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Graphical User Interface for Accessing Water-Quality Data for the Devils Lake Basin, North Dakota

Open-File Report 2005–1419

U.S. Department of the Interior
U.S. Geological Survey

Ryberg, Damschen, and Vecchia—Graphical User Interface for Accessing Water-Quality Data for the Devils Lake Basin, North Dakota—Open-File Report 2005–1419

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By Karen R. Ryberg, William C. Damschen, and Aldo V. Vecchia

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Abstract

Maintaining the quality of surface waters in the Devils Lake Basin in North Dakota is important for protecting the agricultural resources, fisheries, waterfowl and wildlife habitat, and recreational value of the basin. The U.S. Geological Survey, in cooperation with local, State, and Federal agencies, has collected and analyzed water-quality samples from streams and lakes in the basin since 1957, and the North Dakota Department of Health has collected and analyzed water-quality samples from lakes in the basin since 2001. Because water-quality data for the basin are important for numerous reasons, a graphical user interface was developed to access, view, and download the historical data for the basin. The interface is a web-based application that is available to the public and includes data through water year 2003. The interface will be updated periodically to include data for subsequent years.

Introduction

The Devils Lake Basin in North Dakota is a 3,810-square-mile subbasin in the Red River of the North Basin (fig. 1). From 1957 to the present (2005), the U.S. Geological Survey (USGS) has collected and analyzed water-quality samples from streams and lakes in the Devils Lake Basin in cooperation with the Devils Lake Basin Joint Water Resources Board, the North Dakota State Water Commission, the North Dakota Department of Health, the U.S. Army Corps of Engineers, and other local, State, and Federal agencies. From 2001 to the present, the North Dakota Department of Health also has collected and analyzed water-quality samples from the various bays of Devils Lake in conjunction with ongoing USGS sampling programs.

Maintaining the quality of surface waters in the Devils Lake Basin is important for protecting the agricultural resources, fisheries, waterfowl and wildlife habitat, and recreational value of the basin. Water-quality data for the Devils Lake Basin are important for the assessment of water quality in the basin in relation to established water-quality standards and guidelines, the determination of water-quality changes with time, the determination of the causes of and potential mitigation measures for adverse water-quality conditions, and the establishment of an efficient long-term sampling program to monitor future water-quality conditions. Historical water-quality data for the Devils Lake Basin also need to be readily available to numerous agencies and individuals concerned with the aquatic health of the basin. Therefore, for this study, the USGS, in cooperation with the North Dakota State Water Commission, Devils Lake Basin Joint Water Resources Board, and Red River Joint Water Resources Board, developed a graphical user interface to access, view, and download water-quality data for the Devils Lake Basin. This report describes the interface and provides links to Internet addresses used in the interface. Although data for the Devils Lake Basin are available from the USGS National Water Information System (NWISWeb) (http://waterdata.usgs.gov/nwis/qw) and from the North Dakota Department of Health (http://www.health.state.nd.us/wq/sw/A_Publications.htm) databases, graphical user interfaces for accessing the data have not been available.

In the development of the graphical user interface, the large volumes of historical water-quality data available from the USGS and North Dakota Department of Health databases were simplified by selecting the water-quality sampling sites and parameters that provided the most useful and reliable information for the assessment of water quality in the Devils Lake Basin. The most recent data included for this report were for water year[1] 2003. The interface will be updated periodically to include data for subsequent water years.

Graphical User Interface

Water-Quality Sampling Sites and Parameters

The surface-water drainage system of the Devils Lake Basin is a complex system of interconnected tributaries and lakes (Wiche and others, 1986). Most surface runoff from the

[1]A water year is defined as the 12-month period from October 1 through September 30 and is designated by the calendar year in which it ends. Thus, the year ending September 30, 2003, is called water year 2003.

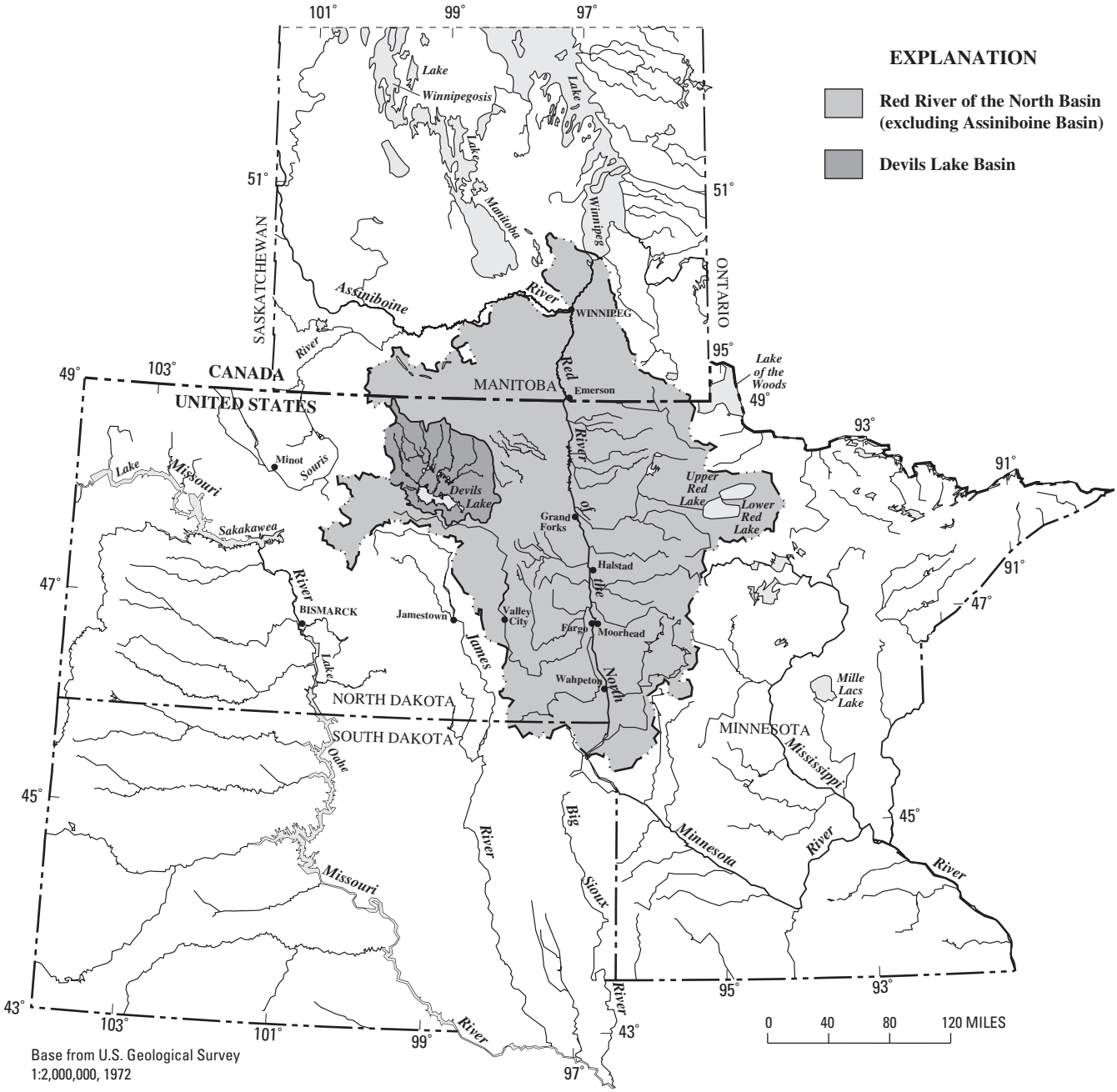

Figure 1. Location of the Devils Lake Basin in North Dakota.

upper basin flows through several major tributaries (Edmore, Starkweather, Calio, and Mauvais Coulees; fig. 2) into a series of interconnected lakes north of Devils Lake (Sweetwater, Morrison, Dry, Mikes, and Chain Lakes and Lakes Alice and Irvine). Outflow from the upstream chain of lakes flows into Devils Lake through either Big Coulee or Channel A. Before 1979, all outflow from the upstream chain of lakes flowed through Big Coulee into Pelican Lake and eventually into Devils Lake. In 1979, the Ramsey County and Cavalier County Water Management Boards constructed Channel A, which connects Dry Lake to Sixmile Bay of Devils Lake (fig. 2), and a levee was constructed across the natural outlet of Dry Lake to Mikes Lake. Thus, since 1979, outflow from Sweetwater, Morrison, and Dry Lakes has flowed through Channel A into Devils Lake and outflow from the remaining lakes has flowed through Big Coulee into Devils Lake. During extremely large floods, Dry Lake has overtopped the levees across the natural outlet, causing some flow to enter the natural watercourse. Because Devils Lake consists of a series of bays that are connected by bridge openings or culverts, the water quality between the bays can differ substantially (Sether and others, 1999).

Stump Lake Basin is a 490-square-mile subbasin within the Devils Lake Basin. Intermittent spills from Devils Lake to Stump Lake, though infrequent, have occurred. The most recent spill began in 2001 and continues to the present (2005). The most recent spill prior to 2001 probably occurred during the early 1800s (Wiche and others, 2000). Stump Lake has spilled to the Sheyenne River (a tributary to the Red River of the North) several times since the end of glaciation. The most recent spill was about 1,800 years ago (Bluemle, 1996). Severe flooding has occurred in the Devils Lake Basin since 1993, and the present (2005) levels of Devils Lake and Stump Lake are higher than at any other time since the early 1800s (Wiche and others, 2000). The potential for a future spill from Devils Lake to the Red River of the North, and recent construction of a temporary outlet from Devils Lake by the North Dakota State Water Commission, has increased the importance of easy access to historical water-quality data for the Devils Lake Basin as well as for downstream interests.

For this report, 21 tributary and lake sampling sites were used in the graphical user interface (table 1). Water-quality data were included for five sites on the upstream tributaries (sites 1 through 4 and site 7), five sites on the chain of lakes (sites 5 and 6 and sites 8 through 10), two sites on Big Coulee (sites 11 and 13), one site on Little Coulee (site 12), and one site on Channel A (site 14) (fig. 2). Water-quality data for three sites on Devils Lake (sites 15 through 17) and four sites in Stump Lake Basin (sites 18 through 21) also were included in the interface. Of the four sites in Stump Lake Basin, two (sites 18 and 19) are located in the upper basin and two (sites 20 and 21) are located on Stump Lake.

The procedures used to collect the water-quality samples and to measure field properties are described by the U.S. Geological Survey (variously dated). The North Dakota Department of Health procedures used to collect water-quality samples and to measure field properties closely follow the USGS procedures (Peter Wax, North Dakota Department of Health, written commun., 2005). The water-quality samples were analyzed by the USGS, National Water Quality Laboratory; the North Dakota Department of Health Laboratory; or the North Dakota State Water Commission Laboratory.

The water-quality parameters used in the graphical user interface (table 2) were determined on the basis of data availability and on the importance of the parameter to the aquatic health of the basin. The parameters were divided into four groups—major ions and dissolved solids, nutrients, trace elements, and physical properties. All available water-quality data for the sites used in the interface were examined.

The major ions and dissolved solids group includes dissolved ions and other dissolved constituents that comprise most of the dissolved-solids content in the stream or lake samples. Parameters in this group include dissolved major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, silica, bicarbonate, and carbonate); dissolved solids (the total dissolved-solids content of the water sample without regard to chemical species); hardness (a measure of the soap-consuming capacity of the water sample, primarily contributed by the divalent cations calcium and magnesium); and alkalinity (a measure of the acid-neutralizing capacity of the water sample, generally primarily related to concentrations of bicarbonate and carbonate). Most parameters in this category were measured in the laboratory using filtered water samples. However, field measurements using unfiltered water samples also were included for three of the parameters (bicarbonate, carbonate, and alkalinity).

The nutrients group includes chemical compounds that contain nitrogen and phosphorus. Because nutrients in surface water generally occur in both dissolved and particulate forms, the nutrient concentrations for both forms were included in the graphical user interface. The dissolved nutrient concentrations were determined using filtered water samples, and the total nutrient concentrations were determined using unfiltered water samples. Ammonia and nitrite plus nitrate are nitrogen compounds that occur primarily in the dissolved form. Concentrations of those parameters were determined using filtered water samples. Concentrations of total ammonia plus organic nitrogen were determined using unfiltered water samples. That parameter generally is mostly organic nitrogen and much of the organic nitrogen content of water samples is in the particulate form. Concentrations of total phosphate and total phosphorus were determined using unfiltered water samples, and concentrations of dissolved phosphorus and dissolved orthophosphate were determined using filtered water samples. Those four parameters are related to phosphorus.

The trace elements group includes parameters that generally are present in lower concentrations than major ions or nutri-

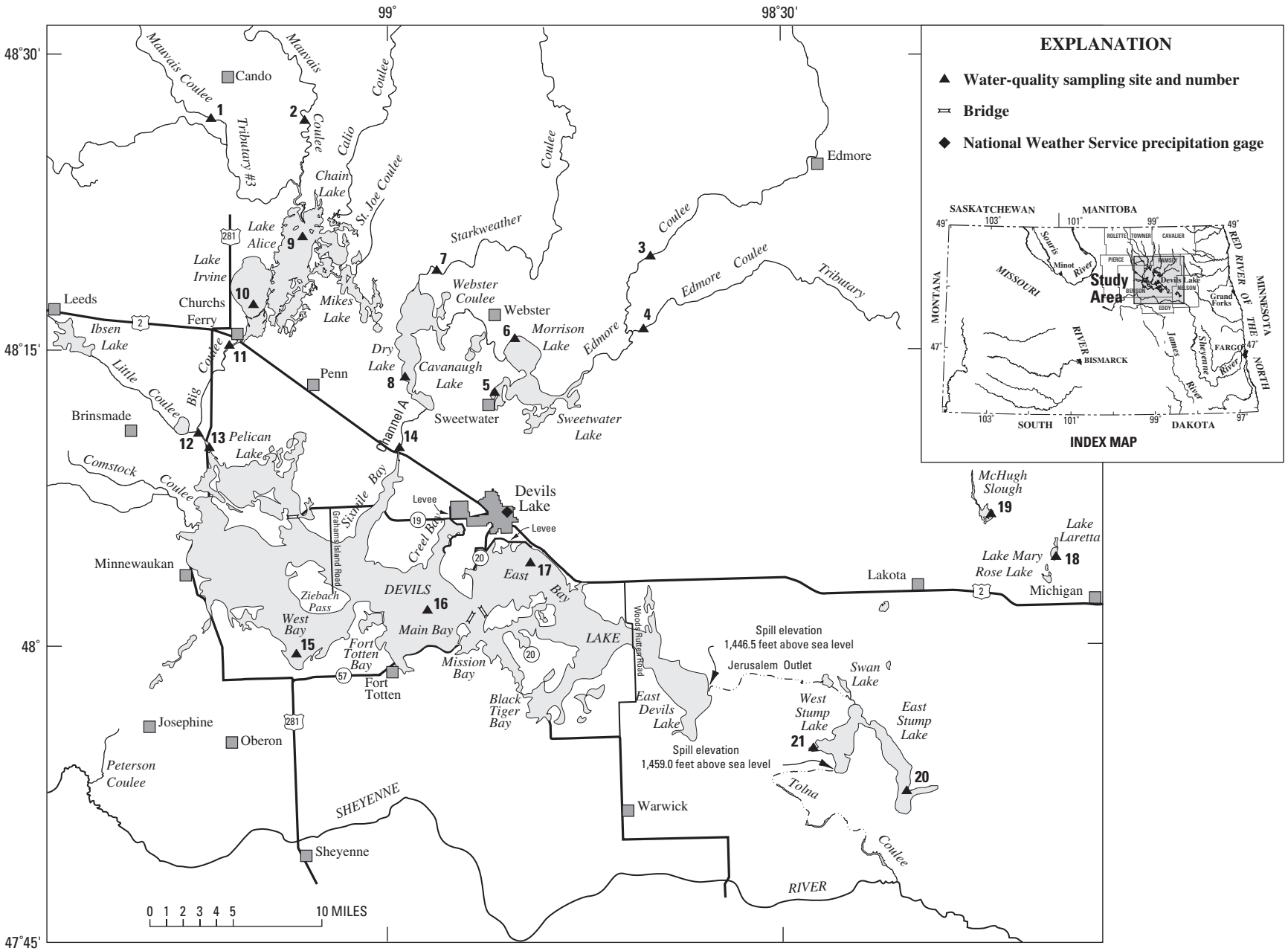

Figure 2. Locations of water-quality sampling sites used in graphical user interface.

Table 1. Water-quality sampling sites used in graphical user interface.

Site number (Figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name
1	05056060	Mauvais Coulee Tributary No. 3 near Cando, North Dakota
2	05056100	Mauvais Coulee near Cando, North Dakota
3	05056200	Edmore Coulee near Edmore, North Dakota
4	05056215	Edmore Coulee Tributary near Webster, North Dakota
5	05056220	Sweetwater Lake at Sweetwater, North Dakota
6	05056222	Morrison Lake near Webster, North Dakota
7	05056239	Starkweather Coulee near Webster, North Dakota
8	05056241	Dry Lake near Penn, North Dakota
9	05056250	Lake Alice near Churchs Ferry, North Dakota
10	05056260	Lake Irvine near Churchs Ferry, North Dakota
11	05056270	Big Coulee below Churchs Ferry, North Dakota
12	05056390	Little Coulee near Brinsmade, North Dakota
13	05056400	Big Coulee near Churchs Ferry, North Dakota
14	05056410	Channel A near Penn, North Dakota
15	480052099065400	Devils Lake, West Bay
16	480147098572200	Devils Lake, Main Bay
17	480407098491900	Devils Lake, East Bay
18	480339098101300	Lake Laretta near Michigan, North Dakota
19	480552098145300	McHugh Slough near Lakota, North Dakota
20	05056665	Eastern Stump Lake near Lakota, North Dakota
21	05056670	Western Stump Lake near Lakota, North Dakota

ents. For all trace elements except iron, concentrations were determined using filtered water samples and are reported as dissolved concentrations. Iron concentrations were included for both unfiltered and filtered water samples. A substantial part of the total iron content in natural waters can be in particulate form, and a substantial number of determinations of unfiltered iron concentrations occurred for the sites used in the interface.

The physical properties group includes parameters that were measured in the field during collection of water samples. Parameters in this group include water temperature, transparency (a measure of water clarity determined for lake samples), specific conductance (a measure of the electrical conductivity of water related to dissolved-solids content), sampling depth (the depth below water surface at which a given lake sample was collected), dissolved oxygen, and pH. The physical property values for stream samples were determined for a single sample because water in the streams in the Devils Lake Basin usually is well mixed. However, the physical property values for lake samples were determined either for a single, depth-integrated sample or for multiple samples collected at different depths. Because the physical and chemical characteristics of lake water can vary with depth, measurements determined for a

Table 2. Water-quality parameters used in graphical user interface.

[Parameters in the major ions and dissolved solids group and in the nutrients group are reported in milligrams per liter; parameters in the trace elements group are reported in micrograms per liter; USGS, U.S. Geological Survey; temperature is reported in degrees Celsius; transparency is reported in inches; specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius; sampling depth is reported in feet; dissolved oxygen is reported in milligrams per liter; pH is reported in standard units]

Major ions and dissolved solids		Nutrients		Trace elements		Physical properties	
USGS parameter code	Parameter name	USGS parameter code	Parameter name	USGS parameter code	Parameter name	USGS parameter code	Parameter name
P00915	Calcium, dissolved	P00608	Ammonia, dissolved	P01000	Arsenic, dissolved	P00010	Temperature, water
P00925	Magnesium, dissolved	P00631	Nitrite plus nitrate, dissolved	P01005	Barium, dissolved	P00077	Transparency
P00930	Sodium, dissolved	P00625	Ammonia plus organic nitrogen, total	P01020	Boron, dissolved	P00095	Specific conductance
P00935	Potassium, dissolved	P00650	Phosphate, total	P01025	Cadmium, dissolved	P00098	Sampling depth
P00940	Chloride, dissolved	P00665	Phosphorus, total	P01030	Chromium, dissolved	P00300	Dissolved oxygen
P00945	Sulfate, dissolved	P00666	Phosphorus, dissolved	P01035	Cobalt, dissolved	P00400	pH
P00950	Fluoride, dissolved	P00671	Orthophosphate, dissolved	P01040	Copper, dissolved		
P00955	Silica, dissolved			P01045	Iron, total recoverable		
P70301	Dissolved solids			P01046	Iron, dissolved		
P00900	Hardness (laboratory, filtered)			P01049	Lead, dissolved		
P00410	Alkalinity (field, unfiltered)			P01056	Manganese, dissolved		
P00440	Bicarbonate (field, unfiltered)			P01060	Molybdenum, dissolved		
P00445	Carbonate (field, unfiltered)			P01065	Nickel, dissolved		
				P01080	Strontium, dissolved		
				P01085	Vanadium, dissolved		
				P01090	Zinc, dissolved		
				P01106	Aluminum, dissolved		
				P01130	Lithium, dissolved		
				P01145	Selenium, dissolved		

single, depth-integrated sample may differ from those determined for multiple samples collected at different depths.

The number and type of water-quality parameters for which historical data are available for the Devils Lake Basin and the number of samples collected vary substantially from site to site and from year to year because of changes in funding levels, sampling objectives, and cooperating agencies that provide shared costs of the sampling programs. Also, because climatic conditions and, thus, water-quality conditions may be subject to long-term trends or patterns, data for different time periods may not be directly comparable. Similarly, data for two sites may not be directly comparable, even if the data were collected during a common time period, unless the number of samples collected and the times of sample collection are comparable. Therefore, because of the nonuniform sampling and because of other complications such as changes in laboratory methods used to determine chemical concentrations, care must be taken when interpreting water-quality data for the Devils Lake Basin.

Many of the nutrient and trace element concentrations given in the USGS and North Dakota Department of Health databases are censored values (values that are known to be less than a certain laboratory reporting level but for which the exact value is not known). The laboratory reporting level depends on the parameter for which the sample is being analyzed, the sensitivity of the laboratory analytical method used to determine the concentration, and the laboratory procedures used to establish the laboratory reporting level. Because the laboratory analytical methods and procedures used to establish laboratory reporting levels can change with time, multiple laboratory reporting levels can exist for any given parameter.

Water-Quality Data

Water-quality data for the sites (table 1) and parameters (table 2) used in the graphical user interface were obtained from USGS and North Dakota Department of Health databases. Using Perl [a high-level computer language well-suited for database access, graphical programming, and world wide web programming (Christiansen and Torkington, accessed January 13, 2005)], the data for each site were divided into separate files for each parameter group used in the interface. To accommodate censored values, the file for each group then was subdivided into two separate files—one for uncensored data and the other for censored values. A row was included in each file if data were available for any parameter in any of the four parameter groups used in the interface. Therefore, although each of the files for a given site [four for the uncensored data (one for each parameter group) and potentially four for the censored values if the data were censored] contains the same number of rows (each row corresponds to a particular water sample or measurement), some files may have a large number of missing values. However, by using this design, the files for the sites used in the interface can be merged easily, if desired. The files for each site and group can be obtained by selecting options given in the following section.

Application of Graphical User Interface

Using Perl, a Common Gateway Interface (CGI) application was programmed for the USGS North Dakota Water Science Center web site. This application allows users to select different site and parameter combinations for the period of record or for specified years and then to graph the data in the form of time-series plots or box plots.

The CGI interface for the generation of time-series plots is located at http://nd.water.usgs.gov/cgi-bin/devils_lake/ts.pl and is shown in figure 3 (see page 9). After a site and parameter combination is selected, the user can click the “Plot” button and the selected time-series plots are generated using Perl and gnuplot (the proper name gnuplot is spelled with a lowercase g). Gnuplot is a command-driven, interactive data file and function plotting program that is designed primarily for visual display of scientific data (Moore, accessed January 13, 2005). Examples of time-series plots generated by user selection of “05056260 Lake Irvine near Churchs Ferry, ND” in the Select Site(s) box, “Nitrite plus nitrate, dissolved” in the Nutrients box, and “Specific conductance” and “Sampling depth” in the Physical Properties box are shown in figures 4 through 6 (see pages 10 through 12). A beginning year of 1965 was selected so the graphs represent a common period for each parameter. The red markers in the figures indicate known values for the selected parameter, and the blue markers indicate censored values. As indicated in figure 4 (see page 10), the laboratory reporting level for dissolved nitrite plus nitrate changed during the sampling period. As indicated in figure 5 (see page 11), the number of specific-conductance values available for the Lake Irvine near Churchs Ferry, N. Dak., site for 1993-2003 was larger than the number available for previous years of record. As indicated in figure 6 (see page 12), physical properties were measured at multiple sampling depths beginning in 1993. Sampling depths for the Lake Irvine near Churchs Ferry, N. Dak., site were not reported for the previous years of record. A specific-conductance value that is not accompanied by a sampling depth generally represents either an average of several measurements that are made at multiple depths or a single measurement that is made approximately midway between the water surface and the lake bottom.

The CGI interface for the generation of box plots is located at http://nd.water.usgs.gov/cgi-bin/devils_lake/bp.pl and is shown in figure 7 (see page 13). Users may select from five groups of sites—(1) all sites, (2) Devils Lake sites, (3) Eastern and Western Stump Lake sites, (4) sites for other lakes in the Devils Lake Basin, and (5) streams in the Devils Lake Basin—and two time periods—the period of record or data

from 1990 through water year 2003. An example of box plots generated by the user selection of "Other Lakes in the Devils Lake Basin" in the Select Group of Sites box, "Boron, dissolved" in the Dissolved Trace Elements box, and "Period of Record" in the Select Time Period box is shown in figure 8 (see page 14). The box plot for a given site consists of a lower whisker that shows the minimum value for that site; a box that shows the lower quartile, median (in red), and upper quartile; and an upper whisker that shows the maximum value. By clicking on a box, a time-series plot of the data for that site also can be obtained.

Time-series plots also can be accessed by clicking on the basin map that is displayed at http://nd.water.usgs.gov/devilslake/waterquality.html and shown in figure 9 (see page 15). The red dots in the figure indicate the water-quality sampling sites used in the graphical user interface. In most Internet browsers, a caption that gives the site number and name will appear by rolling the mouse across one of the dots on the html webpage. Clicking on the dot will generate the time-series plots for all parameters for that site.

A "Get Data" link under each time-series plot provides users with access to the data. A link entitled "Instructions for Downloading Data to Microsoft Excel" also appears under each time-series plot to help users who are interested in downloading the data.

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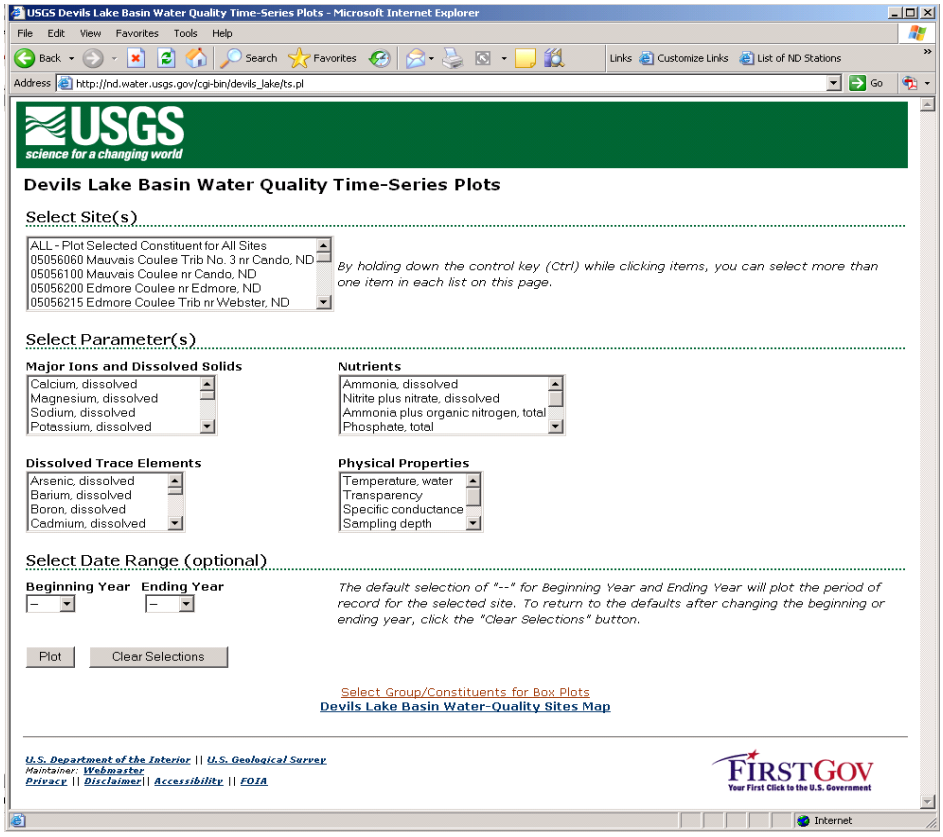

Figure 3. Interface for the generation of time-series plots (located at http://nd.water.usgs.gov/cgi-bin/devils_lake/ts.pl).

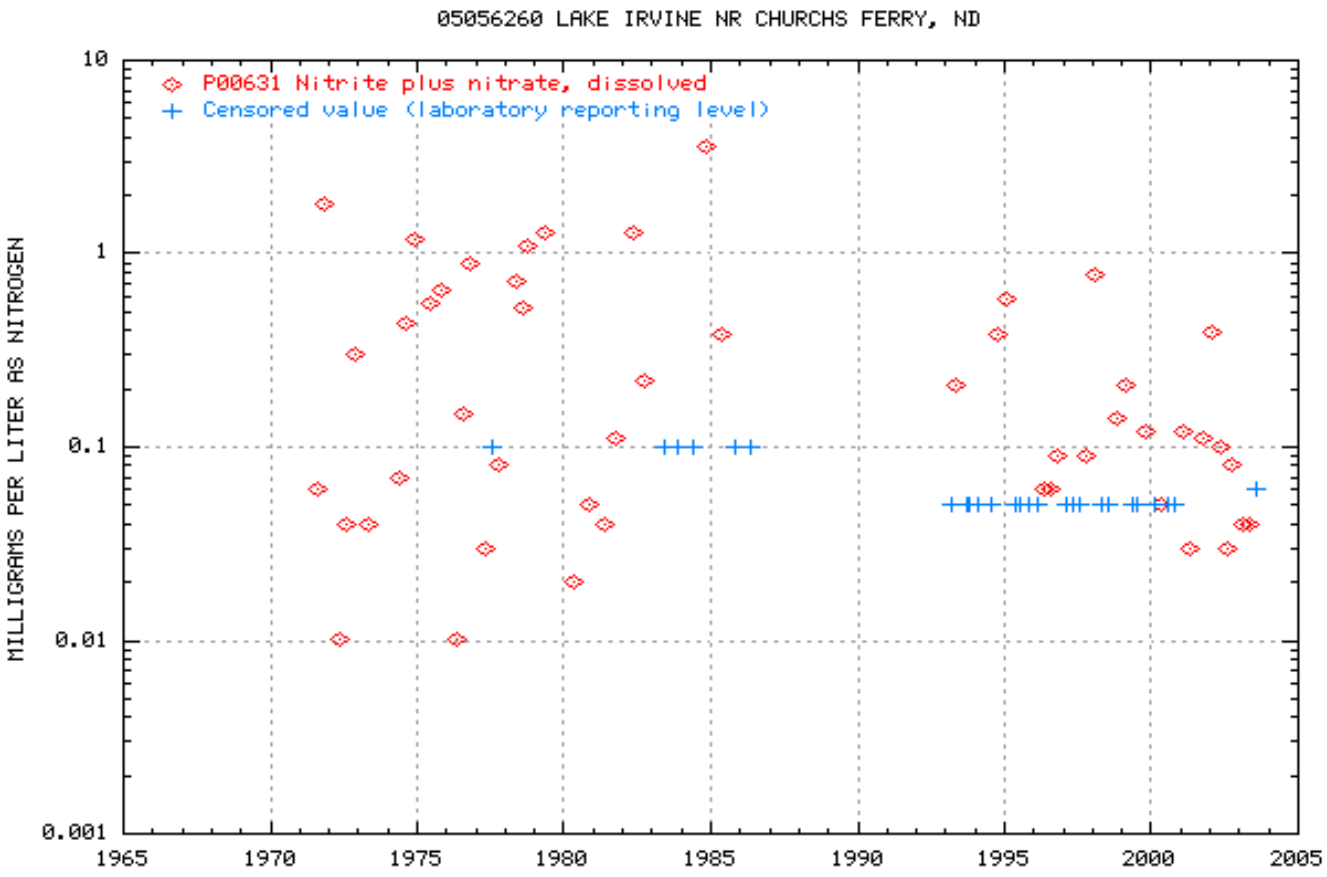

Figure 4. Time-series plot resulting from user selection of "05056260 Lake Irvine near Churchs Ferry, ND" in the Select Site(s) box, "Nitrite plus nitrate, dissolved" in the Nutrients box, and "1965" in the Beginning Year box.

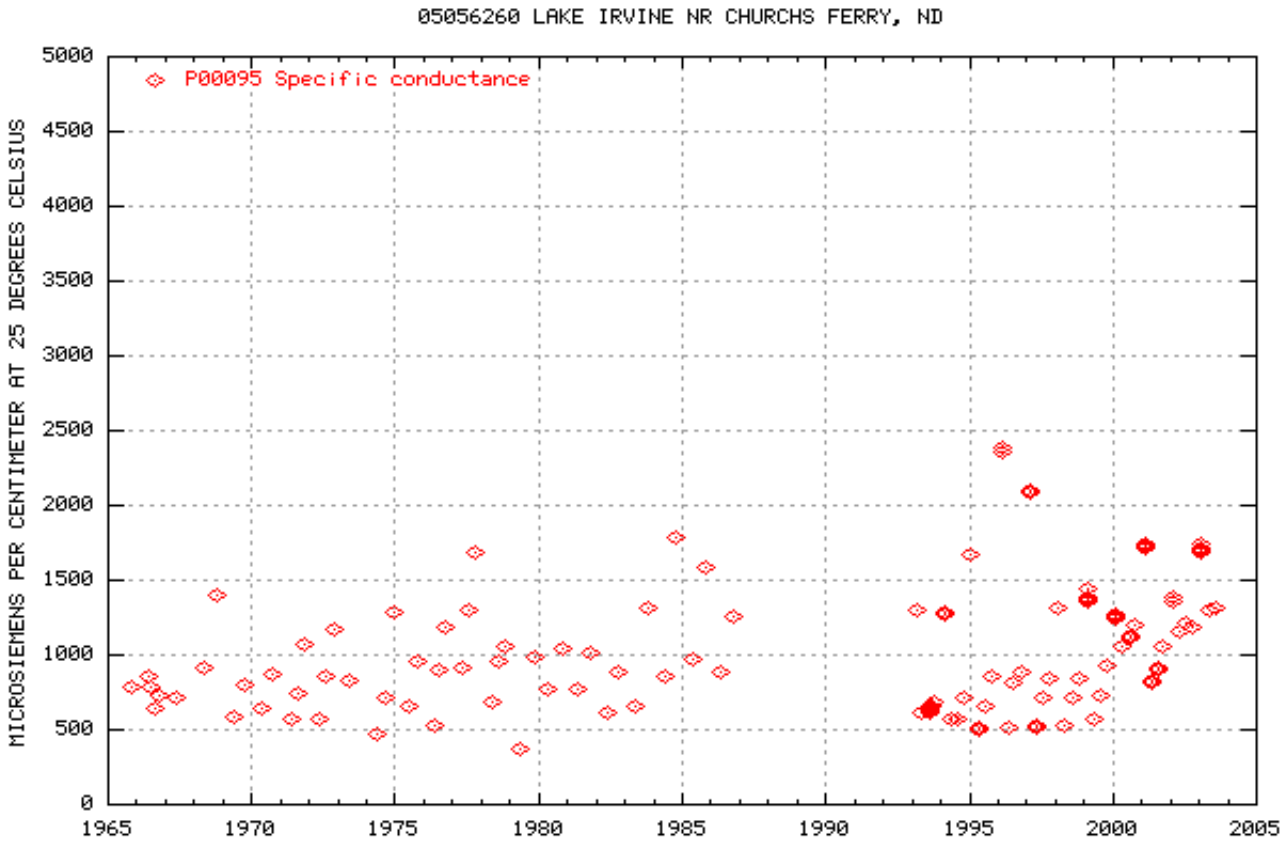

Figure 5. Time-series plot resulting from user selection of "05056260 Lake Irvine near Churchs Ferry, ND" in the Select Site(s) box, "Specific conductance" in the Physical Properties box, and "1965" in the Beginning Year box.

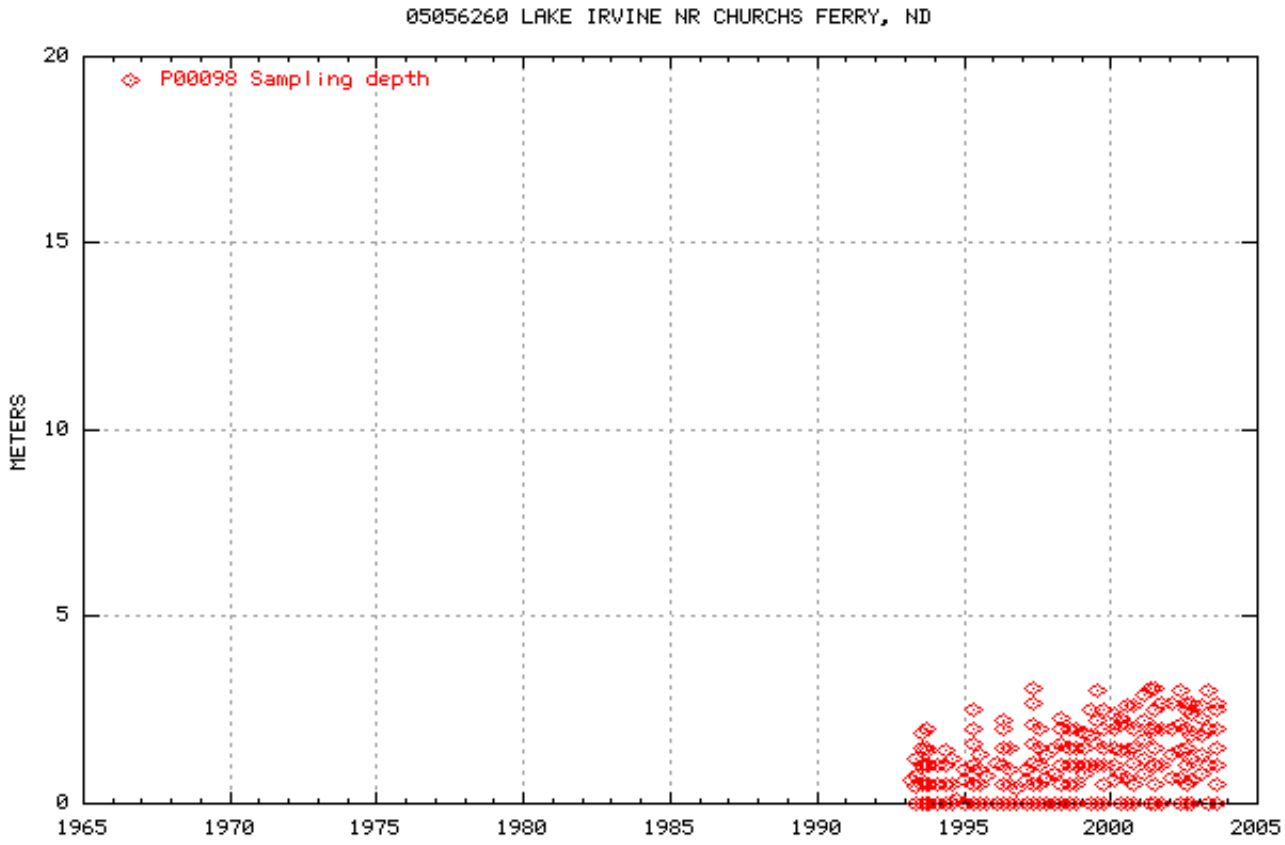

Figure 6. Time-series plot resulting from user selection of "05056260 Lake Irvine near Churchs Ferry, ND" in the Select Site(s) box, "Sampling depth" in the Physical Properties box, and "1965" in the Beginning Year box.

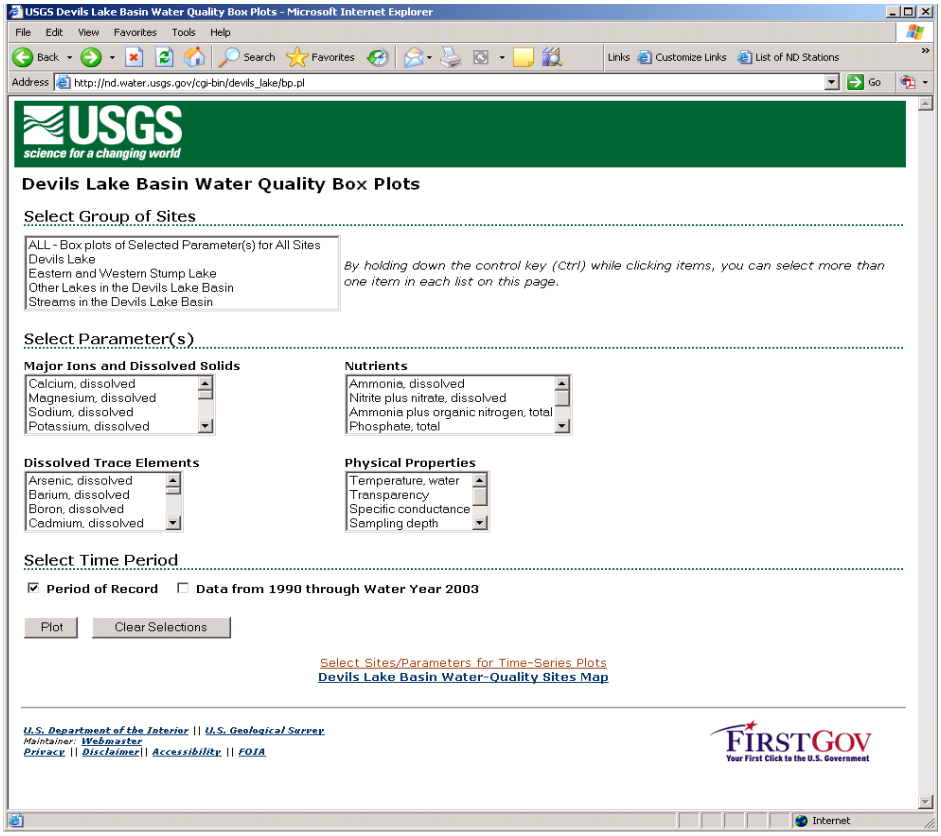

Figure 7. Interface for the generation of box plots (located at http://nd.water.usgs.gov/cgi-bin/devils_lake/bp.pl).

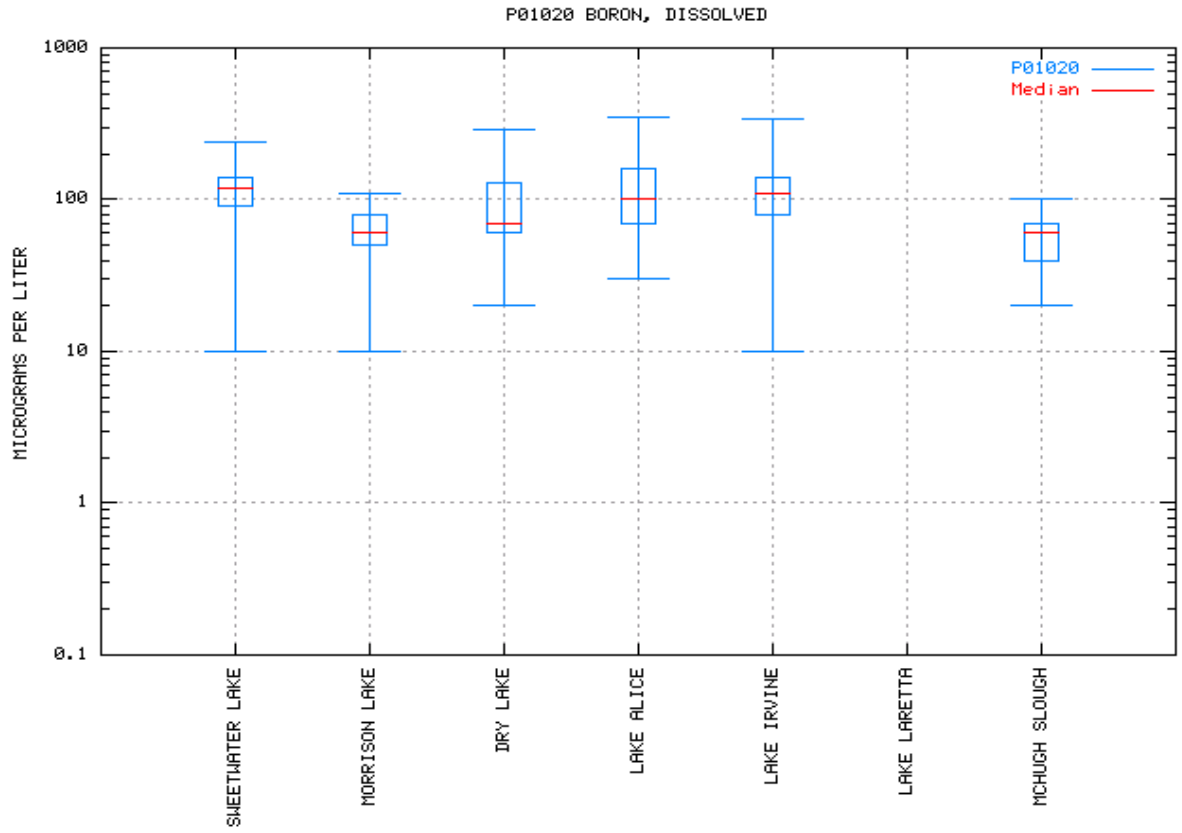

Figure 8. Box plot resulting from user selection of "Other Lakes in the Devils Lake Basin" in the Select Group of Sites box, "Boron, dissolved" in the Dissolved Trace Elements box, and "Period of Record" in the Time Period box. [The missing box plot for Lake Laretta indicates no boron data are available for that site.]

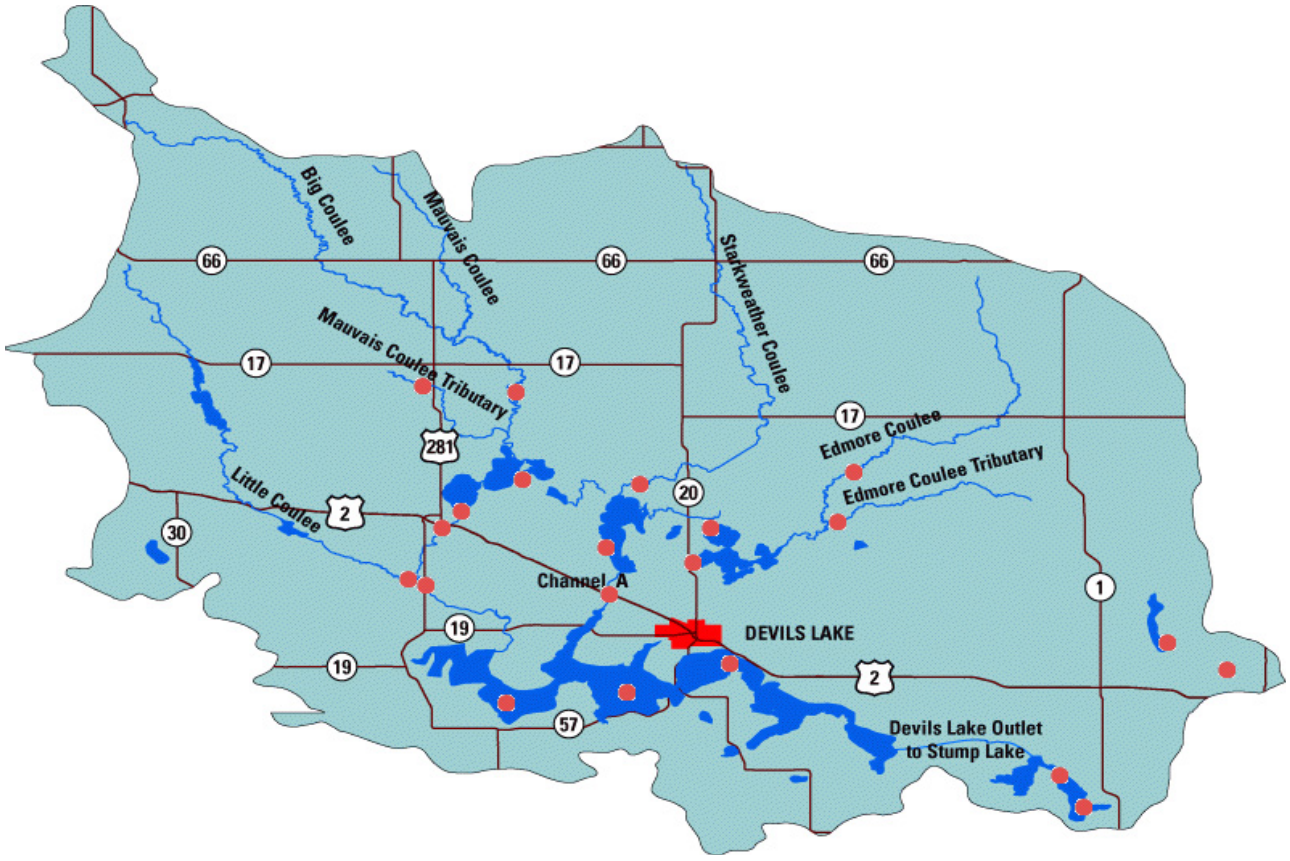

Figure 9. Devils Lake Basin (red dots indicate water-quality sampling sites used in graphical user interface).