Water Quality Analysis for the Heartland Inventory and Monitoring Network (HTLN) of the US National Park Service:

HOT SPRINGS NATIONAL PARK

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Executive Summary

As part of a cooperative agreement between the Heartland Inventory and Monitoring Network (HTLN) of the U.S. National Park Service (NPS) and the Central Plains Center for BioAssessment (CPCB) at the Kansas Biological Survey (KBS), relevant water quality standards, biological & physical habitat sampling methods, biological criteria, methods for determining reference conditions, and water quality data were examined for each HTLN park service unit. When available, legacy data from the NPS and other relevant agencies (e.g. U.S. Environmental Protection Agency, U.S. Geological Survey, Missouri Department of Natural Resources, etc.) were compiled into a relational database and analyzed in order of HTLN priority.

This document constitutes the water quality analysis portion for Hot Springs National Park (HOSP). Listed in order of rank, priorities for this park (as identified by HTLN) were: drinking water quality (springs)*, water clarity*, discharge (springs), pathogens (rivers and streams)*, nutrient loading (rivers and streams)*, core elements (springs)*, water level (wetlands), discharge (rivers and streams)*, metal contamination (rivers and streams)*, sediment toxicity (rivers and streams)*, stream toxicity*, amphibians (wetlands), macroinvertebrates (rivers and streams), and fish (rivers and streams). Priorities marked with an asterisk had statistically viable data for at least one relevant parameter and were included in the analyses of this report. Bull Bayou, Gulpha Creek, Hot Springs Creek, Ricks Pond, and Whitington Creek are the only waterbodies in the park study area with uses specifically designated by the state of Arkansas. These designated uses are (for all four waterbodies): primary contact recreation, secondary contact recreation, domestic water supply, and industrial and agricultural water supply. In addition, Gulpha Creek, Hot Springs Creek and Whitington Creek were designated for seasonal and perennial Ouachita Mountains fisheries, and Ricks Pond was designated for fisheries and for lake and reservoir use. No segments of any of these waterbodies within the park study area were listed as impaired.

Of the 8,684 records of 150 parameters at 108 stations in the park study area (roughly 3 miles upstream and 1 mile downstream from the park boundary), 1,110 records of 29 parameters at 13 stations were suitable for meaningful statistical analyses. The period of record for raw, unfiltered data was from 11 January 1900 to 14 July 1994. Lack of repeated observations for uniquely identified springs appears to be a major concern for the park. Analyses were performed to examine three general areas: core elements (as identified by NPS servicewide), priority concerns (as identified by HTLN), and potential concerns (as determined by comparison of data with relevant criteria).

The core elements – alkalinity, pH, specific conductance (conductivity), dissolved oxygen, water temperature, and flow – were all within acceptable ranges for flowing water systems. Of the priority concerns, only pathogens (specifically fecal and total coliforms) and nutrients (specifically total phosphorus) appear to be consistently above criterion limits or regional benchmarks for some portion of the year. However, stream pathogen counts could not be directly related with actual park use, so impacts on primary

and secondary contact recreation are difficult to assess. Similarly, although total phosphorus levels were often below state criteria, current research by the USEPA Region 7 Regional Technical Assistance Group indicates that regional benchmarks for total phosphorus in high quality streams are significantly lower than currently identified state criteria. In addition, though drinking water quality in springs was the overall highest concern of the park, too little statistically viable or geographically associated data were available to make any meaningful assessment. Based on listed park priorities, further research should be directed in this area. The most apparent potential concern identified by comparison with federal criteria, state criteria, and regional benchmarks is nutrients (specifically total phosphorus and nitrite nitrogen in Gulpha, Hot Springs, and Whitington Creeks). Dissolved oxygen and turbidity may also be potential concerns at isolated locations in Stokes Creek and Bull Bayou, respectively. Park managers should consider including these elements in future research programs.

In addition to these findings, the following recommendations are made: identify springs and study areas clearly and consistently; periodically sample springs for drinking water quality parameters; be sure to document and standardize metadata; standardize database files; be sure to uniquely define sampling locations; relate sampling locations to relevant regulatory waterbody segments; establish a sampling design for long-term trend analysis; take hardness measurements concurrently with metals; take pH and temperature measurements concurrent with ammonia; develop study areas along watershed boundaries; and correlate water quality parameters with actual park use.

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OVERVIEW

Aquatic and water dependent environments are fundamentally important to the ecological, biological, chemical, and physical integrity of significant portions of lands and waters protected by the U.S. National Park Service (NPS). As part of its mission to preserve and protect these aquatic and water dependent resources, NPS has recognized the need for a plan to ensure the integrity of water quality within park service units over the long term.

Accordingly, the Heartland Inventory and Monitoring Network (HTLN) of the National Park Service began the aquatic component of the Servicewide Inventory and Monitoring Program in FY 2001. As part of this aquatic component, HTLN entered into a cooperative agreement with the University of Kansas' Central Plains Center for BioAssessment (CPCB) to aid in the development of a comprehensive Network Monitoring Plan. In this endeavor, CPCB's tasks were: 1) to summarize existing relevant state, national, and tribal water quality standards applicable to waterbodies within each of the HTLN parks, 2) to summarize existing relevant state, national, tribal, and NPS protocols for biological monitoring and to determine, when applicable, whether appropriate methods exist for use by each HTLN park, 3) to recommend monitoring designs based on these findings, 4) to update water quality monitoring data collected for each HTLN park since publication of that park's NPS Water Resources Division (WRD) Baseline Water Quality Report, where possible, 5) to develop an accessible relational database to house these data, 6) to re-analyze and summarize the collected data to reflect current knowledge of the condition of aquatic resources within each of the HTLN park service units, and 7) to make recommendations regarding future research and monitoring efforts based on the information and experience garnered from the previous steps. The first three steps reside in documents previously submitted by CPCB (Goodrich and Huggins 2003; Goodrich et al. 2004). This report represents the documentation of the latter four steps of the plan development process for this park unit.

Project Scope

The intent of this report is to provide further data and analyses regarding the water quality of each HTLN park service unit beyond the published WRD Baseline Water Quality Report, where possible. In the cases where a Baseline Water Quality Report had not yet been published by WRD, an effort was made to collaborate with WRD in order to maximize data continuity. Rather than providing an exhaustive numerical and graphic summary of every parameter monitored at every station, this report focuses on three target areas of water quality in key waterbodies within the park service unit:

1) Core Elements, corresponding with the Servicewide Inventory and Monitoring program's "Level I" water quality parameters,
2) Priority Concerns identified by HTLN as important for this park service unit, and
3) Potential Concerns as determined by comparison of historic and extant data with attainment levels identified through the water quality standards review.

DATA COLLECTION AND HANDLING

Data Collection

Existing water quality and station location data were collected for the 15 Heartland Inventory and Monitoring Network (HTLN) park service units. Additional data beyond those available from the NPS Baseline Water Quality Inventory and Analysis Reports (Baseline Reports) were included from various federal (e.g., USGS) and state (e.g., ARDEQ) agency sources, beginning with the earliest records available in the Baseline Reports and continuing through 2001 where available. Usable records include five general types of information: *where* the sampling event occurred, *when* the sampling event occurred, *what* was measured, the measured *value*, and *additional information* regarding the sampling event or measurement.

In order to determine long-term trends, it is essential that sampling locations and sampling dates and times be clearly recorded. Future efforts by the park unit should take special care in accurately and precisely defining station locations and relating them to specific segments of park waterbodies identified by relevant state and federal regulatory agencies.

Sources

Water quality and station location data were collected from five primary sources: 1) NPS Baseline Reports, 2) USEPA's STORET database, 3) NPS (either from the Water Resources Division, HTLN, or individual park service units), 4) state agencies (e.g., ARDEQ, MODNR), and 5) USGS's National Water Information System. For parks with little available data, notably Wilson's Creek National Battlefield (WICR), additional data were available from published academic studies. The older data were made available in a variety of electronic and/or hard copy formats, depending on the source. For example, data gathered by ARDEQ for several parks in Arkansas were available in relational database (MS Access 2000) files, whereas data from USGS were available for download in tab-delimited flat ASCII files, and data for WICR were provided both in written reports and multiple spreadsheet (MS Excel 2000) files.

Conversion

Because water quality data came in widely varying formats from diverse sources, significant effort was required to convert data into a common format for inclusion in a relational database. Semi-automated processes were developed for converting data files where possible, but due to inconsistencies between and within files, often even those for the same location from the same agency, manual format and field name conversions were necessary. In addition, station location information had to be manually verified to avoid duplication of locations and records. Station locations were assigned to new or correlated with existing NPS Station Identification Numbers, and parameters were correlated with Parameter Codes corresponding to USEPA's STORET database. To facilitate interpretation and summary of the results, stations were also grouped by the waterbody to which they belong (e.g., all of the stations known to be on the same creek were coded the same) and by the waterbody type (i.e., "Main Stem," "Tributaries," or "Springs").

Observations were also coded for the Hydrologic Season in which they occurred, established either by the park-specific Baseline Report, or by separate hydrologic analysis.

Database Development

As part of the cooperative agreement between NPS and CPCB, a relational database incorporating the collected data for this park service unit was developed in MS Access 2000 format, based on the NPS National Relational Database Template and input from HTLN. A copy of this database is provided with this report. As with any study that uses data from a wide range of sources, gathered and compiled in a wide range of formats, significant time and effort is required in the initial construction of the database. Rigorous file naming standards and metadata collection procedures are required for automation of such tasks. At this time, sufficient consistency in file format and naming conventions does not exist to automate data collection from these sources. As a general recommendation, future databases, including georeferenced databases, should be fully standardized and rigorously maintained to insure the possibility of transfer between database file formats.

Data Handling

Location Identification and Handling

Correct assignment of sample locations is a particular challenge for water quality records. For database purposes, the location recorded in the field by GPS or other means is a sampling event attribute subject to a variety of errors (in GPS calibration, transcription of readings, or differences in where the reading was recorded). In older records, location data may have been taken from a map with limited spatial resolution. There can be difficulties even when location information is correct. Distinct sites that are close together may be located in the same section of a waterbody, which may or may not make them analytically unique. CPCB has established stream site grouping rules for the purposes of analysis. Summarized in Appendix A, these rules underline the importance of using GIS to validate location information. Future studies could use a similar approach for lake and reservoir sites. Site identification is a time-consuming task, but one that may become more feasible for NPS units as GIS coverages become more complete and accessible.

For purposes of this project, we reviewed sites previously included in the baseline reports for each park unit. Often sites that were actually the same appeared as different, due to misspellings or other data entry errors. In other instances, sites with similar names were ambiguous due to poor or incomplete spatial information. In all cases, sample sites added from other data sources were matched with previous sites by site description or agency site codes, which were included in the data records' "Other Names" field. After careful inspection, sites that appeared to be the same were assigned to the same location, with original site attribution retained in the database records' "EventID" field.

A related challenge is definition of the relevant water quality sample area for individual NPS units. For the baseline reports, a "study area" was defined as 3 miles upstream and

1 mile downstream of park boundaries. For these analyses, the same, arbitrary boundaries as those in the baseline reports were used for including additional sites. It would be preferable to base the study area on actual watershed boundaries, but that was beyond the scope of this project.

Water Quality Data Screening

Once the gathered water quality data were compiled and converted into a relational database format, data screening was used to ensure data quality. Screening was executed as a layered approach (Figure 1), using multiple screens to remove data unsuitable for statistical analysis. All screens are included as select queries in the relational database. Original data, once converted to the relational database format, were termed "Raw Data" and correspond with Data Screen [0]. An abundance of relatively short-term (minutes to hours) series of observations at several sites, coupled with repeated data from multiple sites required a duplicate screen [0*] to remove repeated information that could artificially skew results. Duplicates were identified initially using repeated values queries, then verified by hand. For series of values, the initial value was used to represent the conditions of the waterbody unless otherwise specified.

Data remaining after the duplicate screen were the input for Screen [1], which was an Observation/Parameter Screen. This screen retained records based on two conditions. First, the parameter measured had to be statistically viable (e.g., a concentration as opposed to a narrative or administrative code), and secondly, that there had to be at least five observations of the parameter in the database. A list of the included parameters appears in Appendix C.

The output of Screen [1] was used as the input for Screen [2], which was a Value Screen. Screen [2] compared the measured values of parameters in the data remaining after Screen [1] to pre-determined minima and maxima for the same parameters. The minima and maxima were the same as those listed in the Baseline Reports, Appendix C ("STORET Water Quality Control/Edit Checking").

The output of Screen [2] was used as the input for Screen [3], which was a Remark Screen. Screen [3] compared the accompanying Remark field to a list of statistically viable Remarks to remove composite values, estimated values, species, sex, and administrative information values, and values of known error. The results of Screen [3] were termed "Data for Analysis" and were comprised the pool of data from which all subsamples for analysis were taken. Remarks for detection limits were not removed by this screen, and detection limits were retained as their full values, rather than as half values as in the Baseline Reports. This approach, though conservative, assumes no information beyond that which is implicit in the data.

Screen [4] is a quality control screen for the data excluded by Screen [1] through [3]. The individual sums of the counts of locations, parameters, and records from Screen [3] and Screen [4] should equal the counts of locations, parameters, and records from the Raw Data (Screen [0]), respectively. The periods of record may differ slightly, as included data may have been gathered over a different period of time than excluded data (and vice versa).

A Data Screen Report (Table 1) for this park service unit is included to show the results of data screening.

Output for Analysis

Once the "Data for Analysis" were obtained via the screening process detailed above, they were subsampled for three specific types of analysis: Core Elements Analysis, Priority Concerns Analysis, and Potential Concerns Analysis. These analyses correspond to the major analysis sections of this report. An Analysis Group Data Report (Table 2) for this park service unit is included to show the results of data subsampling.

Specific information regarding the nature and methods of these analyses are provided in the relevant analysis sections of this report.

Core Elements Data

For the Core Elements Analysis, data were subsampled from the "Data for Analysis" by matching parameters with indicators of the NPS defined "Level I" Water Quality Parameters identified by the Servicewide Inventory and Monitoring Program for "Key" waterbodies, namely alkalinity, pH, conductivity, dissolved oxygen, temperature, and flow. Rapid bioassessment baseline data were generally unavailable in sufficiently robust studies for statistical analysis. Where available, they were included. The subsampling for these Core Elements Data was accomplished via a select query, which is included in the relational database for this park service unit. The statistical software package used in the data analyses (Hintze 2004) also required the data format to be rearranged and additional fields (e.g., observation counts by station, stream codes, waterbody codes) added for analysis. These manipulations were carried out via a crosstab query and subsequent data table modifications. A copy of the output file used for analysis ("tblCoreElements_OutToNCSS") is included in the relational database for this park service unit.

Priority Concerns Data

For the Priority Concerns Analyses, data were subsampled from the "Data for Analysis" by matching parameters with indicators for the park service unit's identified Priority Concerns (Table 6), as provided by direct correspondence with HTLN staff. Similar to the Core Elements Data, subsampling and manipulation for output to NCSS were carried out within the relational database, and a copy of the output file used for analysis ("tblPrimaryConcerns_OutToNCSS") is included therein.

Potential Concerns Data

Unlike the previous analyses, the Potential Concerns Analysis was performed using the relational database software and a spreadsheet. A 2nd Remark Screen was applied to the "Data for Analysis" (Figure 1), to remove all data with remark codes. This was necessary since minimum-reporting limits of certain constituents (e.g., total cadmium) either changed within the period of record or were already above the maximum recommended criterion for those constituents. Once all remarks were removed, including reporting limits, the resulting data were compared with published and developing regional criterion values (USEPA 2004a, b; Huggins 2005) to determine the number and percentage of exceedances of these criteria. The results of these manipulations are included in the relational database for this park service unit (“tblEPACriteriaScreen” and “tblEPACriteriaScreen_HardDep”).

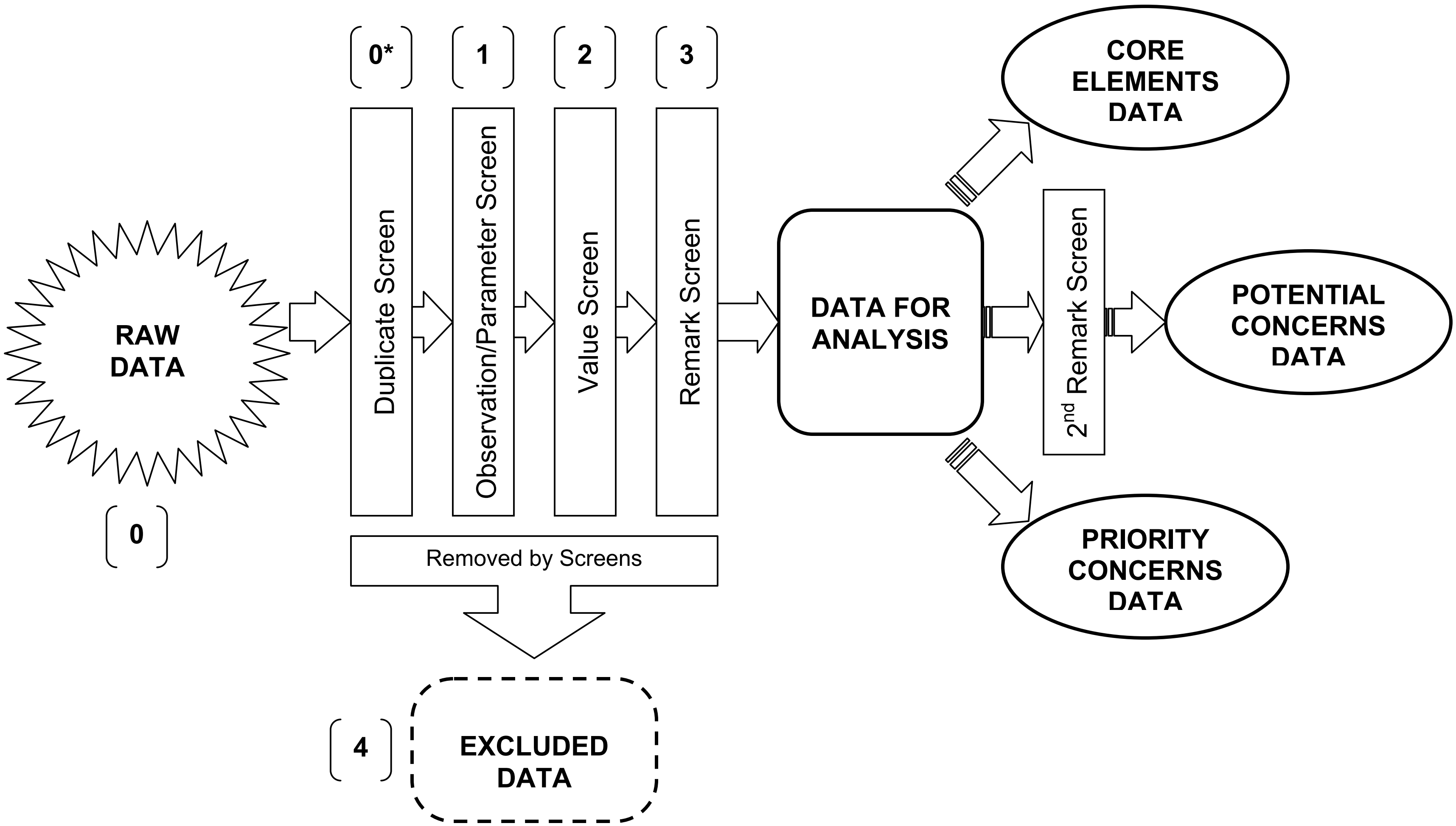


Figure 1. Schematic of Data Screening Process for Analysis.
Numbers in parenthesis indicate corresponding screen number in the associated Data Screen Report. Detailed descriptions of each screen and its effects are given in the Data Handling section of this report.

Table 1. Data Screen Report.

	Data Screens[1]					
	[0] RAW DATA	[0*] DUPLICATE SCREEN	[1] OBS/PARM SCREEN	[2] VALUE SCREEN	[3] REMARK SCREEN	[4] EXCLUDED DATA
Number of Locations	108	108	13	13	13	95
Number of Parameters	150	150	29	29	29	121
Number of Records	8684	4499	4284	1456	1110	7574
Period of Record	01/11/1900 to 07/14/1994	1/11/1900 to 07/14/1994	01/11/1900 to 07/14/1994	09/23/1922 to 07/14/1994	09/23/1922 to 07/14/1994	01/11/1900 to 07/14/1994

[1] Data screens represent the steps for screening data depicted in Figure 1. Screen [0*] removes duplicate sampling events. Screen [1] screens data for statistically viable parameters with at least 5 observations. Screen [2] screens data for values within a reasonable range. Screen [3] screens data for remarks that indicate bad or statistically nonviable observations. Screens [1] through [3] are cumulative (i.e. Screen [1] is used on Raw data, Screen [2] is used on results of Screen [1], Screen [3] is used on results of Screen [2]). Screen [4] is for error checking. Values for Raw Data minus those for Screen [3] should equal Screen [4]. Please see the data handling and analysis sections of this report for more information on screening and analysis.

Table 2. Analysis Group Data Report.

	Analysis Groups[1]		
	CORE ELEMENTS	PRIORITY CONCERNS	POTENTIAL CONCERNS
Number of Locations	5	9	9
Number of Parameters	7	17	11
Number of Records	81	140	397
Period of Record	09/23/1922 to 07/14/1994	09/23/1922 to 01/18/1983	01/24/1972 to 07/14/1994

[1] Analysis groups correspond to the primary analysis sections of this report. Data for each of the Analysis Groups are taken from the results of Data Screen [3] (Table 1), then reduced to those data that correspond to the principal aim of the analysis group (Figure 1). For example, the subset of data from the results of Data Screen [3] corresponds to measurements of Core Elements and is represented in the Core Elements Analysis Group. Please see the data handling and analysis sections of this report for more information on screening and analysis.

Statistical Analysis and Methodology

The statistical analyses for this report were performed using NCSS-PASS statistical software for Windows, developed by Dr. Jerry L. Hintze (Hintze 2004). This software provides a robust platform both for rigorous statistical analyses of flat data files (e.g., dbf files, MS Access data tables, MS Excel spreadsheets, etc.) and extensive visualization capabilities. The development of the specific data files used in each analysis type is described in detail in the Data Handling section of this report.

Graphical techniques are uniquely suited to applications in monitoring and management, since they can convey large amounts of significant information and place that information into a concise, relative context. Four graphical methods for data analysis and visualization were used in this project: box plots, violin plots, error bar charts, and scatter plots. For future, more detailed studies of water quality constituents, other statistical techniques may be more appropriate.

Where relevant data were either unavailable or too sparse to represent in a meaningful way using these techniques, one of two specific notations were used. The note "NO DATA" indicates that no observations were made for the given category of data. The note "INSUFFICIENT DATA" indicates that only 1 to 4 observations were made for the given category of data (at least 5 data points are required to produce most meaningful statistical graphics). In both cases, these notes were added to help identify areas where additional data collection may be appropriate.

Box Plots

Box plots of various parameters were produced to analyze and make multiple comparisons between the distributions of parameters between locations. Originally developed by John Tukey (Tukey 1977), box plots have a long history of use by many scientific disciplines (e.g., hydrologists), but ecologists, fisheries biologists, and others interested in environmental assessment and monitoring have only begun to use this powerful graphic technique relatively recently (Karr et al. 1986; Larsen et al. 1986; Plafkin et al. 1989; Ohio EPA 1990; USEPA 1996). In addition to the usual advantages of graphic techniques, box plots provide a concise visual representation of the central tendency and dispersion of the data distribution. Box plots integrate visual effectiveness with numerical information to provide an excellent overview of the data. From a box plot, it is possible to identify many features of the data distribution of a particular variable, including location, spread, skewness, tail length, and outlying data points (Chambers et al. 1983; Hoaglin et al. 1993).

Box plots can be calculated to include a number of different positional measures, but typically include the median. In this report, the box plots are configured such that quartiles partition the distribution into four equal parts (Figure 2a). Thus, the box (rectangle) is divided by the median (a line). The top and bottom of the box represent the 75^{th} (upper quartile) and 25^{th} (lower quartile) percentiles, respectively. The length of the box is the interquartile range (IQR), a popular measure of spread. That is, the box represents the middle 50 percent of the data. The box plots in this report also display lines that extend from each end of the box. These lines are often referred to as "whiskers." The upper and lower ends of these lines indicate the position of the upper and lower adjacent values. These values represent the largest (upper) and smallest (lower) observation that is either less than or equal to the 75th percentile plus 1.5 times the IQR (upper value), or is greater than or equal to the 25th percentile minus 1.5 times the IQR (lower value). Values outside the upper and lower adjacent values are termed "outside" values or "Mild Outliers," and are represented by green dots. Values outside three IQR's are termed "Severe Outliers" and are represented as red dots.

Box plots are often used for comparing the distribution of several batches of data (e.g., dissolved oxygen for location one versus location two), since they summarize the center and spread of the data. When making strict comparisons among medians from different batches of data (i.e., different locations), a modified box plot called a "notched box plot" is useful. These notches are constructed using the formula: median ± 1.57(IQR / √n), where 1.57 is selected for the 95% level of significance. Therefore, if the notches of two boxes do not overlap, it may be assumed that the medians are significantly different from each other. However, when making multiple comparisons, the notched box plots do not make any adjustment for the multiplicity of tests being conducted. Despite this shortcoming, notched box plots provide a simple, straightforward, and powerful assessment approach. For example, they can help determine if individual locations are members of least impacted reference populations, or if not members, then how far the locations deviate from that reference. Future studies of greater detail should use more formal tests (e.g., t-tests, ANOVA) based on specific study designs to determine whether two or more populations have different mean values for a given parameter. For general assessment of locations on a park unit scale, though, notched box plots provide excellent and easily accessible information.

Violin Plots

Many modifications build on Tukey's original box plot. A proposed further adaptation, the violin plot (Figure 2b), pools the best statistical features of alternative graphical representations of batches of data (Hintze and Nelson 1998). It adds the information available from local density estimates to the basic summary statistics inherent in box plots. This marriage of summary statistics and density shape into a single plot provides a useful tool for data analysis and exploration. A violin plot is a combination of a box plot and a kernel density plot. Specifically, it starts with a box plot. It then adds a rotated kernel density plot to each side of the box plot. A kernel density plot can be considered a refinement of a histogram or frequency plot in which individual bin or bar heights are joined by a line plotted using a data "smoothing" technique.

In NCSS, the statistical software program used to create violin plots for this report, the violin plots are made by combining a form of box plot with two vertical density traces (frequency distributions). One density trace extends to the left while the other extends to the right. The two density traces are both added to the plot to create symmetry, which makes it easier to compare batches. The violin plot highlights the peaks and valleys of a variable's distribution. The box plots within the density traces were modified slightly by showing the median as a circle and the upper quartile and lower quartile boxes as thickened lines. The upper and lower adjacent values are indicated by the endpoints of thinner lines. Through comparison of this plot with the box plot and frequency distribution of the same data, it becomes apparent that although the box plot is useful in a lot of situations, it does not represent data that are clustered (multimodal). On the other hand, although the frequency distribution shows the distribution of the data, it is hard to see the mean and spread. The obvious answer to these shortcomings is to combine the two plots. Comparison of the medians, the box lengths (the spread), and the distributional patterns in the data becomes much easier using violin plots.

Error Bar Plots

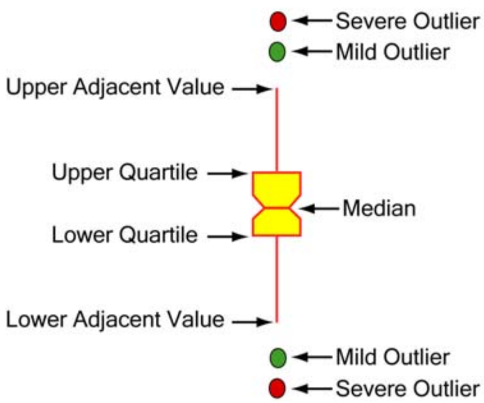
Error bar plots are a graphical technique for condensing discrete ranges of data values into successive categories in order to display potential trends between those categories (Hintze 2004). Error bar plots are a good analytical tool for identification of potential trends in time-series data, because they condense a range of data values from a discrete time period into means for each category of data. In other words, they show a mean value of the given parameter for each time period. They also add error bars to indicate the standard error associated with the calculated mean for each category (Figure 2c). For example, the error bar plots in this report group data by year for a particular parameter, say dissolved oxygen, by waterbody type (main stem, tributary, or spring) and hydrologic season. Then, a mean value for the parameter for each year is produced for each waterbody type and hydrologic season. Error bars are added to the mean to indicate the standard error associated for each calculated annual mean. In addition, the means for each hydrologic season are joined by lines to aid in the general visualization of year-to-year changes. This technique is the first step in identification of both annual trends and areas in which better temporal or sampling resolution may be required to identify any trends. Once potential trends are identified by the error bar plot, further and more formal characterization of those trends may be done using scatter plots and regression analysis.

Scatter Plots

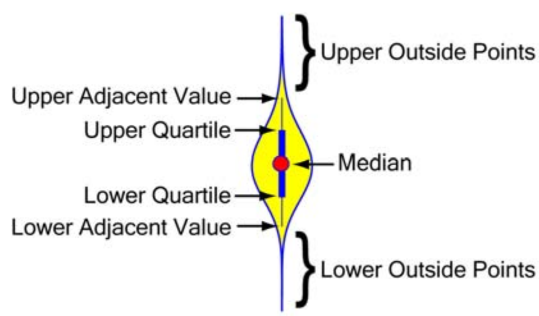
Scatter plots are one of the most commonly employed techniques for visualizing the relationships between two variables (Figure 2d). More extensive descriptions of these plots and their properties are available (Chambers et al. 1983; Tabachnick and Fidell 1996). For a given set of paired data points, for example dissolved oxygen concentration and the date of sampling, one value (e.g. dissolved oxygen concentration) is plotted against the other (e.g. date). Typically, two types of relationships become evident in scatter plots: dependent relationships, where the value of one variable depends directly on the other, or correlative relationships, where the value of each variable is related to the other indirectly. However, there may not be any relationship between the variables at all. One of the strengths of the scatter plot is that each paired data point is included, giving a full picture of the spread and distribution of the data. Without extensive prior knowledge of the variables under examination, a potentially correlative relationship, rather than a direct dependence, is generally assumed. This is especially the case in the examination of isolated water quality variables in complex natural systems.

By convention, the independent or causal variable is plotted on the abscissa (x-axis) and the dependent or response variable is plotted on the ordinate (y-axis). For the scatter plots in this report, the independent variable is typically the date of the sampling event. Various statistical techniques of regression and smoothing are available to quantify the relatedness of the two variables. The technique used in this report is a simple linear regression of the ordinate on the abscissa (y on x). This linear regression produces a trend line that describes the nature of the relationship between the variables. The line has a positive slope if an increase in one variable correlates with an increase in the other and a negative slope if an increase in one variable correlates with a decrease in the other. The extent of this correlation is described by a correlation coefficient ranging in value from +1 (perfect positive correlation) to 0 (no correlation) to –1 (perfect negative correlation).

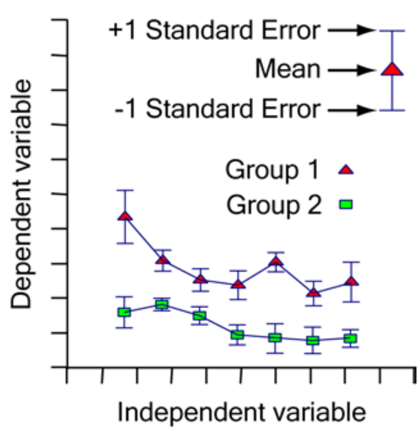
The scatter plots in this report are used primarily to illustrate potential trends of specific parameters in different hydrologic seasons through different time periods. This is achieved by plotting the parameters versus time, while changing the symbols for observations in different hydrologic seasons (i.e. using a square or a triangle instead of a circle to mark the point). Often, it is apparent from the scatter plot that data have been collected at different rates through time (many points in one time period, few in another) or that the available data are too few or too widely spaced to provide useful information in regards to annual trends.



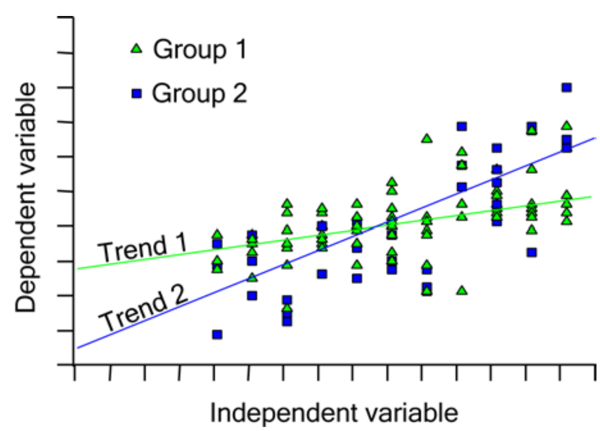
a) typical notched box plot



b) typical violin plot



c) typical error bar chart



d) typical scatter plot

Figure 2. Common features of statistical graphic techniques used in this report.

PARK SPECIFIC INFORMATION

Background Information and Designated Uses

The oldest park service unit in the national park system, Hot Springs National Park (HOSP) was originally established as Hot Springs Reservation in 1832 to protect 47 hot springs and their watershed. Several historic bathhouses are also protected within the park boundary. The park is located in the Ouachita Mountains region of central Arkansas. Waters within the park have several designated uses (Table 3), which correspond to specific standards and criteria as outlined in previous reports within this cooperative agreement (Goodrich and Huggins 2003; Goodrich et al. 2004). Typical uses of the park's resources include bathing, hiking, picnicking, historic tours, and scenic drives.

Table 3. Waterbodies and their designated uses for this park service unit.

Waterbody	Designated Uses
Bull Bayou	Primary Contact Recreation Secondary Contact Recreation Domestic Water Supply Industrial and Agricultural Water Supply
Gulpha Creek	Primary Contact Recreation Secondary Contact Recreation Domestic Water Supply Industrial and Agricultural Water Supply Seasonal and Perennial Ouachita Mountains Fisheries
Hot Springs Creek	Primary Contact Recreation Secondary Contact Recreation Domestic Water Supply Industrial and Agricultural Water Supply Seasonal and Perennial Ouachita Mountains Fisheries
Ricks Pond	Primary Contact Recreation Secondary Contact Recreation Domestic Water Supply Industrial and Agricultural Water Supply Fisheries Lake and Reservoir
Whitington Creek	Primary Contact Recreation Secondary Contact Recreation Domestic Water Supply Industrial and Agricultural Water Supply Seasonal and Perennial Ouachita Mountains Fisheries

For the purposes of this report, the hydrologic seasons for HOSP (Table 4) were defined the same as those previously developed for the park service unit's Baseline Report (National Park Service 1998).

Table 4. Hydrologic seasons determined for this park service unit.

HydroSeasonCode	Hydrologic Season	Start Date	End Date
HOSP_hydro1	Normal Flow	June 15	October 9
HOSP_hydro2	Ascending Flow	October 10	March 31
HOSP_hydro3	Descending Flow	April 1	June 14

Park Map and Stations Included in Analysis

A list of the station locations included in the analyses of this report, their corresponding identification numbers, and their classification as to waterbody type is included for reference (Table 5). A park service unit map is also included, depicting the service unit boundary, the study area, the major hydrography, and the stations used in the analyses in this report (Figure 3). Although more stations occur in the accompanying relational database and in the available data, only those stations actually used in the analyses of this report are included in the table of stations and designated on the park service unit map.

Table 5. Stations used in analyses in this park service unit.

NPS StationID	Waterbody Code	Waterbody Name	Station Location	Other Names
HOSP0002	Tributaries	Gulpha Creek	L CATHERINE MOUTH OF GULPHA CR	060017, 2F017
HOSP0004	Tributaries	Gulpha Creek	GULPA CREEK	0505C1
HOSP0030	Tributaries	Hot Springs Creek	HOT SPRINGS	0510K1
HOSP0031	Tributaries	Hot Springs Creek	HOT SPRINGS CREEK TRIB TO LAKE HAMILTON	LHMON10
HOSP0032	Tributaries	Hot Springs Creek	HOT SPRINGS	0510K2
HOSP0033	Springs	spring	Happy Hollow Spring	HOSP_NPS_HHS
HOSP0060	Springs	spring: central area	Hot Spring #49 - 343035093031001	HOSP_USGS_HS49, 343035093031001
HOSP0099	Tributaries	Stokes Creek	STOKES CREEK TRIB TO LAKE HAMILTON	LHMON11
HOSP0103	Tributaries	misc tributary	STOKES CREEK COVE TRIB TO LAKE HAMILTON	LHMON06
HOSP0104	Tributaries	Bull Bayou	BULL BAYOU	0510J1
HOSP0105	Tributaries	Bull Bayou	BULL BAYOU TRIB TO LAKE HAMILTON	LHMON12
HOSP0109	Lentic Waters	Lake Hamilton (Ouachita R.)	LAKE HAMILTON - UPPER	050048, LOUA018B
HOSP0110	Lentic Waters	Lake Hamilton (Ouachita R.)	LAKE HAMILTON AT HWY 70 BRIDGE-THALWEG	LHMON03

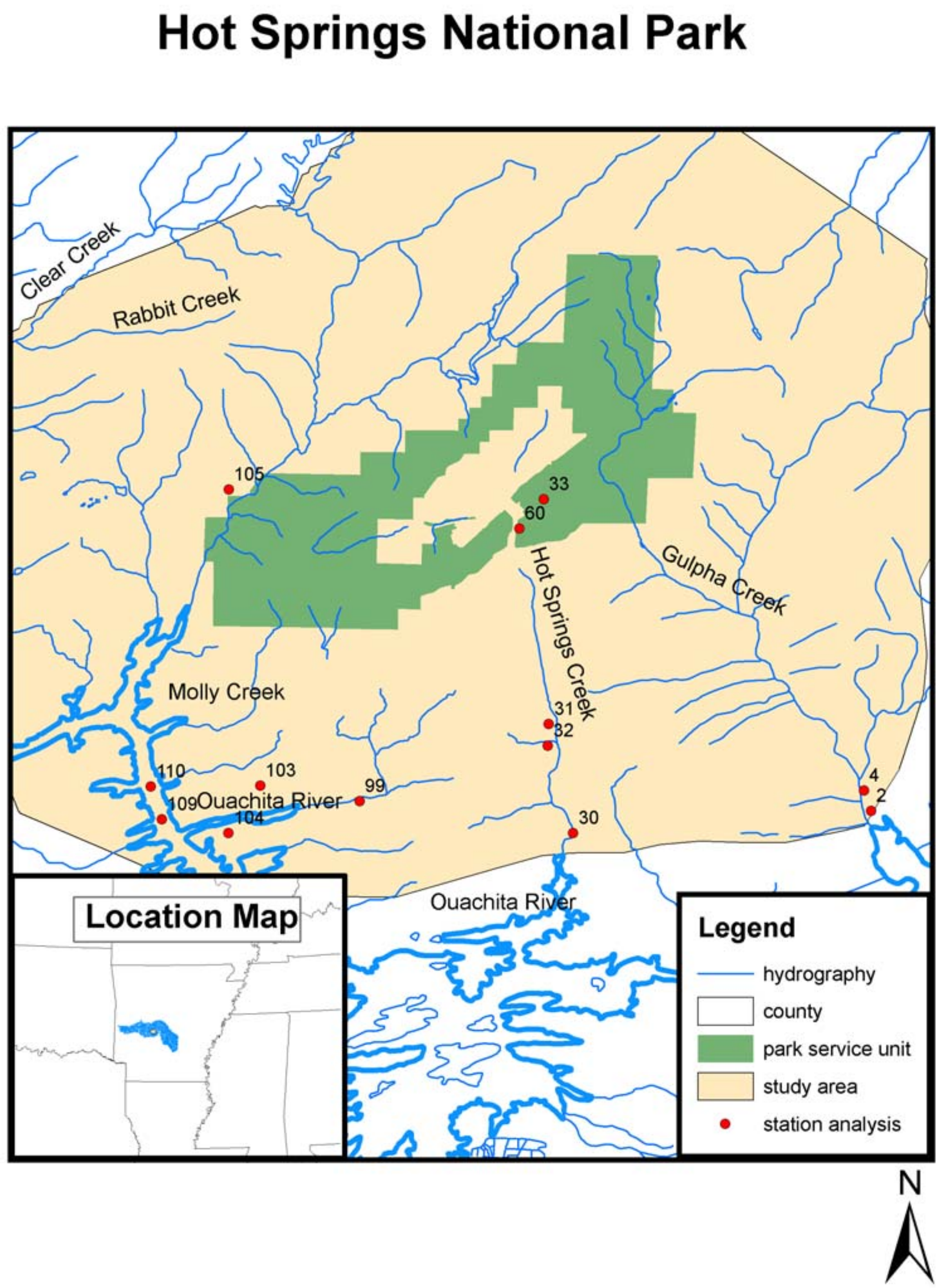


Figure 3. Map of the Hot Springs National Park and associated study area.
Not to scale. Study area is roughly defined as three miles upstream and one mile downstream from the park service unit boundary. Where possible, the spatial coverage as defined by the HOSP Baseline Report was used for determining which stations to include. Water quality stations are those used in the analyses of this report. Stations are identified by the numeric portion of their NPSSTATID code. In other words, station 33 on the map has an NPSSTATID of HOSP0033.

Identified Priority Concerns

HTLN identified specific priority concerns for HOSP (Table 6). When sufficient data were available, relevant water quality concerns from this list were analyzed and specifically addressed in the Analysis sections of this report.

Table 6. Identified concerns and their respective priority ranks for this park service unit.

Rank	Concern	Relevant Parameter(s)[1]
1	Drinking Water Quality (springs)	Parameters with published drinking water criteria
2	Water Clarity	Turbidity
3	Discharge (springs) Pathogens (rivers and streams)	Mean Daily Flow Fecal Streptococci, Fecal Coliform, and Total Coliform counts
5	Nutrient Loading (rivers and streams)	Total Nitrogen, Total Phosphorous
7	Core Elements (springs)	Alkalinity, pH, Specific Conductance, Dissolved Oxygen, Water Temperature, Mean Daily Flow
8	Water Level (wetlands)	Mean Daily Flow
10	Discharge (rivers and streams) Metal Contamination (rivers and streams)	Mean Daily Flow Dissolved and Total Concentrations by Metal where available
11	Sediment Toxicity (rivers and streams)	Pollutants with defined criteria
12	Stream Toxicity	Pollutants with defined criteria
14	Amphibians (wetlands) Macroinvertebrates (rivers and streams)	-[2] -
15	Fish (rivers and streams)	-

[1]These parameters were analyzed as indicators of their respective concerns.
[2]Insuffcent data for analysis or beyond the scope of this water quality assessment.

List of Impaired Waterbodies

At the time of publication of this report, there were no waterbodies or waterbody segments within the park service unit study area that were listed as impaired under section 303(d) of the Clean Water Act.

WATER QUALITY CONCERNS ANALYSIS

Analytical Background for Hot Springs National Park

A series of core water quality parameters were examined individually for each park. These parameters included total alkalinity, pH, specific conductance (conductivity), dissolved oxygen, water temperature, and flow (discharge). In those instances where five or more values of a parameter were taken at a site or for a waterbody type, several graphical methods were used to analyze the data. An explanation of these analytical graphing techniques and their uses is provided in the Overview Section of this report. These graphical methods (e.g. box plots, error bar plots) were used to help determine if there were any deviations from expected conditions and to identify potential areas of concern. First, the data were compared for the three waterbody types with data suitable for analysis – lentic waters (lakes, ponds, or wetlands), tributaries, and springs. Second, the data were compared for three hydrological seasons (hydroperiods) – low or normal flow conditions, periods of generally ascending flow, and periods of peak and descending flow. Within the Hot Springs National Park (HOSP), the low or normal flow period was defined as occurring between June 15 and October 9, the ascending flow period was from October 10 and March 31, while descending flow was determined to be April 1 and June 14 (National Park Service 1998). Finally, the data were analyzed over time to assess temporal trends. However, the variability in data collection through time and space for nearly all variables precluded the use of any statistical time-trend analysis. Discharge records at some collection stations were complete enough that some robust trend analysis might be possible. In general, yearly data collections varied in density and sometimes quality, often exhibiting temporal trends that highlight changes in minimum detection or reporting limits for some of the water quality constituents. Because these analyses are conducted on data collected and analyzed by different organizations and laboratories, special attention must be given in interpreting some of the graphs and raw data.

Several core parameters were identified by the NPS as important water quality variables that should be collected and assessed by virtually all parks. Three of these common water quality constituents display a high degree of natural variability in time as well as space. Dissolved oxygen, pH and water temperature levels vary naturally within differing time scales (e.g. hourly, daily, monthly) due to a number of site-specific to watershed- and regional-scale factors, including but not limited to: primary production, community respiration, instream and near stream habitat, climate, topography and altitude. In order to minimize or account for sources of natural variation in these and other environmental and water quality factors of interest, the timing and frequency of sample collections must be systematic. This is seldom the situation when large, disparate datasets are joined for *posteriori* analyses. Thus, care must be taken in interpreting the data and assessing possible causal factors related to observed changes. Core factors must be collected in a uniform manner and within regular temporal and spatial frameworks appropriate to the NPS facility and the surrounding landscape (e.g. ecoregion, watershed, hydroperiod).

Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist changes in pH. Alkalinity is generally a problem more common in lakes and reservoirs than streams. The most common cause of alkalinity in surface waters is eutrophication that, although a natural process, is accelerated by nutrient pollution and organic enrichment. Because alkalinity varies greatly due to differences in geology, there are no general standards for alkalinity. However, total alkalinity levels of 100-200 mg/L provide for high buffering capacities in streams and thus act to stabilize the pH level in streams. Levels below 10 mg/L indicate that the aquatic ecosystem is poorly buffered and is very susceptible to changes in pH from natural and human-caused sources. The USEPA pH criteria for freshwater are the value range from 6.5 to 9 pH units. However, this range does not take into account some aquatic waterbody types that are naturally acidic, such as fens and bogs.

Specific conductance is a measure of how well water can conduct an electrical current. Conductivity increases with increasing concentrations and mobility of cations and anions found in the water. These ions, which come from the breakdown of compounds, conduct electricity because they are negatively or positively charged when dissolved in water. Therefore, conductivity is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution.

The state of Arkansas's water quality standard for dissolved oxygen (DO) is 6.0 mg/L for all but critical low flows accompanied with high water temperatures. This state DO standard is more restrictive than the broader national standard of 5.0 mg/L supported by USEPA. Some states having cold-water ecosystems that support salmonid fisheries and other cold-water communities often have more stringent dissolved oxygen criteria and standards.

Within the Hot Springs National Park, a water temperature standard of 30 degrees Celsius is proposed for four streams that flow through the park, except when stream flows are less than the applicable critical flow. In addition, a temperature limit of 32 degrees Celsius was listed for Ricks Pond. While we were not able to identify what these critical flow values were for the individual collection sites on each waterbody, we assumed that critical flows would most likely occur during hydrological season 1, the hot, dry, late summer to early autumn period of low stream flows. Like DO values, water temperatures associated with many stream and small lake ecosystems can vary greatly during a single day in addition to the seasonal changes associated with solar radiation and other climate factors.

Assessment of Core Factors

In general, the observed ranges of the six core water quality parameters were within acceptable ranges for flowing water systems located in the Hot Springs National Park. Based on the available data, we did not identify any major areas of concern regarding core factors for this park. The one possible exception was dissolved oxygen that occasionally showed levels below 6.0 mg/L, a state of Arkansas level of concern. These lower dissolved oxygen values occurred principally during low to normal flows (hydroperiod 1). However, nearly all dissolved oxygen concentrations were above the commonly cited USEPA criterion level of 5.0 mg/L, except for a very limited number of tributary values that dropped to a low of almost 3 mg/L during the summer.

Total alkalinity concentrations ranged from about 12 to slightly over 90 mg/L $CaCO_3$ for the three stream sites within the park that had sufficient data to plot (Figure 4 – Figure 6). No alkalinity measures were available for spring or lake environments. The lowest observed alkalinity values were in Bull Bayou (HOSP0105) as shown in Figure 4, while the lowest tributary levels occurred during hydrologic season 3 in the springtime. No statements concerning yearly trends in total alkalinity values are offered as only two separate years (1982; 1983) of data could be plotted, and these data were limited only to tributaries (streams). There appears to be a slight but inconsistent decrease in total alkalinity values for the streams during hydrologic season 3. Overall, the streams within the Hot Springs National Park system appear to be sufficiently buffered and thus resistant to alterations in the natural pH and pH flux associated with these systems.

The range in pH concentrations for streams was narrow, with the majority of values falling between pH 6.5 to 7.5 (Figure 7 – Figure 9). The median values for tributary sites were around pH 7.0 for hydroperiods 1 and 3, while the median value for hydroperiod 2 (fall and winter) dropped to pH 6.6. In general, pH values remained similar between hydrological seasons and over time. Only two years (1982, 1983) of pH data were available for plotting purposes, preventing any meaningful interpretations of yearly trends.

Median specific conductance values for all Hot Springs National Park stream stations ranged from a low of just over 50 umhos/cm for Bull Bayou (HOSP0105) to about 200 umhos/cm for Hot Springs Creek (HOSP0031) (Figure 10). In general, specific conductance for streams was higher during hydrologic season 3 than 1, though both had median values in excess of 125 umhos/cm. Specific conductance was generally lowest in hydrologic season 2, with a median value of 100 umhos/cm. All hydroperiods showed a wide range of values (Figure 11). Again only two separate years of specific conductance data were available and that was only for streams (Figure 12). Like all proceeding core parameters, the mean 1983 values for hydroperiod 2 were lower than 1982 means.

Median dissolved oxygen levels were above 6.0 mg/L for all stream and lake stations during all hydroperiods (Figure 13, Figure 14). Dissolved oxygen levels in hydrologic seasons 2 and 3 (covering most of the fall and winter period) displayed slightly higher median values than the median values found associated with summer values (hydroperiod 1), which were about 6.5 mg/L with the lower quartile values falling below 6.0 mg/L. Overall, most dissolved oxygen values were above the 6.0 mg/L line, but some of the tributary values did dip as low as 3 to 4 mg/L. DO values were also shown to increase in tributaries in 1983, while lake values decreased in that same year. However, such statements are speculative at best, due to spatial and temporal data limits. For the most part, no meaningful time trends could be determined in the error bar charts for dissolved oxygen, since they were again based only on data from two years (Figure 15).

Median water temperature values were only available for stream and lake stations, as no spring stations had five or more temporally distinct values (daily or greater intervals). The median values for tributaries did not vary greatly, with the median values for Bull

Bayou (HOSP0105), Stokes Creek (HOSP0099) and Hot Springs Creek (HOSP0031) all occurring near 20 degrees Celsius (Figure 16). At a median temperature of about 24 degrees Celsius, the single lake station (HOSP0109) tended to have higher temperature values than the tributary sites. The Arkansas standard for stream temperatures for both Bull Bayou (HOSP0105) and Hot Springs Creek (HOSP0031) is 30 degrees Celsius, which was never exceeded, even during warmer months with typical low flows (Figure 16, Figure 17). The same was true of Stokes Creek (HOSP0099), which had a lower median temperature (approximately 18 degrees Celsius). As would be expected, water temperatures were lower during the fall/winter period (hydrologic season 2), with median value for the tributaries occurring between 11 and 12 degrees Celsius. Temperature data for the lake station were limited to measurements taken during hydroperiod 1 (late summer and early fall), resulting in a median temperature value of about 23.5 degrees Celsius and high values up to 28 degrees. Temperature data were only available for two different years, and measurements were taken sporadically throughout the year or only during one hydroperiod. The resulting error bar plot meant to display trend lines (Figure 18) is nearly meaningless due to the infrequent, episodic nature of the temperature data that was collected in different times of the year. The lack of long–term, temporal collections of water temperature to characterize the springs that are the focus of this park is surprising. In fact, of the 87 springs identified in our database about 65 spring sites (i.e. stations) had some temperature measurements. However, only one site had four daily temperature measures while five sites had three measures and the rest had two or less measurements of water temperature.

Five stations associated with this park had flow data, but only one spring (HOSP0060) had five or more data points and could be plotted and characterized statistically (Figure 19 – Figure 21). The daily flow (gal/min) for Hot Spring #49 (HOSP0060) varied between 29 and 35 gallons a minute with a median of about 34 gallons/minute. These data were collected in 1922. All flow measurements were taken during hydroperiod 1 and no trend estimates could be assessed from the data collected in a single year (Figure 21).

Assessment of Priority Concerns

The priority variables associated with the Hot Springs National Park, in order of importance, are drinking water standards for springs, water clarity, spring flows, stream pathogens, macroinvertebrates, nutrient loading, core elements, water levels in wetland environments, stream flows, metal contamination, sediment and stream water toxicity, wetland amphibians, macroinvertebrates, and fish communities in flowing lotic environments (Table 6). Discharge (i.e. daily flows) and other core elements are discussed in the core element section above, but spring discharge data were nearly absent, and no comprehensive flow data for any spring were made available. Unfortunately, data regarding springs appear to be few and sporadic, often with the additional problem of insufficient geographic precision to discriminate between springs. Of the remaining priority concerns, data were available to characterize some drinking water parameters (i.e. nitrite, nitrate, iron), water clarity (as turbidity), stream pathogens, nutrient loading, and metal contamination. Stream toxicity is addressed in the context of these available data, but no sediment toxicity data suitable for analysis were found for those portions of streams and rivers associated with the park.

Assessment of Water Clarity and Pathogens

Violin plots of turbidity for tributaries during all hydrologic seasons (Figure 22) indicated that the medians and 75th percentile (upper quartile) values were always well below the 10 NTU criterion level established by the state of Arkansas to protect these streams. This value is nearly the same as the benchmark value of 10.4 NTUs under investigation by the USEPA Region 7 RTAG. The turbidity criterion for Ricks Pond is 25 NTU, but we were unable to locate turbidity data for this pond. No time trend statements are offered, because of the limited number of records for turbidity (Figure 23).

Counts of fecal streptococci bacteria for tributaries tended to be less in hydroperiods 2 and 3, with hydroperiod 1 having the highest median value of about 600 counts per 100 mL (Figure 24). Only two years of data were available for fecal streptococci, and little can be said regarding trends in this bacterial group (Figure 25). The state of Arkansas has established a fecal coliform criterion based on the geometric mean of no less than 5 samples taken during a period of no more than 30 days. The primary contact recreation value is 200 colony counts per 100 mL of water sample and is applicable to all Extraordinary Resource Waters and Natural and Scenic Waterways in the state, in addition to all streams having a primary contact designated use. This criterion would apply to all tributaries included in our assessment. It appears that in hydroperiods 2 and 3, the median values for tributaries exceed the primary contact value of 200/100 mL. Further, in hydroperiod 2 even the secondary contact criterion (1000/100 mL) was exceeded (Figure 26). In hydroperiod 1 (summer/fall) some tributary fecal coliform counts also exceeded both criterion values (Figure 26), but the median value was below 100/100 ml. No meaningful trends could be discerned from the error bar plot by year, but it did appear that 1976 values associated with hydroperiod 1 were lower in the 1982 survey (Figure 27). Total coliform counts were typically highest in hydroperiod 3 with a median count of about 30,000/100 mL (Figure 28). Hydroperiods 1 and 2 had median counts of approximately 20,000/100 mL, with some counts exceeding 100,000 mL. The error bar plot of hydroseason data by year was not very informative, as only three years of data could be plotted, and means between years were often for different hydroperiods (Figure 29).

Assessment of Nutrient Loading

The USEPA is currently supporting the development of numeric criteria for nutrients for each state. Regional Technical Assistance Groups (RTAGs) supported by USEPA regional offices are facilitating the development of “regional” nutrient criteria. These RTAGs provide the scientific expertise to assess regional data and eutrophic conditions, which can be useful to the states in adopting and developing individual state criteria. While few states have numeric criteria for either total nitrogen (TN) or total phosphorus (TP), the state of Arkansas listed 100 µg/L of total phosphorus as a limit for streams associated with the park for which we have TP values. The state also lists 50 µg/L as the TP limit for Ricks Pond. No suggested concentration limits for total nitrogen for streams in Arkansas were currently listed in any of the literature we examined. Because there are few numeric criteria in use in regulatory organizations that might oversee Heartland facilities, in our evaluations we are using TP and TN benchmark values that are currently under consideration by the USEPA Region 7 RTAG. These TN and TP benchmark values are the means of TN and TP values taken from the literature or derived statistically as ranges of values considered protective and associated with reference stream populations, or "high quality" streams. A summary of values and sources are listed in Table 7, which represents current efforts within USEPA Region 7 RTAG.

Table 7. Potential benchmark values for nutrient stressors and other associated variables derived using multiple approaches.

Parameter	Literature[1] (range)	Nutrient Regions[2] (range)	Reference Streams (median)	Tri-section[3] (median)	25th percentile	MEANS (all methods)
Total nitrogen (mg/L)	**0.7 – 1.5**	**0.54 – 2.18**	**1.08**	**0.81**	**0.82**	**1.03**
Total phosphorus (mg/L)	**0.025 – 0.075**	**0.01 – 0.128**	**0.08**	**0.07**	**0.07**	**0.068**
Sestonic chlorophyll *a* (µg/L)	**10 – 30**	**0.9 – 3.0**	**3.3**	**2.8**	**2.0**	**6.0**
Benthic chlorophyll *a* (mg/m^2)	**20 - 70**	**NA**	**24.2**	**20.3**	**11.9**	**25.4**
Turbidity (NTU)	**NA**	**1.7 – 17.5**	**12.0**	**10.5**	**9.5**	**10.4**

[1] (Dodds et al. 1998). These values are for streams in the mesotrophic range.
[2] (USEPA 2000d, a, b, c, 2001a, b, c).
[3] Tri-section values are for upper one-third streams in US EPA Region 7 having highest total richness for macroinvertebrates.

The median levels for total nitrogen for tributaries were below a suggested benchmark value of 1.03 mg/L for both hydrologic seasons 1 and 3 (Figure 30). The median for hydrologic season 2 was just above this benchmark value, while about 75% of all TN values were also above this value during all hydroseasons. The yearly trends in TN values indicated that a steady decrease in concentrations has been occurring since 1974 (Figure 31). Violin plots for nitrite nitrogen showed that median values for tributaries were always below the federal drinking water standard for nitrite (Figure 32). However, a relatively high number of nitrite values occurring in hydroperiod 2 (i.e. fall/winter) exceeded this drinking water standard. Only in 1974 were enough nitrite samples analyzed to allow them to be plotted using an error bar plot (Figure 33). Two or more sample values are needed to produce an error bar plot. In addition to nitrite, enough nitrate values were available for tributaries to produce violin plots for hydroperiods 1 and 2 (Figure 34). These plots indicate that nitrate values are well below the federal drinking water standard of 10 mg/L. However, nitrate data were only available for 1974, and no trends could be evaluated (Figure 35).

The median values for total phosphorus were at or below the state's benchmark level of 100 µg/L, but were always above the regional benchmark value of 68 µg/L (Figure 36).

The tributary 75th percentile (upper quartile) extended above both benchmark lines during all hydroperiods, with some TP values as high as 1000 µg/L occurring in most hydroperiods. While data were available for only four different years, TP appeared to decrease in the 1980's (Figure 37).

Assessment of Metals

Few metals had sufficient sample sizes to be evaluated using violin or error bar plots for any of the surface water environments in HOSP. While metals contamination was a priority of the park, the nature of the available data prevents any assessment of the temporal or spatial extent of metal occurrence within any group of waterbodies found in or near the park. Tabular information, presented in the Potential Concerns Analysis section of this report, was based on data of known quality (i.e. no flagged data from the database) with quantifiable values above the detection and reporting limits for the given parameter.

The most restrictive criterion value for total iron was from USEPA – 300 µg/L for human health (i.e. water + organism consumption). Iron concentrations found in all hydroperiods were well below this value (Figure 38). Iron also had a chronic value of 1000 µg/L for aquatic life. Total iron varied little between hydroperiods and remained around 0.1 µg/L with occasional values in excess of 0.2 µg/L. Though total iron can be measured to this analytical precision level, it is relatively rarely done. These observations may actually be in mg/L, but no additional information was available to confirm the units. Without contrary information, the data were taken at face value. It should be noted, however, that these data would fall below the criterion value even if they were in mg/L. No potential trends for total iron could be plotted (Figure 39).

Total calcium levels remained fairly constant, with median values varying from a low of about 10.4 mg/L in hydroperiod 3, to a high of nearly 12 mg/L in hydroperiod 2 (Figure 40). These tributary levels appear to be similar to calcium concentrations in other streams within the region. Calcium is typically not viewed as an environmental contaminant, and has no known toxic properties. Only two years of calcium data were plotted (Figure 41), and little can be said about potential trends in calcium levels in streams in or near HOSP.

Core Elements Figures

Please see the "Statistical Analysis and Methodology" and relevant "Water Quality Concerns Analysis" sections of this report for aid in interpreting these figures.

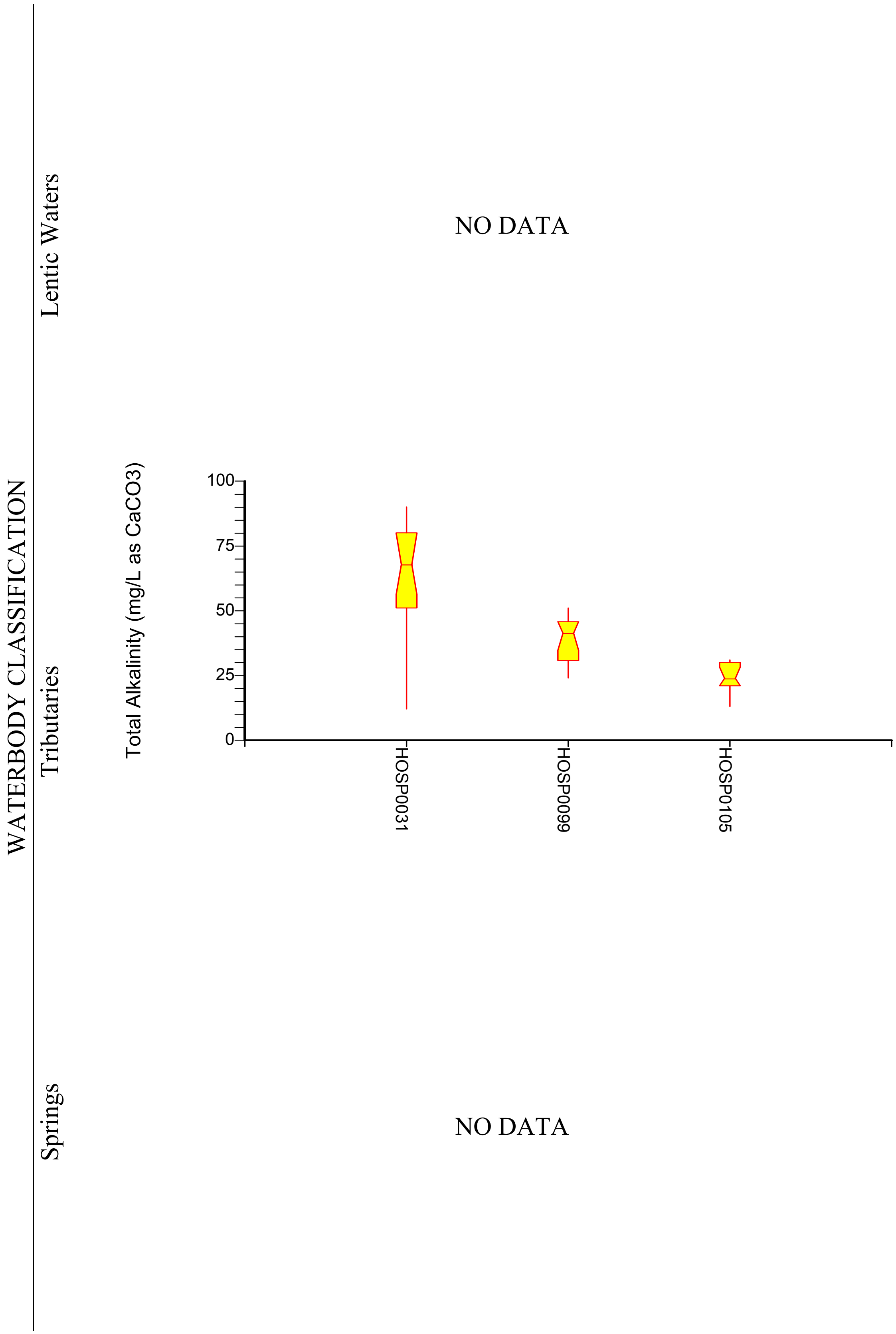


Figure 4. Box plots of total alkalinity for different waterbody types by station.

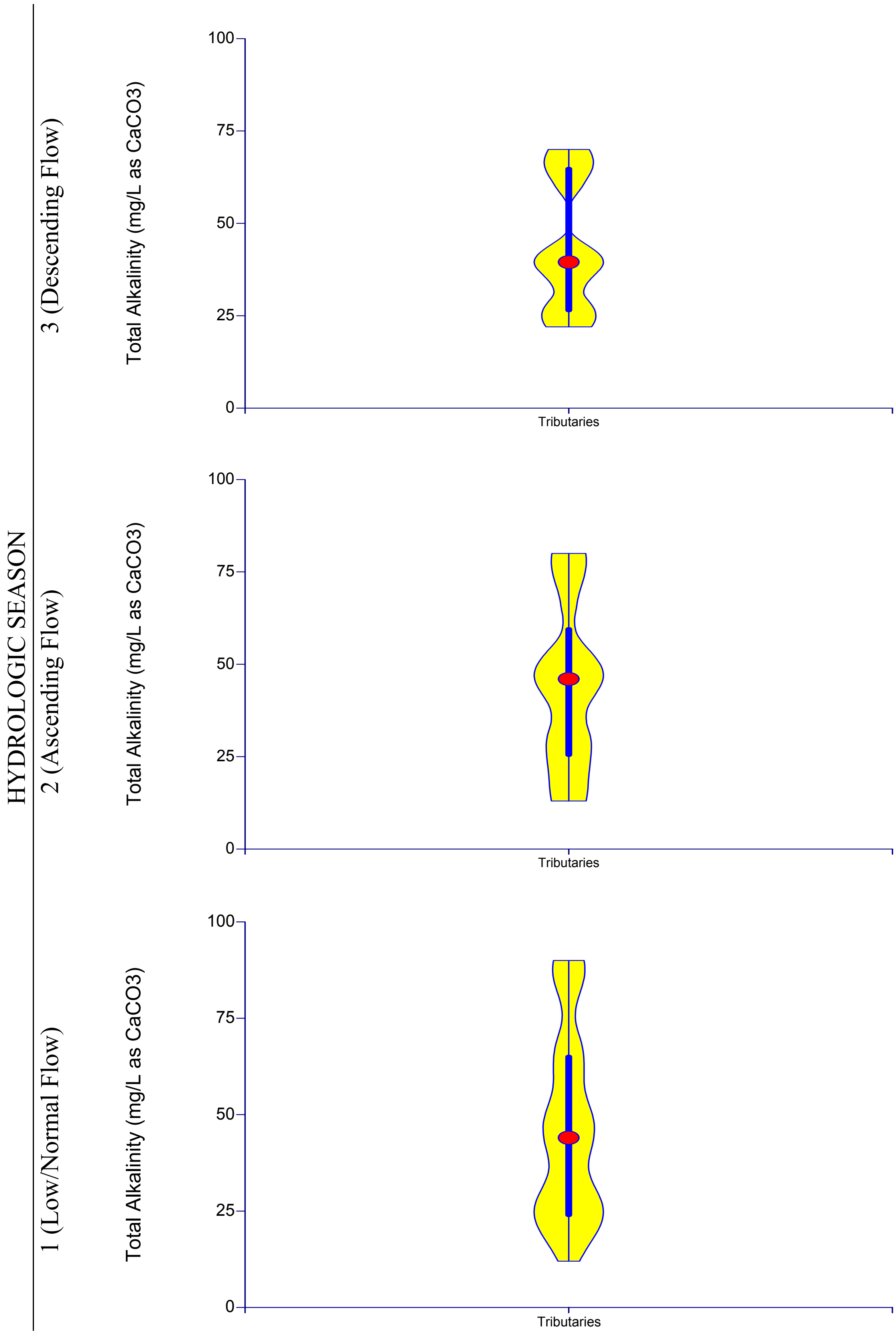


Figure 5. Violin plots of total alkalinity for different hydrologic seasons by waterbody type.

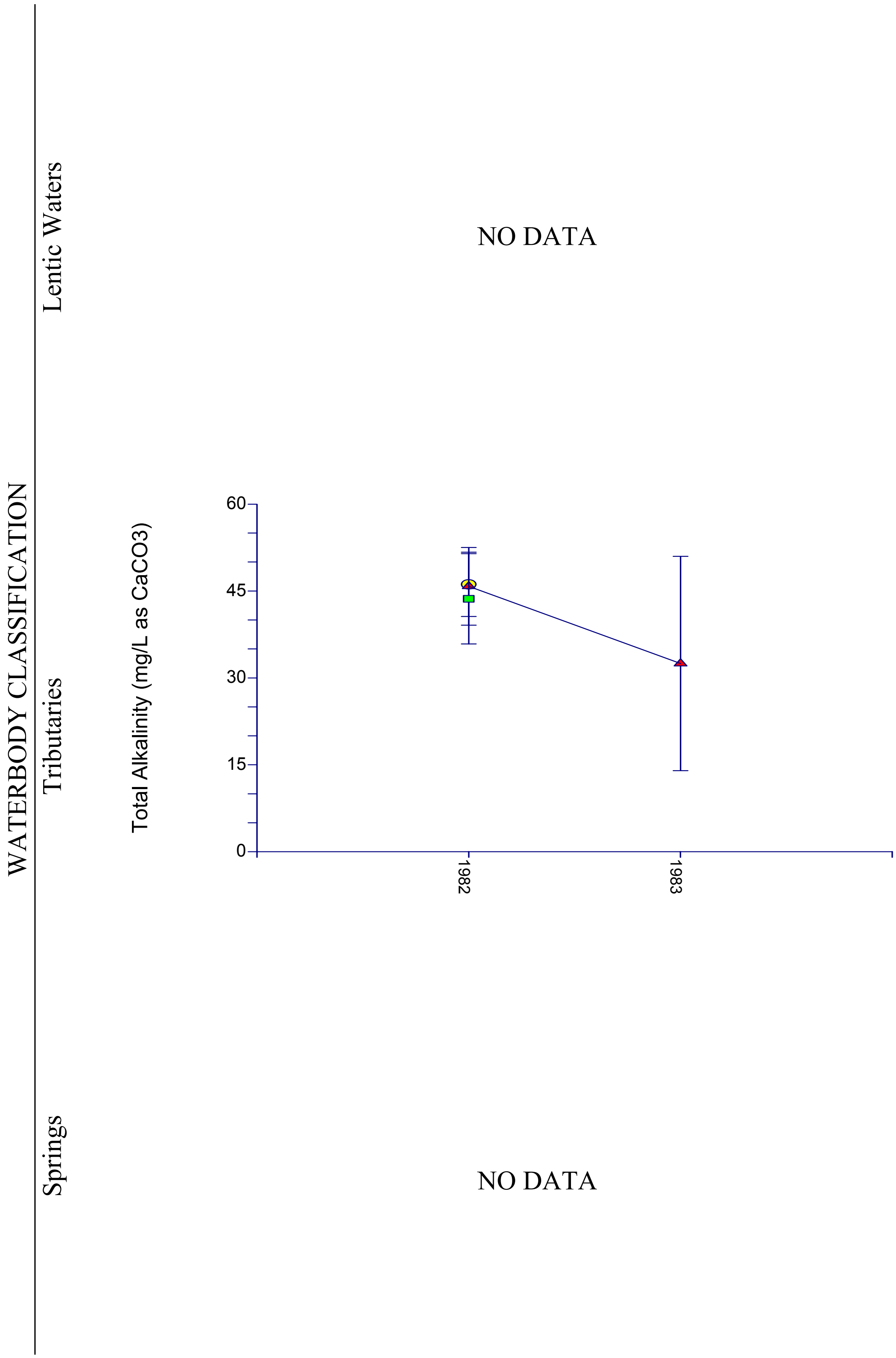


Figure 6. Temporal distribution of total alkalinity for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2 and 3 are represented by circle, triangle and square symbols respectively.

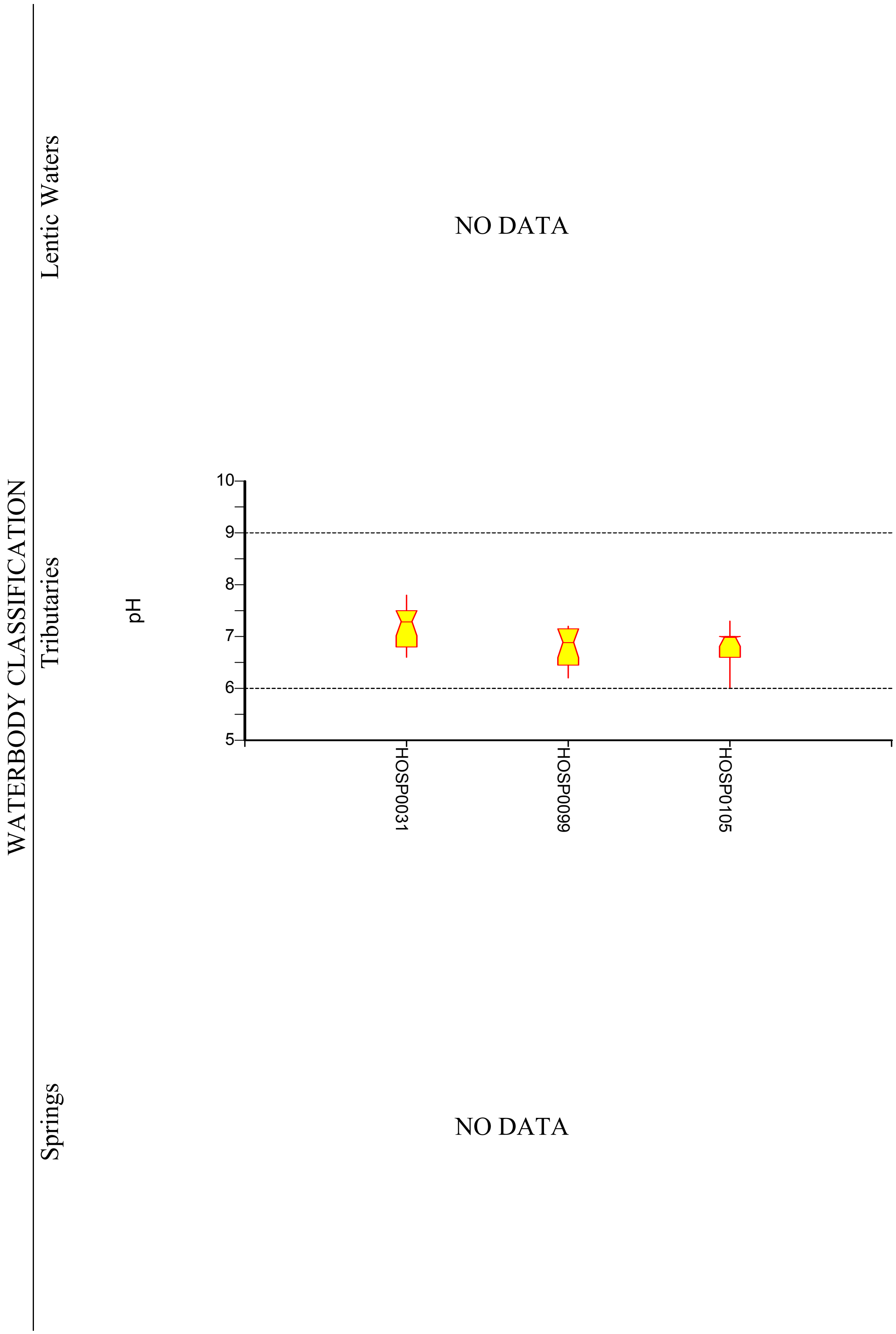


Figure 7. Box plots of pH for different waterbody types by station.
State of Arkansas pH standard range of 6.0-9.0 shown for reference.

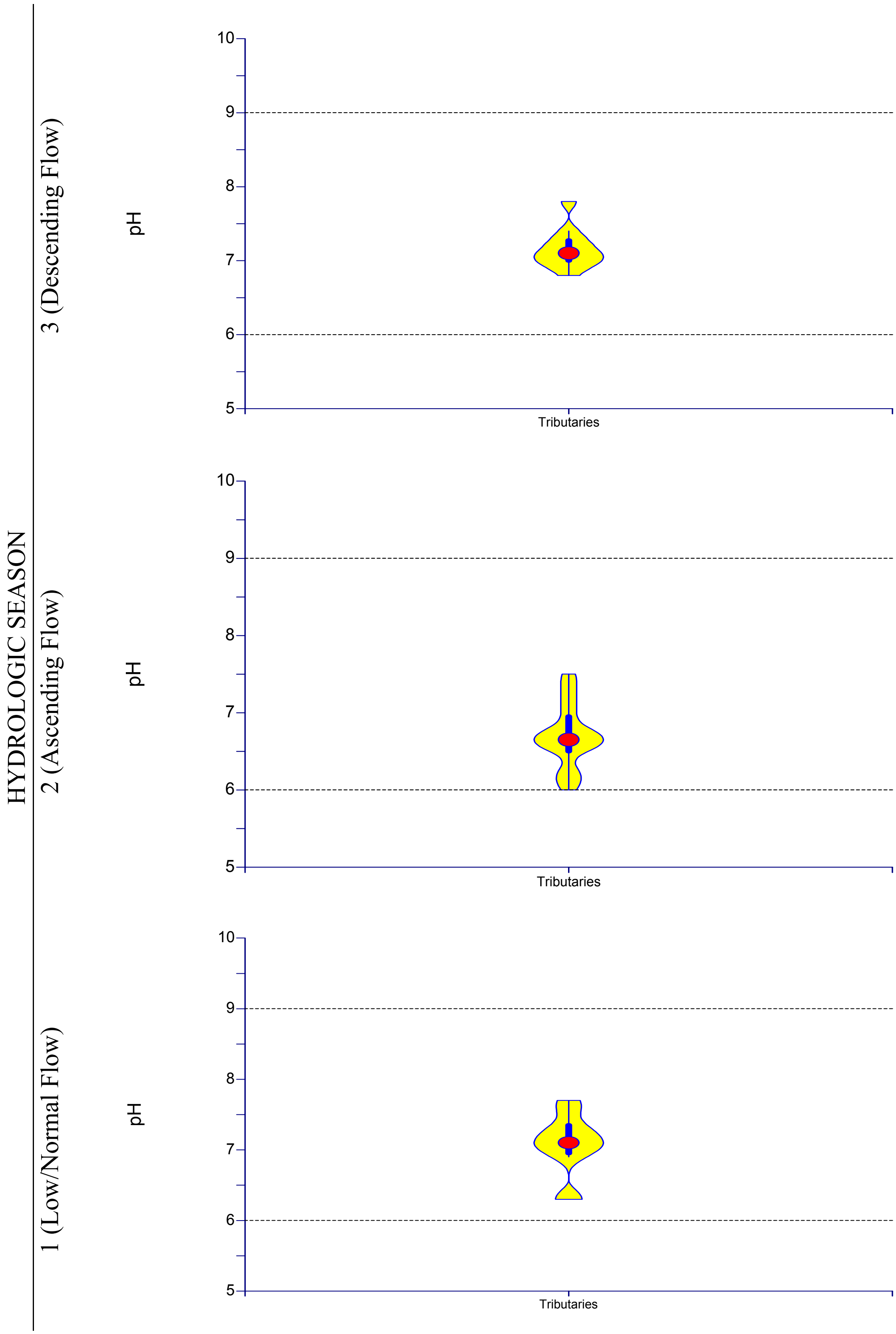


Figure 8. Violin plots of pH for different waterbody types by station.
State of Arkansas pH standard range of 6.0-9.0 shown for reference.

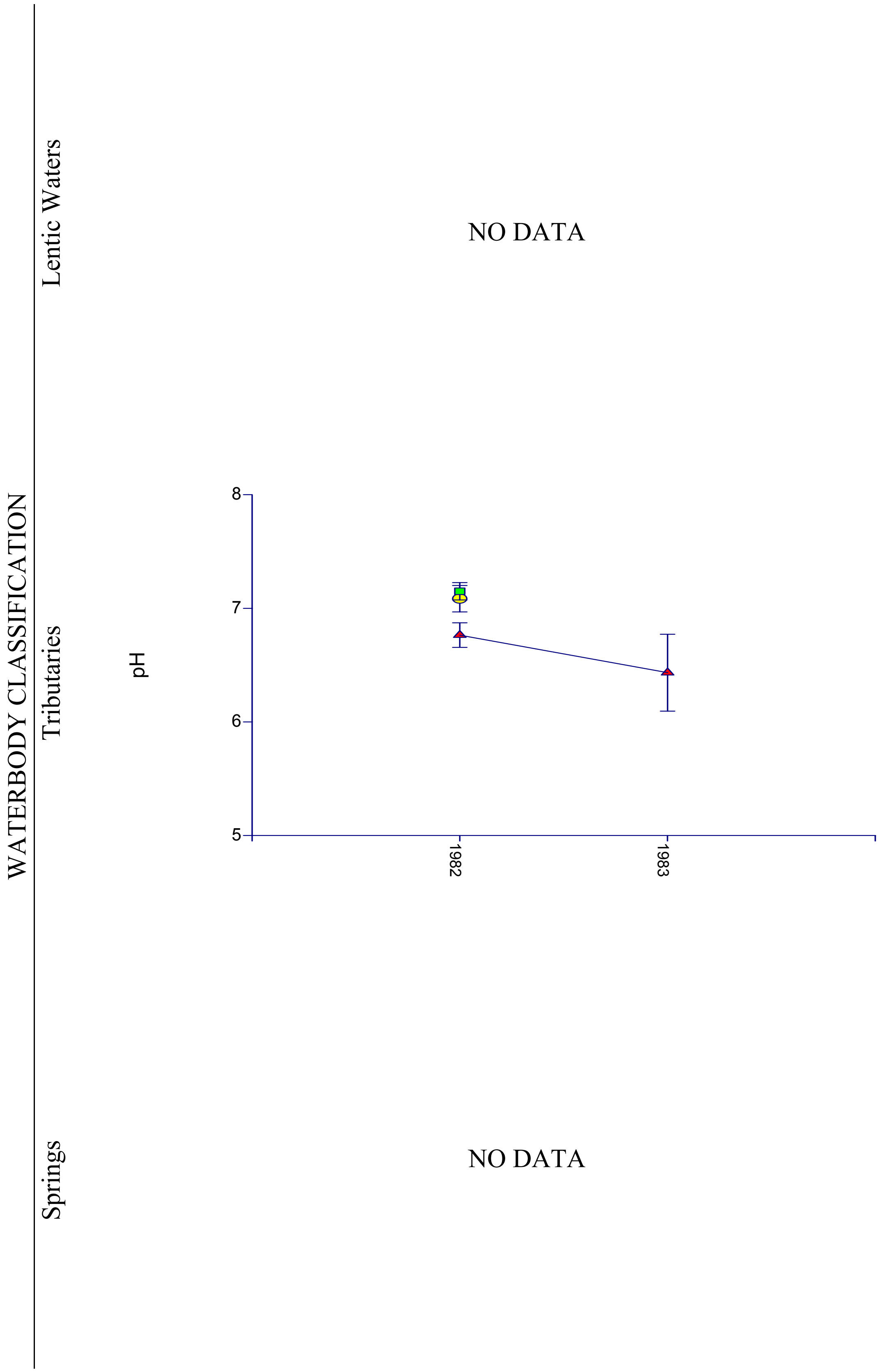


Figure 9. Temporal distribution of pH for different waterbody types by hydrologic season. Hydrologic seasons 1, 2 and 3 are represented by circle, triangle and square symbols respectively.

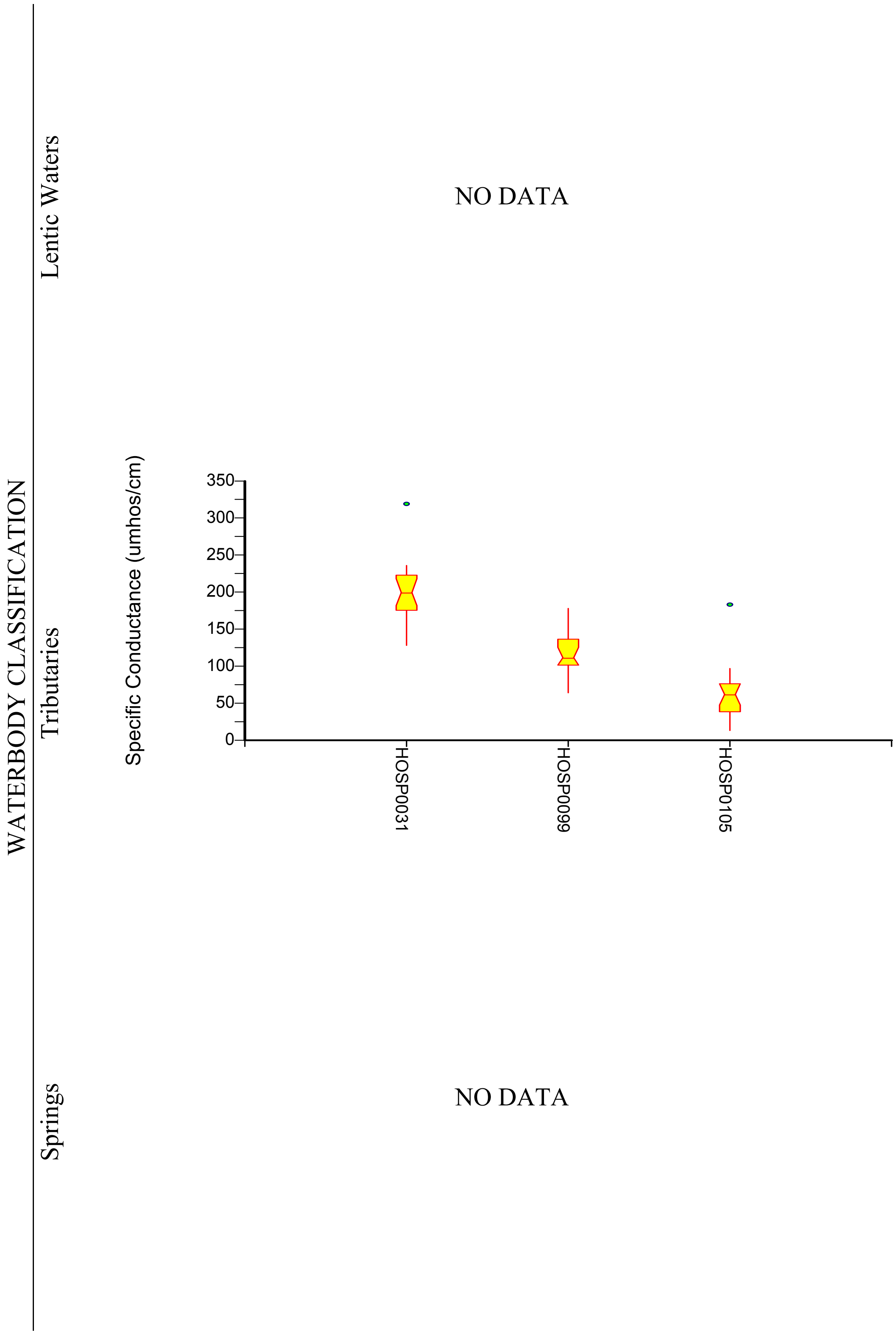


Figure 10. Box plots of specific conductance for different waterbody types by station.

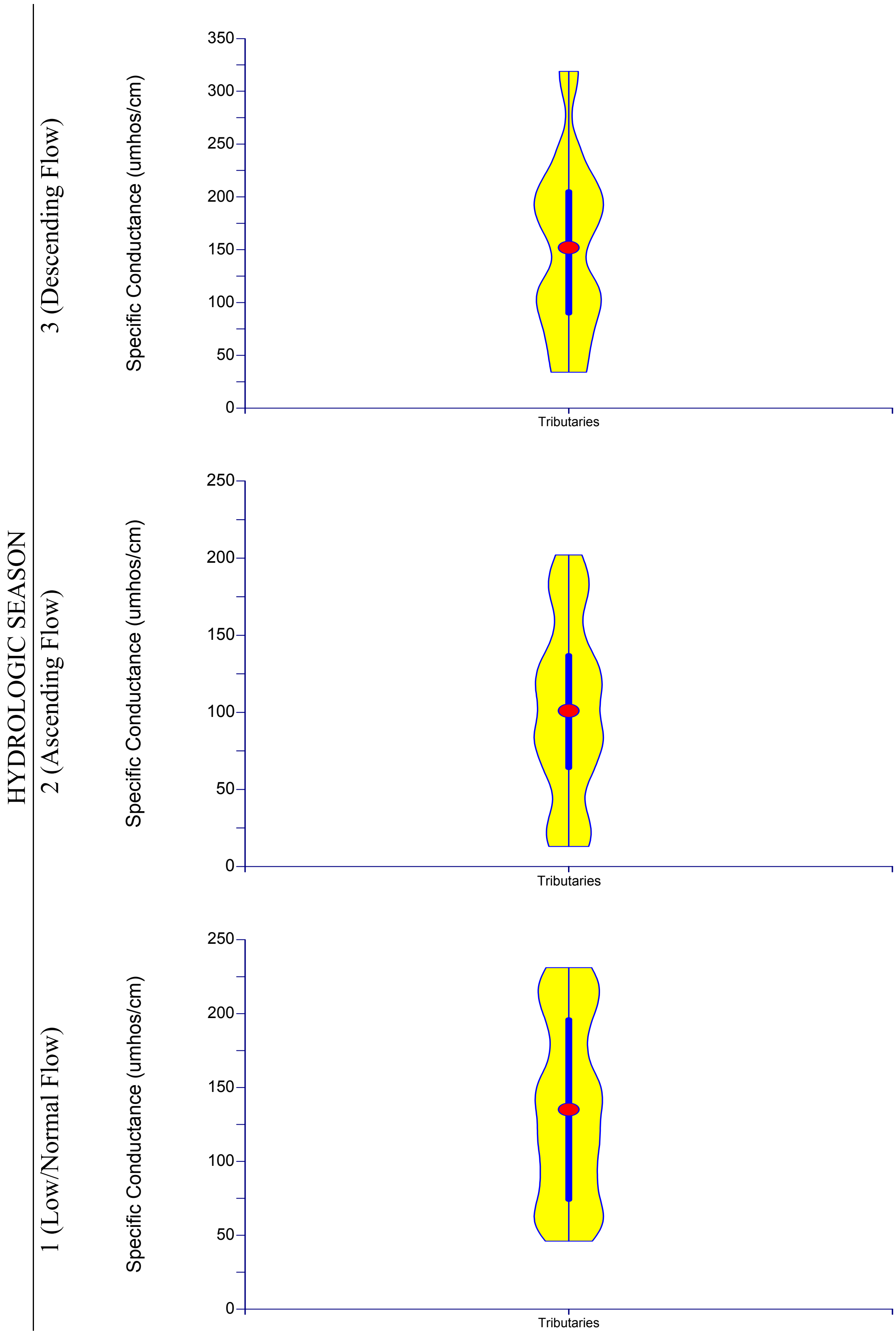


Figure 11. Violin plots of specific conductance for different hydrologic seasons by waterbody type.

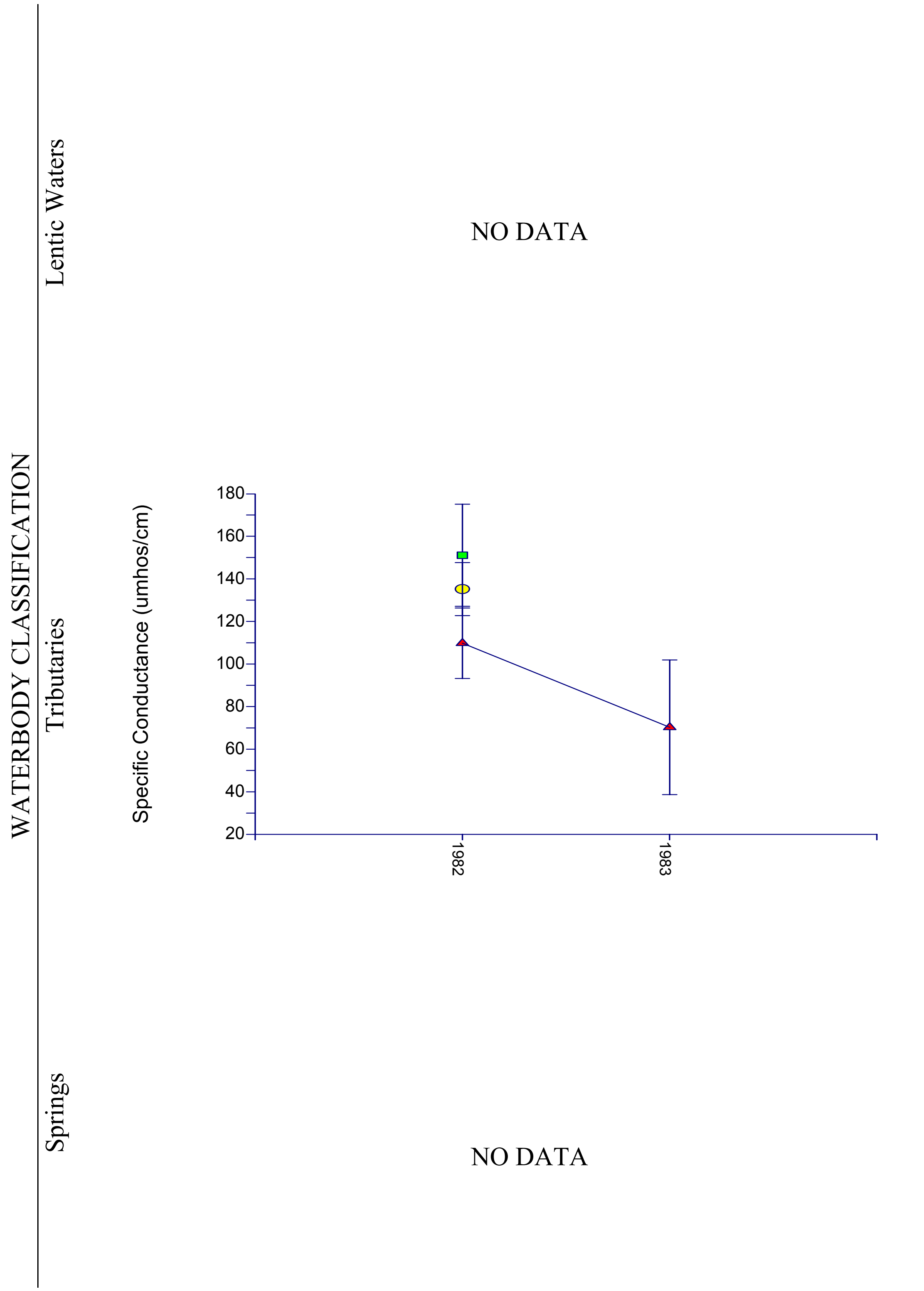


Figure 12. Temporal distribution of specific conductance for different waterbody types by hydrologic season.
Hydrologic season 1, 2, and 3 are represented by circle, triangle, and square symbols, respectively.

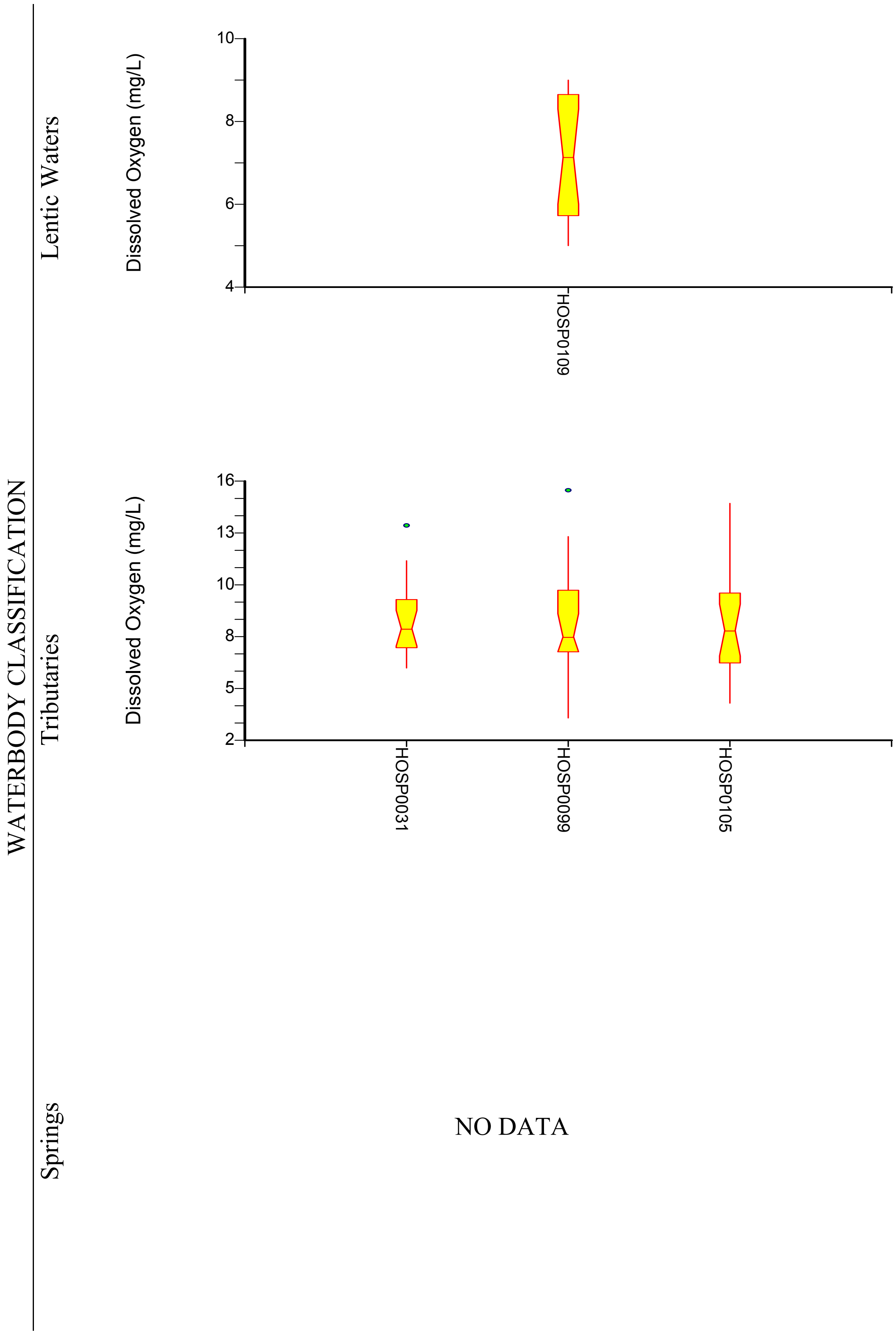


Figure 13. Box plots of dissolved oxygen for different waterbody types by station.

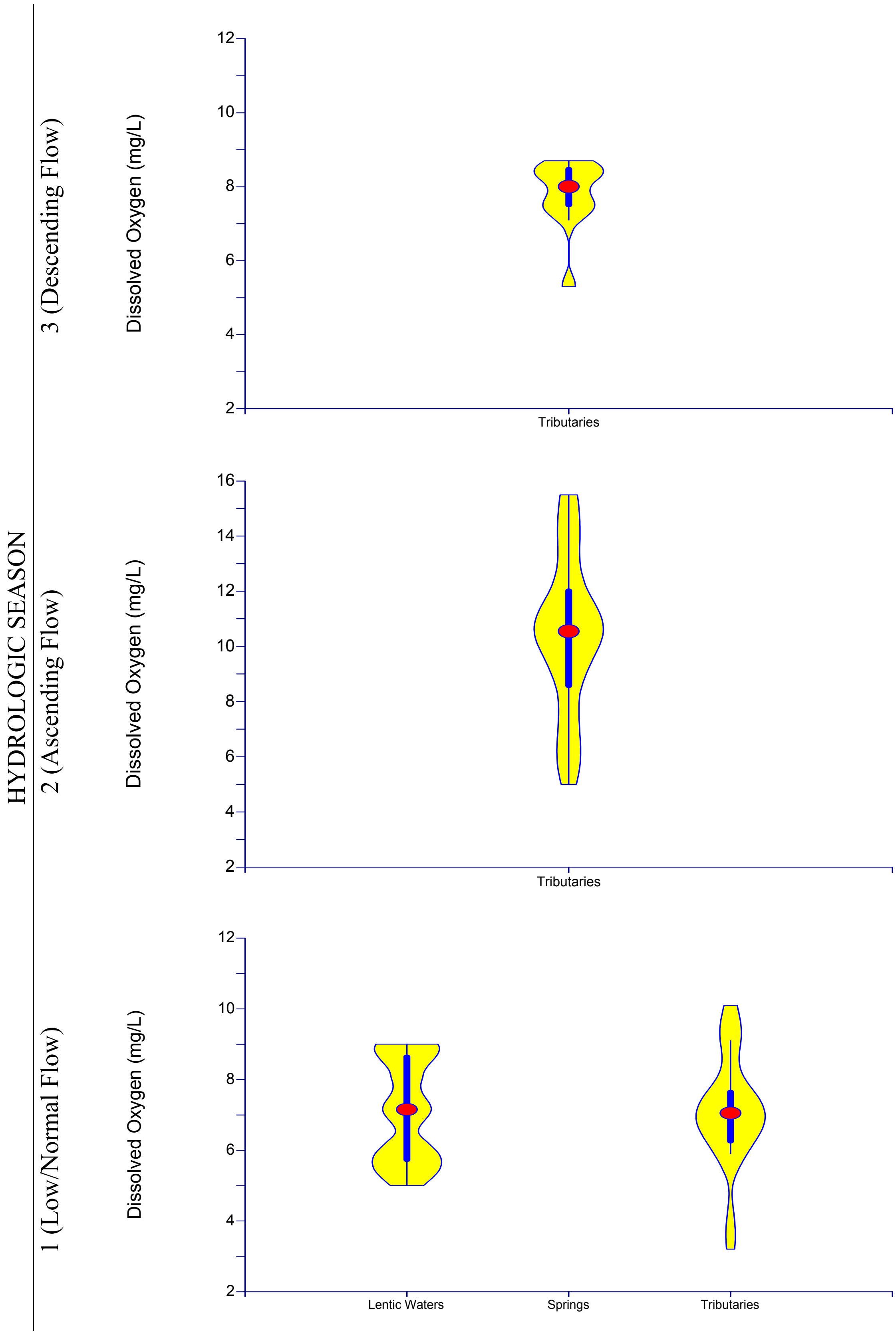


Figure 14. Violin plots of dissolved oxygen for different hydrologic seasons by waterbody type.

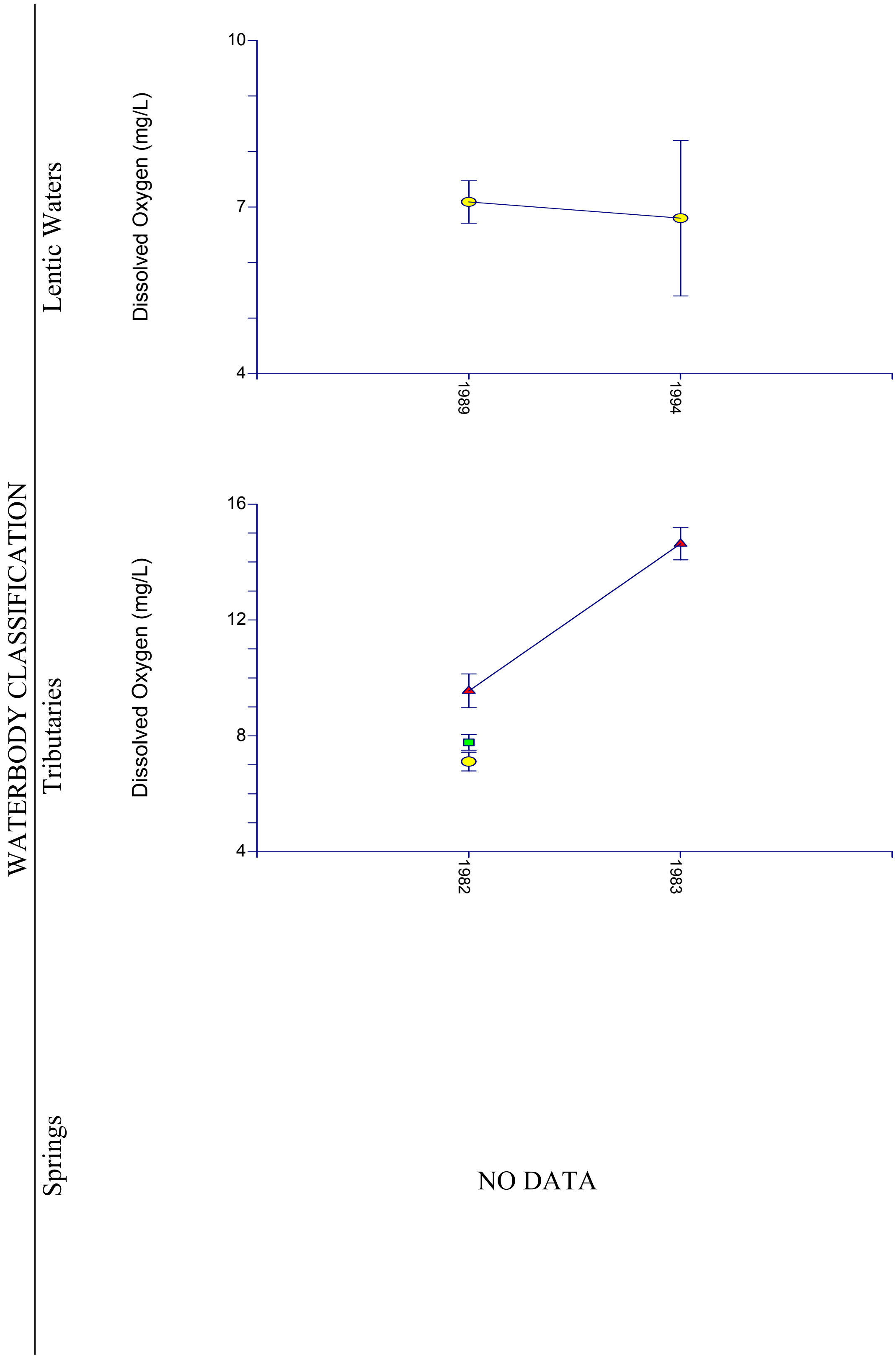


Figure 15. Temporal distribution of dissolved oxygen for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2 and 3 are represented by circle, triangle and square symbols respectively.

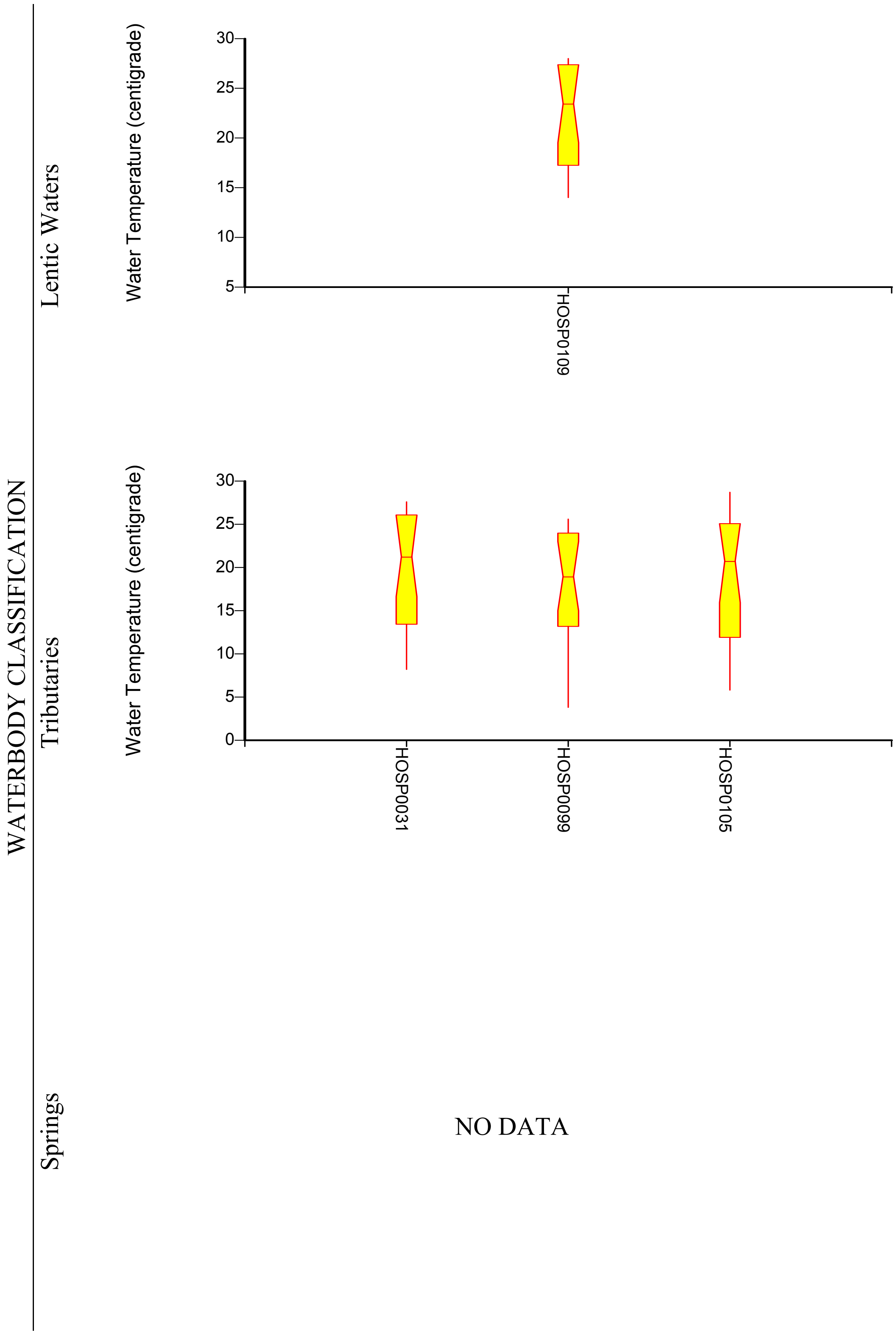


Figure 16. Box plots of water temperature for different waterbody types by station.

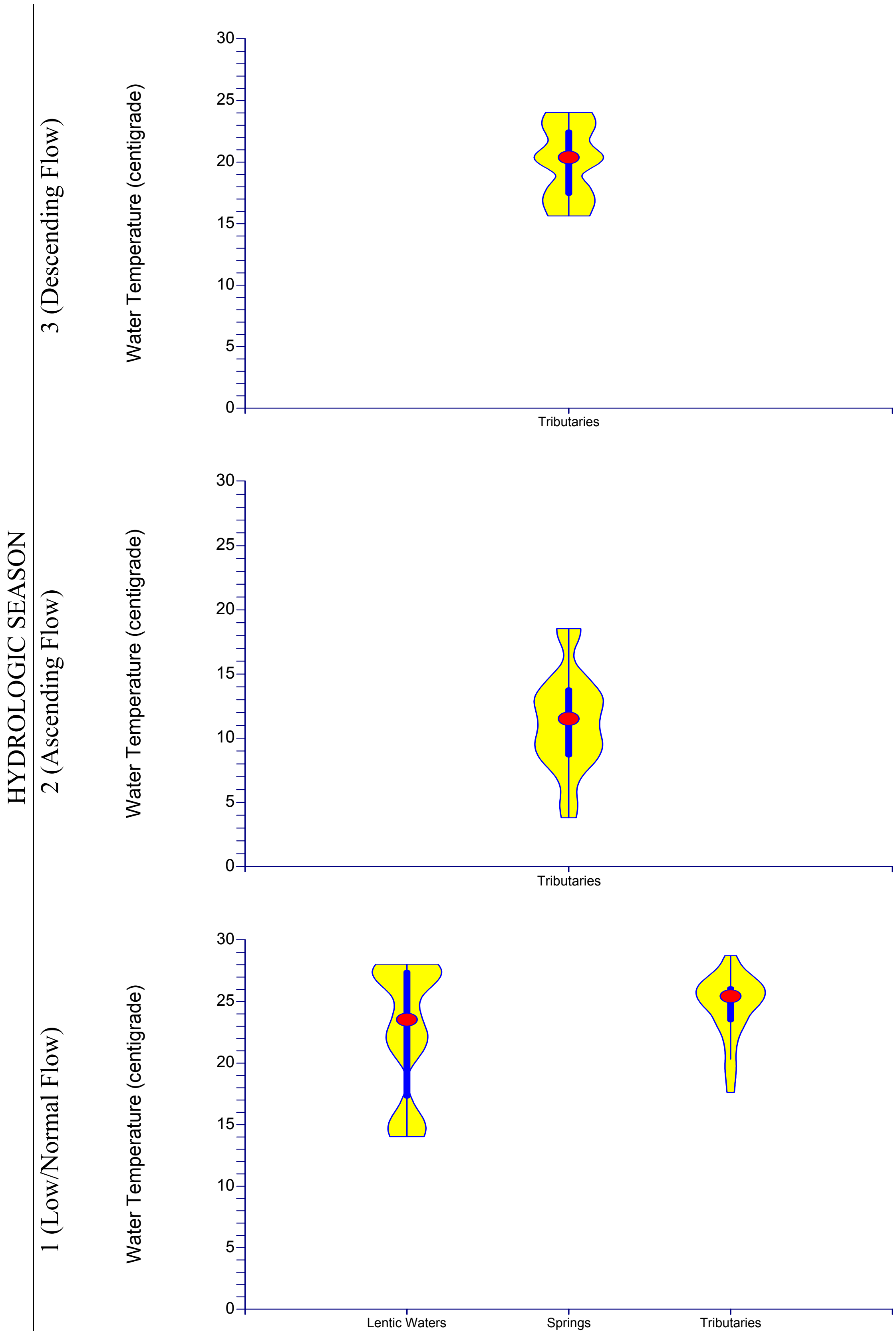


Figure 17. Violin plots of water temperature for different hydrologic seasons by waterbody type.

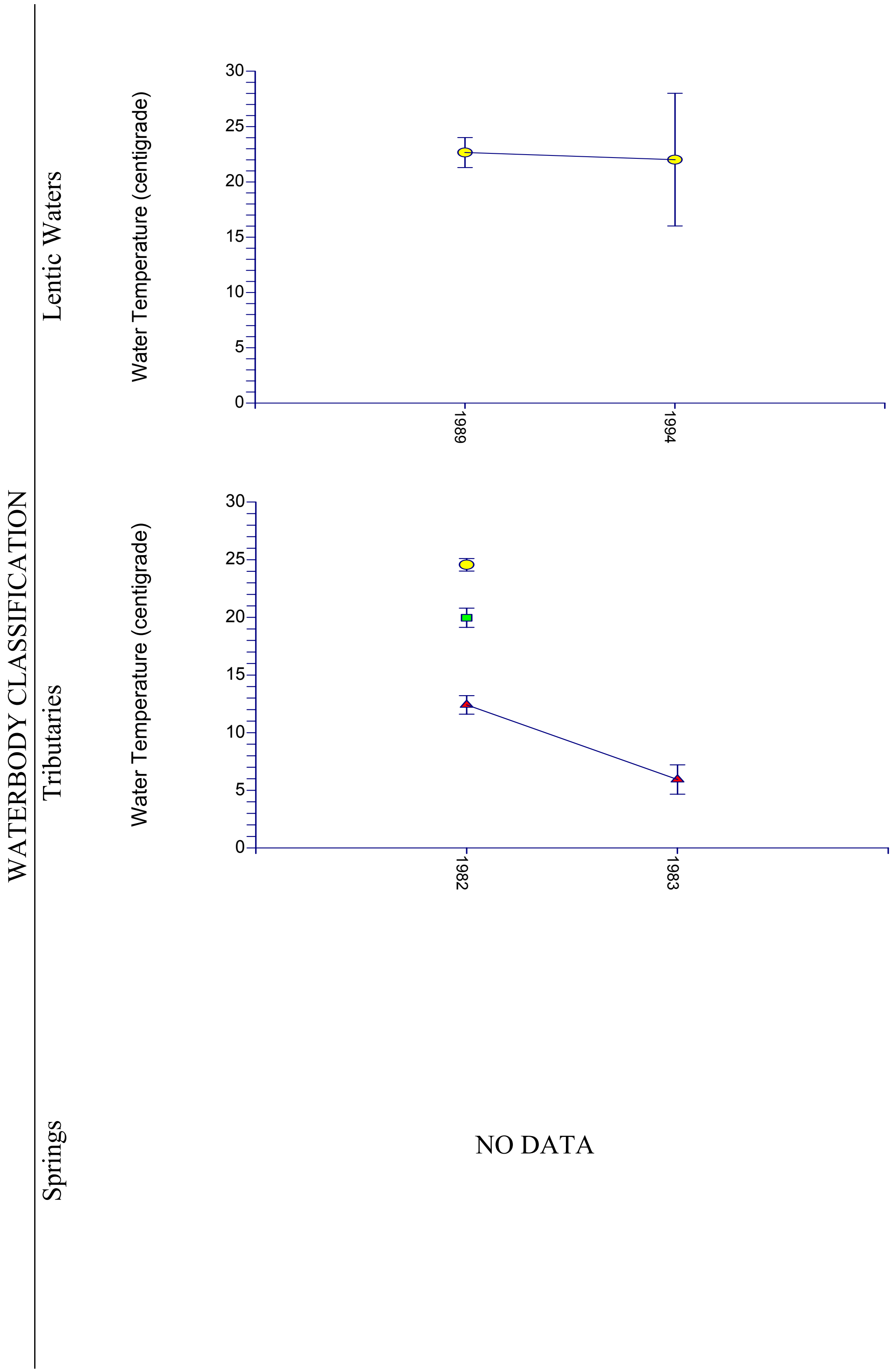


Figure 18. Temporal distribution of water temperature for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2 and 3 are represented by circle, triangle and square symbols respectively.

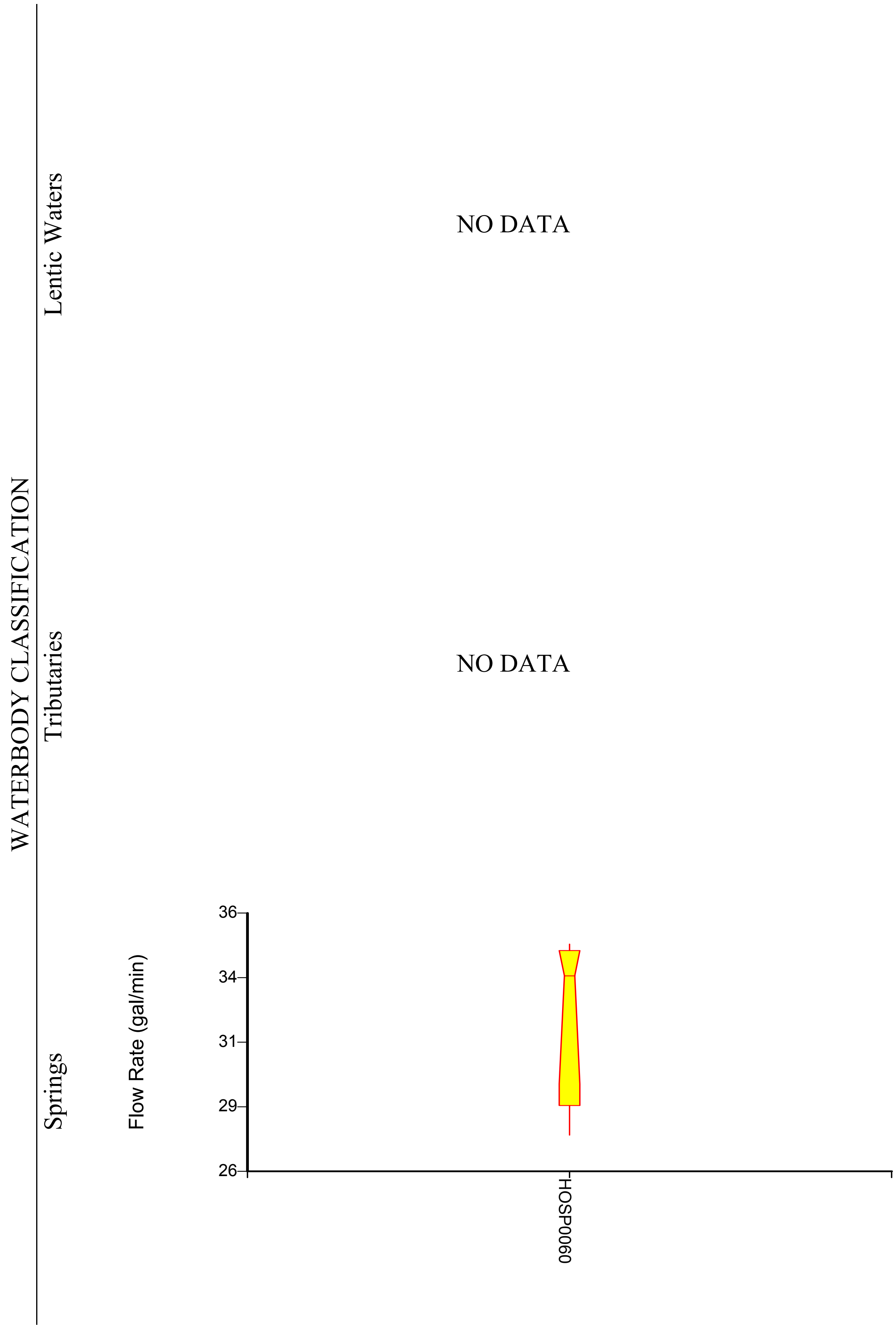


Figure 19. Box plots of flow rate for different waterbody types by station.

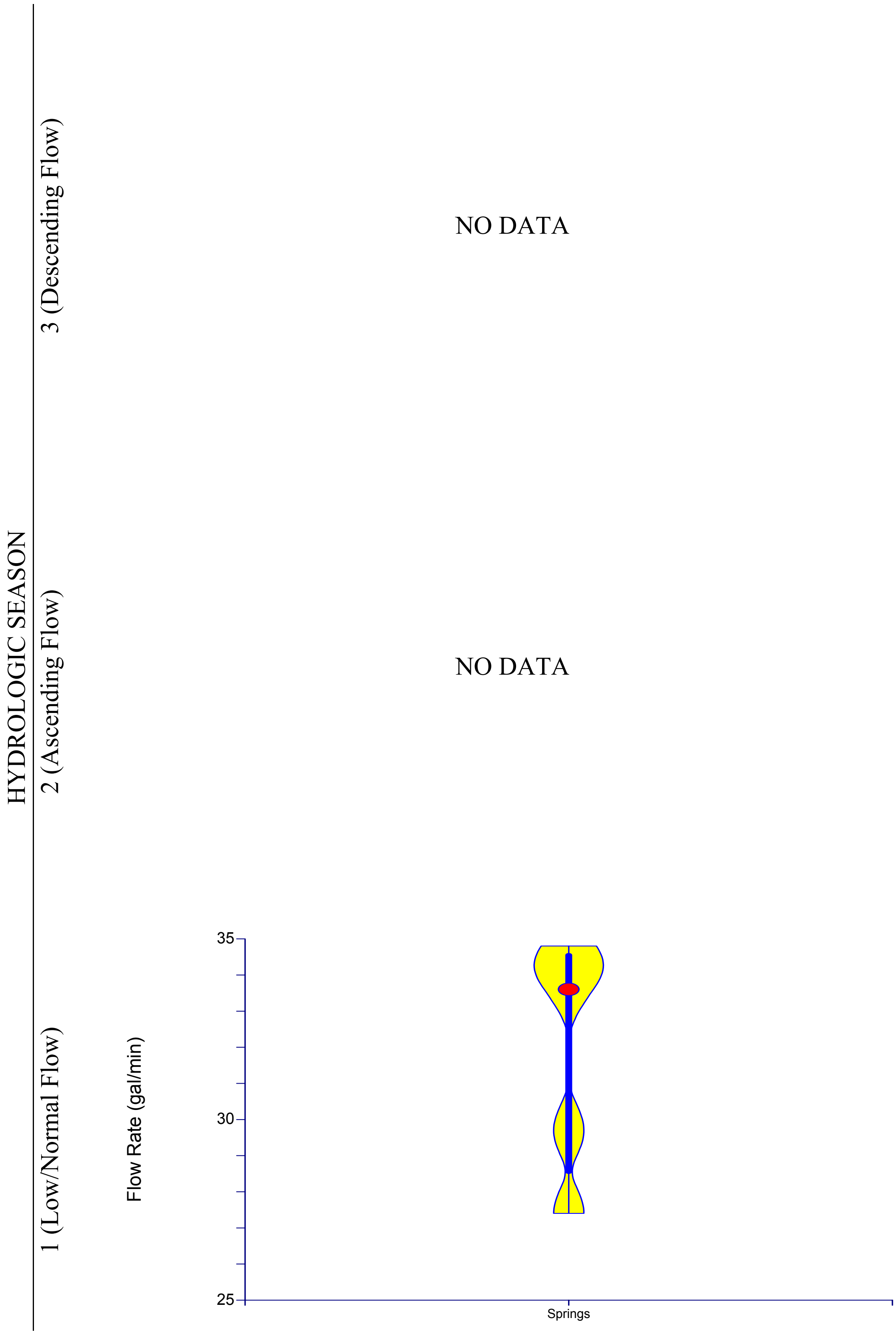


Figure 20. Violin plots of flow rate for different hydrologic seasons by waterbody type.

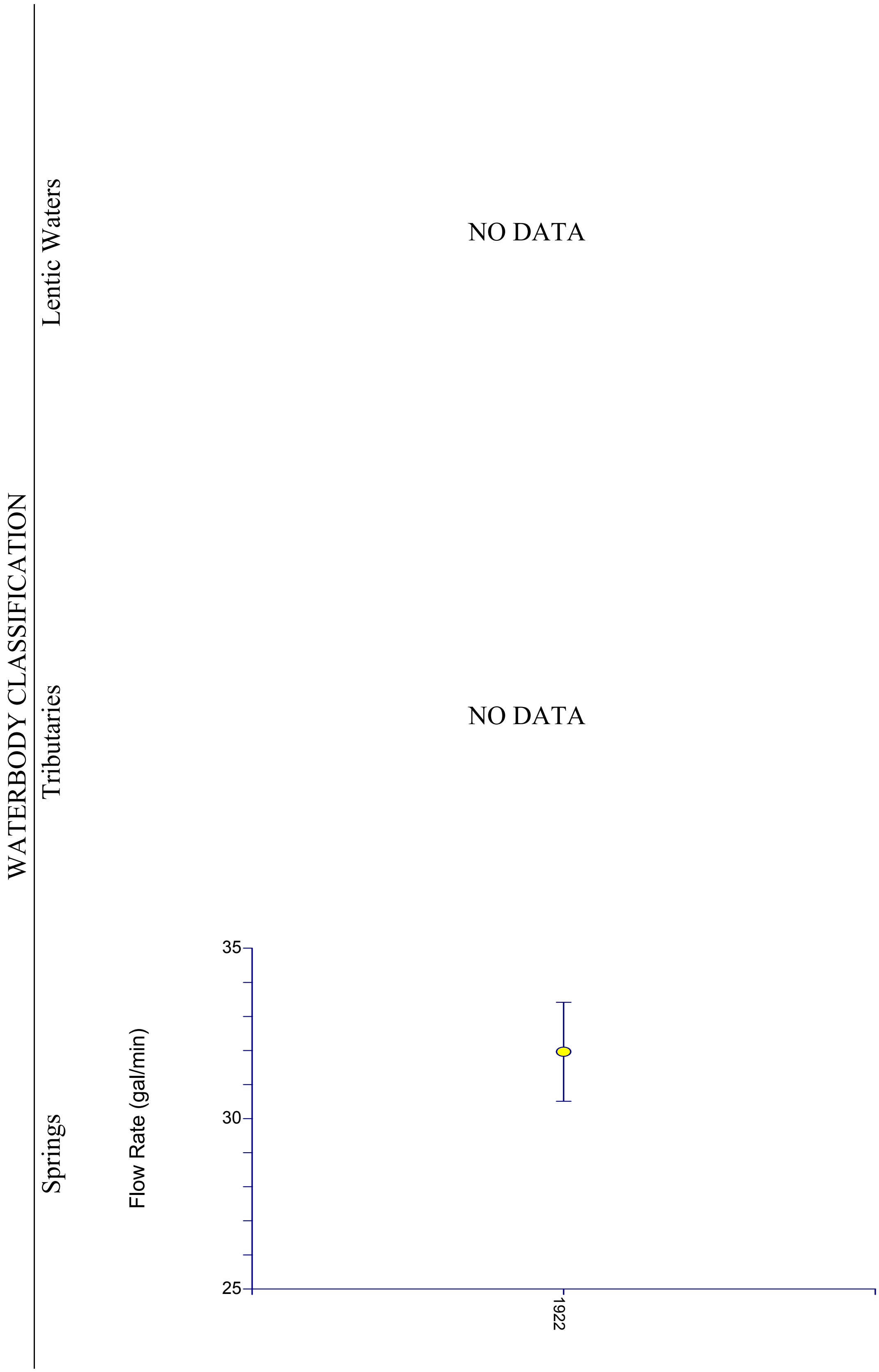


Figure 21. Temporal distribution of flow rate for different waterbody types by hydrologic season. Hydrologic seasons 1, 2 and 3 are represented by circle, triangle and square symbols respectively.

Priority Concerns Figures

Please see the “Statistical Analysis and Methodology” and relevant “Water Quality Concerns Analysis” sections of this report for aid in interpreting these figures.

Clarity and Pathogens

Please see the “Statistical Analysis and Methodology” and relevant “Water Quality Concerns Analysis” sections of this report for aid in interpreting these figures.

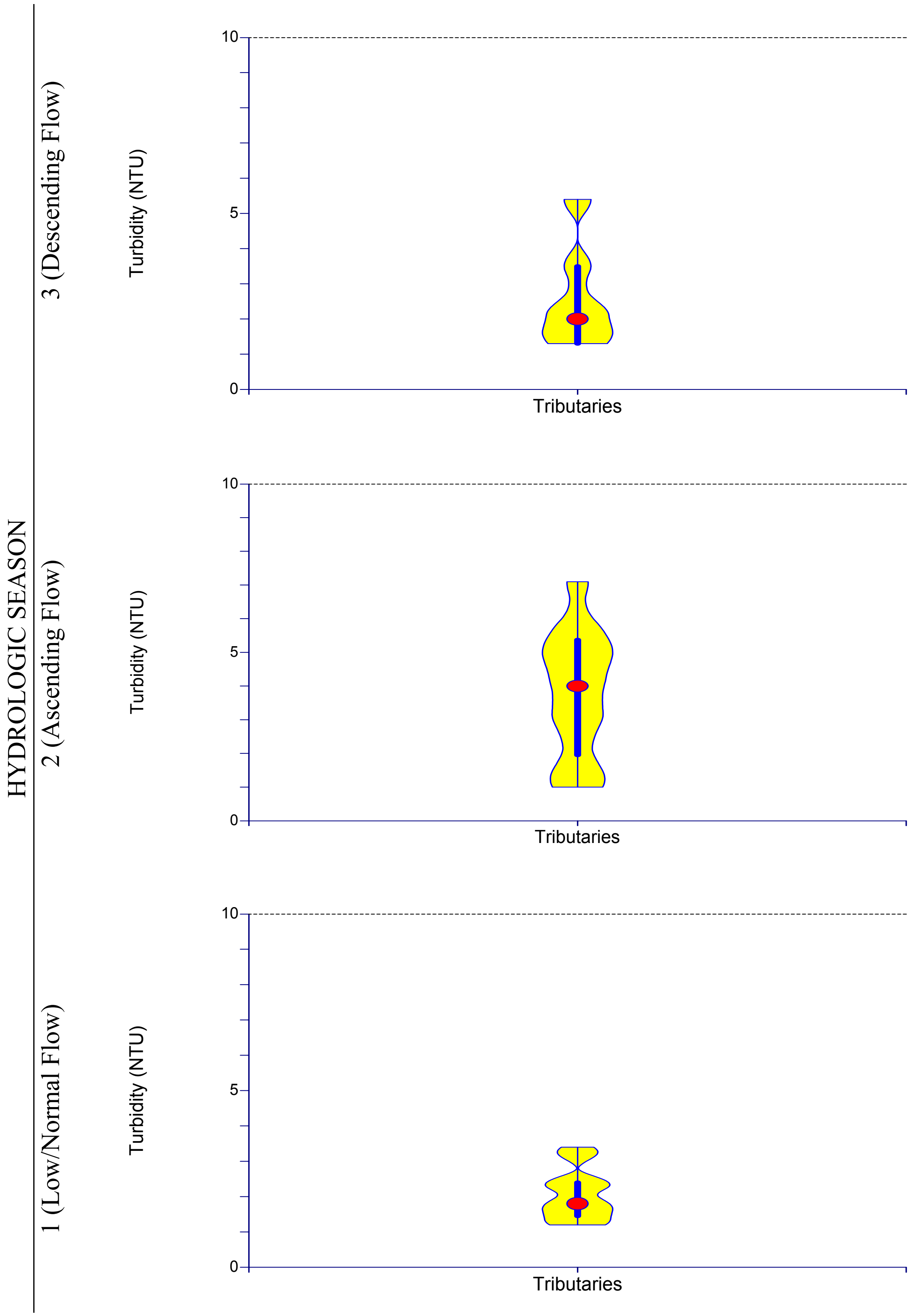


Figure 22. Violin plots of turbidity for different hydrologic seasons by waterbody type.
The dashed line represents both the state of Arkansas criterion value (10 NTU) and a regional benchmark (10.4 NTU) taken from Table 7.

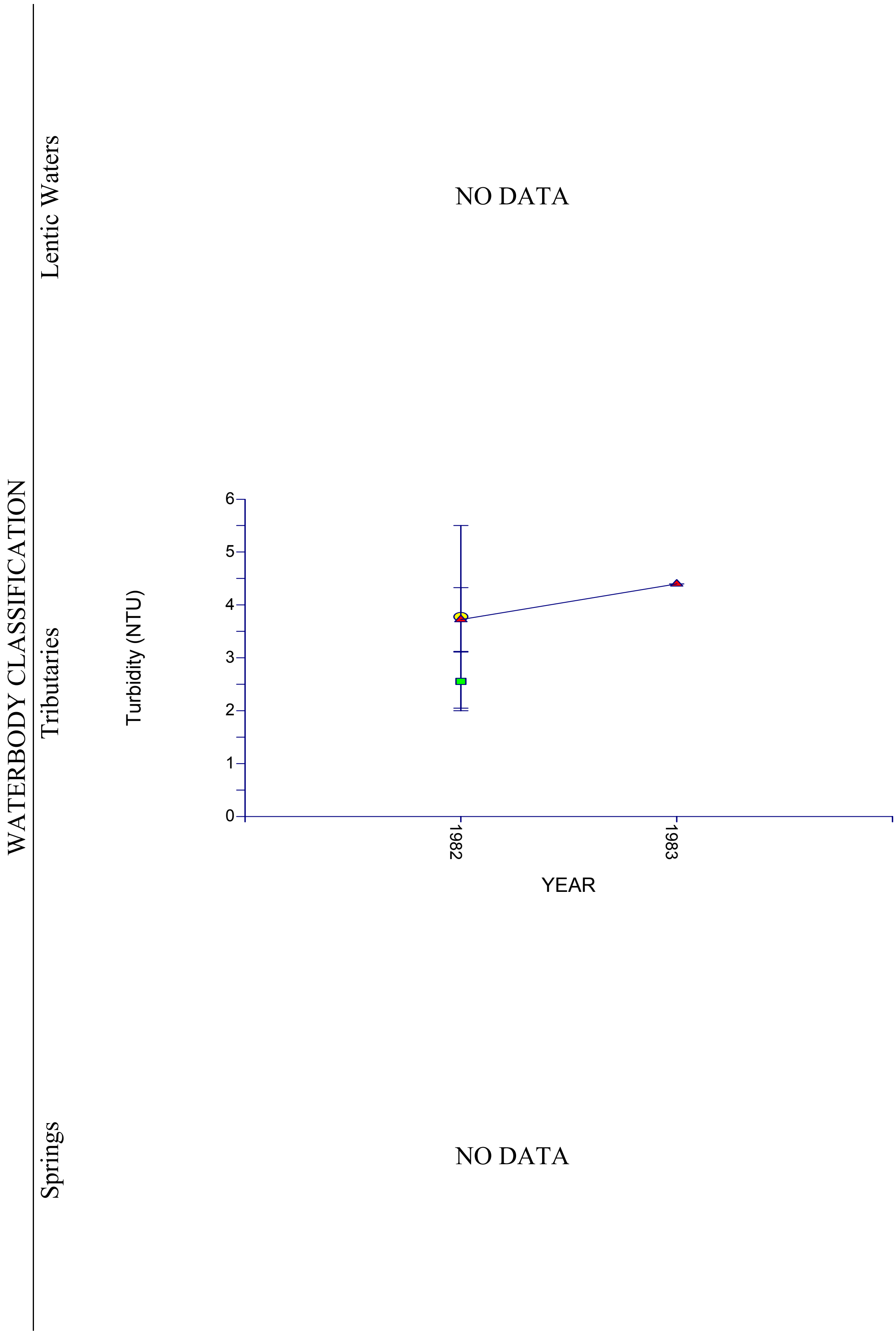


Figure 23. Temporal distribution of turbidity for different waterbody types by hydrologic season. Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

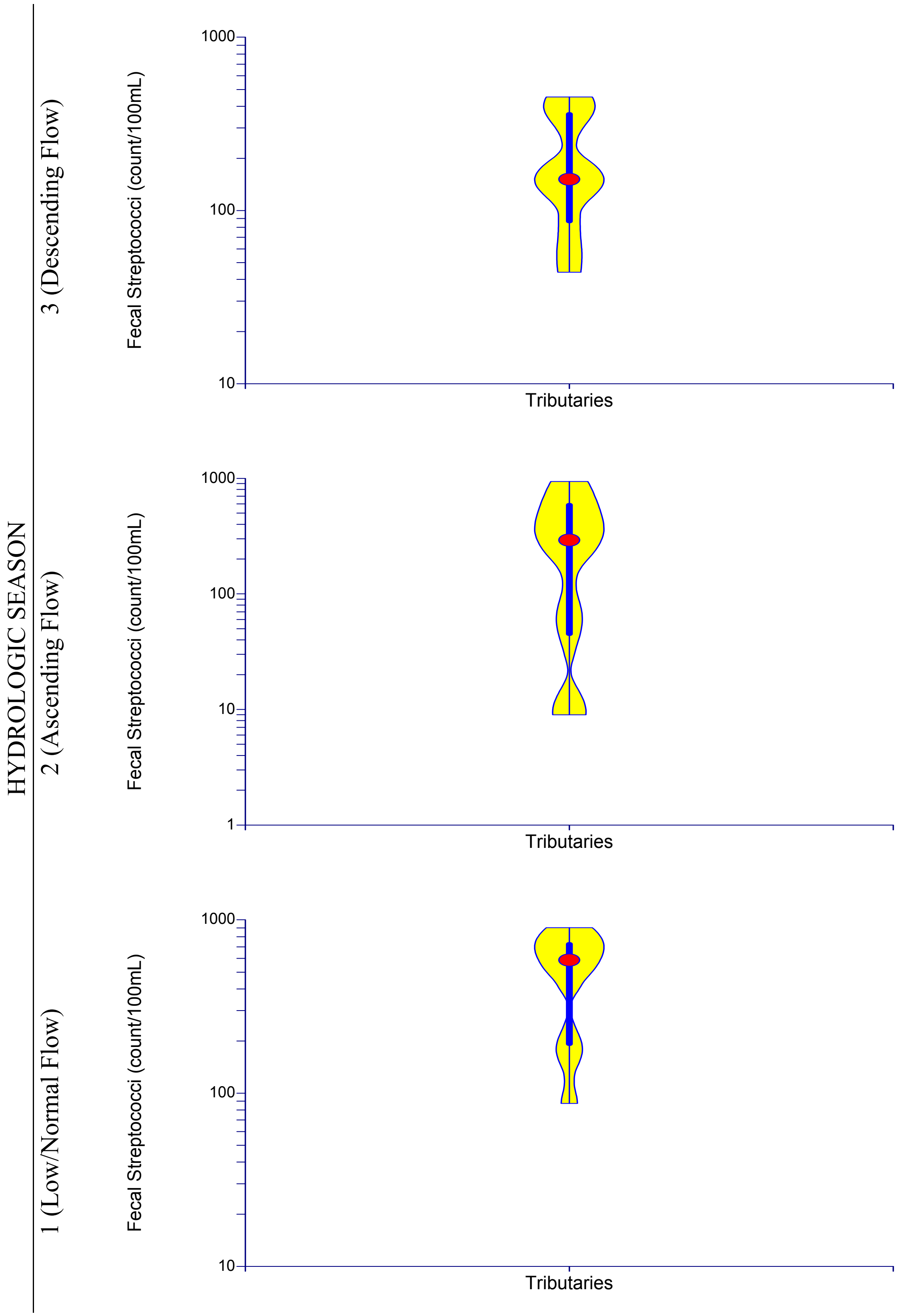


Figure 24. Violin plots of Fecal Streptococci for different hydrologic seasons by waterbody type.

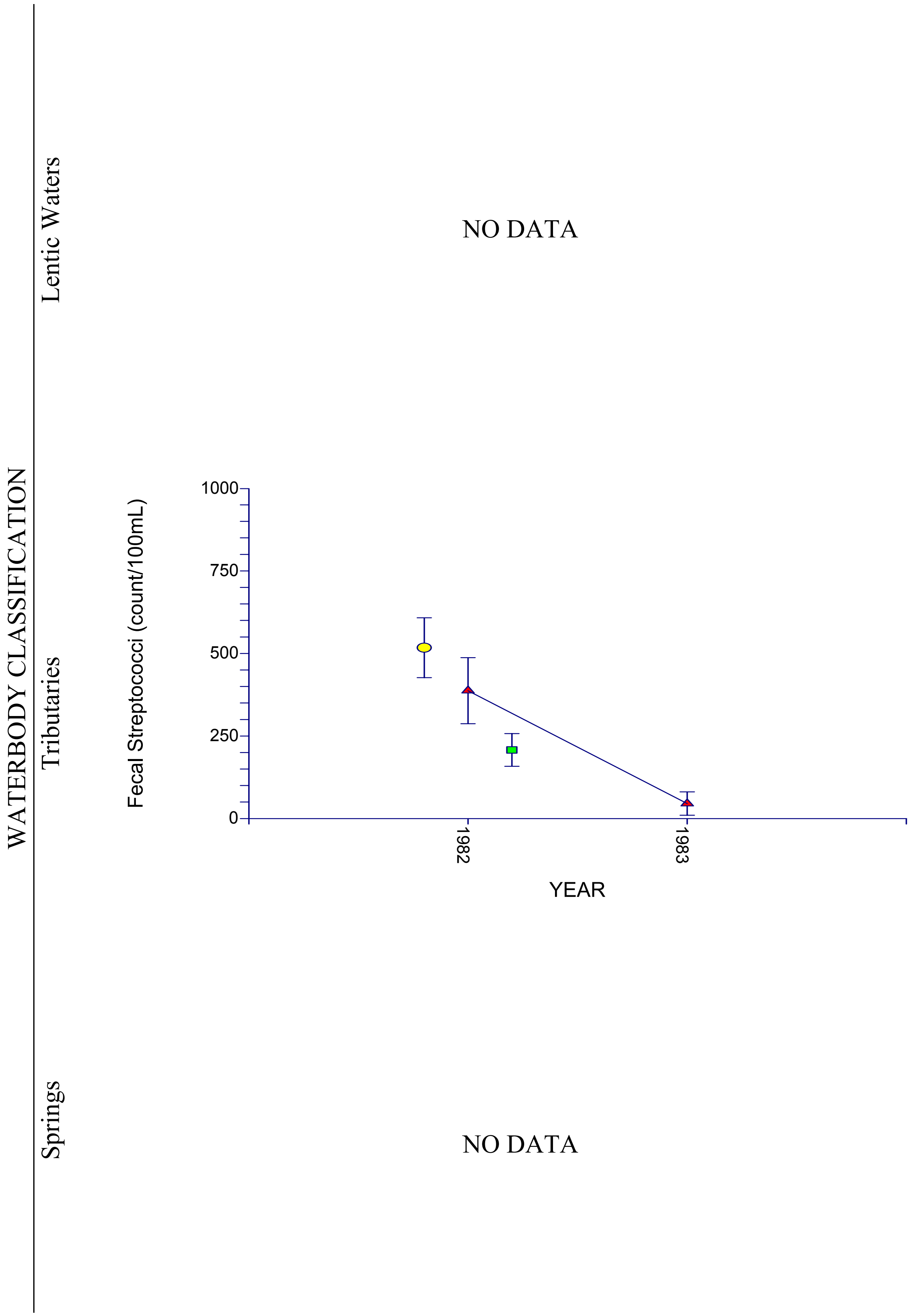


Figure 25. Temporal distribution of fecal streptococci for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

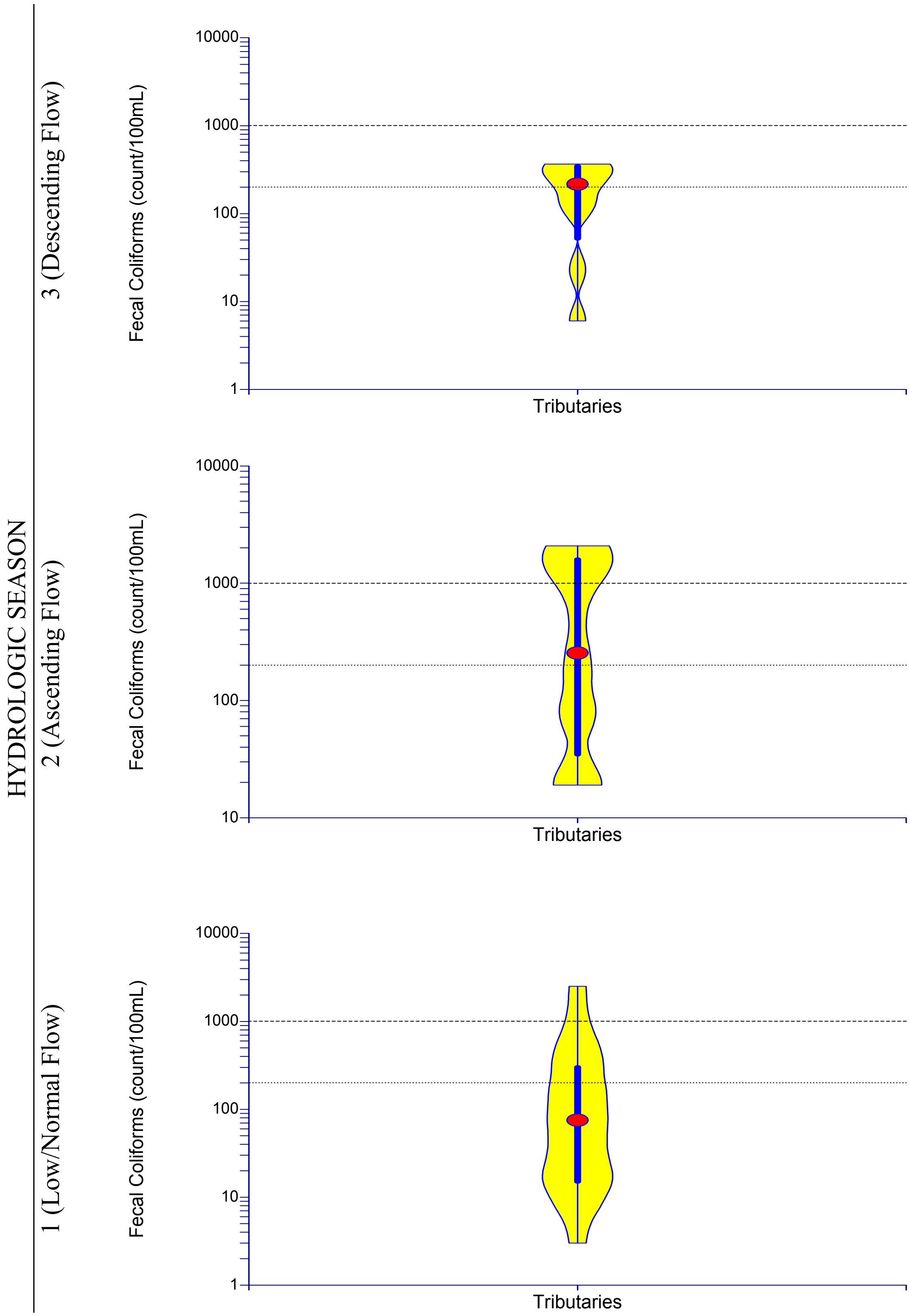


Figure 26. Violin plots of Fecal Coliforms for different hydrologic seasons by waterbody type. The upper and lower lines represent the State of Arkansas criteria for secondary contact (1000/100mL) and primary contact (200/100mL), respectively.

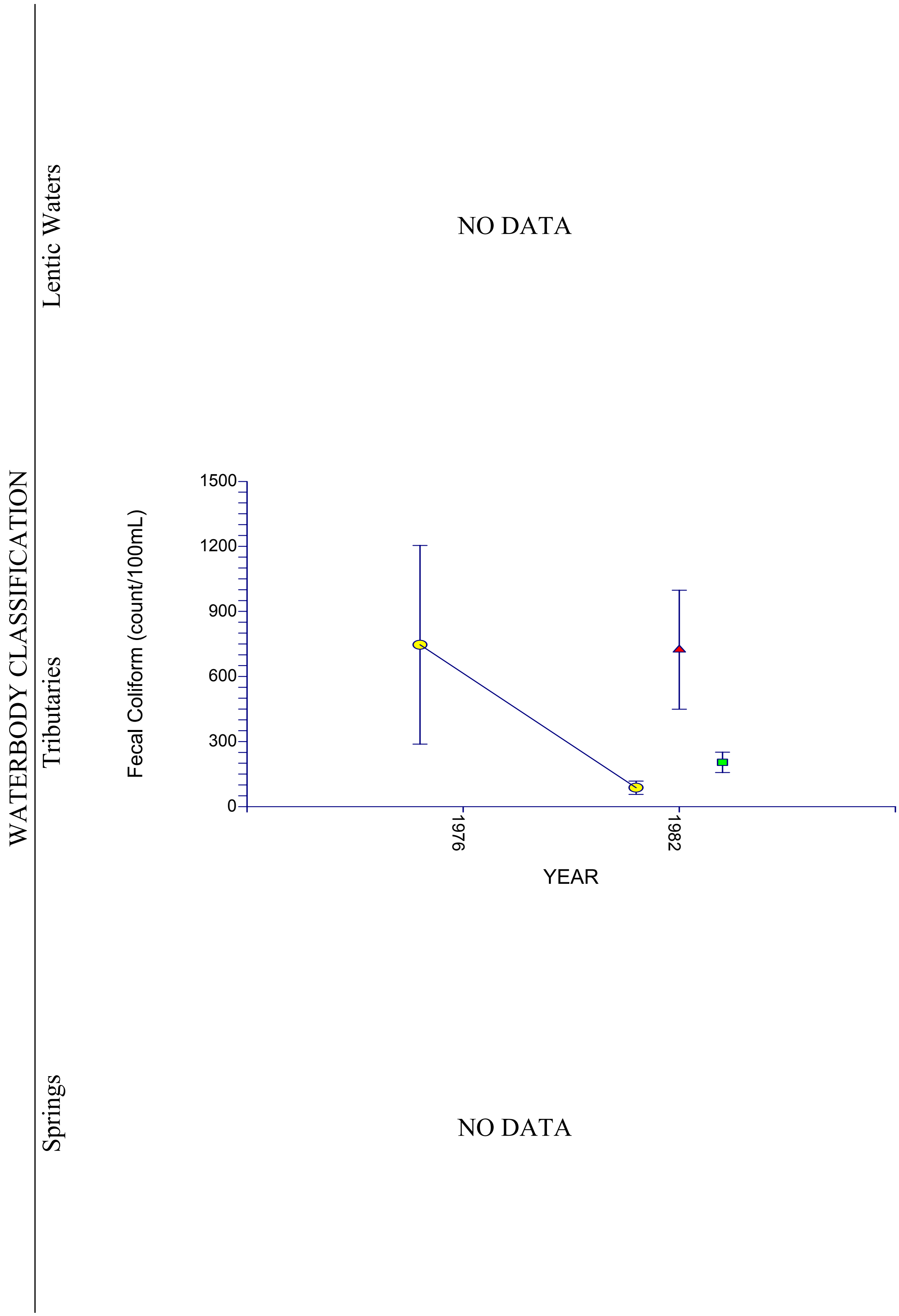


Figure 27. Temporal distribution of fecal coliforms for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

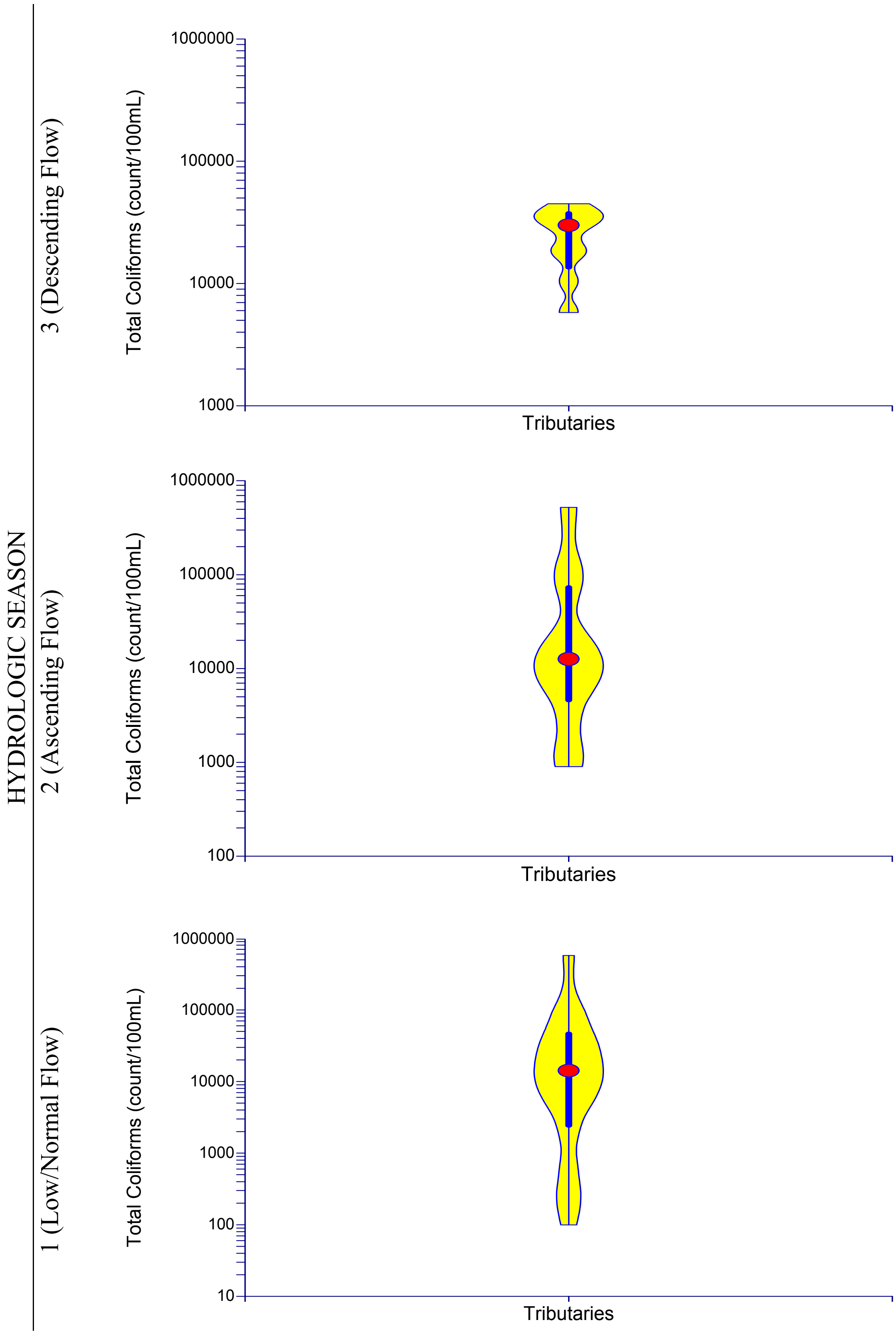


Figure 28. Violin plots of total coliforms for different hydrologic seasons by waterbody type.

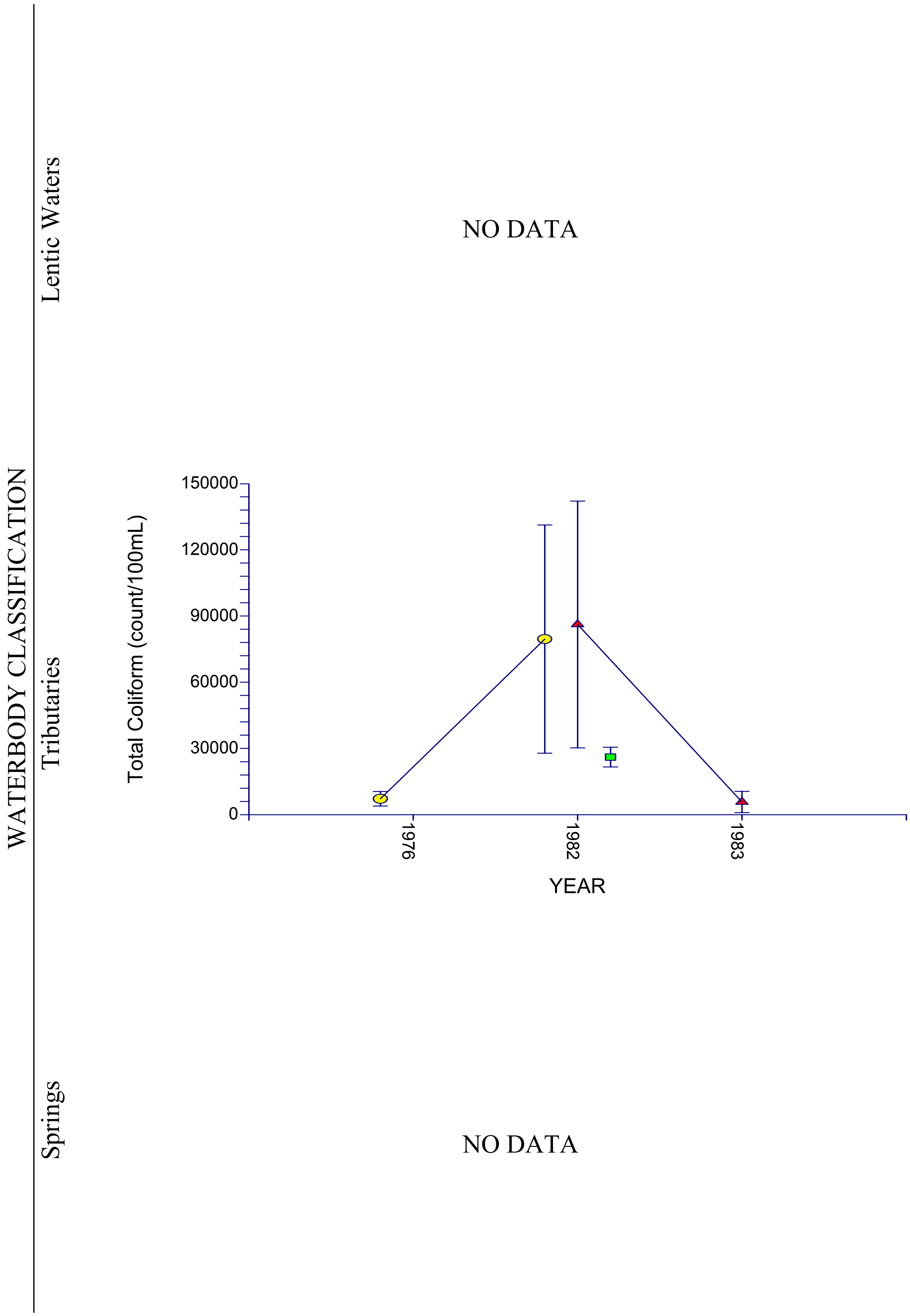


Figure 29. Temporal distribution of total coliforms for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

Nutrient Loading

Please see the “Statistical Analysis and Methodology” and relevant “Water Quality Concerns Analysis” sections of this report for aid in interpreting these figures.

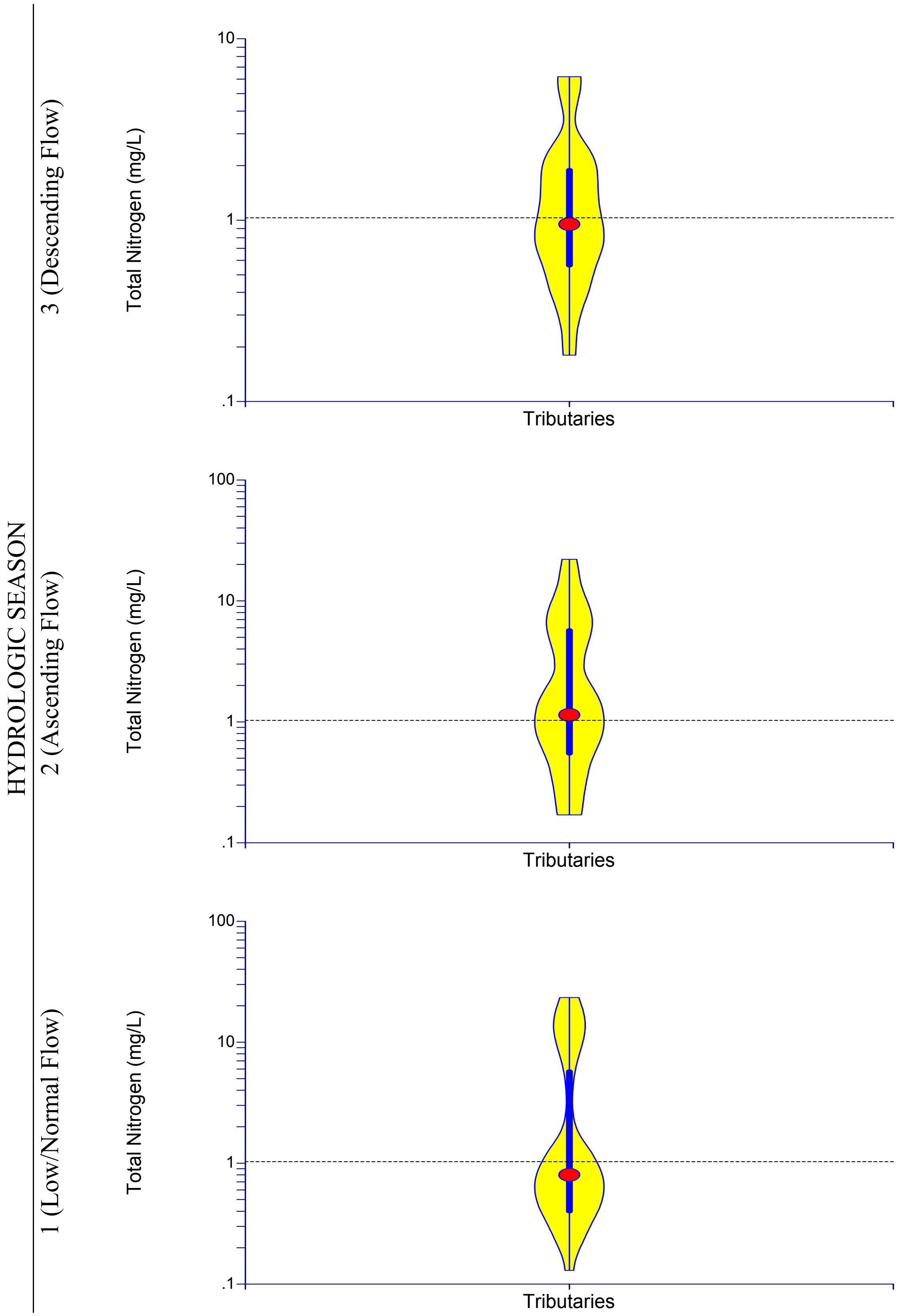


Figure 30. Violin plots of total nitrogen for different hydrologic seasons by waterbody type. The dashed line represents a regional benchmark (1.03 mg/L) taken from Table 7.

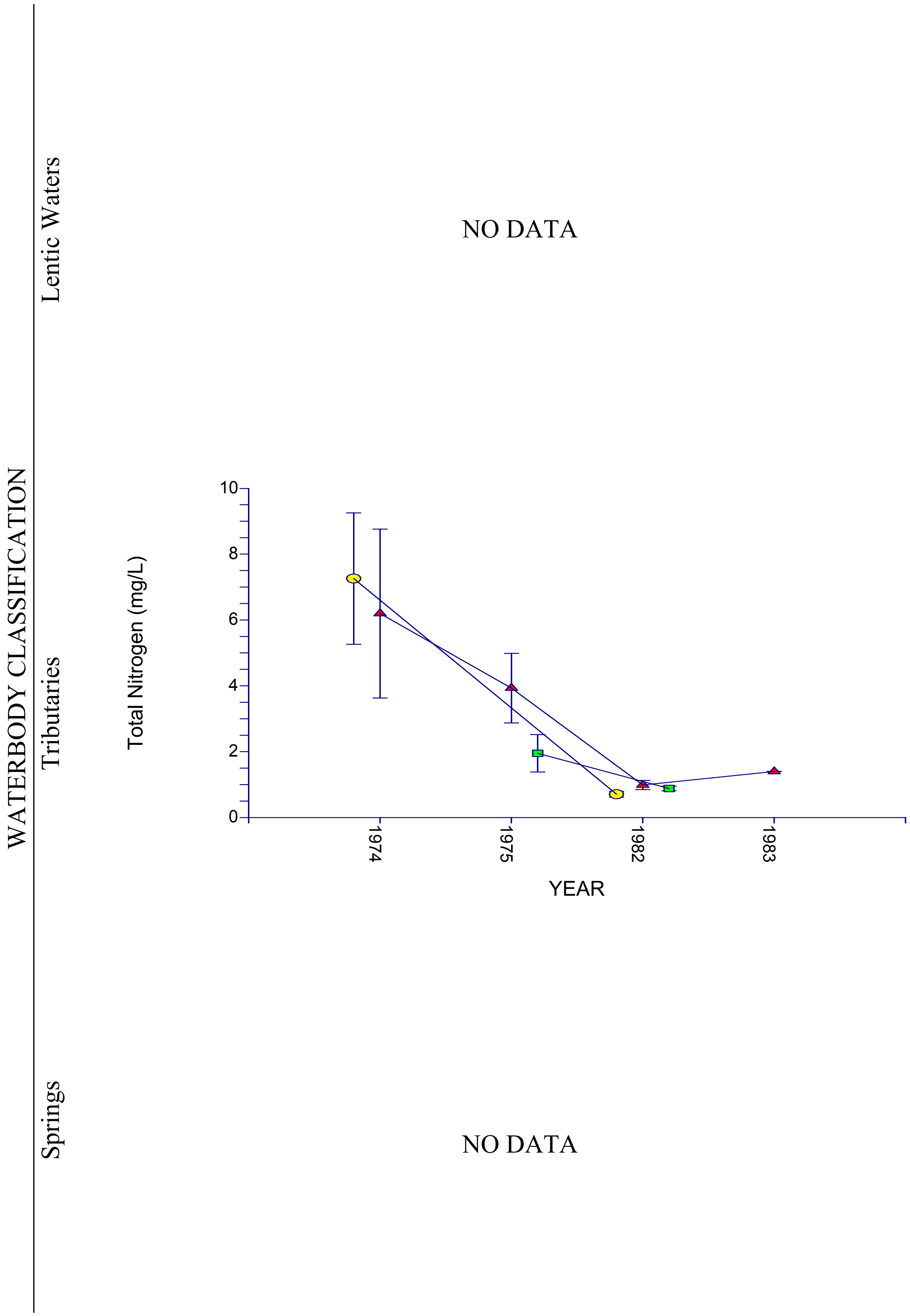


Figure 31. Temporal distribution of total nitrogen for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

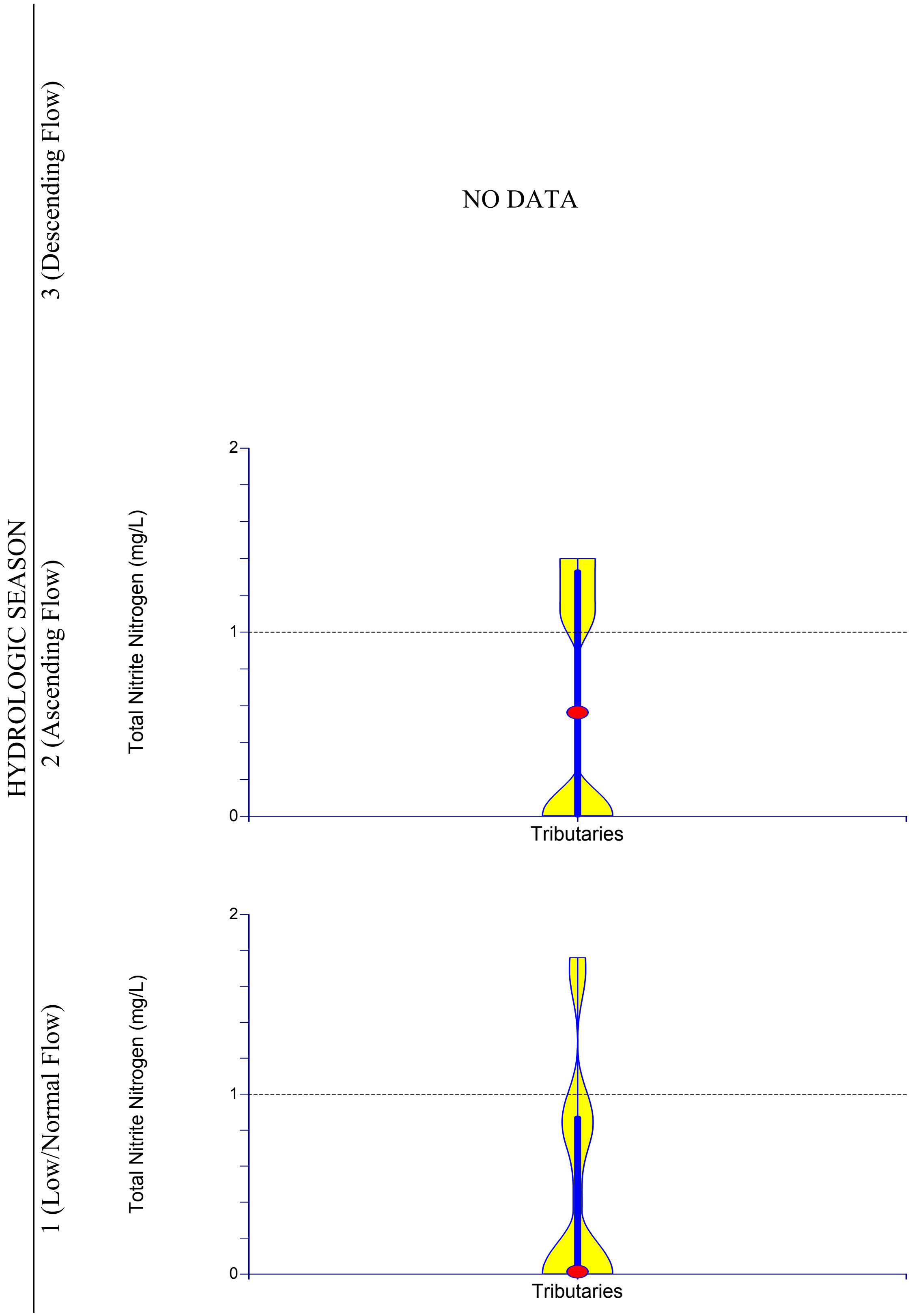


Figure 32. Violin plots of total nitrite nitrogen for different hydrologic seasons by waterbody type. The dashed line represents the federal drinking water maximum contaminant load for this compound (1 mg/L).

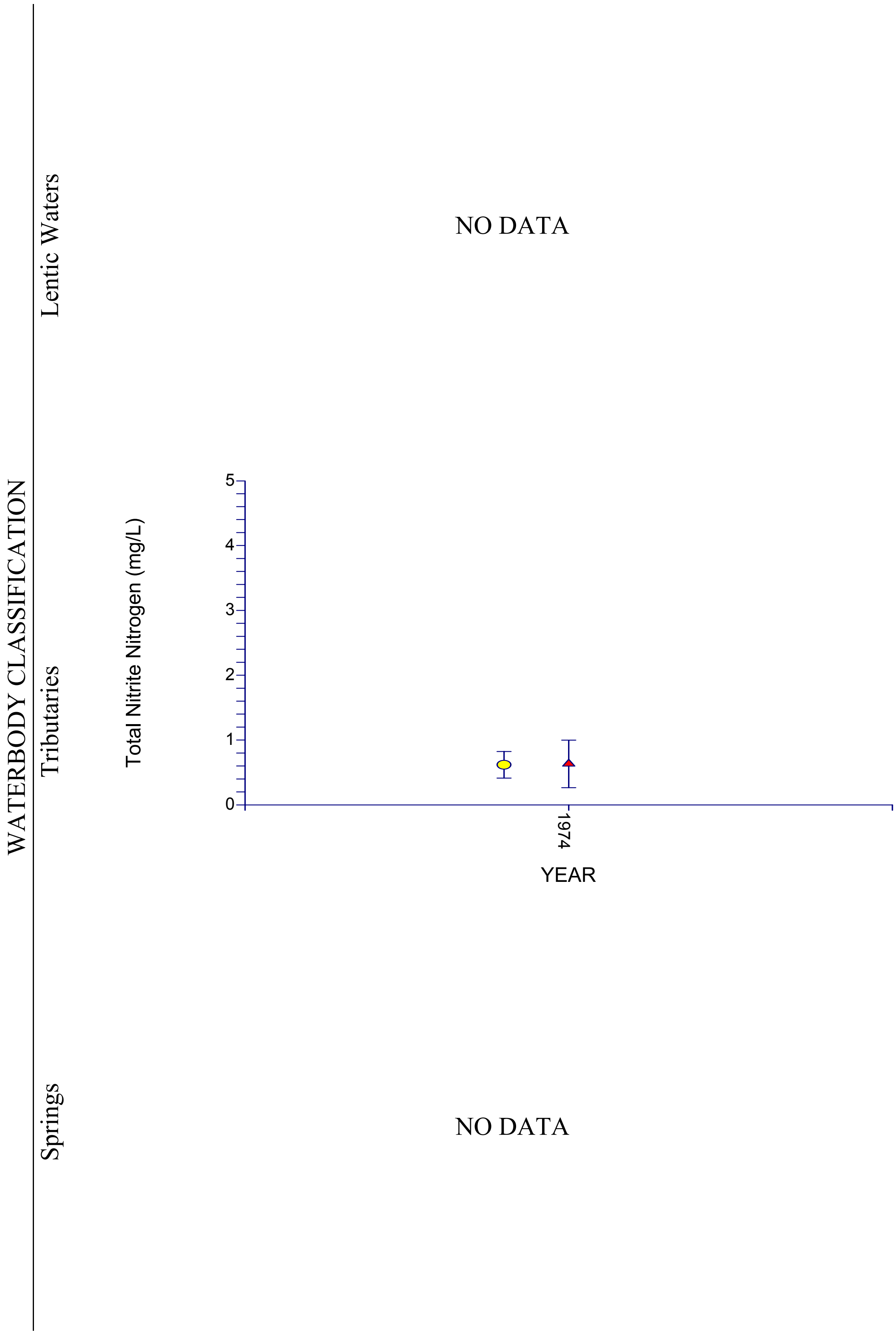


Figure 33. Temporal distribution of total nitrite for different waterbody types by hydrologic season. Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

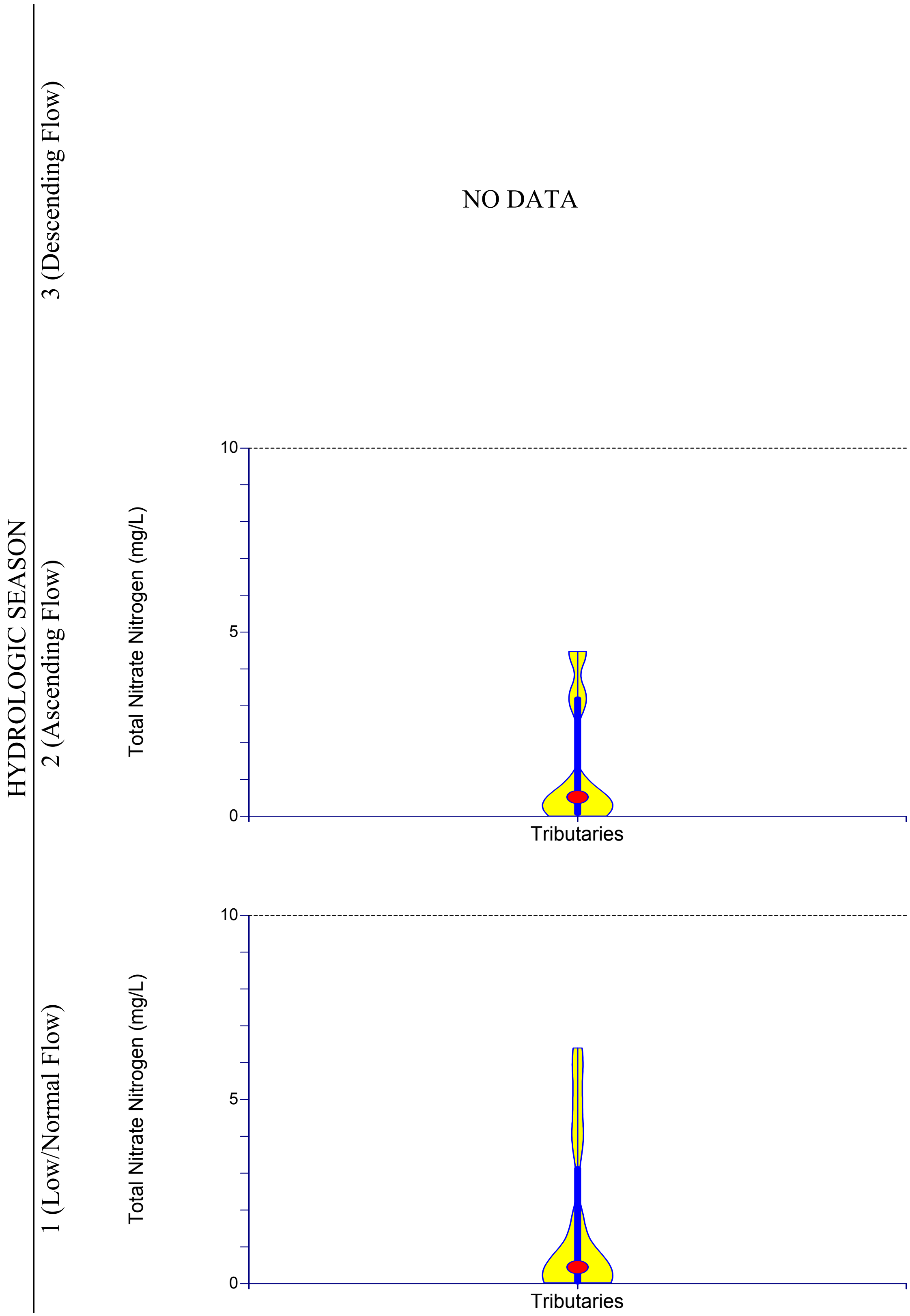


Figure 34. Violin plots of total nitrate nitrogen for different hydrologic seasons by waterbody type. The dashed line represents the federal drinking water maximum contaminant load for this compound (10 mg/L).

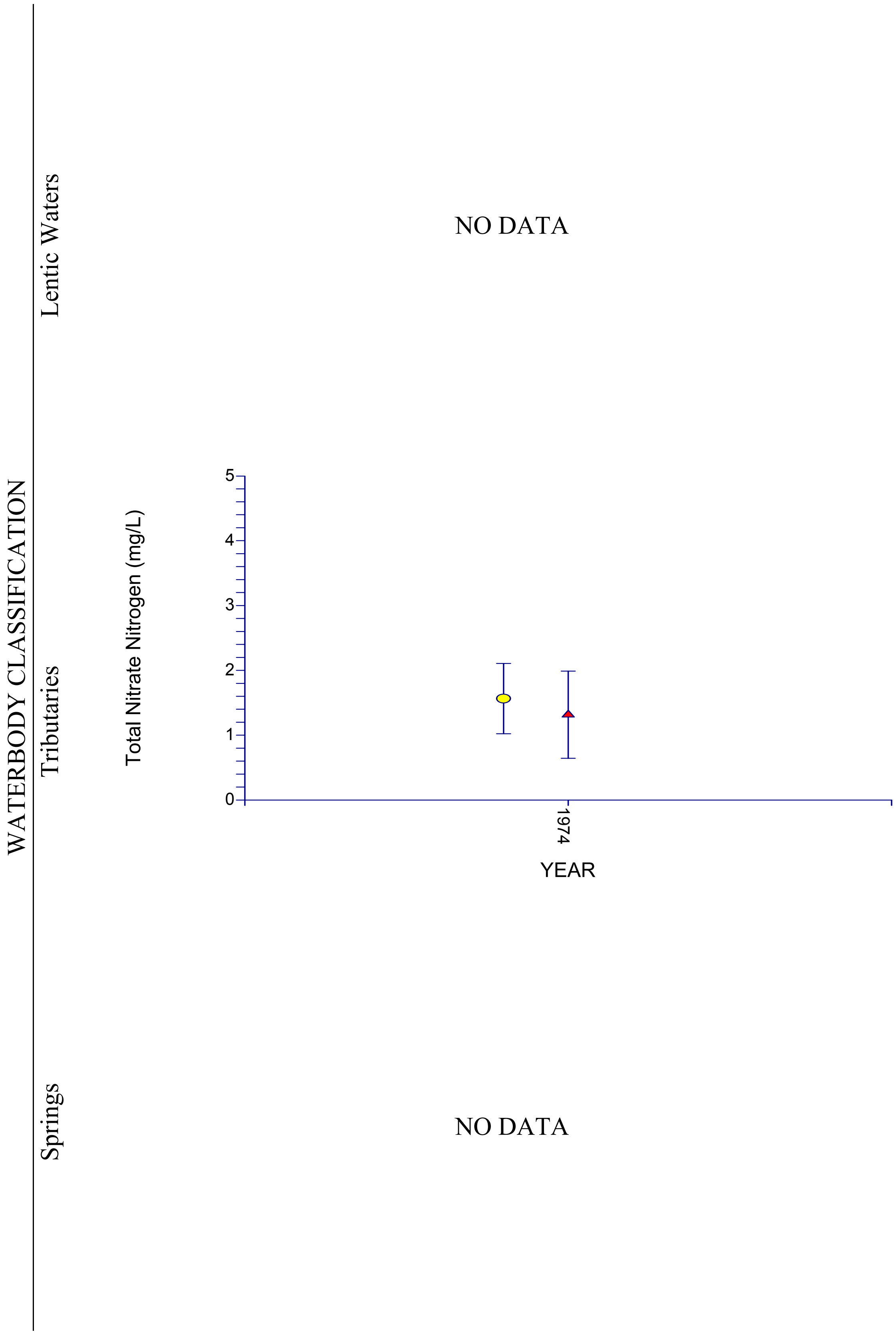


Figure 35. Temporal distribution of total nitrate for different waterbody types by hydrologic season. Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

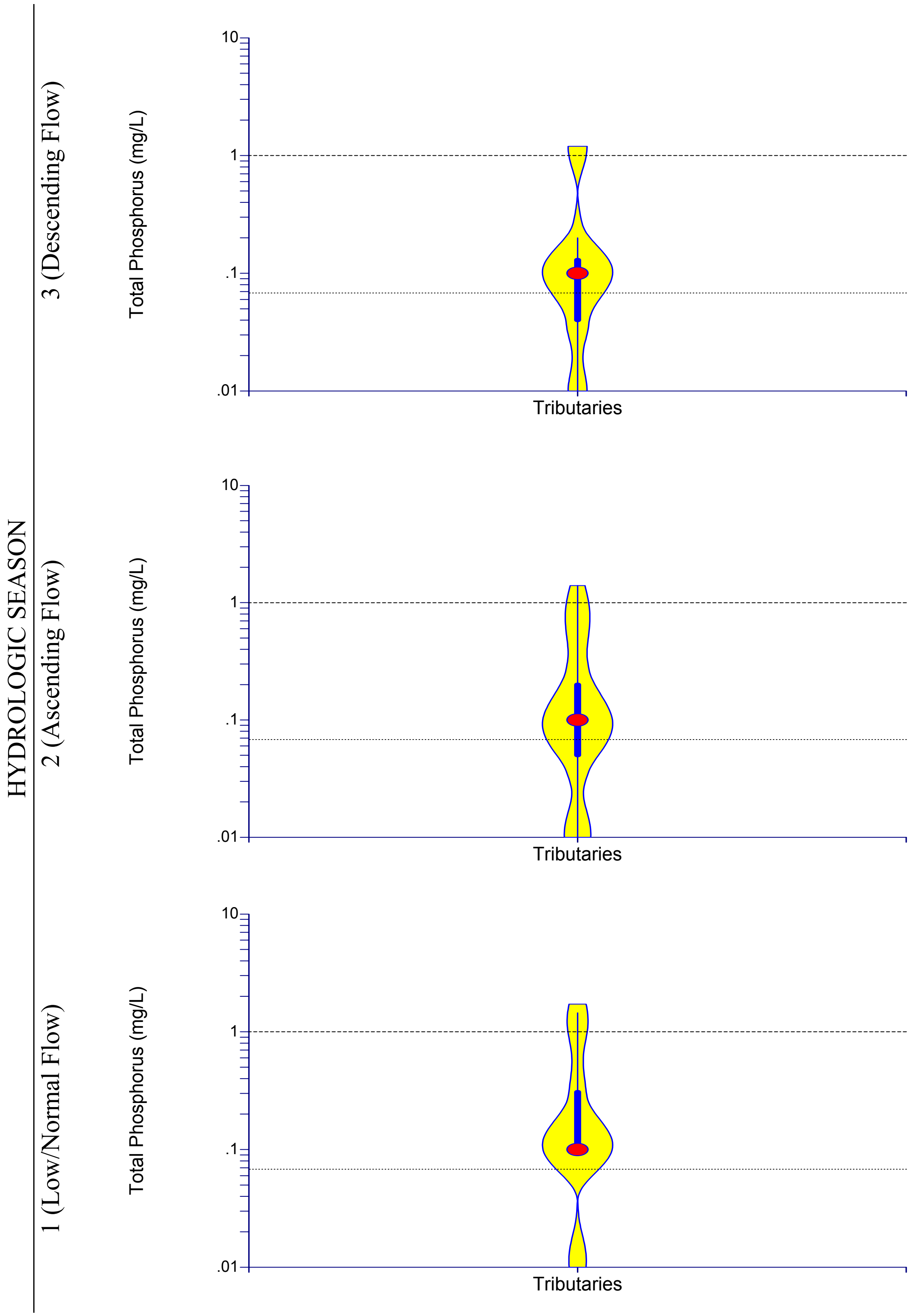


Figure 36. Violin plots of total phosphorus for different hydrologic seasons by waterbody type. The upper line represents the state of Arkansas criterion (0.1 mg/L) while the lower line represents a regional benchmark (0.068 mg/L) taken from Table 7.

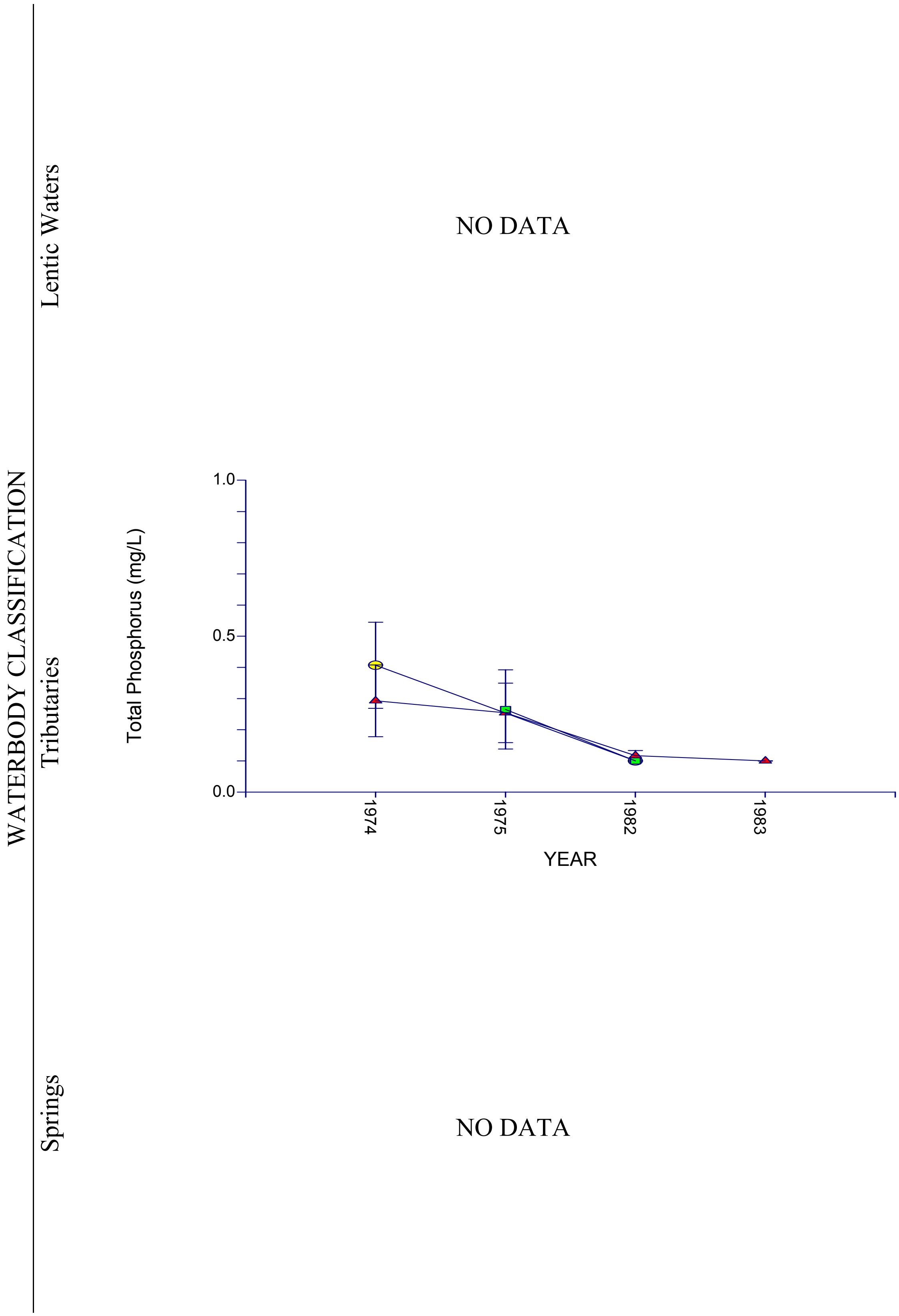


Figure 37. Temporal distribution of total phosphorus for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

Metals

Please see the "Statistical Analysis and Methodology" and relevant "Water Quality Concerns Analysis" sections of this report for aid in interpreting these figures.

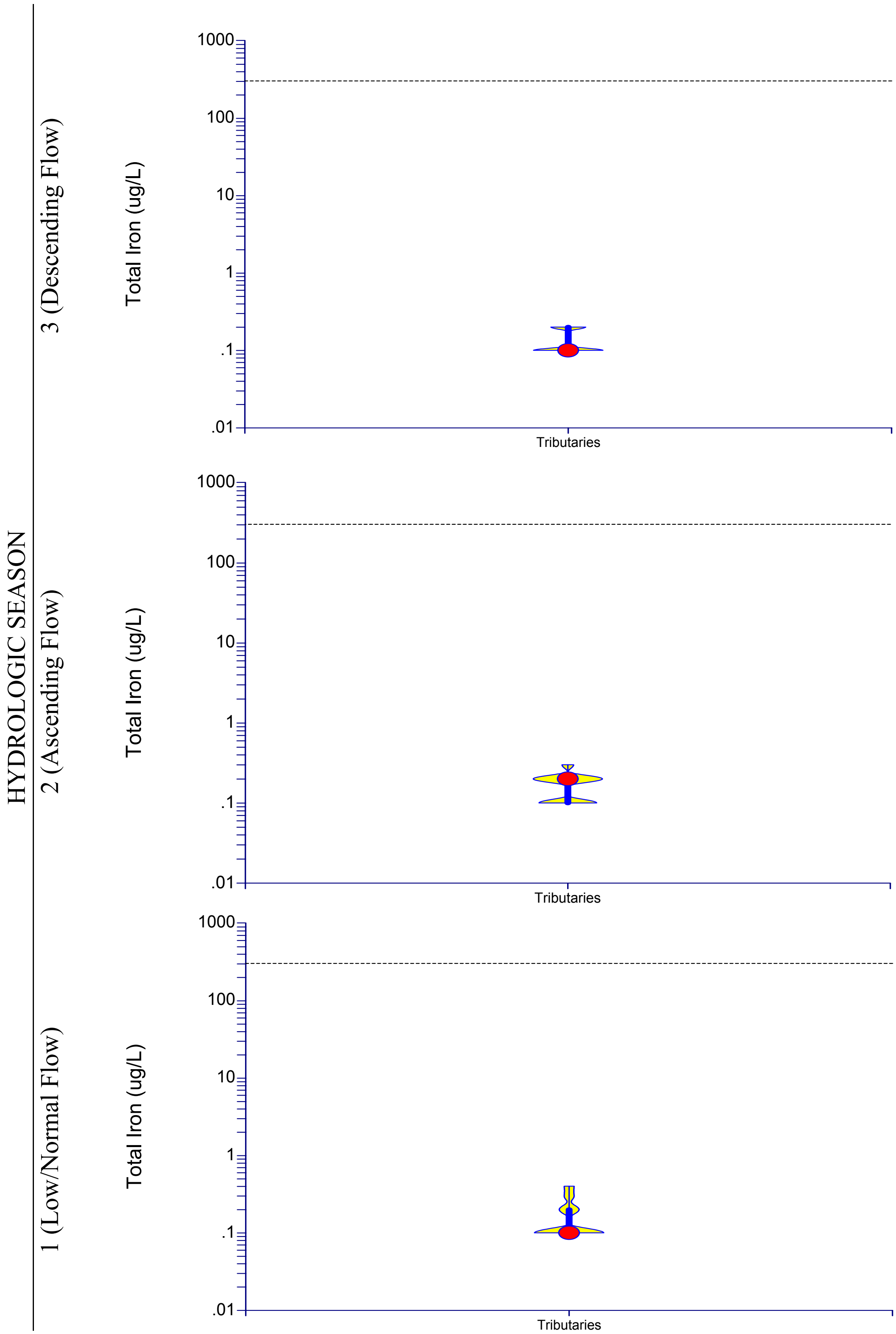


Figure 38. Violin plots of total iron for different hydrologic seasons by waterbody type. The dashed line represents the USEPA aquatic life criteria for all waterbodies.

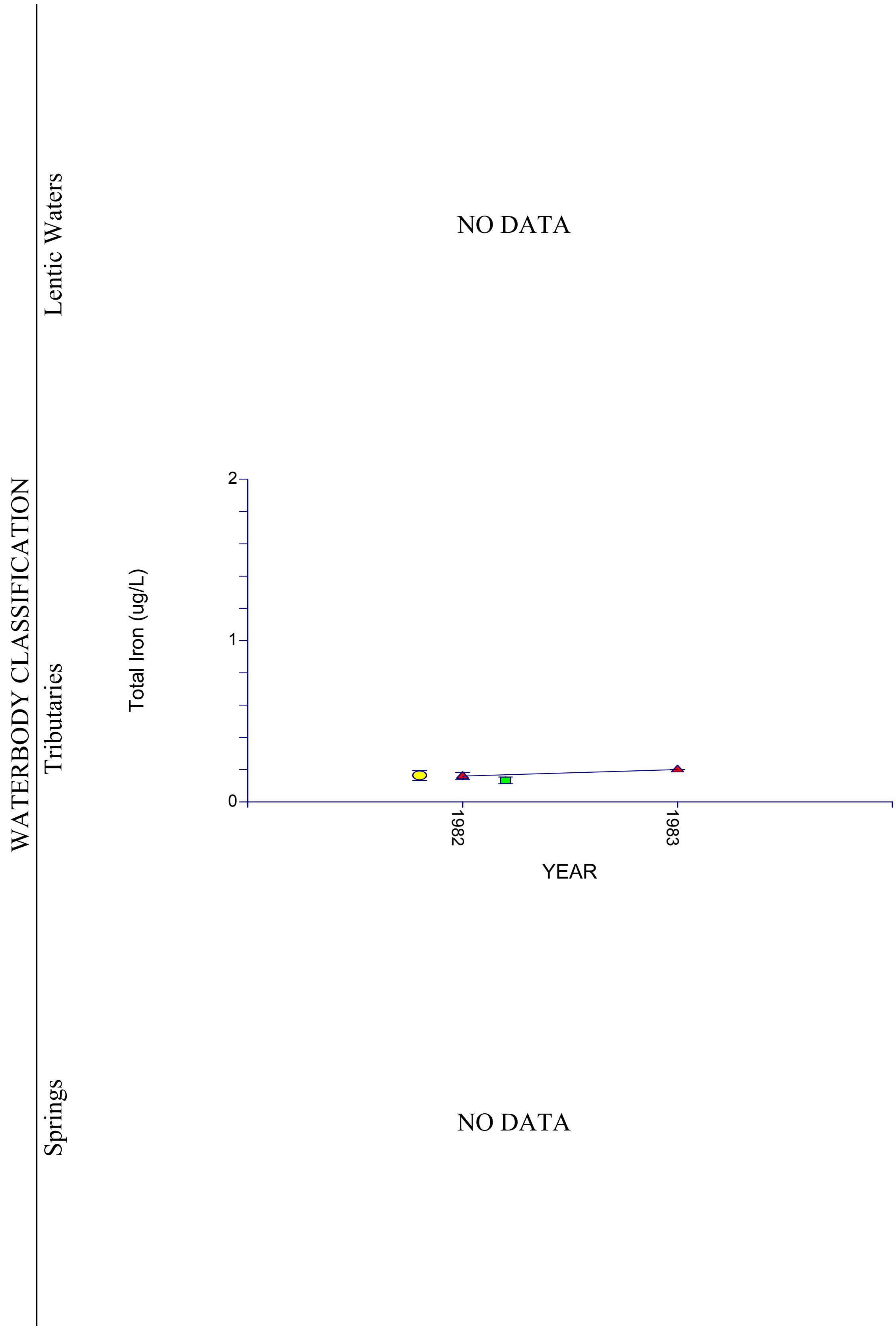


Figure 39. Temporal distribution of total iron for different waterbody types by hydrologic season. Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

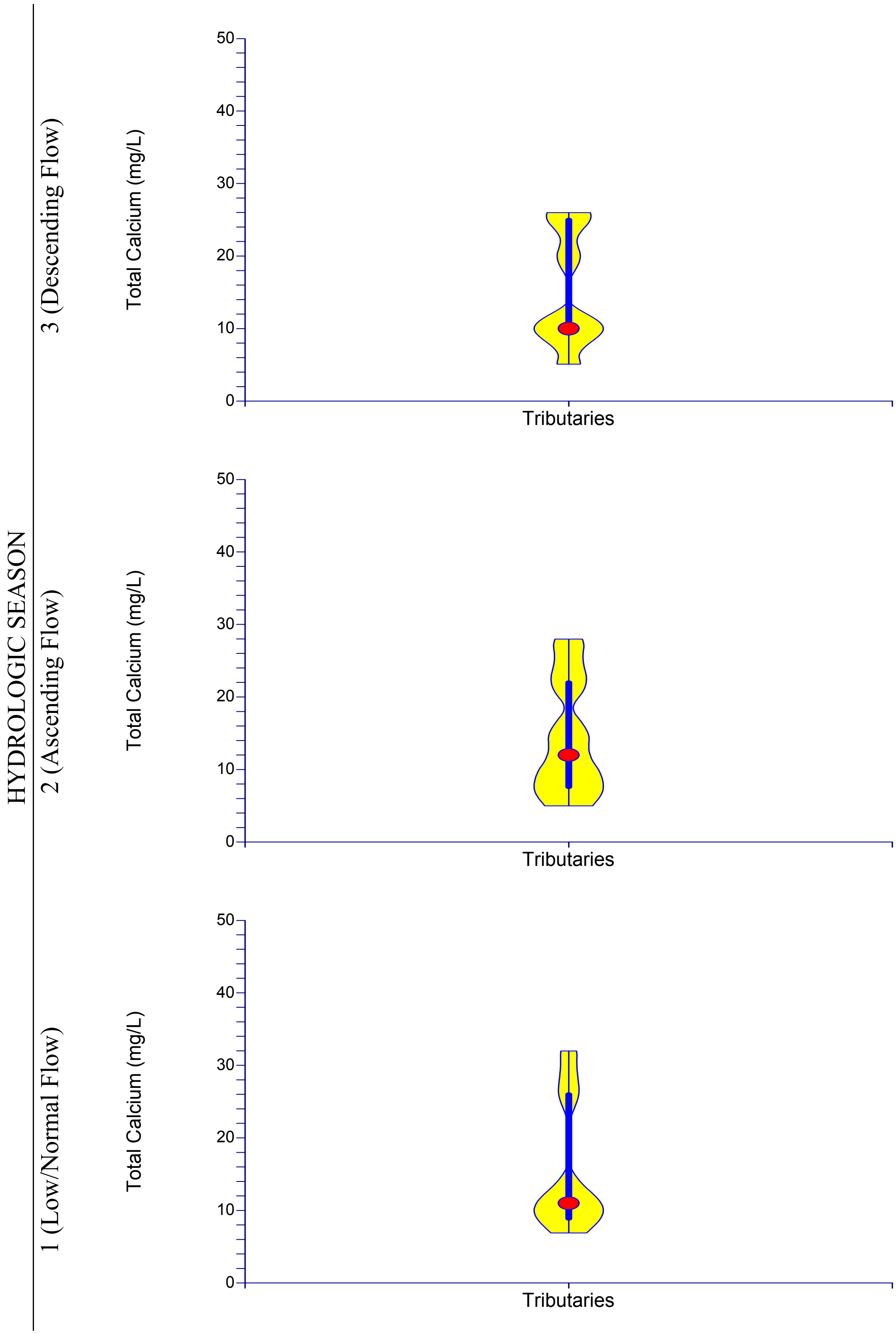


Figure 40. Violin plots of total calcium for different hydrologic seasons by waterbody type.

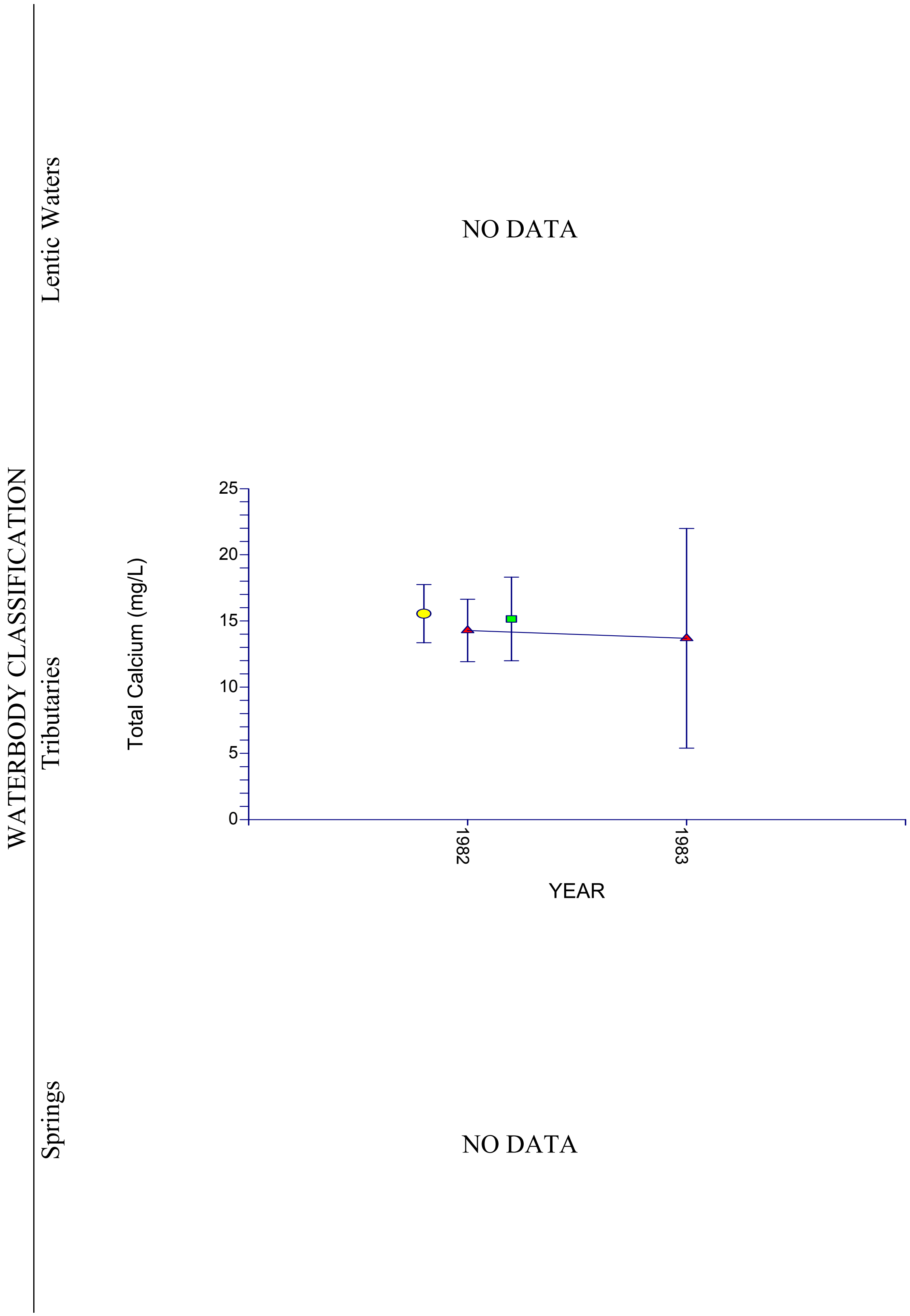


Figure 41. Temporal distribution of total calcium for different waterbody types by hydrologic season.
Hydrologic seasons 1, 2and 3 are represented by circle, triangle and square symbols, respectively.

Assessment of Potential Concerns

Background and Intent of Analysis

Water quality criteria play an important role in the assessment, monitoring, and regulation of waterbodies. Often, many jurisdictions overlap a given park service unit, creating a complex amalgam of criteria. The specifics of these overlapping criteria have been previously described for this park service unit (Goodrich and Huggins 2003). Parameters of potential concern that may or may not currently be known to park management can be identified through comparison of existing data with relevant national criteria for aquatic life, human health, and drinking water.

In order to facilitate the analysis of these potential concerns, national criteria and regional benchmark values were tabulated for comparison. Since the intent of this analysis was to identify parameters of concern, rather than determine specific attainment levels, and since most state, tribal, and local standards adhere in large part to published national criteria, a subset of all of the relevant criteria was used for analysis (Table 8). The aquatic life and human health criteria were either pulled directly from or derived according to the recently updated National Recommended Water Quality Criteria (USEPA 2004b). Similarly, the drinking water standard values for this analysis were those published in the 2004 Edition of the Drinking Water Standards and Health Advisories (USEPA 2004a). Regional benchmark values for total nitrogen, total phosphorous, and turbidity, currently under development by the Regional Technical Assistance Group for USEPA Region 7 (Table 7), were also included to gauge potential nutrient and water clarity concerns. A table of relevant criteria and their associated values and sources is included in the relational database for this park service unit. For actual attainment determinations, park managers should reference and confirm the most current and specific criteria and standards for the designated waterbody in question.

Table 8. Included criteria for potential concern analysis.

Criterion Category	Criterion Name	Criterion Source
Aquatic Life	Freshwater Criterion Maximum Concentration (CMC) (acute)	(USEPA 2004b)
Aquatic Life	Freshwater Criterion Chronic Concentration (CCC)	(USEPA 2004b)
Human Health	Water + Organism Consumption	(USEPA 2004b)
Drinking Water Standard	Maximum Contaminant Load (MCL)	(USEPA 2004a)
Water Quality	Regional Benchmark Value	(Huggins 2005)

To be included in the potential concerns analysis, parameters had to have a published criterion in at least one of the previously detailed categories. For analytical purposes the most restrictive of these criteria for each given parameter was designated the “limit criterion.” For example, total arsenic has a Criterion Maximum Concentration (CMC) of 340 μg/L, a Criterion Chronic Concentration (CCC) of 150 μg/L, a Water-Organism Criterion of 0.018 μg/L, and a Maximum Contaminant Load (MCL) of 10 μg/L. The designated limit criterion is the most restrictive of these, namely 0.018 μg/L, and all of the observations of total arsenic in the screened data for this analysis were compared to this limit. In the case where only one criterion value was available, that criterion was used as the limit criterion. Designated limit criteria and their respective sources are included in Appendix D of this report.

The data for this analysis were screened according to the methods described in the data handling section of this report. It is of particular importance to note that data used in the potential concerns analysis were devoid of remark codes. Ostensibly, this ensures that the results are not clouded by either analytical or reporting limits. However, since a significant portion of the available data were collected from the STORET system, which has had notoriously little data quality assurance, the results of the potential concerns analysis identify exactly that, *potential* concerns. Determination of the true nature and extent of actual water quality problems related to these concerns and any future corrective action that may be necessary will require more detailed, case-specific studies.

Method of Analysis

This approach is intended to summarize a large amount of data into a form that is both intuitively understandable and inherently useful for park management decisions. The general concept of this analysis is to compare each observation to a relevant criterion value. Those parameters found to exceed their respective criteria on a consistent basis are then identified as "potential concerns."

For each waterbody with available data, a potential concerns analysis was performed both by parameter (Table 9) and by specific location and parameter (Table 10). Appendix E contains the data from which these summary tables were constructed. As a framework for interpretation of the results of these analyses, observations were grouped into four major categories: those having less than 20 total observations, those having between 20 and 50 total observations, those having between 50 and 100 total observations, and those having more than 100 observations.

In addition, parameters were compared to criterion values published by USEPA (USEPA 2004a, b) and the state of Arkansas (ADPC&E 1998), and to CPCB recommended potential benchmark criteria (Huggins 2005). For each parameter, the percentage of total observations that exceeded the relevant designated limit criterion (termed "percent exceedance") is noted in the appropriate column for its total observation count. For example, if 25 observations of a given parameter were made for a given waterbody, then its percent exceedance would be recorded in the 20-50 total observations column. Percent exceedance is itself denoted by specific symbols (shown here in parenthesis) for each of the following categories: 0 to 5% exceedance (-), 5 to 10% exceedance (+), 10 to 20% exceedance (++), and greater than 20% exceedance (+++). Each row is marked for percent exceedance in only one of the four columns designating total observation count, since the total observation count categories are mutually exclusive. These percentage groupings were established in order to generally characterize both future and current concerns. Additional analyses could modify the grouping categories to attain higher or lower resolution.

As a rule of thumb, more plus signs to the right of the table identify greater areas of concern. This is for two reasons. First, higher percent exceedance values (i.e. more plus signs) tend to occur in areas with concentrations that are recurrently too high or too low for the parameter in question, compared to a limiting criterion. Second, higher sample sizes (i.e. more to the right) tend to give a better picture of the actual concentration of the parameter in question. For example, total arsenic noted (+++) in the (>100) Total Observations column would indicate more than 20% exceedance of the designated limit criterion for total arsenic in a sample size of more than 100 observations. This example would be a greater potential concern than a lower level of exceedance at the same sample size, since lower exceedance levels probably indicate lower actual concentrations of total arsenic. This would imply a greater potential concern than the same exceedance level at a lower sample size, since high exceedance at low sample sizes could be due to sampling error. Similarly, smaller sample sizes tend to have a greater potential for misrepresenting the actual *in situ* concentrations of a given parameter, since few exceedances in small sample sizes can constitute a relatively high percentage (consider 1 exceedance in two samples, versus 1 in 10 or 1 in 100). By applying this rule of thumb to the summary tables (Table 9, Table 10), park managers can quickly identify parameters and locations of potential concern for those waterbodies, locations, and parameters where data were suitable for analysis.

As a final caveat, even though care has been taken to remove known reporting and detection limit values and poor data, many criterion values are very small. Often these criteria approach analytical limits. In future studies, great care must be taken to limit the impacts of sampling or laboratory errors, which can affect interpretation and management decisions, and to record reporting limits, which can skew data if they are not properly identified.

In the end, it is up to park managers and relevant support staff to determine which levels of exceedance constitute truly significant concerns. Those concerns deemed significant should then be investigated through further sampling and analysis to better quantify the potential and actual impairment of the waterbody in question.

Park Specific Potential Concerns

Few potential concerns were identified for the Hot Springs National Park. It should be noted, however, that this analysis was limited to the water quality data available. Even though water quality of springs is the primary concern of the park, a limited amount of data was available regarding USEPA priority pollutants, drinking water pollutants, and metal toxicity for these waters. Therefore, identified potential concerns do not directly include any springs, though some information may be inferred from tributary conditions downstream. Future park efforts should be directed to characterizing the water quality of springs in particular over the long term, including periodic sampling for compounds with published drinking water criteria.

Station locations with either relatively high numbers of parameters in exceedance of designated limit criteria, or with relatively high exceedance values for a particular parameter suggest potential concern. Of the parameters exceeding published criterion values, only total phosphorus and nitrite nitrogen had at least 20 observations in any single waterbody (Table 9, Table 10). One station on Gulpha Creek (HOSP0004) and three stations on Hot Springs Creek (HOSP0030, HOSP0031, HOSP0032) had between 5 and 10% exceedance of the CPCB recommended benchmark value for total phosphorus of 68 µg/L in relatively many (>100) observations. One station on Stokes Creek (HOSP0099) also had greater than 20% exceedance of CPCB recommended values in relatively few (<20) observations. Further investigation (not shown) revealed similar exceedance patterns for phosphorus using the less restrictive state criterion value for total phosphorus of 1000 µg/L. Small percentages of values exceeding criteria for phosphorus across large numbers of samples may indicate a potential for widespread phosphorus impairment. Similarly, nitrite nitrogen values in Hot Springs Creek exceeded the federal drinking water standard value (MCL) of 1 mg/L in more than 20% of a moderate number (20-50) of observations. Based on these results, the Gulpha Creek, Hot Springs Creek, and Stokes Creek watersheds appear to be areas of potential concern for nutrient loading, and further investigation of these watersheds falls within previously identified HOSP priorities.

Dissolved oxygen levels were below state criterion values in 5 to 10% of relatively few (<20) observations at one station on Stokes Creek (HOSP0090) and one station on Bull Bayou (HOSP0105). Turbidity levels in Bull Bayou also exceeded state criterion values in 5 to 10% of relatively few (<20) observations at the same station.

No other potential concerns were identified by this analytical method.

Table 9. Total observation count and percent criteria exceedance by waterbody and parameter. [1]

Waterbody Code [2]	Waterbody Name	USEPA Priority Pollutant [3]	Parameter Description	Total Observation Count [4]			
				<20	20-50	50-100	>100
2	Gulpha Creek		PHOSPHORUS, TOTAL (MG/L AS P)				+
2	Hot Springs Creek		NITRITE NITROGEN, TOTAL (MG/L AS N)		+++		
			PHOSPHORUS, TOTAL (MG/L AS P)				+
2	Stokes Creek		OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	+			
			PHOSPHORUS, TOTAL (MG/L AS P)	+++			
2	Bull Bayou		OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	+			
			TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)	+			

NOTES:

[1] Percent exceedance is defined as the number of observations that exceed the designated limit criterion value divided by the total number of observations multiplied by 100. As a rule of thumb, more plusses at higher observation counts suggest greater potential concerns. See discussion of limit criterion values in this section. A list of values and sources is in the Appendix.

- indicates 0 to 5% of observations exceed designated limit criterion value.
+ indicates 5 to 10% of observations exceed designated limit criterion value.
++ indicates 10 to 20% of observations exceed designated limit criterion value.
+++ indicates more than 20% of observations exceed designated limit criterion value.

[2] 1 = Main Stem, 2 = Tributaries, 3 = Springs, 4 = Lentic Waters, 5 = Point Sources.

[3] X indicates that this parameter is a USEPA priority pollutant (USEPA 2004b).

[4] Total Observation Counts are for those parameters which have some percentage of exceedance. Parameters without any exceedances were not included in this analysis.

Table 10. Total observation count and percent criteria exceedance by waterbody, location, and parameter. [1]

Waterbody Code [2]	Waterbody Name	NPS STATID[3]	USEPA Priority Pollutant [4]	Parameter Description	Total Observation Count [5]			
					<20	20-50	50-100	>100
2	Gulpha Creek	HOSP0004		PHOSPHORUS, TOTAL (MG/L AS P)				+
	Hot Springs Creek	HOSP0030		NITRITE NITROGEN, TOTAL (MG/L AS N)	+++			
		HOSP0030		PHOSPHORUS, TOTAL (MG/L AS P)				+
		HOSP0031		PHOSPHORUS, TOTAL (MG/L AS P)				+
		HOSP0032		NITRITE NITROGEN, TOTAL (MG/L AS N)	+++			
		HOSP0032		PHOSPHORUS, TOTAL (MG/L AS P)				+
	Stokes Creek	HOSP0099		OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	+			
		HOSP0099		PHOSPHORUS, TOTAL (MG/L AS P)	+++			
	Bull Bayou	HOSP0105		OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	+			
		HOSP0105		TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)	+			

Table 10. Total observation count and percent criteria exceedance by waterbody, location, and parameter. [1] (*continued*)

NOTES:

[1] Percent exceedance is defined as the number of observations that exceed the designated limit criterion value divided by the total number of observations multiplied by 100. As a rule of thumb, more plusses at higher observation counts suggest greater potential concerns. See discussion of limit criterion values in this section. A list of values and sources is in the Appendix.
- indicates 0 to 5% of observations exceed designated limit criterion value.
+ indicates 5 to 10% of observations exceed designated limit criterion value.
++ indicates 10 to 20% of observations exceed designated limit criterion value.
+++ indicates more than 20% of observations exceed designated limit criterion value.

[2] 1 = Main Stem, 2 = Tributaries, 3 = Springs, 4 = Lentic Waters, 5 = Point Sources.

[3] Station code as designated by NPS. See Figure 1, Table 5, and Appendix B for additional station location information.

[4] X indicates that this parameter is a USEPA priority pollutant (USEPA 2004b).

[5] Total Observation Counts are for those parameters which have some percentage of exceedance. Parameters without any exceedances were not included in this analysis.

GENERAL RECOMMENDATIONS

Based on the water quality analyses in this report and on the various processes required for their development, the following recommendations are made:

Identify springs and study areas clearly and consistently. Due to the nature of springs in areas of karst topography, it can be difficult to accurately locate springs as stations. However, without knowledge of which data are associated with which station, meaningful analysis can be difficult to achieve. A rigorous accounting of springs and development of a geospatial database (i.e. a database using Geographic Information Systems (GIS) to identify the geographic location and attributes of each spring) is recommended.

Periodically sample springs for drinking water quality parameters. Since drinking water quality of springs is a major concern of the park service unit, waters from relevant springs should be periodically sampled to ensure relevant drinking water standards are being met. Anecdotal evidence (e.g. the fact that no water-related illnesses are being reported) is sufficient for general information, but actual testing would provide the park a valuable scientific and legal background.

Be sure to document and standardize metadata. Institutional knowledge of station locations, sampling methods, and data handling must be clearly recorded. The implementation of this recommendation is likely a service- or network-wide concern, but each park should be prepared to contribute. The National Research Council has characterized some of the relevant concerns and applications associated with metadata. An executive summary of their recommendations is available at http://www.nap.edu/execsumm_pdf/4896.pdf.

Standardize database files. Rigorous adherence to standards is the key to automating data extraction and analysis, especially with data field names (e.g. DissolvedOxygen, DO, DissOxy) and field types (e.g. text, number, date). NPS has begun to institute servicewide data standards and has been developing new data entry and management tools that should aid in this regard.

Be sure to uniquely define sampling locations. For proper statistical analysis and relational database development, every observation must be linked to a unique place and time. Based on the scale of analysis (e.g. riffle versus watershed), sites may be grouped for analysis, but their original identity should be clearly maintained by documentation.

Relate sampling locations to relevant regulatory waterbody segments. In order to make decisions within a regulatory context, it is important to know which stations are within which regulatory unit. Without easily accessible or fairly precise spatial information, it is difficult to ascertain whether stations contribute to a particular subbasin in a watershed or not. Without this knowledge, it is difficult to assess the relative water quality at a given site in comparison to its relationship with the watershed, both upstream and downstream.

Establish a sampling design for long-term trend analysis. In order to appropriately characterize trends over the long term (decades to centuries), comparable sampling procedures and efforts should be maintained throughout the period of comparison. The goals of trend analysis should be clearly defined to address the scale of the trends being monitored (e.g. differences between months, seasons, years, stations, tributaries, waterbody types), so that sampling design can accommodate the statistical requirements for discerning the desired scale of change.

Take hardness measurements concurrently with metals. Several priority pollutant metals vary in toxicity with hardness. Future studies should include hardness as part of the sampling regime.

Take pH and temperature measurements concurrently with ammonia. Ammonia toxicity is dependent on both pH and water temperature. Since pH and water temperature fluctuate on multiple scales (hourly, daily, weekly, etc.), it is difficult to assess ammonia toxicity without concurrent measurements of these parameters.

Develop study areas along watershed boundaries. Watershed boundaries provide more meaningful study areas than arbitrary upstream or downstream distances. By placing future assessments within a watershed framework, park managers will be better able to recognize the limits of their control over water quality within their parks, and they will also be able to identify the relevant entities whose cooperation will be required for water quality conservation and improvement.

Correlate water quality parameters with actual park use. Some water quality concerns, especially turbidity and fecal coliforms, may be highly correlated to the number of users and the type of use of park waterbodies. Without an understanding of the amount and pattern of park usage, it is difficult to assess its impacts on water quality. In some cases, these impacts may be very significant to waters within and downstream from the park.

REFERENCES CITED

ADPC&E (1998). "Regulation No. 2, as amended. Regulation establishing water quality standards for surface waters of the State of Arkansas." Arkansas Department of Pollution Control and Ecology.

Chambers, J., W. Cleveland, et al. (1983). Graphical Methods for Data Analysis. Boston, MA, Duxbury Press.

Dodds, W. K., J. R. Jones, et al. (1998). "Suggested Classification Of Stream Trophic State: Distributions Of Temperate Stream Types By Chlorophyll, Total Nitrogen, And Phosphorus." Water Resource **32**(5): 1455-1462.

Goodrich, C. and D. Huggins (2003). "National Park Service Inventory and Monitoring Program: Review of state water quality standards applicable to Heartland Network Parks." Central Plains Center for BioAssessment, Kansas Biological Survey.

Goodrich, C., D. Huggins, et al. (2004). "Summary of State and National Biological Assessment Methods, Physical Habitat Assessment Methods, and Biological Criteria." Central Plains Center for BioAssessment, Kansas Biological Survey.

Hintze, J. L. (2004). NCSS: Number Cruncher Statistical Systems. Kaysville, UT, NCSS.

Hintze, J. L. and R. D. Nelson (1998). "Violin Plots: A Box Plot-Density Trace Synergism." The American Statistician **52**: 181-184.

Hoaglin, D., F. Mosteller, et al. (1993). Understanding Robust and Exploratory Data Analysis. New York, NY, John Wiley and Sons, Inc.

Huggins, D. (2005). Potential benchmark values for nutrient stressors and other associated variables derived using multiple approaches, Unpublished. Developed as part of USEPA Region 7 Regional Technical Assistance Group investigation of nutrient criteria for rivers and streams.

Karr, J. R., K. D. Fausch, et al. (1986). "Assessing Biological Integrity in Running Waters A Method and Its Rationale." Special Publication. Illinois Natural History Survey. Champaign.

Larsen, D. P., J. M. Omernik, et al. (1986). "Correspondence between spatial patterns in fish assemblages in Ohio Streams and aquatic ecoregions." Environmental Management **10**(6): 815-828.

National Park Service (1998). "Baseline Water Quality Data Inventory and Analysis: Hot Springs National Park." NPS/NRWRD/NRTR-98/150. Water Res. Div., Nat. Park Serv., US Dept. of Interior. Washington, D.C.

Ohio EPA (1990). "The use of biocriteria in the Ohio EPA surface water monitoring and assessment program." Eco. Assess. Sec., Div. Water Qual. Plan. and Assess, Ohio Environ. Protect. Agency. Columbia, OH.

Plafkin, J. L., M. T. Barbour, et al. (1989). "Rapid Bioassessment Protocols For Use In Streams And Rivers: Benthic Macroinvertebrates And Fish." U. S. Environmental Protection Agency. Washington, D. C.

Tabachnick, B. G. and L. S. Fidell (1996). Using Multivariate Statistics. New York, NY, HarperCollins College Publishers.

Tukey, J. (1977). Exploratory Data Analysis. Reading, MA, Addison-Wesley.

USEPA (1996). "Biological Criteria: Technical guidance for streams and small rivers, revised edition." EPA 822-B-96-001. US Environ. Protect. Agency, Office of Water. Washington, D.C.

USEPA (2000a). "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion 6." EPA 822-B-00-017. USEPA. Washington, D.C.

USEPA (2000b). "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion 7." EPA 822-B-00-018. USEPA. Washington, D.C.

USEPA (2000c). "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion 9." EPA 822-B-00-019. USEPA. Washington, D.C.

USEPA (2000d). "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion 11." EPA 822-B-00-020. USEPA. Washington, D.C.

USEPA (2001a). "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion 4." EPA 822-B-01-013. USEPA. Washington, D.C.

USEPA (2001b). "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion 5." EPA 822-B-01-014. USEPA. Washington, D.C.

USEPA (2001c). "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion 10." EPA 822-B-01-016. USEPA. Washington, D.C.

USEPA (2004a). "2004 Edition of the Drinking Water Standards and Health Advisories." EPA 822-R-04-005. US Environ. Protect. Agency, Office of Water. Washington, D.C.

USEPA (2004b). "National Recommended Water Quality Criteria." US Environ. Protect. Agency, Office of Water. Washington, D.C.

APPENDIX A: CPCB Algorithm for Location Grouping

(November 2003)

For analysis, unique locations were characterized according to the following process:

RULE – Sample sites that are nominally within 2 km of each other are considered to be at the same location.

Exceptions:
1. Look at **Strahler order** - if different - then they are different sites.
2. Look at database information for sites in the same source database: descriptive information may indicate special circumstances or details warranting separate treatment
3. Look on GIS map - does a **tributary** come between the sites? If yes, then the sites are different.
4. Look on GIS map and location description - does a **waste water/sewage treatment plant** come between the sites? If yes, then the sites are different. Upstream of plant is different than downstream regardless of distance.
5. Look on GIS map - **lots of sites in a row.** Weed out those intersected by tributaries or treatment plants. Use measure tool to measure 1st and last site -

if < 2 km, and nothing in between, then all same site.
if > 2 km, then sites closest to each other are same site.

6. Look on GIS map - **if one site is off of the stream** - look in gazetteer to see if there is a tributary not showing up in GIS. If no tributary indicated, then this will be a judgment call based on distance and site description.

APPENDIX B: All Available Stations Included in Database

Observations were made at 108 of 138 stations listed for HOSP. Only those stations with viable observations as described in the data collection and handling sections of this report were included in analyses. However, all 138 stations were included in the database and are listed for reference. Lengthy station descriptions appear in the relational database and were not included here for the sake of brevity. Stream code and waterbody code information was added only for those stations included in the analyses in this report. For additional information concerning stations, see the data collection and handling portions of this report and the relational database.

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0001	Springs	10000	spring	Cluster Spring - 34303092584901	HOSP_USGS_S7, 34303092584901	34.5145	-92.9804	AR	GARLAND	11NPSWRD
HOSP0002	Tributaries	5501	Gulpha Creek	L CATHERINE MOUTH OF GULPHA CR	060017, 2F017	34.4689	-92.9839	AR	GARLAND	21ARAPCC
HOSP0003	Tributaries	5501	Gulpha Creek	EAST BRANCH GULPHA CR AT MOUTH	060008, 2F008	34.4753	-92.9842	AR	GARLAND	21ARAPCC
HOSP0004	Tributaries	5501	Gulpha Creek	GULPA CREEK	0505C1	34.4722	-92.9853	AR		11EPALES
HOSP0005	Tributaries	5501	Gulpha Creek	GULPHA CREEK NEAR HOT SPRINGS, ARK.	07358700	34.4711	-92.9858	AR	GARLAND	112WRD
HOSP0006	Point Sources	100000	WWTP outfall	BELOW GULPHA CR 3.75MI STP	060005, 2F005	34.4753	-92.9861	AR	GARLAND	21ARAPCC
HOSP0007	Tributaries	5501	Gulpha Creek	GULPHA CREEK	2D084058L, 2D02D084058L	34.4744	-92.9864	AR	GARLAND	12NSS
HOSP0008	Springs	10000	spring	Burton Sargo (owner) Spring	HOSP_USGS_S4	34.5612	-92.9905	AR	GARLAND	11NPSWRD
HOSP0009	Springs	10000	spring	Arbordale Spring	HOSP_USGS_S3	34.5702	-92.9964	AR	GARLAND	11NPSWRD
HOSP0010	Tributaries	5501	Gulpha Creek	MIDDLE BRANCH TRIB GULPHA CR	060006, 2F006	34.5156	-93.0053	AR	GARLAND	21ARAPCC
HOSP0011	Point Sources	100000	WWTP outfall	BELOW GULPHA CR 1.8MI STP	060004, 2F004	34.5003	-93.0064	AR	GARLAND	21ARAPCC

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0012	Tributaries	5501	Gulpha Creek	GULPHA CREEK	2D084058U, 2D02D084058U	34.5	-93.0069	AR	GARLAND	12NSS
HOSP0013	Tributaries	5501	Gulpha Creek	MIDDLE BRANCH ABOVE GULPHA CONF.	060007, 2F007	34.5017	-93.0097	AR	GARLAND	21ARAPCC
HOSP0014	Point Sources	100000	WWTP outfall	GULPHA CR .8MI BELOW GULPHA STP	060003, 2F003	34.5047	-93.0181	AR	GARLAND	21ARAPCC
HOSP0015	Springs	10000	spring	Sleepy Valley Spring - 343211093011501	HOSP_USGS_S10, 343211093011501, 02S19W27AAB1SP	34.5368	-93.0212	AR	GARLAND	11NPSWRD
HOSP0016	Springs	10000	spring	Echo Valley Spg (Big Chalybeate)- 343231093012801	HOSP_USGS_S5, 343231093012801, 02S19W22DBC1SP	34.542	-93.0243	AR	GARLAND	11NPSWRD
HOSP0017	Tributaries	5501	Gulpha Creek	GULPHA CR .2MI ABOVE GULPHA STP	060002, 2F002	34.5128	-93.0283	AR	GARLAND	21ARAPCC
HOSP0018	Tributaries	5501	Gulpha Creek	GULPHA CR .3MI ABOVE REC AREA	060001, 2F001	34.5339	-93.0289	AR	GARLAND	21ARAPCC
HOSP0019	Tributaries	5501	Gulpha Creek	GULPHA CR.& STREAM FLOWING FROM RICK'S POND	HOSP_AWRRC_09	34.5356	-93.0309	AR	GARLAND	11NPSWRD
HOSP0020	Tributaries	99999	misc tributary	FIFTY FEET DOWNSTREAM OF RICK'S POND	HOSP_AWRRC_07	34.5366	-93.0329	AR	GARLAND	11NPSWRD
HOSP0021	Lentic Waters	5500	Rick's Pond	RICK'S POND; SOUTHERN END	HOSP_AWRRC_01	34.537	-93.0333	AR	GARLAND	11NPSWRD
HOSP0022	Lentic Waters	5500	Rick's Pond	RICK'S POND; NEAR BOATHOUSE	HOSP_AWRRC_02	34.5373	-93.0338	AR	GARLAND	11NPSWRD
HOSP0023	Tributaries	99999	misc tributary	UNNAMED STREAM ENTERING RICK'S POND FROM NE	HOSP_AWRRC_04	34.5389	-93.0339	AR	GARLAND	11NPSWRD
HOSP0024	Lentic Waters	5500	Rick's Pond	RICK'S POND; NORTHEAST CORNER	HOSP_AWRRC_03	34.5377	-93.0339	AR	GARLAND	11NPSWRD
HOSP0025	Lentic Waters	5500	Rick's Pond	RICK'S POND NW CORNER; WEST OF FOOTBRIDGE	HOSP_AWRRC_05	34.5374	-93.0347	AR	GARLAND	11NPSWRD

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0026	Tributaries	99999	misc tributary	UNNAMED STREAM ENTERING RICK'S POND FROM NW	HOSP_AWRRC_06	34.5374	-93.0354	AR	GARLAND	11NPSWRD
HOSP0027	Tributaries	5501	Gulpha Creek	GULPHA CREEK; 0.25 MILES UPSTREAM OF HW 70	HOSP_AWRRC_10	34.5221	-93.0357	AR	GARLAND	11NPSWRD
HOSP0028	Tributaries	99999	misc tributary	500 FT UPSTREAM FROM PONDS NORTHWESTERN CORNER	HOSP_AWRRC_08	34.5379	-93.0383	AR	GARLAND	11NPSWRD
HOSP0029	Point Sources	100000	WWTP outfall	HOT SPRINGS CR BELOW STP	060680, 2F066	34.4647	-93.0417	AR	GARLAND	21ARAPCC
HOSP0030	Tributaries	5502	Hot Springs Creek	HOT SPRINGS	0510K1	34.4653	-93.0422	AR		11EPALES
HOSP0031	Tributaries	5502	Hot Springs Creek	HOT SPRINGS CREEK TRIB TO LAKE HAMILTON	LHMON10	34.483	-93.047	AR	GARLAND	12CLLK06
HOSP0032	Tributaries	5502	Hot Springs Creek	HOT SPRINGS	0510K2	34.4794	-93.0472	AR		11EPALES
HOSP0033	Springs	10000	spring	Happy Hollow Spring	HOSP_NPS_HHS	34.5194	-93.0481	AR	GARLAND	11NPSWRD
HOSP0034	Springs	10000	spring	02S19W33BDB1SP	343110093025301	34.5194	-93.0481	AR	GARLAND	112WRD
HOSP0035	Springs	10000	spring	Happy Hollow Spring - 343110093025301	HOSP_USGS_S8, 343110093025301	34.5194	-93.0481	AR	GARLAND	11NPSWRD
HOSP0036	Tributaries	5502	Hot Springs Creek	HOT SPRINGS CR. ABOVE STP	060632, 2F068	34.5008	-93.0497	AR	GARLAND	21ARAPCC
HOSP0037	Tributaries	5502	Hot Springs Creek	UNNAMED W FORK OF HOT SPRINGS C	060634, 2F070	34.5169	-93.0506	AR	GARLAND	21ARAPCC
HOSP0038	Tributaries	5502	Hot Springs Creek	HOT SPRINGS CREEK AT MT IDA ST.	060633, 2F069	34.525	-93.0508	AR	GARLAND	21ARAPCC
HOSP0039	Springs	10001	spring: central area	Liver Spring (cold) Exact Location Unknown	HOSP_SEN282_44	34.5153	-93.0516	AR	GARLAND	11NPSWRD

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0040	Springs	10001	spring: central area	Kidney Spring (cold) Exact Location Unknown	HOSP_SEN282_45	34.5153	-93.0516	AR	GARLAND	11NPSWRD
HOSP0041	Springs	10001	spring: central area	ARGA607R	HOSP_NURE_03, NURE_3009943	34.516	-93.0519	AR	GARLAND	11NPSWRD
HOSP0042	Springs	10001	spring: central area	Egg Spring	HOSP_SEN282_01	34.5154	-93.0522	AR	GARLAND	11NPSWRD
HOSP0043	Springs	10001	spring: central area	Hot Spring #48 - 343058093030803	HOSP_USGS_HS48, 343058093030803, 02S19W33BCD1SP	34.5153	-93.0522	AR	GARLAND	11NPSWRD
HOSP0044	Springs	10001	spring: central area	Imperial Spring (north)	HOSP_SEN282_07	34.5152	-93.0524	AR	GARLAND	11NPSWRD
HOSP0045	Springs	10001	spring: central area	Crystal Spring	HOSP_SEN282_08	34.5151	-93.0524	AR	GARLAND	11NPSWRD
HOSP0046	Springs	10001	spring: central area	Arlington Spring	HOSP_SEN282_03	34.5154	-93.0522	AR	GARLAND	11NPSWRD
HOSP0047	Springs	10001	spring: central area	Avenue Spring	HOSP_SEN282_05	34.5152	-93.0522	AR	GARLAND	11NPSWRD
HOSP0048	Springs	10001	spring: central area	W. J. Little Spring	HOSP_SEN282_40	34.5127	-93.0523	AR	GARLAND	11NPSWRD
HOSP0049	Springs	10001	spring: central area	Little Geyser Spring	HOSP_SEN282_12	34.5148	-93.0526	AR	GARLAND	11NPSWRD
HOSP0050	Springs	10001	spring: central area	Imperial Spring (south)	HOSP_SEN282_16	34.5148	-93.0527	AR	GARLAND	11NPSWRD
HOSP0051	Springs	10001	spring: central area	Ral Spring	HOSP_SEN282_14	34.5148	-93.0527	AR	GARLAND	11NPSWRD
HOSP0052	Springs	10001	spring: central area	Cave Spring	HOSP_SEN282_10	34.515	-93.0525	AR	GARLAND	11NPSWRD
HOSP0053	Springs	10001	spring: central area	Army and Navy Spring	HOSP_SEN282_39	34.5131	-93.053	AR	GARLAND	11NPSWRD
HOSP0054	Springs	10001	spring: central area	Cliff Spring Under Wall of Arlington Hotel	HOSP_SEN282_04	34.5155	-93.053	AR	GARLAND	11NPSWRD
HOSP0055	Springs	10001	spring: central area	John W. Noble Spring	HOSP_SEN282_32	34.514	-93.053	AR	GARLAND	11NPSWRD

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0056	Springs	10001	spring: central area	Arsenic Spring (N) (Spring #17 - 343057093031301)	HOSP_SEN282_17, 343057093031301, 02S19W33CBB6SP	34.5157	-93.0529	AR	GARLAND	11NPSWRD
HOSP0057	Springs	10001	spring: central area	02S19W33CBC1SP	343047093031001	34.5131	-93.0528	AR	GARLAND	112WRD
HOSP0058	Springs	10001	spring: central area	Lamar Spring (Spring #33 - 343051093030901)	HOSP_SEN282_33, 343051093030901	34.514	-93.053	AR	GARLAND	11NPSWRD
HOSP0059	Springs	10001	spring: central area	Boiler House Spring in Arlington Hotel Cellar	HOSP_SEN282_06	34.5153	-93.053	AR	GARLAND	11NPSWRD
HOSP0060	Springs	10001	spring: central area	Hot Spring #49 - 343035093031001	HOSP_USGS_HS49, 343035093031001	34.5147	-93.0528	AR	GARLAND	11NPSWRD
HOSP0061	Springs	10001	spring: central area	Superior Spring (north)	HOSP_SEN282_20	34.5146	-93.0529	AR	GARLAND	11NPSWRD
HOSP0062	Springs	10001	spring: central area	Superior Spring (south)	HOSP_SEN282_22	34.5145	-93.0529	AR	GARLAND	11NPSWRD
HOSP0063	Springs	10001	spring: central area	02S19W33CBB2SP	343053093031001	34.5147	-93.0528	AR	GARLAND	112WRD
HOSP0064	Springs	10001	spring: central area	H. W. Wiley Spring	HOSP_SEN282_34	34.5139	-93.0529	AR	GARLAND	11NPSWRD
HOSP0065	Springs	10001	spring: central area	Arsenic Spring Under Wall of Arlington Hotel	HOSP_SEN282_02	34.5156	-93.0529	AR	GARLAND	11NPSWRD
HOSP0066	Springs	10001	spring: central area	Eisele Spring	HOSP_SEN282_36	34.5134	-93.0529	AR	GARLAND	11NPSWRD
HOSP0067	Springs	10001	spring: central area	Haywood Spring Near Road	HOSP_SEN282_31	34.5141	-93.0529	AR	GARLAND	11NPSWRD
HOSP0068	Springs	10001	spring: central area	Sumpter Spring Under Wall of Reservoir	HOSP_SEN282_19	34.5148	-93.0531	AR	GARLAND	11NPSWRD
HOSP0069	Springs	10001	spring: central area	Little Iron Spring (south)	HOSP_SEN282_13	34.515	-93.0531	AR	GARLAND	11NPSWRD
HOSP0070	Springs	10001	spring: central area	80000-gallon Reservoir -343055093031201	HOSP_USGS_80KRE, 343055093031201	34.5151	-93.0531	AR	GARLAND	11NPSWRD
HOSP0071	Springs	10001	spring: central area	Palace Spring	HOSP_SEN282_26	34.5143	-93.0532	AR	GARLAND	11NPSWRD

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0072	Springs	10001	spring: central area	Little Iron Spring (north)	HOSP_SEN282_11	34.5151	-93.0531	AR	GARLAND	11NPSWRD
HOSP0073	Springs	10001	spring: central area	Twin Spring (north) (Spring #23-343053093031101)	HOSP_SEN282_23, 343053093031101	34.5145	-93.0531	AR	GARLAND	11NPSWRD
HOSP0074	Springs	10001	spring: central area	Tunnel Spring	HOSP_SEN282_27	34.5143	-93.0532	AR	GARLAND	11NPSWRD
HOSP0075	Springs	10001	spring: central area	Mud Spring Under Free Bath House	HOSP_SEN282_41	34.5131	-93.0532	AR	GARLAND	11NPSWRD
HOSP0076	Springs	10001	spring: central area	Old Hale Spring Under Hale Bath House	HOSP_SEN282_25	34.5146	-93.0533	AR	GARLAND	11NPSWRD
HOSP0077	Springs	10001	spring: central area	Rector Spring	HOSP_SEN282_09	34.5151	-93.0531	AR	GARLAND	11NPSWRD
HOSP0078	Springs	10001	spring: central area	Stevens Spring	HOSP_SEN282_37	34.5134	-93.0531	AR	GARLAND	11NPSWRD
HOSP0079	Springs	10001	spring: central area	Maurice Spring (Spring #28)	HOSP_SEN282_28	34.5143	-93.0532	AR	GARLAND	11NPSWRD
HOSP0080	Springs	10001	spring: central area	Dripping Spring	HOSP_SEN282_29	34.5143	-93.0532	AR	GARLAND	11NPSWRD
HOSP0081	Springs	10001	spring: central area	Maurice Spring - 343051093031101	HOSP_USGS_MAURI, 343051093031101	34.5141	-93.0532	AR	GARLAND	11NPSWRD
HOSP0082	Springs	10001	spring: central area	Twin Spring (south)	HOSP_SEN282_24	34.5144	-93.0531	AR	GARLAND	11NPSWRD
HOSP0083	Springs	10001	spring: central area	Big Iron Spring	HOSP_SEN282_15	34.5149	-93.0531	AR	GARLAND	11NPSWRD
HOSP0084	Springs	10001	spring: central area	Hitchcock Spring	HOSP_SEN282_18	34.5151	-93.0532	AR	GARLAND	11NPSWRD
HOSP0085	Springs	10001	spring: central area	Ed Hardin Spring	HOSP_SEN282_35	34.5136	-93.0534	AR	GARLAND	11NPSWRD
HOSP0086	Springs	10001	spring: central area	Horse Shoe Spring Under Horse Shoe Bath House	HOSP_SEN282_38	34.5133	-93.0534	AR	GARLAND	11NPSWRD
HOSP0087	Springs	10001	spring: central area	Fordyce Spring (Spring #46 - 343049093031101)	HOSP_SEN282_46, 343049093031101	34.5135	-93.0536	AR	GARLAND	11NPSWRD

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0088	Springs	10000	spring	Reservoir Spring Behind 1902 Supt.'s Office	HOSP_SEN282_43	34.5119	-93.0534	AR	GARLAND	11NPSWRD
HOSP0089	Springs	10001	spring: central area	Magnesia Spring (Spring #42 - 343047093031001)	HOSP_SEN282_42, 343047093031001	34.5131	-93.0534	AR	GARLAND	11NPSWRD
HOSP0090	Springs	10001	spring: central area	Alum Spring at Side of Central Avenue	HOSP_SEN282_21	34.5147	-93.0535	AR	GARLAND	11NPSWRD
HOSP0091	Springs	10001	spring: central area	Arch Spring Under Central Avenue	HOSP_SEN282_30	34.5145	-93.0534	AR	GARLAND	11NPSWRD
HOSP0092	Springs	10000	spring	Ar-Scenic Spring	HOSP_USGS_S6	34.5247	-93.0553	AR	GARLAND	11NPSWRD
HOSP0093	Springs	10000	spring	Diamond Mineral Spring (Lithox) - 343112093033601	HOSP_USGS_W24, 343112093033601, 02S19W32ABD1SP	34.5199	-93.0601	AR	GARLAND	11NPSWRD
HOSP0094	Springs	10000	spring	Whittington Avenue Spring	HOSP_NPS_WAS	34.5144	-93.0689	AR	GARLAND	11NPSWRD
HOSP0095	Springs	10000	spring	Whittington Avenue Spring - 343052093040802	HOSP_USGS_W26, 343052093040802	34.5144	-93.0689	AR	GARLAND	11NPSWRD
HOSP0096	Springs	10000	spring	02S19W32CBA1SP	343052093040802	34.5144	-93.0689	AR	GARLAND	112WRD
HOSP0097	Springs	10000	spring	02S19W31DAD1SP	343051093042001	34.5142	-93.0722	AR	GARLAND	112WRD
HOSP0098	Springs	10000	spring	02S19W31DAA2SP	343053093042101	34.5147	-93.0725	AR	GARLAND	112WRD
HOSP0099	Tributaries	5503	Stokes Creek	STOKES CREEK TRIB TO LAKE HAMILTON	LHMON11	34.4705	-93.0841	AR	GARLAND	12CLLK06
HOSP0100	Tributaries	5503	Stokes Creek	STOKES CR. ABOVE NAT. REJECTORS	060635, 2F071	34.4697	-93.0917	AR	GARLAND	21ARAPCC
HOSP0101	Lentic Waters	5506	Hot Springs Reservoir	HOT SP RES NR HOT SPRINGS ARK	07357840	34.5247	-93.0964	AR	GARLAND	112WRD
HOSP0102	Lentic Waters	55	Lake Hamilton (Ouachita R.)	LAKE HAMILTON COORDINATES (M,13)	060665, 2F101	34.4678	-93.1022	AR	GARLAND	21ARAPCC

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0103	Tributaries	99999	misc tributary	STOKES CREEK COVE TRIB TO LAKE|HAMILTON	LHMON06	34.4729	-93.1035	AR	GARLAND	12CLLK06
HOSP0104	Tributaries	5504	Bull Bayou	BULL BAYOU	0510J1	34.4653	-93.1097	AR		11EPALES
HOSP0105	Tributaries	5504	Bull Bayou	BULL BAYOU TRIB TO LAKE HAMILTON	LHMON12	34.521	-93.1098	AR	GARLAND	12CLLK06
HOSP0106	Tributaries	5504	Bull Bayou	BULL BAYOU ABOVE LAKE HAMILTON	060638, 2F074	34.5175	-93.1142	AR	GARLAND	21ARAPCC
HOSP0107	Tributaries	5505	Hogan Creek	HOGAN CREEK AT HWY 88	060636, 2F072	34.4753	-93.1158	AR	GARLAND	21ARAPCC
HOSP0108	Springs	10000	spring	Music Mountain Spring -342954093070101	HOSP_USGS_S9, 342954093070101	34.4981	-93.117	AR	GARLAND	11NPSWRD
HOSP0109	Lentic Waters	55	Lake Hamilton (Ouachita R.)	LAKE HAMILTON - UPPER	050048, LOUA018B	34.4675	-93.1228	AR	GARLAND	21ARLAKE
HOSP0110	Lentic Waters	55	Lake Hamilton (Ouachita R.)	LAKE HAMILTON AT HWY 70 BRIDGE-THALWEG	LHMON03	34.4728	-93.125	AR	GARLAND	12CLLK06
HOSP0111	Lentic Waters	55	Lake Hamilton (Ouachita R.)	LAKE HAMILTON COORDINATES (O,10)	060666, 2F102	34.4828	-93.1283	AR	GARLAND	21ARAPCC
HOSP0112	Lentic Waters	55	Lake Hamilton (Ouachita R.)	LAKE HAMILTON	051001	34.4847	-93.1308	AR	GARLAND	11EPALES
HOSP0113	Springs	10001	spring: central area	SPRING 49	343054093031201	34.5151	-93.0535	AR		112WRD
HOSP0114	Springs	10001	spring: central area		343054093031101, 02S19W33CBB3SP	34.5151	-93.0532	AR		112WRD
HOSP0115	Springs	10001	spring: central area		343054093030701, 02S19W33CBA1SP	34.5151	-93.0521	AR		112WRD
HOSP0116	Tributaries	5502	Hot Springs Creek	WEST FORK HOT SPRINGS CREEK AT HOT SPRINGS, ARK.	7358250	34.5151	-93.0738	AR		112WRD
HOSP0117	Springs	10000	spring	W Fork Hot Springs Cr at Dierks HQ in Hot Springs	7358251	34.5151	-93.0738	AR		112WRD

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0118	Springs	10001	spring: central area		343053093031002, 02S19W33CBB7SP	34.5148	-93.053	AR		112WRD
HOSP0119	Springs	10000	spring		343055093031201, 02S19W33CBB5SP	34.5154	-93.0535	AR		112WRD
HOSP0120	Tributaries	5502	Hot Springs Creek	Hot Springs at Hot Springs, AR	7358280	34.5118	-93.0535	AR		112WRD
HOSP0121	Springs	10001	spring: central area	SPRING 9	343055093031301	34.5154	-93.0538	AR		112WRD
HOSP0122	Springs	10001	spring: central area	HALE SPRING	343052093031301	34.5145	-93.0538	AR		112WRD
HOSP0123	Tributaries	99999	misc tributary	"Class Site"	7000000	34.5145	-93.0721	AR		112WRD
HOSP0124	Springs	10001	spring: central area	DISPLAY SPRING	343050093031201	34.514	-93.0535	AR		112WRD
HOSP0125	Springs	10001	spring: central area	Quapaw Spring	343048093031301	34.5134	-93.0538	AR		112WRD
HOSP0126	Springs	10000	spring		343033092584601, 02S18W31CAB1SP	34.5093	-92.9796	AR		112WRD
HOSP0127	Tributaries	5504	Bull Bayou	Bull Bayou Tributary near Hot Springs	7357850	34.5018	-93.1238	AR		112WRD
HOSP0128	Tributaries	5503	Stokes Creek	STOKES CREEK AT KIMERY ROAD AT HOT SPRINGS	7357860	34.4768	-93.0813	AR		112WRD
HOSP0129	Springs	10001	spring: central area	SPRING 8	343056093030901	34.5156	-93.0527	AR		112WRD
HOSP0130	Springs	10001	spring: central area	SPRING 47	343058093030901	34.5162	-93.0527	AR		112WRD
HOSP0131	Springs	10001	spring: central area	Fordyce Spring	343049093031301	34.5137	-93.0538	AR		112WRD
HOSP0132	Springs	10000	spring		343102093031601, 02S19W33BCC1SP	34.5173	-93.0546	AR		112WRD
HOSP0133	Springs	10000	spring		343110093025301, 02S19W33BDB1SP	34.5195	-93.0482	AR		112WRD

APPENDIX B: All Available Stations Included in Database (*continued*)

NPS StationID[1]	Waterbody Code[2]	Stream Code[3]	Waterbody Name[4]	Station Location[5]	Other Names[6]	Latitude DD[5,7]	Longitude DD[5,7]	State[5]	County[5]	STORET Agency Code[5]
HOSP0134	Tributaries	5502	Hot Springs Creek	EAST FORK HOT SPRINGS CREEK AT HOT SPRINGS, ARK.	7358260	34.5223	-93.0546	AR		112WRD
HOSP0135	Tributaries	5507	Sleepy Hollow Branch	Sleepy Hollow Branch near Hot Springs	7358554	34.5326	-93.0282	AR		112WRD
HOSP0136	Tributaries	5501	Gulpha Creek	Gulpha Creek near Hot Springs	7358550	34.5343	-93.0299	AR		112WRD
HOSP0137	Springs	10001	spring: central area	hale bath house spring	343056093031301	34.5156	-93.0538	AR		112WRD
HOSP0138	Springs	10000	spring	AR-SCENIC SPRING	343130093021901	34.5251	-93.0388	AR		112WRD

[1] NPS Station ID code. This code has been assigned by NPS for unique identification of locations.
[2] Code added by CPCB to identify classes of waterbodies for analysis. Coded only for those stations included in this table.
[3] Code added by CPCB to identify stations within the same waterbody or segment. Coded only for those stations included in this table.
55 = Lake Hamilton (impoundment of the Ouachita River); 1000 – 9999 indicate various tributaries;99999 indicates miscellaneous unnamed or unassignable tributaries; 10000 indicates springs; 10001 indicates central area springs. Springs were not further separated by stream code, since they are point source stations (i.e. the sampling station is the only location within that spring).
[4] Name of waterbody. Assigned only for those stations included in the analyses of this report, based on best available information. All springs were grouped into one category, since each spring has its own station as a unique identifier.
[5] Field provided by STORET and included in the Baseline Report (National Park Service 1998). Additional descriptive data appear in the accompanying relational database.
[6] Aliases by which this station is identified in databases other than STORET or the Baseline Report (National Park Service 1998).
[7] In decimal degrees. Projection information was derived from NPS GIS metadata files. Refer to available NPS sources for these files.

APPENDIX C: Parameters with Data Suitable for Analysis

The following is a list of the 29 parameters in the "Data for Analysis" (Figure 1), which were used for the analyses in this report. For more information on the origins and screening of the "Data for Analysis," see the Data Collection and Handling section of this report. More extensive information regarding these and other parameters is available in the relational database that accompanies this report, the USEPA STORET system, and the Baseline Report for this park service unit (National Park Service 1998).

PARM CODE[1]	Parameter Description[2]	CAS No [3]	Group Code [4]	Group Name [5]
00010	TEMPERATURE, WATER (DEGREES CELSIUS)		16	
00058	FLOW, RATE GALLONS/MIN		5	Flow
00076	TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)		13	Physical
00078	TRANSPARENCY, SECCHI DISC (METERS)		13	Physical
00094	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)		13	Physical
00299	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7782447	4	Dissolved Oxygen
00300	OXYGEN, DISSOLVED MG/L	7782447	4	Dissolved Oxygen
00400	PH (STANDARD UNITS)		13	Physical
00410	ALKALINITY, TOTAL (MG/L AS CACO3)	471341	6	General Inorganic
00608	NITROGEN, AMMONIA, DISSOLVED (MG/L AS N)	17778880	9	Nitrogen
00610	NITROGEN, AMMONIA, TOTAL (MG/L AS N)	17778880	9	Nitrogen
00615	NITRITE NITROGEN, TOTAL (MG/L AS N)	17778880	9	Nitrogen
00620	NITRATE NITROGEN, TOTAL (MG/L AS N)	17778880	9	Nitrogen
00625	NITROGEN, KJELDAHL, TOTAL, (MG/L AS N)	17778880	9	Nitrogen
00630	NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)	17778880	9	Nitrogen
00665	PHOSPHORUS, TOTAL (MG/L AS P)	7723140	12	Phosphorous
00671	PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)	7723140	12	Phosphorous
00680	CARBON, TOTAL ORGANIC (MG/L AS C)	7440440	7	General Organic
00916	CALCIUM, TOTAL (MG/L AS CA)	7440702	8	Metals
00946	SULFATE, DISSOLVED (MG/L AS SO4)	14808798	6	General Inorganic
00950	FLUORIDE, DISSOLVED (MG/L AS F)	16984488	6	General Inorganic
00955	SILICA, DISSOLVED (MG/L AS SI02)	7631869	6	General Inorganic
01045	IRON, TOTAL (UG/L AS FE)	7439896	8	Metals
01055	MANGANESE, TOTAL (UG/L AS MN)	7439965	8	Metals
31501	COLIFORM,TOT,MEMBRANE FILTER,IMMED.M-ENDO MED,35C		2	Bacteriological
31616	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C		2	Bacteriological
31673	FECAL STREPTOCOCCI, MBR FILT,KF AGAR,35C,48HR		2	Bacteriological

PARM CODE[1]	Parameter Description[2]	CAS No [3]	Group Code [4]	Group Name [5]
32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	479618	3	Biological
70507	PHOSPHORUS,IN TOTAL ORTHOPHOSPHATE (MG/L AS P)	7723140	12	Phosphorous

[1] USEPA Storage and Retrieval (STORET) parameter code. This code is also used in the Baseline Report (National Park Service 1998) and other NPS databases.
[2] Description of the phase and actual measurement technique for this parameter.
[3] Chemical Abstracts Service (CAS) registry number for this compound. This number was used, where available, to aid in matching parameters to pollutants with published criteria values.
[4] STORET parameter group code.
[5] STORET parameter group name

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP)

215 parameter codes have associated parameters with published criterion values relevant to HOSP. Criteria in this table were derived from three sources (ADPC&E 1998; USEPA 2004a, b). Metals with hardness-dependent toxicity were not included in this analysis, since no data suitable for analysis were available for them. Additional regional benchmarks for total nitrogen, total phosphorus, and turbidity were also included (Huggins 2005). These values appear in (Table 7). From these values, the limit criteria were designated. Water quality pollutants with limit criteria were then matched with relevant parameters by description. Additional state criteria were included in the core elements and priority concerns analyses where applicable. However, potential concerns analyses were based solely on the following limit criteria. See the analysis sections of this report for more detailed information on the methods of analysis.

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	1,1,1-Trichloroethane	34506	1,1,1-TRICHLOROETHANE TOTWUG/L		200	4
X	1,1,2,2-Tetrachloroethane	34516	1,1,2,2-TETRACHLOROETHANE TOTWUG/L		0.17	3
X	1,1,2-Trichloroethane	34511	1,1,2-TRICHLOROETHANE TOTWUG/L		0.59	3
X	1,1-Dichloroethylene	34501	1,1-DICHLOROETHYLENE TOTWUG/L		7	4
X	1,2,4-Trichlorobenzene	34551	1,2,4-TRICHLOROBENZENE TOTWUG/L		35	3
X	1,2,4-Trichlorobenzene	49911	TRICHLOROBENZENE-1,2,4 BY VOA, TOTAL, WATER UG/L		35	3
	1,2-Dibromo-3-chloropropane (DBCP)	38760	DBCP WATER, TOTUG/L		0.2	4
	1,2-Dibromo-3-chloropropane (DBCP)	38761	DBCP WATER, DISUG/L		0.2	4
X	1,2-Dichlorobenzene	34536	1,2-DICHLOROBENZENE TOTWUG/L		75	4

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	1,2-Dichlorobenzene	49912	DICHLOROBENZENE-1,2 BY VOA, TOTAL, WATER UG/L		75	4
X	1,2-Dichloroethane	32103	1,2-DICHLOROETHANE,WHOLE WATER,UG/L		0.38	3
X	1,2-Dichloroethane	34531	1,2-DICHLOROETHANE TOTWUG/L		0.38	3
X	1,2-Dichloropropane	34541	1,2-DICHLOROPROPANE TOTWUG/L		0.5	3
X	1,2-Diphenylhydrazine	34346	1,2-DIPHENYLHYDRAZINE TOTWUG/L		0.036	3
X	1,2-Diphenylhydrazine	82626	1,2-DIPHENYLHYDRAZINE,WATER,TOTAL RECOVERABLE,UG/L		0.036	3
X	1,2-Trans-Dichloroethylene	34546	TRANS-1,2-DICHLOROETHENE, TOTAL, IN WATER UG/L		100	4
X	1,3-Dichlorobenzene	34566	1,3-DICHLOROBENZENE TOTWUG/L		320	3
X	1,3-Dichlorobenzene	49913	DICHLOROBENZENE-1,3 BY VOA, TOTAL, WATER UG/L		320	3
X	1,3-Dichlorobenzene	82512	M,P-DICHLOROBENZENE (MEASURES 1,3&1,4)TOTAL UG/L		320	3
X	1,3-Dichloropropene	34561	1,3-DICHLOROPROPENE TOTWUG/L		0.34	3
X	1,3-Dichloropropene	77163	1,3-DICHLOROPROPENE-1 WHOLE WATER,UG/L		0.34	3
X	1,4-Dichlorobenzene	34571	1,4-DICHLOROBENZENE TOTWUG/L		63	3
X	1,4-Dichlorobenzene	49914	DICHLOROBENZENE-1,4 BY VOA, TOTAL, WATER UG/L		63	3
X	2,3,7,8-TCDD (Dioxin)	34675	2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN(TCDD) TOTWUG/L		5E-09	3
X	2,4,6-Trichlorophenol	34621	2,4,6-TRICHLOROPHENOL TOTWUG/L		1.4	3
X	2,4-Dichlorophenol	34601	2,4-DICHLOROPHENOL TOTWUG/L		77	3
X	2,4-Dimethylphenol	34606	2,4-DIMETHYLPHENOL TOTWUG/L		380	3

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	2,4-Dinitrophenol	34616	2,4-DINITROPHENOL TOTWUG/L		69	3
X	2,4-Dinitrotoluene	34611	2,4-DINITROTOLUENE TOTWUG/L		0.11	3
X	2-Chloronaphthalene	34581	2-CHLORONAPHTHALENE TOTWUG/L		1000	3
X	2-Chlorophenol	34586	2-CHLOROPHENOL TOTWUG/L		81	3
X	2-Methyl-4,6-Dinitrophenol	03615	METHYL-4,6-DINITROPHENOL,2-,EFFLUENT,TOTAL UG/L		13	3
X	2-Methyl-4,6-Dinitrophenol	34657	DNOC (4,6-DINITRO-ORTHO-CRESOL) TOTWUG/L		13	3
X	2-Methyl-4,6-Dinitrophenol	78208	2,4-DINITRO-O-CRESOL IN WHOLE WATER UG/L		13	3
X	3,3'-Dichlorobenzidine	34631	3,3'-DICHLOROBENZIDINE TOTWUG/L		0.021	3
X	4,4'-DDD	39310	P,P' DDD IN WHOLE WATER SAMPLE (UG/L)		0.00031	3
X	4,4'-DDD	39360	DDD IN WHOLE WATER SAMPLE (UG/L)		0.00031	3
X	4,4'-DDE	39320	P,P' DDE IN WHOLE WATER SAMPLE (UG/L)		0.00022	3
X	4,4'-DDE	39365	DDE IN WHOLE WATER SAMPLE (UG/L)		0.00022	3
X	4,4'-DDT	39300	P,P' DDT IN WHOLE WATER SAMPLE (UG/L)		0.00022	3
X	4,4'-DDT	39370	DDT IN WHOLE WATER SAMPLE (UG/L)		0.00022	3
X	Acenaphthene	34205	ACENAPHTHENE TOTWUG/L		670	3
X	Acrolein	34210	ACROLEIN TOTWUG/L		190	3
X	Acrylonitrile	34215	ACRYLONITRILE TOTWUG/L		0.051	3
	Alachlor	46342	ALACHLOR (LASSO), WATER, DISSOLVED UG/L		2	4
	Alachlor	50009	ALACHLOR ESA, DISSOLVED, WATER UG/L		2	4
	Alachlor	77825	ALACHLOR WHOLE WATER,UG/L		2	4
X	Aldrin	39330	ALDRIN IN WHOLE WATER SAMPLE (UG/L)		0.000049	3

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	alpha-BHC	39337	ALPHA BENZENE HEXACHLORIDE IN WHOLE WATER SAMP		0.0026	3
X	alpha-Endosulfan	34361	ENDOSULFAN, ALPHA TOTWUG/L		0.056	2
	Aluminum pH 6.5 - 9.0	01104	ALUMINUM,TOTAL RECOVERABLE IN WATER AS AL UG/L		87	2
	Aluminum pH 6.5 - 9.0	01105	ALUMINUM, TOTAL (UG/L AS AL)		87	2
	Aluminum pH 6.5 - 9.0	01106	ALUMINUM, DISSOLVED (UG/L AS AL)		87	2
	Aluminum pH 6.5 - 9.0	49054	ALUMINUM, TOTAL, WATER, TCLP MG/L		0.087	2
X	Anthracene	34220	ANTHRACENE TOTWUG/L		8300	3
X	Anthracene	49748	ANTHRACENE, C1 ALKYL,TOTAL RECOVERABLE, WATER UG/L		8300	3
X	Anthracene	49749	ANTHRACENE, C2 ALKYL,TOTAL RECOVERABLE, WATER UG/L		8300	3
X	Anthracene	49750	ANTHRACENE, C3 ALKYL,TOTAL RECOVERABLE, WATER UG/L		8300	3
X	Anthracene	49751	ANTHRACENE, C4 ALKYL,TOTAL RECOVERABLE, WATER UG/L		8300	3
X	Antimony	01097	ANTIMONY, TOTAL (UG/L AS SB)		5.6	3
X	Arsenic	01000	ARSENIC, DISSOLVED (UG/L AS AS)		0.018	3
X	Arsenic	01002	ARSENIC, TOTAL (UG/L AS AS)		0.018	3
X	Asbestos	34225	ASBESTOS (FIBROUS) TOTWUG/L		7000000	4
	Atrazine	39033	ATRAZINE IN WHOLE WATER SAMPLE UG/L		3	4
	Atrazine	39630	ATRAZINE(AATREX) IN WHOLE WATER SAMPLE (UG/L)		3	4
	Barium	01007	BARIUM, TOTAL (UG/L AS BA)		1000	3
	Barium	49057	BARIUM, TOTAL, WATER, TCLP MG/L		1	3
	Barium	49612	BARIUM TCLP, ICP, TOTAL, WATER MG/L		1	3

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	Benzene	78124	BENZENE IN WATER (VOLATILE ANALYSIS) UG/L		2.2	3
X	Benzidine	39120	BENZIDINE IN WHOLE WATER SAMPLE (UG/L)		0.000086	3
X	Benzo(a) Anthracene	34526	BENZO(A)ANTHRACENE1,2-BENZANTHRACENE TOTWUG/L		0.0038	3
X	Benzo(a) Pyrene	34247	BENZO-A-PYRENE TOTWUG/L		0.0038	3
X	Benzo(b) Fluoranthene	34230	BENZO(B)FLUORANTHENE,WHOLE WATER,UG/L		0.0038	3
X	Benzo(k) Fluoranthene	34242	BENZO(K)FLUORANTHENE, TOTAL, WATER UG/L		0.0038	3
X	Beryllium	01012	BERYLLIUM, TOTAL (UG/L AS BE)		4	4
X	beta-BHC	39338	BETA BENZENE HEXACHLORIDE IN WHOLE WATER SAMP		0.0091	3
X	beta-Endosulfan	34356	ENDOSULFAN, BETA TOTWUG/L		0.056	2
X	beta-Endosulfan	82624	ENDOSULFAN, BETA, WH WATER, TOTAL RECOVERABLE,UG/L		0.056	2
X	Bis(2-Chloroethyl) Ether	34273	BIS (2-CHLOROETHYL) ETHER TOTWUG/L		0.03	3
X	Bis(2-Chloroisopropyl) Ether	73522	PROPANE, 2,2'-OXYBIS(1-CHLORO)- TOTWUG/L		1400	3
X	Bis(2-Ethylhexyl) Phthalate	39100	BIS(2-ETHYLHEXYL) PHTHALATE,WHOLE WATER,UG/L		1.2	3
X	Bromoform	32104	BROMOFORM,WHOLE WATER,UG/L		4.3	3
X	Butylbenzyl Phthalate	34292	N-BUTYL BENZYL PHTHALATE,WHOLE WATER,UG/L		1500	3
	Carbofuran	81405	CARBOFURAN (EURADAN) WHOLE WATER SAMPLE UG/L		40	4
	Carbofuran	82615	CARBOFURAN, WHOLE WATER, TOTAL RECOVERABLE UG/L		40	4
X	Carbon Tetrachloride	32102	CARBON TETRACHLORIDE,WHOLE WATER,UG/L		0.23	3

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	Chlordane	39350	CHLORDANE(TECH MIX & METABS),WHOLE WATER,UG/L		0.0008	3
	Chloride	00940	CHLORIDE,TOTAL IN WATER MG/L		230	2
	Chlorine	50074	CHLORITE WHOLE WATER,MG/L		0.011	2
X	Chlorobenzene	34301	CHLOROBENZENE TOTWUG/L		100	4
X	Chlorodibromomethane	34306	CHLORODIBROMOMETHANE TOTWUG/L		0.4	3
X	Chloroform	32106	CHLOROFORM,WHOLE WATER,UG/L		5.7	3
	Chlorophenoxy Herbicide (2,4,5,-TP)	39760	SILVEX IN WHOLE WATER SAMPLE (UG/L)		10	3
	Chlorophenoxy Herbicide (2,4-D)	39730	2,4-D IN WHOLE WATER SAMPLE (UG/L)		70	4
	Chloropyrifos	38932	CHLORPYRIFOS, TOTAL RECOVERABLE UG/L		0.041	2
	Chloropyrifos	77969	CHLOROPYRIFOS IN WATER UG/L		0.041	2
	Chloropyrifos	81403	DURSBAN(CHLOROPYRIFOS)WHOLE WATER SAMPLE (UG/L)		0.041	2
X	Chrysene	34320	CHRYSENE TOTWUG/L		0.0038	3
	cis-1,2-Dichloroethylene	77093	CIS-1,2-DICHLOROETHYLENE WHOLE WATER,UG/L		70	4
X	Cyanide	00720	CYANIDE, TOTAL (MG/L AS CN) MG/L		0.0052	2
	Dalapon	30200	DALAPON, WATER, WHOLE, RECOVERABLE UG/L		200	4
	Dalapon	38432	DALAPON WATER, TOTUG/L		200	4
X	delta-BHC	34259	DELTA BENZENE HEXACHLORIDE TOTWUG/L		0.0123	3
X	delta-BHC	46323	DELTA-BHC IN WHOLE WATER SMAPLE (UG/L)		0.0123	3
	Demeton	39560	DEMETON IN WHOLE WATER SAMPLE (UG/L)		0.1	2

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	Dibenzo(a,h)Anthracene	34556	1,2,5,6-DIBENZANTHRACENE TOTWUG/L		0.0038	3
X	Dichlorobromomethane	32101	BROMODICHLOROMETHANE,WHOLE WATER,UG/L		0.55	3
	Dichloromethane	03764	DICHLOROMETHANE, TOTAL, EFFLUENT MG/L		0.005	4
	Dichloromethane	03821	DICHLOROMETHANE,TOTAL,EFFLUENT UG/L		5	4
X	Dieldrin	39380	DIELDRIN IN WHOLE WATER SAMPLE (UG/L)		0.000052	3
X	Diethyl Phthalate	34336	DIETHYL PHTHALATE TOTWUG/L		17000	3
X	Dimethyl Phthalate	34341	DIMETHYL PHTHALATE TOTWUG/L		270000	3
X	Di-n-Butyl Phthalate	39110	DI-N-BUTYL PHTHALATE,WHOLE WATER,UG/L		2000	3
	Dinitrophenols	22411	DINITROPHENOL,2,5-, TOTAL, WATER UG/L		69	3
	Dinoseb	30191	DINOSEB, WATER, WHOLE, RECOVERABLE UG/L		7	4
	Diquat	04443	DIQUAT, WATER TOTAL, UG/L		20	4
	Ecoli	31633	E.COLI,THERMOTOL,MF,M-TEC,IN SITU UREASE #/100ML		200	6
	Ecoli	31648	E. COLI - MTEC-MF N0/100ML		200	5
X	Endosulfan Sulfate	34351	ENDOSULFAN SULFATE TOTWUG/L		62	3
	Endothall	38926	ENDOTHALL WHOLE WATER SAMPLE UG/L		100	4
X	Endrin	39390	ENDRIN IN WHOLE WATER SAMPLE (UG/L)		0.036	2
X	Endrin Aldehyde	34366	ENDRIN ALDEHYDE TOTWUG/L		0.29	3
	Ether, Bis(Chloromethyl)	34268	BIS (CHLOROMETHYL) ETHER TOTWUG/L		0.0001	3
X	Ethylbenzene	34371	ETHYLBENZENE TOTWUG/L		530	3

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
	Ethylene dibromide	46369	ETHYLENE DIBROMIDE, TOTAL, WASTE UG/L		0.05	4
X	Fluoranthene	34376	FLUORANTHENE TOTWUG/L		130	3
X	Fluorene	34381	FLUORENE TOTWUG/L		1100	3
	Fluoride	00950	FLUORIDE, DISSOLVED (MG/L AS F)		4	4
	Fluoride	00951	FLUORIDE, TOTAL (MG/L AS F)		4	4
X	gamma-BHC (Lindane)	39340	GAMMA-BHC(LINDANE),WHOLE WATER,UG/L		0.2	4
X	gamma-BHC (Lindane)	39782	LINDANE IN WHOLE WATER SAMPLE (UG/L)		0.2	4
	Glyphosate	79743	GLYPHOSATE(GLYCINE,N-(PHOSPHONOMETHYL)-) TOTWUG/L		700	4
X	Heptachlor	39410	HEPTACHLOR IN WHOLE WATER SAMPLE (UG/L)		0.000079	3
X	Heptachlor	46326	HEPTACHLOR AND METABOLITES IN WHOL H2O SMPL(UG/L)		0.000079	3
X	Heptachlor Epoxide	39420	HEPTACHLOR EPOXIDE IN WHOLE WATER SAMPLE (UG/L)		0.000039	3
X	Hexachlorobenzene	82621	HEXACHLOROBENZENE, WATER, TOTAL RECOVERABLE UG/L		0.00028	3
X	Hexachlorobutadiene	34391	HEXACHLOROBUTADIENE TOTWUG/L		0.44	3
X	Hexachlorobutadiene	49915	HEXACHLOROBUTADIENE BY VOA, TOTAL, WATER UG/L		0.44	3
X	Hexachlorocyclopentadiene	34386	HEXACHLOROCYCLOPENTADIENE TOTWUG/L		40	3
X	Hexachloroethane	34396	HEXACHLOROETHANE TOTWUG/L		1.4	3
X	Ideno(1,2,3-cd)Pyrene	34403	INDENO (1,2,3-CD) PYRENE TOTWUG/L		0.0038	3
	Iron	74010	IRON, TOTAL (MG/L AS FE)		300	3

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	Isophorone	34408	ISOPHORONE TOTWUG/L		35	3
	Malathion	39530	MALATHION IN WHOLE WATER SAMPLE (UG/L)		0.1	2
	Manganese	01055	MANGANESE, TOTAL (UG/L AS MN)		50	3
	Manganese	49065	MANGANESE, TOTAL, WATER, TCLP MG/L		0.05	3
X	Mercury	71890	MERCURY, DISSOLVED (UG/L AS HG)		0.77	2
X	Mercury	71900	MERCURY, TOTAL (UG/L AS HG)		0.91	2
X	Mercury	71901	MERCURY,TOTAL RECOVERABLE IN WATER AS HG UG/L		0.91	2
	Methoxychlor	39480	METHOXYCHLOR IN WHOLE WATER SAMPLE (UG/L)		0.03	2
X	Methyl Bromide	30202	BROMOMETHANE, WATER, WHOLE, RECOVERABLE, UG/L		47	3
X	Methyl Bromide	34413	METHYL BROMIDE TOTWUG/L		47	3
X	Methylene Chloride	34423	METHYLENE CHLORIDE TOTWUG/L		4.6	3
	Mirex	39755	MIREX, TOTAL (UG/L)		0.001	2
	Nitrate (as N)	00620	NITRATE NITROGEN, TOTAL (MG/L AS N)		10	4
	Nitrates	71850	NITRATE NITROGEN,TOTAL (MG/L AS NO3)		10	3
	Nitrates	71887	NITROGEN, TOTAL, AS NO3 - MG/L		10	3
	Nitrite (as N)	00615	NITRITE NITROGEN, TOTAL (MG/L AS N)		1	4
X	Nitrobenzene	34447	NITROBENZENE TOTWUG/L		17	3
	Nitrogen	00600	NITROGEN, TOTAL (MG/L AS N)		1.03	5
	Nitrosodibutylamine,N	78207	N-NITROSODIBUTYLAMINE IN WHOLE WATER UG/L		0.0063	3
	Nitrosodiethylamine,N	73611	ETHANAMINE, N-ETHYL-N-NITROSO- TOTWUG/L		0.0008	3
	Nitrosodiethylamine,N	78200	N-NITROSODIETHYLAMINE IN WHOLE WATER UG/L		0.0008	3

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
	Nitrosopyrrolidine,N	73620	PYRROLIDINE, 1-NITROSO- TOTWUG/L		0.016	3
	Nitrosopyrrolidine,N	78206	N-NITROSOPYRROLIDINE IN WHOLE WATER UG/L		0.016	3
X	N-Nitrosodimethylamine	34438	N-NITROSODIMETHYLAMINE TOTWUG/L		0.00069	3
X	N-Nitrosodi-n-Propylamine	34428	N-NITROSODI-N-PROPYLAMINE TOTWUG/L		0.005	3
X	N-Nitrosodiphenylamine	34433	N-NITROSODIPHENYLAMINE TOTWUG/L		3.3	3
	Oxamyl (Vydate)	38865	OXAMYL WATER, TOTUG/L		200	4
	Oxamyl (Vydate)	50410	OXAMYL OXIME,WATER,FILTERED,RECOVERABLE UG/L		200	4
	Oxygen, Dissolved Freshwater	00299	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	X	5	6
	Oxygen, Dissolved Freshwater	00300	OXYGEN, DISSOLVED MG/L	X	5	6
	Oxygen, Dissolved Freshwater	00389	OXYGEN,DISS.,LAB ANAL BY PROBE OF FIELD SMPL MG/L	X	5	6
	Parathion	39540	PARATHION IN WHOLE WATER SAMPLE (UG/L)		0.013	2
	Parathion	46315	ETHYL PARATHION IN WHOLE WATER SAMPLE (UG/L)		0.013	2
	Pentachlorobenzene	77793	PENTACHLOROBENZENE WHOLE WATER,UG/L		1.4	3
X	Pentachlorophenol	39032	PCP (PENTACHLOROPHENOL) WHOLE WATER SAMPLE UG/L		0.27	3
	pH	00400	PH (STANDARD UNITS)	X	6	6
	pH	00400	PH (STANDARD UNITS)		9	2
	pH	00403	PH, LAB, STANDARD UNITS SU	X	6	6

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
	pH	00403	PH, LAB, STANDARD UNITS SU		9	2
	pH	00406	PH, FIELD, STANDARD UNITS SU	X	6	6
	pH	00406	PH, FIELD, STANDARD UNITS SU		9	2
	pH	00407	PH (FIELD - LITMUS) SU		9	2
	pH	00407	PH (FIELD - LITMUS) SU	X	6	6
X	Phenol	34694	PHENOL(C6H5OH)-SINGLE COMPOUND TOTWUG/L		21000	3
	Phosphorus Elemental	00662	PHOSPHORUS (P), WATER, TOTAL RECOVERABLE UG/L		68	5
	Phosphorus Elemental	00665	PHOSPHORUS, TOTAL (MG/L AS P)		0.1	6
	Phosphorus Elemental	70505	PHOSPHATE,TOTAL,COLORIMETRIC METHOD (MG/L AS P)		0.068	5
	Picloram	39720	PICLORAM IN WHOLE WATER SAMPLE (UG/L)		500	4
X	Polychlorinated Biphenyls PCBs:	79819	POLYCHLORINATED BIPHENYLS (PCBS),TOTAL,WATER PG/L		0.000064	3
X	Pyrene	34469	PYRENE TOTWUG/L		830	3
	Simazine	04035	SIMAZINE, DISSOLVED, WATER, TOTAL RECOVERABLE UG/L		4	4
	Simazine	39055	SIMAZINE IN WHOLE WATER (UG/L)		4	4
	Styrene	77128	STYRENE WHOLE WATER,UG/L		100	4
	Styrene	81708	STYRENE IN THE WHOLE WATER SAMPLE MG/L		100	4
	Sulfide-Hydrogen Sulfide	71875	HYDROGEN SULFIDE (MG/L)		2	2
	Tetrachlorobenzene,1,2,4,5-	77734	1,2,4,5-TETRACHLOROBENZENE WHOLE WATER,UG/L		0.97	3
X	Tetrachloroethylene	34475	TETRACHLOROETHYLENE TOTWUG/L		0.69	3
	Tetrachloroethylene	61037	DELTA HELIUM-3,INGROWTH,ERROR,WATER,UNFILTCC@STP/G		5	4

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

USEPA Priority Pollutant [1]	Pollutant [2]	PARM CODE [3]	Parameter Description [4]	Lower Limit [5]	Limit Criterion[6]	Limit Source [7]
X	Tetrachloroethylene	61057	PERCHLOROETHYLENE,TOT,WATER UG/L		0.69	3
X	Thallium	01059	THALLIUM, TOTAL (UG/L AS TL)		0.24	3
X	Toluene	78131	TOLUENE IN WHOLE WATER (VOLATILE ANALYSIS) UG/L		1000	4
X	Toxaphene	39400	TOXAPHENE IN WHOLE WATER SAMPLE (UG/L)		0.0002	2
	Tributyltin (TBT)	03824	TRIBUTYLTIN,TOTAL,EFFLUENT UG/L		0.072	2
	Tributyltin (TBT)	30340	TRIBUTYLTIN, WATER, WHOLE, AS TIN UG/L		0.072	2
X	Trichloroethylene	39180	TRICHLOROETHYLENE-WHOLE WATER SAMPLE-UG/L		2.5	3
	Trichlorophenol,2,4,5-	77687	2,4,5-TRICHLOROPHENOL WHOLE WATER,UG/L		1800	3
	Turbidity	00076	TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)		10.4	5
	Turbidity	82078	TURBIDITY,FIELD NEPHELOMETRIC TURBIDITY UNITS,NTU		10.4	5
	Turbidity	82079	TURBIDITY,LAB NEPHELOMETRIC TURBIDITY UNITS, NTU		10.4	5
	Uranium	50588	URANIUM TOTAL UG/L		30	4
X	Vinyl Chloride	39175	VINYL CHLORIDE-WHOLE WATER SAMPLE-UG/L		0.025	3
	Xylenes (total)	80353	XYLENE ISOMERS, O+P, WHOLE WATER UG/L		10000	4
	Xylenes (total)	81551	XYLENE WHL WATER SMPL UG/L		10000	4

APPENDIX D: Designated Limit Criteria for Parameters Relevant to Hot Springs National Park (HOSP) (*continued*)

NOTES:
[1] Indicates parameter is categorized by USEPA as a priority pollutant (USEPA 2004b).
[2] Name of pollutant in USEPA criteria documents (USEPA 2004a, b).
[3] USEPA Storage and Retrieval (STORET) parameter code. This code is also used in the Baseline Report (National Park Service 1998) and other NPS databases.
[4] Description of the phase and actual measurement technique for this parameter.
[5] Indicates the criterion for this value is a lower limit (i.e. lowest permissible value). Criteria are upper limits unless indicated here.
[6] Units of limit criterion are the same as those of the parameter. The value is the most restrictive of the following four criteria:

Aquatic Life: Freshwater Criterion Maximum Concentration (CMC) (acute)
Aquatic Life: Freshwater Criterion Chronic Concentration (CCC) (chronic)
Human Health: Water-Organism Consumption
Drinking Water Standard: Maximum Concentration Load (MCL)

"Most restrictive" means the lowest upper limit or the highest lower limit. For example, total arsenic has a Criterion Maximum Concentration (CMC) of 340 µg/L, a Criterion Chronic Concentration (CCC) of 150 µg/L, a Water-Organism Criterion of 0.018 µg/L, and a Maximum Contaminant Load (MCL) of 10 µg/L. The designated limit criterion is the most restrictive of these, namely 0.018 µg/L.
[7] 1 = CMC (USEPA 2004b); 2 = CCC (USEPA 2004b); 3 = Water-Organism (USEPA 2004b); 4 = MCL (USEPA 2004a); 5 = Potential Regional Benchmark Value (Huggins 2005); 6 = State of Arkansas criterion value (ADPC&E 1998)

APPENDIX E: Hot Springs National Park (HOSP) Potential Concerns Exceedance Data

These data were used to develop Table 9 and Table 10 for the identification of potential water quality concerns for this park. For more information on the background and methods of these analyses, please see the potential concerns analysis section of this report.

Hot Springs National Park (HOSP) Exceedances by Waterbody and Parameter

Waterbody Code[1]	Waterbody Name[2]	Parameter Description[3]	Limit Criterion[4]	Limit Source[5]	Exceed. Count[6]	Total Count[7]	% Exceed.[8]	Lower Limit[9]
2	Gulpha Creek	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	11	154	7.1	
2	Hot Springs Creek	NITRITE NITROGEN, TOTAL (MG/L AS N)	1	4	5	25	20.0	
2	Hot Springs Creek	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	39	546	7.1	
2	Stokes Creek	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5	6	1	18	5.6	X
2	Stokes Creek	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	2	4	50.0	
2	Bull Bayou	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5	6	1	18	5.6	X
2	Bull Bayou	TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)	10.4	5	1	11	9.1	

[1] 1 = Main Stem; 2 = Tributaries; 3 = Springs; 4 = Lentic Waters; 5 = Point Sources
[2] Name of waterbody. See Appendix B and park map (Figure 3) for locations of all stations with respect to waterbody. Upstream or downstream refer to the portion of the Current River upstream or downstream of the confluence with the Jacks Fork River.
[3] Description of the phase and actual measurement technique for this parameter.
[4] Units of limit criterion are the same as those of the parameter. The value is the most restrictive of the following four criteria:

Aquatic Life: Freshwater Criterion Maximum Concentration (CMC) (acute)
Aquatic Life: Freshwater Criterion Chronic Concentration (CCC) (chronic)
Human Health: Water-Organism Consumption
Drinking Water Standard: Maximum Concentration Load (MCL)

"Most restrictive" means the lowest upper limit or the highest lower limit. For example, total arsenic has a Criterion Maximum Concentration (CMC) of 340 µg/L, a Criterion Chronic Concentration (CCC) of 150 µg/L, a Water-Organism Criterion of 0.018 µg/L, and a Maximum Contaminant Load (MCL) of 10 µg/L. The designated limit criterion is the most restrictive of these, namely 0.018 µg/L. The aquatic life criteria for these parameters were derived from the hardness-dependent equations published in the National Recommended Water Quality Criteria document (USEPA 2004b).

[5] 1 = CMC (USEPA 2004b); 2 = CCC (USEPA 2004b); 3 = Water-Organism (USEPA 2004b); 4 = MCL (USEPA 2004a); 5 = Potential Regional Benchmark Value (Huggins 2005); 6 = State of Arkansas criterion value (ADPC&E 1998)
[6] Exceedance Count = Number of times observed value exceeded limit criterion for this parameter.
[7] Total Count = Total number of observations of this parameter.
[8] % Exceedance = Exceedance Count divided by Total Count multiplied by 100, or the percentage of observations that exceed the limit criterion for this parameter
[9] This limit criterion is a lower limit. Unless marked in this column, limit criteria are upper limits.

Hot Springs National Park (HOSP) Exceedances by Waterbody, Location, and Parameter

Waterbody Code [1]	Waterbody Name[2]	NPSSTATID[3]	Parameter Description [4]	Limit Criterion[5]	Limit Source[6]	Exceed. Count[7]	Total Count[8]	% Exceed.[9]	Lower Limit[10]
2	Gulpha Creek	HOSP0004	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	11	154	7.1	
2	Hot Springs Creek	HOSP0030	NITRITE NITROGEN, TOTAL (MG/L AS N)	1	4	3	15	20.0	
2	Hot Springs Creek	HOSP0030	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	14	196	7.1	
2	Hot Springs Creek	HOSP0031	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	14	196	7.1	
2	Hot Springs Creek	HOSP0032	NITRITE NITROGEN, TOTAL (MG/L AS N)	1	4	2	10	20.0	
2	Hot Springs Creek	HOSP0032	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	11	154	7.1	
2	Stokes Creek	HOSP0099	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5	6	1	18	5.6	X
2	Stokes Creek	HOSP0099	PHOSPHORUS, TOTAL (MG/L AS P)	0.068	5	2	4	50.0	
2	Bull Bayou	HOSP0105	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5	6	1	18	5.6	X
2	Bull Bayou	HOSP0105	TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)	10.4	5	1	11	9.1	

APPENDIX E: Hot Springs National Park (HOSP) Exceedances by Waterbody, Location, and Parameter (*continued*)

NOTES:
[1] 1 = Main Stem; 2 = Tributaries; 3 = Springs
[2] Name of waterbody. See Appendix B and park map (Figure 3) for locations of all stations with respect to waterbody. Upstream or downstream refer to the portion of the Current River upstream or downstream of the confluence with the Jacks Fork River.
[3] NPS Station ID code. This code has been assigned by NPS for unique identification of locations. See Appendix B for complete list.
[4] Description of the phase and actual measurement technique for this parameter.
[5] Units of limit criterion are the same as those of the parameter. The value is the most restrictive of the following four criteria:

Aquatic Life: Freshwater Criterion Maximum Concentration (CMC) (acute)
Aquatic Life: Freshwater Criterion Chronic Concentration (CCC) (chronic)
Human Health: Water-Organism Consumption
Drinking Water Standard: Maximum Concentration Load (MCL)

"Most restrictive" means the lowest upper limit or the highest lower limit. For example, total arsenic has a Criterion Maximum Concentration (CMC) of 340 µg/L, a Criterion Chronic Concentration (CCC) of 150 µg/L, a Water-Organism Criterion of 0.018 µg/L, and a Maximum Contaminant Load (MCL) of 10 µg/L. The designated limit criterion is the most restrictive of these, namely 0.018 µg/L. The aquatic life criteria for these parameters were derived from the hardness-dependent equations published in the National Recommended Water Quality Criteria document (USEPA 2004b).

[6] 1 = CMC (USEPA 2004b); 2 = CCC (USEPA 2004b); 3 = Water-Organism (USEPA 2004b); 4 = MCL (USEPA 2004a); 5 = Potential Regional Benchmark Value (Huggins 2005) (Huggins 2005); 6 = State of Arkansas criterion value (ADPC&E 1998).
[7] Exceedance Count = Number of times observed value exceeded limit criterion for this parameter.
[8] Total Count = Total number of observations of this parameter.
[9] % Exceedance = Exceedance Count divided by Total Count multiplied by 100, or the percentage of observations that exceed the limit criterion for this parameter.
[10] This limit criterion is a lower limit. Unless marked in this column, limit criteria are upper limits.