Prepared in cooperation with Johnson County Wastewater

Model Documentation for Relations Between Continuous Real-Time and Discrete Water-Quality Constituents in Indian Creek, Johnson County, Kansas, June 2004 through May 2013

By Mandy L. Stone and Jennifer L. Graham

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Contents

Figures

Tables

Conversion Factors and Datum

SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.621	mile (mi)
	Area	
square kilometer (km^2)	0.386	square mile (mi^2)
square meter (m^2)	10.76	square foot (ft^2)
	Volume	
milliliter (mL)	0.0338	ounce, fluid (oz)
cubic decimeter (dm^3)	0.0353	cubic foot (ft^3)
	Flow rate	
milligram per liter (mg/L)	1	parts per million (ppm)
	Mass	
milligram (mg)	0.001	gram (g)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).
Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Abbreviations

119th	Indian Creek at 119th Street, Overland Park, KS
1Q	first quartile
3Q	third quartile
µS/cm	microsiemens per centimeter at 25 degrees Celsius
°C	degrees Celsius
adjr2	adjusted R^2
ANC	acid neutralizing capacity
Ca	calcium
$CaCO_3$	calcium carbonate
Cl	chloride
COD	chemical oxygen demand
col/100 mL	colonies per 100 mL

College	Indian Creek at College Boulevard, Overland Park, KS
cooksD	Cook's distance
cos	cosine
Cp	Mallow's C_p
D	day of year
Df	degrees of freedom
dfits	change in fitted values
DP	dissolved phosphorus
DS	dissolved solids
DTKN	dissolved total Kjeldahl nitrogen
EC	*Escherichia coli* bacteria
E. coli	*Escherichia coli*
ENT	enterococci bacteria
EWI	equal-width-increment
F	fluoride
FC	fecal coliform bacteria
Fe	iron
FNU	formazin nephelometric units
F-statistic	ratio of the mean square of the regression to the estimated variance
ft^3/s	cubic feet per second
F Value	explained variance divided by unexplained variance
K	potassium
km	kilometers
km^2	square kilometers
KS	Kansas
Marty	Indian Creek at Overland Park, KS
Max	maximum
Mean Sq	mean square
Mg	magnesium
mg/L	milligrams per liter
Min	minimum
Mission Farms	Indian Creek at Indian Creek Parkway, Overland Park, KS
MSE	mean square error
MSPE	model standard percentage error
n	number of measurements
N	nitrogen
Na	sodium
NH_4	ammonia
NITRATAX	continuously measured nitrate
NO_2	nitrite
NO_3	nitrate
NO_3NO_2	nitrate plus nitrite
$NO_3NO_{2,m}$	continuously measured nitrate
Nvars	number of explanatory variables
NWIS	Unites States Geological Survey National Water Information System
NWQL	United States Geological Survey National Water Quality Laboratory
OP	orthophosphate
PO_4	orthophosphate

PP	particulate phosphorus
Pr(F)	probability of observing a test statistic that is as extreme or more extreme than currently observed assuming that the null hypothesis is true
Pr(>|t|)	probability of observing a test statistic that is as extreme or more extreme than currently observed assuming that the null hypothesis is true
press	prediction error sum of squares
PRESS	prediction error sum of squares
p-value	probability of observing a test statistic that is as extreme or more extreme than currently observed assuming that the null hypothesis is true
Q	streamflow
QA/QC	quality assurance/quality control
R^2	coefficient of determination
resids	residuals
RMSE	root mean square error
RPD	relative percentage difference
R-squared	coefficient of determination (R^2)
SC	specific conductance
sin	sine
SO_4	sulfate
SSC	suspended sediment
State Line	Indian Creek at State Line Road, Leawood, KS
Stderr	standard error
Std. Error	standard error
stnd.res	standardized residuals
stud.res	studentized residuals
Sum of Sq	sum of squares
TBY	turbidity
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TOC	total organic carbon
Tomahawk	Tomahawk Creek near Overland Park, KS
TP	total phosphorus
TSS	total suspended
t value	coefficient divided by its standard error
USGS	United States Geological Survey
WWTF	wastewater-treatment facility
yhat	predicted values
YSI	Yellow Springs Instruments

Model Documentation for Relations Between Continuous Real-Time and Discrete Water-Quality Constituents in Indian Creek, Johnson County, Kansas, June 2004 through May 2013

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Abstract

Johnson County is the fastest growing county in Kansas, with a population of about 560,000 people in 2012. Urban growth and development can have substantial effects on water quality, and streams in Johnson County are affected by nonpoint-source pollutants from stormwater runoff and point-source discharges such as municipal wastewater effluent. Understanding of current (2014) water-quality conditions and the effects of urbanization is critical for the protection and remediation of aquatic resources in Johnson County, Kansas and downstream reaches located elsewhere. The Indian Creek Basin is 194 square kilometers and includes parts of Johnson County, Kansas and Jackson County, Missouri. Approximately 86 percent of the Indian Creek Basin is located in Johnson County, Kansas. The U.S. Geological Survey, in cooperation with Johnson County Wastewater, operated a series of six continuous real-time water-quality monitoring stations in the Indian Creek Basin during June 2011 through May 2013; one of these sites has been operating since February 2004. Five monitoring sites were located on Indian Creek and one site was located on Tomahawk Creek. The purpose of this report is to document regression models that establish relations between continuously measured water-quality properties and discretely collected water-quality constituents. Continuously measured water-quality properties include streamflow, specific conductance, pH, water temperature, dissolved oxygen, turbidity, and nitrate. Discrete water-quality samples were collected during June 2011 through May 2013 at five new sites and June 2004 through May 2013 at a long-term site and analyzed for sediment, nutrients, bacteria, and other water-quality constituents. Regression models were developed to establish relations between discretely sampled constituent concentrations and continuously measured physical properties to estimate concentrations of those constituents of interest that are not easily measured in real time because of limitations in sensor technology and fiscal constraints. Regression models for 28 water-quality constituents were developed and documented. The water-quality information in this report is important to Johnson County Wastewater because it allows the concentrations of many potential pollutants of interest, including nutrients and sediment, to be estimated in real time and characterized during conditions and time scales that would not be possible otherwise.

Introduction

Johnson County is the fastest growing county in Kansas, with a population of about 560,000 people in 2012. The population in Johnson County has increased by approximately 20 percent every

decade, a growth trajectory that is expected to continue for at least the next 20 years (U.S. Census Bureau, 2013). Infrastructure needs will continue to increase with ongoing population growth and urban development. Urban growth and development can have substantial effects on water quality (Walsh and others, 2005), and streams in Johnson County are affected by nonpoint-source pollutants from stormwater runoff and point-source discharges such as municipal wastewater effluent (Lee and others, 2005). Understanding of current (2014) water-quality conditions and the effects of urbanization is critical for the protection and remediation of aquatic resources in Johnson County, Kansas and downstream reaches located elsewhere.

The Johnson County Douglas L. Smith Middle Basin (Middle Basin) Wastewater-treatment facility (WWTF) is a point-source discharge on Indian Creek in Johnson County, Kansas (fig. 1, available at *http://pubs.usgs.gov/ofr/2014/1170/downloads/*). In summer 2010, upgrades to increase capacity and include biological nutrient removal at the Middle Basin WWTF were completed (Susan Pekarek, Johnson County Wastewater, written commun., 2013).

Figure 1. Map showing location of municipal wastewater treatment facilities and study sites in the Indian Creek Basin.

The U.S. Geological Survey (USGS), in cooperation with Johnson County Wastewater, operated six continuous real-time water-quality monitoring stations along Indian Creek (fig. 1) during June 2011 through May 2013; one of these sites, State Line (table 1, available at *http://pubs.usgs.gov/ofr/2014/1170/downloads/*), has been operating since 2004. Water-quality monitoring along Indian Creek provides continuous measures of streamflow, specific conductance, pH, water temperature, dissolved oxygen, turbidity, and nitrate. Many discrete water-quality samples have been collected at these sites and used to develop regression models establishing relations between continuously monitored water-quality properties and water-quality constituents of interest that are not monitored continuously.

Purpose and Scope

The purpose of this report is to document regression models that establish relations between continuous and discrete water-quality data collected from Indian Creek study sites (fig. 1). These models are useful for evaluating concentrations of water-quality constituents to compare with water-quality criteria and for computing loads and yields to assess constituent transport. The water-quality information in this report is important to Johnson County Wastewater because it allows the concentrations of many potential pollutants of interest, including nutrients and sediment, to be estimated in real time and characterized during conditions and time scales that would not be possible otherwise.

Description of Study Area

The Indian Creek Basin is 194 square kilometers (km^2) and includes parts of Johnson County, Kansas and Jackson County, Missouri. Approximately 86 percent of the Indian Creek Basin is located in Johnson County. The headwaters of Indian Creek are located in central Johnson County and Indian Creek flows east into the Blue River (fig. 1).

Six sites in the Indian Creek Basin were sampled in this study; five sites were located along a 15.6-kilometer (km) reach of Indian Creek [Indian Creek at 119th Street, Overland Park, KS (119th); Indian Creek at College Boulevard, Overland Park, KS (College); Indian Creek at Overland Park, KS (Marty); Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms); and Indian Creek at State Line Road, Leawood, KS (State Line)] and one was located on Tomahawk Creek [Tomahawk

Creek near Overland Park, KS (Tomahawk)], the largest tributary to Indian Creek (fig. 1; table 1). Land use in the Indian Creek Basin is predominantly urban. Overall, about 93 percent of the land use in the Indian Creek Basin is classified as urban and about 47 percent is classified as impervious surface. The Tomahawk Creek sub-basin is the least developed area of the watershed; 83 percent of land use is classified as urban and 47 percent is classified as impervious surface. Land use at all other Indian Creek study sites is predominantly (greater than 80 percent) urban and generally similar among sites (fig. 1; table 1; Mid-America Regional Council, 2013).

Table 1. Location and description of Indian Creek Basin study sites in Johnson County, Kansas, including drainage area, distance from the Middle Basin and Tomahawk Creek wastewater-treatment facility (WWTF) effluent discharges, and urban-land use.

There are two WWTFs, Middle Basin and Tomahawk Creek, that discharge into Indian Creek in Johnson County (fig. 1). The Middle Basin and Tomahawk Creek WWTFs are located upstream from the continuous water-quality monitoring site on Indian Creek at State Line Road (fig. 1; table 1) that has been operating since 2004. The 119th and Tomahawk study sites are located upstream from any WWTF effluent discharges; the College, Marty, and Mission Farms sites are located 0.96, 5.13, and 9.47 km, respectively, downstream from the Middle Basin WWTF effluent discharge, and the State Line site is located 13.2 km downstream from the Middle Basin WWTF effluent discharge and 2.32 km downstream from the Tomahawk Creek WWTF effluent discharge (fig. 1; table 1).

Methods

Continuous and discrete water-quality data collected by the USGS at five sites (119th, College, Marty, Mission Farms, and Tomahawk) starting June 1, 2011, through May 31, 2013, and at State Line starting June 1, 2004, through May 31, 2013, were used to develop site-specific regression models. These periods were selected for comparability because the five new sites were all installed by June 2011. The State Line datasets were split into two periods to develop regression models for dates that incorporated the Middle Basin WWTF pre-upgrade (June 1, 2004, through May 31, 2008) and transitional (June 1, 2008, through May 31, 2010) period (June 1, 2004, through May 31, 2010, collectively referred to hereinafter as the pre-upgrade period) and post-upgrade (June 1, 2010, through May 31, 2013) period. This report includes models developed using all of the State Line data, the pre-upgrade data, and the post-upgrade data. Additional streamflow-based models were developed when necessary for suspended-sediment concentration, total nitrogen, nitrate plus nitrite, total Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, and particulate phosphorus to enable computation of loads for these constituents of particular interest during times when other concomitant data were missing.

Continuous Water-Quality Monitoring

Continuous water-quality and streamflow data were collected from all six study sites. Streamflow gages have been operated at the Marty site since March 1963 and the State Line site since April 2003. Streamflow gages were installed at the 119th, College, and Mission Farms sites in June 2011 and the Tomahawk site in July 2011. Streamflow was computed using standard USGS methods (Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010). A continuous water-quality monitor has been operated at the State Line site since February 2004; monitors were installed at the other five study sites in May 2011. Each site was equipped with a Yellow Springs Instruments (YSI™) 6600 Extended Deployment System water-quality monitor that measured specific conductance, pH, water temperature,

dissolved oxygen (YSI optical dissolved oxygen sensor), and turbidity (YSI 6136 optical turbidity sensor). Nitrate monitors (HACH™ Nitratax plus sc) also were installed at all study sites in March 2012.

Monitors were installed near the centroid of the stream cross-section to best represent conditions across the width of the stream and were maintained in accordance with standard USGS procedures (Wagner and others, 2006; Rasmussen and others, 2009b). Streamflow and continuous water-quality data were recorded at 15-minute intervals. Continuous streamflow and water-quality data are available on the USGS Web site at *http://nrtwq.usgs.gov/ks*. In this report, results are presented for the State Line site for June 1, 2004, through May 31, 2013, and all other sites for the period June 1, 2011, through May 31, 2013; continuous nitrate data are reported for the period March 1, 2012, through May 31, 2013.

Discrete Water-Quality Samples

Discrete water-quality data have been routinely collected from the State Line site since April 2003; previously collected data used in this report are for January 2004 through May 2006. These data allowed comparison of water-quality conditions in Indian Creek before and after upgrades to the Middle Basin WWTF. For comparability, Indian Creek data collected before 2004 were not used in this report because there were no concurrent continuous data. Previously collected samples were analyzed for a variety of water-quality constituents; analyses were most commonly provided by the USGS National Water Quality Laboratory (NWQL), Lakewood, Colorado, and the Johnson County Environmental Laboratory (now called the Johnson County Wastewater Water-Quality Laboratory; Lee and others, 2005; Rasmussen and others, 2008, 2009a, 2012; Rasmussen and Gatotho, 2014). Samples were collected by several methods, including equal-width-increment (EWI) methods, grab samples, and suction-lift peristaltic pump samples (appendix 1, available at *http://pubs.usgs.gov/ofr/2014/1170/downloads/*). Streamflow and water-chemistry data were downloaded from the USGS National Water Information System (NWIS) Web site (*http://waterdata.usgs.gov/nwis*).

Discrete water-quality samples were collected from all six study sites throughout a range of streamflow conditions (fig. 2, available at *http://pubs.usgs.gov/ofr/2014/1170/downloads/*) during June 2011 through May 2013 using primarily depth- and width-integrating sample-collection techniques (appendix 1; Wilde, variously dated; U.S. Geological Survey, 2006). Samples collected by using this approach generally are representative of the average chemical composition of the stream cross-sectional area. Discrete water-quality samples were analyzed for dissolved solids and major ions, alkalinity, suspended solids and sediment, nutrients (nitrogen and phosphorus species), indicator bacteria (enterococci bacteria, *Escherichia coli* bacteria, and fecal coliform bacteria), organic carbon, and chemical oxygen demand (COD). Dissolved solids, major ions, nutrients, indicator bacteria, and COD were analyzed by the Johnson County Wastewater Water-Quality Laboratory according to Standard Methods (American Public Health Association and others, 2005). Total organic carbon was analyzed by the NWQL according to Standard Methods (American Public Health Association and others, 1998) and methods presented in Brenton and Arnett (1993). Select replicate samples and samples collected during evenings and weekends were sent to the NWQL and analyzed according to methods presented in Fishman and Friedman (1989). Suspended sediment was analyzed at the USGS Iowa Sediment Laboratory in Iowa City, Iowa, according to methods described in Guy (1969).

Figure 2. Continuous streamflow duration curves and discrete water-quality samples collected at the Indian Creek study sites during June 2004 through May 2013.

Quality Assurance and Quality Control

Continuous Water-Quality Monitoring

The specific conductance, pH, water temperature, and dissolved oxygen sensors have wide ranges of operation (for example, pH sensors measure from 0 to 14 units; Wagner and others, 2000 and 2006) that were not exceeded in this study. The manufacturer specifications for the YSI 6136 optical turbidity sensor indicate the maxima are 1,000 formazin nephelometric units (FNU). Individual turbidity sensors differ in actual maximum readings. The maximum reading recorded at all sites during 2004 through 2013 was 1,760 FNU at the State Line site (table 2, available at *http://pubs.usgs.gov/ofr/2014/1170/downloads/*). The maximum readings for the 119th, College, Marty, Mission Farms, and Tomahawk sites were 1,290, 1,050, 1,340, 860, and 1,480 FNU, respectively (table 2). Data that exceeded the maximum operation value were retained in datasets and classified as poor.

Continuous data generally required corrections of less than 10 percent during the study, which classifies the data quality rating as good according to established guidelines (Wagner and others, 2006). Zero percent of the streamflow record, 0 to 2 percent of the specific conductance and pH record, 0 to 1 percent of the temperature record, 0 to 6 percent of the dissolved oxygen record, 0 to 4 percent of the turbidity record, and 0 to 10 percent of the nitrate record were missing or deleted for the 119th, College, Marty, Mission Farms, and Tomahawk sites during 2011 through 2013 (table 2). During 2004 through 2013, less than 1 percent of the streamflow and temperature record, 1 percent of the specific conductance record, 2 percent of the pH record, 5 percent of the dissolved oxygen record, 4 percent of the turbidity record, and zero percent of the nitrate record were missing or deleted for the State Line site (table 2). Missing and deleted data were largely because of low flow conditions and, in some cases, sensor fouling (table 2).

Table 2. Summary statistics for variables measured continuously at the Indian Creek wastewater study sites, Johnson County, Kansas June 2004 through May 2013.

Comparison with cross-section measurements provided verification of minimum bias as a result of sonde location within the stream cross-section. Relative percentage difference (*RPD*) was used to evaluate differences in sonde measurements. The *RPD* was calculated using the following equation:

$$RPD = \left[|A - B| / \left(\frac{A+B}{2}\right)\right] \mathbf{x}\ 100 \qquad (1)$$

where A and B are concentrations in each replicate pair.

At all six study sites, median RPDs between cross-section and continuous monitor measurements were less than 5 percent for all water-quality properties except turbidity. Turbidity had median *RPD*s of less than 20 percent at all study sites. The larger *RPD*s for turbidity were caused, in part, by comparisons when turbidities were near the low end of the sensor detection limit (less than 5 FNU). For all water-quality properties, larger differences between cross-section and continuous monitor measurements also occurred during stormwater runoff when conditions were changing rapidly.

Discrete Water-Quality Samples

Replicate, standard reference, and blank samples were collected throughout a range of streamflow conditions as part of quality assurance/quality control (QA/QC). About 16 percent of

discrete water-quality samples were QA/QC samples. Approximately 606 sequential, split, and concurrent replicate constituent pairs were collected during 2004 through 2013 among the six study sites. Replicate samples were analyzed to identify variability in sampling and analysis methods (Wilde, variously dated). *RPD* was used to evaluate differences in analyte concentrations detected in replicate water samples.

Replicate pairs with an *RPD* within 10 percent were considered acceptable for inorganic constituents (Ziegler and Combs, 1997). Replicate pairs with an *RPD* within 20 percent were considered acceptable for nutrient and organic constituents, and *RPD*s within 50 percent were considered acceptable for bacterial analysis. The median *RPD* between all constituent replicate pairs was less than their respective acceptability limits. All constituent replicate pairs had median *RPD*s that were less than 5, except for iron (16 percent), total suspended solids and suspended sediment (10 percent), dissolved total Kjeldahl nitrogen (11 percent), total Kjeldahl nitrogen (10 percent), nitrate (5 percent), total phosphorus (6 percent), enterococci bacteria (18 percent), *Escherichia coli* bacteria (24 percent), fecal coliform bacteria (30 percent), and chemical oxygen demand (7 percent). Larger *RPD*s generally occurred when the values were near the laboratory reporting level.

Development of Regression Models to Compute Constituent Concentrations

Regression models were developed to establish relations between discretely-sampled constituent concentrations from samples collected during 2004 through 2013 and concurrent continuously measured physical properties to estimate concentrations of those constituents of interest that are not easily measured in real time because of limitations in sensor technology and fiscal constraints. Models were developed using simple linear (ordinary least squares) regression analyses to relate discrete sample concentrations or densities of water-quality constituents to continuously measured water-quality properties (Helsel and Hirsch, 2002; Rasmussen and others, 2008). Untransformed and $\log_{10}$ transformations (log-transformed) were used for discrete sample concentrations or densities and continuously measured water-quality properties. The methods used for the development of these models and quantifying uncertainty are described in detail in Rasmussen and others (2009b) and Stone and others (2013). All data for this report were analyzed using TIBCO Spotfire S+® 8.1 for Windows® statistical software (TIBCO Software, Inc., 2008).

To avoid false-positive quantification of a constituent, low concentrations are left-censored and reported as "less than" values by the laboratory (Childress and others, 1999). High concentrations or densities can be right-censored, where the value is at least a certain number and are reported as "greater than" values. Twenty-one constituents had model datasets with left censored data: fluoride (16 percent of the 119th dataset), sulfate (5 percent of the 119th dataset), iron (12 to 30 percent of datasets), total suspended solids (2 to 20 percent of datasets), total nitrogen (8 to 16 percent of datasets), dissolved total Kjeldahl nitrogen (7 to 17 percent of datasets), total Kjeldahl nitrogen (11 to 13 percent of datasets), ammonia (3 to 45 percent of datasets), nitrate plus nitrite (10 to 13 percent of datasets), nitrate (6 percent of the 119th dataset), nitrite (4 to 38 percent of datasets), total phosphorus (30 to 38 percent of datasets), orthophosphate (2 to 7 percent of datasets), dissolved phosphorus (7 percent of the Mission Farms dataset), particulate phosphorus (7 percent of the Mission Farms dataset), enterococci bacteria (6 to 8 percent of datasets), *Escherichia coli* bacteria (2 to 12 percent of datasets), fecal coliform bacteria (2 to 6 percent of datasets), and chemical oxygen demand (5 percent of the 119th dataset). One constituent had model datasets with right censored data—enterococci bacteria (6 to 15 percent of datasets). The left-censored data arbitrarily were assigned a value of one-half of the censoring level and the right-censored data were kept at the censoring level, and the arbitrary assignment of values means that results from this model need to be used with caution. Censored data regression techniques were not

used for left- or right-censored data because statistical output from censored data regression techniques is insufficient for data entry for the USGS National Real Time Water Quality Web site (*http://nrtwq.usgs.gov*). Model datasets with "severe censoring" (greater than 50 percent; Helsel and Hirsch, 2002) were considered unsuitable to use for constituent concentration computations.

In-stream continuous data corresponding to each discrete sample were determined from time-series datasets by using time-weighted averages of continuous data values recorded immediately before, during, and after the discrete sample collection. Concurrent in-stream continuous measurements were used to correspond with discrete measurements as described in Rasmussen and others (2009b). All continuously measured variables and seasonal components (sine and cosine variables) were tested for significance for each response variable.

Outliers in discrete samples were removed only when there were issues with laboratory analysis (such as an orthophosphate concentration being higher than the concomitant total phosphorus concentration). On average, approximately 2 percent of the discrete-sample data were considered outliers and were removed from regression models. Outliers are identified with footnotes in the tables.

Linear regression models were evaluated based on diagnostic statistics (R^2, coefficient of determination; Mallow's C_p; *RMSE*, root mean square error; *PRESS*, prediction error sum of squares), patterns in residual plots, and the range and distribution of discrete and continuous data (Helsel and Hirsch, 2002). The best model for each constituent was selected to maximize the amount of variance in the response variable that is explained by the model (multiple R^2 for models with one explanatory variable and adjusted R^2 for models with more than one explanatory variable), maximize fit to the data (Mallow's C_p), and minimize heteroscedasticity (irregular scatter) in the residual plots and uncertainty associated with computed values (*RMSE* and *PRESS*). Variance Inflation Factor (VIF) was used to measure the exact or approximate linear relation between variables (collinearity; Marquardt, 1970). Model simplicity also was considered for model selection because, as more variables are included, the likelihood that the variability of the system is not described by the sampling dataset increases. Variables were included if *p*-values were significant (less than 0.05) or if *p*-values were insignificant (greater than 0.05) that substantially reduced error as described in Rasmussen and others (2009b). Significant (*p*-value less than 0.05) additional explanatory variables were included in final models when retaining them increased the amount of variance explained by the model by 10 percent or more, decreased Mallow's C_p, and minimized irregular scatter (heteroscedasticity) in residual plots. If a sine or cosine variable was determined to be an explanatory variable, sine and cosine variables were included in the model (Helsel and Hirsch, 2002). Models were considered suitable to use for constituent concentration computations if the amount of variance explained by the models (R^2) was 0.40 or greater. Models that did not meet the selection criteria of having 50 percent or less censored data or an R^2 value of 0.40 or greater were not included in the report with the exception of selected nutrients of interest. The best possible models for these nutrients are included even if selection criteria were not met because of potential for use in preliminary nutrient load calculations needed by local entities.

Mean square error (*MSE*) and *RMSE* were calculated for each model to assess the variance between predicted and observed values (Helsel and Hirsch, 2002). The model standard percentage error (*MSPE*) was calculated as a percentage of the *RMSE* (Hardison, 1969). Because transformation of estimates back into original units results in a low biased estimate (Helsel and Hirsch, 2002), a bias correction factor (*BCF*) was calculated for models with logarithmically transformed response variables (Duan, 1983).

Results of Regression Analysis for Selected Constituents

Relations between in-stream continuous measurements and discrete constituents were developed and evaluated using ordinary least squares regression. Regression models were developed for 28 constituents: acid neutralizing capacity, dissolved solids, calcium, magnesium, potassium, sodium, chloride, fluoride, sulfate, iron, total suspended solids, suspended sediment, total nitrogen, dissolved Kjeldahl nitrogen, total Kjeldahl nitrogen, ammonia, nitrate plus nitrite, nitrate, nitrite, phosphorus, orthophosphate, dissolved phosphorus, particulate phosphorus, enterococci bacteria, *Escherichia coli* bacteria, fecal coliform bacteria, total organic carbon, and chemical oxygen demand. Models are shown in table 3 (available at *http://pubs.usgs.gov/ofr/2014/1107/downloads/*). S+® statistical output is presented in figures 3–480 (available at *http://pubs.usgs.gov/ofr/2014/1107/downloads/*) and model datasets are presented in tables 4–158 (available at *http://pubs.usgs.gov/ofr/2014/1107/downloads/*). Abbreviations used in the figures are defined in the front of this report.

Specific conductance measures the capacity of water to conduct an electrical current and is related to the concentration of ionized substances in water (Hem, 1992). Because major ions affect specific conductivity, specific conductance was commonly an explanatory variable for ions. Turbidity is caused by suspended and dissolved matter such as clay, silt, finely divided organic material, plankton and other microscopic organisms, organic acids, and dyes (ATSM International, 2003; Anderson, 2005). Turbidity was commonly related to constituents associated with particulates because turbidity measures light scattered by particulates in water. Continuously measured nitrate was commonly related to some nitrogen species because the nitrate sensor measured ultraviolet light absorbed by nitrates. Negative associations of some constituents, including some ions, with streamflow and turbidity are likely because of groundwater influences. Some nutrient models included seasonal components as explanatory variables that illustrate the seasonal nature of some nutrient sources.

Streamflow, specific conductance, and turbidity were explanatory variables for acid neutralizing capacity. Models for the downstream sites Marty, Mission Farms, Tomahawk, and State Line (post-wastewater-treatment facility upgrades) included a seasonal component. Acid neutralizing capacity was negatively correlated with streamflow and turbidity.

Specific conductance was generally an explanatory variable for ions and was positively related to ionic constituents. Specific conductance was the single explanatory variable for dissolved solids, sodium, and chloride at all sites. Dissolved solids, sodium, and chloride were all strongly positively correlated with specific conductance. In addition to specific conductance, streamflow was an additional explanatory variable for calcium at 119th, and turbidity was an additional explanatory variable for calcium at Mission Farms, Tomahawk, and State Line (post-wastewater-treatment facility upgrades); calcium was negatively correlated with streamflow and turbidity. In addition to specific conductance, turbidity was an additional explanatory variable for magnesium models at College, Marty, Mission Farms, Tomahawk, and State Line (all available data and State Line post-wastewater-treatment facility upgrades) and was negatively related to magnesium. Streamflow was an additional explanatory variable at 119th and was negatively related to magnesium.

Streamflow was an explanatory variable in sulfate models for 119th, Marty, Tomahawk, and State Line (all available data and pre-wastewater-treatment facility upgrades) and was negatively correlated with sulfate. Turbidity also was an explanatory variable in sulfate models for 119th, College, Mission Farms, and State Line (post-wastewater-treatment facility upgrades) and was negatively related to sulfate. Specific conductance was positively related to sulfate concentrations and was an explanatory variable at Marty, Mission Farms, Tomahawk, and State Line (all available data and pre-wastewater-treatment facility upgrades).

Turbidity was an explanatory variable for total suspended solids, suspended sediment, total nitrogen, and particulate phosphorus. Streamflow also was an additional explanatory variable for total suspended solids and suspended-sediment concentration at the Marty site. Turbidity was positively correlated with total suspended solids, suspended sediment, total nitrogen and particulate phosphorus. Streamflow was positively correlated with total suspended solids and suspended sediment. Continuously measured nitrate was an additional explanatory variable for, and positively correlated with, total nitrogen for 119th, College, Marty, Mission Farms, Tomahawk, and State Line (post-wastewater-treatment facility upgrades). Streamflow was an explanatory variable for total nitrogen when nitrate data were unavailable for those models.

Specific conductance and nitrate generally were explanatory variables for dissolved Kjeldahl nitrogen and turbidity was generally an explanatory variable for total Kjeldahl nitrogen. Nitrate was the single explanatory variable for nitrate plus nitrite and nitrite, except when continuous nitrate data were unavailable for the State Line all available data and pre-wastewater-treatment facility upgrades models. Streamflow, specific conductance, or turbidity generally were explanatory variables for total phosphorus, indicator bacteria, and chemical oxygen demand. Orthophosphate and dissolved phosphorus models usually had a seasonal component in addition to streamflow, turbidity, and specific conductance as explanatory variables. Indicator bacteria were positively related to streamflow and turbidity and negatively related to specific conductance. Streamflow and turbidity generally were explanatory variables for total organic carbon.

Table 3. Regression models and summary statistics for continuous concentration computations for Indian Creek wastewater study sites, Johnson County, Kansas, June 2004 through May 2013.

Table 4. Acid neutralizing capacity dataset for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 3. S+® output of regression model development using turbidity (TBY) as the explanatory variable for acid neutralizing capacity (ANC) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 4. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed acid neutralizing capacity (ANC) concentrations, measured versus predicted ANC concentrations, computed log-transformed ANC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Table 5. Acid neutralizing capacity dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 5. S+® output of regression model development using specific conductance (SC) and turbidity (TBY) as explanatory variables for acid neutralizing capacity (ANC) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 6. S+® output graphs from simple linear regression analysis using log-transformed specific conductance (SC) and turbidity (TBY) as explanatory variables for log-transformed acid neutralizing capacity (ANC) concentrations showing measured versus predicted ANC concentrations, computed log-transformed ANC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for

Figure 30. S+® output graphs from simple linear regression analysis showing log-transformed specific conductance (SC) versus log-transformed dissolved solids (DS) concentrations, measured versus predicted DS concentrations, computed DS concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 31. S+® output of regression model development using specific conductance (SC) as the explanatory variable for dissolved solids (DS) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 32. S+® output graphs from simple linear regression analysis showing log-transformed specific conductance (SC) versus log-transformed dissolved solids (DS) concentrations, measured versus predicted DS concentrations, computed DS concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 33. S+® output of regression model development using specific conductance (SC) as the explanatory variable for dissolved solids (DS) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Figure 34. S+® output graphs from simple linear regression analysis showing log-transformed specific conductance (SC) versus log-transformed dissolved solids (DS) concentrations, measured versus predicted DS concentrations, computed DS concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Table 16. Calcium dataset for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 35. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for calcium (CA) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 36. S+® output graphs from simple linear regression analysis using log-transformed streamflow (Q) and log-transformed specific conductance (SC) as explanatory variables for calcium (CA) concentrations showing measured versus predicted CA concentrations, computed CA concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Table 17. Calcium dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 37. S+® output of regression model development using specific conductance (SC) as the explanatory variable for calcium (CA) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 38. S+® output graphs from simple linear regression analysis showing log-transformed specific conductance (SC) versus log-transformed calcium (CA) concentrations, measured versus predicted CA concentrations,

Figure 117. S+® output of regression model development using turbidity (TBY) as the explanatory variable for fluoride (F) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 118. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed fluoride (F) concentrations, measured versus predicted F concentrations, computed log-transformed F concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Table 48. Fluoride dataset for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 119. S+® output of regression model development using streamflow (Q) as the explanatory variable for fluoride (F) for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 120. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus fluoride (F) concentrations, measured versus predicted F concentrations, computed F concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 49. Fluoride dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 121. S+® output of regression model development using turbidity (TBY) as the explanatory variable for fluoride (F) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 122. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed fluoride (F) concentrations, measured versus predicted F concentrations, computed log-transformed F concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 50. Fluoride dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 123. S+® output of regression model development using streamflow (Q) as the explanatory variable for fluoride (F) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 124. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus fluoride (F) concentrations, measured versus predicted F concentrations, computed F concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Table 51. Fluoride dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 133. S+® output of regression model development using turbidity (TBY) as an explanatory variable for sulfate (SO4) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 134. S+® output graphs from simple linear regression analysis using turbidity (TBY) and log-transformed turbidity (TBY) as explanatory variables for sulfate (SO4) concentrations showing measured versus predicted SO4 concentrations, computed SO4 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard (College, site 385520094420000), June 2011 through May 2013.

Table 54. Sulfate dataset for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 135. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for sulfate (SO4) for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 136. S+® output graphs from simple linear regression analysis using log-transformed streamflow (Q) and log-transformed specific conductance (SC) as explanatory variables for log-transformed sulfate (SO4) concentrations showing measured versus predicted SO4 concentrations, computed log-transformed SO4 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 55. Sulfate dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 137. S+® output of regression model development using specific conductance (SC) and turbidity as explanatory variables for sulfate (SO4) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 138. S+® output graphs from simple linear regression analysis using log-transformed specific conductance (SC) and log-transformed turbidity (TBY) as explanatory variables for log-transformed sulfate (SO4) concentrations showing measured versus predicted SO4 concentrations, computed log-transformed SO4 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 56. Sulfate dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 139. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for sulfate (SO4) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 140. S+® output graphs from simple linear regression analysis using log-transformed streamflow (Q) and log-transformed specific conductance (SC) as explanatory variables for log-transformed sulfate (SO4) concentrations showing measured versus predicted SO4 concentrations, computed log-transformed SO4

Figure 164. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed total suspended solids (TSS) concentrations, measured versus predicted TSS concentrations, computed TSS concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 67. Total suspended solids dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), July 2011 through May 2013.

Figure 165. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total suspended solids (TSS) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), July 2011 through May 2013.

Figure 166. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed total suspended solids (TSS) concentrations, measured versus predicted TSS concentrations, computed TSS concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), July 2011 through May 2013.

Table 68. Total suspended solids dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 167. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total suspended solids (TSS) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 168. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed total suspended solids (TSS) concentrations, measured versus predicted TSS concentrations, computed log-transformed TSS concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 169. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total suspended solids (TSS) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 170. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed total suspended solids (TSS) concentrations, measured versus predicted TSS concentrations, computed TSS concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 171. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total suspended solids (TSS) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Figure 172. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed total suspended solids (TSS) concentrations, measured versus predicted TSS

Table 73. Suspended-sediment dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 189. S+® output of regression model development using turbidity (TBY) as the explanatory variable for suspended sediment (SSC) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 190. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed suspended-sediment (SSC) concentrations, measured versus predicted SSC concentrations, computed SSC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 191. S+® output of regression model development using streamflow (Q) as the explanatory variable for suspended sediment (SSC) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 192. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed suspended-sediment (SSC) concentrations, measured versus predicted SSC concentrations, computed SSC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Table 74. Suspended-sediment dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 193. S+® output of regression model development using turbidity (TBY) as the explanatory variable for suspended sediment (SSC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 194. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed suspended-sediment (SSC) concentrations, measured versus predicted SSC concentrations, computed log-transformed SSC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 195. S+® output of regression model development using streamflow (Q) as the explanatory variable for suspended sediment (SSC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 196. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed suspended-sediment (SSC) concentrations, measured versus predicted SSC concentrations, computed log-transformed SSC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 206. S+® output graphs from simple linear regression analysis using turbidity and log-transformed nitrate (NITRATAX) as explanatory variables for log-transformed total nitrogen (TN) concentrations showing measured versus predicted TN concentrations, computed log-transformed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), March 2012 through May 2013.

Figure 207. S+® output of regression model development using streamflow (Q) as the explanatory variable for total nitrogen (TN) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 208. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus total nitrogen (TN) concentrations, measured versus predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Table 76. Total nitrogen dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 209. S+® output of regression model development using turbidity (TBY) and nitrate (NITRATAX) as explanatory variables for total nitrogen (TN) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), March 2012 through May 2013.

Figure 210. S+® output graphs from simple linear regression analysis using turbidity (TBY) and nitrate (NITRATAX) as explanatory variables for total nitrogen (TN) concentrations showing measured versus predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), March 2012 through May 2013.

Figure 211. S+® output of regression model development using streamflow (Q) as the explanatory variable for total nitrogen (TN) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 212. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed total nitrogen (TN) concentrations, measured versus predicted TN concentrations, computed log-transformed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Table 77. Total nitrogen dataset for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 213. S+® output of regression model development using turbidity (TBY) and nitrate (NITRATAX) as explanatory variables for total nitrogen (TN) for Indian Creek at Overland Park, KS (Marty, site 06893300), March 2012 through April 2013.

Figure 214. S+® output graphs from simple linear regression analysis using log-transformed turbidity (TBY) and nitrate (NITRATAX) as explanatory variables for total nitrogen (TN) concentrations showing measured versus

predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), March 2012 through April 2013.

Figure 215. S+® output of regression model development using streamflow (Q) as the explanatory variable for total nitrogen (TN) for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 216. S+® output graphs from simple linear regression analysis using log-transformed streamflow (Q) versus total nitrogen (TN) concentrations showing measured versus predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 78. Total nitrogen dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 217. S+® output of regression model development using turbidity (TBY) as an explanatory variable for total nitrogen (TN) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 218. S+® output graphs from simple linear regression analysis using turbidity (TBY) and log-transformed TBY as explanatory variables for total nitrogen (TN) concentrations showing measured versus predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 219. S+® output of regression model development using turbidity (TBY) and nitrate (NITRATAX) as explanatory variables for total nitrogen (TN) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), April 2012 through May 2013.

Figure 220. S+® output graphs from simple linear regression analysis using turbidity (TBY) and nitrate (NITRATAX) as explanatory variables for total nitrogen (TN) concentrations showing measured versus predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), April 2012 through May 2013.

Figure 221. S+® output of regression model development using streamflow (Q) as an explanatory variable for total nitrogen (TN) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 222. S+® output graphs from simple linear regression analysis using streamflow (Q) and log-transformed Q as explanatory variables for total nitrogen (TN) concentrations showing measured versus predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 79. Total nitrogen dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), July 2011 through May 2013.

predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), May 2012 through May 2013.

Figure 233. S+® output of regression model development using streamflow (Q) as an explanatory variable for total nitrogen (TN) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Figure 234. S+® output graphs from simple linear regression analysis using streamflow (Q) and log-transformed Q as explanatory variables for total nitrogen (TN) concentrations showing measured versus predicted TN concentrations, computed TN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Table 81. Dissolved total Kjeldahl nitrogen dataset for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), March 2012 through May 2013.

Figure 235. S+® output of regression model development using specific conductance (SC) and nitrate (NO3NO2) as explanatory variables for dissolved total Kjeldahl nitrogen (DTKN) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), March 2012 through May 2013.

Figure 236. S+® output graphs from simple linear regression analysis using log-transformed specific conductance (SC) and nitrate (NO3NO2) as explanatory variables for dissolved total Kjeldahl nitrogen (DTKN) concentrations showing measured versus predicted DTKN concentrations, computed DTKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), March 2012 through May 2013.

Table 82. Dissolved total Kjeldahl nitrogen dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), March 2012 through May 2013.

Figure 237. S+® output of regression model development using specific conductance (SC) and nitrate (NO3NO2) as explanatory variables for dissolved total Kjeldahl nitrogen (DTKN) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), March 2012 through May 2013.

Figure 238. S+® output graphs from simple linear regression analysis using specific conductance (SC) and log-transformed nitrate (NO3NO2) as explanatory variables for dissolved total Kjeldahl nitrogen (DTKN) concentrations showing measured versus predicted DTKN concentrations, computed DTKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), March 2012 through May 2013.

Table 83. Dissolved total Kjeldahl nitrogen dataset for Indian Creek at Overland Park, KS (Marty, site 06893300), March 2012 through May 2013.

Figure 239. S+® output of regression model development using nitrate (NO3NO2) as an explanatory variable for dissolved total Kjeldahl nitrogen (DTKN) for Indian Creek at Overland Park, KS (Marty, site 06893300), March 2012 through May 2013.

Figure 240. S+® output graphs from simple linear regression analysis using nitrate (NO3NO2) and log-transformed NO3NO2 as explanatory variables for log-transformed dissolved total Kjeldahl nitrogen (DTKN) concentrations showing measured versus predicted DTKN concentrations, computed log-transformed DTKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), March 2012 through May 2013.

Table 84. Dissolved total Kjeldahl nitrogen dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Figure 241. S+® output of regression model development using nitrate (NO3NO2) as an explanatory variable for dissolved total Kjeldahl nitrogen (DTKN) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Figure 242. S+® output graphs from simple linear regression analysis using nitrate (NO3NO2) and log-transformed NO3NO2 as explanatory variables for log-transformed dissolved total Kjeldahl nitrogen (DTKN) concentrations showing measured versus predicted DTKN concentrations, computed log-transformed DTKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Table 85. Dissolved total Kjeldahl nitrogen dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), May 2012 through May 2013.

Figure 243. S+® output of regression model development using nitrate (NO3NO2) as the explanatory variable for dissolved total Kjeldahl nitrogen (DTKN) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), May 2012 through May 2013.

Figure 244. S+® output graphs from simple linear regression analysis showing log-transformed nitrate (NO3NO2) versus log-transformed dissolved total Kjeldahl nitrogen (DTKN) concentrations, measured versus predicted DTKN concentrations, computed log-transformed DTKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), May 2012 through May 2013.

Table 86. Total Kjeldahl nitrogen dataset for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 245. S+® output of regression model development using streamflow (Q) and turbidity (TBY) as explanatory variables for total Kjeldahl nitrogen (TKN) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), Overland Park, Kansas, August 2011 through May 2013.

Figure 246. S+® output graphs from simple linear regression analysis using log-transformed streamflow (Q) and log-transformed turbidity (TBY) as explanatory variables for total Kjeldahl nitrogen (TKN) concentrations showing measured versus predicted TKN concentrations, computed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 247. S+® output of regression model development using streamflow (Q) as an explanatory variable for total Kjeldahl nitrogen (TKN) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Figure 248. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed log-transformed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), August 2011 through May 2013.

Table 87. Total Kjeldahl nitrogen dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 249. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total Kjeldahl nitrogen (TKN) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 250. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed log-transformed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 251. S+® output of regression model development using streamflow (Q) as the explanatory variable for total Kjeldahl nitrogen (TKN) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 252. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed log-transformed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Table 88. Total Kjeldahl nitrogen dataset for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 253. S+® output of regression model development using streamflow (Q) as the explanatory variable for total Kjeldahl nitrogen (TKN) for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 254. S+® output graphs from simple linear regression analysis showing streamflow (Q) versus total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 89. Total Kjeldahl nitrogen dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 255. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total Kjeldahl nitrogen (TKN) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 256. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 257. S+® output of regression model development using streamflow (Q) as the explanatory variable for total Kjeldahl nitrogen (TKN) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 258. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 90. Total Kjeldahl nitrogen dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 259. S+® output of regression model development using streamflow (Q) and turbidity (TBY) as explanatory variables for total Kjeldahl nitrogen (TKN) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 260. S+® output graphs from simple linear regression analysis using log-transformed streamflow (Q) and turbidity (TBY) as explanatory variables for total Kjeldahl nitrogen (TKN) concentrations showing measured versus predicted TKN concentrations, computed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 261. S+® output of regression model development using streamflow (Q) as the explanatory variable for total Kjeldahl nitrogen (TKN) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 262. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed TKN concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Table 91. Total Kjeldahl nitrogen dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 263. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total Kjeldahl nitrogen (TKN) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 264. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus total Kjeldahl nitrogen (TKN) concentrations, measured versus predicted TKN concentrations, computed log-transformed

Figure 290. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus nitrate plus nitrite (NO3NO2) concentrations, measured versus predicted NO3NO2 concentrations, computed NO3NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 99. Nitrate plus nitrite dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 291. S+® output of regression model development using nitrate (NITRATAX) as the explanatory variable for nitrate plus nitrite (NO3NO2) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), April 2012 through May 2013.

Figure 292. S+® output graphs from simple linear regression analysis showing nitrate (NITRATAX) versus nitrate plus nitrite (NO3NO2) concentrations, measured versus predicted NO3NO2 concentrations, computed NO3NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), April 2012 through May 2013.

Figure 293. S+® output of regression model development using streamflow (Q) as the explanatory variable for nitrate plus nitrite (NO3NO2) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 294. S+® output graphs from simple linear regression analysis showing streamflow (Q) versus nitrate plus nitrite (NO3NO2) concentrations, measured versus predicted NO3NO2 concentrations, computed NO3NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 100. Nitrate plus nitrite dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 295. S+® output of regression model development using nitrate (NITRATAX) as the explanatory variable for nitrate plus nitrite (NO3NO2) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Figure 296. S+® output graphs from simple linear regression analysis showing nitrate (NITRATAX) versus nitrate plus nitrite (NO3NO2) concentrations, measured versus predicted NO3NO2 concentrations, computed NO3NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Figure 297. S+® output of regression model development using streamflow (Q) as an explanatory variable for nitrate plus nitrite (NO3NO2) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 298. S+® output graphs from simple linear regression analysis using streamflow (Q) and log-transformed Q as explanatory variables for log-transformed nitrate plus nitrite (NO3NO2) concentrations showing measured

Table 112. Nitrite dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Figure 331. S+® output of regression model development using turbidity (TBY) and nitrate (NO3NO2) as explanatory variables for nitrite (NO2) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Figure 332. S+® output graphs from simple linear regression analysis using log-transformed turbidity (TBY) and log-transformed nitrate (NO3NO2) as explanatory variables for nitrite (NO2) concentrations showing measured versus predicted NO2 concentrations, computed NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), March 2012 through May 2013.

Table 113. Nitrite dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 333. S+® output of regression model development using streamflow (Q) as the explanatory variable for nitrite (NO2) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 334. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed nitrite (NO2) concentrations, measured versus predicted NO2 concentrations, computed NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 335. S+® output of regression model development using streamflow (Q) as the explanatory variable for nitrite (NO2) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 336. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed nitrite (NO2) concentrations, measured versus predicted NO2 concentrations, computed log-transformed NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 337. S+® output of regression model development using nitrate (NO3NO2) as the explanatory variable for nitrite (NO2) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), May 2012 through May 2013.

Figure 338. S+® output graphs from simple linear regression analysis showing nitrate (NO3NO2) versus nitrite (NO2) concentrations, measured versus predicted NO2 concentrations, computed NO2 concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), May 2012 through May 2013.

Table 114. Total phosphorus dataset for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), June 2011 through May 2013.

Figure 363. S+® output of regression model development using season (SIN and COS) and streamflow (Q) as explanatory variables for dissolved phosphorus (DP) for Indian Creek at Overland Park, KS (Marty, site 06893300), August 2011 through May 2013.

Figure 364. S+® output graphs from simple linear regression analysis using season (SIN and COS) and streamflow (Q) as explanatory variables for dissolved phosphorus (DP) concentrations showing measured versus predicted DP concentrations, computed DP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), August 2011 through May 2013.

Table 123. Dissolved phosphorus dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 365. S+® output of regression model development using streamflow (Q) as the explanatory variable for dissolved phosphorus (DP) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 366. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed dissolved phosphorus (DP) concentrations, measured versus predicted DP concentrations, computed log-transformed DP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 124. Dissolved phosphorus dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 367. S+® output of regression model development using season (SIN and COS) and turbidity (TBY) as explanatory variables for dissolved phosphorus (DP) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 368. S+® output graphs from simple linear regression analysis using season (SIN and COS) and log-transformed turbidity (TBY) as explanatory variables for log-transformed dissolved phosphorus (DP) concentrations showing measured versus predicted DP concentrations, computed log-transformed DP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 369. S+® output of regression model development using streamflow (Q) as the explanatory variable for dissolved phosphorus (DP) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 370. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed dissolved phosphorus (DP) concentrations, measured versus predicted DP concentrations, computed log-transformed DP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 371. S+® output of regression model development using season (SIN and COS) and turbidity (TBY) as explanatory variables for dissolved phosphorus (DP) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 372. S+® output graphs from simple linear regression analysis using season (SIN and COS) and turbidity (TBY) as explanatory variables for log-transformed dissolved phosphorus (DP) concentrations showing measured versus predicted DP concentrations, computed log-transformed DP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 373. S+® output of regression model development using streamflow (Q) as the explanatory variable for dissolved phosphorus (DP) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 374. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed dissolved phosphorus (DP) concentrations, measured versus predicted DP concentrations, computed log-transformed DP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 375. S+® output of regression model development using season (SIN and COS) and streamflow (Q) as explanatory variables for dissolved phosphorus (DP) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Figure 376. S+® output graphs from simple linear regression analysis using season (SIN and COS) and log-transformed streamflow (Q) as explanatory variables for dissolved phosphorus (DP) concentrations showing measured versus predicted DP concentrations, computed DP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Table 125. Particulate phosphorus dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 377. S+® output of regression model development using turbidity (TBY) as the explanatory variable for particulate phosphorus (PP) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), August 2011 through May 2013.

Figure 378. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus particulate phosphorus (PP) concentrations, measured versus predicted PP concentrations, computed PP concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), August 2011 through May 2013.

Figure 379. S+® output of regression model development using streamflow (Q) as the explanatory variable for particulate phosphorus (PP) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), August 2011 through May 2013.

Figure 380. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed particulate phosphorus (PP) concentrations, measured versus predicted PP

Figure 430. S+® output graphs from simple linear regression analysis using season (SIN and COS) and log-transformed turbidity (TBY) as explanatory variables for log-transformed *Escherichia coli* bacteria (EC) showing measured versus predicted EC concentrations, computed log-transformed EC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 431. S+® output of regression model development using season (SIN and COS) and turbidity (TBY) as explanatory variables for *Escherichia coli* bacteria (EC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Figure 432. S+® output graphs from simple linear regression analysis using season (SIN and COS) and log-transformed turbidity (TBY) as explanatory variables for log-transformed *Escherichia coli* bacteria (EC) showing measured versus predicted EC concentrations, computed log-transformed EC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Table 141. Fecal coliform bacteria dataset for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), June 2011 through May 2013.

Figure 433. S+® output of regression model development using specific conductance (SC) as the explanatory variable for fecal coliform bacteria (FC) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), June 2011 through May 2013.

Figure 434. S+® output graphs from simple linear regression analysis showing log-transformed specific conductance (SC) versus log-transformed fecal coliform bacteria (FC), measured versus predicted FC concentrations, computed log-transformed FC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), June 2011 through May 2013.

Table 142. Fecal coliform bacteria dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 435. S+® output of regression model development using streamflow (Q) as the explanatory variable for fecal coliform bacteria (FC) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Figure 436. S+® output graphs from simple linear regression analysis showing log-transformed streamflow (Q) versus log-transformed fecal coliform bacteria (FC), measured versus predicted FC concentrations, computed log-transformed FC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through May 2013.

Table 143. Fecal coliform bacteria dataset for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 437. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for fecal coliform bacteria (FC) for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 438. S+® output graphs from simple linear regression analysis using log-transformed streamflow (Q) and log-transformed specific conductance (SC) as explanatory variables for log-transformed fecal coliform bacteria (FC) showing measured versus predicted FC concentrations, computed log-transformed FC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 144. Fecal coliform bacteria dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 439. S+® output of regression model development using turbidity (TBY) as an explanatory variable for fecal coliform bacteria (FC) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 440. S+® output graphs from simple linear regression analysis using turbidity (TBY) and log-transformed TBY as explanatory variables for log-transformed fecal coliform bacteria (FC) showing measured versus predicted FC concentrations, computed log-transformed FC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 145. Fecal coliform bacteria dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), July 2011 through May 2013.

Figure 441. S+® output of regression model development using streamflow (Q) and turbidity (TBY) as explanatory variables for fecal coliform bacteria (FC) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), July 2011 through May 2013.

Figure 442. S+® output graphs from simple linear regression analysis using log-transformed specific conductance (SC) and log-transformed turbidity (TBY) as explanatory variables for log-transformed fecal coliform bacteria (FC) showing measured versus predicted FC concentrations, computed log-transformed FC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), July 2011 through May 2013.

Table 146. Fecal coliform bacteria dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 443. S+® output of regression model development using specific conductance (SC) and turbidity (TBY) as explanatory variables for fecal coliform bacteria (FC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 444. S+® output graphs from simple linear regression analysis using log-transformed specific conductance (SC) and log-transformed turbidity (TBY) as explanatory variables for log-transformed fecal coliform bacteria (FC) showing measured versus predicted FC concentrations, computed log-transformed FC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2013.

Figure 445. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for fecal coliform bacteria (FC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), June 2004 through May 2010.

Figure 454. S+® output graphs from simple linear regression analysis showing streamflow (Q) versus total organic carbon (TOC), measured versus predicted TOC concentrations, computed TOC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 150. Total organic carbon dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through April 2013.

Figure 455. S+® output of regression model development using streamflow (Q) and turbidity (TBY) as explanatory variables for total organic carbon (TOC) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through April 2013.

Figure 456. S+® output graphs from simple linear regression analysis using streamflow (Q) and turbidity (TBY) as explanatory variables for total organic carbon (TOC) showing measured versus predicted TOC concentrations, computed TOC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through April 2013.

Table 151. Total organic carbon dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), June 2011 through May 2013.

Figure 457. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total organic carbon (TOC) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), June 2011 through May 2013.

Figure 458. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus total organic carbon (TOC), measured versus predicted TOC concentrations, computed TOC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), June 2011 through May 2013.

Table 152. Total organic carbon dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2013.

Figure 459. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total organic carbon (TOC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2013.

Figure 460. S+® output graphs from simple linear regression analysis showing log-transformed turbidity (TBY) versus log-transformed total organic carbon (TOC), measured versus predicted TOC concentrations, computed log-transformed TOC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2013.

Figure 461. S+® output of regression model development using specific conductance (SC) as the explanatory variable for total organic carbon (TOC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2010.

Figure 462. S+® output graphs from simple linear regression analysis showing specific conductance (SC) versus log-transformed total organic carbon (TOC), measured versus predicted TOC concentrations, computed log-transformed TOC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2010.

Figure 463. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total organic carbon (TOC) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Figure 464. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus total organic carbon (TOC), measured versus predicted TOC concentrations, computed TOC concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Table 153. Chemical oxygen demand dataset for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), June 2011 through May 2013.

Figure 465. S+® output of regression model development using turbidity (TBY) as the explanatory variable for chemical oxygen demand (COD) for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), June 2011 through May 2013.

Figure 466. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus chemical oxygen demand (COD), measured versus predicted COD concentrations, computed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at 119th Street, Overland Park, KS (119th, site 385446094430700), June 2011 through May 2013.

Table 154. Chemical oxygen demand dataset for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through April 2013.

Figure 467. S+® output of regression model development using streamflow (Q) and turbidity (TBY) as explanatory variables for chemical oxygen demand (COD) for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through April 2013.

Figure 468. S+® output graphs from simple linear regression analysis using streamflow (Q) and turbidity (TBY) as explanatory variables for chemical oxygen demand (COD) showing measured versus predicted COD concentrations, computed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at College Boulevard, Overland Park, KS (College, site 385520094420000), June 2011 through April 2013.

Table 155. Chemical oxygen demand dataset for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 469. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for chemical oxygen demand (COD) for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Figure 470. S+® output graphs from simple linear regression analysis using streamflow (Q) and log-transformed specific conductance (SC) as explanatory variables for chemical oxygen demand (COD) showing measured versus predicted COD concentrations, computed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Overland Park, KS (Marty, site 06893300), June 2011 through May 2013.

Table 156. Chemical oxygen demand dataset for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 471. S+® output of regression model development using turbidity (TBY) as the explanatory variable for chemical oxygen demand (COD) for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Figure 472. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus chemical oxygen demand (COD), measured versus predicted COD concentrations, computed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at Indian Creek Parkway, Overland Park, KS (Mission Farms, site 385608094380300), June 2011 through May 2013.

Table 157. Chemical oxygen demand dataset for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 473. S+® output of regression model development using streamflow (Q) and turbidity (TBY) as explanatory variables for chemical oxygen demand (COD) for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Figure 474. S+® output graphs from simple linear regression analysis using streamflow (Q) and turbidity (TBY) as explanatory variables for chemical oxygen demand (COD) showing measured versus predicted COD concentrations, computed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Tomahawk Creek near Overland Park, KS (Tomahawk, site 06893350), November 2011 through May 2013.

Table 158. Chemical oxygen demand dataset for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2013.

Figure 475. S+® output of regression model development using turbidity (TBY) as the explanatory variable for chemical oxygen demand (COD) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2013.

Figure 476. S+® output graphs from simple linear regression analysis showing turbidity (TBY) versus chemical oxygen demand (COD), measured versus predicted COD concentrations, computed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2013.

Figure 477. S+® output of regression model development using specific conductance (SC) as the explanatory variable for chemical oxygen demand (COD) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2010.

Figure 478. S+® output graphs from simple linear regression analysis showing specific conductance (SC) versus log-transformed chemical oxygen demand (COD), measured versus predicted COD concentrations, computed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2008 through May 2010.

Figure 479. S+® output of regression model development using specific conductance (SC) and turbidity (TBY) as explanatory variables for chemical oxygen demand (COD) for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Figure 480. S+® output graphs from simple linear regression analysis using specific conductance (SC) and turbidity (TBY) as explanatory variables for log-transformed chemical oxygen demand (COD) showing measured versus predicted COD concentrations, computed log-transformed COD concentrations versus regression residuals, and standard normal quantiles versus regression residuals for Indian Creek at State Line Road, Leawood, KS (State Line, site 06893390), April 2011 through May 2013.

Summary

Johnson County is the fastest growing county in Kansas, with a population of about 560,000 people in 2012. The U.S. Geological Survey, in cooperation with Johnson County Wastewater, operated a series of six continuous real-time water-quality monitoring stations in the Indian Creek Basin during June 2011 through May 2013; one of these sites has been operating since February 2004. Continuously measured water-quality properties include streamflow, specific conductance, pH, water temperature, dissolved oxygen, turbidity, and nitrate. Discrete water-quality samples were analyzed for dissolved solids and major ions, alkalinity, suspended solids and sediment, nutrients, indicator bacteria, organic carbon, and chemical oxygen demand.

Regression models were developed to establish relations between discretely sampled constituent concentrations from samples collected during 2004 through 2013 and concurrent continuously measured physical properties to estimate concentrations of those constituents of interest that are not easily measured in real time because of limitations in sensor technology and fiscal constraints. Regression models were developed for 28 water-quality constituents: acid neutralizing capacity, dissolved solids, calcium, magnesium, potassium, sodium, chloride, fluoride, sulfate, iron, total suspended solids, suspended sediment, total nitrogen, dissolved Kjeldahl nitrogen, total Kjeldahl nitrogen, ammonia, nitrate plus nitrite, nitrate, nitrite, total phosphorus, orthophosphate, dissolved phosphorus, particulate phosphorus, enterococci bacteria, *Escherichia coli* bacteria, fecal coliform bacteria, total organic carbon, and chemical oxygen demand.

Specific conductance generally was an explanatory variable for ions and was positively related to ionic constituents. Turbidity was an explanatory variable for total suspended solids, suspended sediment, total nitrogen, and particulate phosphorus. Nitrate was the single explanatory variable for nitrate plus nitrite and nitrate except when continuous nitrate data were unavailable for the State Line all available data and pre-wastewater-treatment facility upgrades models. Streamflow, specific conductance, or turbidity generally were explanatory variables for total phosphorus, indicator bacteria, and chemical oxygen demand. Orthophosphate and dissolved phosphorus models usually had a seasonal component in addition to streamflow, turbidity, and specific conductance as explanatory variables. Streamflow and turbidity generally were explanatory variables for total organic carbon.

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Appendix