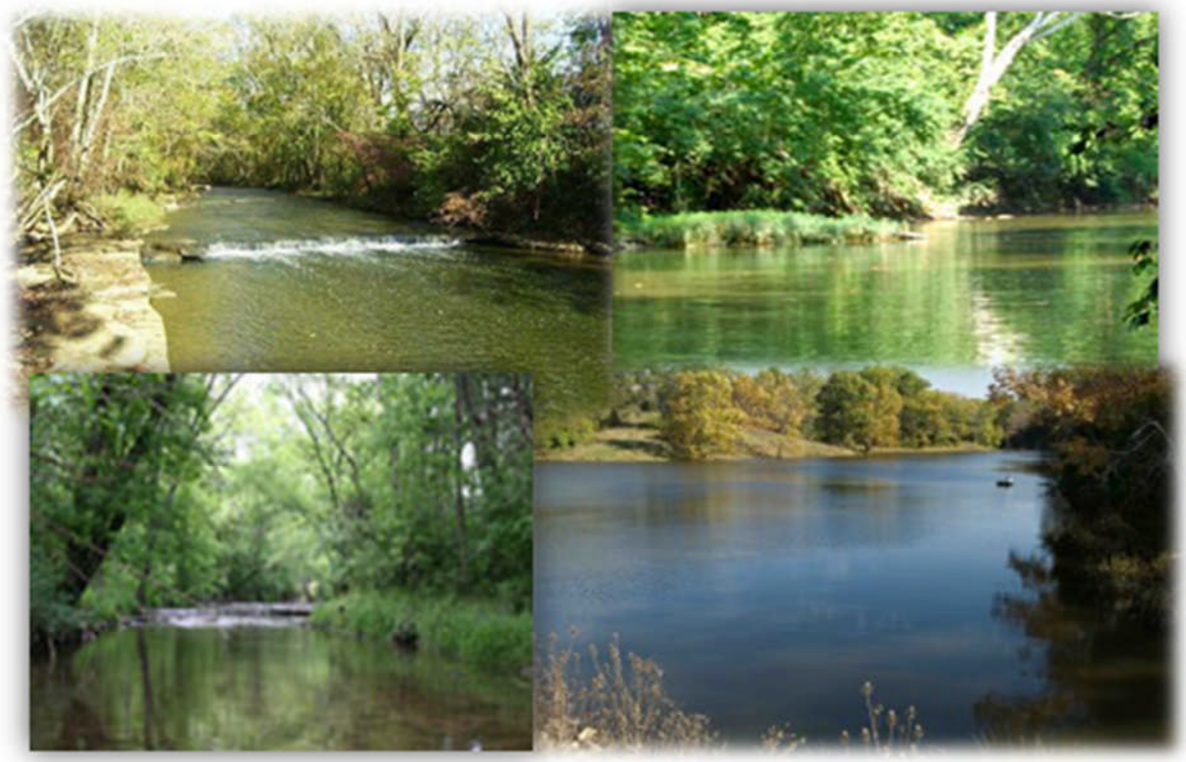
Watershed Hydrology and Water Quality Modeling Report

for

Floyds Fork, Kentucky



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Revision 4

PREPARED FOR:

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Environmental Protection Agency
Region 4
61 Forsyth Street, SW
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Revision History

The following table presents the revision history of the Floyds Fork Watershed Modeling Report.

Table i-1 Revision History of Floyds Fork Watershed Modeling Report

Revision Number	Release Date	Comments
0	December 30, 2011	Initial Release of Report. Hydrology, Temperature/DO, Water Quality and Sediment Calibration/Validation.
1	January 31, 2012	Addressed comments from EPA Region 4.
2	May 4, 2012	Made minor text changes to document. Added Glossary of Terms. Added additional SSO's (section 3.9). Updated non-point source loading tables (section 3.13). Updated water quality scoring system (section 5.11). Added Section 5.12 – Loading Summary.
3	July 13, 2012	Updated point source representation. Updated land use water quality parameters. Updated water quality calibration.
4	August 30, 2012	Added clarifying information in the Meteorological Data (section 3.5). Added clarifying information in the Septics section (section 3.11). Added Springs in the model (section 3.13). Updated and added clarifying information on landuse loading rates (section 3.14). Updated hydrology and land use water quality parameters. Updated hydrology and water quality calibration.

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GLOSSARY OF TERMS

ASAE: American Society of Agricultural Engineers. It is a professional and technical organization dedicated to the advancement of engineering applicable to agriculture, food and biological systems. Information provided on fresh manure production and characteristics per 1000lbs live animal mass per day was used in this model.

ASCII: American Standard Code for Information Interchange. The meteorological data was received in this format.

BASINS: Better Assessment Science Integrating Point & Non-Point Sources. It is a multi-purpose environmental analysis system that integrates a geographical information system, a national watershed data, and state-of-the-art environmental assessment and modeling tools into one convenient package.

BOD_5: 5-day Biochemical Oxygen Demand. It is the amount of oxygen utilized by the microorganisms in breaking down the waste.

CSOs: Combined Sewer Overflows. It contains stormwater in addition to untreated human and industrial waste. There were no reported CSOs to be used in the Floyds Fork watershed model.

DMR: Discharge Monitoring Report. It is a United States regulatory for a periodic water pollution report produced by industries, municipalities and other facilities discharging to surface waters

DO: Dissolved Oxygen. It is the measured oxygen in its dissolved form.

EPA: Environmental Protection Agency. This organization is a federal agency responsible for protecting human health and the environment, by enforcing regulations based on laws passed by Congress.

FTABLE: This table contains information on the reaches in a model. It consists of information on depth, surface area and volume.

HSG: Hydrologic Soil Group. Soils are assigned to these groups based on measured rainfall, runoff and infiltration data.

HSPF: Hydrologic Simulation Program FORTRAN. It is used for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants.

HTRCH: It is a subroutine in HSPF/LSPC that simulates heat exchange and water temperature.

HUC: Hydrologic Unit Code. It is a watershed identifier. This is a standardized watershed classification system developed by United States Geological Survey.

IQUAL: It is a subroutine in HSPF/LSPC that simulates the wash-off of quality constituents associated with particulates using simple relationships.

IWATER: It is a subroutine in HSPF/LSPC that simulates the water budget for impervious land segment.

IWTGAS: It is a subroutine in HSPF/LSPC that estimates water temperatures and dissolved gas concentrations on a segment of impervious land.

KDOW: Kentucky Division of Water. This organization is responsible for protecting, managing and enhancing the quality of the Commonwealth's water resources through voluntary, regulatory and educational programs.

KGS: Kentucky Geological Survey. This organization is responsible for providing the citizens, researchers, industries and government, with scientifically based information on Kentucky's geology, mineral and water resources.

KPDES: Kentucky Pollutant Discharge Elimination System. As authorized by Clean Water Act, KPDES permit program is responsible for controlling water pollution by regulating point sources that discharge pollutants into Kentucky waters. 73 KPDES facilities were identified and used in the Floyds Fork model.

LSPC: Loading Simulation Program in C++. It is a watershed modeling system that includes streamlined HSPF algorithms for simulating hydrology, sediment and general water quality on land as well as a simplified stream transport model. This modeling system was used for the Floyds Fork watershed model.

MDAS: Mining Data Analysis System.

MGD: Million Gallons per Day. This is the unit used by most of the agencies to report flows/overflows.

MON-ACCUM: This subroutine simulates the monthly accumulation of solids independently of runoff.

MRLC: Multi-Resolution Land Characteristics Consortium. It is a group of federal agencies who coordinate and generate consistent and relevant land cover information at a national level. The landuse coverage for this model was used from this agency.

MSD: Municipal Sewer District. It is a non-profit regional utility service. It is responsible for the operation and maintenance of Louisville's combined sanitary and storm sewer system and sanitary-only sewer system. Part of the water quality data, information on CSOs and SSOs used in the Floyds Fork model was obtained from MSD.

NCDC: National Climate Data Center. It is the world's largest active archive of weather data. Weather data for Floyds Fork model was obtained from this agency.

NED: National Elevation Dataset. It is a seamless dataset that contains the best raster elevation data of the conterminous United States. NED of 1/3-arc second resolution was used in the Floyds Fork model.

NGMC (formerly known as NCGC): National Geospatial Management Center. It is a major distributor of geospatial data. It provides technical leadership and expertise in geosciences like geographic information system (GIS), aerial photography, remote sensing and elevation.

NHD: National Hydrography Dataset. It is the surface water component of the National map. The NHD is a digital vector dataset used by GIS. This data is designed to be used in surface water systems. The sub-watersheds for the Floyds Fork model were developed using the NHD catchment data layer (1:100,000) that was obtained from the United States Geological Survey (USGS).

NH_3: Ammonia.

NLCD: National Land Cover Database. It is a land cover mapping program. MRLC has been working towards making NLCD a land-cover monitoring program. For the Floyds Fork model, NLCD coverage for the year 2006 was used.

NOX: Nitrite-Nitrate.

NPDES: National Pollutant Discharge Elimination System. It is a permit program that controls water pollution by regulating point sources that discharge pollutants into waters of United States.

NRCS: National Resources Conservation Service. This agency is the conservation leader for all natural resources, and ensures that the private lands are conserved and restored.

ORGN: Organic Nitrogen.

ORGP: Organic Phosphorus.

OXRX: It is a subroutine in HSPF/LSPC that simulates primary DO and BOD balances.

EPA PCS: Environmental Protection Agency's Permit Compliance System. It is a national computerized management information system that automates the NPDES/KPDES data. It was used to retrieve information on the NPDES/KPDES permits for the Floyds Fork model.

PO_4: Orthophosphate.

P_2O_5: Phosphorus Pentaoxide.

PQUAL: This module in HSPF/LSPC allows data to be entered for the water quality constituents from a pervious land segment.

PSTEMP: This subroutine simulates soil temperatures for the surface, upper and lower layers of a land segment.

PWTGAS: It is a subroutine in HSPF/LSPC that estimates water temperatures and dissolved gas concentrations on a segment of pervious land.

PWATER: This subroutine is used to calculate the components of the water budget, primarily to predict the total runoff from a pervious area.

RMU: Reduced Modeling Unit. This is used to condense similar landuses into one landuse type in the model. There were two RMUs used in the Floyds Fork watershed model for Forest and Wetlands landuses.

SA: Surface Airways. NCDC Surface Airways contains hourly weather observations from the meteorological stations used in this model.

SEDMNT: This subroutine simulates the production and removal of sediment from a pervious land segment.

SEDTRN: It is a subroutine in HSPF/LSPC that simulates the behavior of inorganic sediments.

SOD: Summary of the Day. NCDC Summary of the Day contains daily weather observations from the meteorological stations used in this model.

SOLIDS: This subroutine simulates the accumulation and removal of solids by runoff and other means from impervious land segment.

SSOs: Sanitary Sewer Overflows. They are occasional, yet unintentional discharges of raw sewage from municipal sanitary sewers. SSOs from 8 NPDES facilities were identified for this model.

SSURGO: Soil Survey Geographic Database. It is the digital soils data produced and distributed by NRCS-NCGC. This database was used to retrieve the soils information for Floyds Fork watershed model.

TMDL: Total Maximum Daily Load. It is the maximum amount of pollutants that a waterbody can receive and still safely meet water quality standards.

TP: Total Phosphorus.

TN: Total Nitrogen.

TSS: Total Suspended Solids.

USGS: United States Geological Survey. It is a science organization that provides reliable scientific information to describe and understand the Earth and enhances and protects the quality of life.

WASP: Water Quality Analysis and Simulation Program. It is a dynamic compartment-modeling program for aquatic systems, simulating one-dimensional, two-dimensional, and three-dimensional systems, and a variety of pollutants.

WQTC: Water Quality Treatment Center.

WSQOP: It is the rate of surface runoff that results in 90% washoff in one hour.

WTEMP: Water Temperature.

1.0 INTRODUCTION

Floyds Fork lies in two 10-digit HUC watersheds, Upper Floyds Fork (HUC 0514010208) and the Lower Floyds Fork (HUC 0514010210) watershed in northwestern Kentucky, approximately 10 miles northeast of the city of Louisville. Ranging 62 miles in length, Floyds Fork originates in the southwestern portion of Henry County and flows southwest to unite with the Salt River in Bullitt County which then flows into Ohio River. Floyds Fork is a major tributary of the Salt River. Its drainage area is 285 sq. miles and is within the Salt River basin covering a significant part of central Kentucky. A total of 6 counties (Bullitt, Henry, Jefferson, Oldham, Shelby and Spencer) are located partially in the Floyds Fork watershed, thus making the watershed very important to a wide-range of communities. Figure 1-1 shows Floyds Fork, the Floyds Fork watershed, surrounding Counties and other features of the watershed. This report documents the development and calibration of a watershed model that will be used to approximate watershed flows, temperature, sediments, dissolved oxygen, and nutrient loadings entering Floyds Fork.

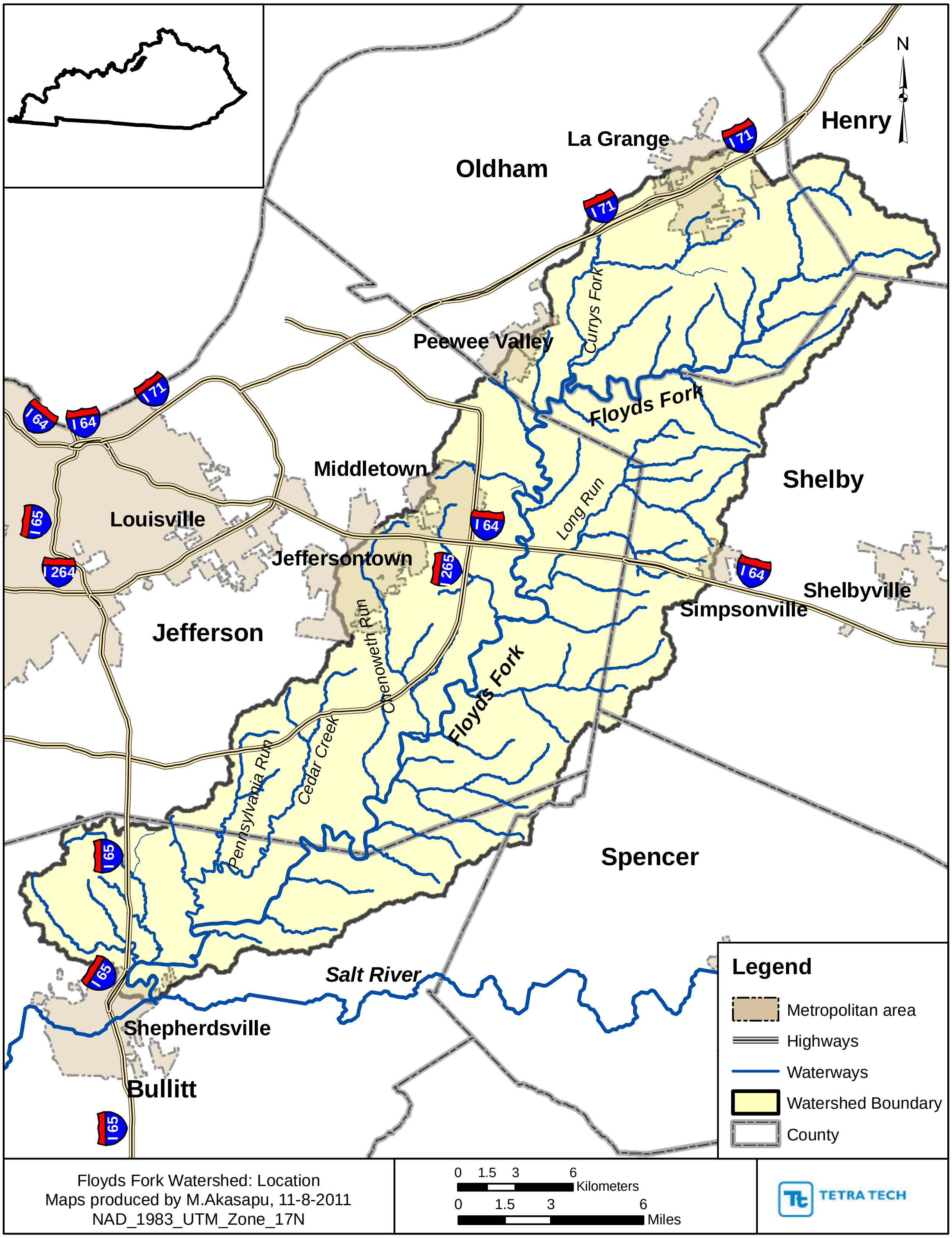


Figure 1-1 Location of Floyds Fork Watershed

2.0 MODEL SELECTION

2.1 LSPC Watershed Model

The Loading Simulation Program C++ (LSPC) was used to develop a watershed model to represent the hydrological and water quality conditions in the Floyds Fork watershed. LSPC is a comprehensive data management and modeling system that is capable of representing loading, both flow and water quality, from point and non-point sources and simulating in-stream processes. It is a dynamic watershed model driven by time-variable weather input data and can simulate flow, sediment, metals, nutrients, pesticides, and other conventional pollutants, as well as temperature and pH for pervious and impervious lands and waterbodies. LSPC was configured to simulate the watershed as a series of hydraulically connected sub-watersheds in which the model will estimate the surface water runoff and the advective transport of constituents. LSPC is based on the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and fecal coliform modeling. MDAS was developed by EPA Region 3 through mining TMDL applications.

2.2 Integration of LSPC with WASP

To address the nutrient loadings and the water quality standards for chlorophyll-a and dissolved oxygen, an in-stream water quality model will also be developed. The Water Quality Analysis Simulation Program (WASP 7.x) will be utilized as the water quality model. WASP is a dynamic compartment-modeling program for aquatic systems, simulating one-dimensional, two-dimensional, and three-dimensional systems, and a variety of pollutants. It is capable of simulating four classes of algae (three free floating and one benthic algae class), sediment-water oxygen, pH/alkalinity and nutrient exchanges. LSPC will be linked to the WASP model by providing flows and concentrations at tributaries and local drainage areas. WASP will then be used to simulate the in-stream water quality of Floyds Fork.

3.0 WATERSHED MODEL DEVELOPMENT

3.1 Overview

The watershed model represents the variability of non-point source contributions through dynamic representation of hydrology and land practices. The watershed model includes contributions from all point and non-point sources. Key components of the watershed modeling include:

- Watershed delineation (Section 3.2)
- Simulation period (Section 3.3)
- Soils (Section 3.4)
- Meteorological data (Section 3.5)
- Reach Characteristics (Section 3.6)
- Land use representation (Section 3.7)
- Point Source Discharges (Section 3.8)
- Sanitary Sewer Overflows (Section 3.9)
- Industrial Water Withdrawals (Section 3.10)
- Septic Tanks (Section 3.11)
- Sinkholes (Section 3.12)
- Springs (Section 3.13)
- Non-Point Source Discharges (Section 3.14)
- Hydrologic representation (Section 4.1)
- Observed Flow Data (Section 4.2)
- Hydrology Calibration (Section 4.3)
- Hydrology Validation (Section 4.4)
- Hydrology Observations and Conclusions (Section 4.5)
- Water Quality Model Overview (Section 5.1)
- Modeled Parameters (Section 5.2)
- Reach Group Representation (Section 5.3)
- Temperature Representation (Section 5.4)
- Dissolved Oxygen Representation (Section 5.5)
- Sediment Representation (Section 5.6)
- Nutrient Representation (Section 5.7)
- Water Quality Development and Calibration (Section 5.8)
- Special Considerations for Water Quality (Section 5.9)
- Observed Water Quality Data Calibration and Validation (Section 5.10)
- Water Quality Observations and Conclusions (Section 5.11)

3.2 Watershed Delineation

In order to evaluate the sources contributing to an impaired waterbody and to represent the spatial variability of these sources within the watershed model, the contributing drainage area was represented by a series of sub-watersheds. The sub-watersheds were developed using the National Hydrography Dataset (NHD) catchment data layer (1:100,000) that was obtained from the United States Geological Survey (USGS). The Floyds Fork watershed consisted of 166 sub-watersheds, based on the NHD coverage (Figure 3-1). These sub-watershed representations were used as a guideline for further delineations.

The entire Floyds Fork watershed was further delineated into 202 sub-watersheds to provide appropriate hydrological connectivity. The sub-watersheds were delineated using the National Elevation Dataset (NED) in 1/3-arc-second resolution, USGS flow gage stations, USGS water quality monitoring stations and other points of interest. The NED coverage is shown in Figure 3-2 whereas, the USGS flow gage and water quality monitoring stations along with other points of interest for the Floyds Fork watershed is shown in Figure 3-3.

Occasionally, the delineations resulted in two sub-watersheds contributing to either a calibration or validation station location. Since the observed data at this station reflects hydrologic and water quality conditions of the combination of the two sub-watersheds, an additional sub-watershed was created to join the two sub-watersheds together. This was done to aid in comparing observed data and simulated results. In the Floyds Fork watershed, these additional sub watersheds were created at 19 locations. These additional sub-watersheds do not affect the calibration or validation of the model.

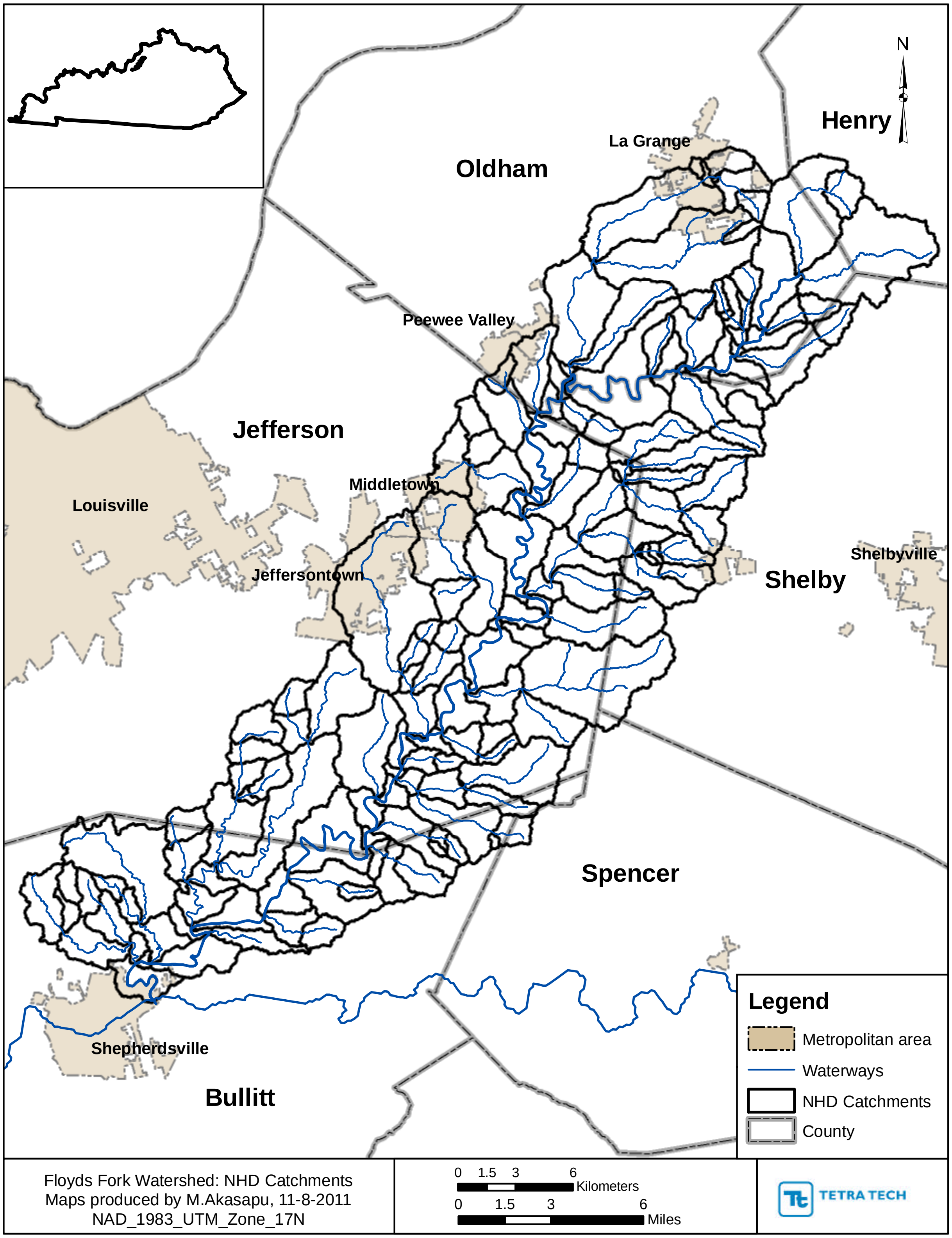


Figure 3-1 NHD Catchment Coverage for the Floyds Fork Watershed

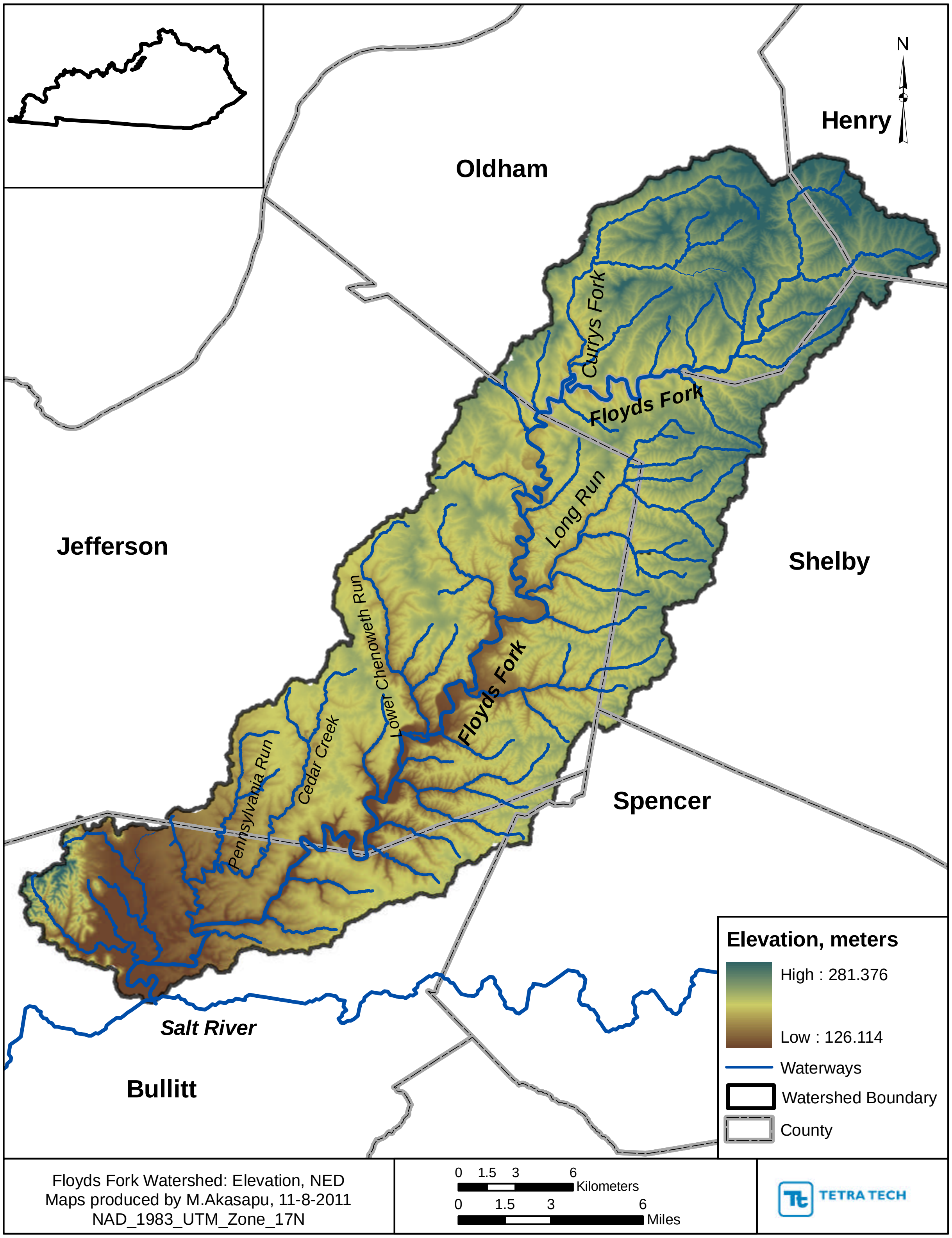


Figure 3-2 National Elevation Dataset (NED) Coverage of the Floyds Fork Watershed

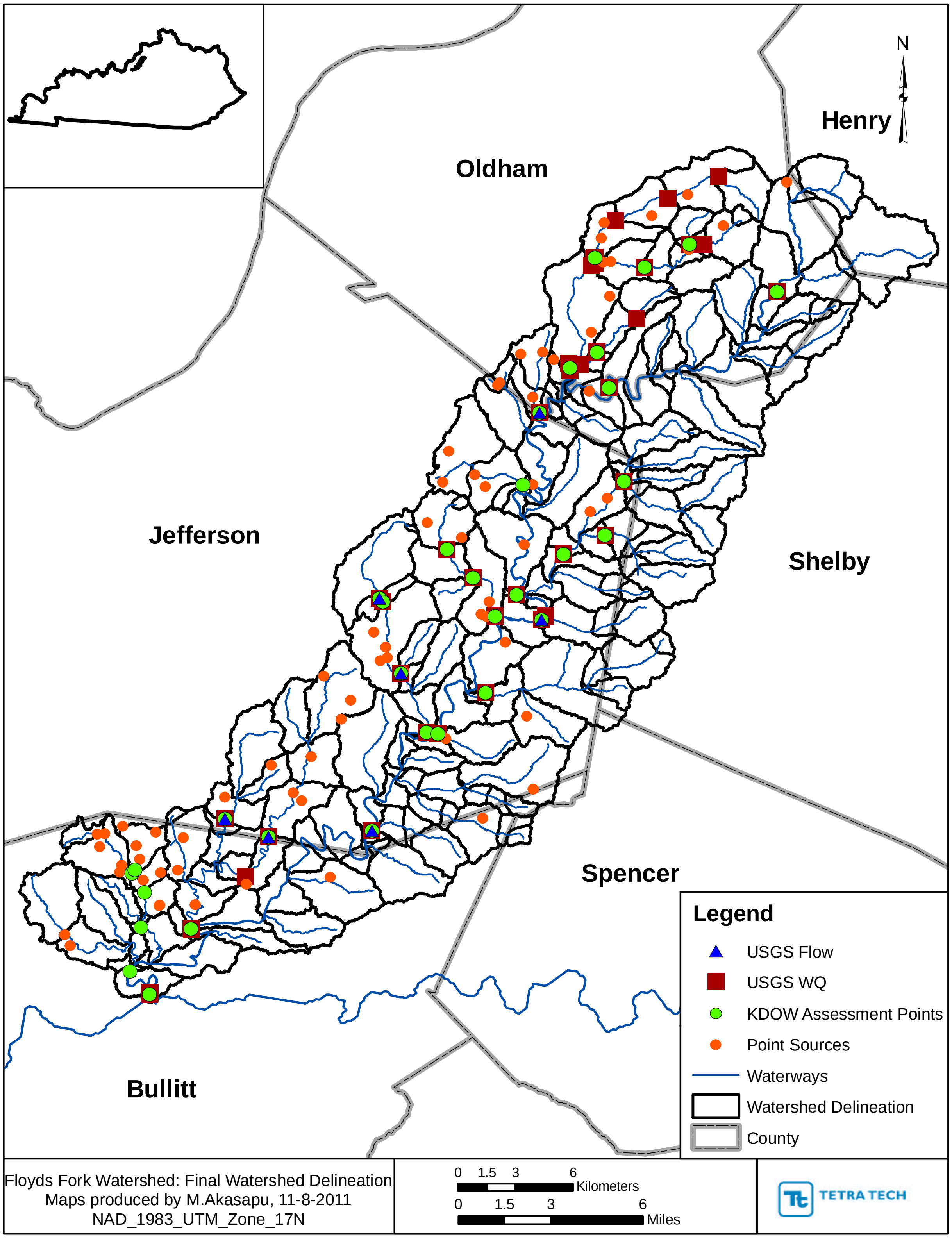


Figure 3-3 Sub-delineated Coverage for the Floyds Fork Watershed

3.3 Simulation Period

The USGS recommends looking at a minimum of a 10-year time period for hydrology calibrations. This is due to the fact that over a 10-year period, a variety of hydrological conditions will exist, and a model that is calibrated over this time period will have a greater chance of success in capturing the trends and processes as well as predicting future hydrological conditions. The LSPC model was simulated for the 10-year period from January 1, 2001 through December 31, 2010. This time period was selected due to the difficulty of acquiring data prior to 2001. In addition, this period captured wet, drought and normal years very well. To allow the model plenty of “spin-up” time, the model was run for a full year (January 2000 to December 2000) before the simulation period began.

3.4 Soils

Soils data for the Floyds Fork watershed was obtained from the Soil Survey Geographic Database (SSURGO). This database was produced and distributed by the Natural Resources Conservation Service (NRCS) - National Geospatial Management Center (NGMC), formerly National Cartography and Geospatial Center (NCGC). The SSURGO data was used to determine the total area that each hydrologic soil group covered within each sub-watershed. The sub-watersheds were represented by the Hydrologic Soil Group (HSG) that had the highest percentage of coverage within the boundaries of the sub-watershed. All of the Floyds Fork sub-watersheds were dominated by the Group C HSG as shown in Figure 3-4. The soil group is described below:

Group C Soils — Have low infiltration rates when thoroughly wet, thus having a moderate to high runoff potential, and consist chiefly of soils with a layer that delays the downward movement of water and soils with moderately coarse textures.

In LSPC, each dominant HSG within the study watershed is assigned a default group number. A standard approach for assigning HSGs to default group numbers included: Group A equals 1, Group B equals 2, Group C equals 3 and Group D equals 4. Although the soils coverage under the heavily impervious land use was labeled as ‘Not assessed’ (see Figure 3-4), in the LSPC model, it was assigned the HSG that covered the next highest area within the sub-watershed.

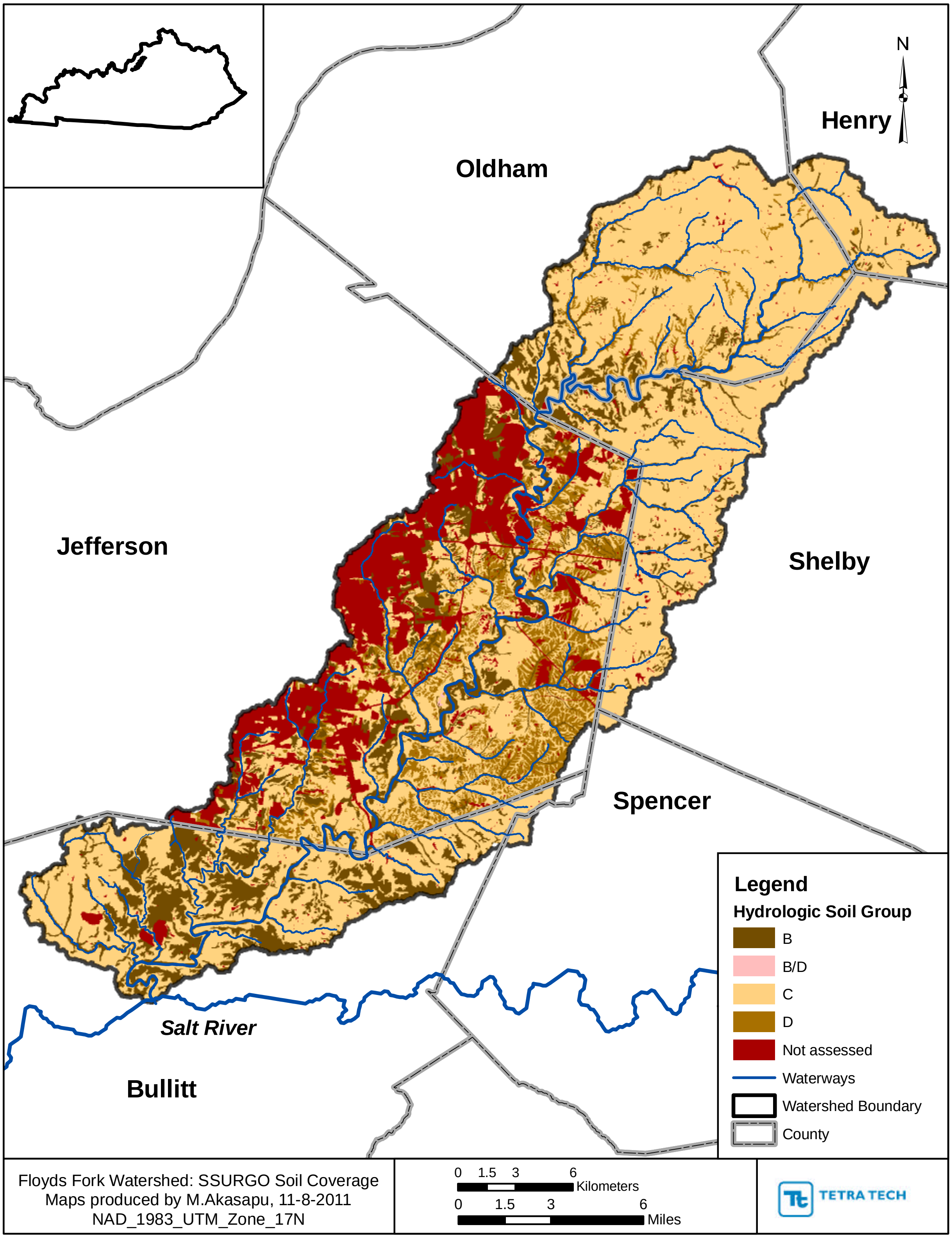


Figure 3-4 Soils Coverage for the Floyds Fork Watershed

3.5 Meteorological Data

Non-point source loadings and hydrological conditions are dependent on weather conditions. Hourly data from weather stations within the boundaries of, or in close proximity to the sub-watersheds were applied to the watershed model. An ASCII file (*.air) was generated for each meteorological and precipitation station used for the hydrologic evaluations in LSPC. Each meteorological and precipitation station file contains atmospheric data used for modeling of the hydrologic processes. These data include precipitation, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation. These data are used directly, or calculated from the observed data.

For the Floyds Fork watershed, 1 meteorological station, 1 mesonet and 37 precipitation stations were available, out of which 3 precipitation stations were used in the hydrologic simulations. Out of the 37 precipitation stations, 7 stations were from Jefferson County Municipal Sewer District (MSD) and the remaining were National Climate Data Center (NCDC) stations. The 39 total weather stations are listed in Table 3-1 and the 3 stations used in the hydrologic simulations have been highlighted. The percent of weather data patched for each of the weather stations is also tabulated in Table 3-1. These stations are shown spatially in Figure 3-5. The precipitation stations used in the model were NCDC Summary of the Day (SOD) and Surface Airways (SA) stations. SOD stations record daily precipitation, and daily minimum and maximum temperatures. Since SOD stations only provided daily precipitation and temperature, the NCDC SA station was used to disaggregate daily values to hourly as well as assign hourly values for dew point, wind speed, cloud cover, evaporation and solar radiation.

Weather stations were assigned to the sub-watersheds using a Thiessen polygon. If a particular watershed was intersected by the polygon boundary, it was assigned to the station that had the greatest area covered by that station's polygon.

Table 3-1 Available Weather Stations in the Floyds Fork Watershed

Weather Station	Staion ID	Station Name	Type	Agency	Elevation (ft)	State	County	Latitude	Longitude	% Complete	% Patched
1	13810_uo	Lou -Bowman Field Airport	Meteorological	NCDC	540	KY	Jefferson	38.228	-85.664	37	63
2	CRMT	Sheperdsville 6 Se	Mesonet	KY Mesonet	546	KY	Bullitt	37.920	-85.660	-	-
3	121814	Corydon	Precipitation	NCDC	590	IN	Harrison	38.218	-86.118	100	0
4	124977	Lexington 3 N	Precipitation	NCDC	630	IN	Scott	38.675	-85.603	78	22
5	127875	Scottsburg	Precipitation	NCDC	570	IN	Scott	38.689	-85.785	66	34
6	150397	Bardstown 5 E	Precipitation	NCDC	780	KY	Nelson	37.819	-85.385	100	0
7	150630	Bernheim Forest	Precipitation	NCDC	550	KY	Bullitt	37.916	-85.657	98	2
8	150875	Boston 6 Sw	Precipitation	NCDC	820	KY	Hardin	37.744	-85.748	100	0
9	150955	Brandenburg	Precipitation	NCDC	655	KY	Meade	37.956	-86.114	100	0
10	151251	Campbellsburg	Precipitation	NCDC	875	KY	Henry	38.516	-85.232	76	24
11	151900	Crestwood 4 Ne	Precipitation	NCDC	780	KY	Oldham	38.364	-85.419	100	0
12	152500	Elizabethtwn Ksp Pst 4	Precipitation	NCDC	780	KY	Hardin	37.712	-85.831	100	0
13	152512	Elizabethtown Wp C S	Precipitation	NCDC	687	KY	Hardin	37.679	-85.878	99	1
14	153030	Frankfort State Police	Precipitation	NCDC	755	KY	Franklin	38.179	-84.901	100	0
15	154954	Louisville Wsfo Ap	Precipitation	NCDC	481	KY	Jefferson	38.177	-85.730	100	0
16	154955	Louisville Upper Gage	Precipitation	NCDC	440	KY	Jefferson	38.283	-85.800	100	0
17	157334	Shepherdsville 5 Ne	Precipitation	NCDC	580	KY	Bullitt	38.054	-85.624	98	2
18	157604	Springfield	Precipitation	NCDC	760	KY	Washington	37.694	-85.234	100	0
19	157948	Taylorsville 2 Sw	Precipitation	NCDC	500	KY	Spencer	38.014	-85.371	100	0
20	154746	Lexington Bluegrass	Precipitation	NCDC	980	KY	Fayette	38.033	-84.600	100	0
21	IN1814	Corydon	Precipitation	NCDC	590	IN	Harrison	38.218	-86.118	31	69
22	IN6697	Palmyra	Precipitation	NCDC	770	IN	Harrison	38.408	-86.111	24	76
23	KY4954	Louisville Wsfo Ap	Precipitation	NCDC	481	KY	Jefferson	38.177	-85.730	64	36
24	KY4955	Louisville Upper Gage	Precipitation	NCDC	440	KY	Jefferson	38.283	-85.800	38	62
25	KY7074	Sadieville	Precipitation	NCDC	945	KY	Scott	38.408	-84.684	40	60
26	KY7096	St Mary	Precipitation	NCDC	743	KY	Marion	37.583	-85.350	0	100
27	KY7473	Smithfield 4 S	Precipitation	NCDC	850	KY	Shelby	38.333	-85.286	47	53
28	KY8719	Willisburg	Precipitation	NCDC	870	KY	Washington	37.801	-85.113	37	63
29	93820_uo	Klex - Blue Grass Airport	Precipitation	NCDC	980	KY	Fayette	38.041	-84.606	100	0
30	93821_uo	Ksdf - Louisville Intl-Standiford Field Ap	Precipitation	NCDC	488	KY	Jefferson	38.177	-85.730	100	0
31	63838_uo	7350 -University Of Kentucky	Precipitation	NCDC	891	KY	Woodford	38.094	-84.746	31	69
32	53841_uo	Fft - Capital City Airport	Precipitation	NCDC	804	KY	Franklin	38.185	-84.903	100	0
33	TR15	Jeffersontown Wqtc	Precipitation	MSD	594	KY	Jefferson	38.193	-85.555	-	-
34	TR09	Cedar Creek Wqtc	Precipitation	MSD	623	KY	Jefferson	38.119	-85.594	-	-
35	TR10	Camp Horine(Jefferson Forest)	Precipitation	MSD	873	KY	Jefferson	38.078	-85.753	-	-
36	TR11	Northern Ditch Ps	Precipitation	MSD	459	KY	Jefferson	38.158	-85.757	-	-
37	TR14	Lea Ann Way Ps	Precipitation	MSD	469	KY	Jefferson	38.148	-85.669	-	-
38	TR08	Fern Creek Fire Station #3	Precipitation	MSD	728	KY	Jefferson	38.127	-85.470	-	-
39	TR01	D. R . Guthrie Wqtc	Precipitation	MSD	433	KY	Jefferson	38.086	-85.893	-	-

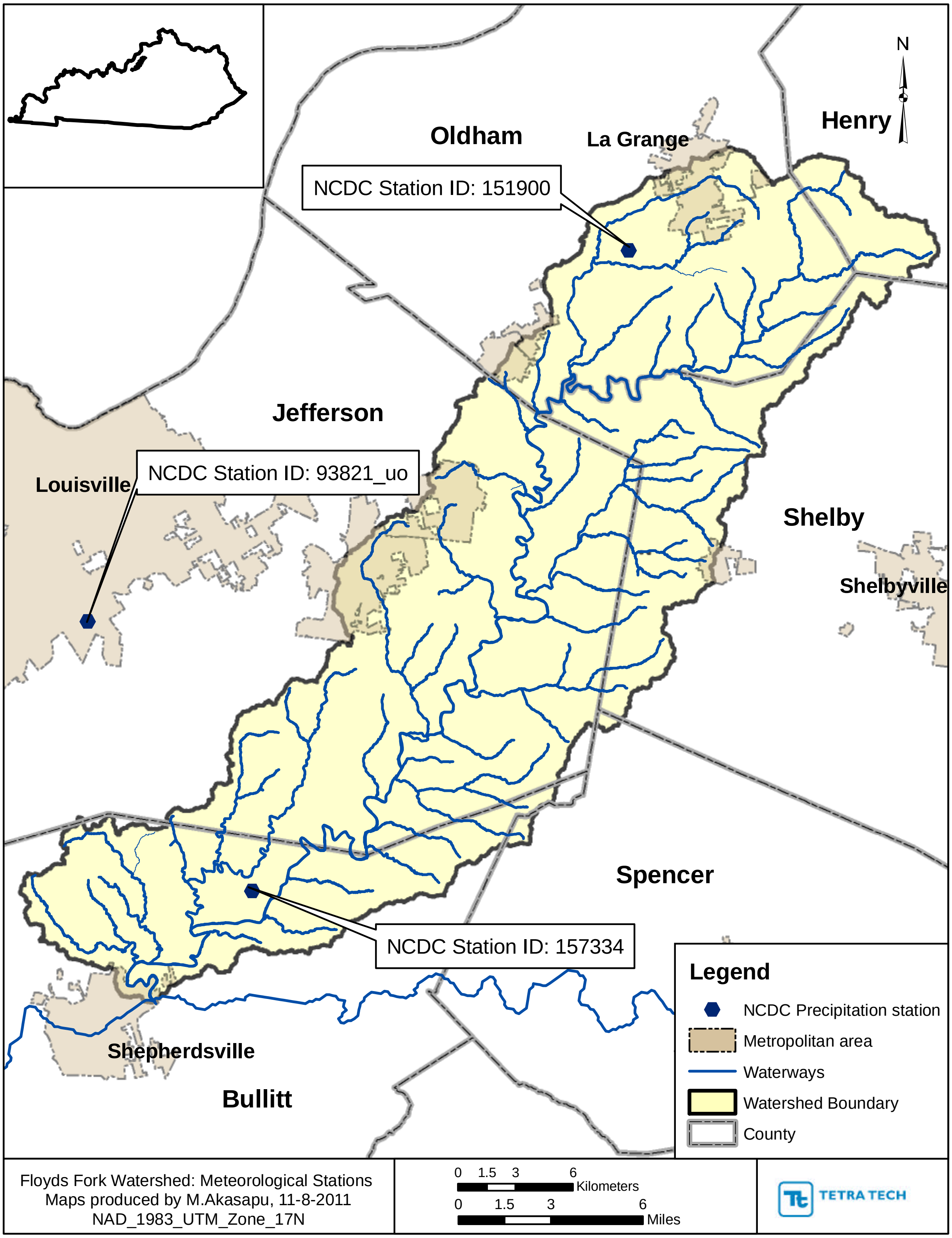


Figure 3-5 Location of Weather Stations used in the LSPC Watershed Model

3.6 Reach Characteristics

The LSPC model must have a representative reach defined for each sub-watershed. The characteristics for each reach include the length and slope of the reach, the channel geometry and the connectivity between the sub-watersheds. Length and slope data for each reach was obtained using the National Elevation Dataset (NED) and the National Hydrography Dataset (NHD). The channel geometry is described by a bank full width and depth (the main channel), a bottom width factor, a flood plain width factor and slope of the flood plain.

LSPC takes the attributes supplied for each reach and develops a function table, or FTABLE. The FTABLE describes the hydrology, of a river reach or reservoir segment, by defining the functional relationship between water depth, surface area, water volume, and outflow in the segment. The assumption of a fixed depth, area, volume, and outflow relationship rules out cases where the flow reverses direction or where one reach influences another upstream of it in a time-dependent way. The routing technique falls in the class known as "storage routing" or "kinematic wave" methods. In these methods, momentum is not considered (EPA, 2007).

3.7 Land Use Representation

The watershed model uses land use data as the basis for representing hydrology and non-point source loadings. Land use data was obtained from the Multi-Resolution Land Characteristics Consortium (MRLC) - National Land Cover Database (NLCD), and included the following 15-Class categories: Open Water, Developed Open Space, Developed Low Intensity, Developed Medium Intensity, Developed High Intensity, Barren, Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/Scrub, Grassland/Herbaceous, Pasture/Hay, Cultivated Crops, Woody Wetlands and Emergent Herbaceous Wetlands. The NLCD coverage represented conditions in the year 2006 and is shown in Figure 3-6. For the LSPC simulation, similar land use classes were grouped together into reduced modeling units (RMU) shown in Figure 3-7. For example, Deciduous Forest, Evergreen Forest and Mixed Forest were grouped together into an RMU called Forest.

The LSPC model requires division of land uses in each sub-watershed into separate pervious and impervious land units. For this, the NLCD impervious cover, Figure 3-8, was intersected with the NLCD land use cover. Any impervious areas associated with Developed Open Space and Developed Low Intensity, were grouped together and placed into a new RMU for Low Intensity Development Impervious. Impervious areas associated with Medium Intensity Development and High Intensity Development, were kept separate and placed into two new RMU's for Medium Intensity Development Impervious and High Intensity Development Impervious, respectively. Finally, any impervious area not already accounted for in the three developed impervious RMU's, were grouped together into a fourth new RMU, called "All Other Impervious".

Amendments were made to the NLCD land use in order to incorporate Failing Septic Tanks and Sinkholes into the model. Table 3-2 lists the land use categories used in the LSPC model with their respective areas. Sections 3.11 and 3.12 discuss where the data sets were obtained from, how they were processed, and how they were incorporated as unique land uses into the model.

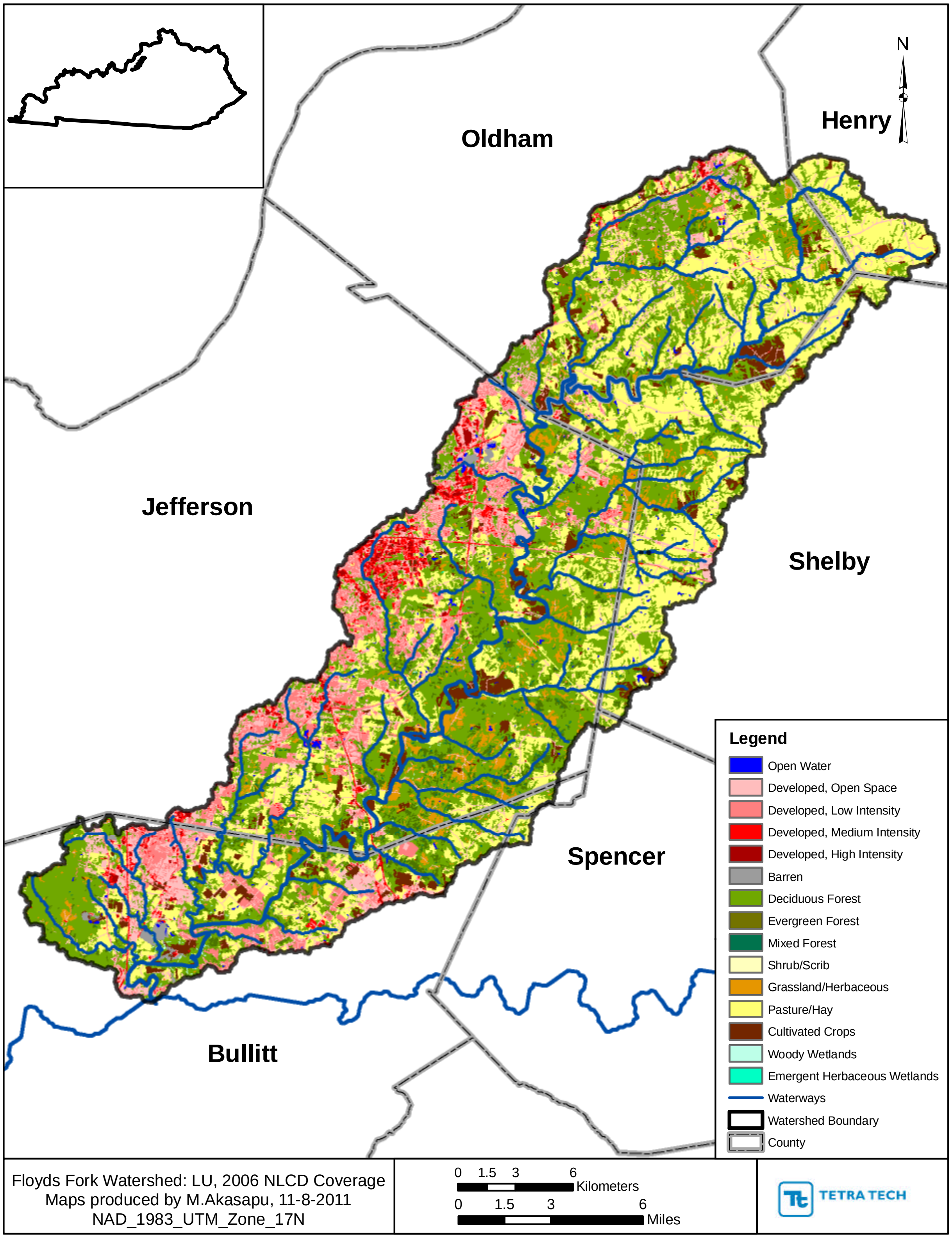


Figure 3-6 NLCD 2006 Coverage of the Floyds Fork Watershed

Table 3-2 Land Use Representation within the Floyds Fork LSPC Model

RMU Land Use Category	RMU Land Use Code	Original NLCD Classification	NLCD Land Use Code	Area (acres)	Area (%)
Water	1	11	Open Water	1108.53	0.61%
LowDevPerv	2	21	Developed, Open space	18209.81	10.00%
LowDevPerv	2	22	Developed, Low Intensity	10398.04	5.71%
MediumDevPerv	3	23	Developed, Medium Intensity	1884.20	1.03%
HighDevPerv	4	24	Developed, High Intensity	237.46	0.13%
Barren	5	31	Barren Land	499.57	0.27%
Forest	6	41	Deciduous Forest	72420.59	39.76%
Forest	6	42	Evergreen Forest	5088.63	2.79%
Forest	6	43	Mixed Forest	478.50	0.26%
Shrub	7	52	Shrub/Scrub	8.01	0.00%
Grassland	8	71	Grassland	6449.78	3.54%
Pasture	9	81	Pasture/Hay	48961.15	26.88%
Crop	10	82	Cultivated Crops	8378.59	4.60%
Wetlands	11	90	Woody Wetlands	880.06	0.48%
Wetlands	11	95	Emergent Herbaceous Wetlands	130.35	0.07%
LowDevImperv	12	222*	21+22, Low Intensity Impervious	2944.30	1.62%
MediumDevImperv	13	232*	23, Medium Intensity Impervious	2045.03	1.12%
HighDevImperv	14	242*	24, High Intensity Impervious	895.06	0.49%
AllOtherImperv	15	332*	Catchall Impervious	379.74	0.21%
FSS	16	888*	Failing Septics	629.61	0.35%
SinkWater	17	990*	Sinkhole Openwater	0.16	0.00%
SinkUrban	18	991*	21+22+23+24 Sinkhole Urban	29.63	0.02%
SinkBarren	19	992*	Sinkhole Barren	1.52	0.00%
SinkForest	20	993*	Sinkhole Forest	43.47	0.02%
SinkGrass	21	994*	Sinkhole Grassland	2.86	0.00%
SinkPasture	22	995*	Sinkhole Pasture	32.49	0.02%
SinkCrop	23	996*	Sinkhole Crop	22.01	0.01%
SinkWet	24	997*	Sinkhole Wetland	0.33	0.00%

* Codes/Classifications added after processing the additional land uses

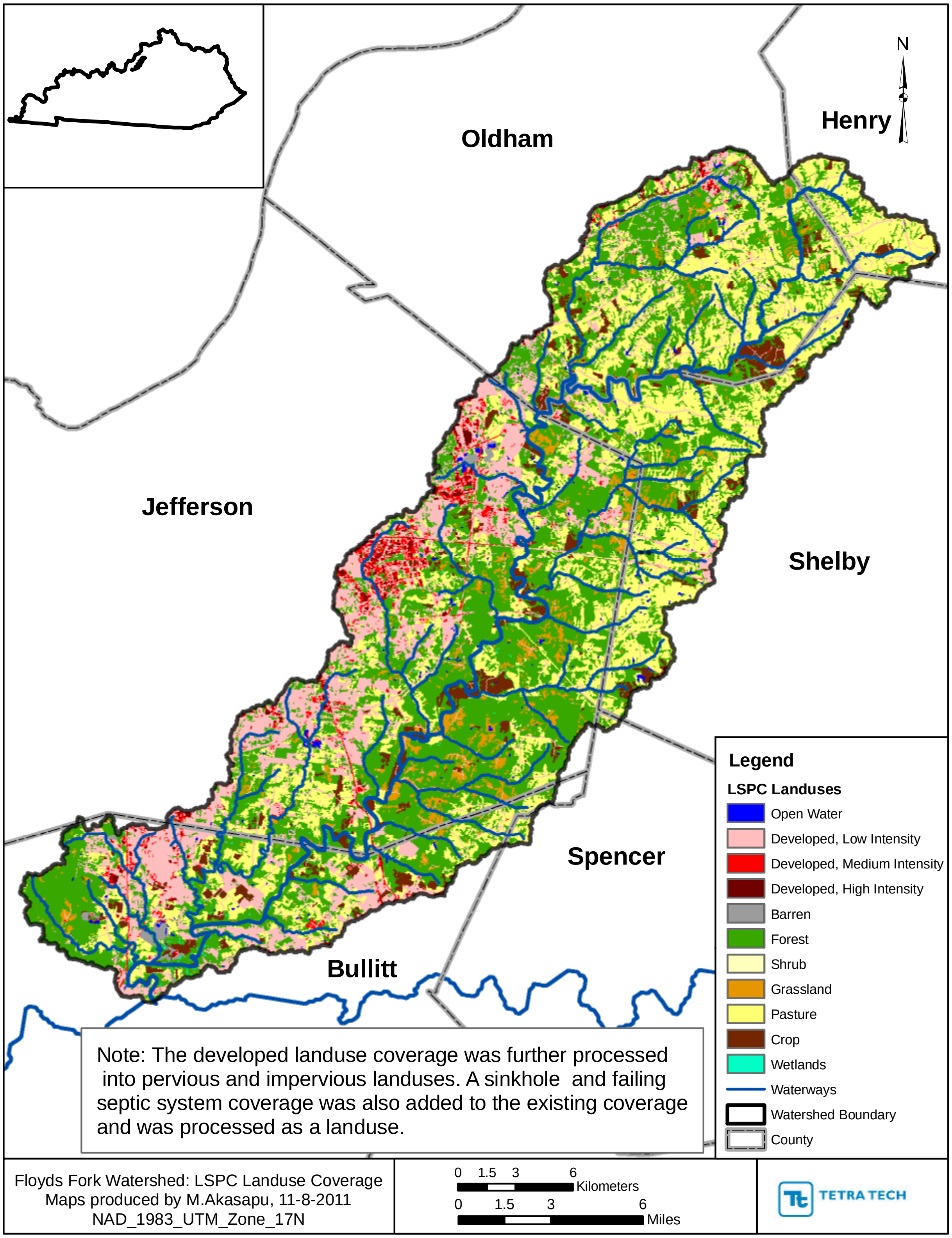


Figure 3-7 LSPC Land use Coverage of the Floyds Fork Watershed showing RMUs

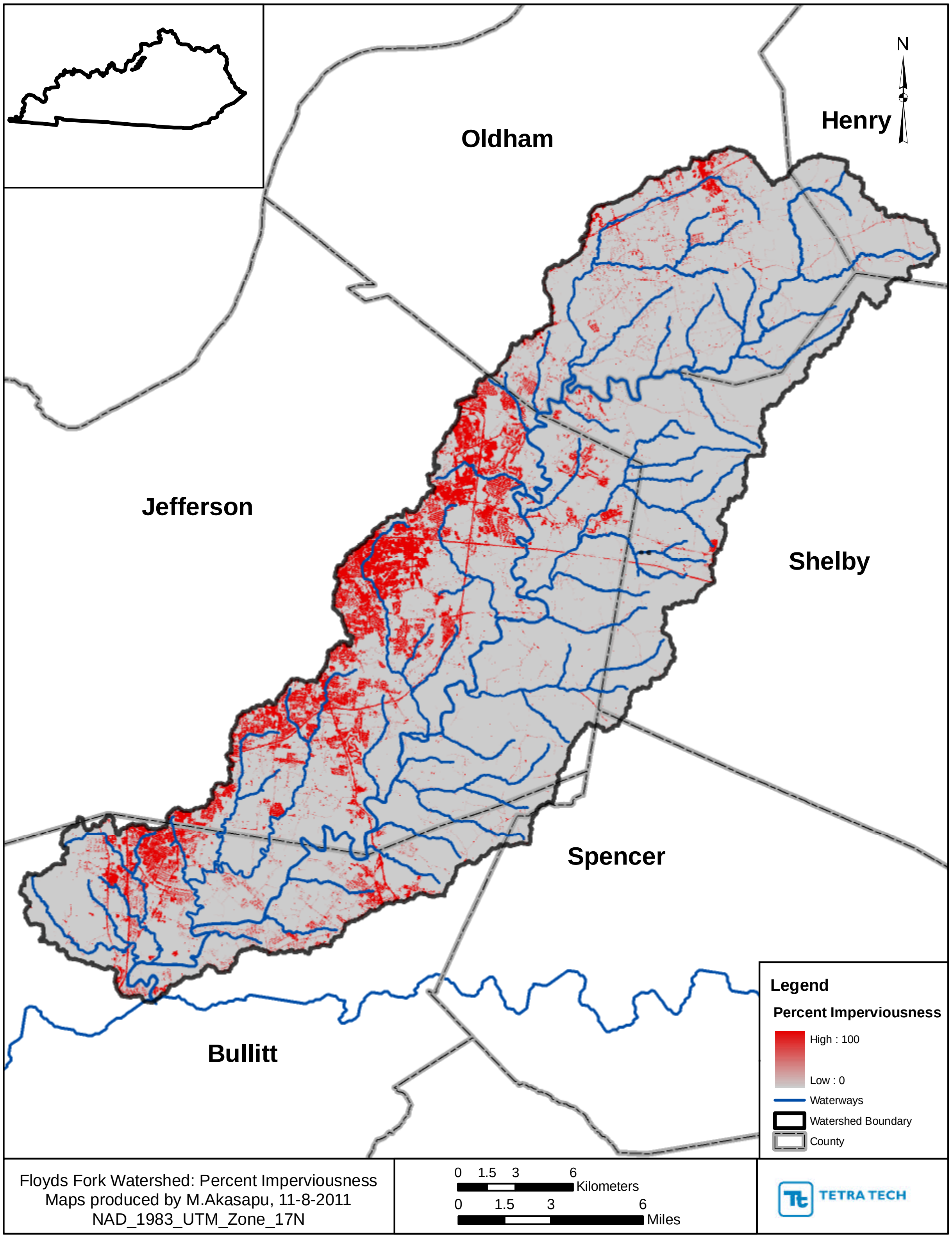


Figure 3-8 NLCD Impervious Coverage of the Floyds Fork Watershed

3.8 Point Source Discharges

Facilities permitted under the National Pollutant Discharge Elimination System (NPDES) are, by definition, considered point sources. There are 73 point source discharges located in the Floyds Fork watershed (Table 3-3 and Figure 3-9). Of the 73 point sources, 6 are Municipal, 20 are Subdivisions, 4 are Schools and 43 are Small Sewage (including general residences) facilities. Flows and effluent monitoring data for these point source discharges were obtained from both the Kentucky Division of Water (KDOW) and the Environmental Protection Agency's (EPA's) Permit Compliance System (PCS) in the form of Discharge Monitoring Reports (DMR). Data obtained from these reports were input directly into the LSPC model as monthly average time-series data from 2001 to 2010. Nine of the facilities were input into the model as monthly average time-series from 2001through 2007 and daily time-series from 2008 through 2010 and in some cases from 2007 through 2010.

Many of the permitted dischargers did not report loads or concentrations for one or more constituents used in the LSPC model. Therefore in these cases, default concentrations were assumed. This was especially true for temperature as none of the facilities are required by their permit to report effluent temperatures. The default concentrations adopted for the missing constituents are presented in Table 3-4 and Table 3-5. Two sets of default concentrations were developed for Major (>1 MGD) and Minor (<1 MGD) Municipal facilities. In assigning default concentrations, Subdivisions were treated the same as Schools.

KDOW provided default concentrations for the Small Sewage facilities (Table 3-5). To develop the default concentrations for the remaining facilities, KDOW first provided assumed influent concentrations for Kentucky's NPDES point sources. Averaged percent removal of nitrogen and phosphorus (Metcalf & Eddy 1991) along with the assumed influent concentrations, were then utilized to estimate the effluent concentrations. Typical effluent quality published by Metcalf and Eddy was utilized to estimate the default concentrations for BOD_5 and TSS.

There were 33 facilities with monthly effluent monitoring data. Out of those 33 facilities, 27 facilities had Total Phosphorus (TP) data and all 33 facilities had Ammonia (NH_3) data. In addition there were 4 facilities with TP, NH_3, Total suspended solids (TSS) and Dissolved Oxygen (DO) data. Some of the effluent monitoring data contained missing periods or data gaps. For these occurrences, if the gap was less than three months, then an average of the before and after gap value was supplied. If the gap was greater than three months, then the long term monthly average was supplied.

Of the 9 facilities with daily or sub-monthly effluent monitoring data, all had data for TP, NH_3, TSS and Biochemical oxygen demand (BOD_5) and only 3 facilities had DO data. Similar to the monthly average effluent monitoring data in the DMR's, the daily or sub-monthly DMR's also contained missing periods or data gaps. For these occurrences, if the gap was less than three days, then an average of the before and after gap value was supplied. If the gap was greater than three days, then the monthly average for that month was supplied.

Table 3-3 Summary of Point Source Discharges to the Floyds Fork Watershed

NPDES Number	Facility Name	Facility Type	Receiving Water	Sub-Watershed	Frequency of Input Data
KY0020001	Lagrange STP	Municipal	Currys Fork/North Fork Currys Fork/UT	213	Monthly
KY0023078	Whispering Oaks MFG Home Comm	Small Sewage*	Brooks Run/UT/Floyds Fork	116	Monthly
KY0024724	Ash Avenue STP	Subdivision	UT/Floyds Fork	197	Monthly
KY0025194	Jeffersontown WQTC MSD	Municipal	Chenoweth Run (Lower)	165	Daily
KY0026972	Bates Elementary School	Schools	Big Run/UT	151	Constant
KY0029416	Mcneely Lake WQTC MSD	Subdivision	UT/Pennsylvania Run	130	Sub-monthly
KY0029441	Green Valley Apartments	Small Sewage*	UT/South Fork Currys Fork/Currys Fork	222	Monthly
KY0029459	Chenoweth Hills WQTC MSD	Subdivision	UT/Chenoweth Run (Lower)	162	Sub-monthly
KY0031712	Starview Estates WQTC MSD	Subdivision	Chenoweth Run (Upper)	192	Sub-monthly
KY0031798	Cedar Lake Lodge, Inc.	Small Sewage*	UT/North Fork Floyds Fork/Floyds Fork	247	Monthly
KY0034151	Hillview Sewer System Plant #1	Subdivision	Cedar Creek/Tanyard Branch	124	Monthly
KY0034169	BCSD Hillview #2	Subdivision	UT/Brooks Run	119	Monthly
KY0034177	BCSD Hillview #3 (Maryville #3)	Subdivision	UT/Brooks Run	119	Monthly
KY0034185	Pioneer Village Sewer Plant #1	Subdivision	Brooks Run	115	Monthly
KY0034801	BCSD Bullitt Hills Subdivision	Subdivision	UT/Tanyard Branch	124	Monthly
KY0036501	Berrytown WQTC MSD	Subdivision	UT/Chenoweth Run (Upper)	192	Sub-monthly
KY0038610	Hunters Hollow Subd	Subdivision	Brooks Run	119	Monthly
KY0039004	KJC Institute for Women	Small Sewage*	Floyds Fork	198	Monthly
KY0039870	Lakewood Valley Subd STP	Subdivision	UT/South Fork Currys Fork/Currys Fork	220	Constant
KY0040193	Overdale Elementary School	Schools	Tanyard Branch/ Cedar Creek/ Floyds Fork	124	Constant
KY0042153	Cedar Ridge Camp, Inc.	Small Sewage*	UT/Floyds Fork	172	Monthly
KY0042226	Chenoweth Run WQTC	Subdivision	UT/Chenoweth Run (Upper)	191	Sub-monthly
KY0044342	Lake Of The Woods WQTC MSD	Subdivision	UT/Chenoweth Run (Lower)	162	Sub-monthly
KY0054674	Lockwood Estates Subd STP	Subdivision	South Fork Currys Fork/ Currys Fork	211	Monthly
KY0060577	Country Village STP	Subdivision	UT/Currys Fork	207	Monthly
KY0069485	Friendship Manor	Small Sewage*	UT/Floyds Fork	196	Monthly
KY0072168	Big Valley MHP	Small Sewage*	Bluelick Creek	106	Monthly
KY0073059	Camp Shantituck Girl Scout CMP	Small Sewage*	Cedar Creek	122	Constant
KY0076732	Centerfield Elementary School	Schools	Currys Fork/South Fork Currys Fork	211	Constant
KY0076741	Cherrytree Apartments	Small Sewage*	Floyds Fork	199	Constant
KY0077666	The Crossings Golf Club	Small Sewage*	Brooks Run	117	Constant
KY0077674	Lake Columbia Subdivision	Subdivision	Cedar Creek/UT	133	Constant
KY0086843	Middletown Industrial Park	Small Sewage*	Chenoweth Run (Upper)	191	Monthly
KY0090956	Persimmon Ridge Phase 14	Subdivision	Floyds Fork	228	Monthly
KY0094307	BCSD Willabrook Sanitation	Subdivision	Brooks Run	116	Monthly
KY0098540	Cedar Creek WQTC MSD	Municipal	Cedar Creek	135	Daily
KY0100994	Bullitt Co BD of ED	Schools	Brooks Run/UT	114	Monthly
KY0101419	Kingswood Subd	Subdivision	Broad Run	293	Constant
KY0101885	Riedling Building	Small Sewage*	Tanyard Branch	124	Monthly
KY0102784	Floyds Fork WQTC MSD	Municipal	Floyds Fork	185	Daily
KY0102873	Brooks Mobile Home & RV Park	Small Sewage*	Brooks Run	116	Monthly
KY0103110	Buckner STP	Municipal	UT/North Fork Currys Fork	210	Monthly
KY0103900	Hillview STP	Municipal	UT/Brooks Run/Floyds Fork	116	Monthly
KY0105384	Advanced Child Care West	Small Sewage*	Ditch/UT/Floyds Fork	203	Monthly
KYG400010	Edaward A Zuercher Jr. Residence	Small Sewage*	Back Run	293	Constant
KYG400028	Anthony T Aulbach Residence	Small Sewage*	Pope Lick/UT	178	Constant
KYG400032	Melvin & Shirley Williams Residence	Small Sewage*	Cedar Creek	137	Constant
KYG400082	Reed Wilcox Residence	Small Sewage*	Floyds Fork/UT	199	Constant
KYG400105	Maria E McCarson Residence	Small Sewage*	North Fork Currys Fork	210	Constant
KYG400112	Charles G Parrot Residence	Small Sewage*	North Fork Currys Fork	212	Constant
KYG400128	Kamal Fathaltzadeh Residence	Small Sewage*	Long Run/UT	259	Constant
KYG400137	Raymond R Peters Sr. Residence	Small Sewage*	Pennsylvania Run	132	Constant
KYG400139	Ernest & Patricia Entin Residence	Small Sewage*	Cedar Creek/UT	134	Constant
KYG400147	Ebbs Residence	Small Sewage*	Currys Fork/Floyds Fork	207	Constant
KYG400150	Robert & Mary Miller Residence	Small Sewage*	Chenoweth Run (Lower)	162	Constant
KYG400153	Victor J Diorio Jr. Residence	Small Sewage*	Floyds Fork	174	Constant
KYG400161	Mckee Residence	Small Sewage*	Razor Branch	163	Constant
KYG400166	James L Shipp Residence	Small Sewage*	Cedar Creek	134	Constant
KYG400177	William E Berryman Residence	Small Sewage*	Cedar Creek	137	Constant
KYG400189	Susan Weis Residence	Small Sewage*	Brush Run	171	Constant
KYG400194	Ken & Alice Weber Residence	Small Sewage*	Pope Lick	178	Constant
KYG400235	Steven & Cheryl Powers Residence	Small Sewage*	Floyds Fork/UT	195	Constant
KYG400250	Joe and Pam Brooks Residence	Small Sewage*	Long Run/UT	259	Constant
KYG400251	Marguerite R Weber Residence	Small Sewage*	Chenoweth Run (Lower)	162	Constant
KYG400259	Dennis & Sherry Ballard Residence	Small Sewage*	Floyds Fork/ UT	174	Constant
KYG400289	Patricia H Gibson Residence	Small Sewage*	South Fork Currys Fork	211	Constant
KYG400329	Larry & Angelyn Carlisle Residence	Small Sewage*	Brooks Run/UT	116	Constant
KYG400403	Chris Freundenburger Residence	Small Sewage*	Sheckels Run	285	Constant
KYG400420	Melvin Seals Residence	Small Sewage*	Bluelick Creek	106	Constant
KYG400613	Brad Murrell Residence	Small Sewage*	Floyds Fork/UT	189	Constant
KYG401875	Wood Residence	Small Sewage*	Wells Run	141	Constant
KYG401905	Fladung Residence	Small Sewage*	Broad Run	298	Constant
KYG402142	Carpenter Residence	Small Sewage*	Pope Lick	174	Constant

Small Sewage* includes general residences as well

3.8.1 Nutrient Speciation

Nitrogen and phosphorus sub-species ratios were computed using in-stream monitoring data. For minor point source discharges with measured TP and/or NH_3 data, the phosphorus and nitrogen sub-species were calculated using the in-stream ratios shown below.

Organic Phosphorus = Total Phosphorous * 0.43

Orthophosphate = Total Phosphorous * 0.57

Ammonia = Total Nitrogen * 0.02

Nitrite-Nitrate = Total Nitrogen * 0.78

Organic Nitrogen = Total Nitrogen * 0.20

For major point source discharges with measured TP and/or NH_3 data, the phosphorus and nitrogen sub-species were calculated using the in-stream ratios shown below.

Organic Phosphorus = Total Phosphorous * 0.55

Orthophosphate = Total Phosphorous * 0.45

Ammonia = Total Nitrogen * 0.03

Nitrite-Nitrate = Total Nitrogen * 0.86

Organic Nitrogen = Total Nitrogen * 0.11

If the point source discharge, either major or minor, did not have measured TP data, then the default value was applied for TP for that facility type and the Organic Phosphorus and Orthophosphate concentrations were then calculated using the ratios above. For facilities with measured NH_3 data, the default values were applied for Nitrate+Nitrite and Organic Nitrogen concentrations. All the concentrations from the Nitrogen species were then summed to get TN concentration. If the point source discharge did not have measured NH_3 data, then the default TN value was used for that facility type and the individual species were then calculated using the ratios above.

KDOW provided TP, NH_3 and TKN (Total Kjehdahl Nitrogen) data for 9 facilities, of which 5 were used to calculate the individual nitrogen and phosphorus species for those facilities. Of the 9 facilities, 3 were majors (>1 MGD) and contained daily data. Therefore, the speciation ratios were used for these facilities to develop daily time-series. There was one facility under the subdivision/school category with speciation ratios. The nitrogen and phosphorus species were quantified using these ratios for the remaining 6 facilities under this category with sub-monthly data. However, for McNeely Lake WQTC MSD (KY00296416, Subdivision/School), speciation ratios for City of Lagrange (KY0020001, < 1 MGD, Municipal) were provided for better representation of the data with respect to the measured data. Table 3-6 shows the nutrient speciation ratios used in the model for the 5 facilities with daily/sub-monthly data.

For facilities with daily/sub-monthly measured NH_3 data, Nitrate+Nitrite and Organic Nitrogen concentrations were calculated by first determining the assumed Total Nitrogen concentration using the NH_3 to TN ratio, then multiplying the TN by the ratios for Nitrate+Nitrite and Organic Nitrogen.

Table 3-4 Assumed Water Quality Concentrations for Municipal facilities/ Subdivisions/ Schools without Data

Parameter ID	Name	Assumed concentrations/ Temperature		
		Minor (<1 MGD)	Major (>1 MGD)	Subdivisions/ Schools
TP	Total Phosphorus	2.3	1.0	1.2
PO4	Orthophosphate	1.3	0.5	0.7
OrgP	Organic Phosphorus	1.0	0.5	0.5
TN	Total Nitrogen	17.0	10.0	8.0
NH3	Ammonia	0.4	0.3	0.2
NOx	Nitrite-Nitrate	13.3	8.6	6.3
OrgN	Organic Nitrogen	3.3	1.1	1.6
BOD_5	5-day Biochemical Oxygen Demand	10.0	5.0	10.0
DO	Dissolved Oxygen	5.0	5.0	5.0
TSS	Total Suspended solids	20.0	20.0	20.0
Chlorophyll-a	Chlorophyll-a	0.0	0.0	0.0
WTEMP	Water Temperature	15° C October through March 25° C April through	15° C October through March 25° C April through	15° C October through March 25° C April through

Table 3-5 Assumed Water Quality Concentrations for Small Sewage facilities without Data

Parameter ID	Name	Assumed concentrations/ Temperature	
		Small Package WWTP's	Individual Family Residences
TP	Total Phosphorus	4.0	4.0
PO4	Orthophosphate	3.0	3.0
OrgP	Organic Phosphorus	1.0	1.0
TN	Total Nitrogen	20.0	20.0
NH3	Ammonia	12.0	12.0
NOx	Nitrite-Nitrate	0.0	0.0
OrgN	Organic Nitrogen	8.0	8.0
BOD_5	5-day Biochemical Oxygen Demand	10.0	10.0
DO	Dissolved Oxygen	5.0	5.0
TSS	Total Suspended solids	30.0	30.0
Chlorophyll-a	Chlorophyll-a	0.0	0.0
WTEMP	Water Temperature	15° C October through March 25° C April through September	15° C October through March 25° C April through September

Table 3-6 Nutrient speciation ratios used for the facilities with daily/sub-monthly data

NPDES Number	NPDES Name	Design Flow, MGD	Type of Facility	Speciation Ratios				
				NH_3	NO_X	ORGN	PO_4	ORGP
KY0020001	City of Lagrange	0.8	Municipal (<1 MGD)	0.1	0.8	0.1	0.7	0.3
KY0025194	Jeffersontown WQTC MSD	4.0	Municipal (>1 MGD)	0.1	0.8	0.1	0.3	0.7
KY0034151	Hillview # 1 Outfall	0.2	Subdivision/School	0.4	0.2	0.4	0.9	0.1
KY0098540	MSD Cedar Creek WQTC	7.5	Municipal (>1 MGD)	0.1	0.8	0.1	0.2	0.8
KY0102784	MSD Floyds Fork WQTC	3.3	Municipal (>1 MGD)	0.1	0.8	0.1	0.8	0.2

3.8.2 Adjustments to Default Concentrations

During the calibration it was observed that at a couple stations, the default concentrations that were applied were affecting the results. This mainly occurred at water quality stations that were highly dominated by point source loading for which the point source did not have measured DMR data. To improve the calibration, the default concentrations for those facilities were changed accordingly.

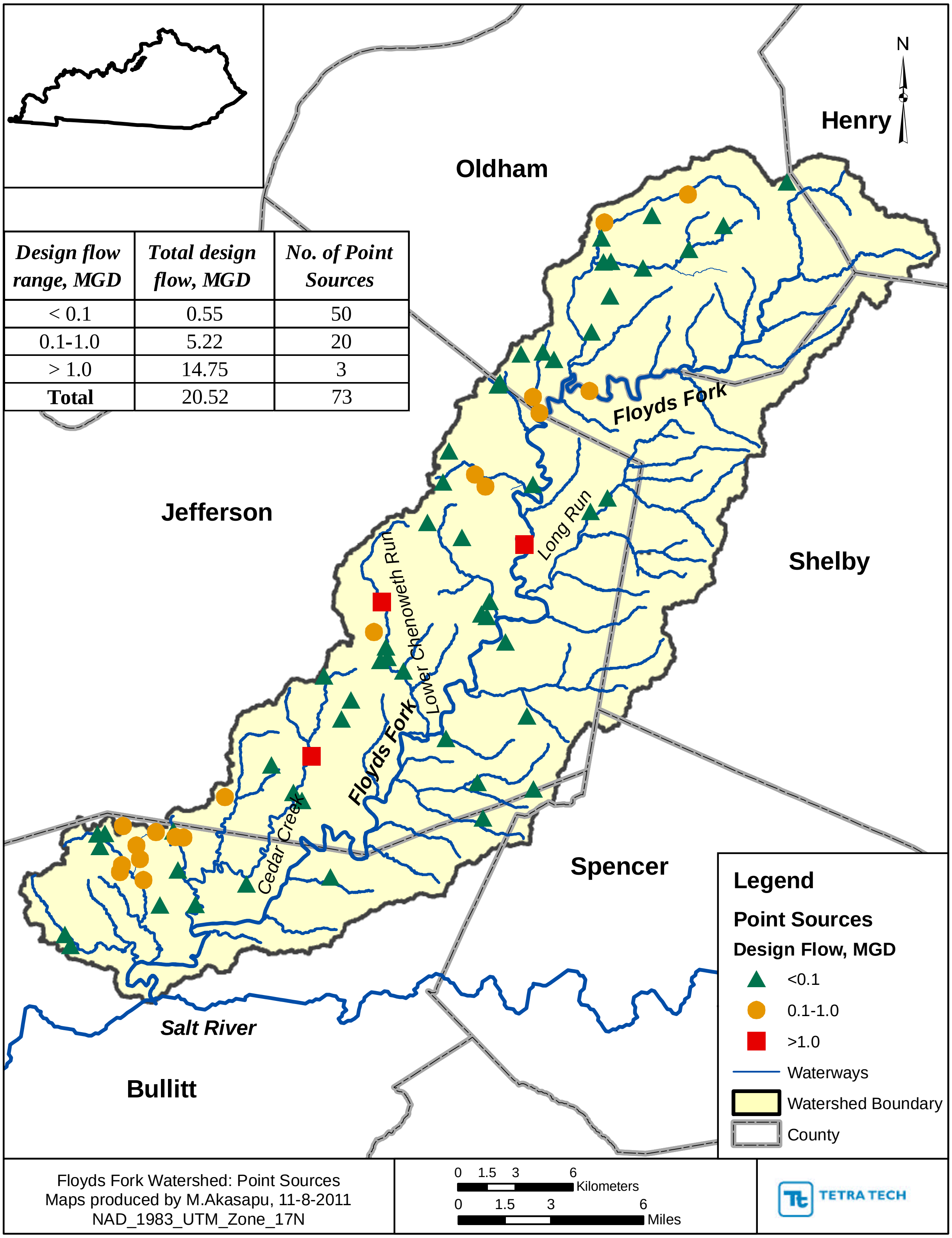
The BOD_5 calibration on the Chenoweth Run (Lower) was affected by the assumed default concentrations. The simulated results for BOD_5 concentrations at the confluence of Chenoweth Run (Lower) and Razor Branch were higher with a magnitude of 9 mg/L compared to the measured concentrations of < 5mg/L. Among the four point source discharges upstream of the station, the one with the highest design flow (KY0029459) was impacting the results the most. The default concentration for BOD_5 was decreased from 10 to 5 mg/L to better capture the magnitude. With the adjusted default value the results were greatly improved and the simulated BOD_5 was in the range of 4-6mg/L. This was the only point source where the default value of BOD_5 was changed. The remaining facilities were assigned the defaults as mentioned in Table 3-4 and Table 3-5.

Similarly, for the TP calibration on an unnamed tributary (UT) to South Fork Currys Fork, the assumed default concentration for TP was affecting the results at USGS station 03297850. The simulated concentrations were not capturing the peaks of the measured data. With the measured TP concentrations up to 3.5 mg/L at this water quality station, the default concentration for TP was increased from 2 to 3 mg/L for facility KY0039870 to improve the results. Table 3-7 summarizes the defaults assigned to all the point source discharges.

Table 3-7 Assumed Water Quality Concentrations for all Point Source Discharges

NPDES Number	Facility Type	Design Flow, MGD	Defaults/DMR concentrations, mg/L										
			TSS	Chlorophyll-a	BOD5	DO	TP	PO4	Organic P	TN	NH3	NOX	Organic N
KY0020001	Municipal	0.775	DMR	0.0	10.0	DMR		Calculated			DMR	19.5	4.8
KY0023078	Small Sewage*	0.125	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0024724	Subdivision	0.300	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0025194	Municipal	4.000	DMR	0.0	DMR	DMR		Calculated			DMR	Calculated	
KY0026972	Schools	0.013	20.0	0.0	10.0	5.0	1.2	0.7	0.5	8.0	0.2	6.3	1.3
KY0029416	Subdivision	0.205	DMR	0.0	DMR	5.0	DMR	Calculated			DMR	Calculated	
KY0029441	Small Sewage*	0.030	20.0	0.0	10.0	5.0	4.0	3.0	1.0	Calculated	DMR	Calculated	
KY0029459	Subdivision	0.200	DMR	0.0	DMR	5.0	DMR	Calculated			DMR	Calculated	
KY0031712	Subdivision	0.100	DMR	0.0	DMR	5.0	DMR	Calculated			DMR	Calculated	
KY0031798	Small Sewage*	0.020	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0034151	Subdivision	0.231	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0034169	Subdivision	0.317	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0034177	Subdivision	0.148	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0034185	Subdivision	0.310	20.0	0.0	10.0	5.0	1.2	0.7	0.5	Calculated	DMR	Calculated	
KY0034801	Subdivision	0.350	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0036501	Subdivision	0.075	DMR	0.0	DMR	5.0	DMR	0.7	0.5	8.0	DMR	6.3	1.6
KY0038610	Subdivision	0.240	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0039004	Small Sewage*	0.125	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0039870	Subdivision	0.100	20.0	0.0	10.0	5.0	3.0	1.7	1.3	8.0	0.2	6.3	1.6
KY0040193	Schools	0.010	20.0	0.0	10.0	5.0	1.2	0.7	0.5	8.0	0.2	6.3	1.6
KY0042153	Small Sewage*	0.005	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0042226	Subdivision	0.470	DMR	0.0	DMR	DMR		Calculated			DMR	Calculated	
KY0044342	Subdivision	0.044	DMR	0.0	DMR	5.0	DMR	0.7	0.5	8.0	DMR	6.3	1.6
KY0054674	Subdivision	0.045	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0060577	Subdivision	0.060	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0069485	Small Sewage*	0.017	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0072168	Small Sewage*	0.070	20.0	0.0	10.0	5.0	4.0	3.0	1.0	Calculated	DMR	Calculated	
KY0073059	Small Sewage*	0.010	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KY0076732	Schools	0.010	20.0	0.0	10.0	5.0	1.2	0.7	0.5	8.0	0.2	6.3	1.6
KY0076741	Small Sewage*	0.008	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KY0077666	Small Sewage*	0.005	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KY0077674	Subdivision	0.012	20.0	0.0	10.0	5.0	1.2	0.7	0.5	8.0	0.2	6.3	1.6
KY0086843	Small Sewage*	0.160	20.0	0.0	10.0	5.0	4.0	3.0	1.0	Calculated	DMR	Calculated	
KY0090956	Subdivision	0.142	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0094307	Subdivision	0.120	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0098540	Municipal	7.500	DMR	0.0	DMR	DMR		Calculated			DMR	Calculated	
KY0100994	Schools	0.043	20.0	0.0	10.0	5.0	1.2	0.7	0.5	Calculated	DMR	Calculated	
KY0101419	Subdivision	0.040	20.0	0.0	10.0	5.0	1.2	0.7	0.5	8.0	0.2	6.3	1.6
KY0101885	Small Sewage*	0.001	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0102784	Municipal	3.250	DMR	0.0	DMR	DMR		Calculated			DMR	Calculated	
KY0102873	Small Sewage*	0.015	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0103110	Municipal	0.135	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0103900	Municipal	0.150	20.0	0.0	10.0	5.0	DMR	Calculated			DMR	Calculated	
KY0105384	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	Calculated	DMR	Calculated	
KYG400010	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400028	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400032	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400082	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400105	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400112	Small Sewage*	0.000	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400128	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400137	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400139	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400147	Small Sewage*	0.000	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400150	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400153	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400161	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400166	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400177	Small Sewage*	0.000	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400189	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400194	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400235	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400250	Small Sewage*	0.000	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400251	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400259	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400289	Small Sewage*	0.000	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400329	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400403	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400420	Small Sewage*	0.000	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG400613	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG401875	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG401905	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0
KYG402142	Small Sewage*	0.001	20.0	0.0	10.0	5.0	4.0	3.0	1.0	20.0	12.0	0.0	8.0

Small Sewage* includes general residences as well



Design flow range, MGD	*Total design flow, MGD*	*No. of Point Sources*
< 0.1	0.55	50
0.1-1.0	5.22	20
> 1.0	14.75	3
Total	20.52	73

Figure 3-9 Permitted Discharges to the Floyds Fork Watershed

3.9 Sanitary Sewer Overflows

Sanitary Sewer Overflows (SSOs) are occasional, yet unintentional discharges of raw sewage from municipal sanitary sewers. Apart from SSOs, Combined Sewer Overflows (CSOs) contain stormwater in addition to untreated human and industrial waste. The untreated sewage from these discharges has a high risk of contaminating the waters causing serious water quality problems (EPA, 2011). Data on CSOs/SSOs for the Floyds Fork watershed model was obtained from the Kentucky Pollutant Discharge Elimination system's (KPDES) DMR and the incident and facility reports on Sanitary Sewer Overflows. The data was validated by the Water Quality Treatment Center Reports posted on MSD's Project WIN website (www.msdlouky.org/projectwin/). Project WIN is MSD's program to respond to the Federal Consent Decree to resolve violations of the Clean Water Act for untreated overflows from MSD's separate and combined sewer systems.

According to the CSOs/SSOs overflow locations published on Project WIN, there were no CSO's in the Floyds Fork watershed. However, SSOs from 27 NPDES facilities were reported for their respective WQTC permit (Table 3-9 and Figure 3-10). These unintentional discharges were caused mainly by a lack of system capacity, storm flows, structural failures and in some cases, bypasses at the treatment centers.

The reported discharge amount for the SSOs was utilized to develop flow time-series inputs on a daily scale. To develop daily time-series inputs for loads, published concentrations for typical composition of untreated domestic wastewater of medium or weak strength was used based on the impact observed at the facilities (Table 3-8) (Metcalf & Eddy, 1991). Flows and loads for the SSO's were only developed for the days with data (i.e., only when SSO's occurred). It was assumed that for all other days, there were no SSO's, so the flow and loads were zero.

Table 3-8 Assumed Water Quality Concentrations for SSOs

Parameter ID	Name	Assumed concentrations/ Temperatures		
		Strong	Medium	Weak
TP	Total Phosphorus	15.0	8.0	4.0
PO4	Orthophosphate	10.0	5.0	3.0
OrgP	Organic Phosphorus	5.0	3.0	1.0
TN	Total Nitrogen	85.0	40.0	20.0
NH3	Ammonia	50.0	25.0	12.0
NOx	Nitrite-Nitrate	0.0	0.0	0.0
OrgN	Organic Nitrogen	35.0	15.0	8.0
BOD_5	5-day Biochemical Oxygen Demand	400.0	220.0	110.0
DO	Dissolved Oxygen	10.0	10.0	10.0
TSS	Total Suspended solids	350.0	220.0	100.0
Chlorophyll-a	Chlorophyll-a	0.0	0.0	0.0
WTEMP	Water Temperature	15° C October through March 25° C April	15° C October through March 25° C April	15° C October through March 25° C April

Table 3-9 Data on SSOs

Source: Incident and Facility reports			
NPDES Point Source	No. of events recorded	No. of events quantified	Range of Dates
KY0020001	93	26	12/18/2002-11/26/2010
KY0023078	1	0	6/1/2003
KY0024724	87	19	1/2/2003-10/2/2009
KY0025194	140	70	7/9/2003-12/10/2010
KY0029416	4	4	5/2/2008-7/22/2010
KY0029441	17	8	2/21/2003-9/9/2009
KY0029459	21	19	3/31/2004-12/8/2010
KY0031712	10	6	9/8/2003-5/2/2010
KY0034151	9	2	8/20/2003-12/12/2010
KY0034169	10	2	1/25/2005-9/14/2008
KY0034177	7	2	5/26/2006-9/14/2008
KY0034185	24	6	5/9/2005-10/9/2009
KY0034801	15	0	2/23/2003-6/23/2008
KY0036501	9	5	1/2/2003-5/2/2010
KY0038610	90	51	4/18/2003-11/30/2010
KY0039004	4	2	9/14/2008-2/19/2010
KY0039870	7	5	11/12/2003-7/29/2009
KY0042153	3	0	5/23/2003-9/20/2007
KY0042226	13	13	6/13/2003-10/12/2010
KY0044342	1	0	8/24/2007
KY0054674	14	7	1/16/2004-9/27/2009
KY0060577	20	7	2/21/2003-7/9/2009
KY0069485	5	2	5/23/2007-7/10/2008
KY0077674	8	5	1/1/2003-5/6/2010
KY0086843	6	2	7/28/2003-7/21/2010
KY0090956	4	0	3/4/2008-11/29/2010
KY0094307	3	1	2/1/2003-9/14/2008
KY0098540	64	49	1/2/2003-11/16/2010
KY0100994	4	0	1/10/2003
KY0101419	12	6	5/20/2003-11/26/2010
KY0102784	26	18	5/5/2003-11/19/2010
KY0103110	96	91	8/25/2003-10/28/2009
KY0103900	25	2	9/2/2003-9/19/2010
Source: DMR			
NPDES Point Source	No. of events recorded	No. of events quantified	Range of Dates
KY0025194	-	155	1/2/2005-12/10/2010
KY0029416	-	4	5/3/2008-7/22/2010
KY0029459	-	17	4/4/2008-12/8/2010
KY0031712	-	5	1/24/2008-5/2/2010
KY0036501	-	5	3/13/2006-5/2/2010
KY0039004	-	0	-
KY0042226	-	20	1/1/2005-10/12/2010
KY0044342	-	0	-
KY0098540	-	47	1/4/2005-11/16/2010
KY0102784	-	16	3/9/2005-11/19/2010

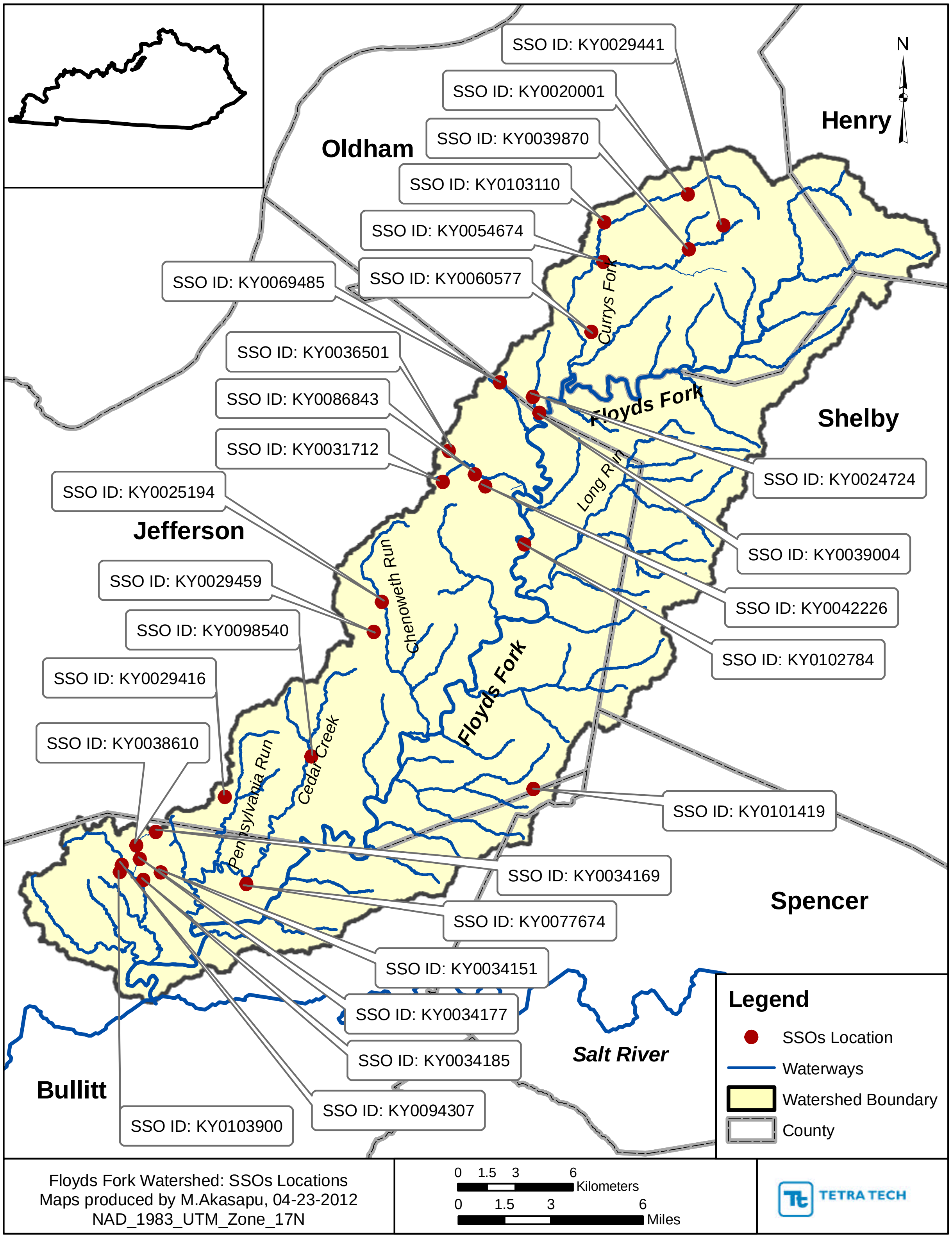


Figure 3-10 SSOs identified in the Floyds Fork Watershed

3.10 Industrial Water Withdrawals

There are 11 industrial water withdrawals located in the Floyds Fork watershed that were represented in the LSPC watershed model (Table 3-10). Monthly average water withdrawal data were obtained from KDOW. For security purposes, the locations of the water withdrawals cannot be disclosed.

Table 3-10 Summary of Industrial Withdrawal in the Floyds Fork Watershed

Withdrawal Name	Permit Number	Source Water	Sub-Watershed	Monthly Permitted Withdrawal	
				Month	Limit (MGD)
KY Solite Corp	0987	Large reservoir south of Brooks Run	107	October - March	0.202
				April - September	0.310
Persimmon Ridge Subdivision	1020	Irrigation lake#1	228	October - April	0.000
				May - September	0.300
Persimmon Ridge Subdivision	1090	Irrigation lake#1	228	November - February	0.000
				March - October	0.300
Quail Chase Golf Club	1093	McNeely lake, an impoundment of Pennsylvania Run	131	December - March	0.000
				April and November	1.000
				May - October	1.250
Polo Fileds Golf Course	1257	Polo fields Lake, an impoundment of Brush Run	187	November - March	0.000
				April and October	0.250
				May - September	0.500
Polo Fileds Golf Course	1258	Polo fields Lake, an impoundment of Brush Run	187	November - March	0.000
				April and October	0.250
				May - September	0.500
Action Landscape, Inc.	1264	RM 4.3 OF Chenoweth Run	167	March - May and September	0.010
				June	0.018
				July - August	0.024
Midland Trail Golf Club	1315	RM 37.55 of Floyds Fork	185	December - February	0.000
				March and November	0.250
				April - May and October	0.500
				June and Spetember	0.800
Rogers Group, Inc.- Bullitt Co Stone	1353	Bullitt County Stone quarry pit	109	January - December	1.100
Rogers Group, Inc.- Jefferson Co Stone	1355	Jefferson County Stone quarry	192	January - December	0.350
The Cardinal Club, LLC	1460	RM 5.2 of South Long Run (impoundment), a tributary of Long Run	278	October - April	0.000
				May - September	0.100

3.11 Septic Tanks

Information on septic systems was obtained from the County's health departments. The data obtained was either a rough estimate of the number of septic tanks in the County or a rough percentage of the homes running on septic tanks. A rough estimate of the septic tanks was provided by the County health departments in Henry, Oldham and Shelby County. In addition, a rough percentage of homes running on septic tanks were obtained from the Bullitt and Spencer County's health departments. The counties with data on estimated septic tanks were used to estimate septic tanks in the watershed. However, for the counties with limited information from the County health departments, such as Jefferson County, data on septic tanks for the year 1990 was retrieved from the 1990 Census Report. This Census was used as it was the last Census that contained information on septic systems. Factors like increase in population and housing from the year 1990 until 2010 was used to extrapolate the 1990 number of septic tanks to get data estimated values for the year 2010. The number of septic tanks in Jefferson County in the year 2010 was further validated using the data obtained from Jefferson County MSD. Therefore, each County had information on the number of septic tanks that reflected the number of existing septic tanks in the year 2010.

The number of total septic tanks in each sub-watershed was determined through an area weighting method. Sub-watersheds were assigned to counties based on their outfall or pour point. The percentage of County area, represented by the sub-watersheds assigned to that County, was used to determine the total number of septic tanks represented in those sub-watersheds. The number represented in each sub-watershed was determined by area weighting the individual sub-watershed to the total area of each watershed assigned to the same County.

Septic tanks contribute to water quality whether they are functioning properly or failing. Both failing and non-failing septics were modeled to incorporate the transport of pollutants from all septics. Often times the scum layer on top of the wastewater hardens on the liquid surface which results in clogging the tank's inlet/outlet. This causes the septic tanks to fail (AGR-166). Therefore, a failing septic, as represented in the model, contributed pollutant to the land surface and was available for runoff to the streams during rain events, and non-failing septics contributed to the groundwater. For all counties, except for Oldham, it was assumed, that at any given time, there are 20% of the overall number of septic tanks that are failing, and 80% that are working properly. However, Oldham County had a reported annual failing percentage of 30% that was assigned to the overall number of septic tanks. The portion of the septic tanks that were considered failing were modeled as a land use (Failing Septic) because it was assumed that no decay occurs and raw effluent is directly applied to the land. It was determined that the average area of a septic field is 6,750 ft^2 (Inspectapedia 2009). The land use that was represented for Failing Septics was subtracted from the Low Intensity Urban Pervious land use for each sub-watershed or Developed Open Space, if Low Intensity Urban Pervious land use was absent. For a few of the sub-watersheds there was no area under Low Intensity Urban Pervious or Developed Open Space. For these sub-watersheds, all of the land use for Failing Septics was assigned to the sub-watershed downstream of it. The non-failing septic tanks were modeled as very small individual point sources for each sub-watershed. Section 5.9 further discusses how both failing and non-failing septic tanks were handled in the water quality model.

3.12 Sinkholes

The Floyd's Fork watershed falls in the Outer Bluegrass physiographic region characterized by deep valleys followed by little flat land and karst features like sinkholes and springs. At the confluence of Floyds Fork with the Salt River, two tributaries, Blue Lick creek and Clear Run along with western portion of Brooks run fall in the Knobs physiographic region (KGS 2011). With the presence of Karst features, the ground water becomes vulnerable to pollution due to the rapid rate of flow and lack of natural filtration system for the contaminants. The transportation of the pollutants between the surface water and the ground water gets affected and results in pollution of the groundwater and contamination of the wells and eventually the surface water.

As shown in Figure 3-11, the Floyds Fork watershed has three karst classifications: 'Karst Major', 'Karst Minor' and 'Non-Karst'. 'Karst Major' represents the areas of high potential for karst and it covers 18% of Floyds Fork watershed. In addition, Karst Minor represents the areas of low potential of karst development and it covers 76% of the region. The remaining area has little to no potential for karst development. The classification of the potential for karst development was based on the field experience of Geologists from the Kentucky Geological Survey (KGS) and the percentage of land underlain by limestone and other carbonate rocks. The most significant karst feature in the Floyds Fork watershed is sinkholes. A sinkhole is a depression in the surface of the ground that is formed when a fracture in the limestone becomes enlarged (Currens 2002). KGS has identified 416 sinkholes in the Floyds Fork watershed covering an area of 0.207 sq. miles.

Sinkholes were processed as a separate land use in the Floyds Fork watershed model to assign representative parameters with respect to the karst features. The coverage for sinkholes was intersected with the sub-watersheds to assign each of the intersected sinkhole to a sub-watershed. It was then processed with the NLCD land use coverage and percent impervious coverage to estimate the land use under the sinkholes. The sinkholes were processed under 8 land use categories: Open Water, Urban, Barren, Forest, Grassland, Pasture/Hay, Cultivated Crops and Wetland. The land use that was represented by the sinkholes was subtracted from the respective land uses in the model. The Urban land use for sinkhole was the sum of the Pervious Developed Open Space, Low Intensity, Medium Intensity and High Intensity developments and was subtracted from its respective land use categories before the summation as Urban land use.

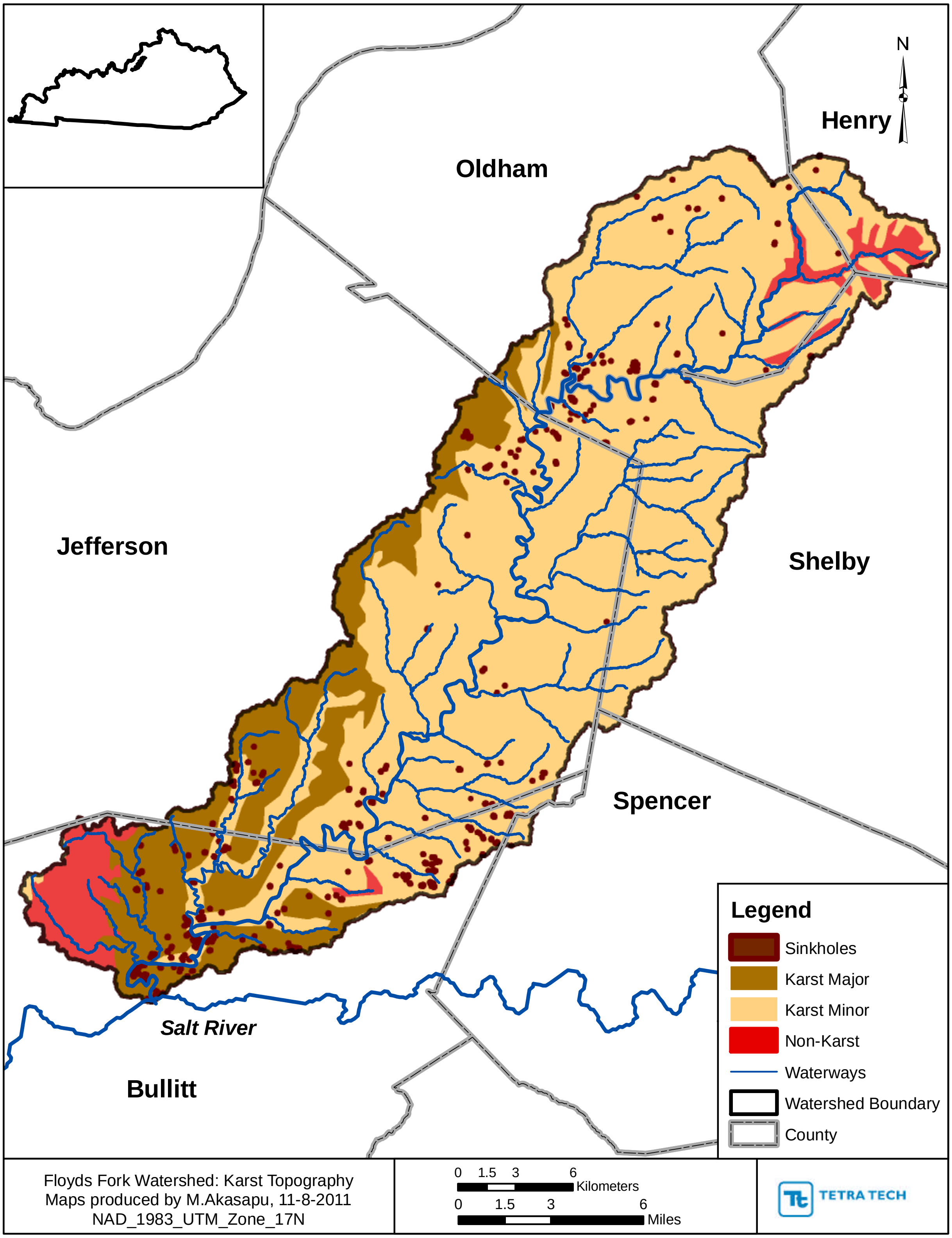


Figure 3-11 Sinkholes in the Floyds Fork Watershed

3.13 Springs

In addition to Sinkholes, another significant karst feature are subsurface springs. Springs are sites where the groundwater surfaces to become surface water. This generally occurs along the creeks and rivers where the top of the groundwater meets the land surface. The discharge at a spring can have large volumes as the water discharging is the collective water flowing from each of the sinkholes joined together underground (Currens 2002).

USGS has identified 20 springs in the Floyds Fork watershed which are concentrated along the main stem of Floyds Fork (Figure 3-12). A list of the 20 springs with their respective discharges used in the model is tabulated in Table 3-11. The water quality concentrations used for the springs were average groundwater concentrations taken from KGS's groundwater-quality database of the Kentucky groundwater data repository (Table 3-12). The flow and groundwater concentration for the springs were input directly into the LSPC model as time-series from 2000 to 2010.

Table 3-11 Springs included in the Floyds Fork watershed model

Spring Number	USGS Name	County	Discharge, cfs
SPR1	E17CS001	Bullitt	0.10
SPR2	E17BS002	Jefferson	0.10
SPR3	E17BS004	Jefferson	0.10
SPR4	E17BS001	Jefferson	0.10
SPR5	E18AS002	Jefferson	0.10
SPR6	E18AS001	Jefferson	0.10
SPR7	E17BS003	Jefferson	1.30
SPR8	E17BS006	Jefferson	0.10
SPR9	E17BS005	Jefferson	0.10
SPR10	D18C009	Jefferson	0.05
SPR11	D18CS004	Jefferson	0.05
SPR12	D18CS006	Jefferson	0.05
SPR13	D18C005	Jefferson	0.05
SPR14	D18CS007	Jefferson	0.10
SPR15	D18CS008	Jefferson	0.10
SPR16	D18CS011	Shelby	0.05
SPR17	D18BS002	Oldham	0.05
SPR18	D18BS003	Oldham	0.05
SPR19	D18BS004	Oldham	0.10
SPR20	ANITA SPRGS. WATER CO. - 1185001	Oldham	0.10

Table 3-12 Averaged groundwater concentrations for Springs

Constituent	Average GW concentration, mg/L
TN	3.57
NH3	0.06
NOX	3.31
ORGN	0.20
TP	0.14
PO4	0.08
ORGP	0.06
DO	1.85
BOD5	0.55
WTEMP	15.09

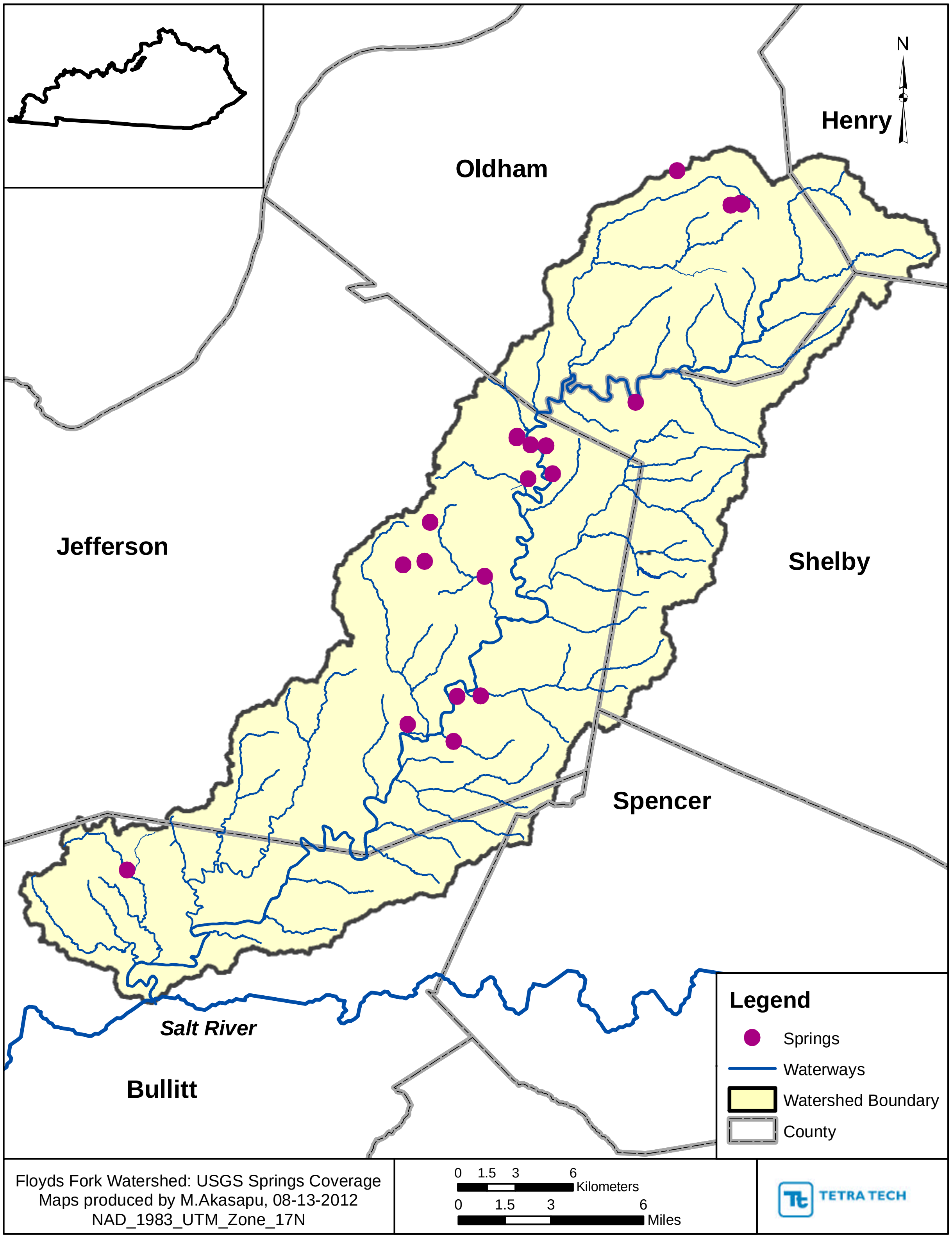


Figure 3-12 Springs in the Floyds Fork Watershed

3.14 Non-point source discharges

Pollution from diffuse sources, for instance, oil/grease from urban runoff or excess fertilizers/nutrients from livestock on agricultural lands, by definition, are non-point sources. It is difficult to estimate these sources as they are dispersed over a wide area and are variable in time. Nutrient loads from non-point sources, such as agricultural landuse, can be estimated based on applied fertilizer rates, crop requirements and livestock manure. For the Floyds Fork watershed model, loads from fertilizers and livestock manure were estimated for the Cropland and Pastureland landuse and are presented in sections 3.14.1-3. Nutrient loads from Golf Courses are presented in section 3.14.4. For all other landuses, nutrient loads were determined through calibration of the model.

3.14.1 Nutrient Loads from Fertilizers

Total Nitrogen (TN) and Total Phosphorus (TP) loads were estimated as average loading rates on a daily basis. The estimation of nutrient loads from fertilizers was based on the assumption that the farm fertilizer was applied only to Cropland. The tonnage report of the N and P_2O_5 based fertilizer was obtained from the quarterly distribution reports submitted by the University of Kentucky's Division of Regulatory Services. The tonnage reports provide data on the volume and distribution of fertilizer sales within the state of Kentucky. These reports state that some of data received from the companies show only the county to which the fertilizer was shipped to. Since the fertilizer shipped to one county may have been used in another, the information reported may not exactly represent fertilizers used in a given county. However, these publications seek to represent the fertilizer distribution in Kentucky as accurately as possible based on the available data, but the reported values do not necessarily reflect where the fertilizers are applied. This is particularly true in counties containing a fertilizer distribution center (e.g. Jefferson County). In counties without a distribution center (e.g. Bullitt, Henry, Oldham, Shelby, and Spencer counties), the amount exported may approximate the amount imported. However, the amount of fertilizer crossing county lines is not quantifiable. Therefore, when using the fertilizer data from the tonnage reports, it was assumed that the fertilizers sold in the County remained in the County. Data from 2007 was used to estimate the amount of fertilizers used in the six counties in the watershed. The 2007 report was used because the census data available for the crop yields were also for 2007. The 'All Fertilizer' for N and P_2O_5 based fertilizer in the quarterly reports, from January 2007 through December 2007, were summed to get the total fertilizer sales for the year 2007. The fertilizer application rates used in the Floyds Fork watershed are shown in Table 3-13. To get the application rates for Phosphorus, the P_2O_5 based fertilizer was divided by 2.3 (AGR-1). The fertilizer application rate was estimated based on the following equation.

$$\text{Fertilizer application rate}\left(\frac{\frac{\text{lbs}}{\text{acre}}}{\text{day}}\right) = \frac{\left(\begin{matrix}\text{Total amount of}\\ \text{Fertilizer used}\end{matrix} \times 2000\right) \times \dfrac{\text{Total Cropland area in the watershed}}{\text{Total Cropland area in the County}}}{(\text{Total Cropland area in the watershed}) \times (365)}$$

The crops used for Floyds Fork watershed model were Corn, Wheat, Soybeans and Tobacco. To represent the fertilizer rates for these crops better, the fertilizer application rates were divided equally among the crops except for Corn and Soybeans in Jefferson and Oldham counties (Table 3-14). According to USDA-NRCS, Jefferson and Oldham county farmers apply TN on corn annually ranging from 150-180 lbs/acre/year. The year they have soybeans, the average TN application is about 30 lbs/acre/year. The TP application ranges from 60-80 lbs/acre/year according to the same source. An average application of 165 lbs/acre/year for TN based fertilizer and 70 lbs/acre/year for TP based fertilizer was used in this model for Corn and Soybean for the two counties.

Table 3-13 Fertilizer application rates in the Floyds Fork Watershed

County	Total cropland area in the County (Acres)	Total cropalnd area in the watershed (Acres)	TN			TP		
			Total amount of fertilizer used (Tons)	Fertilizer application rate (Lbs/acre/year)	Fertilizer application rate (Lbs/acre/day)	Total amount of fertilizer used (Tons)	Fertilizer application rate (Lbs/acre/year)	Fertilizer application rate (Lbs/acre/day)
Bullitt	7253	1675	107	29.600	0.081	33	9.231	0.025
Henry	6421	208	2121	660.793	1.810	396	123.237	0.338
Jefferson*	4576	2846	2818	1231.513	3.374	361	157.920	0.433
Oldham*	7879	2380	767	194.782	0.534	150	37.967	0.104
Shelby	26685	1255	2840	212.887	0.583	653	48.978	0.134
Spencer	9118	3	490	107.405	0.294	127	27.849	0.076

* The fertilizer application rates were obtained from the 2007 Tonnage report. These are not the rates utilized in the watershed model. The rates for Corn and Soybean were obtained from USDA-NRCS.

Table 3-14 Fertilizer application rates for each crop in the Floyds Fork Watershed

County	N based Fertilizer application rate (Lbs/acre/day)				P based Fertilizer application rate (Lbs/acre/day)			
	Corn	Wheat	Soybeans	Tobacco	Corn	Wheat	Soybeans	Tobacco
Bullitt	0.020	0.020	0.020	0.020	0.006	0.006	0.006	0.006
Henry	0.453	0.453	0.453	0.453	0.084	0.084	0.084	0.084
Jefferson*	0.493	0.844	0.082	0.844	0.219	0.108	0.219	0.108
Oldham*	0.493	0.133	0.082	0.133	0.219	0.026	0.219	0.026
Shelby	0.146	0.146	0.146	0.146	0.034	0.034	0.034	0.034
Spencer	0.074	0.074	0.074	0.074	0.019	0.019	0.019	0.019

* The N and P based fertilizer application rates for Corn and Soybean for Jefferson and Oldham counties were obtained from USDA-NRCS.

Crops remove nutrients required for growth and development from the supply of nutrients from the fertilizers. By definition, crop nutrient removal rates are the quantity of nutrients removed from a harvested portion of the crop (AGR-1). The crop removal rates used for Floyds Fork watershed are a result of soil fertility research and soil test data in Kentucky. These rates are published by the University of Kentucky's Cooperative extension service (Table 3-15).

The literature crop nutrient removal rates at standard harvest moisture were used to estimate the crop removal rates for each County. To estimate these rates on a daily basis, the yield data for the representative crops was obtained from the 2007 Census Report except for Corn for Jefferson and Oldham counties. According to USDA-NRCS, the yield rate in the watershed for Corn is about 150-190 bushels/acre. The yield was back calculated for Corn for Jefferson and Oldham counties using 170 bushels/acre as the yield rate .The yield data used for the Floyds Fork watershed is tabulated in Table 3-16.

Table 3-15 Literature crop removal rates used in the Floyds Fork Watershed

Crop	Yield Unit	Nutrients removed, lbs/Yield unit	
		N	P_2O_5
Corn for grain	bu	0.7	0.4
Corn for silage	ton	7.5	3.5
Wheat for grain	bu	1.2	0.5
Soybeans	bu	3	0.7
Tobacco*	100 lbs	7	0.8

*Tobacco is the average of Burley, Dark-air and Dark fired tobacco.

Table 3-16 Yield data for crops used in the Floyds Fork Watershed

County	Corn for grain yield (Bushels)	Corn for silage or greenchop (Tons)	Wheat for grain yield (Bushels)	Soybeans yield (Bushels)	Tobacco yield (Lbs)
Bullitt	200939	6157	27479	80089	129460
Henry	259374	14942	5678	74610	5744800
Jefferson	869399**	0*	0*	49005	96900
Oldham	1496942**	6641	47309	87655	228030
Shelby	1821125	38736	91618	386029	5700798
Spencer	194361	0*	21250	56288	1278847

* Withheld to avoid disclosing data for individual farms.

** The Corn yield for Jefferson and Oldham counties was calculated based on the information on the yield rates from USDA-NRCS.

The crop removal rates were estimated using the following equations. As shown in the equation for crop removal rates for P, the removal rate was divided by 2.3 to convert P_2O_5 to P. The results are shown in Table 3-17.

$$\text{Crop removal rates for N}\left(\frac{\frac{\text{lbs}}{\text{acre}}}{\text{day}}\right) = \frac{\sum \begin{matrix}\text{Yield of}\\ \text{the crop}_c\end{matrix} \text{ x } \left(\begin{matrix}\text{Crop removal}\\ \text{rate}_c \text{ for N}\end{matrix}\right) \text{ x } \left(\frac{\text{Total Cropland area in the watershed}}{\text{Total Cropland area in the County}}\right)}{\left(\begin{matrix}\text{Total Cropland}\\ \text{area in the watershed}\end{matrix}\right) \text{ x } (365)}$$

$$\text{Crop removal rates for P}\left(\frac{\frac{\text{lbs}}{\text{acre}}}{\text{day}}\right) = \frac{\sum \begin{matrix}\text{Yield of}\\ \text{the crop}_c\end{matrix} \text{ x } \left(\begin{matrix}\text{Crop removal}\\ \text{rate}_c \text{ for N}\end{matrix}\right) \text{ x } \left(\frac{\text{Total Cropland area in the watershed}}{\text{Total Cropland area in the County}}\right)}{\left(\begin{matrix}\text{Total Cropland}\\ \text{area in the watershed}\end{matrix}\right) \text{ x } (365)}$$

where c represents the individual crop.

As shown in Table 3-18, the loading rates from fertilizers for each of the counties was calculated by subtracting the crop removal rates (Table 3-17) from the fertilizer application rates (Table 3-14). The crop removal rate for Corn for grain and Corn for silage was summed and then subtracted from the fertilizer application rate for Corn for the respective County. If the crop removal rate was greater than the fertilizer application rate then the loading rate was set to zero.

Table 3-17 Crop removal rates for the six counties in the Floyds Fork Watershed

County	TN removed, lbs/acre/day					TP removed, lbs/acre/day				
	Corn for grain	Corn for silage	Wheat for grain	Soybeans	Tobacco	Corn for grain	Corn for silage	Wheat for grain	Soybeans	Tobacco
Bullitt	0.053	0.017	0.012	0.091	0.003	0.013	0.004	0.002	0.009	0.000
Henry	0.077	0.048	0.003	0.096	0.172	0.019	0.010	0.001	0.010	0.008
Jefferson	0.364	0.000	0.000	0.088	0.004	0.091	0.000	0.000	0.009	0.000
Oldham	0.364	0.017	0.020	0.091	0.006	0.091	0.004	0.000	0.009	0.000
Shelby	0.131	0.030	0.011	0.119	0.041	0.033	0.006	0.002	0.012	0.002
Spencer	0.041	0.000	0.008	0.051	0.027	0.010	0.000	0.001	0.005	0.001

Table 3-18 Loading rates from Fertilizers for the six counties used in the Floyds Fork Watershed

County	TN, lbs/acre/day				TP, lbs/acre/day			
	Corn	Wheat	Soybeans	Tobacco	Corn	Wheat	Soybeans	Tobacco
Bullitt	0.000*	0.008	0.000*	0.017	0.000*	0.004	0.000*	0.006
Henry	0.327	0.450	0.357	0.281	0.055	0.084	0.075	0.076
Jefferson	0.129	0.844	0.000*	0.839	0.129	0.108	0.210	0.108
Oldham	0.111	0.114	0.000*	0.128	0.125	0.026	0.210	0.026
Shelby	0.000*	0.135	0.027	0.105	0.000*	0.032	0.021	0.032
Spencer	0.033	0.066	0.023	0.047	0.009	0.018	0.014	0.018

* The calculated crop removal rates were greater than the fertilizer application rates, therefore, was set to 0.

3.14.2 Nutrient Loads from Livestock Manure

Another economical and significant source of nutrients to Cropland and Pastureland is livestock manure. The nutrient content of manure varies by factors such as the type of animal, manure's moisture content and type and amount of bedding used (AGR-146). The manure production and characteristics published by Natural Resources Conservation Service (NRCS) and American Society of Agricultural Engineers (ASAE) was used to characterize the livestock manure (Table 3-17). The fresh manure characteristics for TN and TP were for 1000lbs of live animal per day (ASAE, 2003). The animals considered are: Beef cattle, Dairy cattle, Hogs and Pigs, Poultry (layer only) and Horses. The estimated nutrients produced by these animals were based on a typical live animal for which these manure values were reported.

Table 3-19 Typical manure characteristics used in the Floyds Fork watershed

Animal	Nutrient produced (Lbs)/animal/day	
	TN	TP
Dairy cow	0.603	0.221
Beef cow	0.345	0.096
Hogs and Pigs	0.040	0.017
Poultry (Layer)	0.004	0.007
Horses	0.300	0.071

For the Floyds Fork watershed model, it was assumed that the manure from Beef cattle, Dairy cattle, Hogs and Pigs, Poultry and Horses is applied to Cropland and manure from Beef cattle, Dairy cattle and Horses is also applied to Pastureland. The number of animals present in the County was obtained from the 2007 Census Report. The number of animals present in the watershed was area weighted between the County and watershed. The manure of the animals (Beef cattle, Dairy cattle and Horses) shared between Cropland and Pastureland was divided between the two based on their respective areas (Table 3-20). The manure loads for Cropland and Pastureland was estimated by multiplying the number of animals in the watershed (Table 3-20) by its respective manure nutrient content (Table 3-19). The manure loads for Cropland and Pasture land are presented in Table 3-21.

Table 3-20 Number of agricultural animals used in the Floyds Fork watershed

County	Cropland in the watershed (Acres)	Pastureland in the watershed (Acres)	Cropland area in the County (Acres)	Pastureland area in the County (Acres)	No. of Hogs	No. of Beef cattle		No. of Dairy cattle		No. of Horses		No. of Poultry
						Cropland	Pastureland	Cropland	Pastureland	Cropland	Pastureland	
Bullitt	1675	6417	7253	24564	103	194	745	12	48	60	229	336
Henry	208	3966	6421	90629	2	31	598	3	53	4	75	38
Jefferson	2846	12619	4576	19198	45	212	938	0	0	228	1011	703
Oldham	2380	12969	7879	40204	5	210	1145	18	100	140	765	202
Shelby	1255	12651	26685	125103	2	134	1349	17	170	42	423	225
Spencer	3	381	9118	39808	0	0	54	0	3	0	7	1

Table 3-21 Manure loads from Cropland and Pastureland used in the Floyds Fork watershed

County	N loads (Lbs/day)					P loads (Lbs/day)				
Cropland										
	Beef cattle	Dairy cattle	Horses	Poultry	Hogs	Beef cattle	Dairy cattle	Horses	Poultry	Hogs
Bullitt	67.056	7.524	17.968	1.477	4.094	18.638	2.754	4.252	2.321	1.780
Henry	10.844	1.673	1.176	0.167	0.075	3.014	0.613	0.278	0.263	0.033
Jefferson	73.020	0.000	68.416	3.089	1.809	20.295	0.000	16.192	4.855	0.787
Oldham	72.477	11.017	42.144	0.888	0.217	20.144	4.033	9.974	1.395	0.094
Shelby	46.183	10.143	12.598	0.990	0.096	12.836	3.713	2.981	1.555	0.042
Spencer	0.129	0.013	0.014	0.002	0.003	0.036	0.005	0.003	0.004	0.001
Pastureland										
County	N loads (Lbs/day)					P loads (Lbs/day)				
	Beef cattle	Dairy cattle	Horses	Poultry	Hogs	Beef cattle	Dairy cattle	Horses	Poultry	Hogs
Bullitt	256.940	28.828	68.849	-	-	71.415	10.553	16.294	-	-
Henry	206.362	31.844	22.385	-	-	57.357	11.656	5.298	-	-
Jefferson	323.765	0.000	303.351	-	-	89.988	0.000	71.793	-	-
Oldham	394.906	60.029	229.633	-	-	109.762	21.974	54.346	-	-
Shelby	465.555	102.251	126.992	-	-	129.398	37.429	30.055	-	-
Spencer	18.742	1.881	2.058	-	-	5.209	0.689	0.487	-	-

The fraction of manure applied each month and the manure incorporated into the soil for the individual animal was assumed based on best professional judgment. Based on these two fractions, the fraction of the manure incorporated into the soil every month was estimated. Based on the percent of nutrients available from the animal manure incorporated into the soil, the nutrients available for the crops were estimated. The fraction of animal manure taken up by the respective crop for Cropland was calculated using the following equations:

$$\begin{array}{c}\text{Fraction of monthly}\\ \text{manure incorporated}\\ \text{into the soil}\end{array} = \begin{array}{c}\text{Fraction of manure}\\ \text{applied each month}\end{array} \times \begin{array}{c}\text{Fraction of manure}\\ \text{incorporated into the soil}\end{array}$$

$$\begin{array}{c}\text{Monthly fraction of}\\ \text{animal manure taken}\\ \text{up by the crop}\end{array} = \sum \left[\begin{array}{c}\text{Fraction of manure}\\ \text{incorporated into the soil}\end{array} \times \begin{array}{c}\text{Fraction of manure}\\ \text{taken up by the crop}\end{array}_{c} \right]$$

where c is the fraction of manure taken up by: corn, soybean, tobacco and wheat.

The same methodology was applied for Pastureland and only forage crops were used for the estimation of these fractions. Table 3-22 shows the monthly fractions of Cattle manure taken up by the crops on Cropland and Pastureland. As tabulated in Table 3-23, the loading rates from livestock manure for Cropland and Pastureland for each of the six counties were calculated as shown below.

The monthly loading rate for Pastureland was estimated based on the following equation:

$$\text{Loading rate}\left(\frac{\text{lbs}}{\frac{\text{acre}}{\text{day}}}\right) = \frac{\sum \left[\left(1- \begin{array}{c}\text{Monthly fraction of}\\ \text{the animal manure}\\ \text{taken up by the crop}^{c}\end{array} \right) \times \left(\begin{array}{c}\text{Manure loads}\\ \text{for Pastureland}\end{array} \right) \right]}{\begin{array}{c}\text{Total Pastureland}\\ \text{area in the watershed}\end{array}}$$

where c is the monthly fraction of animal manure by the individual crop.

Table 3-22 Monthly fractions of Cattle manure taken up by crops from Cropland and Pastureland used in the Floyds Fork watershed

Cropland												
Month	January	February	March	April	May	June	July	August	September	October	November	December
P_2O_5	0.384	0.384	0.384	0.043	0.043	0.043	0.043	0.043	0.043	0.384	0.384	0.384
Nitrogen	0.204	0.204	0.204	0.023	0.023	0.023	0.023	0.023	0.023	0.204	0.204	0.204
Pastureland												
P_2O_5	0.096	0.096	0.096	0.011	0.011	0.011	0.011	0.011	0.011	0.096	0.096	0.096
Nitrogen	0.072	0.072	0.072	0.008	0.008	0.008	0.008	0.008	0.008	0.072	0.072	0.072

Table 3-23 Loading rates from Livestock Manure from Cropland and Pastureland for the six counties used in the Floyds Fork Watershed

Cropland												
TN, Lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
Bullitt	0.048	0.048	0.048	0.056	0.056	0.056	0.056	0.056	0.056	0.048	0.048	0.048
Henry	0.054	0.054	0.054	0.065	0.065	0.065	0.065	0.065	0.065	0.054	0.054	0.054
Jefferson	0.044	0.044	0.044	0.828	0.049	0.049	0.049	0.049	0.049	0.044	0.044	0.044
Oldham	0.045	0.045	0.045	0.054	0.051	0.051	0.051	0.051	0.051	0.045	0.045	0.045
Shelby	0.046	0.046	0.046	0.054	0.054	0.054	0.054	0.054	0.054	0.046	0.046	0.046
Spencer	0.050	0.050	0.050	0.092	0.060	0.060	0.060	0.060	0.060	0.050	0.050	0.050
TP, Lbs/acre/day												
Bullitt	0.012	0.012	0.012	0.017	0.017	0.017	0.017	0.017	0.017	0.012	0.012	0.012
Henry	0.013	0.013	0.013	0.019	0.019	0.019	0.019	0.019	0.019	0.013	0.013	0.013
Jefferson	0.011	0.011	0.011	0.014	0.014	0.014	0.014	0.014	0.014	0.011	0.011	0.011
Oldham	0.011	0.011	0.011	0.014	0.014	0.014	0.014	0.014	0.014	0.011	0.011	0.011
Shelby	0.011	0.011	0.011	0.016	0.016	0.016	0.016	0.016	0.016	0.011	0.011	0.011
Spencer	0.012	0.012	0.012	0.017	0.017	0.017	0.017	0.017	0.017	0.012	0.012	0.012
Pastureland												
TN, Lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
Bullitt	0.052	0.052	0.052	0.055	0.055	0.055	0.055	0.055	0.055	0.052	0.052	0.052
Henry	0.061	0.061	0.061	0.065	0.065	0.065	0.065	0.065	0.065	0.061	0.061	0.061
Jefferson	0.047	0.047	0.047	0.049	0.049	0.049	0.049	0.049	0.049	0.047	0.047	0.047
Oldham	0.050	0.050	0.050	0.052	0.052	0.052	0.052	0.052	0.052	0.050	0.050	0.050
Shelby	0.051	0.051	0.051	0.054	0.054	0.054	0.054	0.054	0.054	0.051	0.051	0.051
Spencer	0.056	0.056	0.056	0.059	0.059	0.059	0.059	0.059	0.059	0.056	0.056	0.056
TP, Lbs/acre/day												
Bullitt	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.014	0.014
Henry	0.017	0.017	0.017	0.018	0.018	0.018	0.018	0.018	0.018	0.017	0.017	0.017
Jefferson	0.012	0.012	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.012	0.012	0.012
Oldham	0.013	0.013	0.013	0.014	0.014	0.014	0.014	0.014	0.014	0.013	0.013	0.013
Shelby	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.014	0.014
Spencer	0.015	0.015	0.015	0.017	0.017	0.017	0.017	0.017	0.017	0.015	0.015	0.015

3.14.3 Calculated loading rates from Fertilizers and Livestock Manure for Cropland and Pastureland

The fertilizer loading rates for N based fertilizer for Wheat was applied in the month of March, Corn and Soybeans in April and Tobacco in the month of June. The P based fertilizer loading rate for all crops was applied in the Fall months of September through December. The initial loading rates for Cropland and Pastureland from fertilizers and livestock manure were estimated by summing the loading rates from fertilizers and livestock manure accordingly (Table 3-24). The loading rates were further area weighted to eliminate bias.

Table 3-24 Calculated loading rates from Fertilizers and Livestock Manure for Cropland and Pastureland used in the Floyds Fork watershed

Area weighted average loading rates for Cropland, Lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
TN	0.045	0.045	0.398	0.149	0.052	0.400	0.052	0.052	0.052	0.045	0.045	0.045
TP	0.011	0.011	0.011	0.015	0.015	0.015	0.015	0.015	0.336	0.332	0.332	0.332
Area weighted average loading rates for Pastureland, Lbs/acre/day												
TN	0.051	0.051	0.051	0.053	0.053	0.053	0.053	0.053	0.053	0.051	0.051	0.051
TP	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.014	0.014

3.14.4 Nutrient Loads from Golf Courses

Estimates of fertilizer application for golf courses in the watershed were based on conversations with the Superintendent of Golf Courses in the Louisville Metro Parks and Recreation Department who manages nine Metro Golf Courses in the Louisville area, two of which lie in the Floyds Fork Watershed. These are the Long Run and Charlie Vettiner Courses. Based on the information obtained on these golf courses and their location the calculated fertilizer application rates were applied to the Grassland land use. The fertilizer application to these golf courses is tabulated in Table 3-25.

Table 3-25 Typical Fertilizer application to Golf courses used in the Floyds Fork watershed

TN Fertilizer application rate, lbs/acre/day												
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Greens	-	-	-	0.290	0.281	0.290	0.281	0.281	0.290	-	-	-
Fairways	-	-	-	1.452	-	-	-	-	-	-	-	-
Rough areas	-	-	-	-	-	0.703	-	-	-	-	-	-
Tea Tops	-	-	-	-	2.904	-	-	-	2.904	-	-	-
Total application rate from golf courses, lbs/acre/day	-	-	-	1.742	3.185	0.993	0.281	0.281	3.194	-	-	-
TP Fertilizer application rate, lbs/acre/day												
Greens	-	-	-	1.089	-	-	-	-	-	-	-	-
Fairways	-	-	-		-	-	-	-	-	-	-	-
Rough areas	-	-	-		-	-	-	-	-	-	-	-
Tea Tops	-	-	-		-	-	-	-	-	-	-	-
Total application rate from golf courses, lbs/acre/day	-	-	-	1.089	-	-	-	-	-	-	-	-

3.14.5 Final Loading rates for all landuse categories used in the Calibrated Watershed Model

Nutrient loading rates were calculated for the Cropland, Pastureland and Grassland land use categories. The initial loading rates for the remaining landuse categories were assumed based on literature loading rates. These loading rates were then adjusted during the calibration process. The final loading rates for TN and TP for all the landuse categories input into the watershed model are tabulated in Tables 3-26 and 3-27 respectively.

Table 3-26 Applied TN loading rates for all landuse categories used in the Floyds Fork watershed model

TN, lbs/acre/day												
Soil Group: B												
Landuse Category	January	February	March	April	May	June	July	August	September	October	November	December
Low Intensity Developed, Pervious	0.043	0.054	0.065	0.076	0.097	0.130	0.151	0.162	0.162	0.108	0.076	0.043
Medium Intensity Developed, Pervious	0.020	0.025	0.030	0.035	0.045	0.060	0.070	0.075	0.075	0.050	0.035	0.020
High Intensity Developed, Pervious	0.030	0.035	0.040	0.040	0.055	0.085	0.095	0.100	0.100	0.075	0.045	0.030
Low Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
Medium Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
High Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
All Other Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
Barren	0.025	0.030	0.035	0.035	0.050	0.080	0.090	0.095	0.095	0.070	0.040	0.025
Forest	0.015	0.015	0.020	0.020	0.025	0.045	0.055	0.060	0.060	0.050	0.025	0.010
Shrub	0.015	0.015	0.020	0.020	0.025	0.045	0.055	0.060	0.060	0.050	0.025	0.010
Cropland	0.045	0.045	0.398	0.149	0.052	0.400	0.052	0.052	0.052	0.045	0.045	0.045
Pastureland	0.051	0.051	0.051	0.053	0.053	0.053	0.053	0.053	0.053	0.051	0.051	0.051
Grassland	0.045	0.045	0.095	0.115	0.185	0.305	0.305	0.305	0.305	0.200	0.055	0.040
Soil Group: C												
Low Intensity Developed, Pervious	0.058	0.077	0.096	0.154	0.173	0.173	0.169	0.163	0.163	0.134	0.096	0.038
Medium Intensity Developed, Pervious	0.030	0.035	0.040	0.040	0.055	0.085	0.095	0.100	0.100	0.075	0.045	0.030
High Intensity Developed, Pervious	0.030	0.035	0.040	0.040	0.055	0.085	0.095	0.100	0.100	0.075	0.045	0.030
Low Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
Medium Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
High Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
All Other Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
Barren	0.025	0.030	0.035	0.035	0.050	0.080	0.090	0.095	0.095	0.070	0.040	0.025
Forest	0.014	0.024	0.025	0.036	0.054	0.072	0.084	0.090	0.090	0.053	0.027	0.014
Shrub	0.020	0.025	0.030	0.030	0.045	0.060	0.070	0.075	0.075	0.065	0.035	0.020
Cropland	0.045	0.045	0.398	0.149	0.052	0.400	0.052	0.052	0.052	0.045	0.045	0.045
Pastureland	0.127	0.127	0.127	0.135	0.135	0.135	0.135	0.135	0.135	0.127	0.127	0.127
Grassland	0.124	0.124	0.124	0.150	0.306	0.397	0.397	0.397	0.397	0.260	0.202	0.182
Soil Group: D												
Low Intensity Developed, Pervious	0.024	0.032	0.040	0.064	0.088	0.136	0.152	0.160	0.160	0.080	0.040	0.016
Medium Intensity Developed, Pervious	0.030	0.035	0.040	0.040	0.055	0.085	0.095	0.100	0.100	0.075	0.045	0.030
High Intensity Developed, Pervious	0.030	0.035	0.040	0.040	0.055	0.085	0.095	0.100	0.100	0.075	0.045	0.030
Low Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
Medium Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
High Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
All Other Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015
Barren	0.025	0.030	0.035	0.035	0.050	0.080	0.090	0.095	0.095	0.070	0.040	0.025
Forest	0.023	0.023	0.031	0.031	0.039	0.070	0.073	0.068	0.068	0.065	0.039	0.016
Shrub	0.020	0.025	0.030	0.030	0.045	0.060	0.070	0.075	0.075	0.065	0.035	0.020
Cropland	0.045	0.045	0.398	0.149	0.052	0.400	0.052	0.052	0.052	0.045	0.045	0.045
Pastureland	0.051	0.051	0.051	0.053	0.053	0.053	0.053	0.053	0.053	0.051	0.051	0.051
Grassland	0.045	0.045	0.095	0.115	0.185	0.305	0.305	0.305	0.305	0.200	0.055	0.040

Table 3-27 Applied TP loading rates for all landuse categories used in the Floyds Fork watershed model

TP, lbs/acre/day												
Soil Group: B												
Landuse Category	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Low Intensity Developed, Pervious	0.002	0.005	0.005	0.005	0.011	0.011	0.011	0.011	0.011	0.011	0.009	0.005
Medium Intensity Developed, Pervious	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
High Intensity Developed, Pervious	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
Low Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
Medium Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
High Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
All Other Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
Barren	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
Forest	0.001	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.003
Shrub	0.001	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.003
Cropland	0.011	0.011	0.011	0.015	0.015	0.015	0.015	0.015	0.336	0.332	0.332	0.332
Pastureland	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.014	0.014
Grassland	0.006	0.005	0.005	0.005	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.005
Soil Group: C												
Low Intensity Developed, Pervious	0.002	0.002	0.002	0.002	0.005	0.005	0.005	0.005	0.005	0.003	0.002	0.002
Medium Intensity Developed, Pervious	0.001	0.003	0.003	0.003	0.005	0.005	0.005	0.005	0.005	0.005	0.002	0.002
High Intensity Developed, Pervious	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003
Low Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
Medium Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
High Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
All Other Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
Barren	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
Forest	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.004
Shrub	0.001	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.003
Cropland	0.011	0.011	0.011	0.015	0.015	0.015	0.015	0.015	0.336	0.332	0.332	0.332
Pastureland	0.050	0.050	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.050
Grassland	0.059	0.083	0.083	0.108	0.253	0.253	0.253	0.253	0.253	0.091	0.091	0.058
Soil Group: D												
Low Intensity Developed, Pervious	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
Medium Intensity Developed, Pervious	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
High Intensity Developed, Pervious	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
Low Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
Medium Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
High Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
All Other Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002
Barren	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004
Forest	0.001	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.003
Shrub	0.001	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.003
Cropland	0.011	0.011	0.011	0.015	0.015	0.015	0.015	0.015	0.336	0.332	0.332	0.332
Pastureland	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.014	0.014
Grassland	0.006	0.005	0.005	0.005	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.005

4.0 Watershed Hydrology Model

4.1 Hydrologic Representation

Watershed hydrology plays an important role in the determination of non-point source flow and ultimately non-point source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of the hydrological characteristics within a watershed. Key hydrological characteristics include interception storage capacities, infiltration properties, evaporation and transpiration rates, and watershed slope and roughness. LSPC's algorithms are identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent watershed hydrology include PWATER (water budget simulation for pervious land units) and IWATER (water budget simulation for impervious land units). A detailed description of relevant hydrological algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Initial values for the hydrological parameters were taken from a default data set from work done on Carter's Lake watershed, located in north Georgia. The reason behind using the Carter's Lake watershed parameters is that the Carter's Lake watershed is physiographically similar to the Floyds Fork watershed. This helped to represent the initial physiographic conditions better. However, during the calibration process, model parameters were adjusted, based on local knowledge of soil types and groundwater conditions, within reasonable constraints until an acceptable agreement was achieved between simulated and observed stream flow. Model parameters adjusted included: evapo-transpiration, infiltration, upper and lower zone storage, groundwater storage, and losses to the deep groundwater system.

4.2 Observed Flow Data

Short-term USGS flow stations located in the Floyds Fork watershed were used to calibrate and validate the LSPC watershed hydrology model (Figure 4-1). There are a total of 7 USGS flow stations in the Floyds Fork watershed that have an overlapping period of record with the model simulation. Three of the USGS flow stations contained a complete flow record for the simulation period from January 1, 2000 through December 31, 2010, three contained a nearly complete flow record for the simulation period January 1, 2000 through December 15, 2010 and one station contained flow record for the simulation period January 1, 2000 through September 30, 2002. Five of the seven stations were used as calibration stations. Three of the calibration stations were located on the main stem of Floyds Fork (USGS 03297900, USGS 03298000 and USGS 03298200) and the other two were on the Chenoweth Run (Lower) (USGS 03298135) and on Pennsylvania Run (USGS 03298300). The remaining two stations (USGS 03298150 and USGS 03298250) were used as validation stations. These stations are shown spatially in Figure 4-1.

Table 4-1 presents the USGS gages utilized for the Floyds Fork watershed and contains the following information: published USGS drainage area, corresponding LSPC sub-watershed, LSPC simulated drainage area, type of station, and the period of record utilized for each gage.

Table 4-1 USGS Flow Gauges used for Calibration and Validation in the Floyds Fork Watershed Model

Location: Main Stem: Floyds Fork							
USGS Gage ID	**Site Name**	**USGS Drainage Area (mi^2)**	**USGS Drainage Area (acres)**	**LSPC Sub-Watershed**	**LSPC Drainage Area (acres)**	**Type**	**Period of Record Utilized**
03297900	Floyds Fork near Peewee Valley	80	51136	615	53084	**Calibration**	1/1/2001-12/31/2010
03298000	Floyds Fork at Fisherville	138	88320	180	88803	**Calibration**	1/1/2001-12/31/2010
03298200	Floyds Fork near Mt. Washington	213	136320	606	137052	**Calibration**	1/1/2001-11/30/2010
Location: Tributaries							
03298135	Chenoweth Run at Ruckriegal Parkway	5	3501	167	3449	**Calibration**	1/1/2001-11/30/2010
03298150	Chenoweth Run at Gelhaus Lane	12	7424	609	8176	**Validation**	1/1/2001-12/31/2010
03298250	Cedar Creek at Thixton Road	11	7104	134	7212	**Validation**	1/1/2001-9/30/2002
03298300	Pennsylvania Run at Mt. Washington	6	4096	130	4182	**Calibration**	1/1/2001-11/30/2010

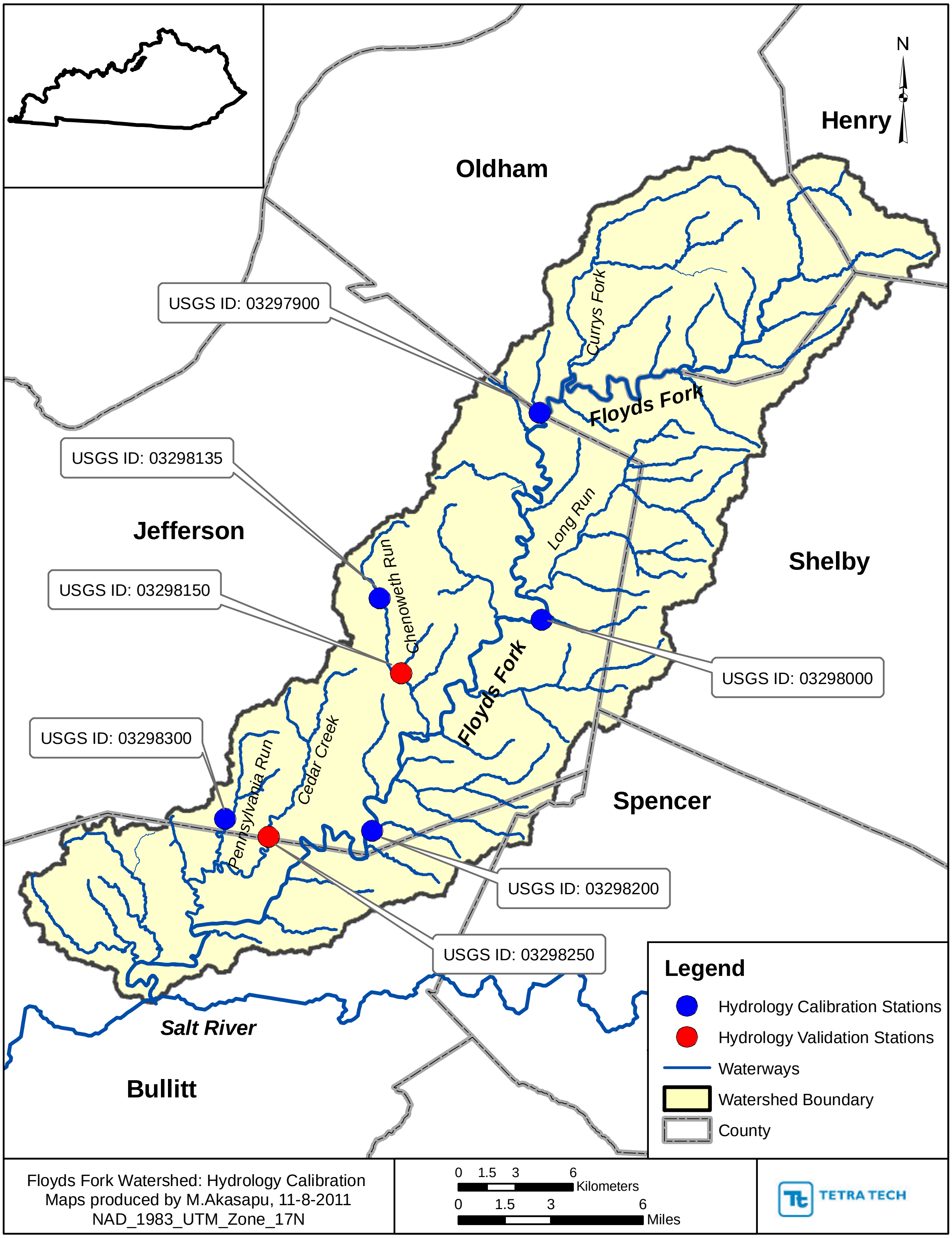


Figure 4-1 Calibration and Validation Stations used in the Hydrology Model

4.3 Hydrology Model Calibration

The calibration of the LPSC watershed hydrology model involved comparing simulated stream flows to five USGS flow stations. The calibration of the hydrologic parameters was performed from January 1, 2001 through December 31, 2010. Results of the model calibrations are presented in Appendix A.

4.4 Hydrology Model Validation

An important step of the modeling process is model validation. Model validation is the process of taking the hydrological parameters that have been calibrated, applying those parameters to other watersheds, and comparing the simulated flow to measured flow from a USGS stream gauging station for the same period of time. Model validation is sometimes called model verification, as essentially the model is being validated or verified with the hydrological parameters calibrated in one watershed to produce acceptable results in another watershed. It is important that when selecting watersheds to perform validations, those watersheds represent a wide variety of land uses as well as drainage areas. This will help to ensure that the hydrological parameters that were calibrated apply to a wide range of conditions. Validation of the hydrologic parameters was performed by comparing simulated flow data to measured data collected at two separate USGS flow gages. The validation of the hydrological parameters was performed from January 1, 2001 through December 31, 2010 for USGS 03298150 and from January 1, 2001 through September 30, 2002 for USGS 03298250. Results of the model validation are also presented in Appendix A.

4.5 Hydrology Observations and Conclusions

For the hydrology calibration, the observed and simulated flows were analyzed based on a quantitative statistical analysis. There are 9 volume based metrics that were evaluated for the calibration. They are: Total Volume, 50% Lowest Flows, 10% Highest Flows, Seasonal Volume for Summer, Fall, Winter and Spring, Storm Volumes and Summer Storm Volumes. Based on the quantitative scores and validation of the model, the model performs very well.

Two of the flow stations on the main stem of Floyds Fork were over predicting the base flows (USGS 03297900 and USGS 03298000). However, the base flow on the downstream most flow station on the main stem lost this excess flow and was well within the metric for 50% lowest flows. A similar trend was observed on the flow stations located on Chenoweth Run (Lower). The upstream flow station is under predicting the base flow and the flows estimated downstream of this station are well within the range of this metric. The under prediction of base flows for the station on Chenoweth Run (Lower) was attributed to the location of these stations which occur in areas identified as having minor karst development. It could be theorized that the karst flow channel was adding/removing the flows to/from the system. After springs were identified upstream of this flow station, the under prediction of the base flows was corrected. The metrics of this flow station and the station downstream of it were all within the range. The USGS flow station on the Chenoweth Run (Lower) (USGS 03298135) was located in a heavily impervious area and was responding differently to the adjusted parameters compared to the rest of the stations. During the calibration process, a large amount of work was put into making this gage better. Adjustments to this gage were made judiciously to make sure that they would not impact other stations in the watershed negatively.

A qualitative grading scale (VG=Very Good, G=Good, F=Fair, and P=Poor) was developed based on the quantitative statistical analysis. Table 4-2 shows the period of record quantitative statistical analysis for gage USGS 03298200. The numbers in the column "Error Statistics" were utilized to calculate a score based on their deviation from zero with zero meaning that simulated and observed are equal. The column "Recommended Criteria" is the USGS recommended maximum deviation (+/-) of simulated and observed flows for acceptable calibration of a watershed model. The flow summary types are also in ascending order of those easiest to hardest to obtain. An example of the grading technique is discussed in detail below.

Period of record error statistics have been placed in the model stat column in Table 4-3. For each flow summary statistic, the absolute value of the model statistic is compared against the values in columns VG, G, F and P. If the value is less than VG then it is given a value of 4, if less then G but greater than VG it is given a value of 3, if less then F but greater than G it is given a value of 2, and if it is greater than P it is given a value of 1 (Table 4-4). The assigned value of the flow summary statistic is multiplied by the weight to produce a score for each flow summary type. Flow summary types have been assigned a weight based on their overall importance for a successful calibration. The error in total volume is most important followed by the errors in the high and low flows, then the error in seasonal volumes and finally the errors in storm volumes. The score for the flow summary statistics are then summed to produce a total score for each gage. This total score is then compared against the minimum score for each qualitative grade (Table 4-5) and the grade assigned.

Table 4-2 Summary Statistics: Model Outlet 606 vs. USGS 03298200 Floyds Fork Near Mt. Washington, KY

LSPC Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM SUBBASIN 606 9.91-Year Analysis Period: 1/1/2001 - 11/30/2010 Flow volumes are (inches/year) for upstream drainage area		USGS 03298200 FLOYDS Hydrologic Unit Code: 5140102 Latitude: 38.08534216 Longitude: -85.5549556 Drainage Area (sq-mi): 213	
Total Simulated In-stream Flow:	**20.99**	Total Observed In-stream Flow:	**22.53**
Total of simulated highest 10% flows:	**12.62**	Total of Observed highest 10% flows:	**13.49**
Total of Simulated lowest 50% flows:	**1.51**	Total of Observed Lowest 50% flows:	**1.57**
Simulated Summer Flow Volume (months 7-9):	**3.04**	Observed Summer Flow Volume (7-9):	**2.62**
Simulated Fall Flow Volume (months 10-12):	**5.91**	Observed Fall Flow Volume (10-12):	**5.44**
Simulated Winter Flow Volume (months 1-3):	**6.09**	Observed Winter Flow Volume (1-3):	**7.87**
Simulated Spring Flow Volume (months 4-6):	**5.95**	Observed Spring Flow Volume (4-6):	**6.60**
Total Simulated Storm Volume:	**12.39**	Total Observed Storm Volume:	**13.71**
Simulated Summer Storm Volume (7-9):	**1.95**	Observed Summer Storm Volume (7-9):	**1.92**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	-6.85	10	
Error in 50% lowest flows:	-3.76	10	
Error in 10% highest flows:	-6.49	15	
Seasonal volume error - Summer:	15.73	30	
Seasonal volume error - Fall:	8.62	30	
Seasonal volume error - Winter:	-22.52	30	
Seasonal volume error - Spring:	-9.89	30	
Error in storm volumes:	-9.66	20	
Error in summer storm volumes:	1.45	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.697	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.547	as E or E' approaches 1.0	

Table 4-3 Qualitative Grading Scale for USGS 03298200 Floyds Fork Near Mt. Washington

Flow Summary Type	VG	G	F	P	Weight	Model Stat	Model Stat Ab. Val	Score		
Error in total volume	10	15	20	25	4	-6.85	6.85	16	Score	80
Error in 50% lowest flows	10	15	20	25	3	-3.76	3.76	12	Grade	VG
Error in 10% highest flows	15	20	25	30	3	-6.49	6.49	12		
Seasonal volume error - Summer	30	40	50	60	2	15.73	15.73	8		
Seasonal volume error - Fall	30	40	50	60	2	8.62	8.62	8		
Seasonal volume error - Winter	30	40	50	60	2	-22.52	22.52	8		
Seasonal volume error - Spring	30	40	50	60	2	-9.89	9.89	8		
Error in storm volumes	20	30	40	50	1	-9.66	9.66	4		
Error in summer storm volumes	50	60	70	80	1	1.45	1.45	4		

Table 4-4 Potential Scores Based on Qualitative Grade and Weighting Factor

Error	VG	G	F	P	Weight	VG Score	G Score	F Score	P Score
Error in total volume	4	3	2	1	4	16	12	8	4
Error in 50% lowest flows	4	3	2	1	3	12	9	6	3
Error in 10% highest flows	4	3	2	1	3	12	9	6	3
Seasonal volume error - Summer	4	3	2	1	2	8	6	4	2
Seasonal volume error - Fall	4	3	2	1	2	8	6	4	2
Seasonal volume error - Winter	4	3	2	1	2	8	6	4	2
Seasonal volume error - Spring	4	3	2	1	2	8	6	4	2
Error in storm volumes	4	3	2	1	1	4	3	2	1
Error in summer storm volumes	4	3	2	1	1	4	3	2	1
Sum						80	60	40	20

Table 4-5 Score Minimum and Corresponding Qualitative Grade

Grade	VG	G	F	P
Score Minimum	75	55	35	20

Table 4-6 shows the score and grade for each of the USGS flow gages utilized in the Floyds Fork watershed model. The summary provided in Table 4-6, along with the other visual and statistical summaries in Appendix A indicate that the hydrology model will perform well for the intended purpose of approximating watershed flows for the Floyds Fork watershed. The quantitative scores of these flow stations are shown spatially in Figure 4-2.

Table 4-6 Score and Grade for USGS flow gages utilized in the Floyds Fork Watershed model

Location: Main Stem- Floyds Fork			
USGS Gage ID	**Station name**	**Qualitative Score**	**Quantitative Score**
03297900	Floyds Fork near Peewee Valley	VG	80
03298000	Floyds Fork at Fisherville	VG	80
03298200	Floyds Fork near Mt. Washington	VG	80
Location: Tributaries			
03298135	Chenoweth Run at Ruckriegal Parkway	VG	80
03298150	Chenoweth Run at Gelhaus Lane	VG	80
03298300	Pennsylvania Run at Mt. Washington	VG	76
03298250	Cedar Creek at Thixton Road	G	67

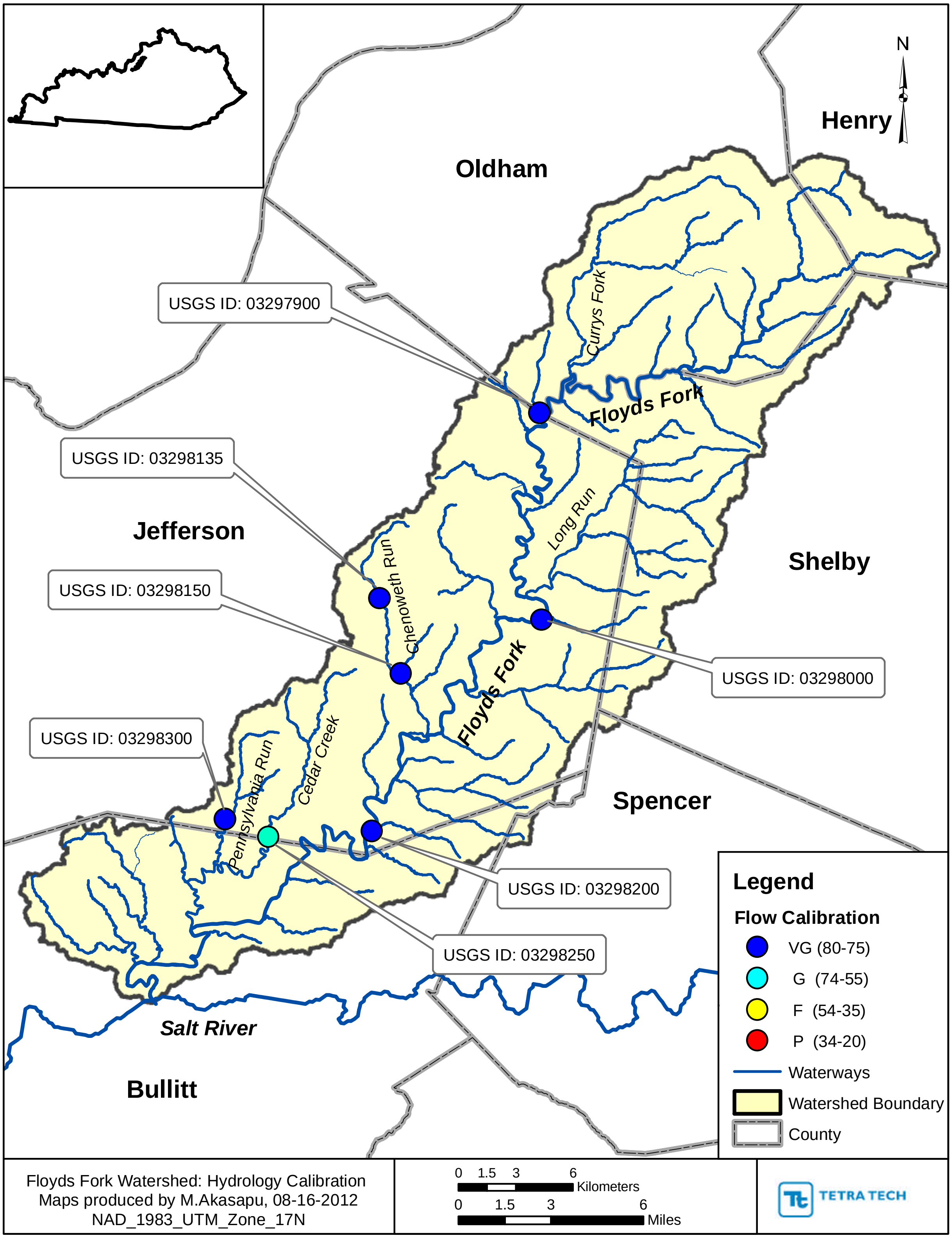


Figure 4-2 Hydrology Calibration in the Floyds Fork Watershed

5.0 Watershed Water Quality Model

5.1 Water Quality Model Overview

Once the LSPC watershed hydrology model was calibrated, the model was used to create a water quality model of the Floyds Fork watershed. Many components of the water quality model were established during hydrology modeling. These components included watershed segmentation, meteorological data, land use representation, soils, reach characteristics, and point source discharges. The watershed water quality model included all point and non-point source contributions. Nutrient loadings from point sources were represented by developing direct input time series, for each point source, using discharge monitoring report data. Non-point source nutrient loadings were represented by build-up and wash off algorithms and assigning nutrient concentrations to the interflow and groundwater flow paths. Nutrients in the stream experienced dilutions, accumulations, assimilation, biochemical cycling, and transport to downstream and out of the watershed.

5.2 Modeled Parameters

The LSPC water quality model was setup to model Temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS).

5.3 Reach Group

For in-stream water quality simulation, the user has the ability to model in-stream processes for the reaches by assigning them to reach groups. Reaches were assigned into reach groups based on the Strahler stream order number. The Strahler stream order system classifies the stream segments based on the number of tributaries upstream of it. A headwater stream (stream with no tributaries) is considered first order stream. A stream located downstream of the confluence of two first order streams is a second order stream (Strahler 1957). Assigning reaches into groups allows for the assignment of unique values for each reach group for certain LSPC parameters.

The parameters that can be assigned differently by reach group include: sediment bed storage parameters, cohesive and non-cohesive suspended sediment variables for in-stream transport, temperature for stream groups, bed heat conduction parameters, land to stream mapping, variables associated with BOD sinking, decay, and benthic release, variables for dissolved oxygen reaeration, benthic oxygen demand, and oxygen scour. In LSPC, reach group is analogous to the RCHRES block in HSPF. A detailed description of relevant in-stream and transport algorithms is presented in the HSPF (v12) User’s Manual (Bicknell et al. 2004).

5.4 Water Temperature

In-stream temperature is an important parameter for simulating biochemical transformations. LSPC models in-stream temperatures by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent water temperature include PSTEMP (soil temperature) and HTRCH (heat exchange and water temperature). A detailed description of relevant temperature algorithms is presented in the HSPF (v12) User’s Manual (Bicknell et al. 2004).

Soil temperature is only used to determine the water temperature of the three different flow paths (surface outflow, upper subsurface/interflow outflow, lower subsurface/groundwater outflow) contributing to stream flow. Once the water is in the stream, the temperature is impacted by mechanisms that can increase or decrease the heat content of the water. Mechanisms which can increase the heat content of the water are absorption of solar radiation, absorption of long-wave radiation, and conduction-convection. Mechanisms which decrease the heat content are emission of long-wave radiation, conduction-convection and evaporation (Bicknell et al. 2004).

For the calibration of water temperature, the existing reach geometry became an important parameter. The reach bank full depth for most of the headwater sub-watersheds were close to or in many cases less than 1.92″, forcing the in-stream temperature to be air temperature. In order to simulate the in-stream temperatures better, the reach bank full widths and the reach ratio of bottom width to bank full width (r1) corresponding to these sub-watersheds was decreased. This forced the reach bank full depths to be greater than 1.92″.

5.5 Dissolved Oxygen

Dissolved oxygen concentration is generally viewed as an indicator of the overall well-being of streams or lakes and their associated ecological systems. In relatively unpolluted waters, sources and sinks of oxygen are in approximate balance and the concentration remains close to saturation. By contrast, in a stream receiving untreated waste waters, the natural balance is upset, bacteria predominate, and a significant depression of DO results (Bicknell et al. 2004).

LSPC models in-stream DO by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF module used to represent DO include PWTGAS (pervious water temperature and dissolved gas concentrations), IWTGAS (impervious water temperature and dissolved gas concentrations), and OXRX (primary DO and BOD balances). A detailed description of relevant temperature algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Setting aside in-stream transformations, which either consume or produce DO, a major player in the DO concentration is stream temperature. It is well known that colder water can dissolve more gas than warmer water. Another major player is atmospheric reaeration. Atmospheric reaeration takes into consideration the DO concentration to start with, oxygen saturation level for a given water temperature, water depth, water velocity, circulation, reaeration rate, and a temperature correction coefficient for surface gas invasion. LSPC allows for user defined DO concentrations in interflow and groundwater by land use and month.

The BOD decay and settling parameterization is important in the process of reaeration (Bicknell et al. 2004). The BOD decay rate at 20°C (KBOD20) was an important calibration parameter for capturing of the DO processes. This parameter was set lower for headwater sub-watersheds and higher for non-headwater sub-watersheds as the decay would be more in shallower and narrower streams compared to the much deeper and wider streams.

5.6 Sediment

LSPC models sediment by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF module used to represent sediment include SEDMNT (pervious production and removal of sediment), SOLIDS (accumulation and removal of solids), and SEDTRN (behavior of inorganic sediment). A detailed description of relevant sediment algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Sediment is one of the most difficult water quality parameters to accurately simulate with watershed models. Therefore, the approach to modeling sediment in the Floyds Fork watershed consisted of using the final calibrated parameter values generated during the Carter's Lake LSPC model development. The used parameters were adjusted in accordance with guidelines established in EPA BASINS Technical Note 8 Sediment Parameters and Calibration guidance to HSPF (EPA, 2006) and Sediment Calibration Procedures and Guidelines for Watershed Modeling (Donigian et al. 2003), to represent the local conditions better.

A detailed description of relevant sediment algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004). Key processes for sediment include: soil detachment, soil compaction, fraction of land use shielded from rain drop impact, sediment washoff rate, and in-stream transport which includes settling velocities and flow velocities that contribute to deposition and re-suspension of sediment particles.

5.7 Nutrients

LSPC models nutrients by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF module used to represent nutrients include PQUAL (quality constituents using simple relationships) and IQUAL (wash-off of quality constituents using simple relationships). A detailed description of relevant nutrient algorithm is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Accumulation and wash-off rates play an important role in the determination of non-point source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of hydrological characteristics within a watershed. It must also appropriately represent the rate at which nutrient components build-up between rain events and wash off during rain events. Key general water quality characteristics include initial storage, wash-off and scour potency, accumulation rates, and maximum storage amounts. The water supplied to a stream from groundwater and through interflow also plays an important role in loading to a waterbody. LSPC allows the user to supply groundwater and interflow concentrations, by hydrologic soil group and land use, by month. The accumulation and wash-off and interflow strongly influence peak flow water quality while groundwater reflects base flow water quality.

Biochemical in-stream processes play an important role on nutrient concentrations spatially and temporally. Biochemical processes also has a large influence on DO and ultimately water quality. The watershed model should appropriately represent some of the major biochemical processes occurring within in the stream, including DO and biochemical oxygen demand balances, organic and inorganic nutrient balances. In order to accurately represent biochemical processes, temperature must be modeled because all transformation rates are temperature dependent. Key processes for oxygen include: benthic oxygen demand, sinking and benthic release of BOD material, reaeration, and oxygen depletion due to decay of BOD. Key processes for nutrients include: buildup and washoff rates, interflow and groundwater concentrations and rate of surface runoff that removes 90% of stored nutrient (WSQOP).

5.8 Water Quality Development and Calibration

Temperature was the constituent calibrated after hydrology because the remaining parameters use water temperature in their algorithms. Temperature was calibrated by adjusting the widths of the reaches, the correction factor for solar radiation and the water-ground heat conduction coefficients, by reach group, until the simulated data captured the trend of the observed data. After temperature was calibrated, DO was brought into close agreement with the observed data by adjusting reaeration coefficients, BOD decay rate and benthic oxygen demand. At this point DO was only partially calibrated because the water quality simulation was only partially active. Next, the sediment module was turned on and the parameters used from the Carter's Lake LSPC model development were adjusted until the simulated data closely matched the observed data. After the above three modules were either calibrated or brought into reasonable agreement, the calibration process turned to nutrients.

The first step in nutrient calibration involved looking at BOD, TN, and TP. These three constituents were modeled by build-up/wash-off and assigning land use associated concentrations in groundwater and interflow. Build-up/wash-off removes constituents from the land and carries them into the stream. The loading rates from fertilizers and manure for each County were the area weighted average and was applied to the model as initial monthly accumulation rate (MON-ACCUM) to both Cropland and Pastureland. The loading rates for all other land uses were taken from the Carter's Lake watershed model and was changed accordingly. The land uses associated with sinkholes were assigned the same loading rates as its respective land use. Adjustments were made to monthly accumulation rate, monthly storage limit, interflow concentration, and groundwater concentration for BOD, TN, and TP until the simulated data was in range with the observed field data.

Once the build-up/wash-off rates were close, decay rates became the last step in calibrating the watershed model for nutrients. Decay rates were calibrated by balancing DO and in-stream nutrient concentrations. For example, if a modeled parameter is simulating too high and DO was simulated low then a change was made to reduce the BOD decay rate. This change will decrease the modeled constituent and also increase the DO because not as much of the constituent is being decayed, therefore decreasing the amount of DO consumed.

5.9 Septic Tanks

To represent the contribution of water quality from non-failing septic tanks, literature concentration data was used (Gerner 2004, Lihua 2002, Jones 2005). It was assumed that each septic tank serves a household of 2.8 people, each person accounts for 70 gallons/day of water use and 15% of the water used in the house never makes it to the septic tank. It was also assumed that it takes an average of 60 days for the septic flow to reach a body of water, so a first order decay rate was applied to each constituent to determine the concentration after 60 days. Table 5-1 presents the concentration of septic tank effluent, decay rates for each parameter, and the concentration after 60 days of decay. For phosphorus, it was also assumed that 90% of it was sorbed to sediment; therefore only 10% of the effluent concentration was used to calculate decay after 60-days. Non-Failing septic tank data was developed into a direct input time-series and in the computational domain is handled like a point source.

For failing septic tank land use loading representation, effluent loadings were obtained from literature (USEPA 2002) and are shown in Table 5-2. Septic tank loadings were allowed to accumulate on the land for a period of 5-days before reaching the maximum storage value.

Table 5-1 Non-Failing Septic Tank Water Quality Concentrations

Parameter	Effluent Concentration (mg/l)	Decay Rate (1/day)	Concentration at Stream (mg/l)**
BOD5	105	0.16	0.003
Total Nitrogen	70.258	0.1	0.1263
Organic Nitrogen	0.458	0.1	0.0008
Ammonia	10.5	0.1	0.0189
Nitrate_Nitrite	59.3	0.1	0.1066
Total Phosphorus*	0.3	0.014	0.1287
Organic Phosphorus*	0.3	0.014	0.1287
Ortho-Phosphorus*	0	0.014	0
TSS	10	0	10
Dissolved Oxygen	--	--	4
WTEM	--	--	GW Temp***

*It was assumed that 90% of phosphorus is sorbed to sediment
**Assumes Septic Flow takes an average of 60 days to reach stream
***Supplied groundwater temperature from temperature component of simulation

Table 5-2 Failing Septic Land Use Nutrient Loading Rates

Parameter	Effluent Loading (lb/acre/day)
BOD5	0.309
Total Nitrogen	0.0701
Total Phosphorus*	0.00926

*It was assumed that 90% of phosphorus is sorbed to sediment

5.10 Observed Water Quality Data Calibration and Validation

During the simulation period, water quality observations were collected approximately monthly at 26 USGS stations within the Floyds Fork watershed. The primary period of data collection was from 2007 through 2008. A majority of the USGS stations were located on the western side of Floyds Fork watershed which was dominated by point sources and urban land use. From 2000 through 2010, Jefferson County MSD collected water quality data at five stations within the Floyds Fork watershed. Three out of the 5 MSD stations were located on the main stem of Floyds Fork (EFFFF001, EFFFF002 and EFFFF003) and the remaining 2 stations on Chenoweth Run (Lower) (EFFCR001 and EFFCR002).

Data collected at the USGS stations included Temperature, DO, pH, Ammonia (NH_3), Nitrate+Nitrite (NO_X), Total Kjeldahl Nitrogen (TKN), TP, Orthophosphate (PO_4), BOD_5, TSS, Conductivity and Turbidity. At the MSD stations, data was collected on Temperature, DO, pH, NH_3, NO_X, TKN, TP, PO_4, BOD_5, TSS, Conductivity and Hardness.

All 26 USGS stations were used as calibration stations and the 5 MSD stations were used as validation stations. The 5 MSD stations have the same location as 5 USGS calibration stations (USGS 03297900-EFFFF001, USGS 03298200-EFFFF002, USGS 03298000-EFFFF003, USGS 03298150-EFFCR001 and USGS 03298135-EFFCR002).

Figures 5-1, 5-2 show the location of the USGS and MSD water quality stations respectively. Table 5-3 tabulates the USGS calibration and the MSD validation stations.

Table 5-3 Water Quality Calibration and Validation Stations used in the Floyds Fork Watershed

Water Quality Station location: Main Stem- Floyds Fork			
USGS Station ID	**Station name**	**Agency**	**Type**
03297830	Floyds Fork at Highway 53	USGS	Calibration
03297845	Floyds Fork near Crestwood	USGS	Calibration
03297900	Floyds Fork near Peewee Valley	USGS	Calibration
03297930	Floyds Fork at Echo trail bridge	USGS	Calibration
03298000	Floyds Fork at Fisherville	USGS	Calibration
03298120	Floyds Fork at Seatonville Road	USGS	Calibration
03298200	Floyds Fork near Mt. Washington	USGS	Calibration
03298470	Floyds Fork near Shepherdsville	USGS	Calibration
EFFFF001	Floyds Fork at Ash Avenue	MSD	Validation
EFFFF002	Floyds Fork at BardStown Road	MSD	Validation
EFFFF003	Floyds Fork at Old Taylorsville Road	MSD	Validation
Water Quality Station location: Tributaries			
03297850	South Fork Curry's Fork at Moody Lane	USGS	Calibration
03297855	South Fork Curry's Fork at Highway 393	USGS	Calibration
03297860	North Fork Curry's Fork at Stone Ridge road	USGS	Calibration
03297875	Ashers Run at Abbott lane near Crestwood	USGS	Calibration
03297880	Currys Fork near Crestwood	USGS	Calibration
03297950	Long Run at Old stage coach road	USGS	Calibration
03297975	South Long Run at Hobbs Lane	USGS	Calibration
03297980	Long Run near Fisherville	USGS	Calibration
03298005	Pope lick at South poope lick road near Fisherville	USGS	Calibration
03298020	Chenoweth Run at Gelhaus Lane	USGS	Calibration
03298100	Pope lick at pope lick road near Middletown	USGS	Calibration
03298110	Pope lick at Rehl road near Fisherville	USGS	Calibration
03298135	Chenoweth Run at Ruckriegal Parkway	USGS	Calibration
03298138	Chenoweth Run at Jeffersontown STP at Jeffersontown	USGS	Calibration
03298150	Chenoweth Run at Gelhaus Lane near Fern creek	USGS	Calibration
03298160	Chenoweth Run at Seatonville road near Jeffersontown	USGS	Calibration
03298250	Cedar Creek at Thixton Road	USGS	Calibration
03298300	Pennsylvania Run at Mt. Washington	USGS	Calibration
EFFCR001	Chenoweth Run # 1 at Gelhaus Lane	MSD	Validation
EFFCR002	Chenoweth Run # 1 at Rickriegal Parkway	MSD	Validation

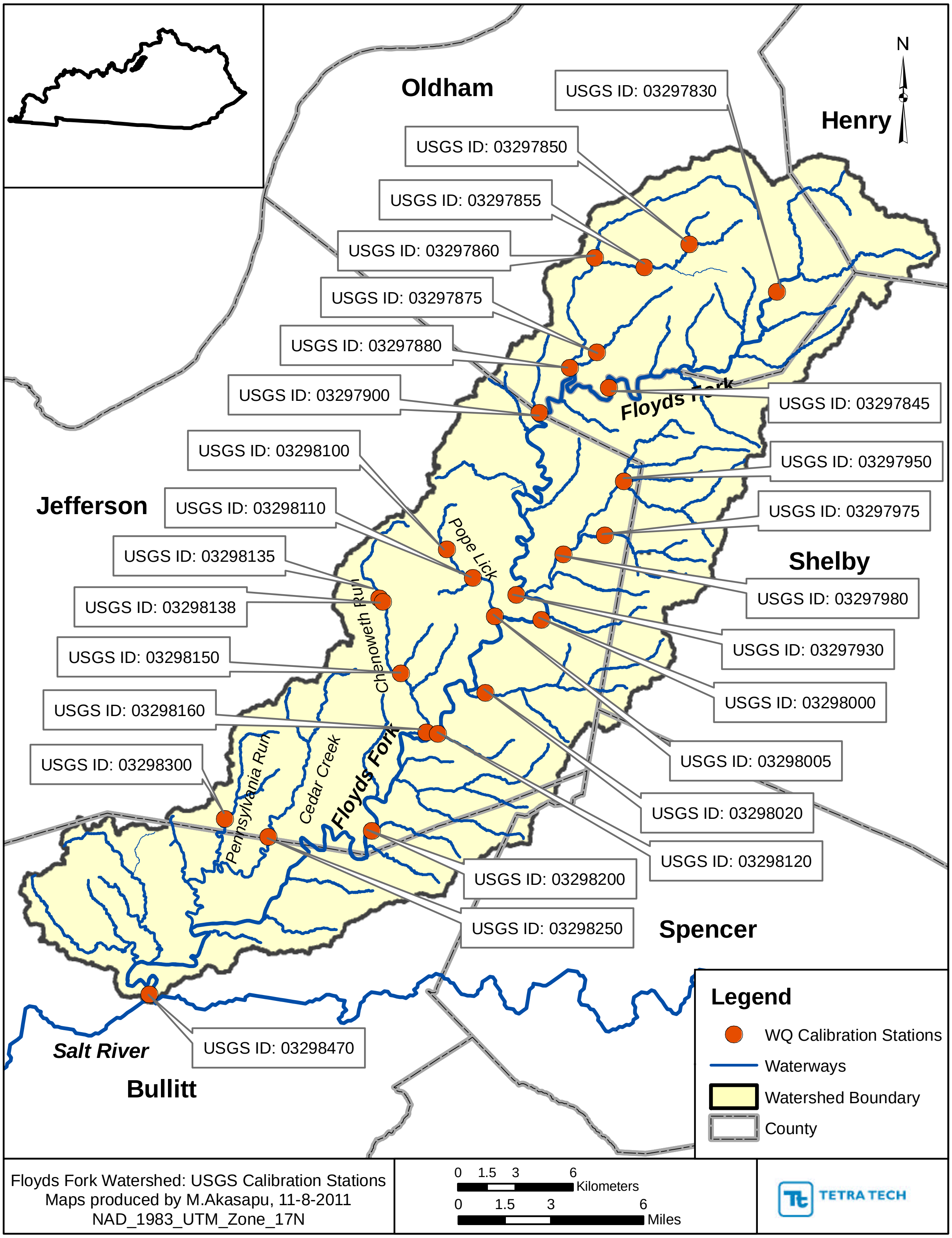


Figure 5-1 USGS Calibration Stations used in the Water Quality Model

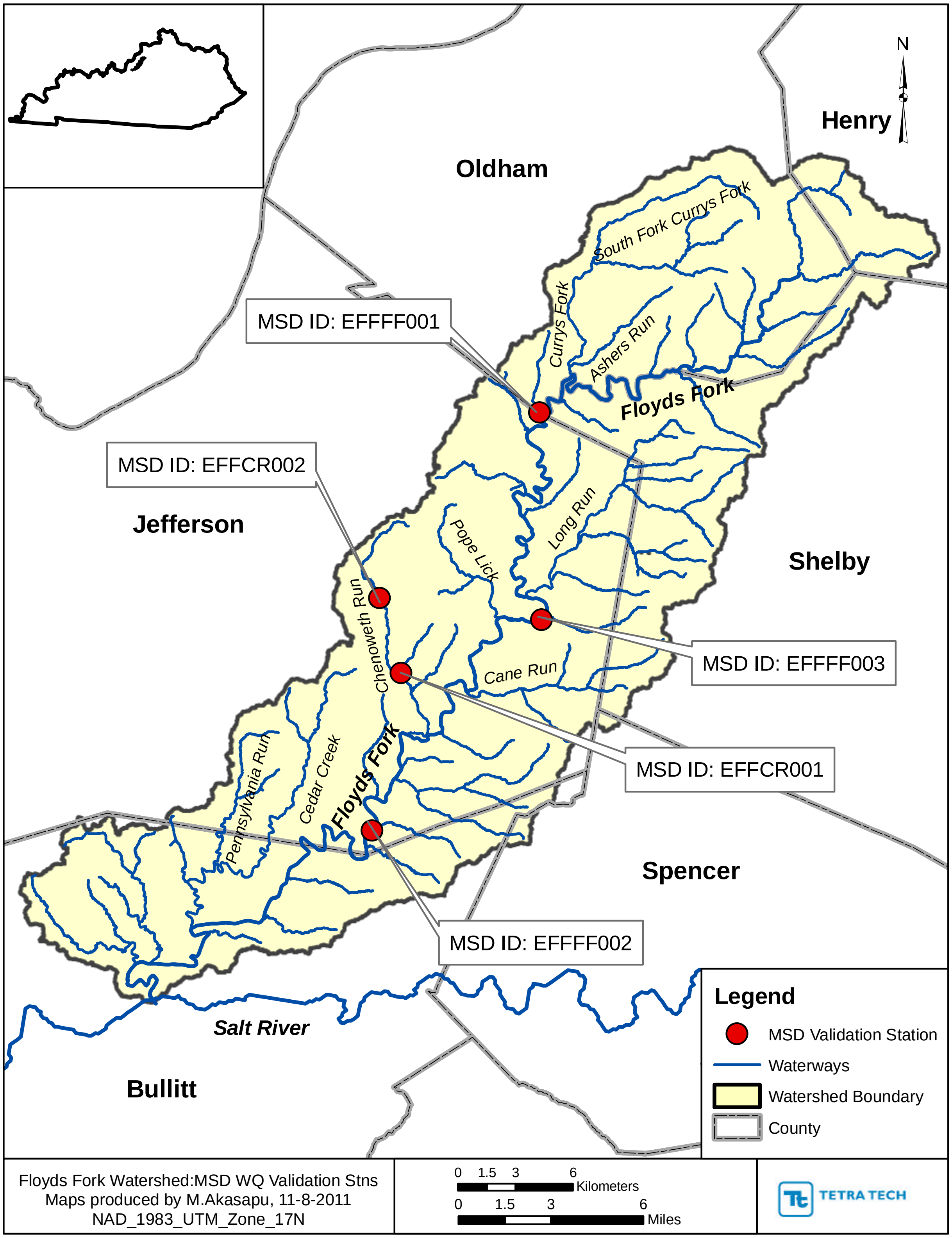


Figure 5-2 MSD Validation Stations used in the Water Quality Model

5.11 Water Quality Observations and Conclusions

The LSPC model simulated temperature very well at all calibration and validation stations. The model captured the highs and lows of the seasonal variations very well at all USGS calibration and at two of the 5 MSD validation stations (EFFCR001 and EFFFF003). The temperature data of the remaining 3 validation stations (EFFCR002, EFFFF001 and EFFFF002) matched very well in terms of magnitude but the data appeared shifted by 2-3 months. Overall the LSPC model temperature calibration is very good.

The LSPC model simulated DO fairly well at all calibration and two of the MSD validation stations on Chenoweth Run (Lower). This was expected since temperature and DO concentrations are highly correlated with one another. There were a few locations where the LSPC model did not have low DO concentration in the summertime or high DO concentrations during wintertime. This trend was observed at water quality stations dominated by agricultural land. This could be attributed to localized oxygen demands or low velocities which is not advantageous for DO reaeration. This could also be due to the limited data for only 2 years to calibrate the model to. Generally speaking, the LSPC model DO calibration is good.

It has been well documented that sediment loading from the land occurs during very intense rain events. Because of this fact and also infrequent sampling events during low-flow/low-rain events, sediment was a difficult parameter to calibrate. At all the USGS calibration stations the model properly captured the trends and the magnitudes of the sediments during low flow events. The peaks at high flow events were also captured well. The model simulated low suspended sediment concentrations almost all of the time except for when rain events came through and washed some sediment into the streams. Without having monitored data during these times of sediment delivery to the stream, it was hard to determine how well the model is calibrated for sediment.

Much of the monitored BOD data was very near or below the method detection limit of 5 mg/l. With this in mind, the goal was to try to simulate BOD concentrations in and around 5 mg/l. The model does a fairly good job at simulating BOD less than 5 mg/l.

TN and TP were also simulated fairly well. The focus of the watershed model calibration for TN and TP was to properly represent the magnitudes and to capture the trends of the nutrients entering Floyds Fork. Similar trends were observed for water quality stations dominated by non-point sources and those dominated by point sources. All the stations unaffected by point sources were calibrated very well in capturing the trends and magnitudes of the nutrients. However, there were few stations in this category that did not capture the nutrient loads as well as the rest. This could be attributed to the measured flow data used for these stations. The water quality stations dominated significantly by point sources often resulted in higher concentrations than the measured data, although capturing the trend well. This was especially true for TP. This could be attributed to the assumed defaults assigned to these point source or low measured flow data for the estimated of loads.

By comparing the simulated and observed data at the downstream most Floyds Fork water quality station (USGS 03298470), it could be concluded that the model does a pretty well in capturing both the magnitude and the seasonality. Below (Figures 5-3 through 5-6) are the plots showing paired comparisons of simulated and observed measurements and annual box and whisker plots at the station located on the Floyds Fork near Shepherdsville as it enters Salt River.

Paired comparison means that on any day that an observation was recorded it was compared with the simulated average daily concentration. Both the observed and simulated concentrations were converted to pounds per day by utilizing observed and simulated flow respectively. The observed data was from the USGS station at that location. Figure 5-3 and 5-4 suggests that the model is slightly over predicting the nutrients. However, the plots also indicate that for TN and for TP, the comparison between observed and simulated is good as the cluster of data is concentrated fairly close at the center of the line.

Box and Whisker plots (Figure 5-5 and 5-6) are another graphical way of analyzing measured and modeled data and the distribution of key statistics for both. It is based on the median of measured and modeled data. It helps depict the data through: smallest observation, lower quartile, median, upper quartile and the largest observation. The median for modeled TN and TP is fairly close to the measured TN and TP median. This suggests that the simulation for the nutrients is good.

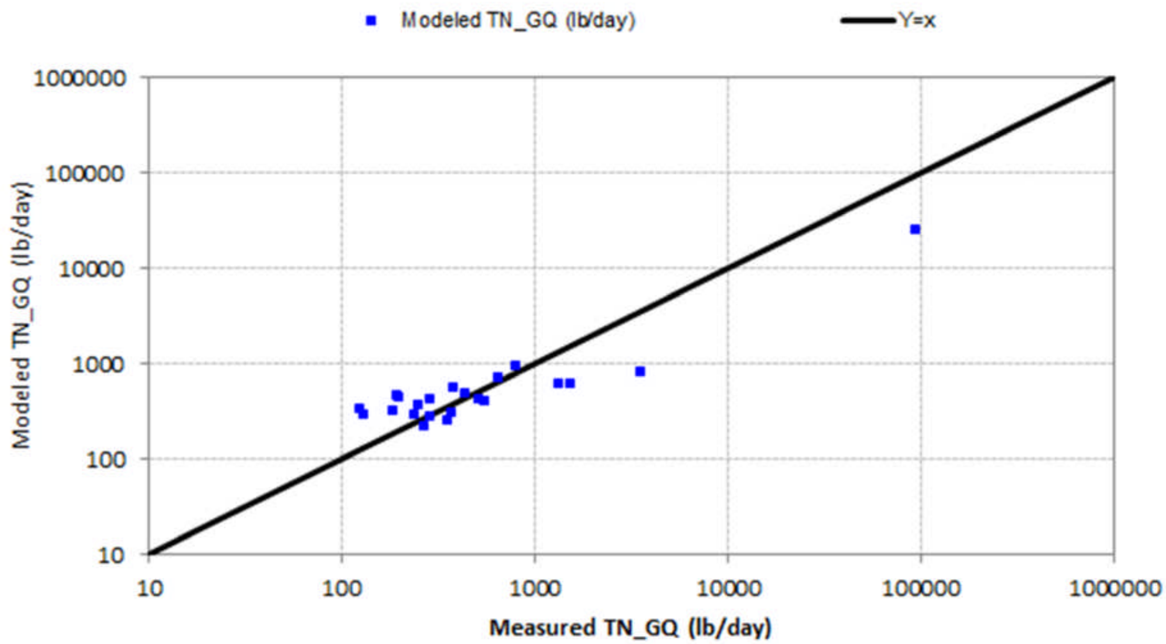


Figure 5-3 USGS 03298470 Modeled vs Observed paired comparison for Total Nitrogen

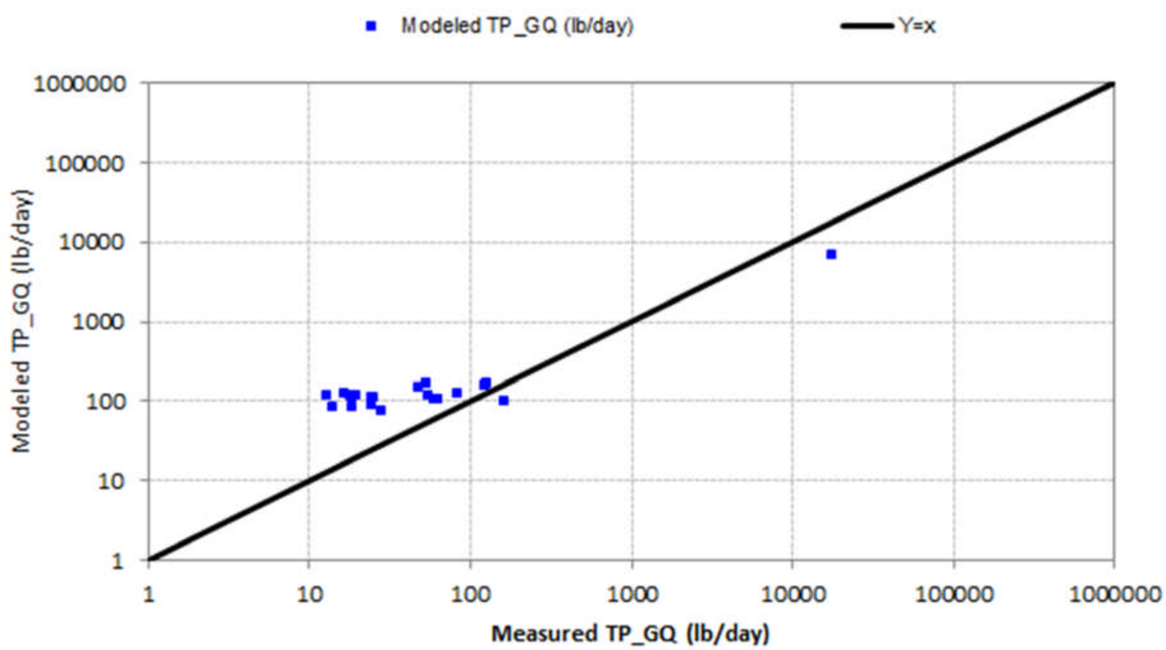


Figure 5-4 USGS 03298470 Modeled vs Observed paired comparison for Total Phosphorus

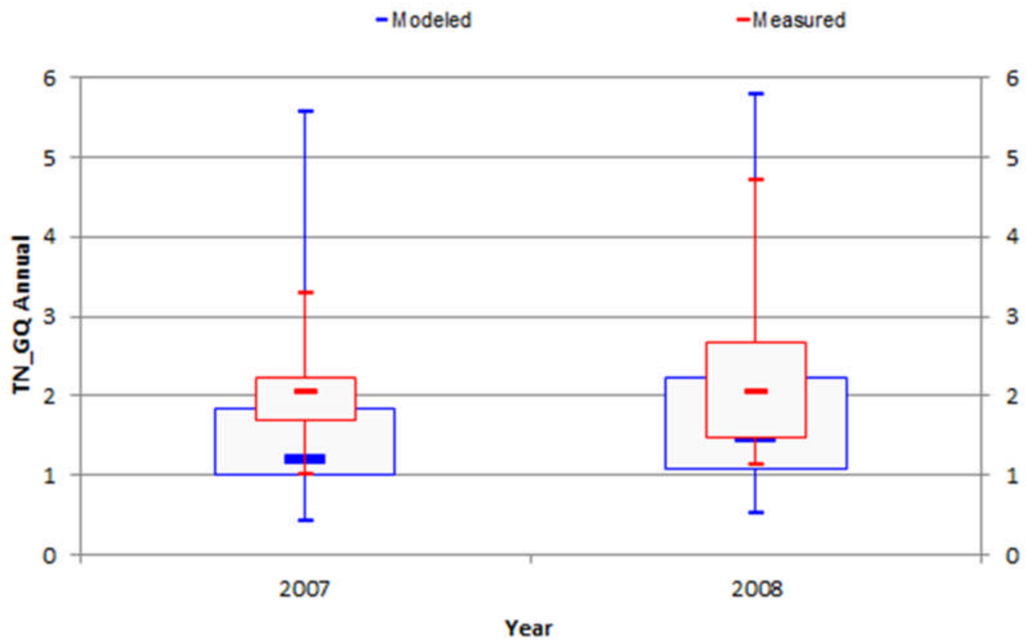


Figure 5-5 USGS 03298470 Modeled vs Observed Annual Box and Whisker plot for Total Nitrogen

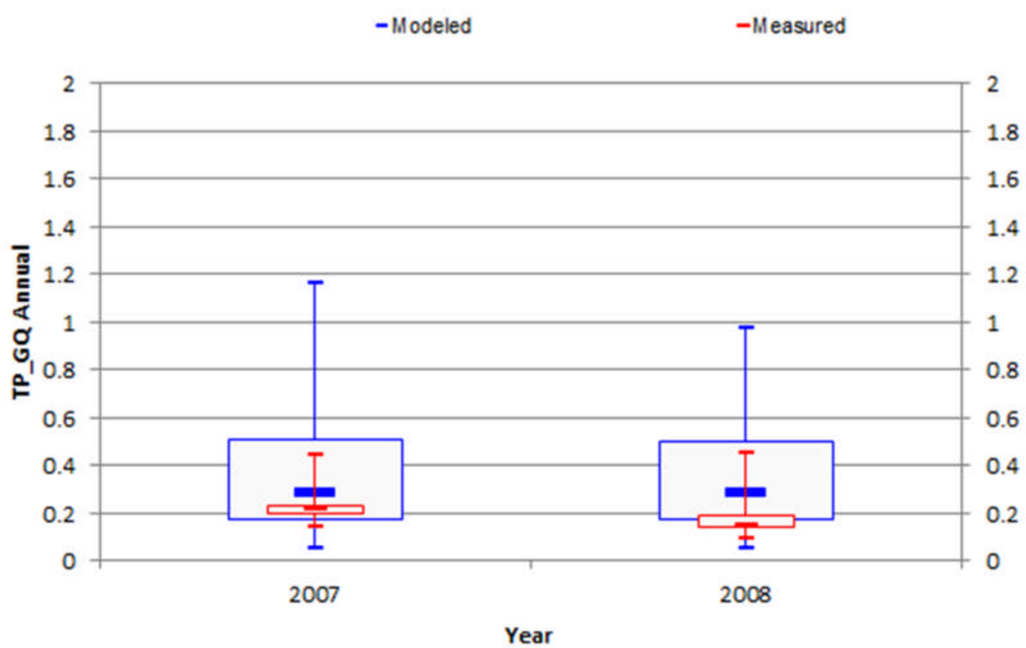


Figure 5-6 USGS 03298470 Modeled vs Observed Annual Box and Whisker plot for Total Phosphorus

Similar to hydrology, a qualitative grading ranking (VG=Very Good, G=Good, F=Fair, and P=Poor) was developed based on the quantitative analysis, comparing simulated and observed loads, from the spreadsheet utilized for calibrating and validating watershed water quality models. However, unlike hydrology, there were not 9 error statistics for comparison and calculation. Instead, the water quality qualitative grading ranking utilized the period of record average, observed and simulated annual load difference, and compared it to criteria defined for the water quality calibration. An example of the grading technique is discussed in detail below for one constituent at one location.

The average annual 'Modeled' and Measured' loads for the Nutrients were computed for the period of record (Table 5-4). The absolute percentage error was then estimated and compared with the values found in Table 5-5. A qualitative grade was then assigned based on the obtained absolute percentage error. For this example, the TP period of record yearly average load percent differences absolute value of 7.0, is less than 30, which is the maximum difference allowed to be considered 'Very Good', so this gage has a qualitative grade of VG=Very good for TP. Table 5-5 shows the range of absolute percentage error set up for Nutrients. To be very good for Nutrients the error needs to be within 30%.

Table 5-6 shows the score and grade for each of the USGS water quality calibration stations and MSD validation stations for which the loads were developed. The summary provided in Table 5-6, along with the other visual and statistical summaries in Appendix B indicate that the Water Quality model should perform reasonably well for the intended purpose of approximating nutrient loads in Floyds Fork. The quantitative scores of the USGS stations for TN and TP are shown spatially in Figure 5-7 and 5-8 respectively. The quantitative scores of the MSD stations for TN and TP are shown spatially in Figure 5-9 and 5-10 respectively.

Table 5-4 Measured and Simulated TP Loads for USGS 03298470

Year	Total Phosphorus (lbs/yr)			Score	Ranking
	Measured	Modeled	% Error		
2007	207,454	164,993	20.5	7.0	VG
2008	153,489	170,568	-11.1		
Average	180,472	167,781	7.0		

Table 5-5 Score Minimum and Corresponding Qualitative Grade for Nutrients

Ranking	VG	G	F	P
Absolute Percentage Error	30	70	120	180

Table 5-6 Water Quality Calibration and Validation stations in the Floyds Fork Watershed

Water Quality Station location: Main Stem- Floyds Fork					
USGS Station ID	Station name	Qualitative Score		Quantitative Score	
		TN	TP	TN	TP
03297830	Floyds Fork at Highway 53	G	VG	40	3
03297845	Floyds Fork near Crestwood	G	G	49	58
03297900	Floyds Fork near Peewee Valley	G	G	45	57
03297930	Floyds Fork at Echo trail bridge	F	G	70	67
03298000	Floyds Fork at Fisherville	G	VG	50	20
03298120	Floyds Fork at Seatonville Road	G	G	51	42
03298200	Floyds Fork near Mt. Washington	G	VG	57	29
03298470	Floyds Fork near Shepherdsville	G	VG	57	7
EFFFF001	Floyds Fork at Ash Avenue	VG	VG	21	19
EFFFF002	Floyds Fork at BardStown Road	G	VG	49	19
EFFFF003	Floyds Fork at Old Taylorsville Road	G	VG	46	10
Water Quality Station location: Tributaries					
03297850	South Fork Curry's Fork at Moody Lane	G	G	65	65
03297855	South Fork Curry's Fork at Highway 393	VG	G	0	64
03297860	North Fork Curry's Fork at Stone Ridge road	G	F	50	72
03297875	Ashers Run at Abbott lane near Crestwood	G	G	49	47
03297880	Currys Fork near Crestwood	VG	VG	22	26
03297950	Long Run at Old stage coach road	VG	VG	4	16
03297975	South Long Run at Hobbs Lane	VG	G	15	53
03297980	Long Run near Fisherville	VG	G	24	40
03298005	Pope lick at South poope lick road near Fisherville	VG	VG	8	24
03298020	Chenoweth Run at Gelhaus Lane	VG	G	27	49
03298100	Pope lick at pope lick road near Middletown	G	G	51	53
03298110	Pope lick at Rehl road near Fisherville	G	G	35	30
03298135	Chenoweth Run at Ruckriegal Parkway	VG	G	21	55
03298138	Chenoweth Run at Jeffersontown STP at Jeffersontown	G	G	66	52
03298150	Chenoweth Run at Gelhaus Lane near Fern creek	G	VG	65	25
03298160	Chenoweth Run at Seatonville road near Jeffersontown	G	G	44	40
03298250	Cedar Creek at Thixton Road	G	VG	61	1
03298300	Pennsylvania Run at Mt. Washington	G	G	46	42
EFFCR001	Chenoweth Run # 1 at Gelhaus Lane	G	VG	50	21
EFFCR002	Chenoweth Run # 1 at Rickriegal Parkway	F	G	76	70

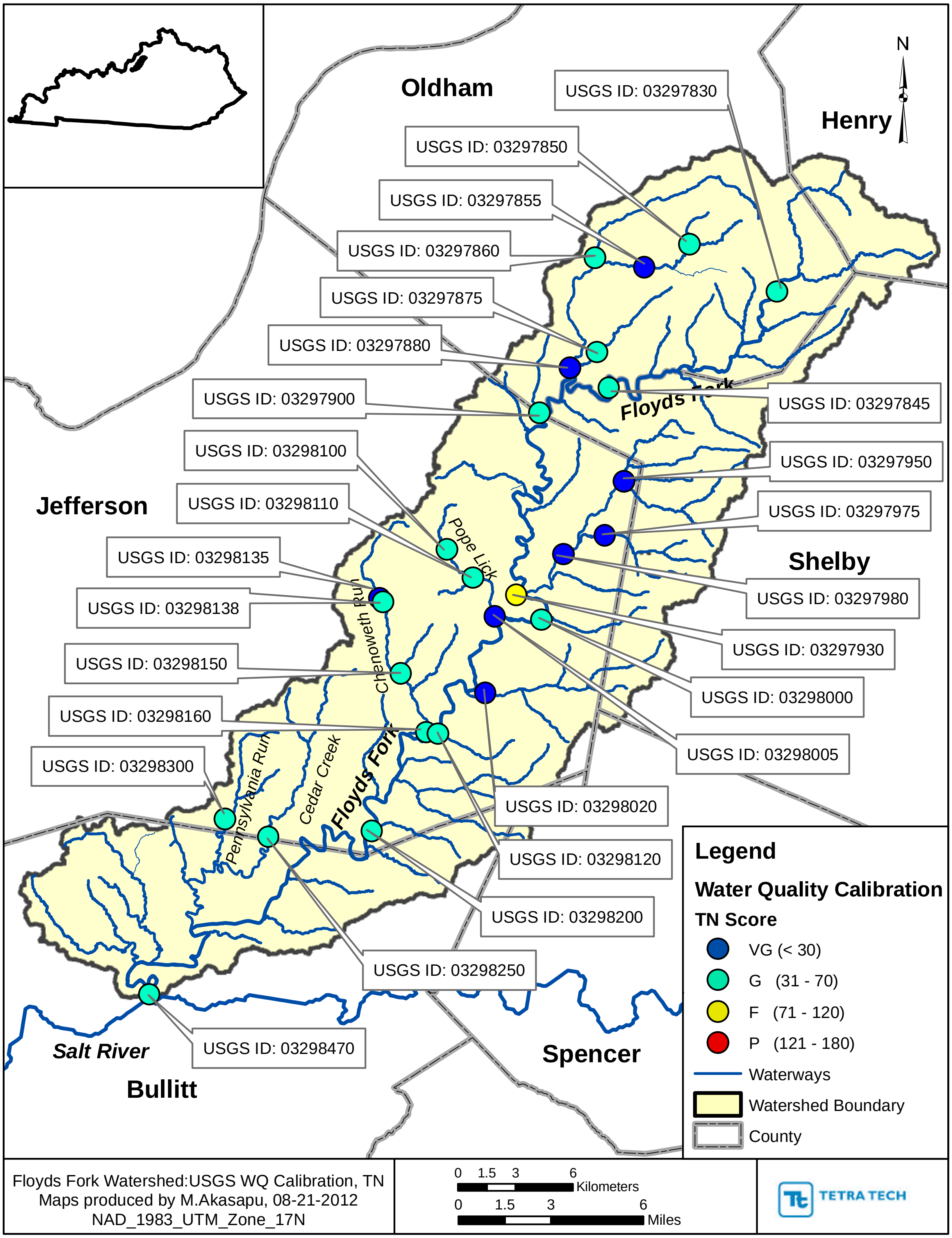


Figure 5-7 USGS WQ Calibration for TN in the Floyds Fork Watershed

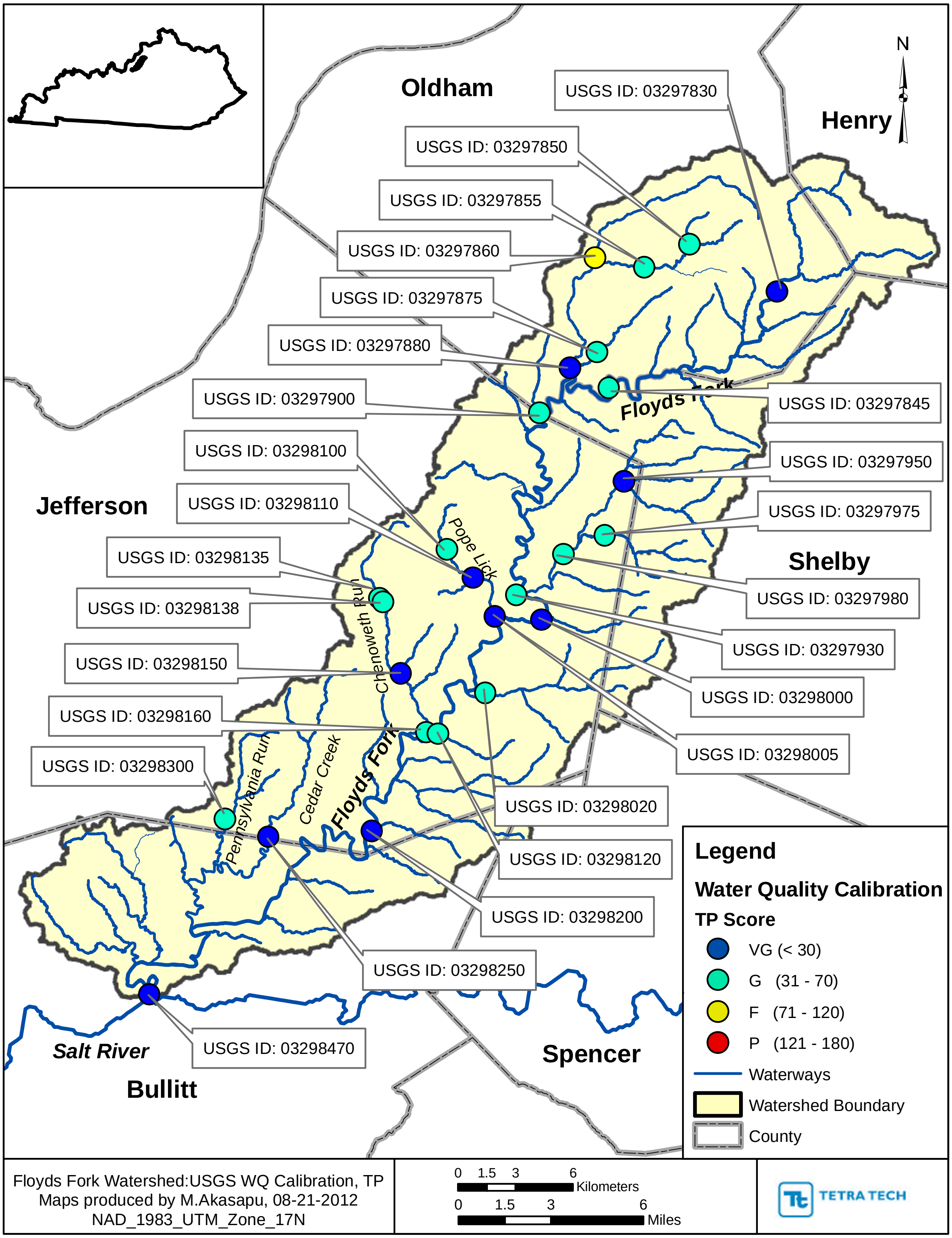


Figure 5-8 USGS WQ Calibration for TP in the Floyds Fork Watershed

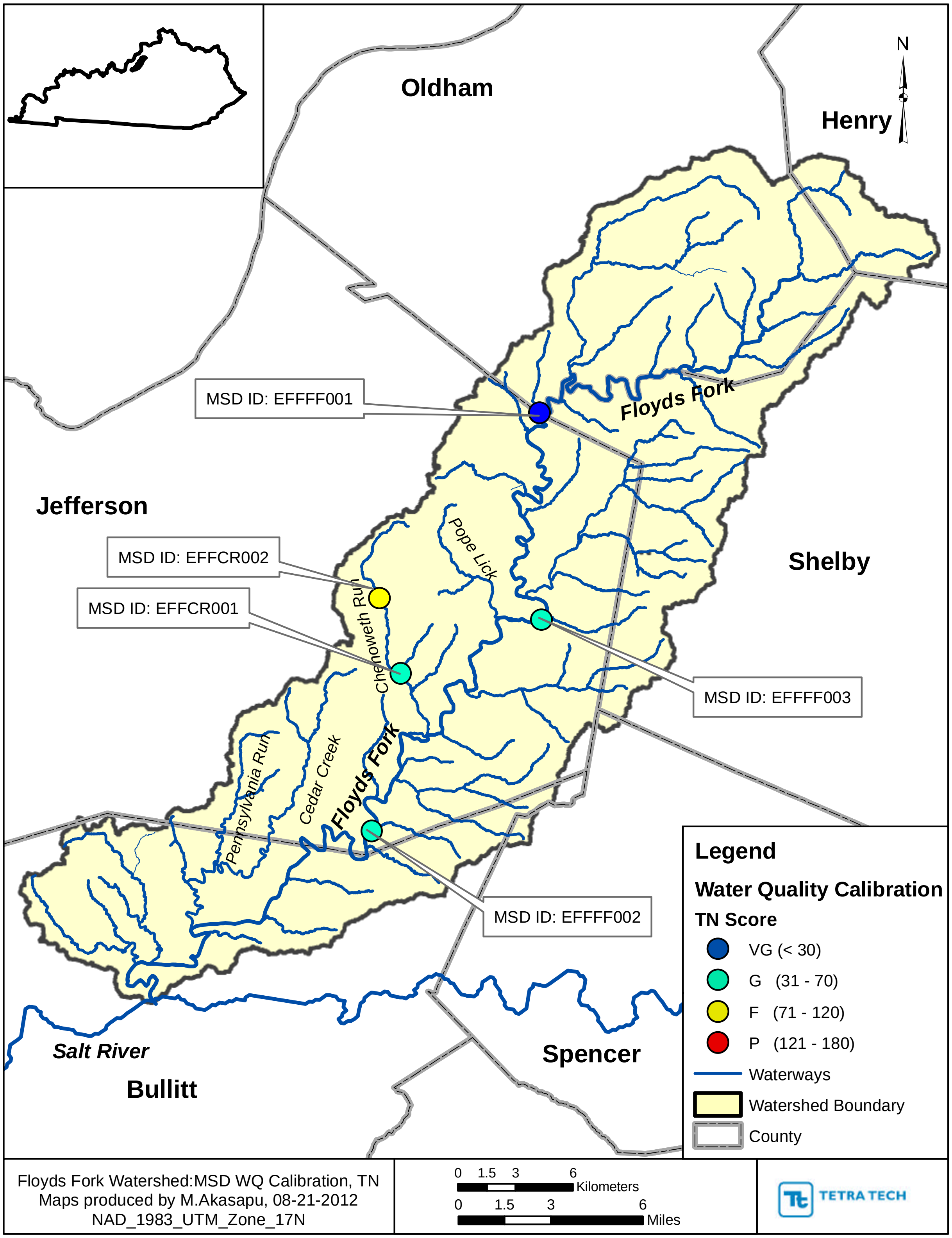


Figure 5-9 MSD WQ Validation for TN in the Floyds Fork Watershed

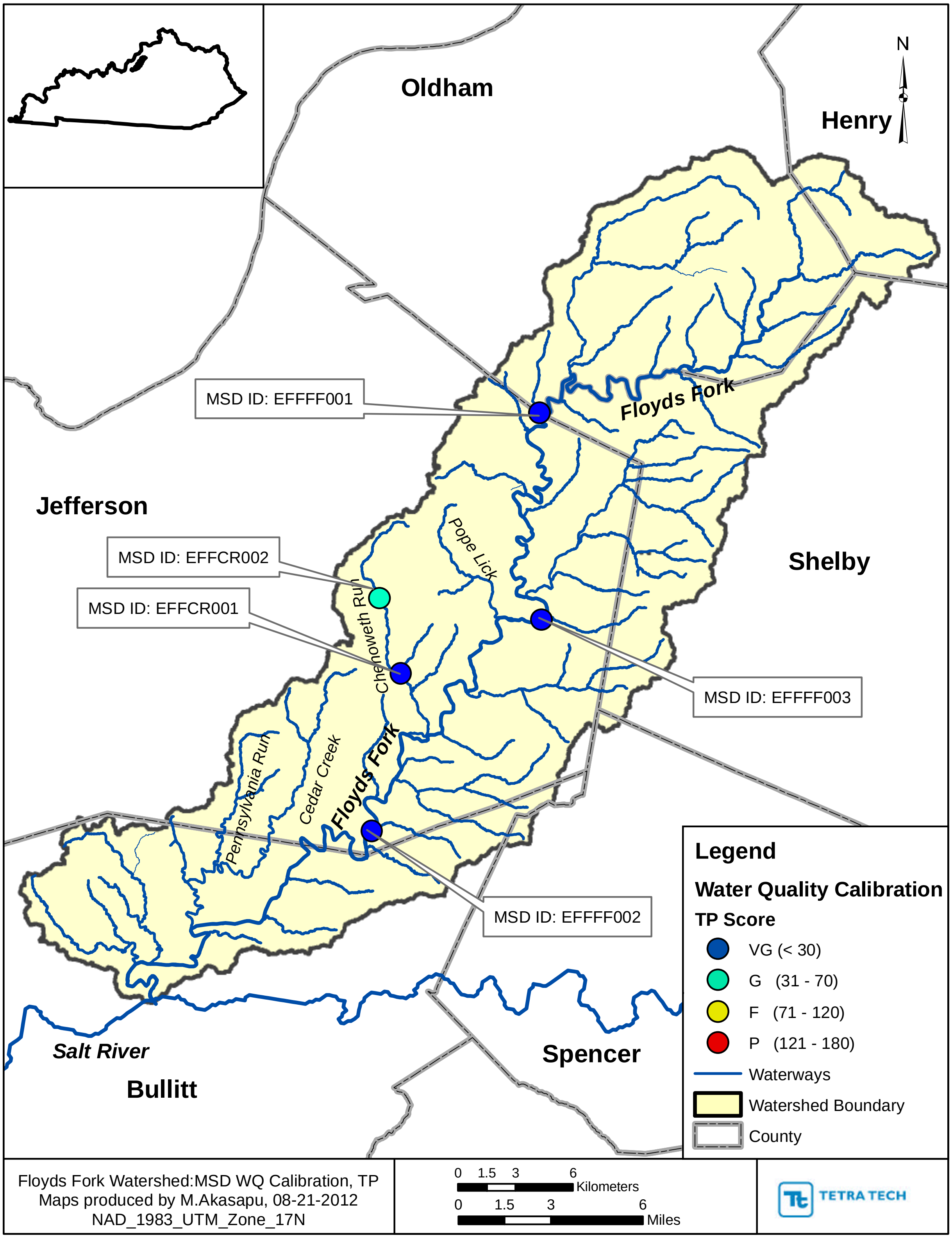


Figure 5-10 MSD WQ Validation for TP in the Floyds Fork Watershed

5.12 Loading Summary

Once the watershed model was calibrated, the percent loading by each source was computed at each USGS flow gages. This information was particularly important in identifying the dominant source of load. Table 5-7 summarizes the percent loading breakdown by source for TN and TP at the seven USGS flow gages. This information is presented graphically in Figures 5-11 and 5-12.

Table 5-8 presents the percent breakdown of the magnitude of loads from TN and TP at all 26 USGS water quality stations. The numbers represent the percent of load (both TN and TP) at a particular water quality station with respect to the loads at the outlet of the Floyds Fork watershed. Negative percentages indicate influence from water withdrawals and sinkholes.

Table 5-7 Summary of the percent loading breakdown for TN and TP at USGS Flow gages

Percent Loading Breakdown Summary for TN							
Location:	**Main Stem: Floyds Fork**			**Chenoweth Run (Lower)**		**Cedar Creek**	**Pennsylvania Run**
Station / Source	**03297900**	**03298000**	**03298200**	**03298135**	**03298150**	**03298250**	**03298300**
Point Source	24%	24%	30%	0%	75%	69%	15%
Sanitary Sewer Overflow	0%	0%	0%	0%	1%	0%	0%
Septics	0%	0%	0%	1%	0%	0%	1%
Water Withdrawal	0%	0%	0%	0%	0%	0%	-2%
MS4	8%	11%	14%	92%	18%	17%	53%
Non-MS4	68%	65%	56%	7%	6%	14%	33%
Percent Loading Breakdown Summary for TP							
Station / Source	**03297900**	**03298000**	**03298200**	**03298135**	**03298150**	**03298250**	**03298300**
Point Source	15%	19%	20%	0%	73%	64%	33%
Sanitary Sewer Overflow	0%	0%	0%	0%	2%	0%	0%
Septics	0%	0%	1%	2%	1%	1%	1%
Water Withdrawal	0%	0%	0%	0%	0%	0%	-1%
MS4	2%	2%	3%	73%	9%	6%	15%
Non-MS4	83%	79%	76%	25%	15%	29%	52%

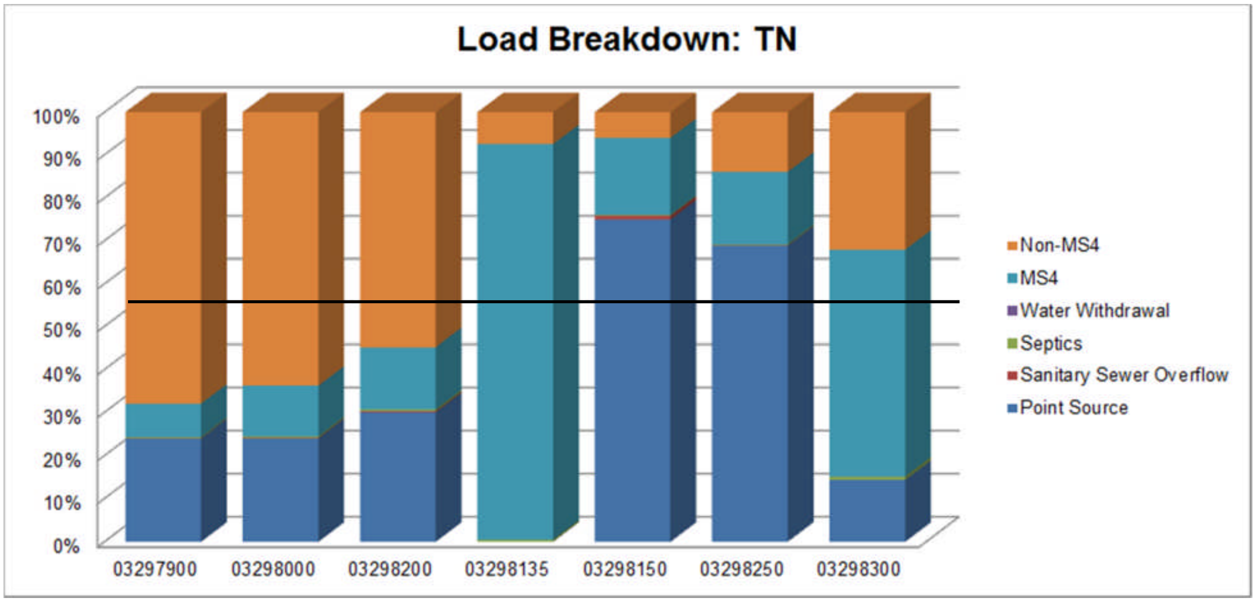


Figure 5-11 Percent Loading Breakdown for TN at USGS Flow gages

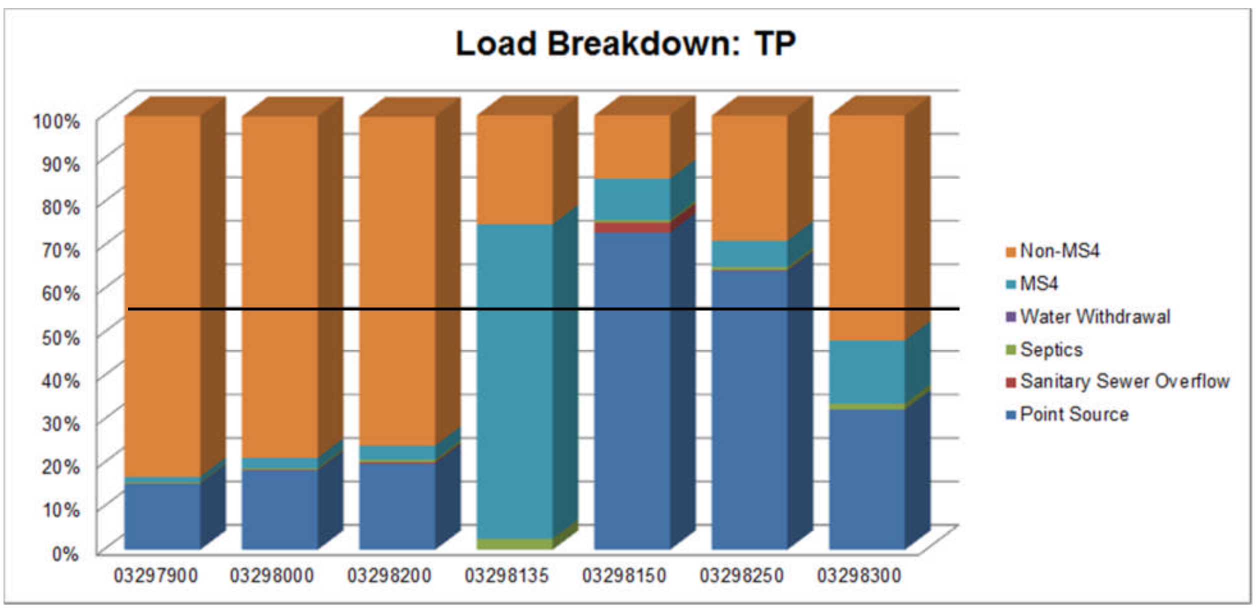


Figure 5-12 Percent Loading Breakdown for TP at USGS Flow gages

Table 5-8 Summary of the percent breakdown of magnitudes of loads for TN and TP at all USGS Water Quality Stations

USGS Station	SWS	TN			TP		
		Total (PS+NPS)	PS	NPS	Total (PS+NPS)	PS	NPS
03297830	244	8%	0%	8%	8%	0%	8%
03297845	229	10%	0%	10%	11%	0%	11%
03297850	220	1%	0%	0%	1%	0%	1%
03297855	215	2%	0%	2%	2%	0%	3%
03297860	210	11%	7%	3%	4%	2%	2%
03297875	225	1%	0%	1%	1%	0%	1%
03297880	617	2%	0%	2%	3%	1%	3%
03297900	615	3%	1%	2%	4%	2%	2%
03297930	185	10%	5%	5%	9%	5%	4%
03297950	263	2%	0%	2%	2%	0%	2%
03297975	274	3%	0%	3%	3%	0%	3%
03297980	258	4%	0%	4%	5%	0%	5%
03298000	180	3%	0%	3%	3%	0%	3%
03298005	174	2%	0%	2%	2%	0%	1%
03298020	283	4%	0%	4%	3%	0%	3%
03298100	178	1%	0%	1%	0%	0%	0%
03298110	176	0%	0%	0%	0%	0%	0%
03298120	169	0%	-1%	1%	3%	0%	3%
03298135	167	2%	0%	2%	1%	0%	1%
03298138	610	13%	13%	0%	5%	5%	0%
03298150	609	2%	0%	2%	2%	1%	1%
03298160	158	1%	0%	1%	1%	0%	1%
03298200	606	3%	-2%	4%	7%	0%	6%
03298250	134	10%	7%	3%	5%	3%	2%
03298300	130	2%	0%	2%	1%	0%	1%
03298470	102	2%	-2%	4%	13%	5%	8%
Total		***100%***	***30%***	***70%***	***100%***	***25%***	***75%***

6.0 References

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