Quabbin Reservoir and Ware River Watersheds Ten-Year Water Quality Data Review 2000-2009

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Massachusetts Department of Conservation and Recreation
Office of Watershed Management
Division of Water Supply Protection

Ten-Year Water Quality Data Review 2000-2009

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1 Introduction

The Department of Conservation and Recreation, Office of Watershed Management (DCR/OWM), monitors and manages the watersheds of Quabbin Reservoir, Ware River, and Wachusett Reservoir to protect the drinking water sources for over 2 million people in Massachusetts. These sources are monitored routinely to ensure a safe and sufficient water supply for the long term. The Massachusetts Water Resources Authority (MWRA) manages and operates the infrastructure for drinking water treatment, transmission, and distribution and also monitors water quality throughout its system.

Ten years of water quality data for the Quabbin Reservoir and Ware River watersheds were reviewed to evaluate trends during 2000 through 2009. This report summarizes changes in the DCR/OWM water quality monitoring program during that time and provides summary statistics for all routine sampling sites. A separate report on water quality in the Wachusett Reservoir watershed for 1998 through 2007 is available at http://www.mass.gov/dcr/watersupply/watershed/documents/wachusettwq98to07.pdf. Additional water quality data are available at http://www.mwra.com/watertesting/watertests.htm.

1.1.1.1 Sampling Program Philosophy

The primary focus of the water quality sampling program is to address federal and state regulatory requirements for source water protection and in particular, the filtration avoidance criteria under the Surface Water Treatment Rule. Beyond meeting the needs of regulatory compliance, the sampling program provides data for evaluating water quality trends over the short and long term. The sampling program is one of several tools to identify contaminants and potential sources of pollution, along with periodic field surveys and site investigations. While results from the routine sampling program may indicate impacts to water quality, the sampling program to date has not been designed to evaluate specific activities under forestry management or impacts of stormwater. Special sampling efforts have been conducted in collaboration with University of Massachusetts at Amherst to investigate stormwater impacts, reservoir hydrodynamics and water quality, and nutrient trends (see Rees et al., 2006; Garvey et al., 2001; Worden, 2000; Tobiason et al., 1998).

In addition to regulatory compliance and proactive surveillance of water quality trends, routine monitoring supports ongoing evaluations of threats to water quality, referred to as Environmental Quality Assessments (EQAs). EQAs are conducted at a subwatershed level, called a Sanitary District, and incorporate field surveys, site investigations, file reviews, and water quality data to provide a comprehensive evaluation of contamination sources and potential environmental impacts. An EQA provides a periodic, in-depth analysis, and is conducted for each Sanitary District on a rotating basis. In 2005, the water quality sampling program was revised to include sampling sites within one or more Sanitary Districts, in advance of each respective EQA, to support the EQA process.

1.1.1.2 Limitations of Sampling Program and Data

As described above, the water quality sampling program has multiple aims of regulatory compliance, trend surveillance, and EQA support. Limitations on the sampling program include staff time and resources, so the Quabbin Reservoir and Ware River watersheds are monitored on a biweekly basis, alternating between the two watersheds. In addition, the sampling plan is reviewed annually and revised as needed to refocus efforts on a different part of each watershed. Finally, laboratory analyses being requested in the sampling plan are coordinated with MWRA, who provides laboratory services.

Limitations on the sampling data analysis include limited or no stream flow data, since few streams have gages for routine flow monitoring. Stream gages monitored by the US Geological Survey are maintained along the West Branch of the Swift River (at Shutesbury), East Branch of the Swift River (at Hardwick), and the Ware River (near the intake works in Barre). Only qualitative flow data are recorded during tributary sampling (*e.g.*, high flow, good flow, or slow flow). Limited precipitation data are available, usually as daily precipitation totals for one to two locations per watershed. Hourly precipitation totals are available through the National Weather Service website but are not usually compiled or require a fee for access. Consequently, while samples are collected under different weather conditions, the limited data on precipitation and stream flow allows for only a very limited evaluation of stormwater impacts.

1.1.1.3 MWRA's Routine Monitoring

MWRA monitors water quality entering the treatment works at the Ware Disinfection Facility (WDF), which supplies drinking water to three communities (Chicopee, South Hadley Fire District #1, and Wilbraham) via the Chicopee Valley Aqueduct (CVA). Temperature, pH, specific conductance, and turbidity have been monitored using autoanalyzers since February 2004. Source water samples are collected daily at the WDF for laboratory analysis of fecal coliform bacteria, temperature, and pH. Biweekly samples are collected at the WDF for laboratory analysis of *Giardia* and *Cryptosporidium*. Samples are collected monthly or quarterly, depending on analyte, for analysis of metals, nutrients, and physicochemical parameters – see http://www.mwra.com/monthly/wqupdate/qual3wq.htm for MWRA's monthly water quality reports. A list of contaminants tested at least annually is available at http://www.mwra.com/watertesting/watertestlist.htm.

2 Sampling Program during 2000-2009

In the previous 10-year data review, for the period 1990-1999, data summaries were presented for 31 sampling stations. This report presents data summaries for 61 stations, which reflects changes in sampling stations and sampling plan priorities. Additionally, the sampling parameters (*i.e.*, analytes) have changed significantly since 1999 to include nutrients, ultraviolet absorbance (as a measure of natural organic matter), and bacterial indicator *Escherichia coli*, as well as discontinuing chloride, iron, hardness, and color. Changes also included field determination of Specific Conductance and pH using multi-probe meters, instead of laboratory analysis, and discontinuing alkalinity at some sites.

Just as importantly, a number of major organizational changes occurred since 1999. In 2000, the Metropolitan District Commission, Division of Watershed Management (MDC /DWM, predecessor of DCR/OWM) was operating the laboratory and conducting most of the routine analyses for the watershed sampling program. In October 2000, quality assurance testing for the Chicopee Valley Aqueduct was transferred from MWRA to the MDC laboratory. In 2001, the events of September 11 led to heightened security and increased surveillance, with lasting effects on overall watershed monitoring.

In 2002, long-time field and laboratory analyst and data manager Dave Chandler retired from MDC. On June 30, 2003, MDC and the former Department of Environmental Management were merged to form the current agency DCR, with MDC's responsibilities of overseeing watershed management transferred to DCR/OWM. In July 2004, the operation and management of Quabbin Laboratory was transferred to MWRA, while DCR maintained responsibility of sample collection in the watersheds and chemical analysis of tributary samples (DCR, 2005). Throughout this time, personnel have adapted as needed to changes in priorities and responsibilities.

Several special investigations have directly influenced the sampling program during 2000-2009. Investigations into nutrient and plankton dynamics (Worden, 2000) resulted in the quarterly nutrient monitoring within Quabbin Reservoir that continue through today. Research conducted at University of Massachusetts, Amherst, on natural organic matter (Garvey *et al.*, 2001) and stormwater impacts (Rees *et al.*, 2006) informed many aspects of the overall watershed sampling program, such as monitoring of ultraviolet absorbance and nutrients. MDC/DCR personnel assisted in sampling and/or analysis in collaboration with researchers on these special investigations. Results from these investigations are not specifically discussed here, and the respective reports should be consulted instead.

2.1.1.1 Changes in Sampling Program during 2000-2009

All sampling stations in the Ware River watershed that were monitored routinely during 2000-2009 are shown in **Figure 1** and listed in **Table 1**. Sampling stations in the Quabbin Reservoir watershed, including those within the reservoir itself, are shown in **Figure 2. Table 2** lists tributary sampling sites, and **Table 3** lists reservoir sampling sites. The tables summarize years of sampling, sampling frequency, and sampling parameters. A brief discussion of the sampling stations follows in Sections 2.1.1 and 2.1.2.

2.1.2 Tributary Sampling Stations

In general, samples were collected on a biweekly schedule at tributary sites, with sampling alternating between Quabbin Reservoir tributaries one week and Ware River tributaries the following week. During 2000 through early 2005, tributary samples were analyzed for the following parameters.

Tributary Samples, 2000-early 2005

Bacteria:	Total Coliform and Fecal Coliform
Physicochemical parameters:	Temperature, Dissolved Oxygen, pH, Specific Conductance, Turbidity, and Alkalinity

For limited periods prior to 2005, samples were also analyzed for chloride, iron, hardness, color, and *E. coli*. Until early 2005, the sampling station at Shaft 11A was occasionally monitored for bacteria and physicochemical parameters during active diversion of Ware River water into Quabbin Reservoir.

Significant changes in the tributary sampling plan were implemented in Spring of 2005. Sampling stations were selected to support upcoming EQAs in one or more Sanitary Districts of each watershed. These "EQA" sites would be monitored for one to two years, overlapping some with the EQA field work. To maintain some continuity in the long-term record, several stations were selected in each watershed as "core" sites, to be monitored routinely over many years. In addition to sampling site changes, new analytes were added to monitor nutrients and ultraviolet absorbance at wavelength 254 nanometers (UV_{254}, which is measured as a surrogate for natural organic matter). Nutrients and UV_{254} would be monitored biweekly for EQA sites, and quarterly for core sites. Since Spring 2005, tributary samples have been analyzed for the following parameters.

<u>Tributary Samples, Spring 2005-2009</u>

Bacteria:	Total Coliform and Fecal Coliform; *E. coli* starting in November 2005
Physicochemical parameters:	Temperature, Dissolved Oxygen, pH, Specific Conductance, Turbidity; Alkalinity for EQA sites only
Nutrients:	Nitrate, Nitrite, Total Kjeldahl Nitrogen, Total Phosphorus
Natural Organic Matter:	UV_{254} for all EQA sites and Ware River core sites

Because UV_{254} data were available for the major and many minor tributaries to Quabbin Reservoir through Garvey *et al.* (2001), it was decided that additional UV_{254} monitoring in tributaries to Quabbin Reservoir was less critical than for EQA sites and Ware River sites in general. Consequently, core sites in the Quabbin Reservoir watershed were not monitored for UV_{254} until 2009, which marked 10 years after the 1998-99 monthly monitoring by Garvey *et al.* (2001).

Starting in 2005, core sites in the Ware River watershed included Sites 101, 103A, 107A, 108, and 121A. As of May 2007, Site 121B replaced Site 121A as a core site because of continuous beaver activity at the outlet of Thayer Pond. See **Figure 1** and **Table 1** for locations and years of sampling for Ware River sites. From March/April 2005 to April 2007, EQA sites included Sites 108A, 108B, 108C, 116, and 116B, to support work on the East Branch Ware River Sanitary District EQA. EQA sites from May 2007 to December 2008 included Sites 105, 110, 121, and 121H, supporting work on the Coldbrook and Longmeadow Sanitary District EQA. For January to December 2009, EQA sites included Sites 103, 111A, B4, C2, and N1, which supported EQA work in the Burnshirt, Canesto, and Natty Sanitary District. Ware River watershed sampling sites are shown in **Figure 1**, and a summary of sampling stations, years of sampling, and sampling parameters is presented in **Table 1**.

For 2005-2009 in the Quabbin Reservoir watershed, core sites included Sites 211, 212, 213, 215, and 216, Boat Cove Brook, and Gates Brook. See **Figure 2** and **Table 2** for locations and years of sampling for tributaries in the Quabbin Reservoir watershed. EQA sites from March/April 2005 to April 2007 included Sites 211E, 211F, 211G, 212A, 212B, 213A, and 213B, supporting EQA work in Quabbin Northwest Sanitary District. From May 2007 to December 2008, EQA sites included Sites 215B, 215H, and 215F, to support work on the Fever Brook Sanitary District EQA. Sites 216G and 216I-X, within the East Branch Swift Sanitary District, were also monitored between May 2007 and December 2008. EQA sites in January through December 2009, Sites 211B-X and 211A-1, supported EQA work within the Quabbin Reservation Sanitary District. For tributaries to Quabbin Reservoir, **Figure 2** shows sampling site locations, and **Table 2** summarizes sampling station name, years of sampling, and sampling parameters. Reservoir sampling stations are listed in **Table 3** and discussed in the next section.

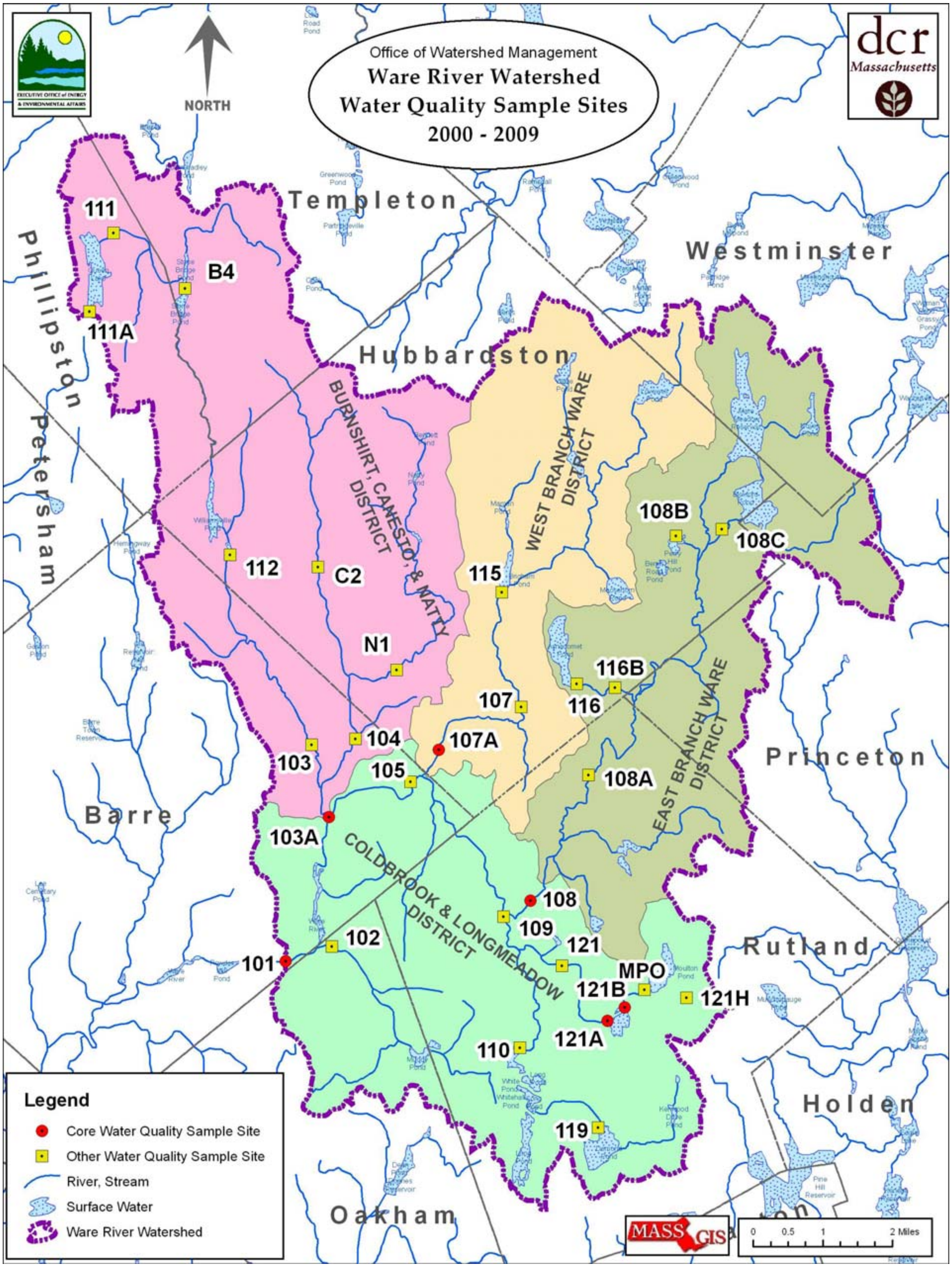

Figure 1. Map of Ware River Watershed Sampling Stations, 2000-2009

Table 1. Sampling Stations, Ware River Watershed, 2000-2009

STATION	SITE #	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Shaft 8	101	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; Nq, Uw (Apr-Dec)	X, Nq, Uw	X, Nq, Uw	X, Nq, Uw	X, Nq, Uw
Parker Brook @ mouth	102	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Burnshirt River at Rt. 62	103	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				X, N, U
Burnshirt and Canesto River	103A						X1; Nq, U (Mar-Dec)	X, Nq, U	X, Nq, U	X, Nq, U	X, Nq, U
Canesto/Natty @ Rt. 62	104	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Barre Falls Dam (Upstream)	105	X, Iq	X, Iq	X, Iq	X, Iq	X	X (Jan-Feb)		X3, N, U	X, N, U	
West Branch Ware @ Rt. 62	107	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
West Branch Ware @ Brigham Rd	107A						X1; Nq, U (Apr-Dec)	X, Nq, U	X, Nq, U	X, Nq, U	X, Nq, U
East Branch Ware River	108	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; Nq, U (Apr-Dec)	X, Nq, U	X, Nq, U	X, Nq, U	X, Nq, U
East Branch Ware @ Rt. 68	108A						X1; N, U (Apr-Dec)	X, N, U	X2, N, U		
Cushing Pond Outlet @ Bemis Rd	108B						X1; N, U (Apr-Dec)	X, N, U	X2, N, U		
East Branch Ware River (Bickford) @ Lombard Rd	108C						X1; N, U (Apr-Dec)	X, N, U	X2, N, U		
Longmeadow Brook @ mouth	109	X, Iq	X, Iq	X, Iq	X, Iq	X					
Whitehall Pond Outlet (Rutland State Park)	110	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)		X3, N, U	X, N, U	
Queen Lake @ road culvert	111	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Queen Lake at Rt. 101 (Beach)	111A										X, N, U
Burnshirt River @ Williamsville Pond	112	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Brigham Pond @ outlet	115	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Asnacomet Pond @ Outlet	116	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; N, U (Apr-Dec)	X, N, U	X2, N, U		

Table 1 (continued).

STATION	SITE #	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Comet Pond Outlet Tributary Near Clark Rd	116B						X1; N, U (Apr-Dec)	X, N, U	X2, N, U		
Demond Pond @ outlet	119	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Mill Brook @ Charnock Hill Rd	121	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)		X3, N, U	X, N, U	
Thayer Pond @ Outlet	121A						X1; N, U (Apr-Dec)	X, Nq, U	X2, Nq, U		
Thayer Pond @ Inlet	121B								X3, Nq, U	X, Nq, U	X, Nq, U
Moulton Pond Trib @ Britney Dr	121H								X3, N, U	X, N, U	
Moulton Pond @ outlet	MPO	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Burnshirt River at Stone Bridge	B4										X, N, U
Canesto Brook at Williamsville Rd	C2										X, N, U
Natty Pond Brook at Hale Rd	N1	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				X, N, U

Key:

X: Bacteria and Physicochemical parameters (biweekly)

X1: Bacteria and Physicochemical parameters (biweekly, from March/April to December)

X2: Bacteria and Physicochemical parameters (biweekly, from January to April)

X3: Bacteria and Physicochemical parameters (biweekly, from May to December)

Iq: Chloride, Fe, Hardness and Color (quarterly; Chloride until August 2002, Fe and Hardness until March 2003, Color until March 2004)

N: NO3,TKN, TPH (biweekly)

Nq: NO3,TKN, TPH (quarterly)

U: UV254 (biweekly)

Uw: UV254 (weekly)

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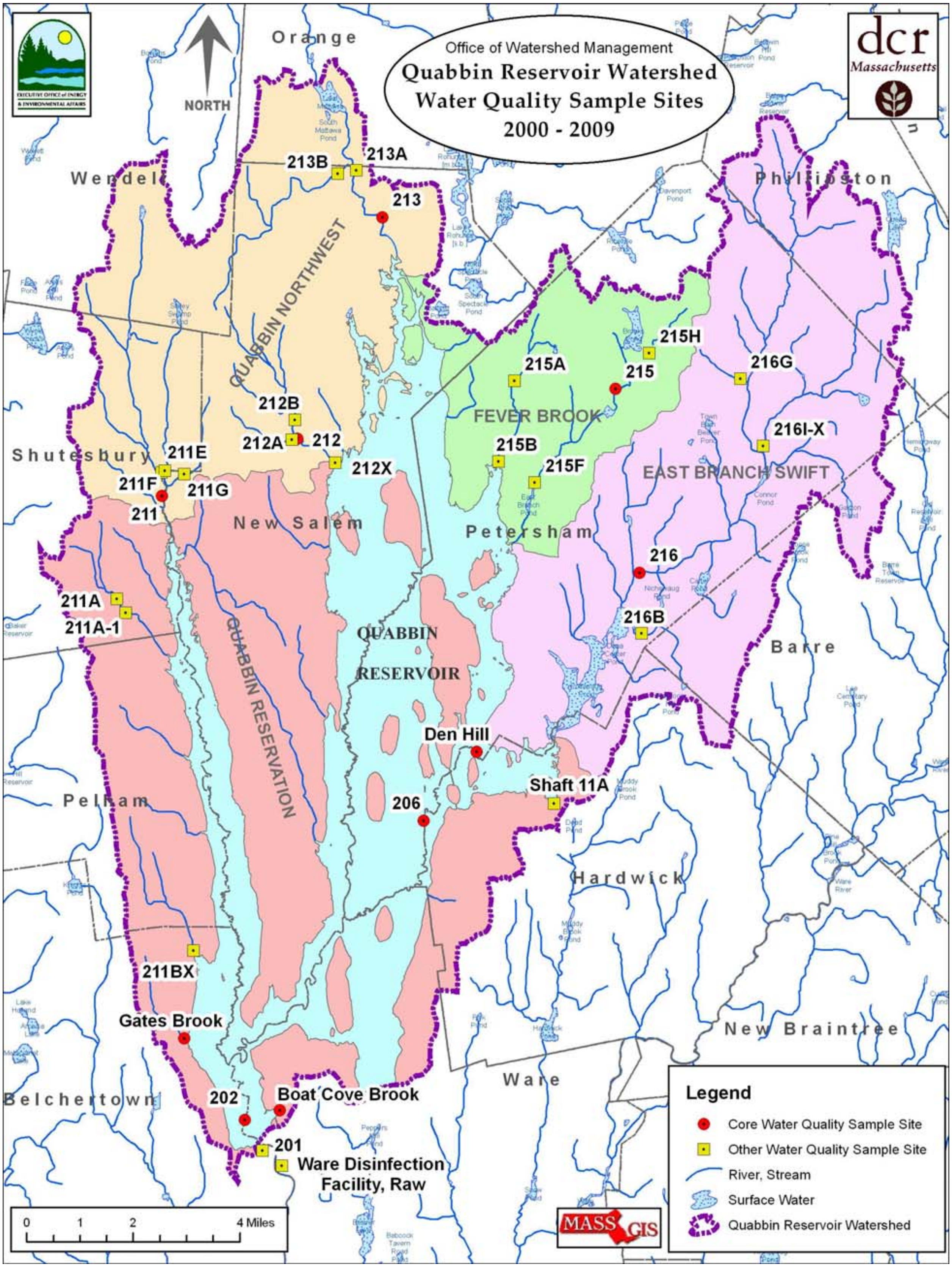

Figure 2. Map of Quabbin Reservoir Watershed Sampling Stations, 2000-2009

Table 2. Sampling Stations, Tributaries to Quabbin Reservoir, 2000-2009

STATION	SITE #	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
West Branch Swift River @ Rt. 202	211	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; Nq (Mar-Dec)	X, Nq	X, Nq	X,Nq	X, Nq, Uq
Atherton Brook @ Rt. 202	211A	X, Iq	X, Iq	X, Iq	X, Iq	X	X (Jan-Feb)				
Atherton Brook, Downhill from Gate 15	211A-1										X, N, U
Cadwell Creek @ mouth	211B-X	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				X, N, U
West Branch Swift River (Sibley Branch)	211E						X1; N, U (Mar-Dec)	X, N, U	X2, N, U		
West Branch Swift River (New Boston Branch)	211F						X1; N,U (Apr-Dec)	X, N, U	X2, N, U		
West Branch Swift River (Cooleyville Branch)	211G						X1; N, U (Mar-Dec)	X, N, U	X2, N, U		
Hop Brook Inside Gate 22	212	X, Iq	X, Iq	X, Iq	X, Iq	X	X; Nq (Mar-Dec)	X, Nq	X, Nq	X, Nq	X, Nq, Uq
Hop Brook @ Gate 22	212A						X1; N, U (Mar-Dec)	X, N, U	X2, N, U		
Hop Brook @ Gate 24	212B						X1; N, U (Mar-Dec)	X, N, U	X2, N, U		
Hop Brook @ mouth	212-X	X, Iq	X, Iq	X, Iq							
Middle Branch Swift River @ Gate 30	213	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; Nq (Mar-Dec)	X, Nq	X, Nq	X,Nq	X, Nq, Uq
Middle Branch Swift River @ Fay Road, New Salem	213A						X1; N, U (Mar-Dec)	X, N, U	X2, N, U		
Middle Branch Swift River @ Elm Street	213B						X1; N, U (Mar-Dec)	X, N, U	X2, N, U		
East Branch Fever Brook @ West Rd	215	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; Nq (Mar-Dec)	X, Nq	X, Nq	X, Nq	X, Nq, Uq
West Branch Fever Brook @ Women's Fed	215A	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				

Table 2 (continued).

STATION	SITE #	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
West Branch Fever Brook @ mouth	215B								X3, N, U	X, N, U	
East Branch Fever Brook @ road above mouth	215F								X3, N, U	X, N, U	
Harvard Pond Inlet	215H								X3, N, U	X, N, U	
East Branch Swift River @ Rt. 32A	216	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; Nq (Mar-Dec)	X, Nq	X, Nq	X, Nq	X, Nq, Uq
Rand Brook @ Rt. 32A	216B	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X (Jan-Feb)				
Roaring Brook @ East St, Petersham Center	216G								X3, N, U	X, N, U	
Moccasin Brook above Quaker Road	216I-X								X3, N, U	X, N, U	
Boat Cove Brook @ mouth	BC	X, Iq	X, Iq	X, Iq	X, Iq	X	X; Nq (Mar-Dec)	X, Nq	X, Nq	X, Nq	X, Nq, Uq
Gates Brook @ mouth	Gates	X, Iq	X, Iq	X, Iq	X, Iq	X, Iq	X; Nq (Mar-Dec)	X, Nq	X, Nq	X, Nq	X, Nq, Uq
Shaft 11A	Shaft 11A	X4	X4	X4	X4	X4	X4				

Key:

X: Bacteria and Physicochemical parameters (biweekly)

X1: Bacteria and Physicochemical parameters (biweekly, from March/April to December)

X2: Bacteria and Physicochemical parameters (biweekly, from January to April)

X3: Bacteria and Physicochemical parameters (biweekly, from May to December)

X4: Bacteria and Physicochemical parameters taken during active diversion

Iq: Chloride, Fe, Hardness and Color (quarterly; Chloride until August 2002, Fe and Hardness until March 2003, Color until March 2004)

N: NO3,TKN, TPH (biweekly)

Nq: NO3,TKN, TPH (quarterly)

U: UV254 (biweekly)

Uq: UV254 (quarterly)

Table 3. Sampling Stations, Quabbin Reservoir, 2000-2009

STATION	SITE #	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Winsor Power Station	201	X1, Iq	X1, Iq	X1, Iq	X1, Iq	X1 (Jan-Jul)					
Ware Disinfection Facility, Raw Water	WDFR					X2 (Jul-Dec)	X2	X2	X2	X2	X2
Shaft 12 Shore	206	X3, Iq	X3, Iq	X3, Iq	X3, Iq	X3	X3 (Jan-Feb)				
Winsor Dam CVA Intake-Reservoir	QR01/202	X, I, Nq, Uq	X, I, Nq, Uq	X, I, Nq, Uq	X, I, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq
Shaft 12 Reservoir	QR06/206	X, I, Nq, Uq	X, I, Nq, Uq	X, I, Nq, Uq	X, I, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq
North of Den Hill	QR10/Den Hill	X, I, Nq, Uq	X,I, Nq, Uq	X, I, Nq, Uq	X, I, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq	X, Nq, Uq

Key:

X: Bacteria and Physicochemical parameters (monthly)

X1: Bacteria (daily) and Physicochemical parameters (weekly)

X2: Bacteria and Physicochemical parameters (daily)

X3: Bacteria and Physicochemical parameters (weekly)

I: Chloride, Fe, Hardness and Color (monthly; Chloride until August 2002, Fe and Hardness until March 2003, Color until March 2004)
Iq: Chloride, Fe, Hardness and Color (quarterly; Chloride until August 2002, Fe and Hardness until March 2003, Color until March 2004)

Nq: NH3, NO3, SiO2, TPH (quarterly)

Uq: UV254 (quarterly)

2.1.3 Quabbin Reservoir Sampling Stations

During 2000 through 2009, monitoring of Quabbin Reservoir water quality was conducted at the Chicopee Valley Aqueduct (CVA) outflow, from the shore near Shaft 12, and within the reservoir. The six sites monitored routinely between 2000 and 2009 are shown in **Figure 2** and summarized in **Table 3**.

The CVA outflow was monitored at the Winsor Power Station (Site 201) until July 2004, when the sampling station was changed to the WDF. Until July 2004, samples from Site 201 were analyzed daily for bacteria and weekly for physicochemical parameters, as listed below.

Site 201 Samples, 2000-July 2004

Bacteria:	Total Coliform and Fecal Coliform
Physicochemical parameters:	Temperature, Dissolved Oxygen, pH, Specific Conductance, Turbidity, and Alkalinity

For limited periods during this time, samples were also analyzed for chloride, iron, hardness, color, and *E. coli*. Since February 2004, autoanalyzers have been used to monitor temperature, pH, specific conductance, and turbidity at the WDF. Starting in July 2004, samples from WDF were analyzed at Quabbin Laboratory for bacteria, temperature, and pH only. Additional water quality data for the WDF are available from MWRA (see http://www.mwra.com/monthly/wqupdate/qual3wq.htm).

The Shaft 12 shore (Site 206) was monitored to assess water quality leaving Quabbin Reservoir via the Quabbin Aqueduct. Samples were analyzed for the same bacteria and physicochemical parameters as for the CVA outflow, but on a weekly basis. Monitoring at the Shaft 12 shore was discontinued after February 2005 since occasional shoreline disturbances (*e.g.*, wave action) influenced water quality results that were not representative of water entering Shaft 12.

Three sampling stations within Quabbin Reservoir were monitored during 2000 through 2009. These stations are shown in **Figure 2** as Winsor Dam (Site 202), Shaft 12 (Site 206), and Den Hill, with a sampling summary presented in **Table 3**. Monitoring was conducted monthly, weather permitting, generally during the months of April through December. Field measurements of temperature, dissolved oxygen, pH, and specific conductance were recorded at multiple depths. Samples were collected from two to three depths at each site, with exact depths depending on whether the reservoir was stratified and what analyses (*i.e.*, bacterial, physicochemical, and/or nutrients) were to be performed.

In general, samples for bacterial analysis were collected at three depths: surface (0 to 0.5 m), a middle depth (most typically 6 m), and respective water supply intake depth (18 m for Site 202, 24 m for Site 206) or simply a "deep" location (13 m for Den Hill). For turbidity and alkalinity analyses, samples were sometimes collected at two depths and other times at three depths: surface (0 to 1 m) and/or a middle depth, and a deep location (within 2 to 3 m of bottom, or mid-hypolimnion if the reservoir was stratified). When only two depths were sampled, the shallower depth would often be labeled as a mid-depth, which means that the middle depth for turbidity and alkalinity samples could vary from near-surface (0.5 to 1 m) or mid-depth if the reservoir was not stratified, to mid-epilimnion or mid-metalimnion if the reservoir was stratified. For quarterly nutrient analyses, samples were collected at three depths: surface (0 to 1 m), mid-depth (unstratified conditions) or mid-metalimnion (stratified conditions), and deep (within 2 to 3 m of bottom).

Sampling depths have become more systematic since 2006, with samples for bacterial analysis collected at three fixed depths: surface, 6 meters, and respective intake depth (Site 202 and Site 206) or “deep” (13 m at Den Hill). After June 2010, sampling depths for physicochemical analyses were the same three as would be used for nutrient analyses: surface, mid-depth (unstratified conditions) or mid-metalimnion (stratified conditions), and within 2-3 m of bottom.

During 2005 through 2009, samples were collected monthly for bacteria analyses and physicochemical parameters and collected quarterly for nutrients and UV_{254} analyses, as listed below.

Reservoir Samples, 2000-2009

Bacteria:	Total Coliform and Fecal Coliform; *E. coli* starting in April 2006
Physicochemical parameters:	Turbidity and Alkalinity
Nutrients:	Nitrate, Ammonia, Total Kjeldahl Nitrogen, Total Phosphorus, and Silica
Natural Organic Matter:	UV_{254}

As with the tributary samples, reservoir samples were also analyzed for chloride, iron, hardness, color and *E. coli* between 2000 and 2005. Because the reservoir data were compiled among various databases over the years, the review of reservoir water quality focused on bacteria, nutrient, and UV_{254} data between 2005 and 2009 only.

2.1.3.1 Changes in Laboratory Analysis, 2000-2009

As noted in Section 2.1, several analytes were discontinued, and others were added as the sampling program evolved. Sampling parameters also changed as technology and laboratory methods improved. This section summarizes the major changes in laboratory analysis during 2000 through 2009.

2.1.4 Discontinued Analyses

Chloride was discontinued in August 2002. This parameter had been monitored at tributary sites on a quarterly basis since 1990, and previously on a biweekly basis (MDC, 2003). At reservoir stations, chloride was monitored on a monthly basis until being discontinued.

Iron and hardness were discontinued in March 2003. Both parameters had been monitored at tributary sites on a quarterly basis since 1990, and previously on a biweekly basis (DCR, 2004). At reservoir stations, iron and hardness were monitored on a monthly basis until being discontinued.

Color was discontinued in March 2004. This parameter had been monitored at tributary sites on a quarterly basis and monthly at reservoir stations since 1990 (DCR, 2005).

Alkalinity was discontinued at core sites only in the Ware River and Quabbin Reservoir watersheds by July 2005. At the recently established EQA sites, alkalinity analysis would continue on a biweekly basis. Monitoring of alkalinity continued unchanged at the three in-reservoir stations on a monthly basis.

Dissolved silica was discontinued from the reservoir monitoring program in 2008. Monitoring of total silica has continued at the three in-reservoir stations. Tributary monitoring has not included silica, except for the special monitoring efforts of 1998-1999, which were discussed by Garvey (2001).

2.1.5 Analyses Added

Routine nutrient analysis was added in March 2005 to tributary monitoring. Analyses included nitrate, nitrite, total Kjeldahl nitrogen, and total phosphorus. Nutrient analysis for the three in-reservoir stations remained consistent through 2000-2009.

Ultraviolet absorbance at wavelength 254 nm (UV_{254}) was also added in March 2005 to monitor natural organic matter in the watersheds. The primary concern with organic matter is the potential for forming disinfection byproducts during treatment, some of which may be carcinogenic over a person's lifetime. The UV_{254} analysis complements the nutrient monitoring. The use of UV_{254} is discussed further in Section 4.

E. coli was added to the sampling program in November 2005, using Standard Method 9223B, Enzyme Substrate Procedure, for Colilert. This method offers results for both total coliform and *E. coli* in one procedure, with a shorter incubation time.

2.1.6 Other Modifications

Starting in May 2005, specific conductance and pH were no longer analyzed in the laboratory. These parameters, along with temperature and dissolved oxygen, were now measured in the field using a multiprobe sonde and handheld computer. For accuracy, pH is best measured promptly, in the field.

Total coliform by the membrane filtration method was discontinued for tributary and reservoir samples in November 2005. Analysis of source water samples at the WDF, however, has continued using membrane filtration, in accordance with drinking water regulations. For tributary and reservoir samples, total coliform analysis was changed to an enzyme substrate procedure under Standard Method 9223B for Colilert, which combines total coliform and *E. coli* analysis in one test.

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3 Graphs and Summary Statistics

This section presents graphs and tables summarizing all sampling results from 2000-2009 for the sites listed in **Table 1**, for Ware River and tributaries, and **Table 2**, for tributaries to Quabbin Reservoir. Graphs and tables are also presented for the in-reservoir monitoring sites listed in **Table 3** (*i.e.*, Winsor Dam, Shaft 12, and Den Hill), summarizing data from 2005-2009.

Results are shown graphically using boxplots, followed by tables of summary statistics. A boxplot provides a graphical representation of the data range and variability. The maximum, median, and minimum values for each site are shown as individual points. The box represents the middle 50 percent of the data (i.e., values between the 25th and 75th percentiles), indicating whether the values tended to vary from the median value. Through boxplots, data range and variability can be compared easily among several sites. The number of samples by site is indicated by N.

Graphs and tables of summary statistics are presented in the following order:

1. Bacteria, which include Total Coliform, Fecal Coliform, and E. coli;
2. Physicochemical parameters, which include Turbidity and Alkalinity for all sites and Temperature, Dissolved Oxygen, pH, and Specific Conductance for tributary sites;
3. Nutrients, which include Nitrate, Total Kjeldahl Nitrogen, and Total Phosphorus for all sites, Nitrite, for tributary sites, and Ammonia and Silica for reservoir sites; and
4. Natural Organic Matter by UV_{254}.

Sites are grouped by watershed. For Quabbin Reservoir watershed, tributary sites are shown separately from in-reservoir sites.

3.1.1.1 Bacteria

Total coliform bacteria were measured by membrane filtration until November 2005 at tributary sites and through December 2005 at reservoir sites. Starting in November 2005, tributary and reservoir samples were tested for total coliform using Colilert, which also provided *E. coli* results in one procedure. Total coliform results did not correlate well between the two methods in side-by-side testing, but the advantages of Colilert outweighed the disadvantages (DCR, 2006). Results for membrane filtration are reported in colony forming units (CFU) per 100 milliliters (mL), while total coliform and *E. coli* results from Colilert are reported in most probable number (MPN) per 100 mL. Fecal coliform analysis was completed by membrane filtration throughout 2000-2009 and is reported in CFU per 100 mL.

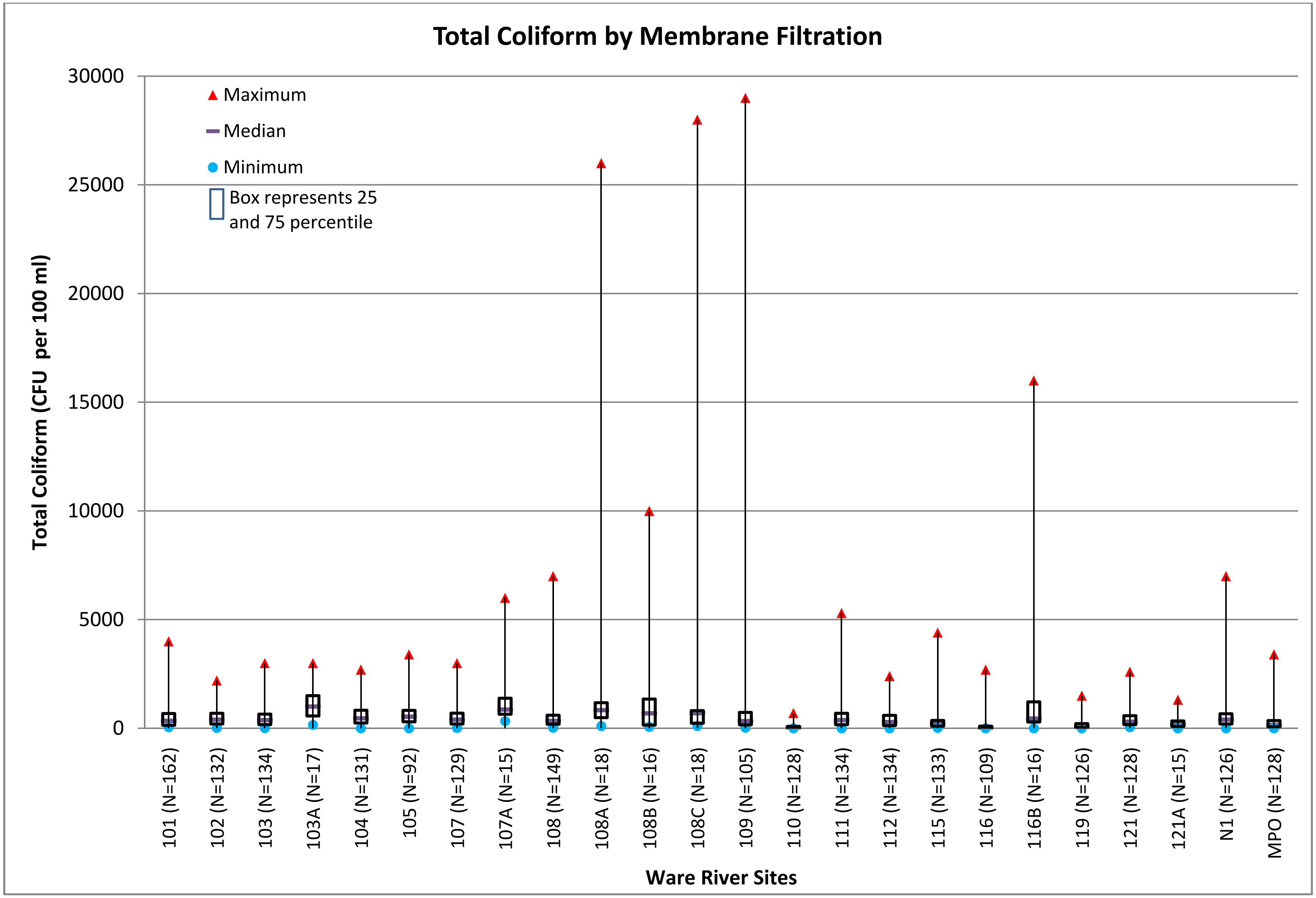

Figure 3. Boxplot of Total Coliform Data (Membrane Filtration), Ware River Sites, 2000-2005

Table 4. Summary Statistics for Total Coliform by Membrane Filtration (CFU/100 mL), Ware River Sites, 2000-2005

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	498	531	506	1140	624	699	550	1310	514	2280	1410
75 percentile	683	693	655	1500	833	826	700	1390	600	1180	1350
Maximum	4000	2200	3000	3000	2700	3400	3000	6000	7000	26000	10000
Median	347	400	376	1000	460	533	400	861	340	833	688
Minimum	50	20	14	157	2	0	18	333	30	100	71
25 percentile	141	200	171	571	245	300	200	648	188	490	152
N all samples	162	132	134	17	131	92	129	15	149	18	16

SITE	108C	109	110	111	112	115	116	116B	119	121	121A
Mean	2140	901	77	586	430	368	112	1750	199	443	311
75 percentile	813	733	90	692	595	360	100	1220	215	580	338
Maximum	28000	29000	700	5300	2400	4400	2700	16000	1500	2600	1310
Median	694	333	40	375	288	200	33	450	82	304	175
Minimum	106	30	0	3	0	20	0	0	0	51	0
25 percentile	235	163	21	166	126	100	14	290	35	173	87
N all samples	18	105	128	134	134	133	109	16	126	128	15

SITE	N1	MPO
Mean	766	363
75 percentile	667	356
Maximum	7000	3400
Median	397	150
Minimum	0	0
25 percentile	198	71
N all samples	126	128

Notes:
Total coliform by membrane filtration was discontinued for tributary samples by November 2005.
A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL.

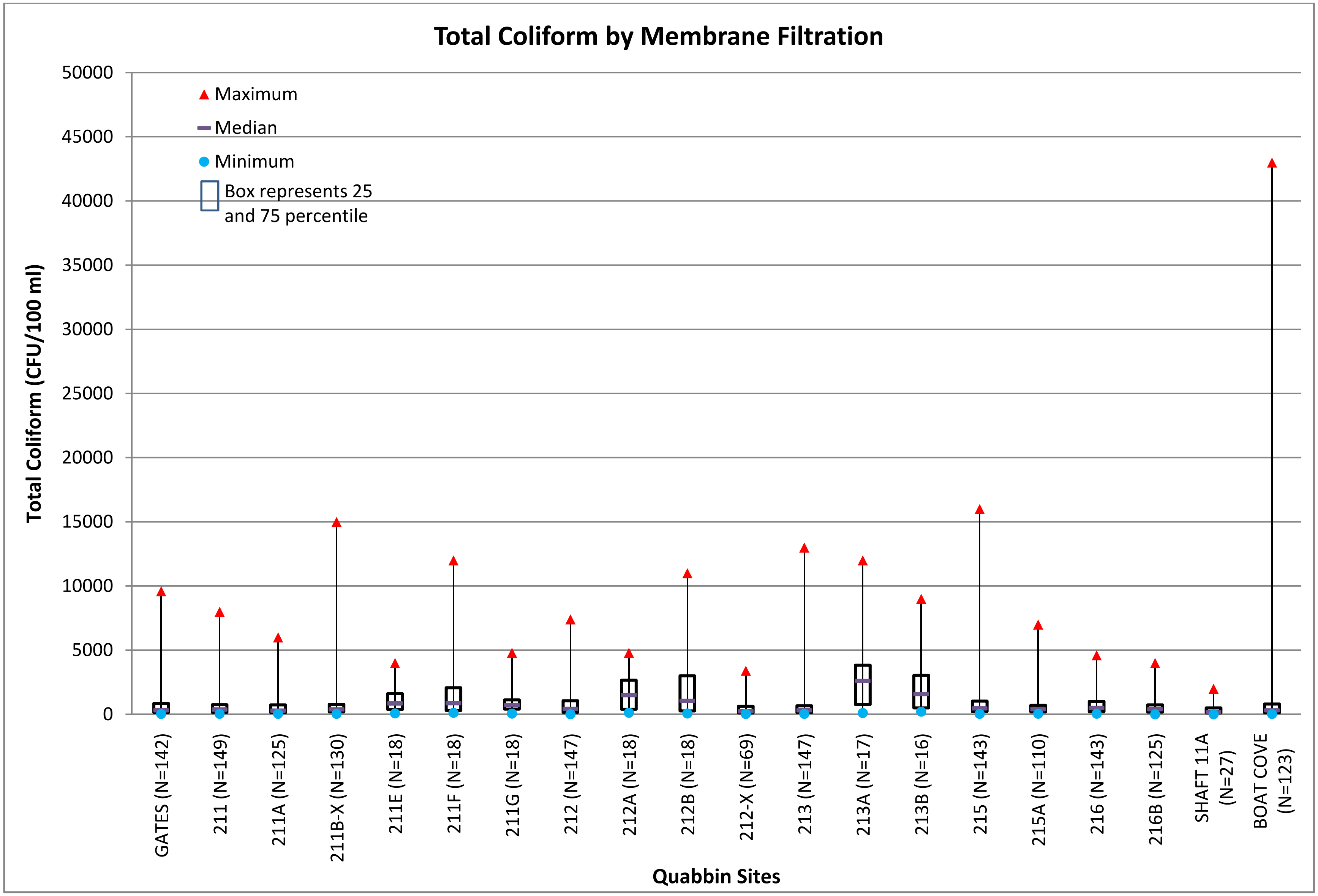

Figure 4. Boxplot of Total Coliform Data (Membrane Filtration), Quabbin Tributary Sites, 2000-2005

Table 5. Summary Statistics for Total Coliform by Membrane Filtration (CFU/100 mL), Quabbin Tributary Sites, 2000-2005

SITE	GATES	211	211A	211B-X	211E	211F	211G	212	212A	212B	212-X
Mean	726	671	619	830	1180	1770	975	798	1730	2660	522
75 percentile	850	750	733	777	1610	2070	1130	1060	2660	3000	633
Maximum	9600	8000	6000	15000	4000	12000	4800	7400	4800	11000	3400
Median	315	373	290	385	844	875	719	433	1500	1060	240
Minimum	30	35	40	40	75	125	60	7	125	66	25
25 percentile	151	160	130	200	375	303	411	158	393	264	114
N all samples	142	149	125	130	18	18	18	147	18	18	69

SITE	213	213A	213B	215	215A	216	216B	SHAFT 11A	BOAT COVE
Mean	672	3280	2400	1150	610	715	622	337	1420
75 percentile	667	3830	3040	1030	700	1000	733	497	807
Maximum	13000	12000	9000	16000	7000	4600	4000	2000	43000
Median	314	2600	1590	460	400	500	400	170	312
Minimum	40	103	210	40	50	50	0	0	24
25 percentile	140	767	500	220	200	205	180	111	126
N all samples	147	17	16	143	110	143	125	27	123

Notes:

Total coliform by membrane filtration was discontinued for tributary samples by November 2005.

A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL.

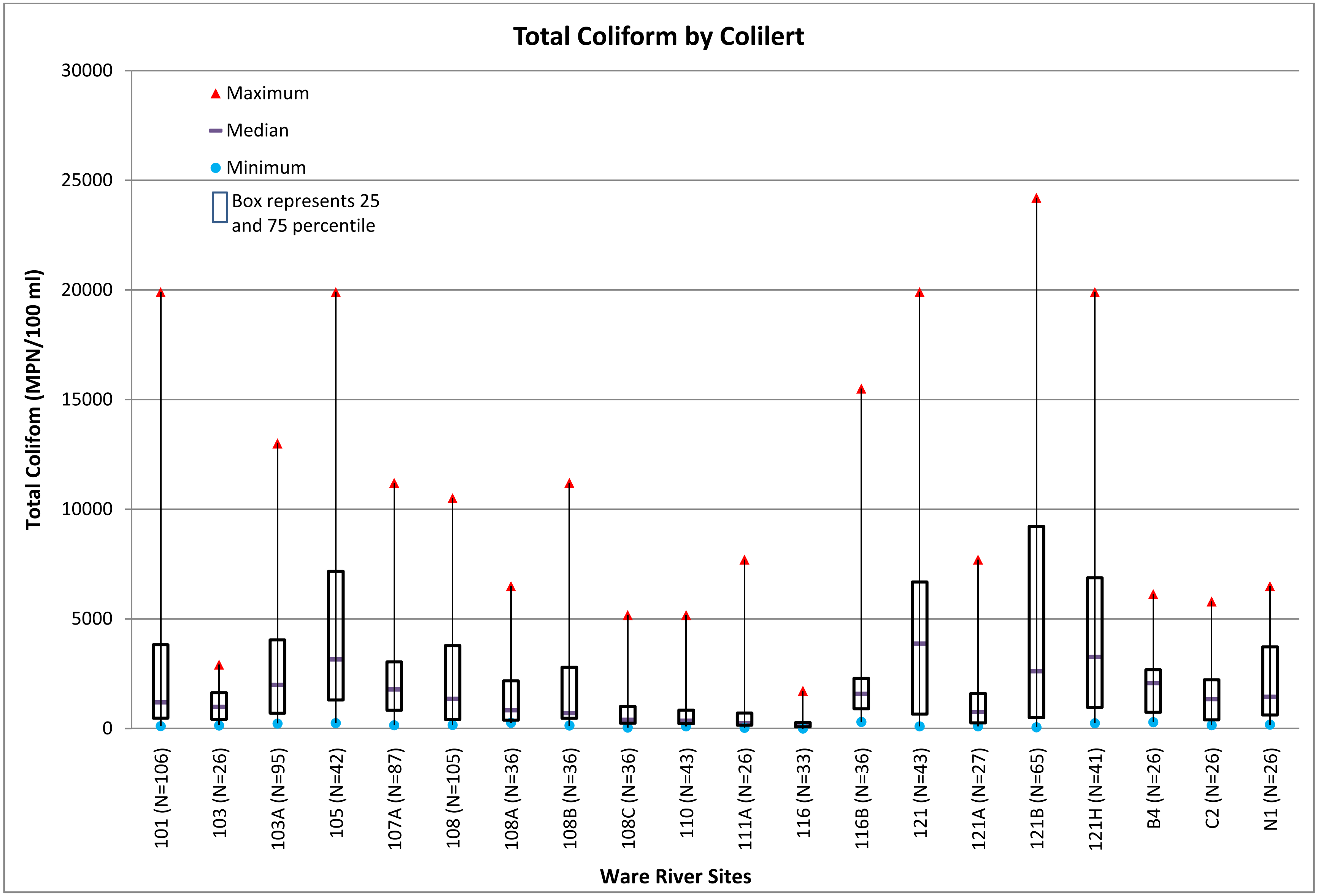

Figure 5. Boxplot of Total Coliform Data (Colilert), Ware River Sites, 2005-2009

Table 6. Summary Statistics for Total Coliform by Colilert (MPN/100 mL), Ware River Sites, 2005-2009

SITE	101	103	103A	105	107A	108	108A	108B	108C	110	111A
Mean	2613	1094	2887	4573	2354	2392	1632	2062	847	806	893
75 percentile	3815	1633	4040	7170	3035	3780	2168	2795	1003	838	705
Maximum	19900	2910	13000	19900	11200	10500	6490	11200	5170	5170	7700
Median	1190	985	1990	3150	1780	1350	828	701	397	355	251
Minimum	109	134	228	249	148	160	256	135	41	97	31
25 percentile	475	418	700	1298	832	410	378	465	237	215	149
N all samples	106	26	95	42	87	105	36	36	36	43	26

SITE	116	116B	121	121A	121B	121H	B4	C2	N1
Mean	316	2405	4802	1298	5932	4381	2086	1755	2212
75 percentile	266	2288	6680	1600	9210	6870	2675	2220	3723
Maximum	1720	15500	19900	7700	24200	19900	6130	5790	6490
Median	171	1580	3870	749	2610	3260	2065	1335	1445
Minimum	0	295	97	98	52	243	285	146	173
25 percentile	73	899	654	258	496	960	738	395	619
N all samples	33	36	43	27	65	41	26	26	26

Notes:
Total coliform by Colilert began for Ware River tributary samples in November 2005 (Site 101) or December 2005 (all other sites).
A value of "0" indicates "Not Detected." Detection limit was generally 10 MPN/100 mL.

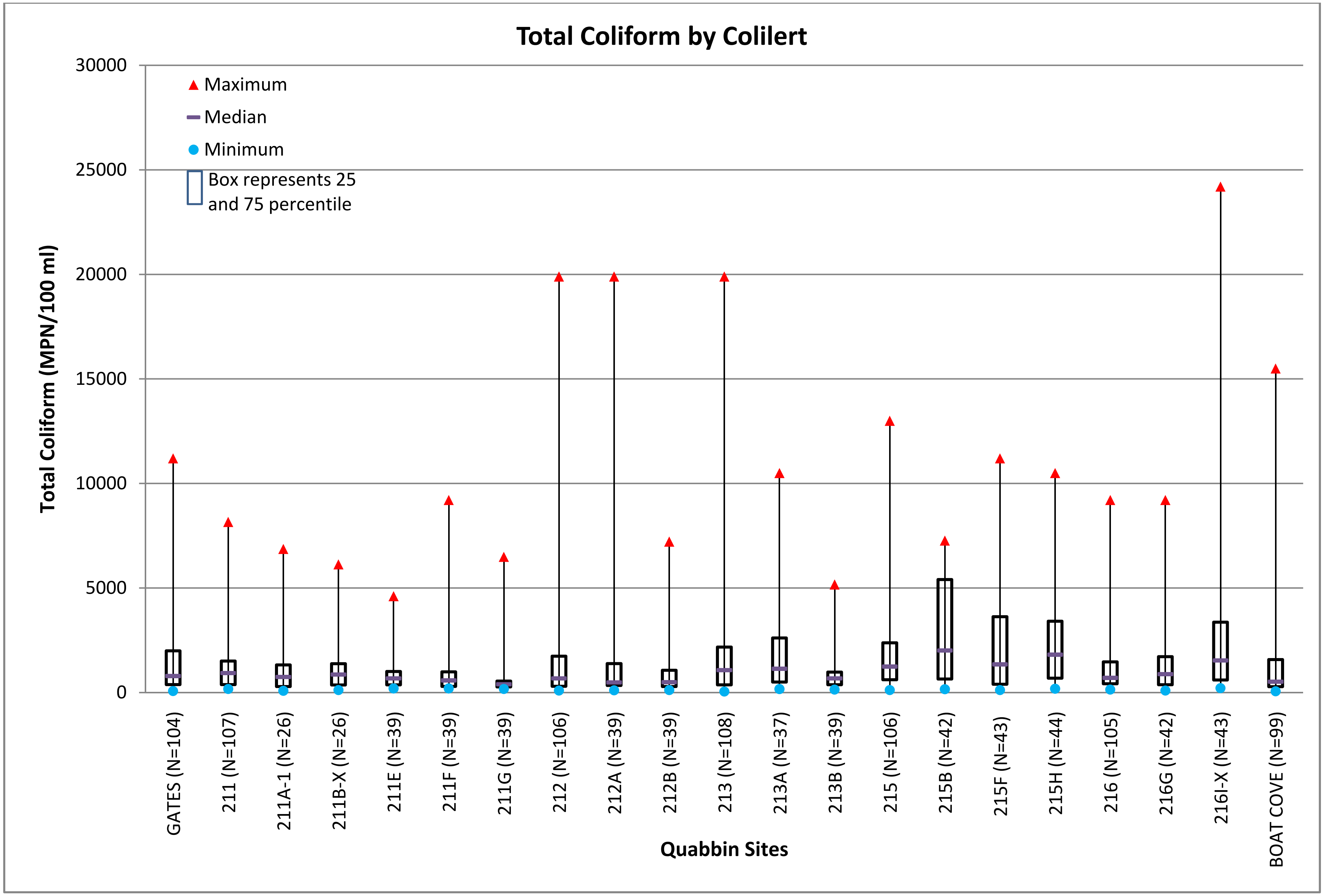

Figure 6. Boxplot of Total Coliform Data (Colilert), Quabbin Tributary Sites, 2005-2009

Table 7. Summary Statistics for Total Coliform by Colilert (MPN/100 mL), Quabbin Tributary Sites, 2005-2009

SITE	GATES	211	211A-1	211B-X	211E	211F	211G	212	212A	212B	213
Mean	1644	1376	1192	1124	906	1099	663	1953	1869	1155	1713
75 percentile	1995	1510	1323	1383	1012	990	548	1740	1385	1065	2175
Maximum	11200	8160	6870	6130	4610	9210	6490	19900	19900	7220	19900
Median	792	932	747	863	677	581	399	680	487	496	1075
Minimum	74	173	85	122	199	199	173	97	109	121	52
25 percentile	380	380	290	362	372	292	271	300	341	289	371
N all samples	104	107	26	26	39	39	39	106	39	39	108
SITE	**213A**	**213B**	**215**	**215B**	**215F**	**215H**	**216**	**216G**	**216I-X**	**BOAT COVE**	
Mean	2293	960	2135	2764	2472	2523	1327	1401	3158	1737	
75 percentile	2610	982	2380	5403	3630	3413	1470	1718	3365	1580	
Maximum	10500	5170	13000	7270	11200	10500	9210	9210	24200	15500	
Median	1140	677	1245	2015	1350	1815	703	883	1540	520	
Minimum	171	146	120	160	121	185	145	97	213	63	
25 percentile	504	376	616	650	402	691	422	373	600	282	
N all samples	37	39	106	42	43	44	105	42	43	99	

Notes:
Total coliform by Colilert began for Quabbin tributary samples in November 2005.
A value of "0" indicates "Not Detected." Detection limit was generally 10 MPN/100 mL.

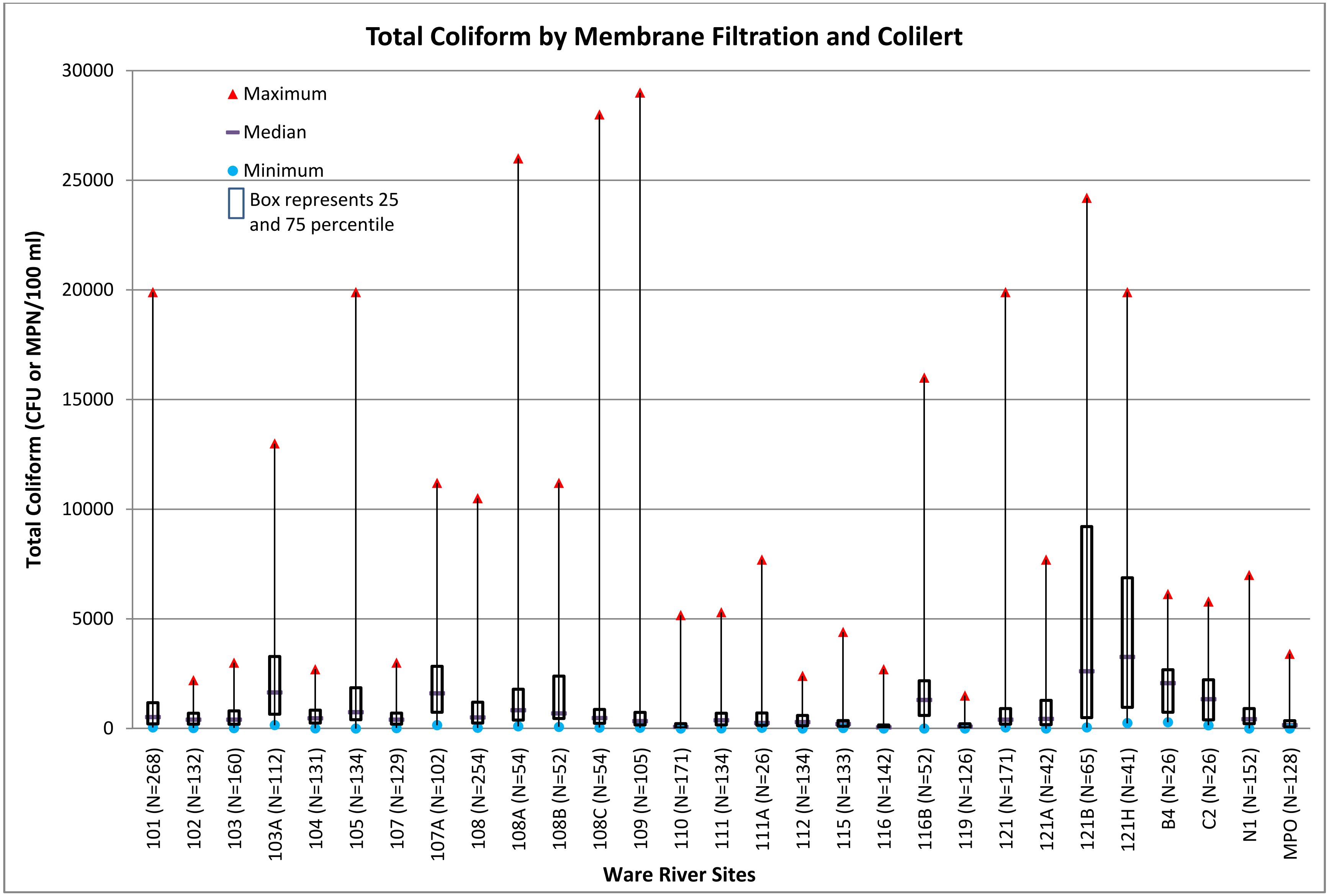

Figure 7. Boxplot of Total Coliform Data (Either Method), Ware River Sites, 2000-2009

Table 8. Summary Statistics for Total Coliform (CFU or MPN/100 mL), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	1330	531	602	2620	624	1910	550	2200	1290	1850	1860
75 percentile	1180	693	799	3280	833	1860	700	2840	1200	1790	2390
Maximum	19900	2200	3000	13000	2700	19900	3000	11200	10500	26000	11200
Median	520	400	400	1640	460	742	400	1600	500	833	688
Minimum	50	20	14	157	2	0	18	148	30	100	71
25 percentile	211	200	190	649	245	400	200	742	250	383	456
N all samples	268	132	160	112	131	134	129	102	254	54	52

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	1280	901	260	586	893	430	368	159	2200	199	1540
75 percentile	867	733	218	692	705	595	360	157	2180	215	908
Maximum	28000	29000	5170	5300	7700	2400	4400	2700	16000	1500	19900
Median	475	333	65	375	251	288	200	52	1300	82	400
Minimum	41	30	0	3	31	0	20	0	0	0	51
25 percentile	234	163	28	166	149	126	100	17	595	35	200
N all samples	54	105	171	134	26	134	133	142	52	126	171

SITE	121A	121B	121H	B4	C2	N1	MPO
Mean	946	5930	4380	2090	1760	1010	363
75 percentile	1280	9210	6870	2680	2220	909	356
Maximum	7700	24200	19900	6130	5790	7000	3400
Median	437	2610	3260	2070	1340	425	150
Minimum	0	52	243	285	146	0	0
25 percentile	174	496	960	738	395	219	71
N all samples	42	65	41	26	26	152	128

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL or 10 MPN/100 mL.

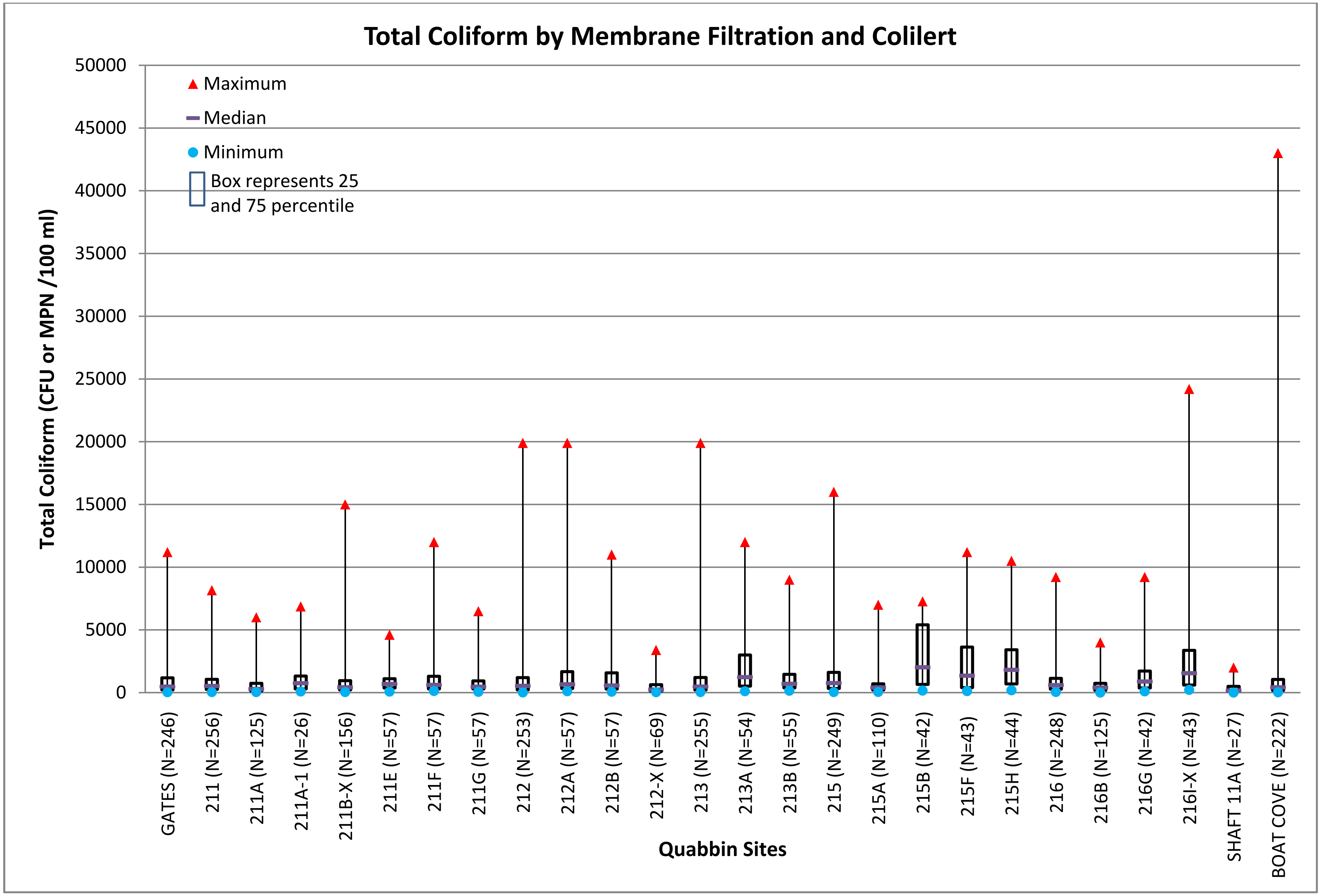

Figure 8. Boxplot of Total Coliform Data (Either Method), Quabbin Tributary Sites, 2000-2009

Table 9. Summary Statistics for Total Coliform (CFU or MPN/100 mL), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	1110	966	619	1190	879	994	1310	762	1280	1830	1630
75 percentile	1170	1060	733	1320	950	1110	1300	933	1190	1670	1570
Maximum	11200	8160	6000	6870	15000	4610	12000	6490	19900	19900	11000
Median	480	527	290	747	420	688	613	464	537	657	563
Minimum	30	35	40	85	40	75	125	60	7	109	66
25 percentile	210	257	130	290	214	367	292	288	210	332	285
N all samples	246	256	125	26	156	57	57	57	253	57	57

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	522	1110	2600	1380	1570	610	2760	2470	2520	974	622
75 percentile	633	1200	3000	1450	1610	700	5400	3630	3410	1130	733
Maximum	3400	19900	12000	9000	16000	7000	7270	11200	10500	9210	4000
Median	240	480	1240	703	760	400	2020	1350	1820	597	400
Minimum	25	40	103	146	40	50	160	121	185	50	0
25 percentile	114	200	510	379	332	200	650	402	691	270	180
N all samples	69	255	54	55	249	110	42	43	44	248	125

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	1400	3160	337	1560
75 percentile	1720	3370	497	1050
Maximum	9210	24200	2000	43000
Median	883	1540	170	414
Minimum	97	213	0	24
25 percentile	373	600	111	177
N all samples	42	43	27	222

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL or 10 MPN/100 mL.

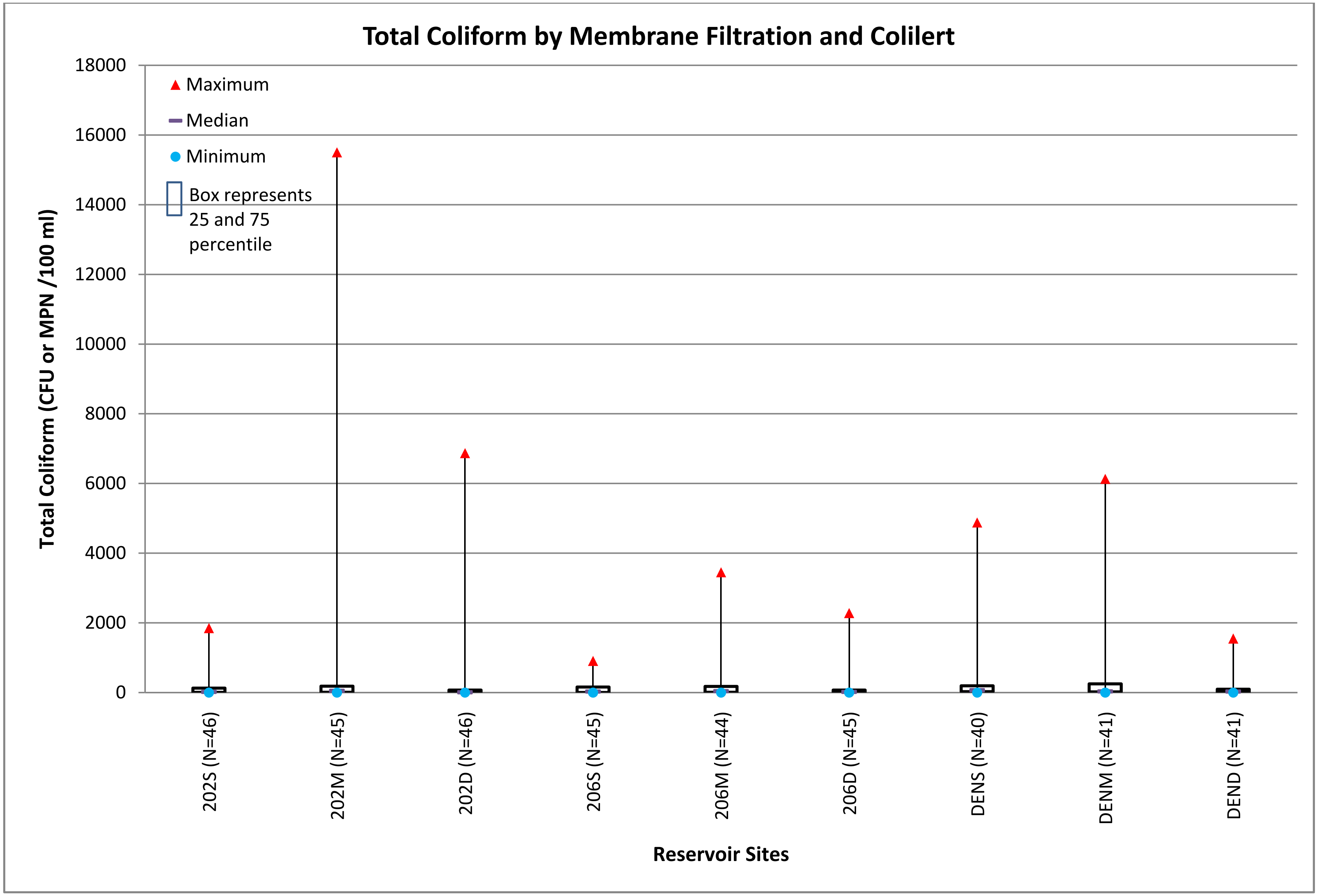

Figure 9. Boxplot of Total Coliform Data (Either Method), Quabbin Reservoir Sites, 2005-2009

Table 10. Summary Statistics for Total Coliform (CFU or MPN/100 mL), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	146	566	413	108	199	139	390	416	148
75 percentile	130	185	74	158	177	73	196	250	98
Maximum	1850	15500	6870	908	3450	2280	4880	6130	1550
Median	20	52	10	31	42	20	69	35	31
Minimum	0	0	0	0	0	0	0	0	0
25 percentile	6	10	0	2	8	2	28	20	10
N all samples	46	45	46	45	44	45	40	41	41

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-0.5 m

-M = Middle; generally 6 m for bacteria, but a few instances in 2005 at mid-metalimnion (9-10 m) or intake depth

-D = Deep; 18 m for Site 202, 24 m for Site 206, 13 m for Den Hill

A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL or 10 MPN/100 mL.

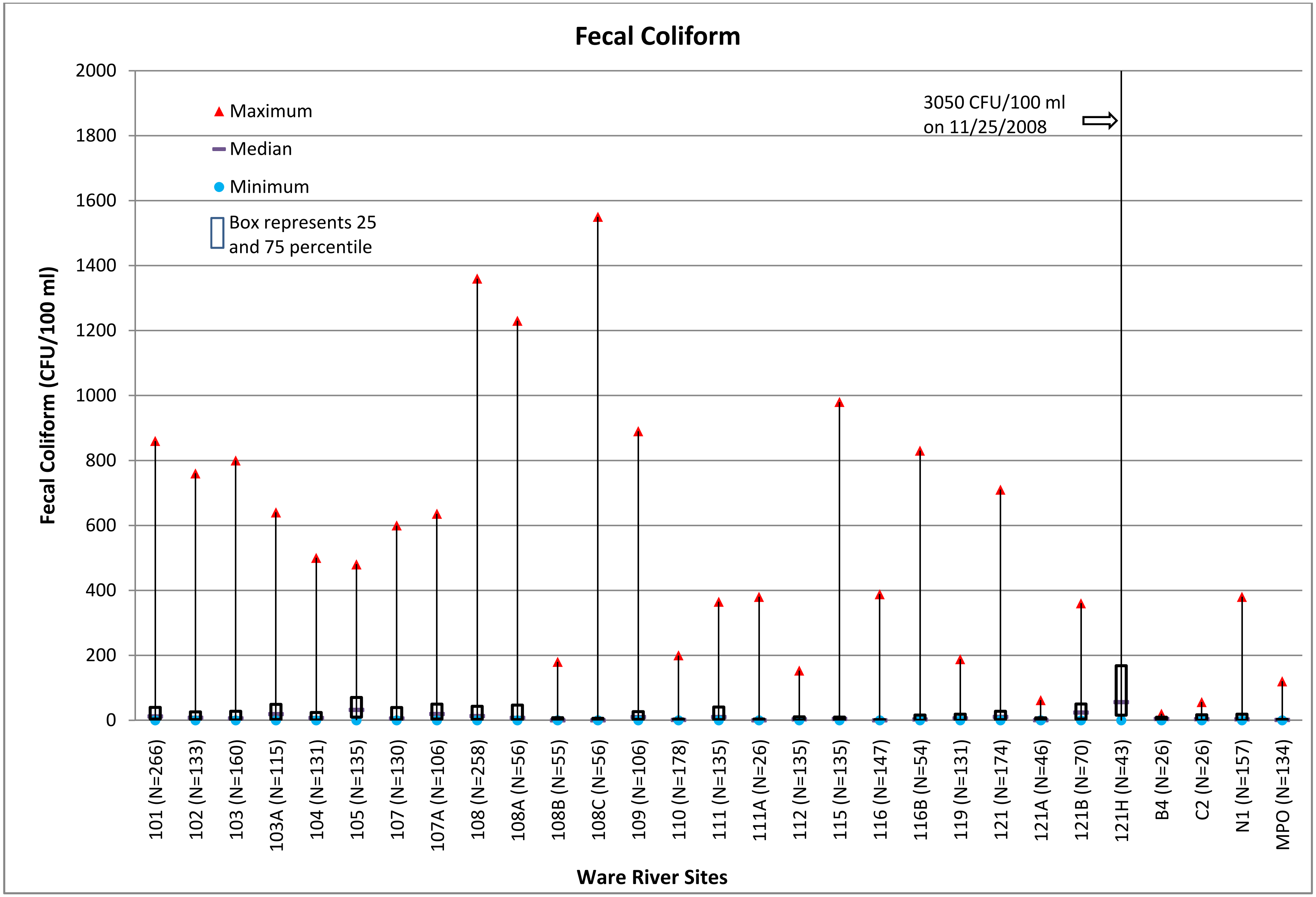

Figure 10. Boxplot of Fecal Coliform Data, Ware River Sites, 2000-2009

Table 11. Summary Statistics for Fecal Coliform (CFU/100 mL), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	33	25	25	43	33	53	33	51	45	68	9
75 percentile	40	26	28	49	24	71	39	50	43	47	8
Maximum	860	760	800	640	500	480	600	636	1360	1230	180
Median	12	8	6	19	7	32	6	20	13	8	0
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	4	2	1	3	1	10	1	4	3	2	0
N all samples	266	133	160	115	131	135	130	106	258	56	55

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	32	32	6	34	17	13	16	6	26	15	32
75 percentile	6	27	4	41	4	11	10	2	16	19	28
Maximum	1550	890	200	365	380	153	980	388	830	188	710
Median	0	10	1	10	0	3	4	0	3	6	11
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	0	3	0	2	0	1	1	0	0	0	2
N all samples	56	106	178	135	26	135	135	147	54	131	174

SITE	121A	121B	121H	B4	C2	N1	MPO
Mean	7	47	186	6	11	20	5
75 percentile	8	50	168	10	17	19	3
Maximum	62	360	3050	20	56	380	120
Median	1	24	56	4	4	3	1
Minimum	0	0	0	0	0	0	0
25 percentile	0	4	16	2	0	0	0
N all samples	46	70	43	26	26	157	134

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL.

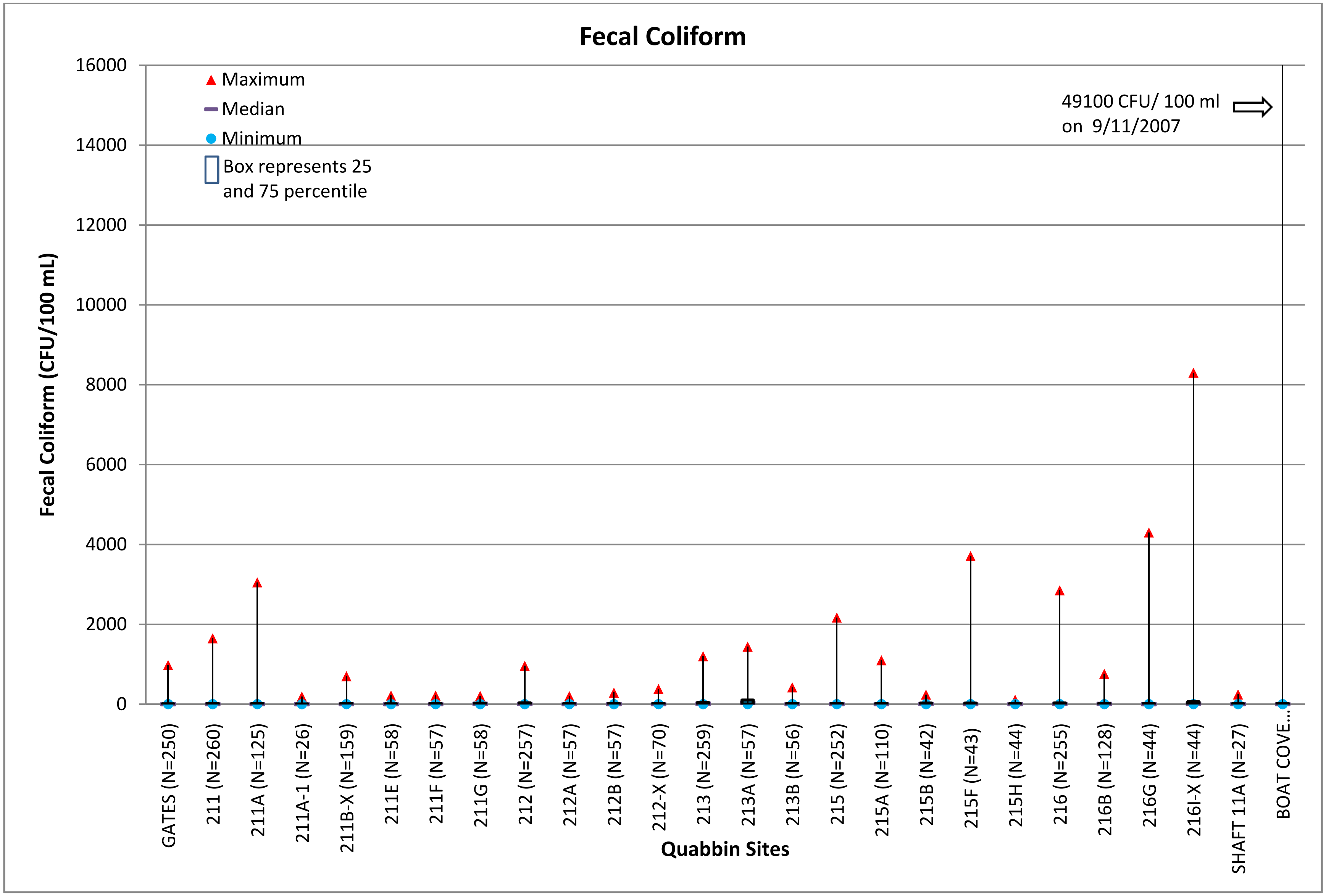

Figure 11. Boxplot of Fecal Coliform Data, Quabbin Tributary Sites, 2000-2009

Table 12. Summary Statistics for Fecal Coliform (CFU/100 mL), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	17	25	54	15	33	14	18	28	34	19	22
75 percentile	10	20	14	5	20	8	14	25	32	11	16
Maximum	980	1650	3050	192	700	215	215	205	960	200	290
Median	1	4	3	0	4	2	3	11	6	3	4
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	0	1	1	0	0	0	0	2	1	1	1
N all samples	250	260	125	26	159	58	57	58	257	57	57

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	23	41	108	28	46	27	25	103	9	45	22
75 percentile	20	44	103	19	18	19	29	27	11	30	18
Maximum	380	1200	1440	420	2170	1100	240	3710	110	2850	760
Median	6	14	35	4	4	4	8	4	4	9	6
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	1	4	5	1	1	1	4	0	0	3	1
N all samples	70	259	57	56	252	110	42	43	44	255	128

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	125	221	16	318
75 percentile	15	61	12	22
Maximum	4300	8300	245	49100
Median	2	11	3	5
Minimum	0	0	0	0
25 percentile	0	4	1	0
N all samples	44	44	27	232

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL.

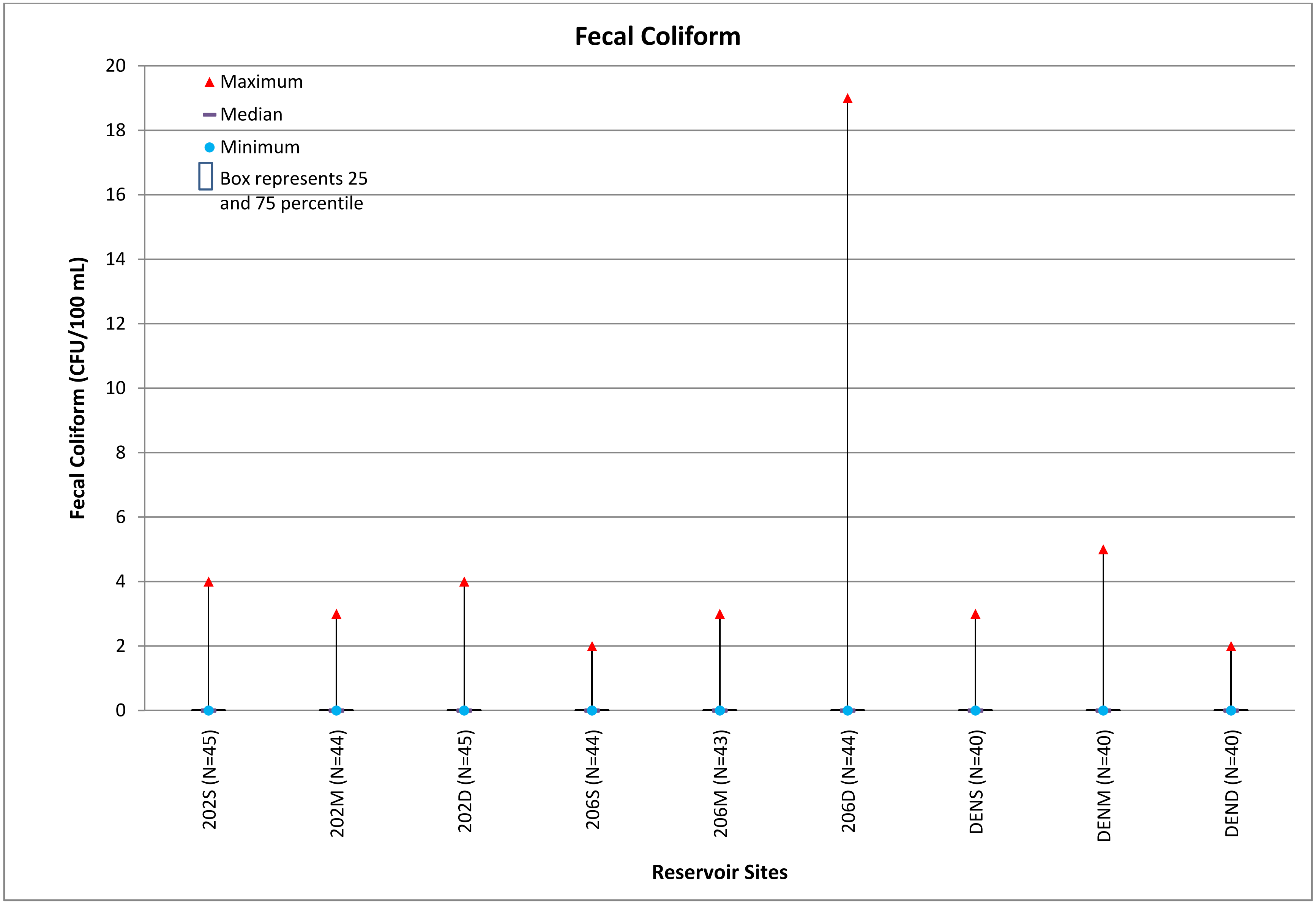

Figure 12. Boxplot of Fecal Coliform Data, Quabbin Reservoir Sites, 2005-2009

Table 13. Summary Statistics for Fecal Coliform (CFU/100 mL), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.2	0.3	0.2	0.1	0.1	0.5	0.2	0.3	0.2
75 percentile	0	0	0	0	0	0	0	0	0
Maximum	4	3	4	2	3	19	3	5	2
Median	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0
N all samples	45	44	45	44	43	44	40	40	40

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-0.5 m

-M = Middle; generally 6 m for bacteria, but a few instances in 2005 at mid-metalimnion (9-10 m) or intake depth

-D = Deep; 18 m for Site 202, 24 m for Site 206, 13 m for Den Hill

A value of "0" indicates "Not Detected." Detection limit was generally 1 CFU/100 mL.

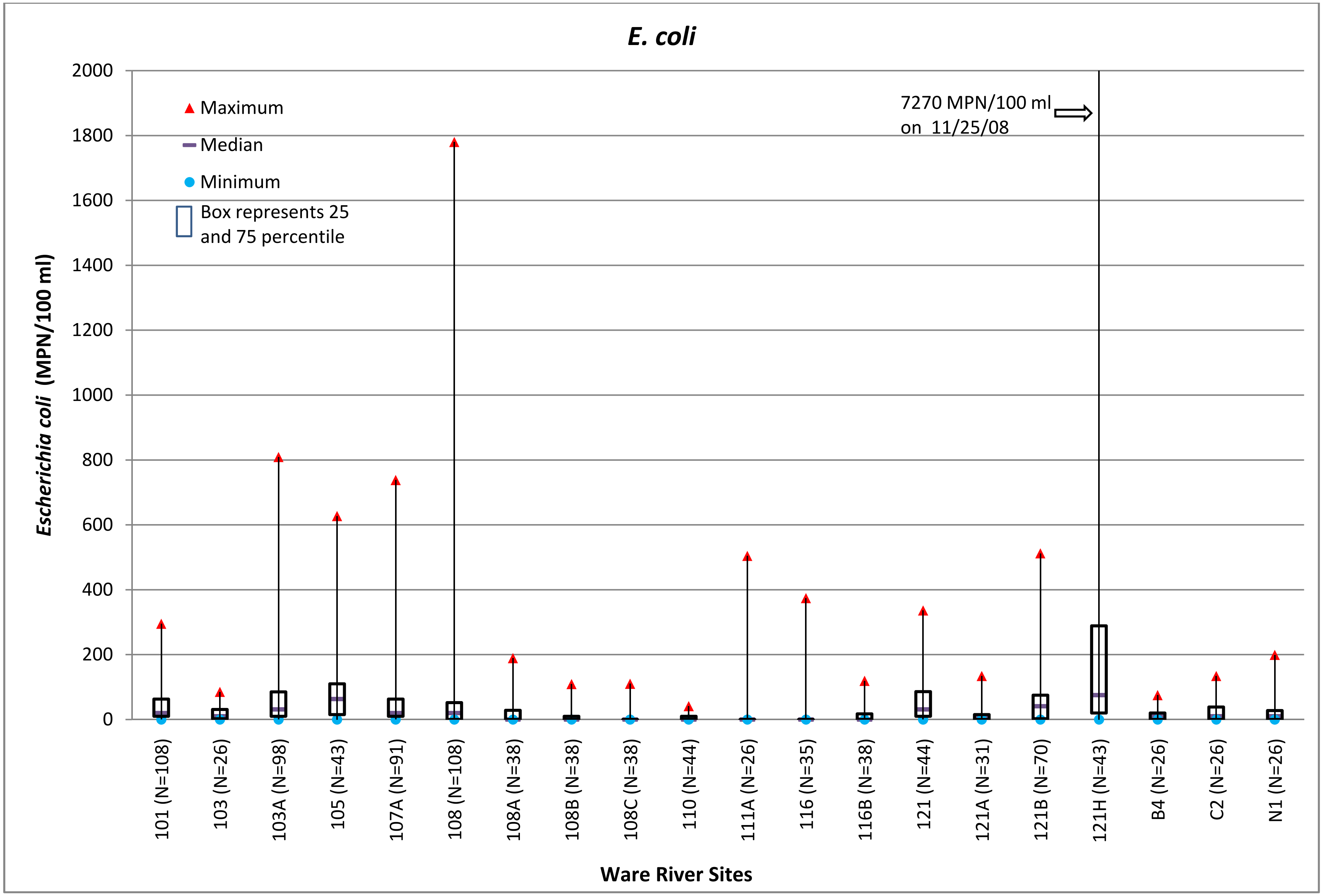

Figure 13. Boxplot of *E. coli* Data, Ware River Sites, 2005-2009

Table 14. Summary Statistics for *E. coli* (MPN/100 mL), Ware River Sites, 2005-2009

SITE	101	103	103A	105	107A	108	108A	108B	108C	110	111A
Mean	43	21	62	88	72	57	22	8	8	5	22
75 percentile	63	31	85	110	63	52	28	10	0	10	0
Maximum	295	85	809	627	738	1780	189	109	110	41	504
Median	20	10	31	63	20	20	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	10	3	10	15	10	0	0	0	0	0	0
N all samples	108	26	98	43	91	108	38	38	38	44	26
SITE	**116**	**116B**	**121**	**121A**	**121B**	**121H**	**B4**	**C2**	**N1**		
Mean	14	14	70	15	68	326	13	24	27		
75 percentile	0	18	86	15	75	289	20	39	28		
Maximum	374	119	336	134	512	7270	75	134	199		
Median	0	0	31	10	41	75	10	10	10		
Minimum	0	0	0	0	0	0	0	0	0		
25 percentile	0	0	10	0	3	20	0	0	0		
N all samples	35	38	44	31	70	43	26	26	26		

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 10 MPN/100 mL.

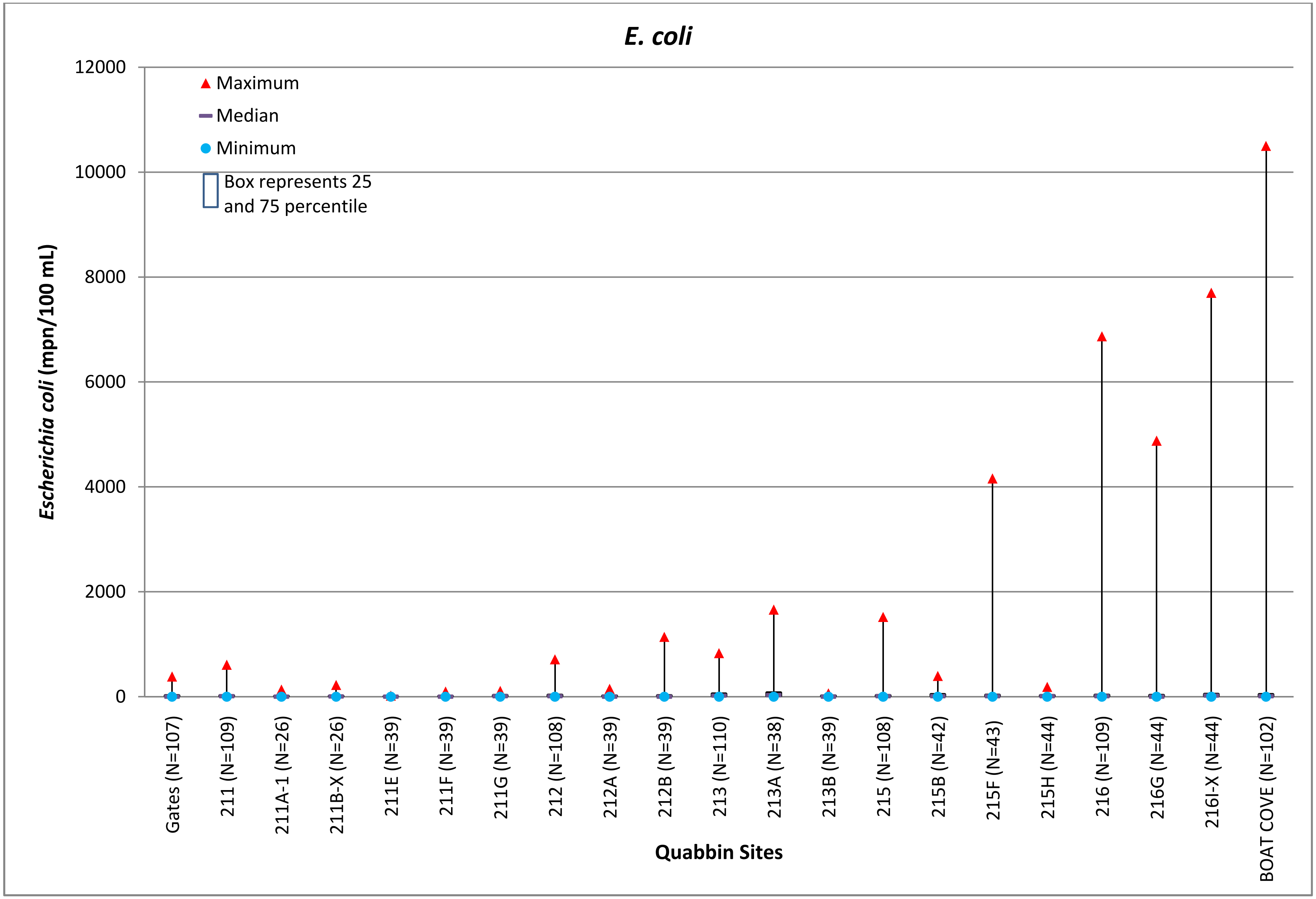

Figure 14. Boxplot of *E. coli* Data, Quabbin Tributary Sites, 2005-2009

Table 15. Summary Statistics for *E. coli* (MPN/100 mL), Quabbin Tributary Sites, 2005-2009

SITE	GATES	211	211A-1	211B-X	211E	211F	211G	212	212A	212B	213
Mean	18	20	15	19	3	8	22	30	15	43	49
75 percentile	20	20	10	10	0	10	26	31	15	20	52
Maximum	384	609	134	223	20	97	109	712	148	1140	830
Median	0	10	0	5	0	0	10	10	0	0	20
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0	0	10
N all samples	107	109	26	26	39	39	39	108	39	39	110
SITE	**213A**	**213B**	**215**	**215B**	**215F**	**215H**	**216**	**216G**	**216I-X**	**BOAT COVE**	
Mean	154	10	38	38	122	25	102	145	242	214	
75 percentile	75	15	23	41	31	23	31	25	47	41	
Maximum	1660	63	1520	395	4160	187	6870	4880	7700	10500	
Median	31	0	10	10	10	10	10	0	20	10	
Minimum	0	0	0	0	0	0	0	0	0	0	
25 percentile	10	0	0	0	0	0	0	0	10	0	
N all samples	38	39	108	42	43	44	109	44	44	102	

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 10 MPN/100 mL.

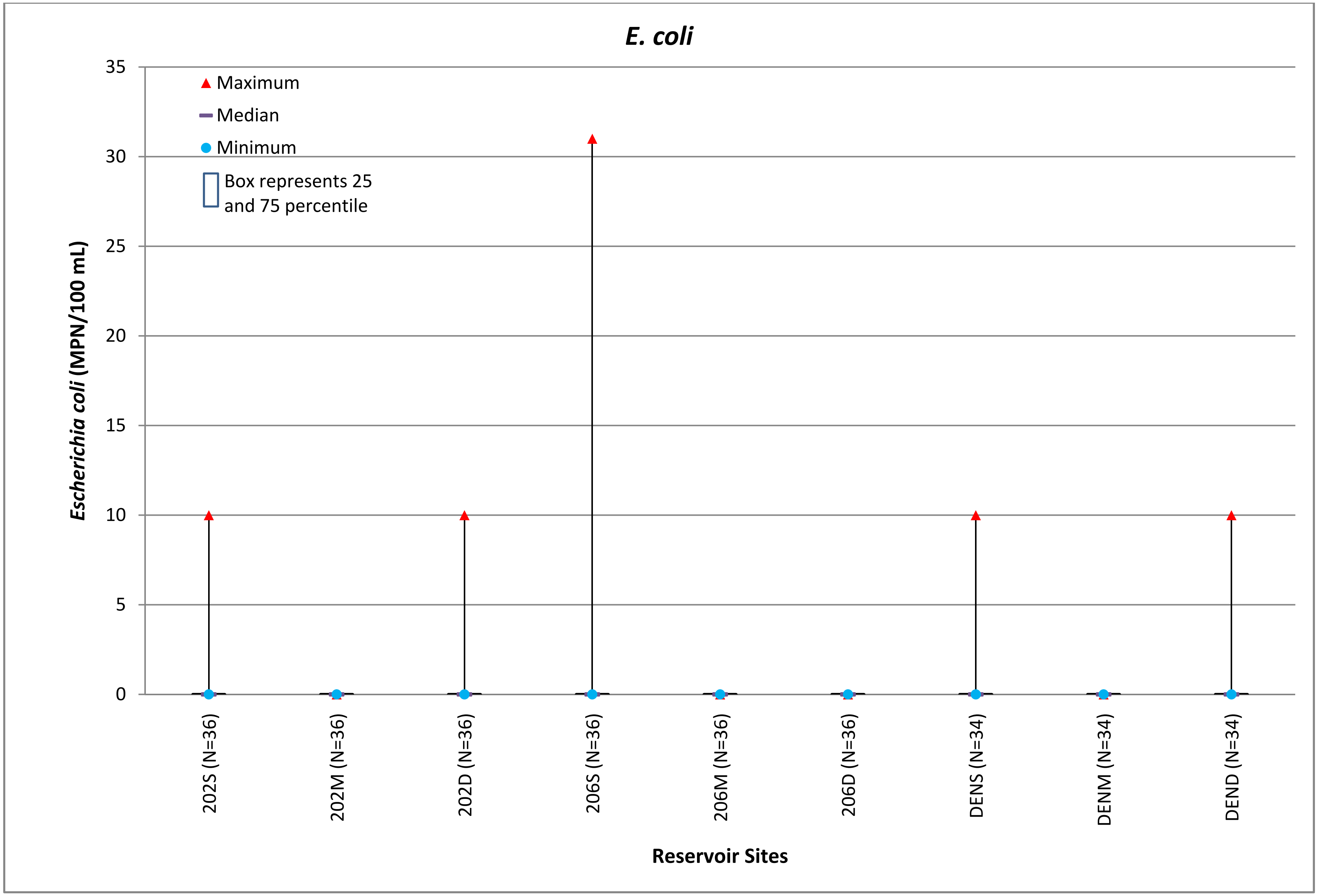

Figure 15. Boxplot of *E. coli* Data, Quabbin Reservoir Sites, 2005-2009

Table 16. Summary Statistics for *E. coli* (MPN/100 mL), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.8	0	0.3	1.1	0	0	0.3	0	0.3
75 percentile	0	0	0	0	0	0	0	0	0
Maximum	10	0	10	31	0	0	10	0	10
Median	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0
N all samples	36	36	36	36	36	36	34	34	34

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-0.5 m

-M = Middle; generally 6 m for bacteria, but a few instances in 2005 at mid-metalimnion (9-10 m) or intake depth

-D = Deep; 18 m for Site 202, 24 m for Site 206, 13 m for Den Hill

A value of "0" indicates "Not Detected." Detection limit was generally 10 MPN/100 mL.

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3.1.1.2 Physicochemical parameters

Temperature and dissolved oxygen were measured in the field throughout 2000-2009. Reporting units for temperature are degrees Celsius and for dissolved oxygen, milligrams per liter (mg/L) and percent saturation. pH (in standard units) and specific conductance (in microsiemens per centimeter, µs/cm) were measured in the laboratory until May 2005, and in the field using a multi-probe sonde thereafter. Because of incompatible databases, temperature, dissolved oxygen, pH, and specific conductance data for reservoir sites are not presented here.

Turbidity is reported in nephelometric turbidity units (NTU), and alkalinity is reported in mg/L as calcium carbonate ($CaCO_3$). Alkalinity was discontinued for tributary core sites in 2005.

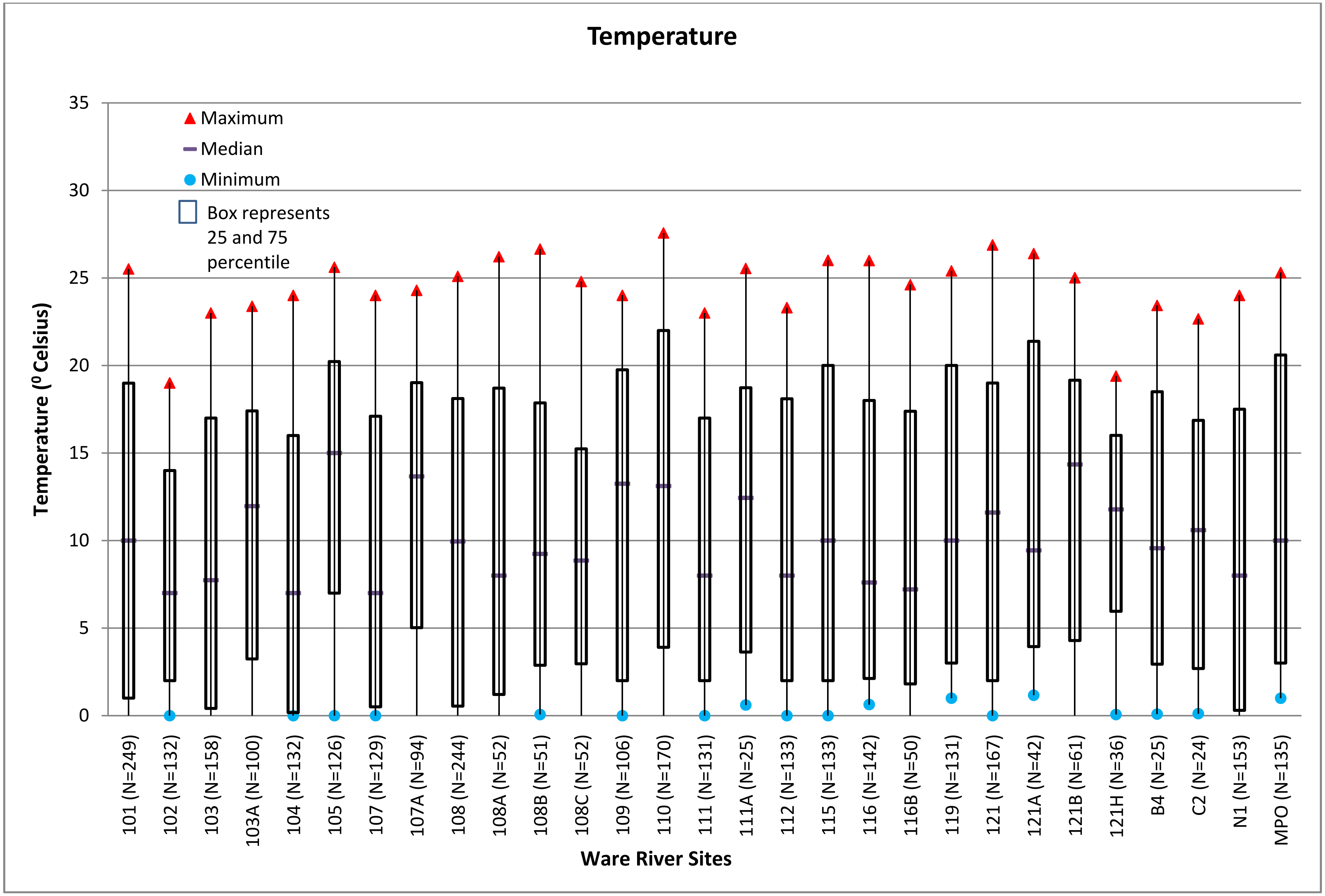

Figure 16. Boxplot of Temperature Data, Ware River Sites, 2000-2009

Table 17. Summary Statistics for Temperature (°Celsius), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	10.36	8.02	9.24	11.20	8.42	13.83	8.89	12.08	10.03	9.89	10.58
75 percentile	18.99	14.00	17.00	17.41	16.00	20.23	17.10	19.02	18.12	18.71	17.87
Maximum	25.51	19.00	23.00	23.38	24.00	25.61	24.00	24.29	25.09	26.21	26.65
Median	10.00	7.00	7.74	11.97	7.00	15.00	7.00	13.67	9.95	8.00	9.24
Minimum	-0.47	0.00	-0.01	-0.41	0.00	0.00	0.00	-0.45	-0.47	-0.44	0.06
25 percentile	1.00	2.00	0.41	3.24	0.18	7.00	0.50	5.02	0.55	1.21	2.88
N all samples	249	132	158	100	132	126	129	94	244	52	51

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	9.64	11.28	12.89	9.34	12.01	9.83	10.76	10.35	9.20	11.15	10.93
75 percentile	15.24	19.75	22.00	17.00	18.73	18.10	20.00	18.00	17.38	20.00	19.00
Maximum	24.79	24.00	27.57	23.00	25.54	23.30	26.00	25.99	24.61	25.40	26.88
Median	8.86	13.25	13.12	8.00	12.44	8.00	10.00	7.61	7.21	10.00	11.60
Minimum	-0.49	0.00	-0.05	0.00	0.61	0.00	0.00	0.64	-0.30	1.00	0.00
25 percentile	2.96	2.00	3.90	2.00	3.63	2.00	2.00	2.13	1.81	3.00	2.00
N all samples	52	106	170	131	25	133	133	142	50	131	167

SITE	121A	121B	121H	B4	C2	N1	MPO
Mean	11.54	12.21	10.64	10.87	10.30	9.33	11.55
75 percentile	21.38	19.16	16.01	18.50	16.86	17.50	20.60
Maximum	26.39	25.01	19.39	23.43	22.66	24.00	25.30
Median	9.44	14.35	11.78	9.56	10.60	8.00	10.00
Minimum	1.16	-0.04	0.06	0.09	0.12	-0.02	1.00
25 percentile	3.94	4.29	5.96	2.94	2.69	0.30	3.00
N all samples	42	61	36	25	24	153	135

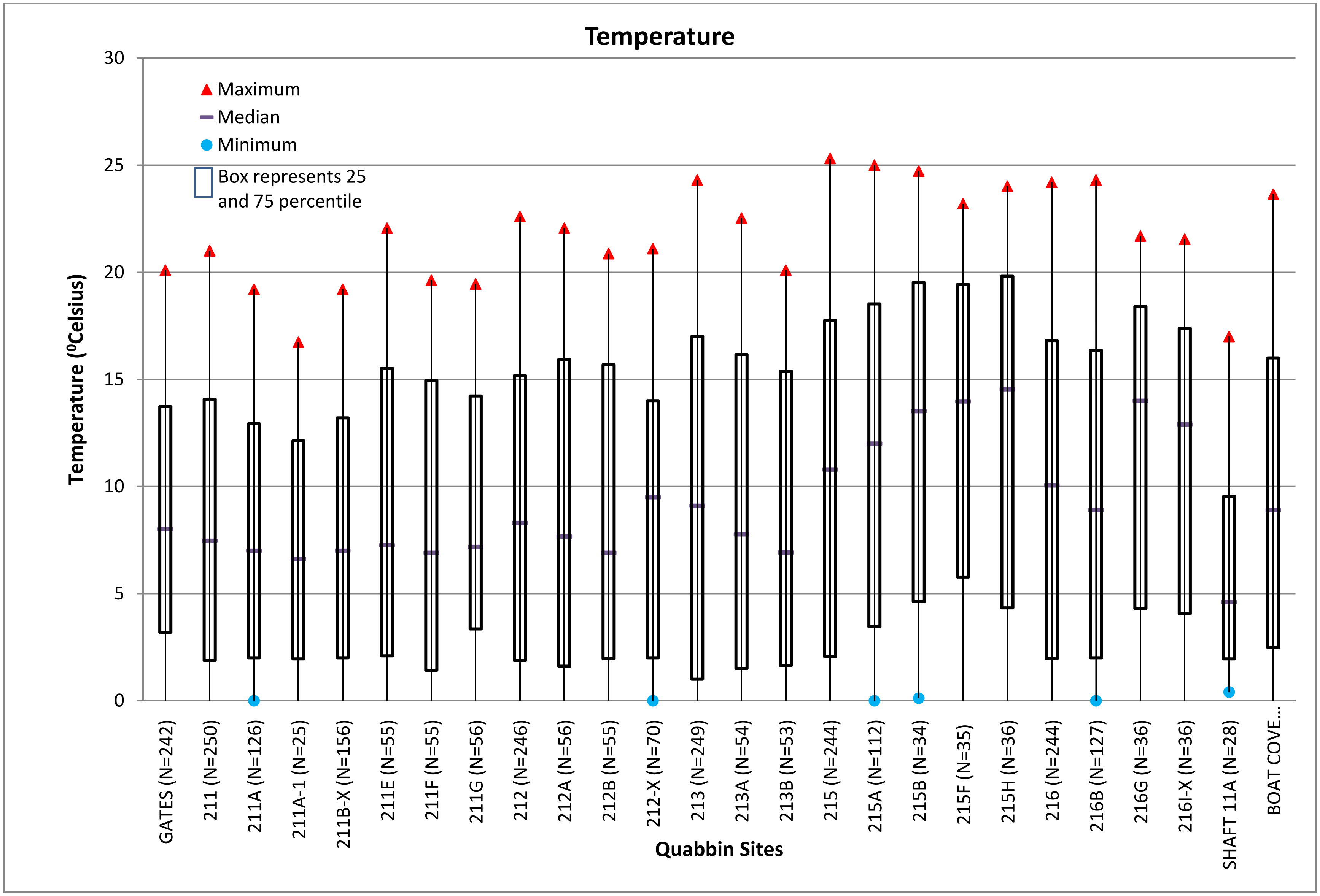

Figure 17. Boxplot of Temperature Data, Quabbin Tributary Sites, 2000-2009

Table 18. Summary Statistics for Temperature (°Celsius), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	8.62	8.26	7.88	7.62	7.96	8.47	7.89	8.26	8.76	8.71	8.37
75 percentile	13.72	14.08	12.93	12.13	13.20	15.52	14.95	14.23	15.17	15.93	15.69
Maximum	20.10	21.00	19.20	16.73	19.20	22.06	19.62	19.45	22.60	22.06	20.87
Median	8.01	7.47	7.00	6.61	7.00	7.26	6.90	7.18	8.30	7.66	6.90
Minimum	-0.43	-0.40	0.00	-0.05	-0.01	-0.40	-0.46	-0.46	-0.42	-0.44	-0.41
25 percentile	3.20	1.88	2.00	1.95	2.00	2.10	1.42	3.35	1.87	1.61	1.96
N all samples	242	250	126	25	156	55	55	56	246	56	55

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	8.83	9.71	9.06	8.21	10.39	11.46	12.72	12.73	12.54	10.01	9.64
75 percentile	14.00	17.00	16.16	15.39	17.75	18.53	19.52	19.43	19.82	16.81	16.35
Maximum	21.10	24.30	22.53	20.10	25.31	25.00	24.72	23.20	24.02	24.20	24.30
Median	9.50	9.10	7.77	6.91	10.79	12.00	13.52	13.97	14.54	10.05	8.90
Minimum	0.00	-0.42	-0.40	-0.43	-0.04	0.00	0.12	-0.01	-0.05	-0.47	0.00
25 percentile	2.00	1.00	1.50	1.64	2.06	3.45	4.62	5.77	4.33	1.96	2.00
N all samples	70	249	54	53	244	112	34	35	36	244	127

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	11.98	11.37	6.11	9.55
75 percentile	18.40	17.39	9.53	16.00
Maximum	21.69	21.54	17.00	23.64
Median	14.00	12.90	4.60	8.90
Minimum	-0.07	-0.06	0.40	-0.39
25 percentile	4.31	4.05	1.95	2.48
N all samples	36	36	28	216

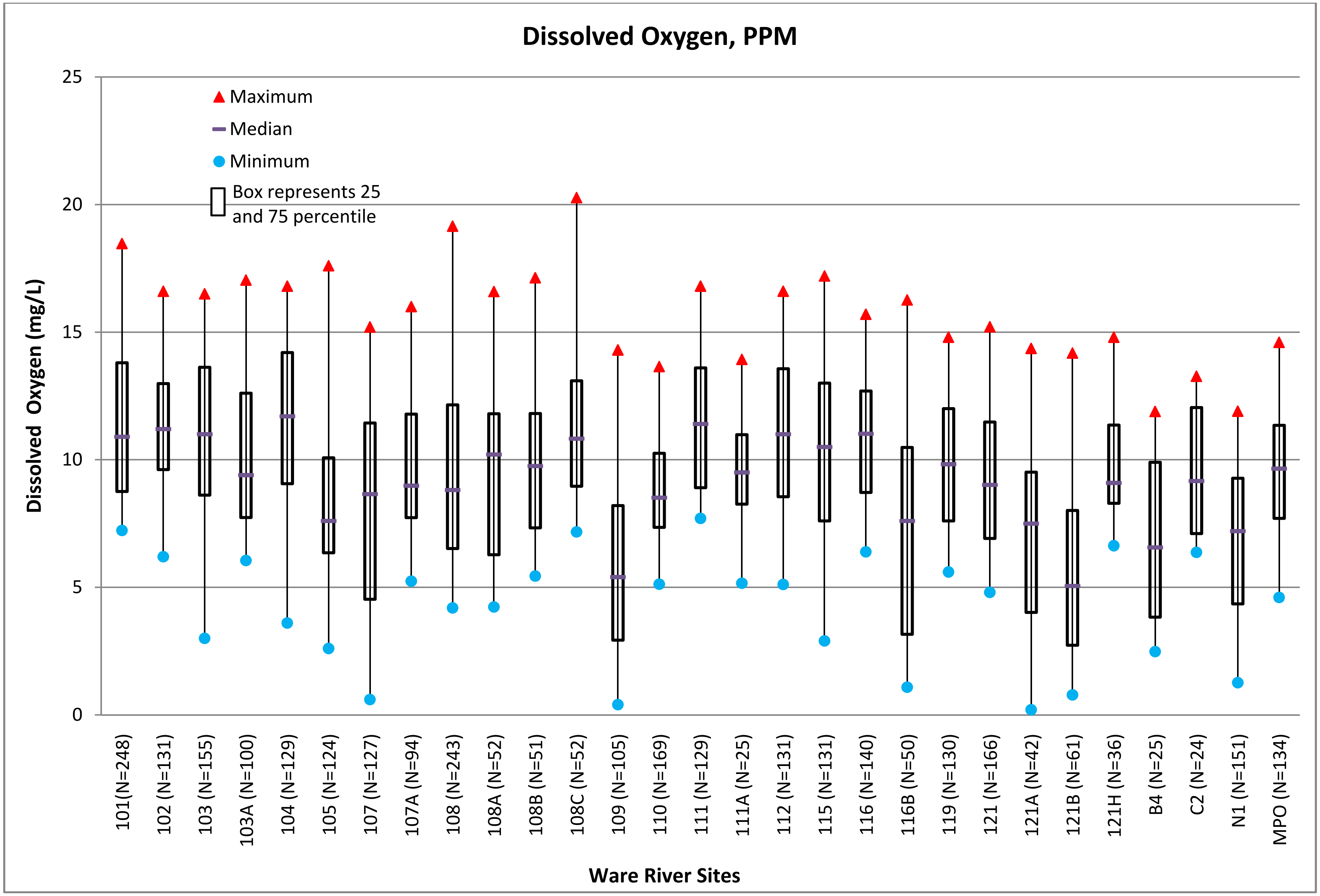

Figure 18. Boxplot of Dissolved Oxygen (mg/L) Data, Ware River Sites, 2000-2009

Table 19. Summary Statistics for Dissolved Oxygen (mg/L), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	11.31	11.39	11.10	10.16	11.63	8.30	7.97	9.80	9.46	9.64	9.77
75 percentile	13.80	12.99	13.62	12.61	14.20	10.08	11.44	11.79	12.15	11.80	11.81
Maximum	18.47	16.60	16.50	17.04	16.80	17.60	15.20	16.00	19.15	16.59	17.13
Median	10.90	11.20	11.00	9.40	11.70	7.60	8.65	8.98	8.81	10.21	9.75
Minimum	7.23	6.20	3.00	6.05	3.60	2.60	0.60	5.24	4.19	4.23	5.44
25 percentile	8.75	9.61	8.61	7.74	9.06	6.35	4.53	7.73	6.52	6.28	7.33
N all samples	248	131	155	100	129	124	127	94	243	52	51

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	11.26	5.64	8.75	11.40	9.65	10.98	10.29	10.87	7.37	9.89	9.40
75 percentile	13.09	8.20	10.25	13.60	10.98	13.57	13.00	12.69	10.48	12.00	11.48
Maximum	20.27	14.30	13.65	16.80	13.93	16.60	17.20	15.70	16.26	14.80	15.21
Median	10.83	5.40	8.51	11.40	9.50	11.00	10.50	11.02	7.60	9.83	9.01
Minimum	7.17	0.40	5.12	7.70	5.16	5.11	2.90	6.39	1.08	5.60	4.80
25 percentile	8.96	2.93	7.35	8.90	8.26	8.55	7.60	8.72	3.16	7.60	6.91
N all samples	52	105	169	129	25	131	131	140	50	130	166

SITE	121A	121B	121H	B4	C2	N1	MPO
Mean	6.80	5.82	10.10	7.14	9.58	6.80	9.58
75 percentile	9.51	8.01	11.36	9.90	12.04	9.28	11.35
Maximum	14.36	14.18	14.80	11.89	13.27	11.90	14.60
Median	7.50	5.05	9.09	6.56	9.17	7.20	9.65
Minimum	0.20	0.78	6.63	2.48	6.37	1.26	4.60
25 percentile	4.02	2.73	8.29	3.83	7.10	4.35	7.70
N all samples	42	61	36	25	24	151	134

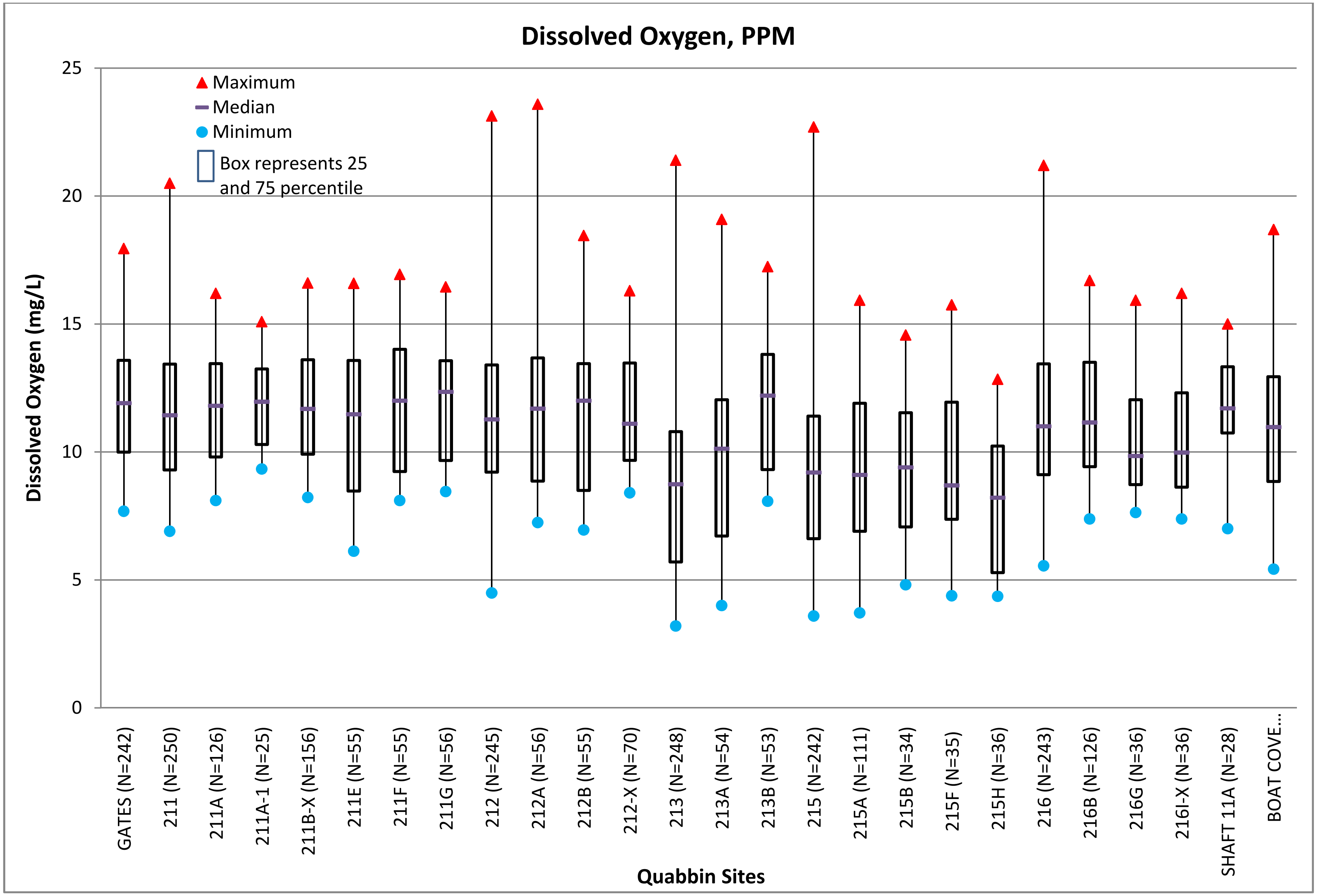

Figure 19. Boxplot of Dissolved Oxygen (mg/L) Data, Quabbin Tributary Sites, 2000-2009

Table 20. Summary Statistics for Dissolved Oxygen (mg/L), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	11.98	11.54	11.69	11.79	11.78	11.36	11.97	11.95	11.46	11.91	11.47
75 percentile	13.58	13.43	13.45	13.24	13.60	13.58	14.01	13.57	13.40	13.68	13.45
Maximum	17.95	20.50	16.20	15.09	16.60	16.59	16.94	16.45	23.13	23.59	18.46
Median	11.91	11.43	11.80	11.96	11.68	11.47	12.00	12.35	11.27	11.69	12.00
Minimum	7.68	6.90	8.10	9.33	8.22	6.12	8.10	8.45	4.49	7.24	6.95
25 percentile	9.99	9.30	9.80	10.29	9.91	8.47	9.24	9.67	9.21	8.86	8.50
N all samples	242	250	126	25	156	55	55	56	245	56	55
SITE	**212-X**	**213**	**213A**	**213B**	**215**	**215A**	**215B**	**215F**	**215H**	**216**	**216B**
Mean	11.56	8.51	9.83	11.95	9.18	9.55	9.24	9.54	7.84	11.35	11.51
75 percentile	13.48	10.79	12.04	13.81	11.40	11.90	11.53	11.95	10.23	13.44	13.50
Maximum	16.30	21.40	19.09	17.24	22.70	15.93	14.57	15.75	12.84	21.20	16.70
Median	11.10	8.74	10.13	12.20	9.20	9.10	9.40	8.69	8.21	11.00	11.15
Minimum	8.40	3.20	4.00	8.07	3.59	3.71	4.81	4.38	4.36	5.55	7.38
25 percentile	9.67	5.70	6.71	9.31	6.61	6.90	7.07	7.37	5.28	9.11	9.43
N all samples	70	248	54	53	242	111	34	35	36	243	126
SITE	**216G**	**216I-X**	**SHAFT 11A**	**BOAT COVE**							
Mean	10.47	10.53	11.68	11.03							
75 percentile	12.04	12.31	13.33	12.94							
Maximum	15.93	16.20	15.00	18.69							
Median	9.84	9.98	11.70	10.97							
Minimum	7.63	7.38	7.00	5.42							
25 percentile	8.72	8.62	10.74	8.85							
N all samples	36	36	28	215							

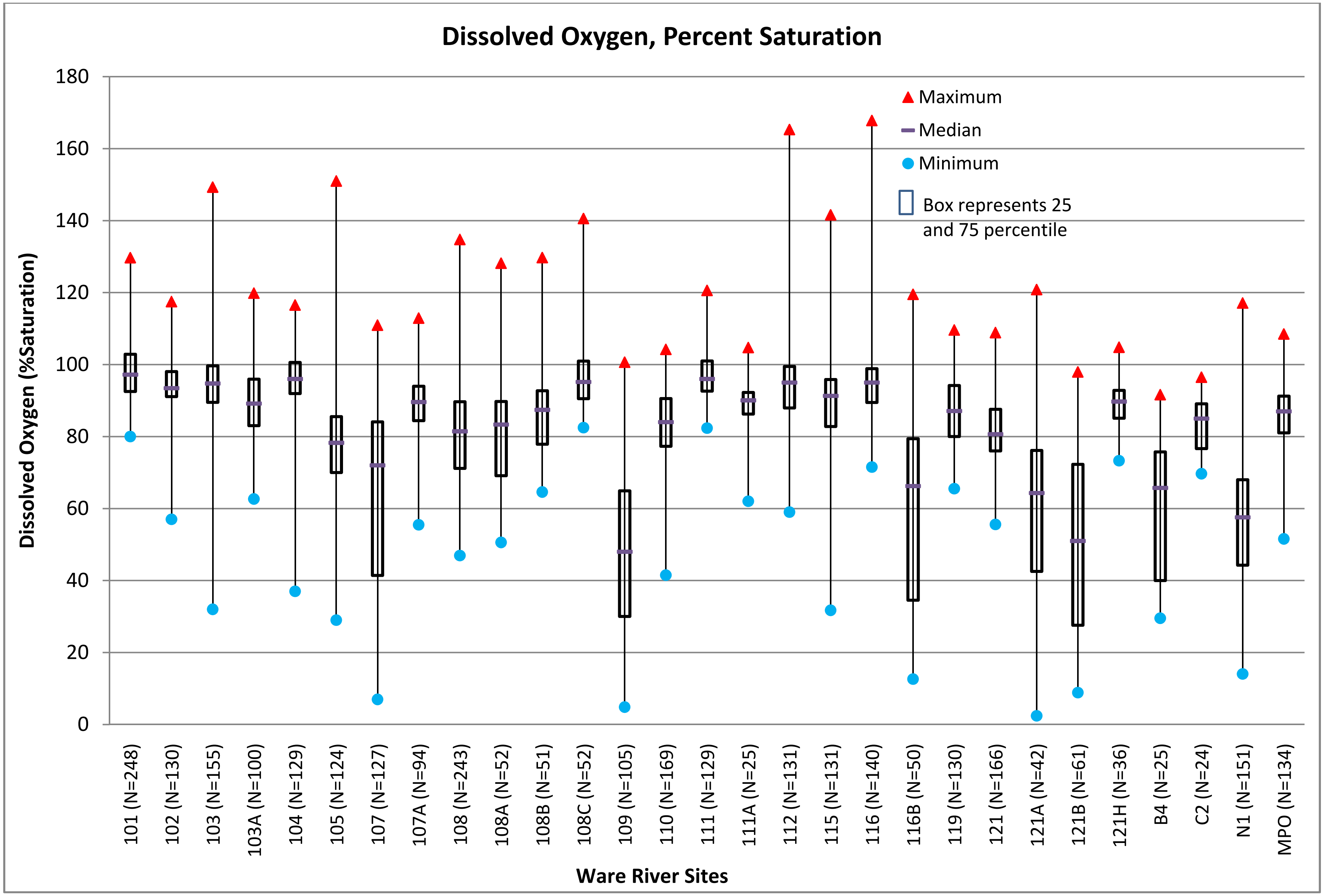

Figure 20. Boxplot of Dissolved Oxygen (% Saturation) Data, Ware River Sites, 2000-2009

Table 21. Summary Statistics for Dissolved Oxygen (% Saturation), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	98.23	95.02	93.52	90.23	95.71	77.48	63.53	89.15	80.32	81.76	85.85
75 percentile	102.86	98.06	99.65	95.94	100.60	85.55	84.08	93.97	89.66	89.74	92.74
Maximum	129.70	117.50	149.30	119.85	116.55	151.00	110.95	112.90	134.76	128.16	129.73
Median	97.20	93.45	94.74	89.16	96.00	78.27	72.00	89.59	81.45	83.33	87.42
Minimum	80.00	57.00	32.00	62.65	37.00	29.00	6.98	55.48	46.93	50.58	64.58
25 percentile	92.51	91.09	89.51	83.03	91.94	70.00	41.42	84.43	71.15	69.12	77.88
N all samples	248	130	155	100	129	124	127	94	243	52	51

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	97.39	47.25	81.69	96.87	88.26	93.69	89.05	95.30	59.55	87.31	82.07
75 percentile	100.97	64.90	90.54	101.00	92.26	99.49	95.85	98.86	79.39	94.20	87.57
Maximum	140.58	100.66	104.23	120.60	104.74	165.30	141.60	167.80	119.51	109.61	108.89
Median	95.17	48.00	84.00	96.00	90.06	95.00	91.30	95.00	66.24	87.10	80.65
Minimum	82.46	4.84	41.49	82.34	62.03	59.00	31.73	71.51	12.63	65.52	55.58
25 percentile	90.53	30.00	77.30	92.61	86.25	87.95	82.78	89.46	34.53	80.00	76.00
N all samples	52	105	169	129	25	131	131	140	50	130	166

SITE	121A	121B	121H	B4	C2	N1	MPO
Mean	59.99	50.49	89.76	60.88	83.46	55.91	85.80
75 percentile	76.14	72.28	92.83	75.75	89.09	68.00	91.22
Maximum	120.84	97.96	104.82	91.65	96.49	117.10	108.50
Median	64.30	50.99	89.73	65.72	85.00	57.56	87.00
Minimum	2.42	8.86	73.27	29.52	69.67	14.04	51.56
25 percentile	42.53	27.59	85.10	39.98	76.63	44.25	81.01
N all samples	42	61	36	25	24	151	134

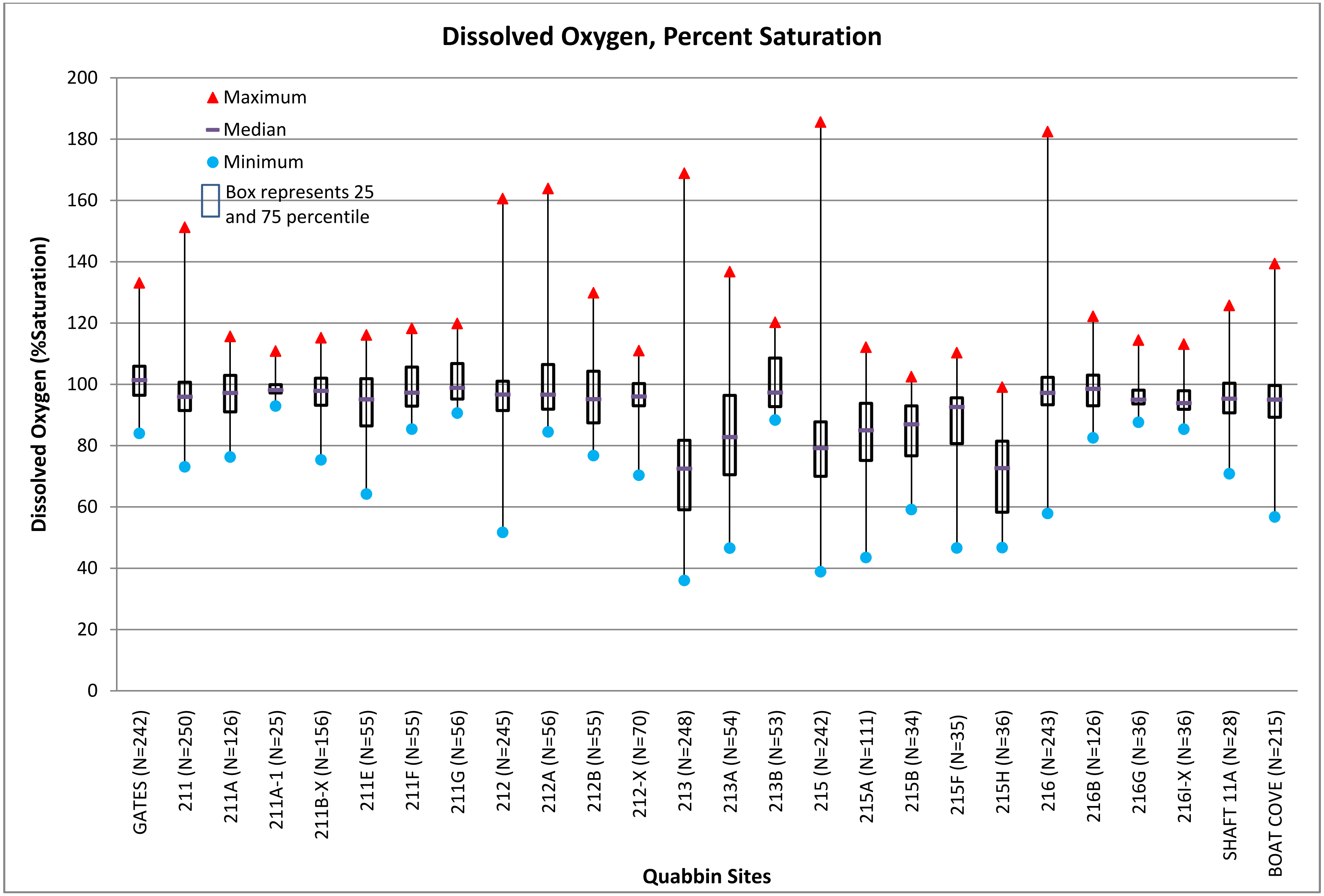

Figure 21. Boxplot of Dissolved Oxygen (% Saturation) Data, Quabbin Tributary Sites, 2000-2009

Table 22. Summary Statistics for Dissolved Oxygen (% Saturation), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	101.76	96.55	96.95	98.71	98.03	95.07	99.44	101.15	96.55	100.25	95.83
75 percentile	105.90	100.70	102.90	99.88	102.00	101.84	105.61	106.78	101.00	106.46	104.26
Maximum	133.11	151.25	115.64	110.85	115.20	116.11	118.27	119.86	160.61	163.91	129.87
Median	101.36	95.93	97.17	98.15	97.87	95.09	97.25	98.86	96.66	96.62	95.16
Minimum	84.00	73.10	76.30	92.93	75.36	64.20	85.41	90.65	51.70	84.48	76.75
25 percentile	96.44	91.44	91.00	97.20	93.14	86.45	92.89	95.21	91.43	91.88	87.41
N all samples	242	250	126	25	156	55	55	56	245	56	55

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	96.94	71.67	82.12	100.07	79.13	83.73	84.86	87.76	71.66	98.19	98.58
75 percentile	100.25	81.75	96.38	108.57	87.74	93.81	92.97	95.57	81.44	102.29	103.00
Maximum	111.00	168.89	136.78	120.26	185.60	112.10	102.49	110.31	99.09	182.45	122.20
Median	96.02	72.49	82.78	97.30	79.18	85.00	86.95	92.59	72.63	97.20	98.52
Minimum	70.35	36.00	46.56	88.37	38.84	43.49	59.15	46.58	46.70	57.88	82.55
25 percentile	93.00	59.07	70.48	92.72	70.00	75.15	76.68	80.65	58.25	93.32	93.00
N all samples	70	248	54	53	242	111	34	35	36	243	126

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	96.12	95.11	94.05	94.89
75 percentile	98.10	97.89	100.35	99.60
Maximum	114.44	113.12	125.75	139.41
Median	94.98	93.87	95.31	95.01
Minimum	87.64	85.38	70.84	56.74
25 percentile	93.59	91.85	90.69	89.26
N all samples	36	36	28	215

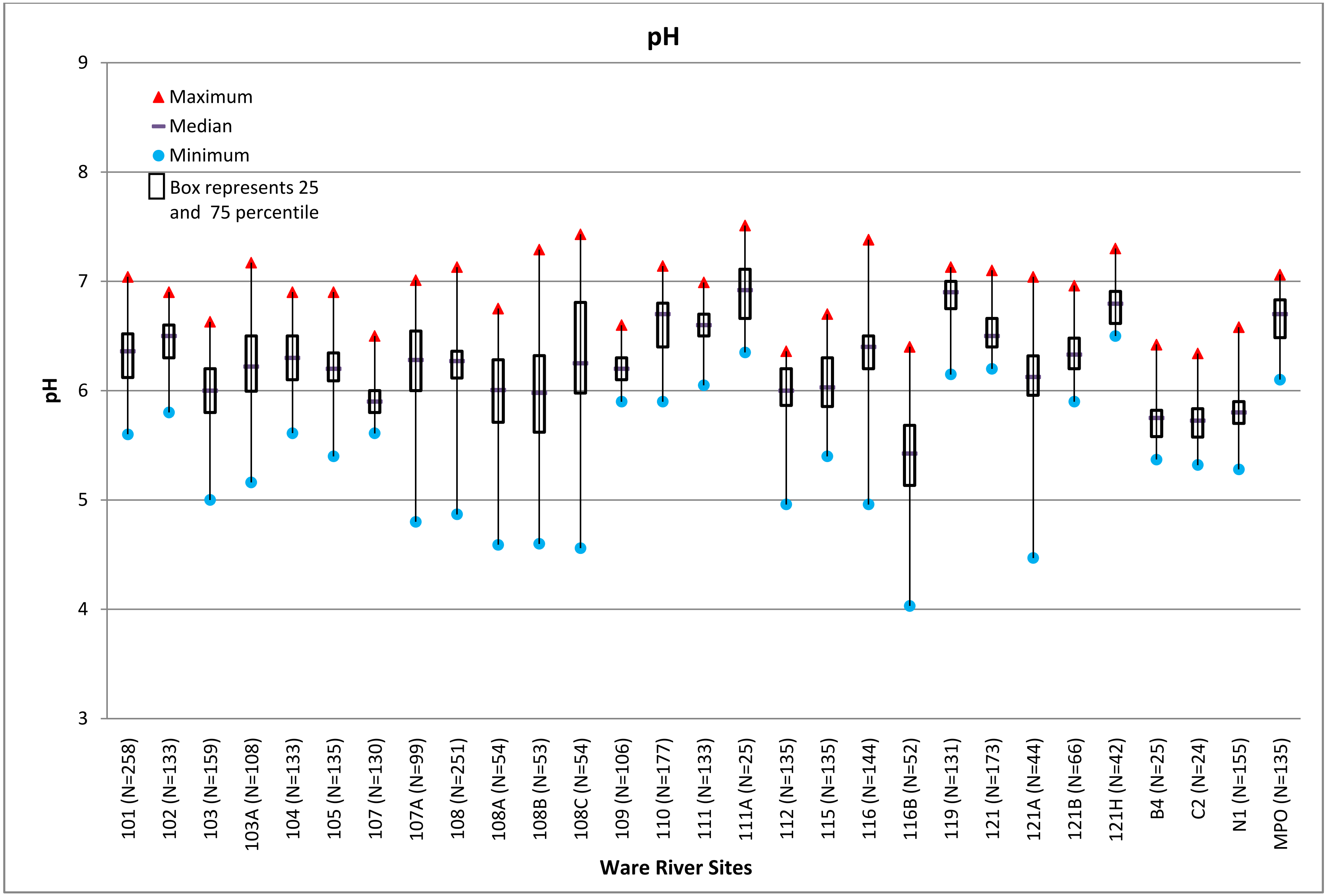

Figure 22. Boxplot of pH Data, Ware River Sites, 2000-2009

Table 23. Summary Statistics for pH (standard units), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	6.34	6.45	5.98	6.20	6.28	6.20	5.89	6.22	6.23	5.95	5.93
75 percentile	6.52	6.60	6.20	6.50	6.50	6.35	6.00	6.55	6.36	6.28	6.32
Maximum	7.04	6.90	6.63	7.17	6.90	6.90	6.50	7.01	7.13	6.75	7.29
Median	6.36	6.50	6.00	6.22	6.30	6.20	5.90	6.28	6.27	6.01	5.98
Minimum	5.60	5.80	5.00	5.16	5.61	5.40	5.61	4.80	4.87	4.59	4.60
25 percentile	6.12	6.30	5.80	6.00	6.10	6.09	5.80	6.00	6.12	5.71	5.62
N all samples	258	133	159	108	133	135	130	99	251	54	53

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	6.31	6.23	6.62	6.59	6.93	6.00	6.06	6.32	5.36	6.83	6.54
75 percentile	6.81	6.30	6.80	6.70	7.11	6.20	6.30	6.50	5.68	7.00	6.66
Maximum	7.43	6.60	7.14	6.99	7.51	6.36	6.70	7.38	6.40	7.13	7.10
Median	6.25	6.20	6.70	6.60	6.92	6.00	6.03	6.40	5.43	6.90	6.50
Minimum	4.56	5.90	5.90	6.05	6.35	4.96	5.40	4.96	4.03	6.15	6.20
25 percentile	5.98	6.10	6.40	6.50	6.66	5.87	5.86	6.20	5.13	6.75	6.40
N all samples	54	106	177	133	25	135	135	144	52	131	173

SITE	121A	121B	121H	B4	C2	N1	MPO
Mean	6.07	6.37	6.79	5.78	5.76	5.83	6.64
75 percentile	6.32	6.48	6.91	5.82	5.84	5.90	6.83
Maximum	7.04	6.96	7.30	6.42	6.34	6.58	7.06
Median	6.13	6.33	6.80	5.75	5.73	5.80	6.70
Minimum	4.47	5.90	6.50	5.37	5.32	5.28	6.10
25 percentile	5.96	6.20	6.62	5.58	5.58	5.70	6.49
N all samples	44	66	42	25	24	155	135

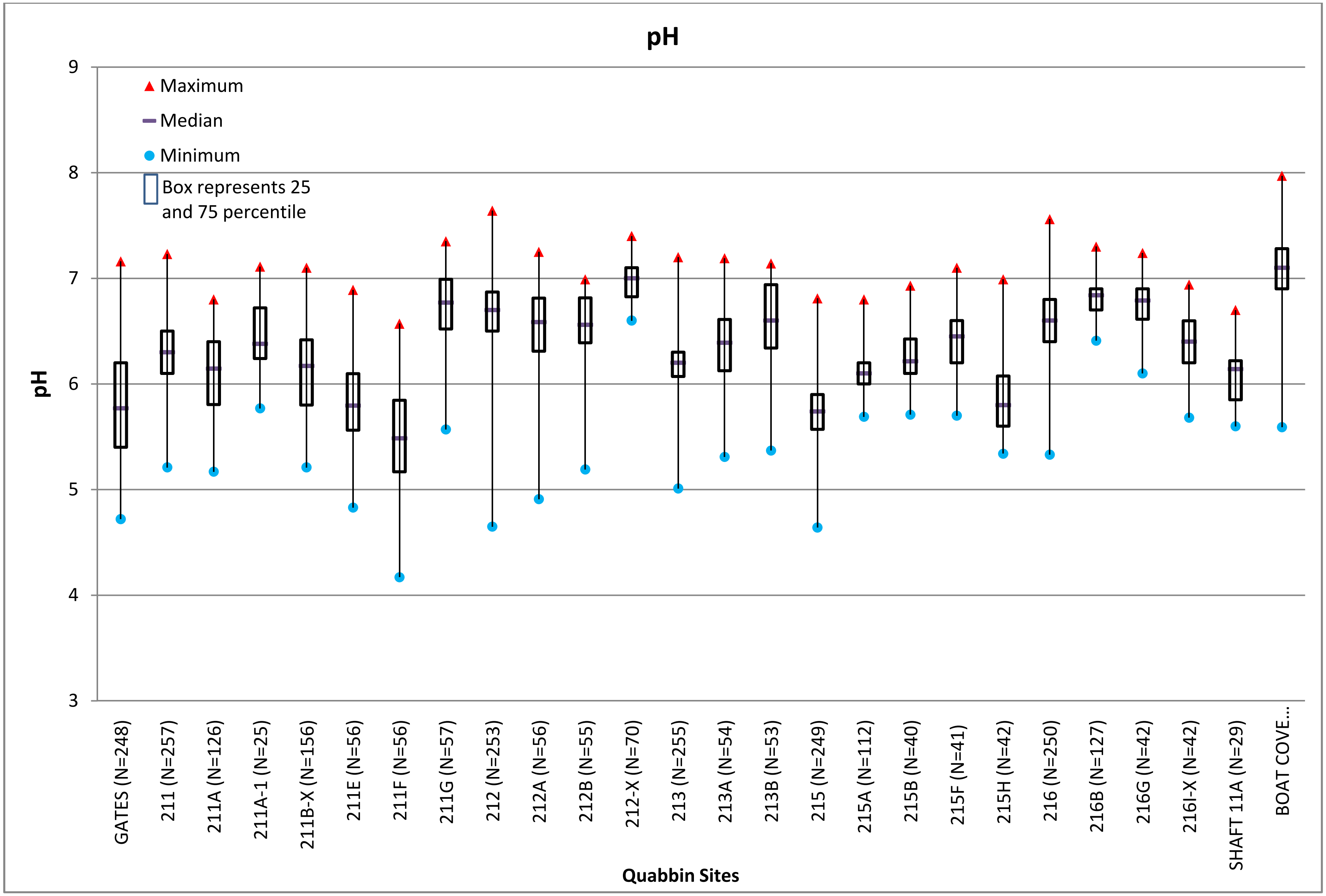

Figure 23. Boxplot of pH Data, Quabbin Tributary Sites, 2000-2009

Table 24. Summary Statistics for pH (standard units), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	5.80	6.29	6.10	6.44	6.12	5.80	5.48	6.72	6.67	6.49	6.47
75 percentile	6.20	6.50	6.40	6.72	6.42	6.10	5.85	6.99	6.87	6.81	6.82
Maximum	7.16	7.23	6.80	7.11	7.10	6.89	6.57	7.35	7.64	7.25	6.99
Median	5.77	6.30	6.15	6.38	6.17	5.80	5.49	6.77	6.70	6.59	6.56
Minimum	4.72	5.21	5.17	5.77	5.21	4.83	4.17	5.57	4.65	4.91	5.19
25 percentile	5.40	6.10	5.81	6.24	5.80	5.56	5.17	6.52	6.50	6.31	6.39
N all samples	248	257	126	25	156	56	56	57	253	56	55

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	6.97	6.17	6.35	6.57	5.75	6.09	6.26	6.39	5.88	6.59	6.83
75 percentile	7.10	6.30	6.61	6.94	5.90	6.20	6.43	6.60	6.08	6.80	6.90
Maximum	7.40	7.20	7.19	7.14	6.81	6.80	6.93	7.10	6.99	7.56	7.30
Median	7.00	6.20	6.39	6.60	5.74	6.10	6.22	6.45	5.80	6.60	6.84
Minimum	6.60	5.01	5.31	5.37	4.64	5.69	5.71	5.70	5.34	5.33	6.41
25 percentile	6.83	6.07	6.13	6.34	5.57	6.00	6.10	6.20	5.60	6.40	6.70
N all samples	70	255	54	53	249	112	40	41	42	250	127

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	6.77	6.40	6.12	7.08
75 percentile	6.90	6.60	6.22	7.28
Maximum	7.24	6.94	6.70	7.97
Median	6.79	6.40	6.14	7.10
Minimum	6.10	5.68	5.60	5.59
25 percentile	6.61	6.20	5.85	6.90
N all samples	42	42	29	221

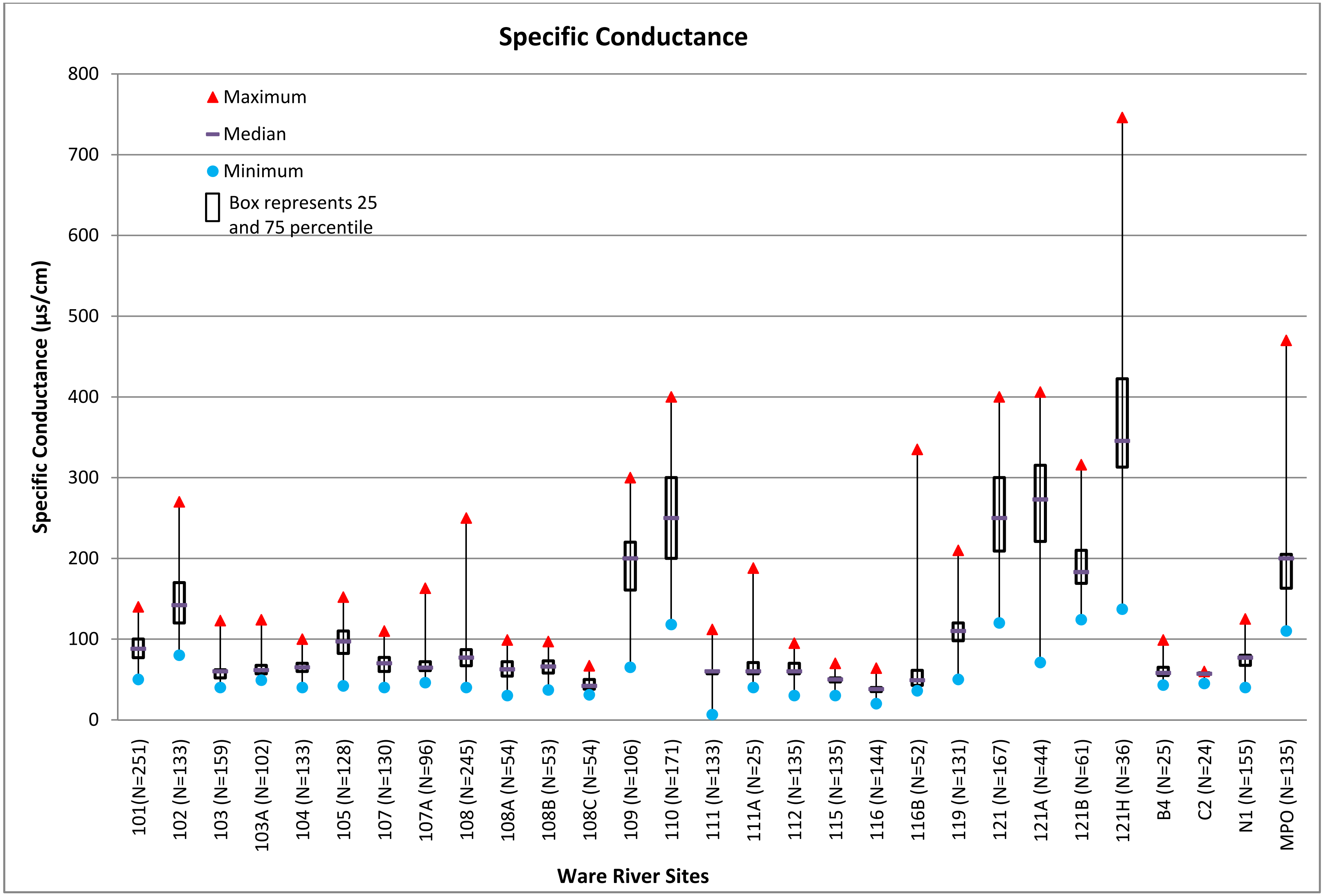

Figure 24. Boxplot of Specific Conductance Data, Ware River Sites, 2000-2009

Table 25. Summary Statistics for Specific Conductance (µs/cm), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	88	146	60	64	65	96	68	68	77	65	66
75 percentile	100	170	62	68	70	110	77	72	87	72	73
Maximum	140	270	123	124	100	152	110	163	250	99	97
Median	88	142	60	62	65	97	70	65	77	63	66
Minimum	50	80	40	49	40	42	40	46	40	30	37
25 percentile	77	120	52	57	60	82	60	61	67	54	58
N all samples	251	133	159	102	133	128	130	96	245	54	53
SITE	**108C**	**109**	**110**	**111**	**111A**	**112**	**115**	**116**	**116B**	**119**	**121**
Mean	45	191	248	60	72	62	50	37	66	108	254
75 percentile	50	220	300	60	71	70	52	40	61	120	300
Maximum	67	300	400	112	188	95	70	64	335	210	400
Median	42	200	250	60	60	60	50	38	49	110	250
Minimum	31	65	118	7	40	30	30	20	36	50	120
25 percentile	38	161	200	57	57	57	47	35	43	98	209
N all samples	54	106	171	133	25	135	135	144	52	131	167
SITE	**121A**	**121B**	**121H**	**B4**	**C2**	**N1**	**MPO**				
Mean	273	193	390	61	56	76	199				
75 percentile	315	210	423	65	58	80	205				
Maximum	406	316	746	99	60	125	470				
Median	273	183	346	58	57	77	200				
Minimum	71	124	137	43	45	40	110				
25 percentile	221	169	313	55	56	68	163				
N all samples	44	61	36	25	24	155	135				

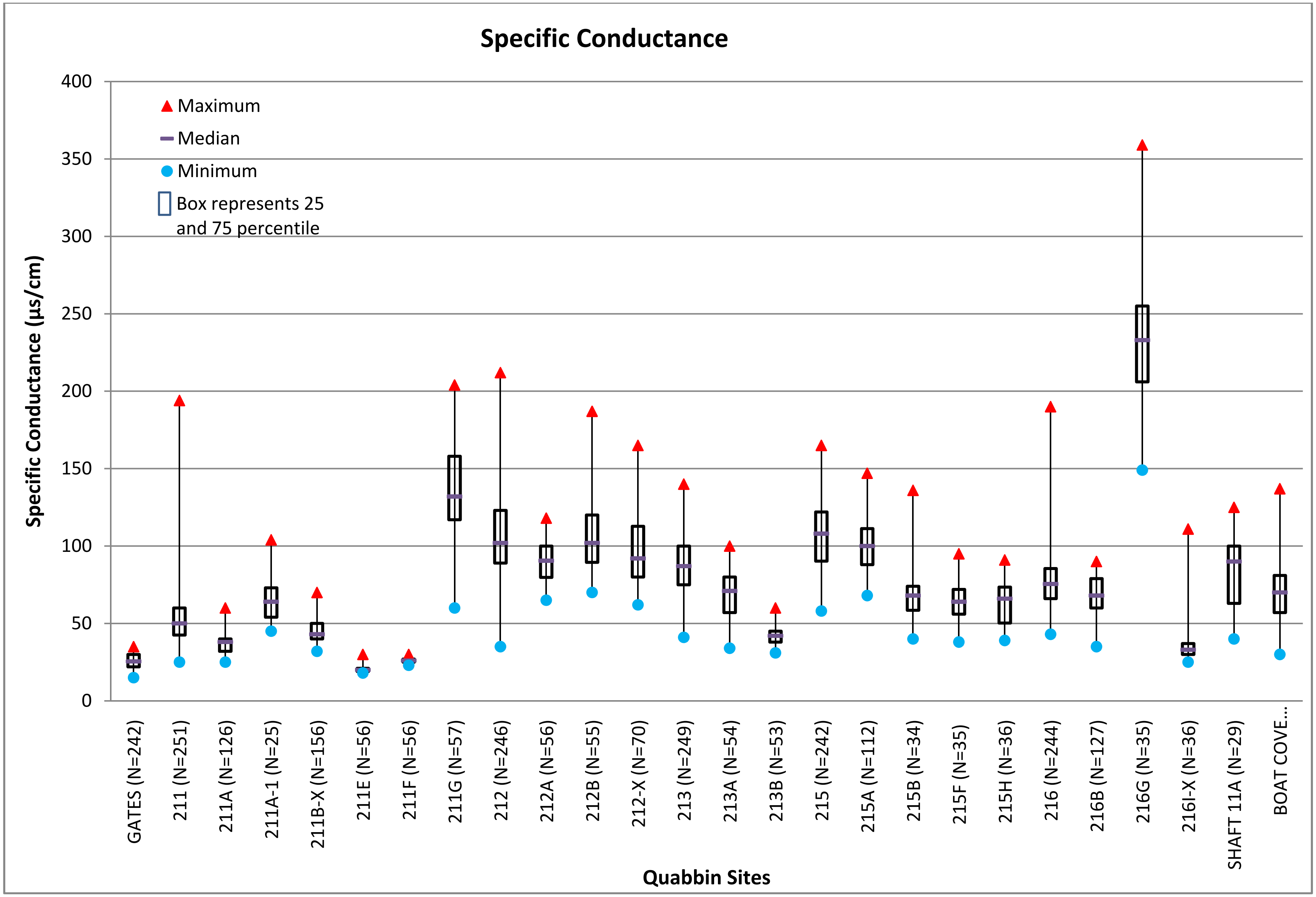

Figure 25. Boxplot of Specific Conductance Data, Quabbin Tributary Sites, 2000-2009

Table 26. Summary Statistics for Specific Conductance (µs/cm), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	26	57	38	66	45	20	26	135	108	91	105
75 percentile	30	60	40	73	50	21	27	158	123	100	120
Maximum	35	194	60	104	70	30	30	204	212	118	187
Median	26	50	38	64	43	20	26	132	102	91	102
Minimum	15	25	25	45	32	18	23	60	35	65	70
25 percentile	22	43	32	54	40	19	25	117	89	80	90
N all samples	242	251	126	25	156	56	56	57	246	56	55

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	99	88	69	42	108	102	70	64	64	78	68
75 percentile	113	100	80	45	122	111	74	72	74	86	79
Maximum	165	140	100	60	165	147	136	95	91	190	90
Median	92	87	71	42	108	100	68	64	66	76	68
Minimum	62	41	34	31	58	68	40	38	39	43	35
25 percentile	80	75	57	38	90	88	59	56	50	66	60
N all samples	70	249	54	53	242	112	34	35	36	244	127

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	235	35	82	71
75 percentile	255	37	100	81
Maximum	359	111	125	137
Median	233	33	90	70
Minimum	149	25	40	30
25 percentile	206	30	63	57
N all samples	35	36	29	214

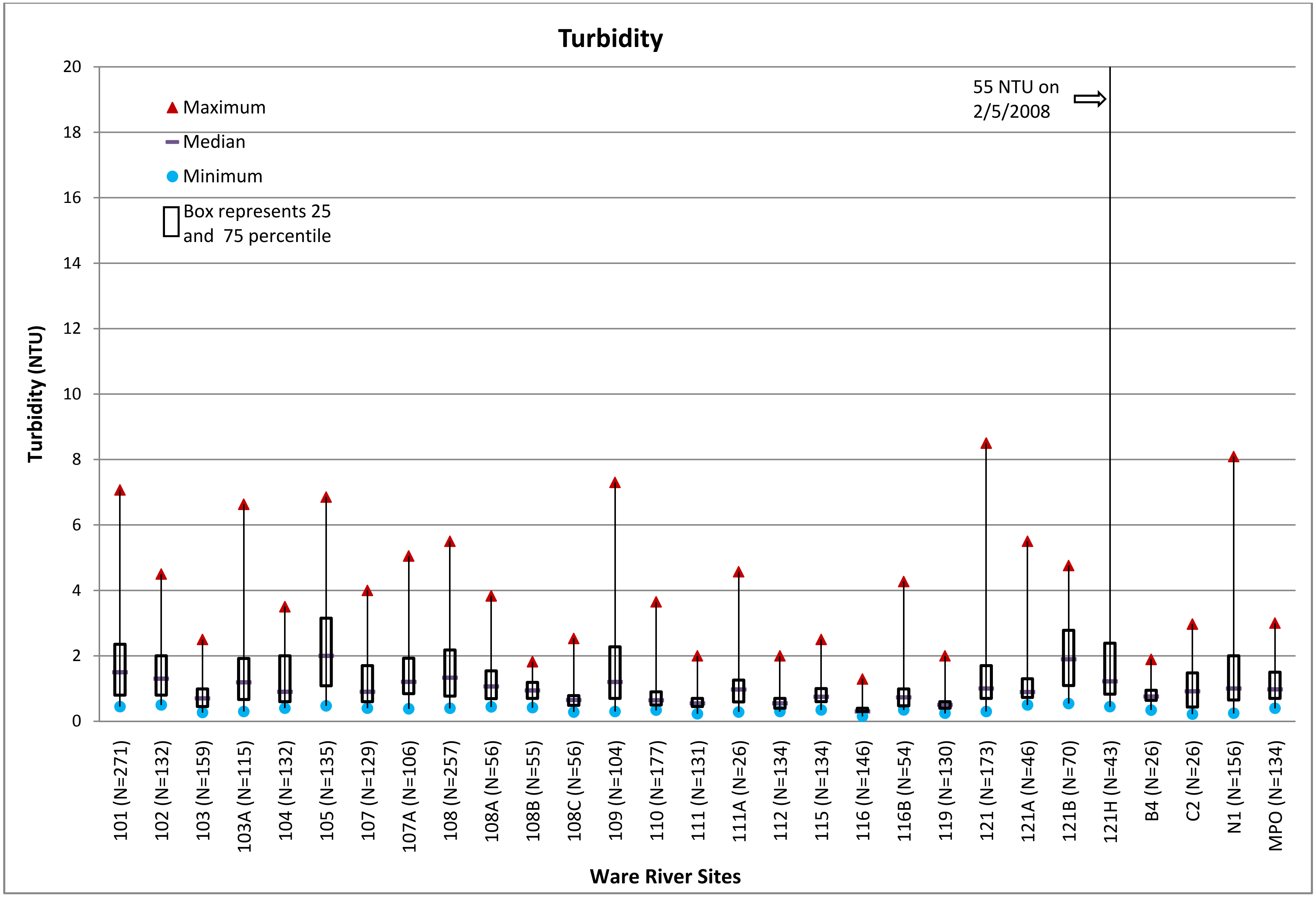

Figure 26. Boxplot of Turbidity Data, Ware River Sites, 2000-2009

Table 27. Summary Statistics for Turbidity (NTU), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	1.70	1.56	0.75	1.47	1.28	2.25	1.31	1.44	1.56	1.21	0.97
75 percentile	2.36	2.00	0.99	1.92	2.00	3.15	1.70	1.93	2.18	1.54	1.19
Maximum	7.07	4.50	2.50	6.63	3.50	6.85	4.00	5.05	5.50	3.83	1.82
Median	1.50	1.30	0.70	1.19	0.90	2.00	0.90	1.21	1.33	1.07	0.94
Minimum	0.45	0.50	0.27	0.30	0.40	0.47	0.40	0.38	0.40	0.44	0.42
25 percentile	0.80	0.80	0.45	0.67	0.60	1.09	0.60	0.85	0.77	0.69	0.70
N all samples	271	132	159	115	132	135	129	106	257	56	55

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	0.76	1.73	0.78	0.60	1.18	0.61	0.87	0.36	0.88	0.53	1.49
75 percentile	0.78	2.28	0.90	0.70	1.26	0.70	1.00	0.40	0.99	0.60	1.70
Maximum	2.53	7.30	3.65	2.00	4.57	2.00	2.50	1.29	4.27	2.00	8.50
Median	0.65	1.20	0.64	0.55	0.97	0.55	0.75	0.30	0.73	0.50	1.00
Minimum	0.28	0.30	0.34	0.23	0.28	0.30	0.35	0.15	0.35	0.25	0.30
25 percentile	0.49	0.70	0.50	0.45	0.59	0.40	0.60	0.30	0.47	0.40	0.70
N all samples	56	104	177	131	26	134	134	146	54	130	173

SITE	121A	121B	121H	B4	C2	N1	MPO
Mean	1.25	1.98	4.37	0.80	1.02	1.46	1.19
75 percentile	1.30	2.78	2.39	0.95	1.48	2.00	1.50
Maximum	5.50	4.76	55.00	1.9	2.97	8.09	3.00
Median	0.90	1.90	1.22	0.76	0.92	1.00	0.98
Minimum	0.50	0.54	0.45	0.34	0.22	0.25	0.40
25 percentile	0.73	1.09	0.83	0.64	0.44	0.65	0.70
N all samples	46	70	43	26	26	156	134

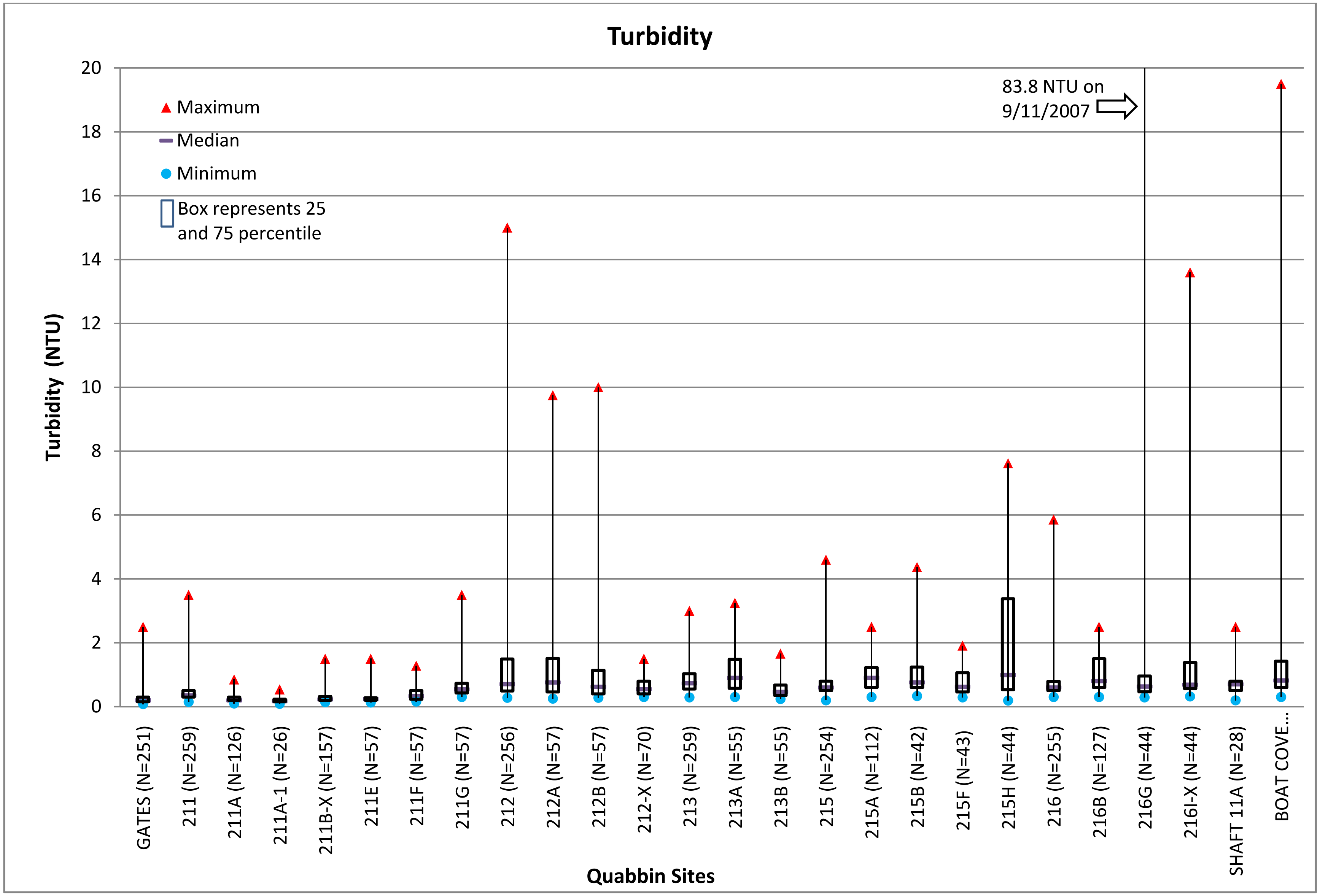

Figure 27. Boxplot of Turbidity Data, Quabbin Tributary Sites, 2000-2009

Table 28. Summary Statistics for Turbidity (NTU), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	0.25	0.44	0.24	0.20	0.31	0.28	0.41	0.67	1.16	1.28	0.96
75 percentile	0.30	0.50	0.30	0.24	0.32	0.28	0.50	0.73	1.49	1.51	1.14
Maximum	2.50	3.50	0.85	0.54	1.50	1.50	1.28	3.50	15.0	9.75	10.0
Median	0.20	0.35	0.20	0.17	0.23	0.24	0.33	0.54	0.71	0.76	0.62
Minimum	0.08	0.15	0.10	0.09	0.14	0.13	0.16	0.30	0.28	0.25	0.28
25 percentile	0.15	0.30	0.20	0.15	0.20	0.20	0.23	0.43	0.49	0.46	0.40
N all samples	251	259	126	26	157	57	57	57	256	57	57

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	0.63	0.84	1.09	0.55	0.72	0.95	1.05	0.80	2.21	0.71	1.04
75 percentile	0.80	1.03	1.49	0.68	0.80	1.23	1.24	1.06	3.38	0.79	1.50
Maximum	1.50	3.00	3.25	1.66	4.60	2.50	4.37	1.91	7.62	5.86	2.50
Median	0.55	0.73	0.90	0.46	0.60	0.90	0.76	0.62	0.99	0.60	0.80
Minimum	0.30	0.29	0.30	0.24	0.20	0.30	0.33	0.29	0.19	0.30	0.30
25 percentile	0.40	0.55	0.58	0.35	0.50	0.60	0.60	0.46	0.53	0.50	0.60
N all samples	70	259	55	55	254	112	42	43	44	255	127

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	2.86	1.32	0.73	1.28
75 percentile	0.96	1.38	0.80	1.43
Maximum	83.8	13.6	2.50	19.5
Median	0.63	0.69	0.70	0.82
Minimum	0.29	0.32	0.20	0.30
25 percentile	0.47	0.57	0.50	0.60
N all samples	44	44	28	226

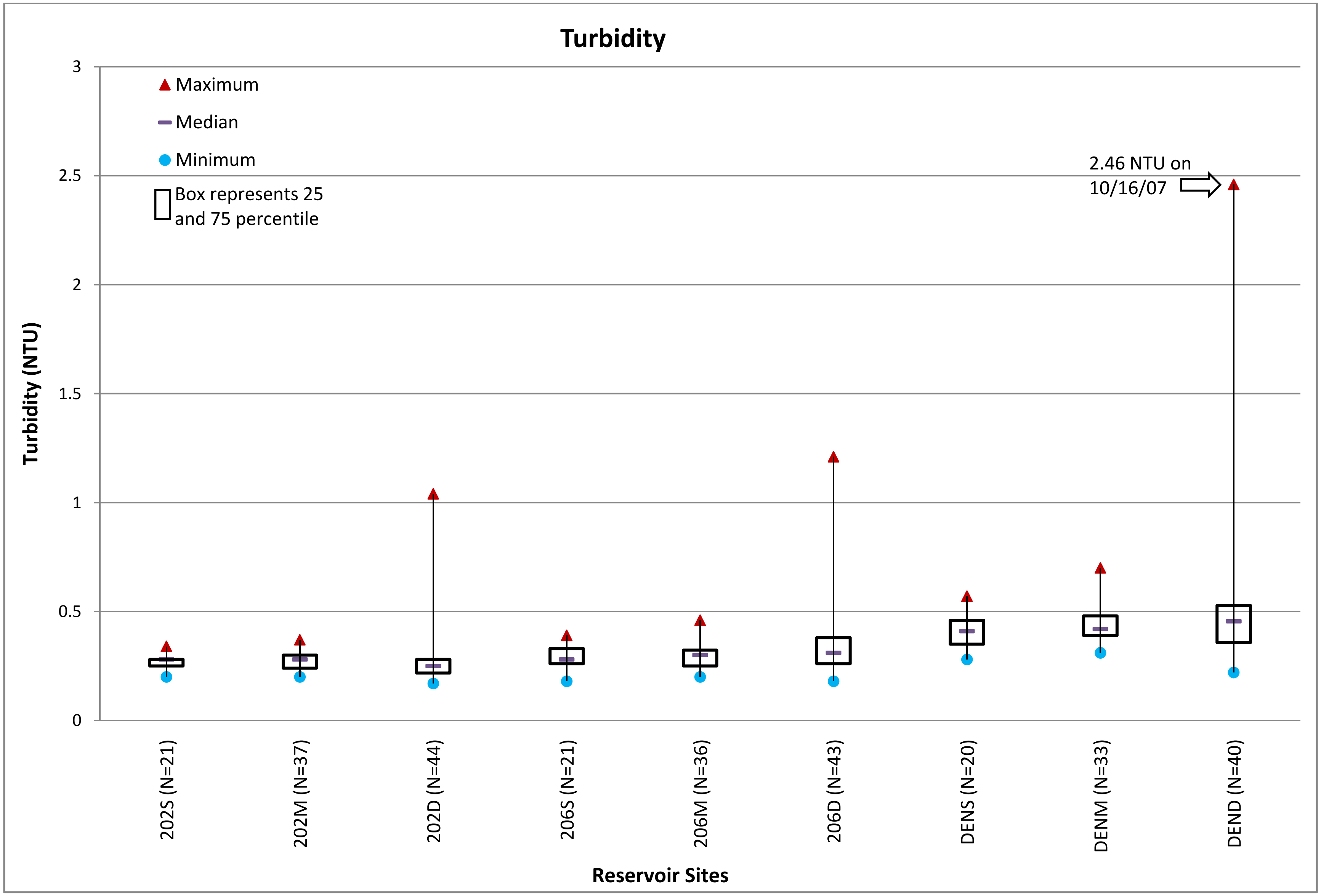

Figure 28. Boxplot of Turbidity Data, Quabbin Reservoir Sites, 2005-2009

Table 29. Summary Statistics for Turbidity (NTU), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.27	0.28	0.27	0.29	0.30	0.36	0.41	0.45	0.57
75 percentile	0.28	0.30	0.28	0.33	0.32	0.38	0.46	0.48	0.53
Maximum	0.34	0.37	1.04	0.39	0.46	1.21	0.57	0.70	2.46
Median	0.28	0.28	0.25	0.28	0.30	0.31	0.41	0.42	0.46
Minimum	0.20	0.20	0.17	0.18	0.20	0.18	0.28	0.31	0.22
25 percentile	0.25	0.24	0.22	0.26	0.25	0.26	0.35	0.39	0.36
N all samples	21	37	44	21	36	43	20	33	40

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0.5-1 m

-M = Middle; near surface (0.5-1 m) or mid-depth if reservoir is not stratified, or mid-epilimnion or mid-metalimnion if stratified

-D = Deep; within 2-3 m of bottom or mid-hypolimnion

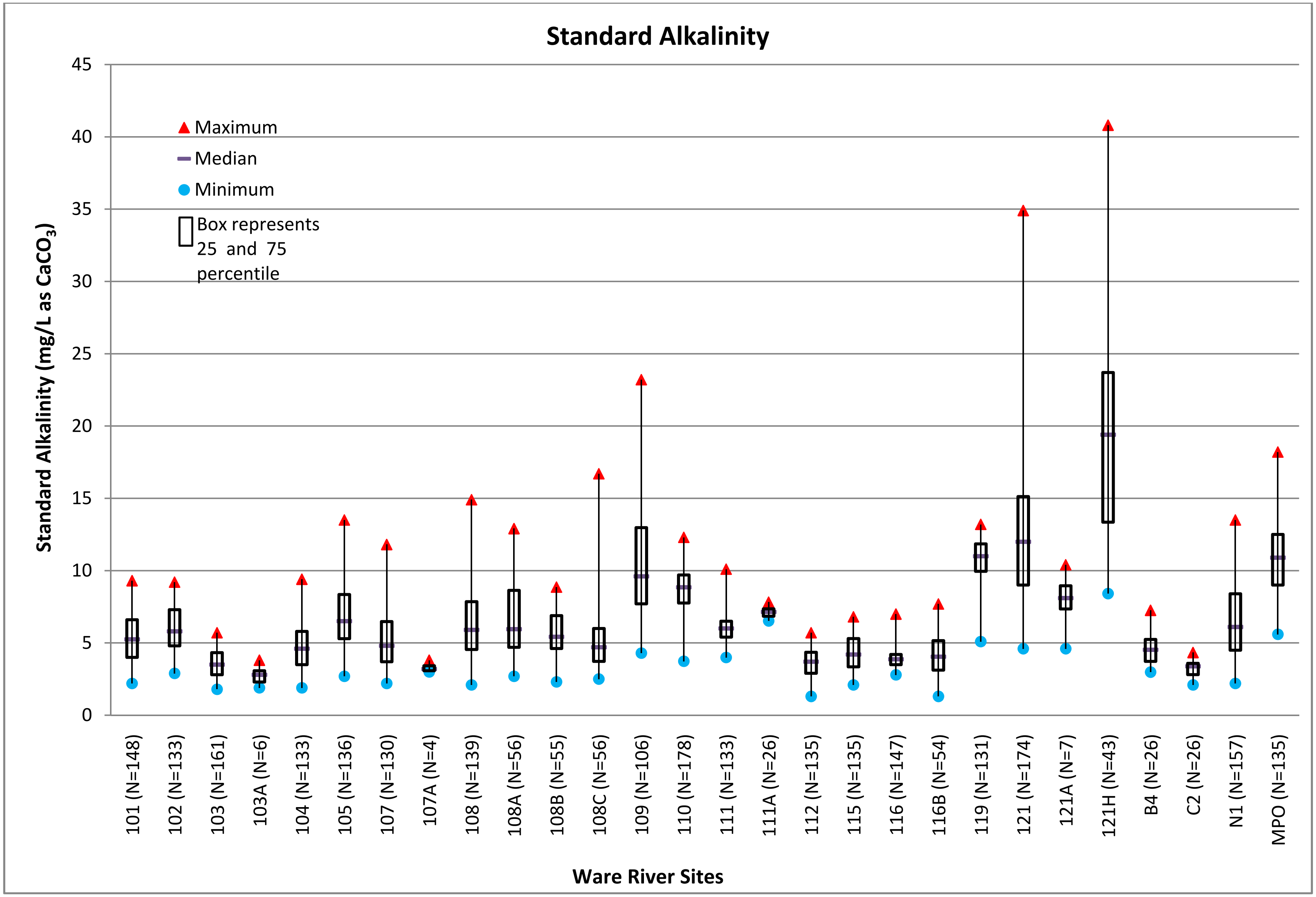

Figure 29. Boxplot of Alkalinity Data, Ware River Sites, 2000-2009

Table 30. Summary Statistics for Alkalinity (mg/L as $CaCO_3$), Ware River Sites, 2000-2009

SITE	101	102	103	103A	104	105	107	107A	108	108A	108B
Mean	5.31	5.90	3.60	2.77	4.73	6.95	5.21	3.30	6.45	6.72	5.42
75 percentile	6.60	7.30	4.33	3.08	5.80	8.35	6.48	3.43	7.85	8.64	6.89
Maximum	9.30	9.20	5.70	3.80	9.40	13.5	11.8	3.80	14.9	12.9	8.86
Median	5.25	5.80	3.50	2.80	4.60	6.51	4.80	3.20	5.90	5.96	5.42
Minimum	2.20	2.90	1.80	1.90	1.90	2.70	2.20	3.00	2.10	2.70	2.31
25 percentile	4.00	4.80	2.80	2.30	3.50	5.30	3.70	3.08	4.55	4.70	4.62
N all samples	148	133	161	6	133	136	130	4	139	56	55

SITE	108C	109	110	111	111A	112	115	116	116B	119	121
Mean	6.25	10.7	8.68	6.03	7.12	3.63	4.29	3.92	4.40	10.7	12.6
75 percentile	6.00	13.0	9.70	6.50	7.36	4.35	5.30	4.20	5.16	11.9	15.1
Maximum	16.7	23.2	12.3	10.1	7.82	5.70	6.80	6.99	7.69	13.2	34.9
Median	4.71	9.60	8.85	6.00	7.15	3.70	4.20	3.87	4.05	11.0	12.0
Minimum	2.50	4.30	3.74	4.00	6.52	1.30	2.10	2.80	1.30	5.10	4.60
25 percentile	3.73	7.70	7.76	5.40	6.85	2.90	3.35	3.50	3.12	9.95	9.00
N all samples	56	106	178	133	26	135	135	147	54	131	174

SITE	121A	121H	B4	C2	N1	MPO
Mean	7.96	19.7	4.67	3.28	6.52	10.8
75 percentile	8.95	23.7	5.25	3.59	8.40	12.5
Maximum	10.4	40.8	7.25	4.33	13.5	18.2
Median	8.10	19.4	4.53	3.39	6.10	10.9
Minimum	4.60	8.41	2.98	2.10	2.20	5.60
25 percentile	7.35	13.4	3.73	2.81	4.50	9.00
N all samples	7	43	26	26	157	135

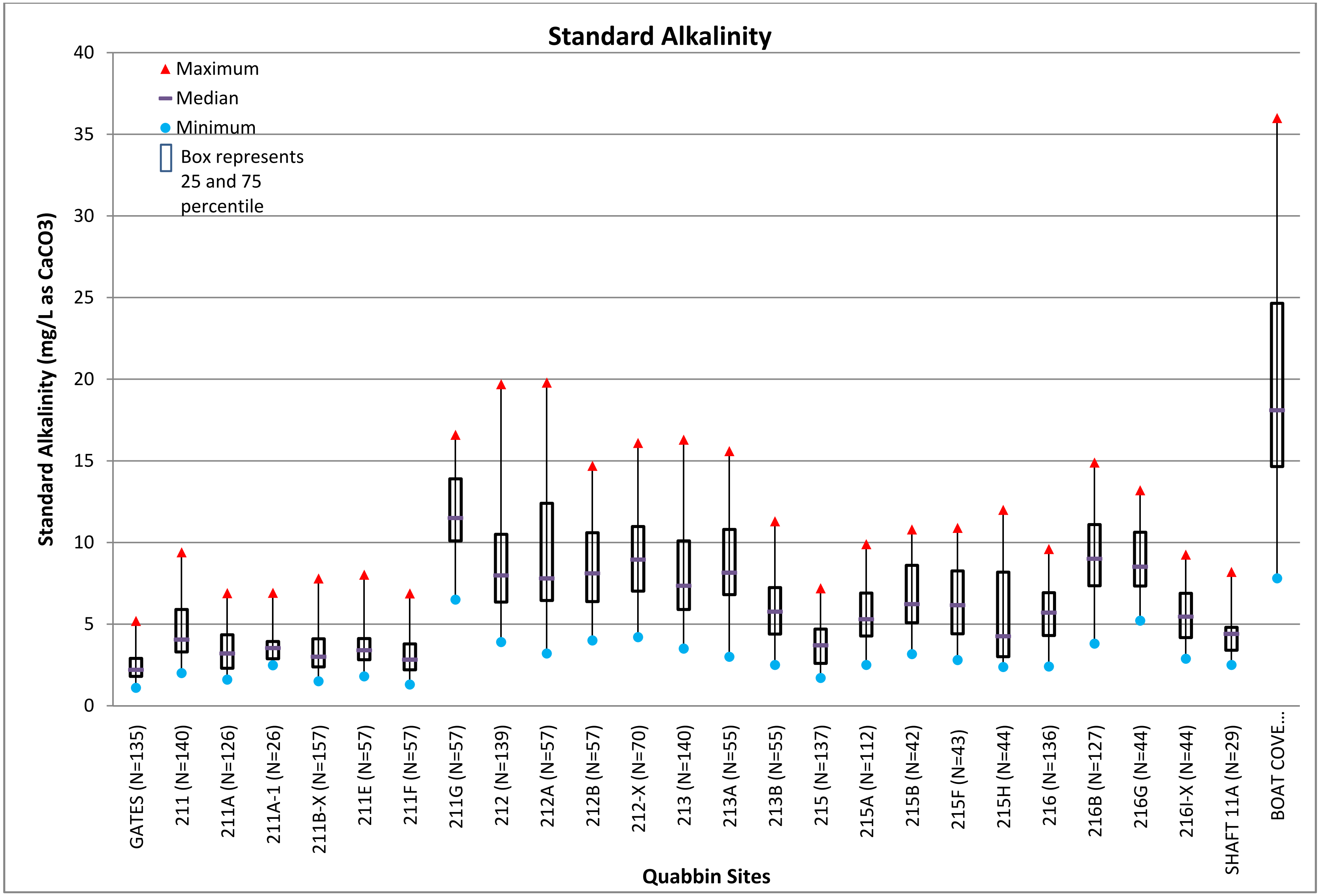

Figure 30. Boxplot of Alkalinity Data, Quabbin Tributary Sites, 2000-2009

Table 31. Summary Statistics for Alkalinity (mg/L as $CaCO_3$), Quabbin Tributary Sites, 2000-2009

SITE	GATES	211	211A	211A-1	211B-X	211E	211F	211G	212	212A	212B
Mean	2.45	4.64	3.43	3.72	3.50	3.74	3.12	12.0	8.61	9.53	8.66
75 percentile	2.90	5.90	4.35	3.94	4.10	4.12	3.79	13.9	10.5	12.4	10.6
Maximum	5.20	9.40	6.90	6.92	7.80	8.03	6.88	16.6	19.7	19.8	14.7
Median	2.20	4.05	3.20	3.54	3.00	3.40	2.82	11.5	7.98	7.80	8.11
Minimum	1.10	2.00	1.60	2.48	1.50	1.80	1.30	6.50	3.90	3.20	4.00
25 percentile	1.80	3.30	2.30	2.88	2.38	2.82	2.20	10.10	6.35	6.45	6.38
N all samples	135	140	126	26	157	57	57	57	139	57	57

SITE	212-X	213	213A	213B	215	215A	215B	215F	215H	216	216B
Mean	9.14	8.12	8.86	6.20	3.77	5.58	6.78	6.26	5.60	5.73	9.27
75 percentile	11.0	10.1	10.8	7.24	4.70	6.90	8.61	8.26	8.19	6.93	11.1
Maximum	16.1	16.3	15.6	11.3	7.20	9.90	10.8	10.9	12.0	9.60	14.9
Median	8.95	7.35	8.15	5.76	3.70	5.30	6.23	6.16	4.26	5.70	9.00
Minimum	4.20	3.50	3.00	2.50	1.70	2.50	3.16	2.80	2.37	2.40	3.80
25 percentile	7.03	5.90	6.81	4.40	2.60	4.28	5.09	4.41	3.01	4.30	7.35
N all samples	70	140	55	55	137	112	42	43	44	136	127

SITE	216G	216I-X	SHAFT 11A	BOAT COVE
Mean	8.97	5.72	4.36	19.7
75 percentile	10.6	6.89	4.80	24.7
Maximum	13.2	9.26	8.20	36.0
Median	8.52	5.46	4.40	18.1
Minimum	5.21	2.88	2.50	7.80
25 percentile	7.34	4.17	3.40	14.7
N all samples	44	44	29	118

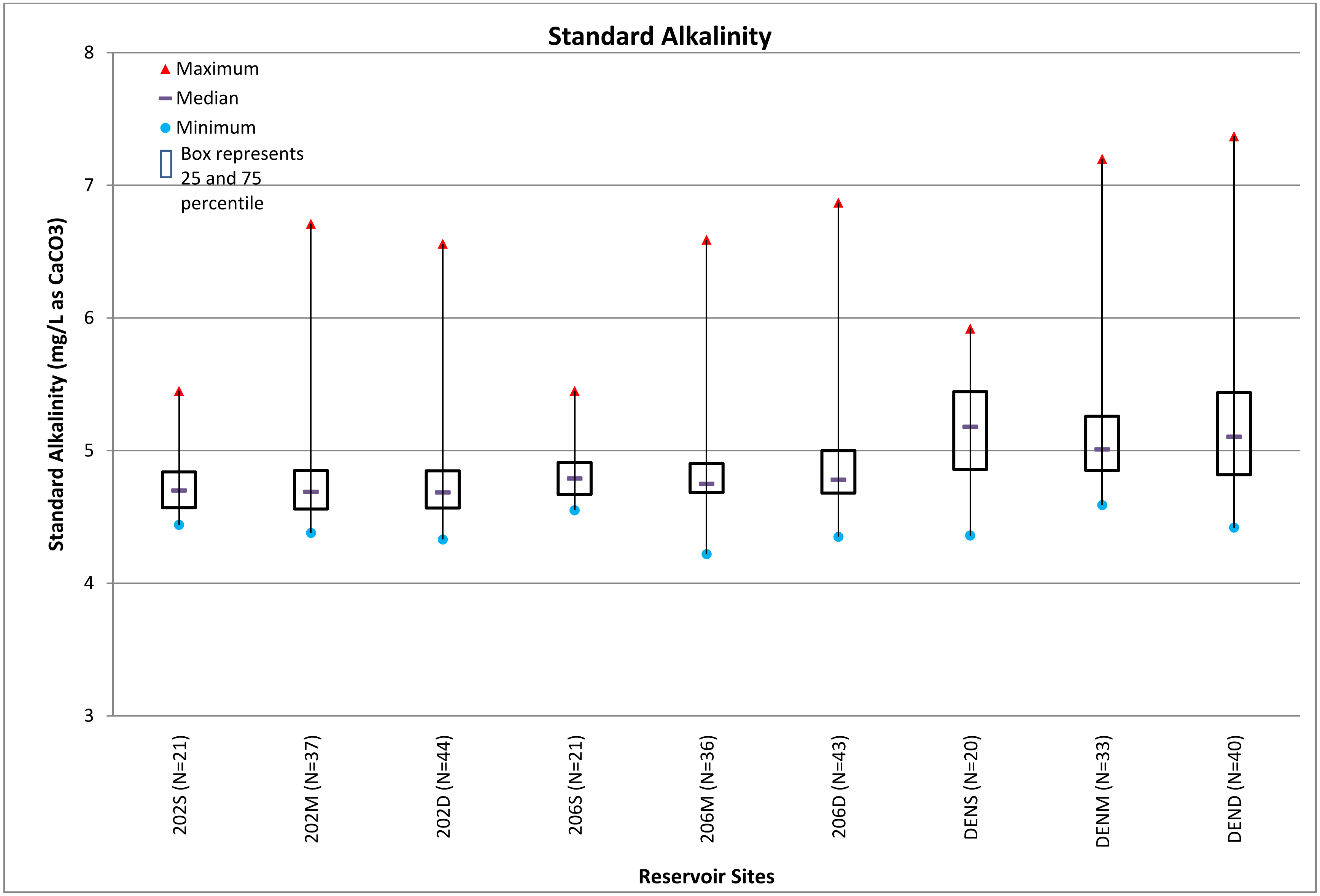

Figure 31. Boxplot of Alkalinity Data, Quabbin Reservoir Sites, 2005-2009

Table 32. Summary Statistics for Alkalinity (mg/L as $CaCO_3$), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	4.76	4.67	4.79	4.83	4.86	4.89	5.16	5.14	5.20
75 percentile	4.84	4.85	4.85	4.91	4.90	5.00	5.45	5.26	5.44
Maximum	5.45	6.71	6.56	5.45	6.59	6.87	5.92	7.20	7.37
Median	4.70	4.69	4.69	4.79	4.75	4.78	5.18	5.01	5.11
Minimum	4.44	4.38	4.33	4.55	4.22	4.35	4.36	4.59	4.42
25 percentile	4.57	4.56	4.57	4.67	4.69	4.68	4.86	4.85	4.82
N all samples	21	37	44	21	36	43	20	33	40

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0.5-1 m

-M = Middle; near surface (0.5-1 m) or mid-depth if reservoir is not stratified, or mid-epilimnion or mid-metalimnion if stratified

-D = Deep; within 2-3 m of bottom or mid-hypolimnion

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3.1.1.3 Nutrients

Nitrate, total Kjeldahl nitrogen, and total phosphorus were analyzed in tributary and reservoir samples. Nitrite was also analyzed in tributary samples only and, as might be expected in aerobic environments, was generally low. Additional nutrients, ammonia and silica, were analyzed in reservoir samples only. Except for silica, nutrients are reported in milligrams per liter (mg/L). Silica is reported in micrograms per liter (µg/L).

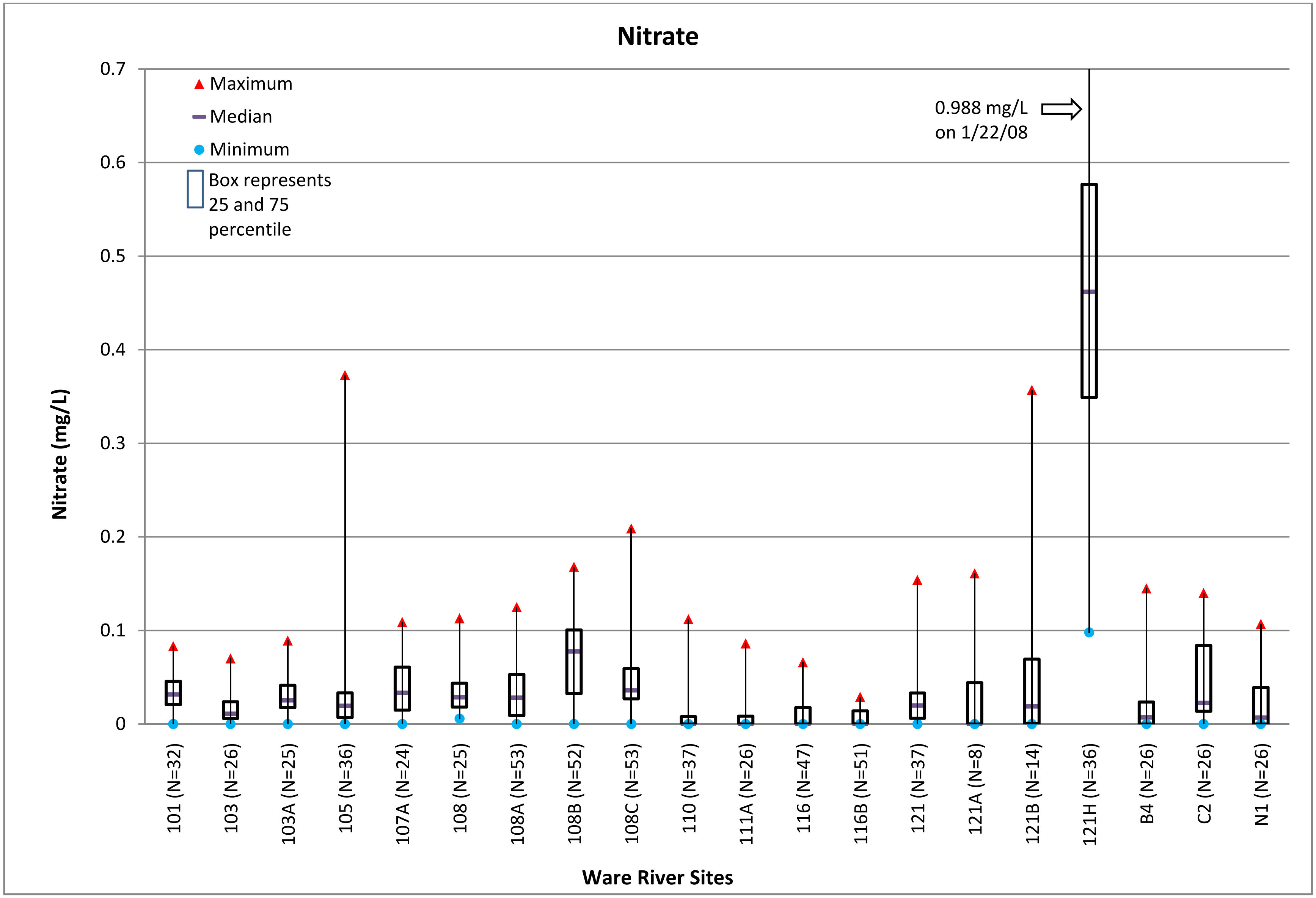

Figure 32. Boxplot of Nitrate Data, Ware River Sites, 2005-2009

Table 33. Summary Statistics for Nitrate (mg/L), Ware River Sites, 2005-2009

SITE	101	103	103A	105	107A	108	108A	108B	108C	110	111A
Mean	0.033	0.017	0.031	0.032	0.040	0.036	0.035	0.071	0.050	0.012	0.013
75 percentile	0.046	0.024	0.041	0.033	0.061	0.044	0.053	0.101	0.059	0.008	0.008
Maximum	0.083	0.070	0.089	0.373	0.109	0.113	0.125	0.168	0.209	0.112	0.086
Median	0.032	0.011	0.025	0.020	0.034	0.029	0.028	0.078	0.036	0	0
Minimum	0	0	0	0	0	0.006	0	0	0	0	0
25 percentile	0.021	0.006	0.018	0.007	0.015	0.018	0.009	0.033	0.027	0	0
N all samples	32	26	25	36	24	25	53	52	53	37	26

SITE	116	116B	121	121A	121B	121H	B4	C2	N1
Mean	0.010	0.008	0.032	0.039	0.057	0.487	0.018	0.051	0.022
75 percentile	0.018	0.014	0.033	0.044	0.069	0.577	0.024	0.084	0.039
Maximum	0.066	0.029	0.154	0.161	0.357	0.988	0.145	0.14	0.107
Median	0	0	0.020	0	0.019	0.462	0.007	0.023	0.007
Minimum	0	0	0	0	0	0.098	0	0	0
25 percentile	0	0	0.006	0	0.001	0.349	0	0.014	0
N all samples	47	51	37	8	14	36	26	26	26

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

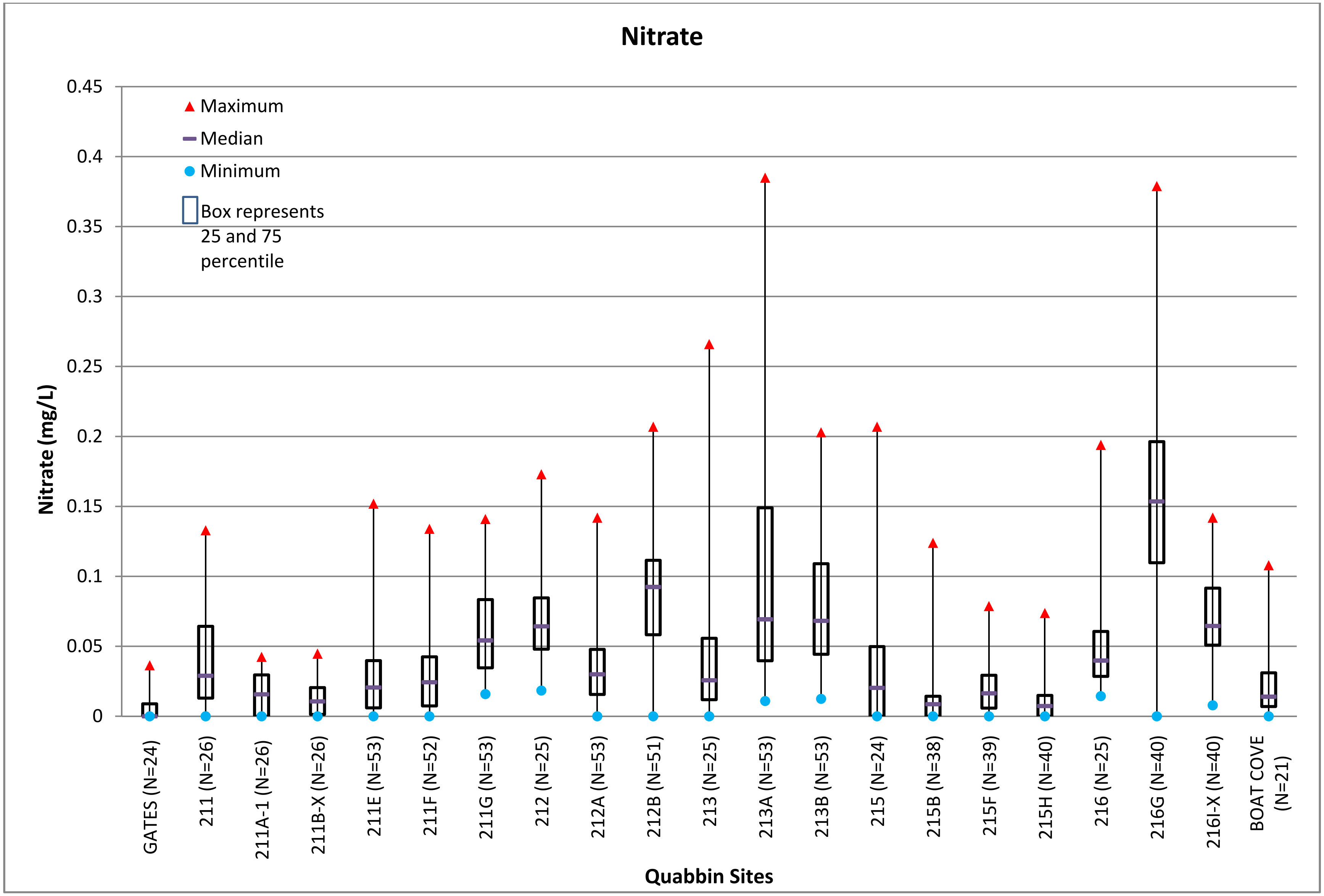

Figure 33. Boxplot of Nitrate Data, Quabbin Tributary Sites, 2005-2009

Table 34. Summary Statistics for Nitrate (mg/L), Quabbin Tributary Sites, 2005-2009

SITE	GATES	211	211A-1	211B-X	211E	211F	211G	212	212A	212B	213
Mean	0.006	0.043	0.017	0.013	0.027	0.032	0.060	0.067	0.040	0.092	0.042
75 percentile	0.009	0.064	0.030	0.020	0.040	0.042	0.083	0.085	0.048	0.112	0.056
Maximum	0.037	0.133	0.043	0.045	0.152	0.134	0.141	0.173	0.142	0.207	0.266
Median	0	0.029	0.016	0.011	0.021	0.024	0.054	0.064	0.030	0.092	0.026
Minimum	0	0	0	0	0	0	0.016	0.018	0	0	0
25 percentile	0	0.013	0	0.001	0.006	0.007	0.035	0.048	0.016	0.058	0.012
N all samples	24	26	26	26	53	52	53	25	53	51	25
SITE	**213A**	**213B**	**215**	**215B**	**215F**	**215H**	**216**	**216G**	**216I-X**	**BOAT COVE**	
Mean	0.104	0.081	0.038	0.012	0.020	0.012	0.049	0.162	0.069	0.025	
75 percentile	0.149	0.109	0.050	0.014	0.029	0.015	0.061	0.196	0.092	0.031	
Maximum	0.385	0.203	0.207	0.124	0.079	0.074	0.194	0.379	0.142	0.108	
Median	0.069	0.068	0.020	0.009	0.016	0.007	0.040	0.154	0.065	0.014	
Minimum	0.011	0.013	0	0	0	0	0.014	0	0.008	0	
25 percentile	0.040	0.044	0	0	0.006	0	0.029	0.110	0.051	0.007	
N all samples	53	53	24	38	39	40	25	40	40	21	

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

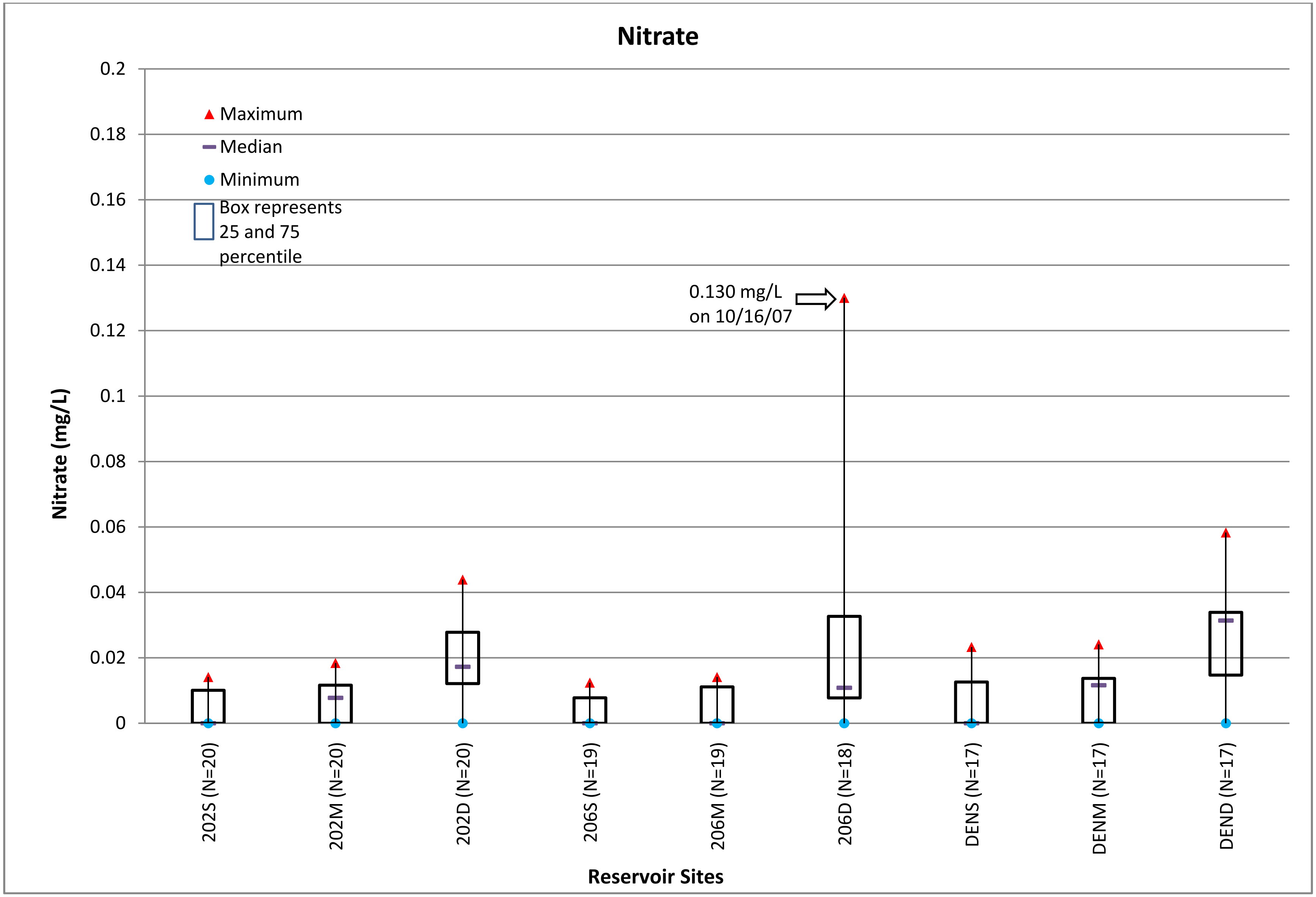

Figure 34. Boxplot of Nitrate Data, Quabbin Reservoir Sites, 2005-2009

Table 35. Summary Statistics for Nitrate (mg/L), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.005	0.006	0.020	0.004	0.005	0.029	0.006	0.010	0.029
75 percentile	0.010	0.012	0.028	0.008	0.011	0.033	0.013	0.014	0.034
Maximum	0.014	0.018	0.044	0.012	0.014	0.130	0.023	0.024	0.058
Median	0	0.008	0.017	0	0	0.011	0	0.012	0.031
Minimum	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0.012	0	0	0.008	0	0	0.015
N all samples	20	20	20	19	19	18	17	17	17

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-1 m

-M = Middle; mid-depth if reservoir is not stratified, mid-metalimnion if stratified

-D = Deep, within 2-3 m of bottom

A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

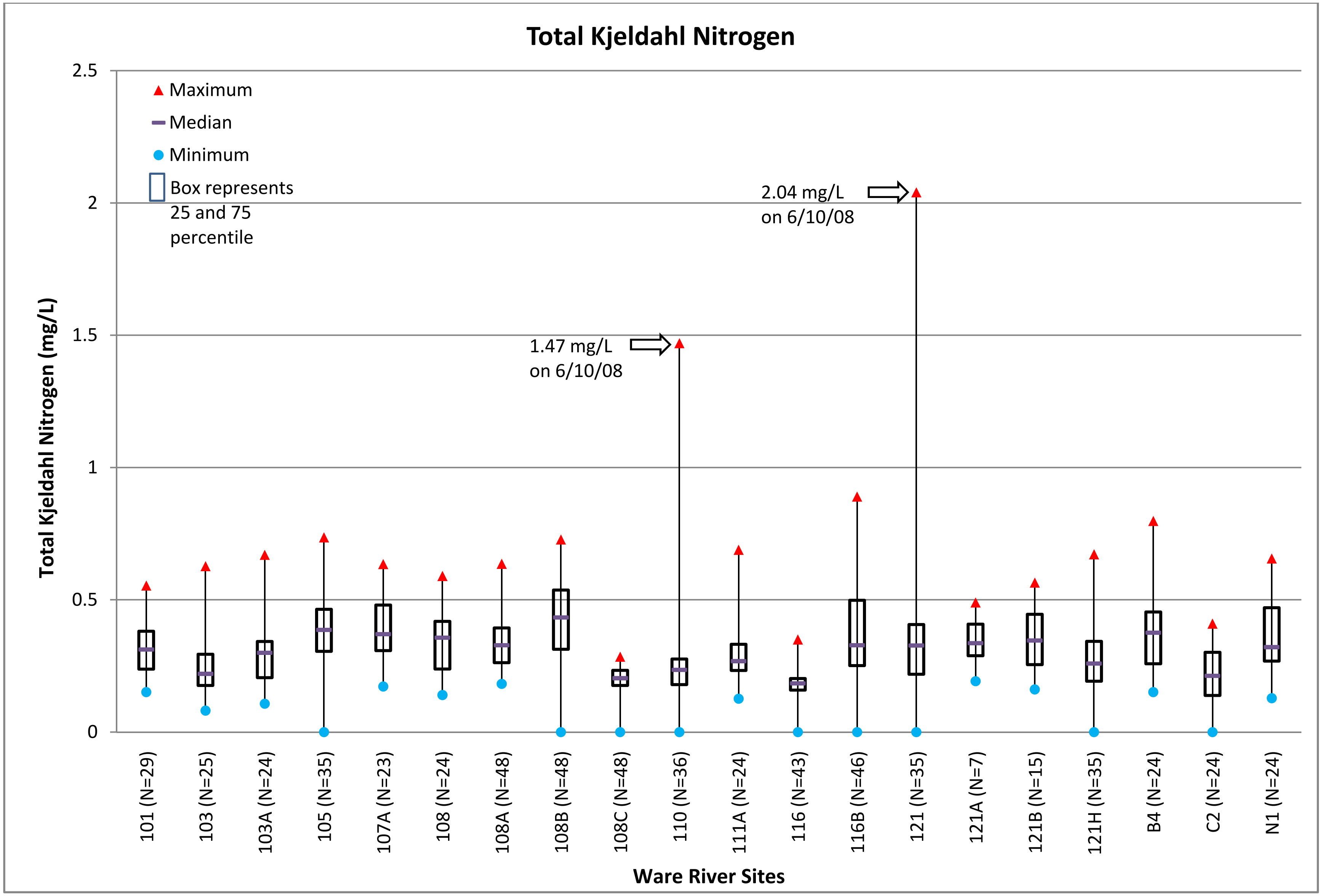

Figure 35. Boxplot of Total Kjeldahl Nitrogen Data, Ware River Sites, 2005-2009

Table 36. Summary Statistics for Total Kjeldahl Nitrogen (mg/L), Ware River Sites, 2005-2009

SITE	101	103	103A	105	107A	108	108A	108B	108C	110	111A
Mean	0.320	0.251	0.307	0.383	0.381	0.345	0.342	0.424	0.192	0.279	0.299
75 percentile	0.381	0.294	0.342	0.464	0.480	0.418	0.394	0.537	0.234	0.276	0.332
Maximum	0.554	0.627	0.670	0.736	0.635	0.590	0.636	0.728	0.285	1.47	0.689
Median	0.312	0.220	0.300	0.386	0.370	0.357	0.328	0.433	0.204	0.235	0.268
Minimum	0.151	0.081	0.107	0	0.172	0.140	0.182	0	0	0	0.126
25 percentile	0.238	0.176	0.206	0.305	0.308	0.239	0.263	0.313	0.177	0.178	0.233
N all samples	29	25	24	35	23	24	48	48	48	36	24

SITE	116	116B	121	121A	121B	121H	B4	C2	N1
Mean	0.182	0.396	0.362	0.344	0.343	0.293	0.377	0.221	0.367
75 percentile	0.203	0.498	0.407	0.408	0.445	0.343	0.454	0.301	0.470
Maximum	0.350	0.890	2.04	0.490	0.565	0.672	0.798	0.410	0.656
Median	0.184	0.328	0.327	0.336	0.346	0.259	0.376	0.213	0.321
Minimum	0	0	0	0.192	0.161	0	0.151	0	0.128
25 percentile	0.159	0.251	0.219	0.289	0.255	0.193	0.258	0.138	0.269
N all samples	43	46	35	7	15	35	24	24	24

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

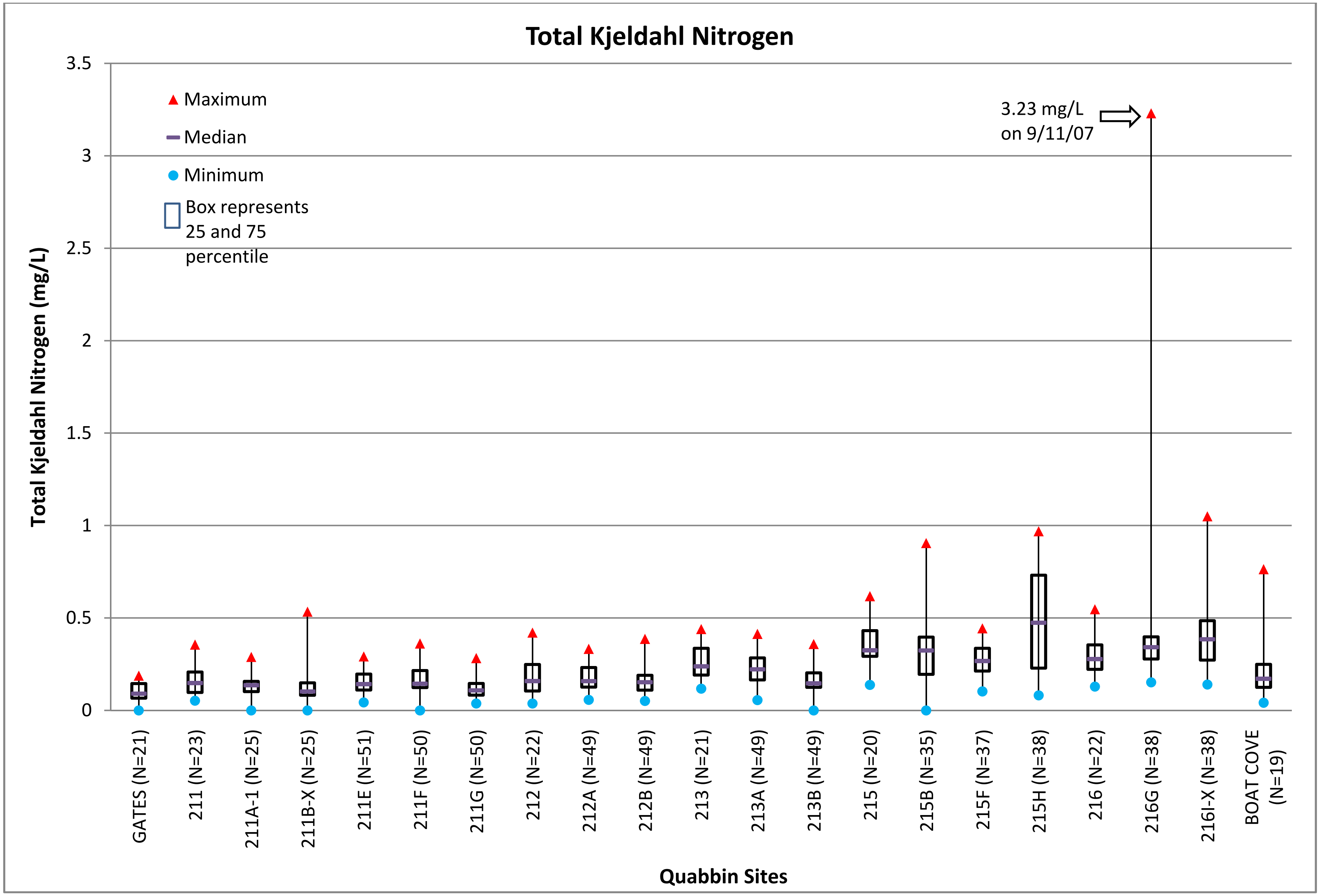

Figure 36. Boxplot of Total Kjeldahl Nitrogen Data, Quabbin Tributary Sites, 2005-2009

Table 37. Summary Statistics for Total Kjeldahl Nitrogen (mg/L), Quabbin Tributary Sites, 2005-2009

SITE	GATES	211	211A-1	211B-X	211E	211F	211G	212	212A	212B	213
Mean	0.103	0.165	0.133	0.126	0.149	0.167	0.117	0.180	0.179	0.160	0.266
75 percentile	0.145	0.208	0.157	0.149	0.197	0.216	0.146	0.249	0.232	0.190	0.336
Maximum	0.188	0.356	0.289	0.534	0.292	0.362	0.283	0.421	0.333	0.387	0.440
Median	0.090	0.148	0.136	0.102	0.142	0.144	0.108	0.159	0.158	0.152	0.238
Minimum	0	0.053	0	0	0.044	0	0.038	0.037	0.057	0.052	0.118
25 percentile	0.066	0.097	0.102	0.082	0.111	0.124	0.083	0.105	0.126	0.110	0.191
N all samples	21	23	25	25	51	50	50	22	49	49	21
SITE	213A	213B	215	215B	215F	215H	216	216G	216I-X	BOAT COVE	
Mean	0.229	0.167	0.341	0.313	0.273	0.483	0.289	0.411	0.403	0.221	
75 percentile	0.284	0.203	0.431	0.397	0.336	0.731	0.354	0.398	0.485	0.249	
Maximum	0.414	0.359	0.618	0.905	0.444	0.969	0.547	3.23	1.05	0.764	
Median	0.222	0.146	0.325	0.324	0.267	0.474	0.278	0.342	0.385	0.171	
Minimum	0.056	0	0.138	0	0.103	0.082	0.129	0.152	0.140	0.042	
25 percentile	0.165	0.125	0.293	0.195	0.213	0.229	0.222	0.278	0.273	0.125	
N all samples	49	49	20	35	37	38	22	38	38	19	

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

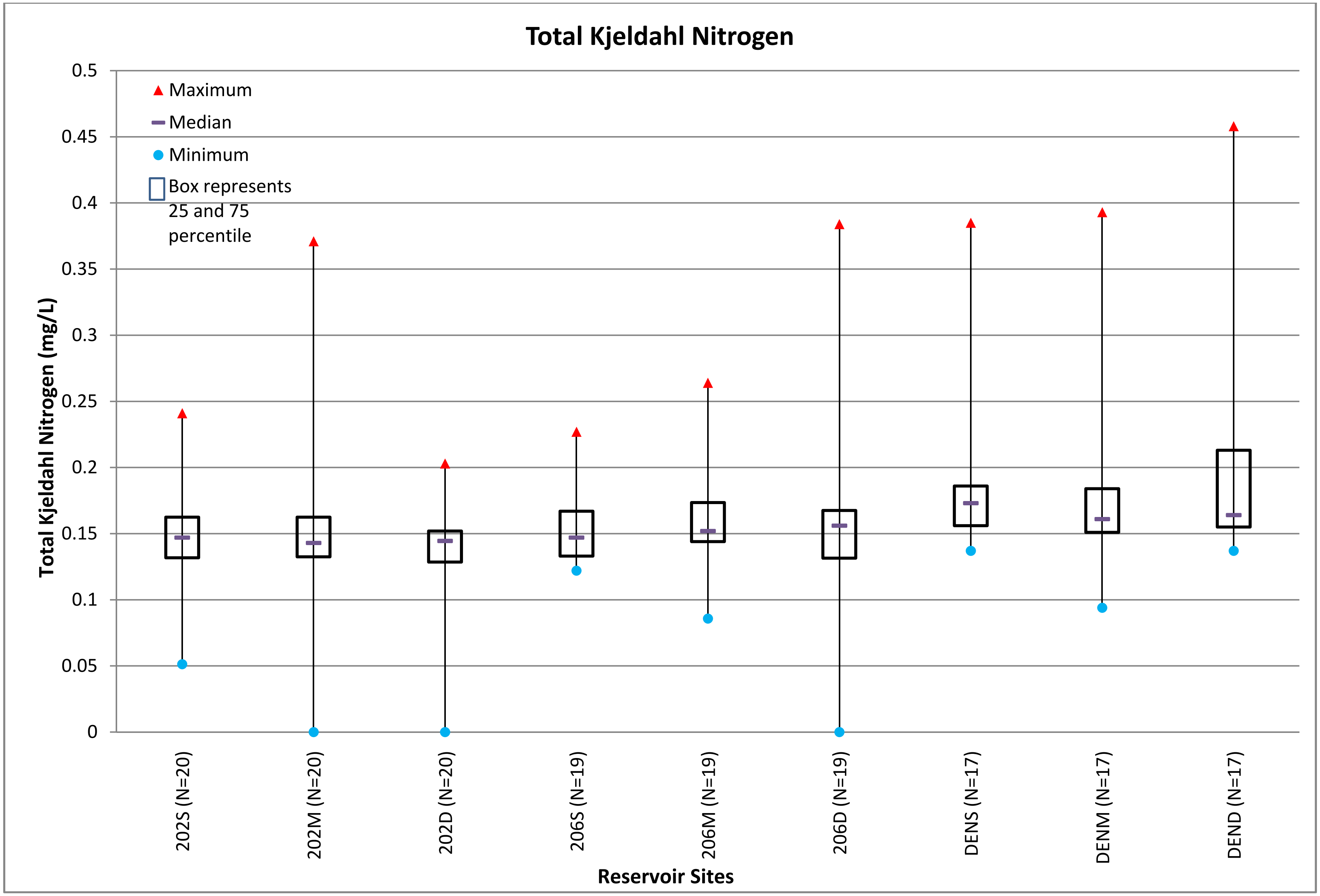

Figure 37. Boxplot of Total Kjeldahl Nitrogen Data, Quabbin Reservoir Sites, 2005-2009

Table 38. Summary Statistics for Total Kjeldahl Nitrogen (mg/L), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.149	0.163	0.137	0.156	0.161	0.153	0.186	0.183	0.195
75 percentile	0.163	0.163	0.152	0.167	0.174	0.168	0.186	0.184	0.213
Maximum	0.241	0.371	0.203	0.227	0.264	0.384	0.385	0.393	0.458
Median	0.147	0.143	0.145	0.147	0.152	0.156	0.173	0.161	0.164
Minimum	0.051	0	0	0.122	0.086	0	0.137	0.094	0.137
25 percentile	0.132	0.133	0.129	0.133	0.144	0.132	0.156	0.151	0.155
N all samples	20	20	20	19	19	19	17	17	17

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-1 m

-M = Middle; mid-depth if reservoir is not stratified, mid-metalimnion if stratified

-D = Deep, within 2-3 m of bottom

A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

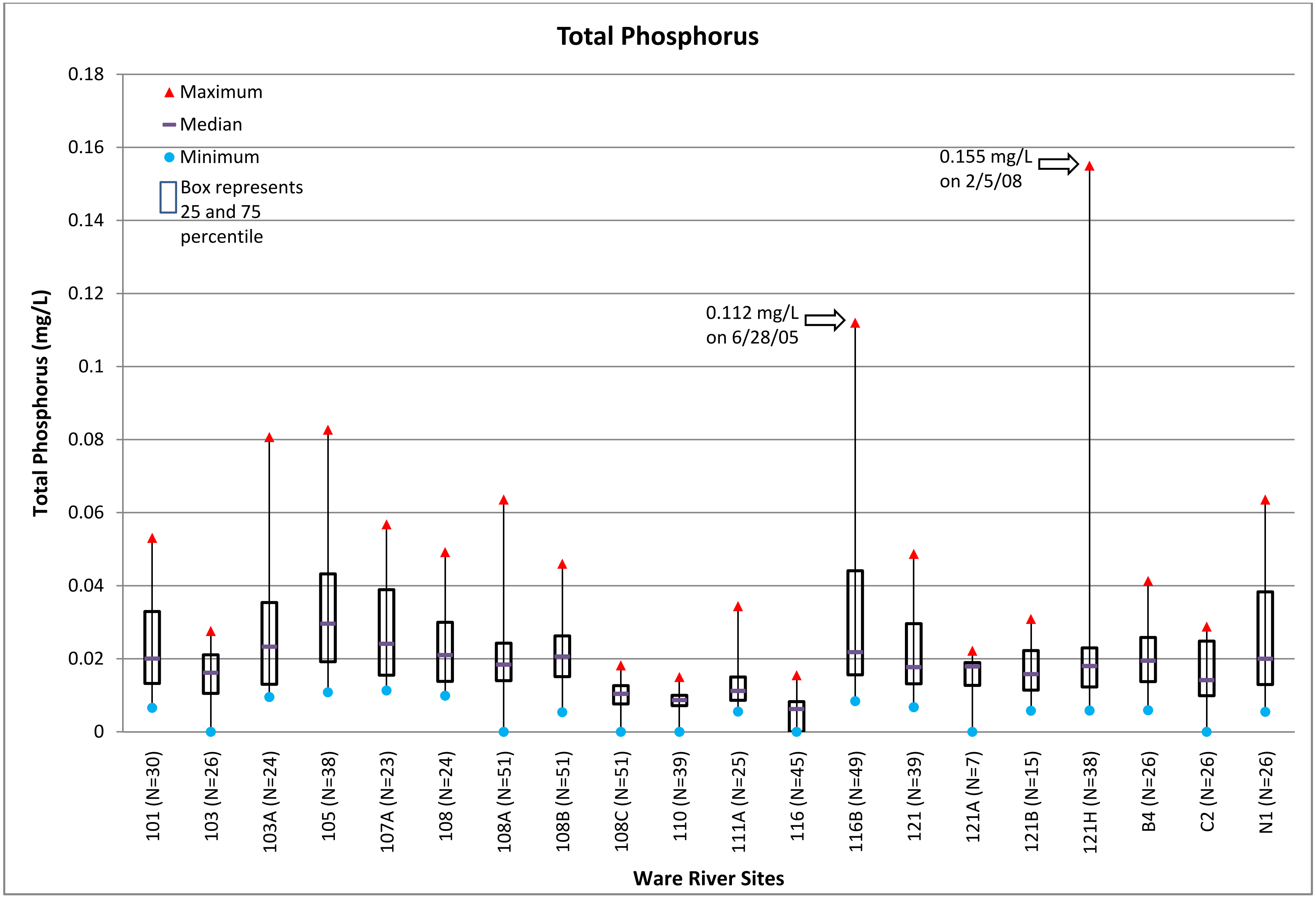

Figure 38. Boxplot of Total Phosphorus Data, Ware River Sites, 2005-2009

Table 39. Summary Statistics for Total Phosphorus (mg/L), Ware River Sites, 2005-2009

SITE	101	103	103A	105	107A	108	108A	108B	108C	110	111A
Mean	0.023	0.016	0.026	0.032	0.027	0.023	0.022	0.021	0.009	0.008	0.012
75 percentile	0.033	0.021	0.035	0.043	0.039	0.030	0.024	0.026	0.013	0.010	0.015
Maximum	0.053	0.028	0.081	0.083	0.057	0.049	0.064	0.046	0.018	0.015	0.034
Median	0.020	0.016	0.023	0.030	0.024	0.021	0.018	0.021	0.010	0.009	0.011
Minimum	0.007	0	0.010	0.011	0.011	0.010	0	0.005	0	0	0.006
25 percentile	0.013	0.011	0.013	0.019	0.016	0.014	0.014	0.015	0.008	0.007	0.009
N all samples	30	26	24	38	23	24	51	51	51	39	25
SITE	**116**	**116B**	**121**	**121A**	**121B**	**121H**	**B4**	**C2**	**N1**		
Mean	0.006	0.033	0.022	0.015	0.017	0.023	0.020	0.016	0.027		
75 percentile	0.008	0.044	0.030	0.019	0.022	0.023	0.026	0.025	0.038		
Maximum	0.016	0.112	0.049	0.022	0.031	0.155	0.041	0.029	0.064		
Median	0.006	0.022	0.018	0.018	0.016	0.018	0.019	0.014	0.020		
Minimum	0	0.008	0.007	0	0.006	0.006	0.006	0	0.005		
25 percentile	0	0.016	0.013	0.013	0.011	0.012	0.014	0.010	0.013		
N all samples	45	49	39	7	15	38	26	26	26		

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

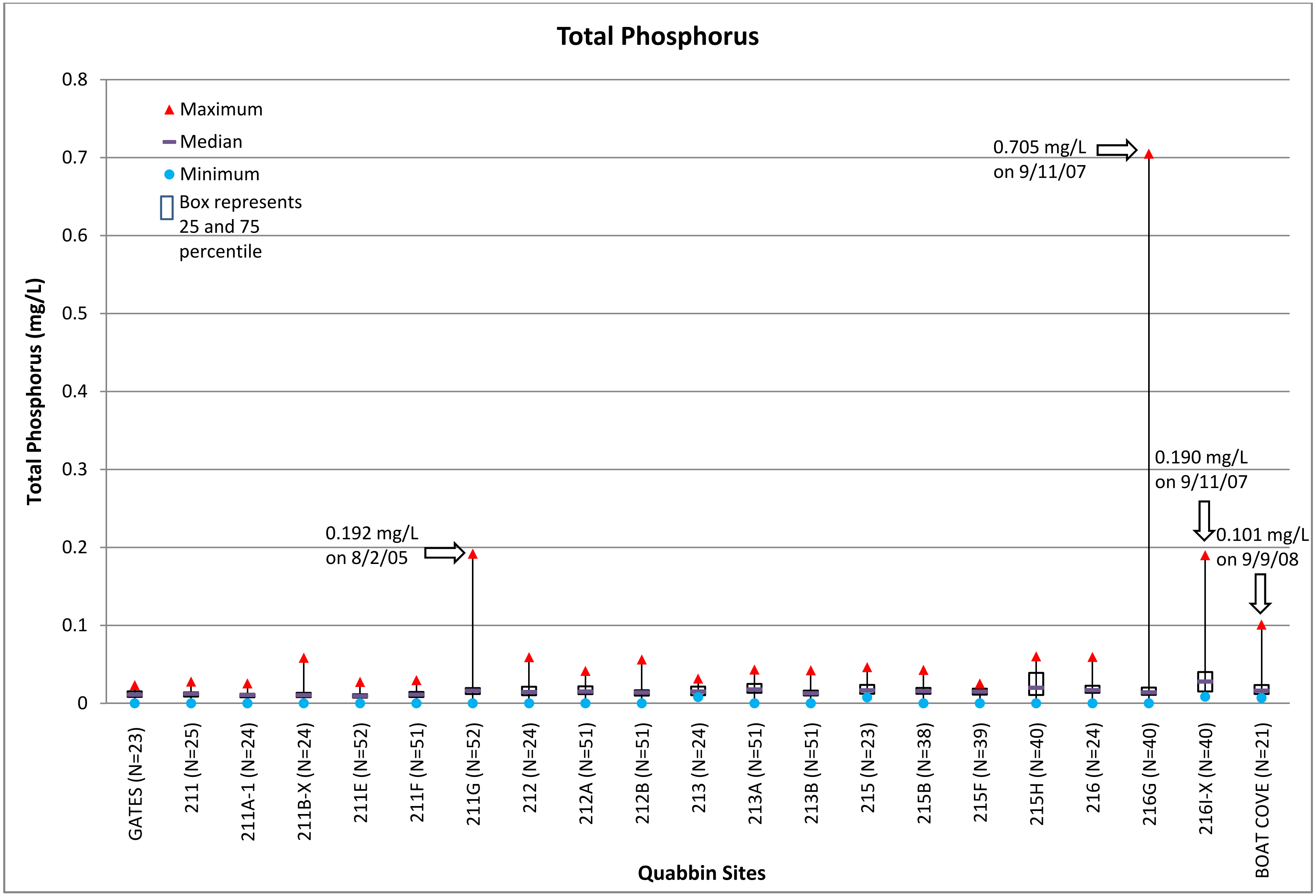

Figure 39. Boxplot of Total Phosphorus Data, Quabbin Tributary Sites, 2005-2009

Table 40. Summary Statistics for Total Phosphorus (mg/L), Quabbin Tributary Sites, 2005-2009

SITE	GATES	211	211A-1	211B-X	211E	211F	211G	212	212A	212B	213
Mean	0.012	0.012	0.010	0.012	0.009	0.011	0.019	0.018	0.016	0.014	0.016
75 percentile	0.015	0.014	0.012	0.014	0.012	0.015	0.020	0.021	0.022	0.017	0.021
Maximum	0.023	0.028	0.026	0.059	0.028	0.030	0.192	0.059	0.042	0.056	0.032
Median	0.011	0.012	0.011	0.011	0.009	0.011	0.016	0.015	0.015	0.014	0.015
Minimum	0	0	0	0	0	0	0	0	0	0	0.008
25 percentile	0.008	0.009	0.008	0.008	0.007	0.008	0.012	0.010	0.012	0.010	0.010
N all samples	23	25	24	24	52	51	52	24	51	51	24

SITE	213A	213B	215	215B	215F	215H	216	216G	216I-X	BOAT COVE
Mean	0.019	0.013	0.019	0.017	0.015	0.025	0.020	0.033	0.033	0.024
75 percentile	0.025	0.016	0.024	0.020	0.019	0.039	0.023	0.020	0.040	0.024
Maximum	0.043	0.042	0.046	0.043	0.025	0.060	0.060	0.705	0.190	0.101
Median	0.018	0.013	0.017	0.016	0.015	0.020	0.017	0.014	0.028	0.016
Minimum	0	0	0.008	0	0	0	0	0	0.008	0.007
25 percentile	0.013	0.010	0.012	0.012	0.011	0.011	0.014	0.011	0.015	0.012
N all samples	51	51	23	38	39	40	24	40	40	21

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

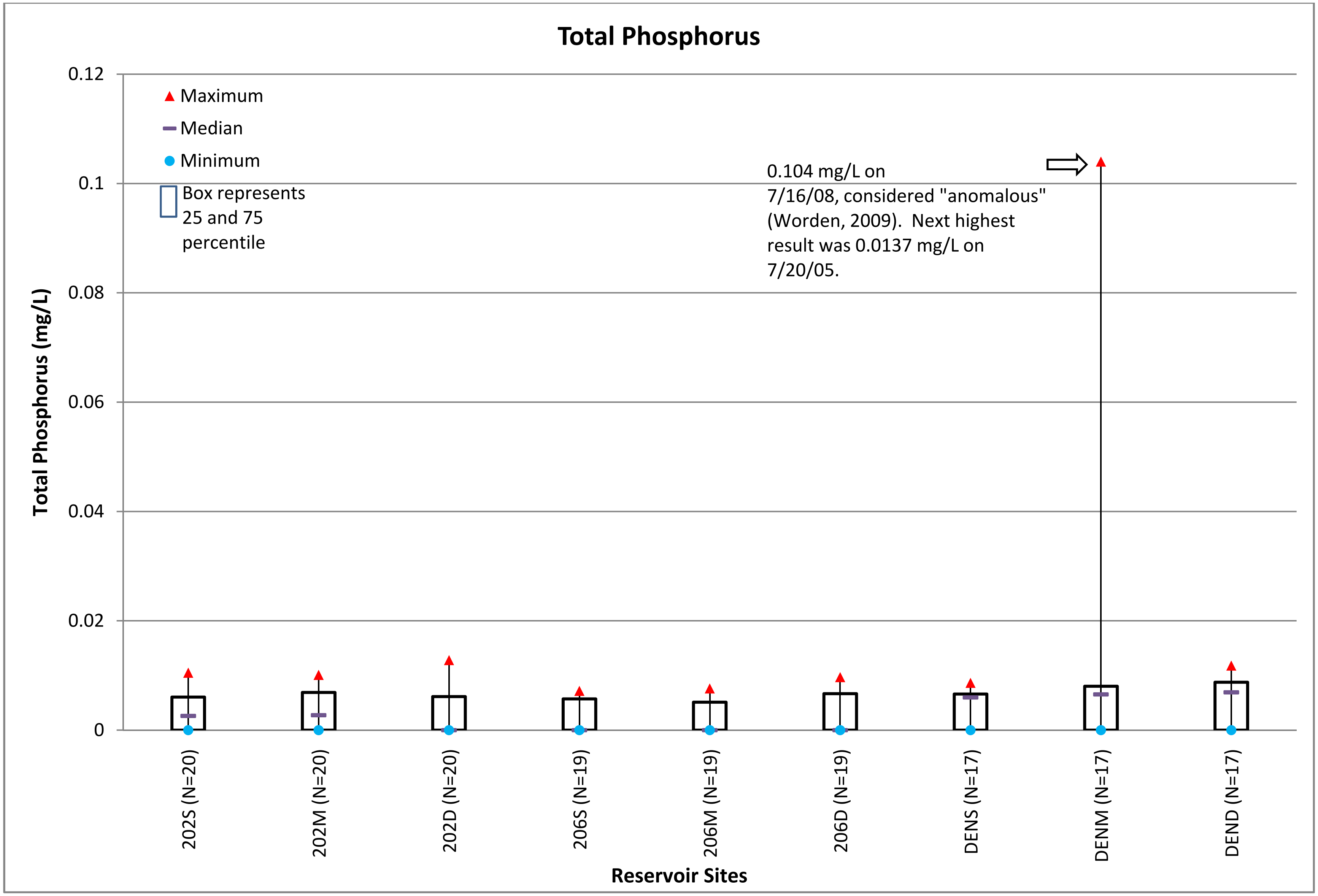

Figure 40. Boxplot of Total Phosphorus Data, Quabbin Reservoir Sites, 2005-2009

Table 41. Summary Statistics for Total Phosphorus (mg/L), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.003	0.004	0.003	0.003	0.002	0.003	0.004	0.011	0.006
75 percentile	0.006	0.007	0.006	0.006	0.005	0.007	0.007	0.008	0.009
Maximum	0.011	0.010	0.013	0.007	0.008	0.010	0.009	0.104	0.012
Median	0.003	0.003	0	0	0	0	0.006	0.007	0.007
Minimum	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0
N all samples	20	20	20	19	19	19	17	17	17

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-1 m

-M = Middle; mid-depth if reservoir is not stratified, mid-metalimnion if stratified

-D = Deep, within 2-3 m of bottom

A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

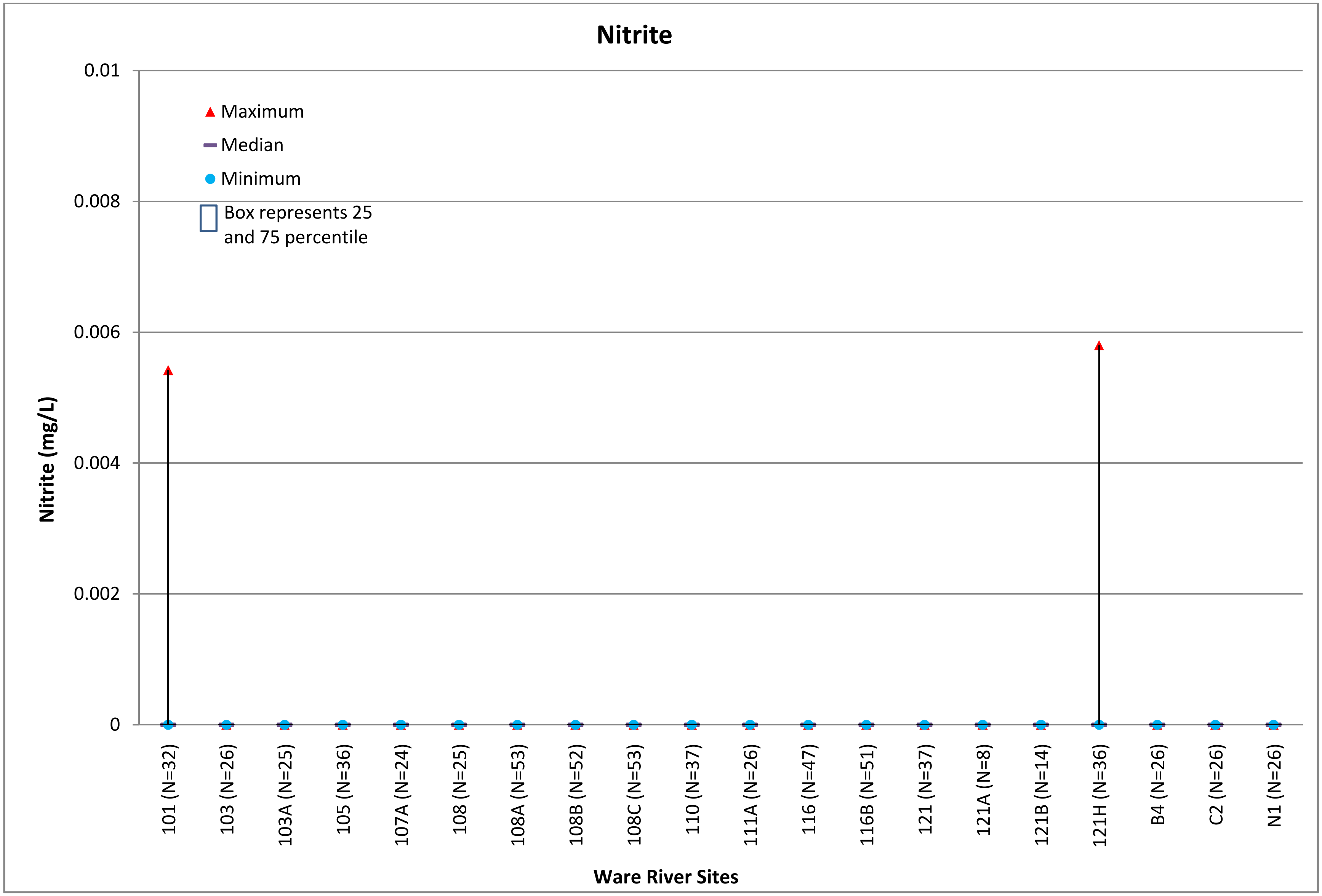

Figure 41. Boxplot of Nitrite Data, Ware River Sites, 2005-2009

Table 42. Summary Statistics for Nitrite (mg/L), Ware River Sites, 2005-2009

SITE	101	103	103A	105	107A	108	108A	108B	108C	110	111A
Mean	0	0	0	0	0	0	0	0	0	0	0
75 percentile	0	0	0	0	0	0	0	0	0	0	0
Maximum	0.00542	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0	0	0
N all samples	32	26	25	36	24	25	53	52	53	37	26

SITE	116	116B	121	121A	121B	121H	B4	C2	N1
Mean	0	0	0	0	0	0	0	0	0
75 percentile	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0.00580	0	0	0
Median	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0
N all samples	47	51	37	8	14	36	26	26	26

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

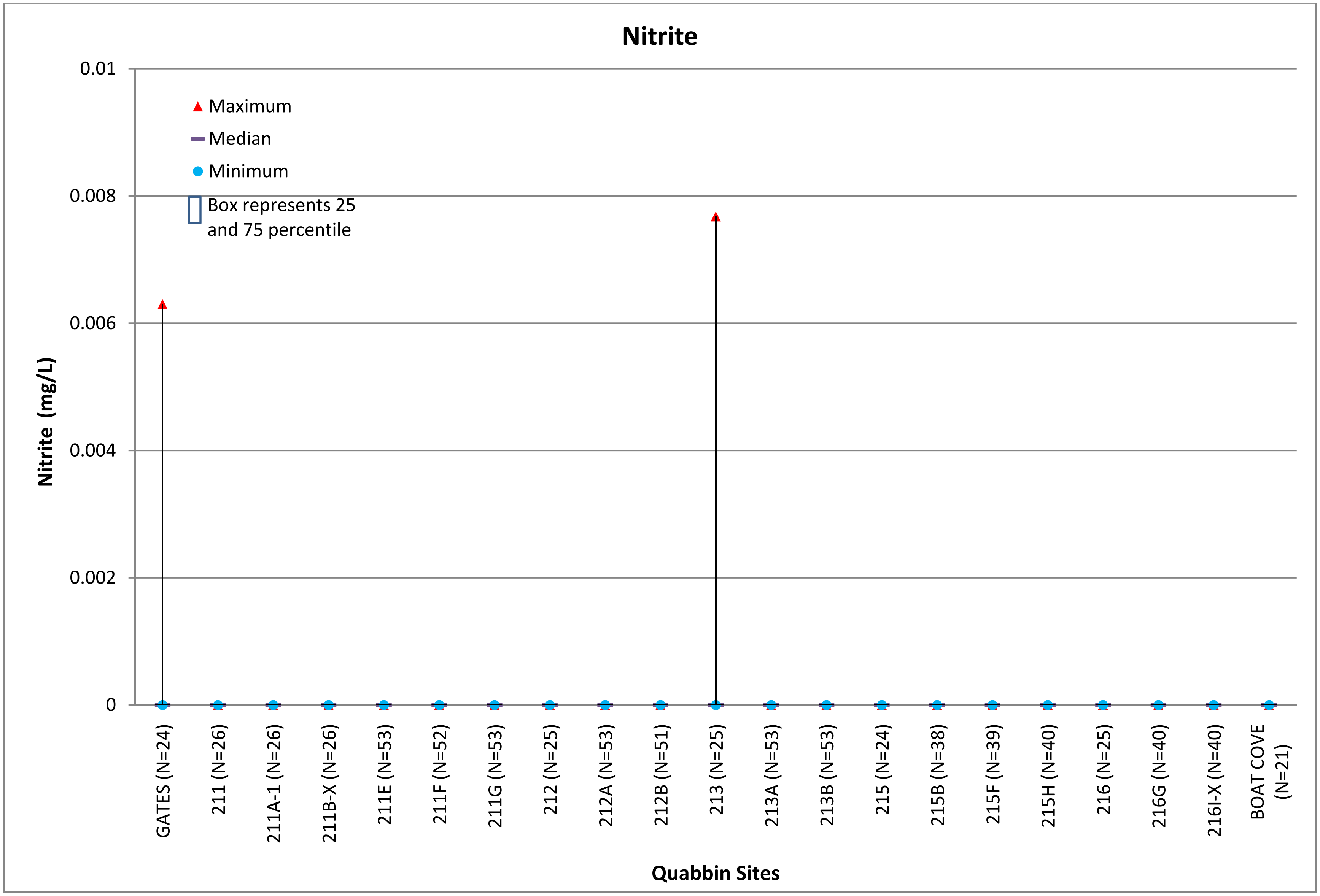

Figure 42. Boxplot of Nitrite Data, Quabbin Tributary Sites, 2005-2009

Table 43. Summary Statistics for Nitrite (mg/L), Quabbin Tributary Sites, 2005-2009

SITE	GATES	211	211A-1	211B-X	211E	211F	211G	212	212A	212B	213
Mean	0	0	0	0	0	0	0	0	0	0	0
75 percentile	0	0	0	0	0	0	0	0	0	0	0
Maximum	0.00630	0	0	0	0	0	0	0	0	0	0.00768
Median	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0	0	0
N all samples	24	26	26	26	53	52	53	25	53	51	25

SITE	213A	213B	215	215B	215F	215H	216	216G	216I-X	BOAT COVE
Mean	0	0	0	0	0	0	0	0	0	0
75 percentile	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0
25 percentile	0	0	0	0	0	0	0	0	0	0
N all samples	53	53	24	38	39	40	25	40	40	21

Note:
A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

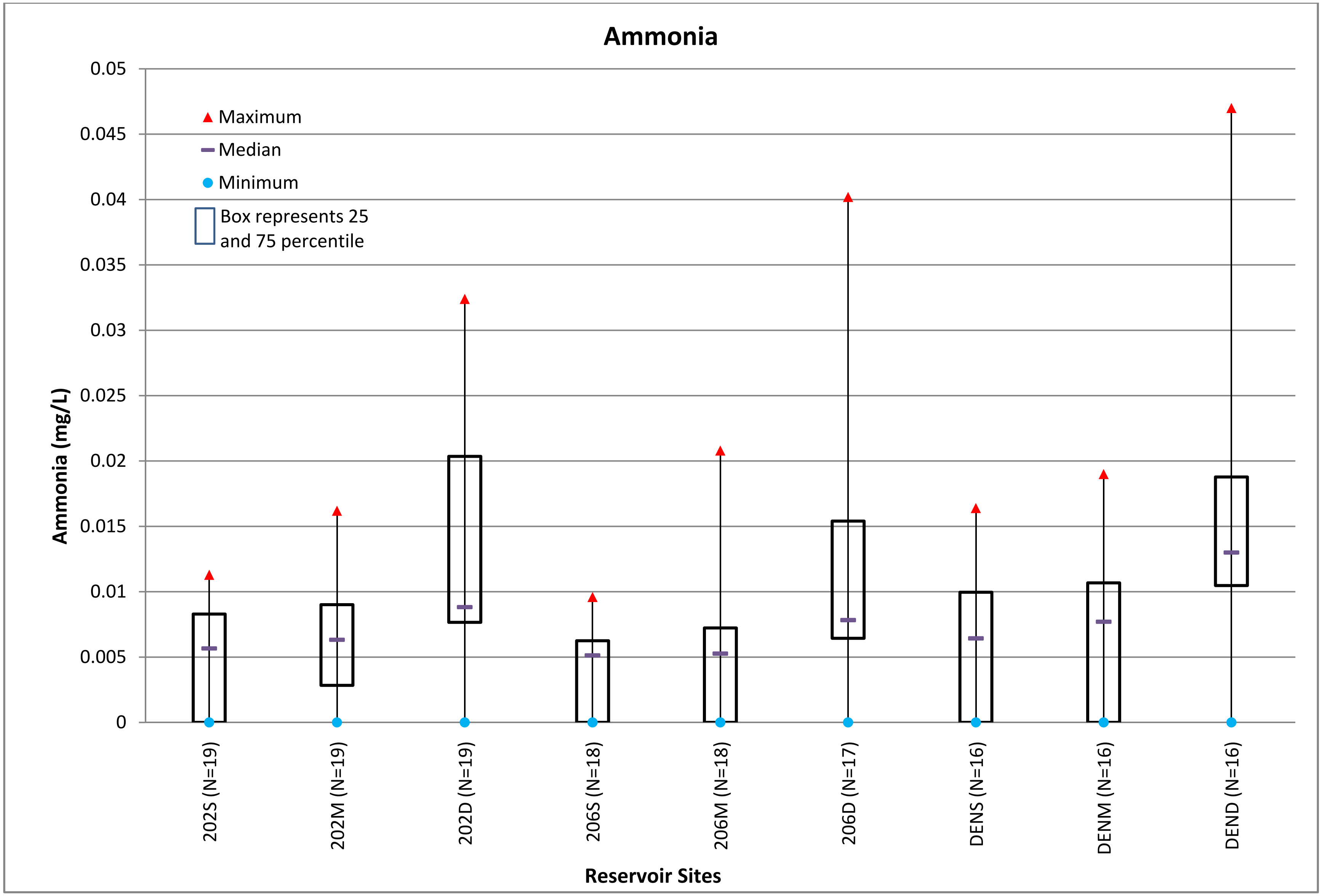

Figure 43. Boxplot of Ammonia Data, Quabbin Reservoir Sites, 2005-2009

Table 44. Summary Statistics for Ammonia (mg/L), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.005	0.006	0.014	0.004	0.006	0.014	0.006	0.007	0.016
75 percentile	0.008	0.009	0.020	0.006	0.007	0.015	0.010	0.011	0.019
Maximum	0.011	0.016	0.032	0.010	0.021	0.040	0.016	0.019	0.047
Median	0.006	0.006	0.009	0.005	0.005	0.008	0.006	0.008	0.013
Minimum	0	0	0	0	0	0	0	0	0
25 percentile	0	0.003	0.008	0	0	0.006	0	0	0.010
N all samples	19	19	19	18	18	17	16	16	16

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-1 m

-M = Middle; mid-depth if reservoir is not stratified, mid-metalimnion if stratified

-D = Deep, within 2-3 m of bottom

A value of "0" indicates "Not Detected." Detection limit was generally 0.005 mg/L.

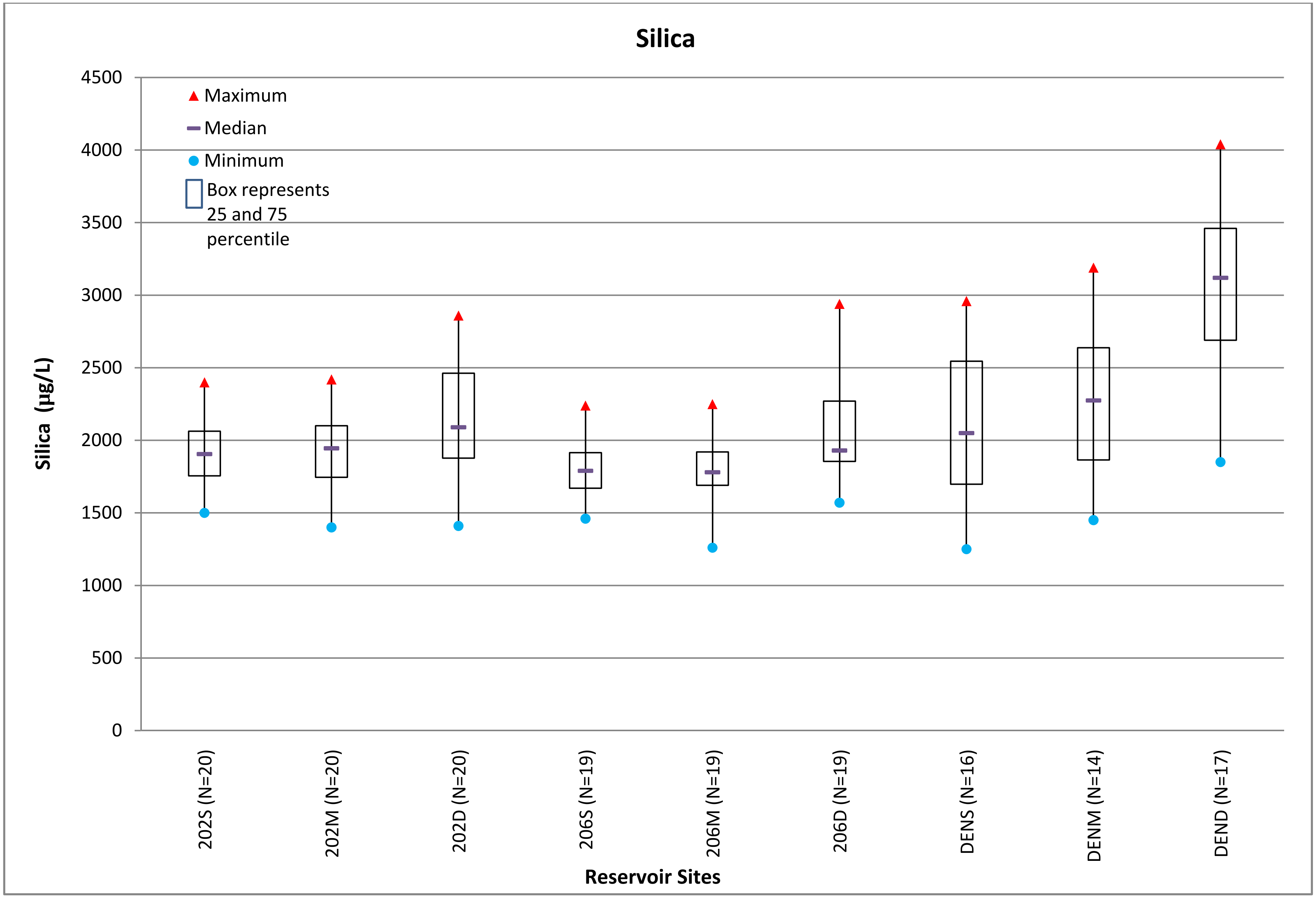

Figure 44. Boxplot of Silica Data, Quabbin Reservoir Sites, 2005-2009

Table 45. Summary Statistics for Silica (µg/L), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	1930	1940	2150	1800	1800	2090	2130	2270	3070
75 percentile	2060	2100	2460	1920	1920	2270	2550	2640	3460
Maximum	2400	2420	2860	2240	2250	2940	2960	3190	4040
Median	1910	1950	2090	1790	1780	1930	2050	2280	3120
Minimum	1500	1400	1410	1460	1260	1570	1250	1450	1850
25 percentile	1760	1750	1880	1670	1690	1860	1700	1870	2690
N all samples	20	20	20	19	19	19	16	14	17

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-1 m

-M = Middle; mid-depth if reservoir is not stratified, mid-metalimnion if stratified

-D = Deep, within 2-3 m of bottom

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3.1.1.4 Natural Organic Matter

Natural organic matter was monitored using UV_{254} in tributary and reservoir samples. Note that UV_{254} was not monitored at tributary core sites in the Quabbin Reservoir watershed until 2009, and only on a quarterly basis. UV_{254} has units of absorbance per centimeter (abs/cm or cm^{-1}). Further discussion of UV_{254} is provided in Section 4.

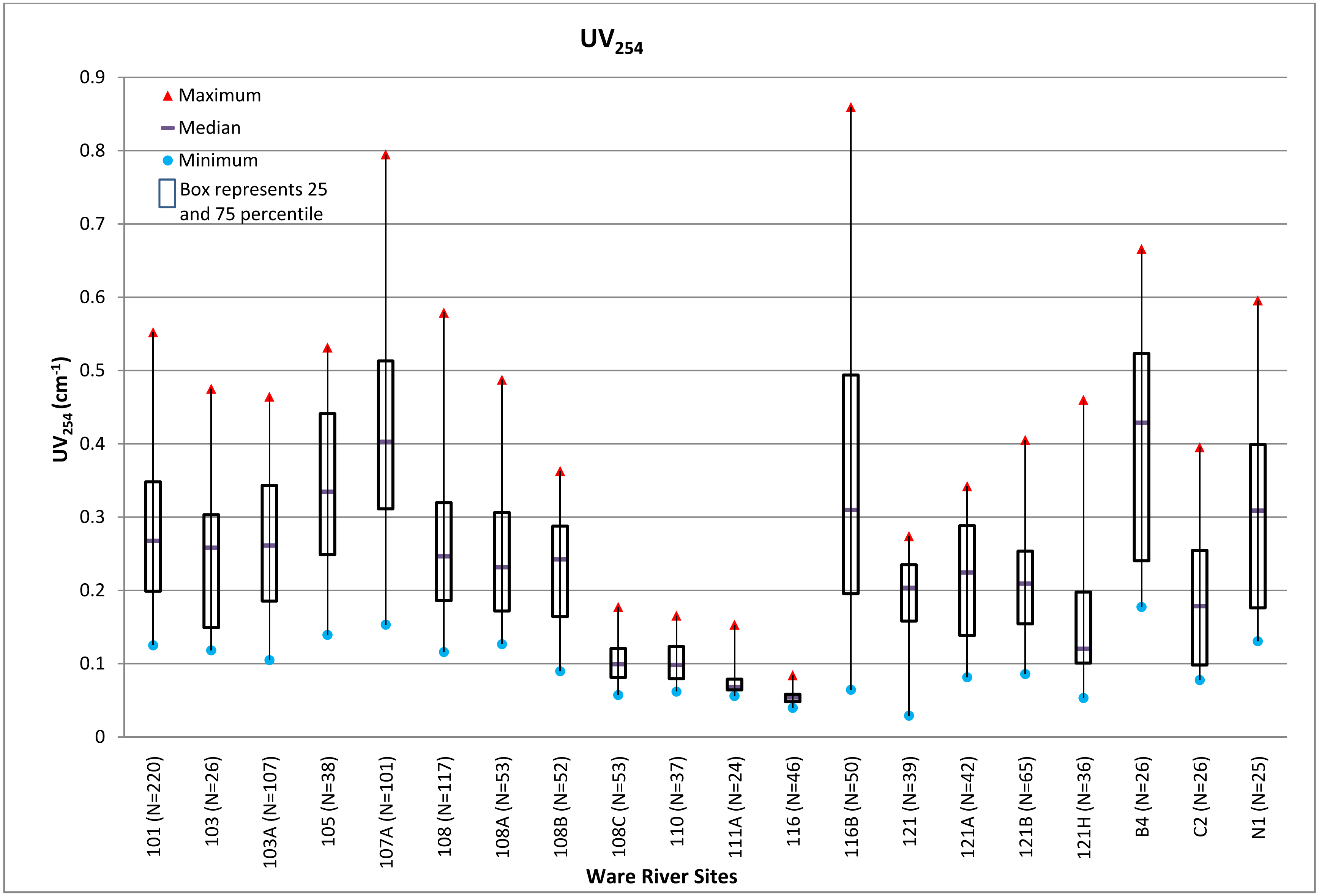


Figure 45. Boxplot of UV_{254} Data, Ware River Sites, 2005-2009

Table 46. Summary Statistics for UV_{254} (cm^{-1}), Ware River Sites, 2005-2009

SITE	101	103	103A	105	107A	108	108A	108B	108C	110	111A
Mean	0.2793	0.2519	0.2638	0.3407	0.4100	0.2567	0.2482	0.2263	0.1000	0.1018	0.0782
75 percentile	0.3481	0.3032	0.3432	0.4411	0.5131	0.3196	0.3064	0.2877	0.1206	0.1234	0.0790
Maximum	0.5522	0.4751	0.4643	0.5314	0.7948	0.5790	0.4875	0.3630	0.1773	0.1655	0.1532
Median	0.2676	0.2583	0.2612	0.3347	0.4028	0.2465	0.2316	0.2424	0.0992	0.0983	0.0681
Minimum	0.1250	0.1183	0.1049	0.1394	0.1532	0.1160	0.1268	0.0898	0.0573	0.0620	0.0559
25 percentile	0.1989	0.1492	0.1854	0.2488	0.3112	0.1859	0.1719	0.1641	0.0813	0.0795	0.0641
N all samples	220	26	107	38	101	117	53	52	53	37	24

SITE	116	116B	121	121A	121B	121H	B4	C2	N1
Mean	0.0541	0.3753	0.1924	0.2178	0.2107	0.1587	0.4098	0.1944	0.3200
75 percentile	0.0581	0.4938	0.2350	0.2884	0.2535	0.1977	0.5232	0.2547	0.3989
Maximum	0.0842	0.8594	0.2740	0.3422	0.4052	0.4600	0.6658	0.3952	0.5957
Median	0.0540	0.3099	0.2036	0.2244	0.2092	0.1205	0.4289	0.1785	0.3090
Minimum	0.0397	0.0645	0.0292	0.0815	0.0860	0.0531	0.1775	0.0776	0.1307
25 percentile	0.0480	0.1956	0.1582	0.1383	0.1544	0.1008	0.2405	0.0981	0.1762
N all samples	46	50	39	42	65	36	26	26	25

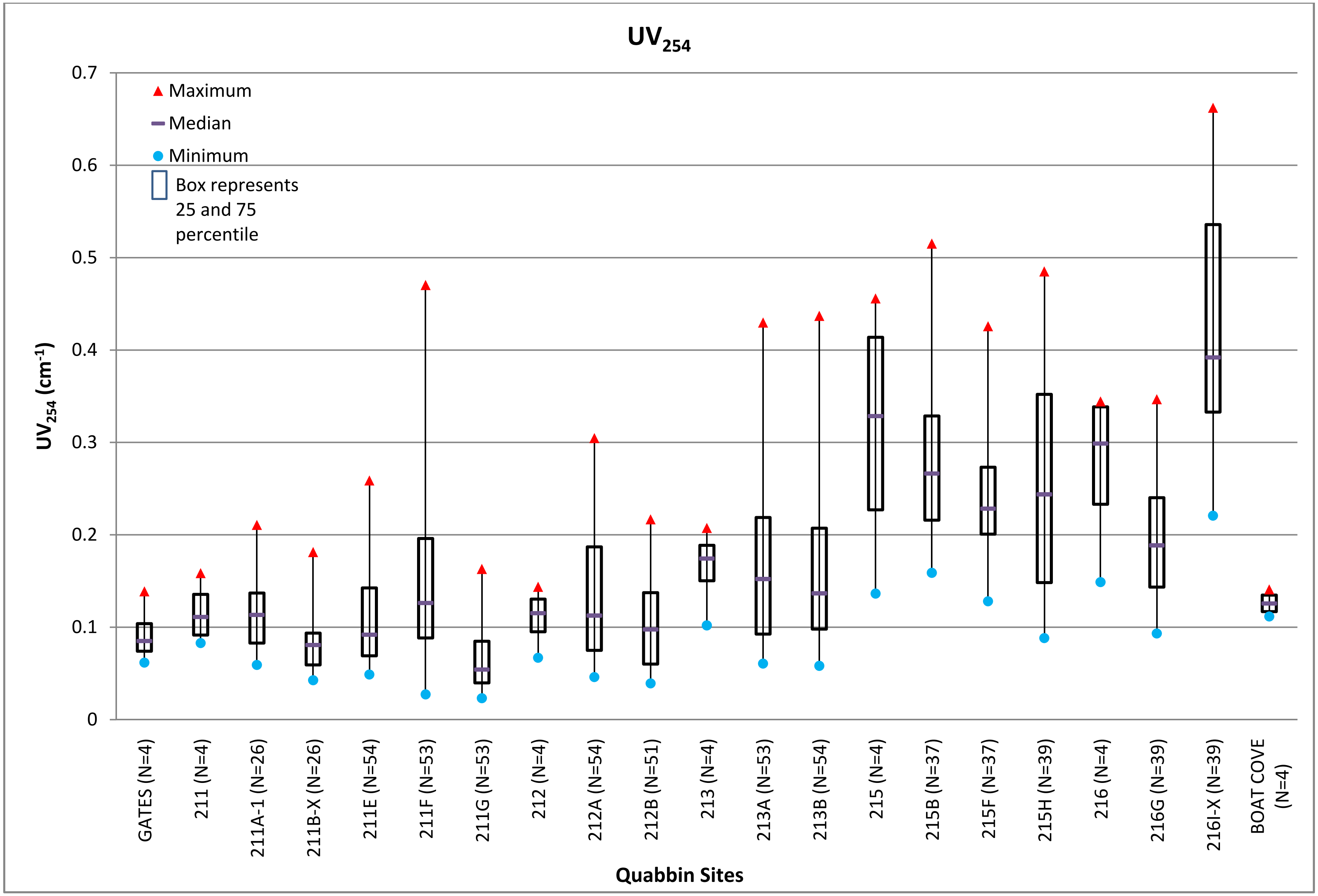


Figure 46. Boxplot of UV_{254} Data, Quabbin Tributary Sites, 2005-2009

Table 47. Summary Statistics for UV_{254} (cm^{-1}), Quabbin Tributary Sites, 2005-2009

SITE	GATES	211	211A-1	211B-X	211E	211F	211G	212	212A	212B	213
Mean	0.0927	0.1159	0.1140	0.0846	0.1088	0.1476	0.0650	0.1103	0.1349	0.1034	0.1646
75 percentile	0.1038	0.1356	0.1369	0.0936	0.1426	0.1960	0.0847	0.1305	0.1870	0.1374	0.1887
Maximum	0.1389	0.1586	0.2108	0.1814	0.2589	0.4704	0.1631	0.1438	0.3047	0.2168	0.2075
Median	0.0851	0.1111	0.1134	0.0807	0.0919	0.1262	0.0542	0.1152	0.1127	0.0976	0.1744
Minimum	0.0617	0.0828	0.0592	0.0426	0.0488	0.0273	0.0232	0.0670	0.0461	0.0392	0.1020
25 percentile	0.0740	0.0914	0.0828	0.0592	0.0690	0.0883	0.0397	0.0950	0.0749	0.0601	0.1502
N all samples	4	4	26	26	54	53	53	4	54	51	4
SITE	**213A**	**213B**	**215**	**215B**	**215F**	**215H**	**216**	**216G**	**216I-X**	**BOAT COVE**	
Mean	0.1616	0.1587	0.3123	0.2798	0.2414	0.2565	0.2727	0.1957	0.4251	0.1260	
75 percentile	0.2187	0.2071	0.4138	0.3286	0.2732	0.3520	0.3385	0.2402	0.5358	0.1348	
Maximum	0.4298	0.4370	0.4559	0.5152	0.4258	0.4851	0.3444	0.3468	0.6622	0.1410	
Median	0.1522	0.1367	0.3285	0.2664	0.2284	0.2438	0.2989	0.1886	0.3920	0.1257	
Minimum	0.0607	0.0582	0.1364	0.1589	0.1281	0.0883	0.1488	0.0932	0.2207	0.1116	
25 percentile	0.0925	0.0980	0.2270	0.2159	0.2007	0.1483	0.2331	0.1435	0.3328	0.1169	
N all samples	53	54	4	37	37	39	4	39	39	4	

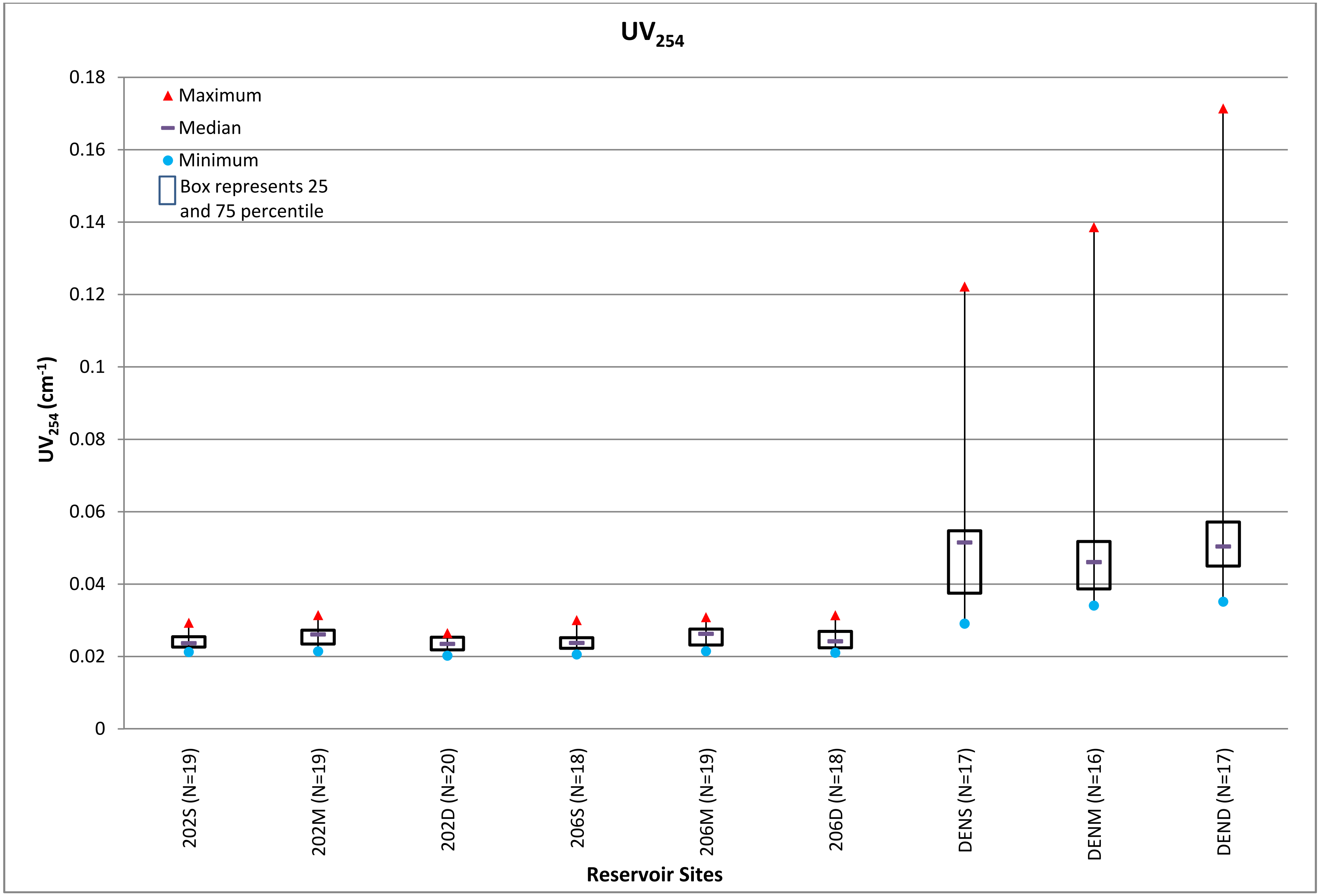


Figure 47. Boxplot of UV_{254} Data, Quabbin Reservoir Sites, 2005-2009

Table 48. Summary Statistics for UV_{254} (cm^{-1}), Quabbin Reservoir Sites, 2005-2009

SITE	202S	202M	202D	206S	206M	206D	DENS	DENM	DEND
Mean	0.02403	0.02579	0.02345	0.02403	0.02567	0.02492	0.05174	0.05139	0.05782
75 percentile	0.02545	0.02726	0.02532	0.02519	0.02759	0.02693	0.05472	0.05177	0.05716
Maximum	0.02932	0.03143	0.02646	0.03004	0.03086	0.03139	0.12220	0.13860	0.17140
Median	0.02368	0.02608	0.02348	0.02373	0.02626	0.02419	0.05148	0.04606	0.05038
Minimum	0.02122	0.02140	0.02020	0.02054	0.02144	0.02102	0.02906	0.03407	0.03513
25 percentile	0.02259	0.02344	0.02183	0.02225	0.02318	0.02241	0.03748	0.03867	0.04497
N all samples	19	19	20	18	19	18	17	16	17

Notes:

-S, -M, and -D denote the three depths:

-S = Surface, 0-1 m

-M = Middle; mid-depth if reservoir is not stratified, mid-metalimnion if stratified

-D = Deep, within 2-3 m of bottom

3.1.1.5 Seasonal Analysis for Sites 101, 211, 213, and 216

Preliminary seasonal analysis was performed for selected core sites in order to evaluate seasonality in sampling parameters. These four sites were selected to represent major tributary inflows to Quabbin Reservoir. As core sites, they have relatively long monitoring records, although some parameters were discontinued (*e.g.*, alkalinity) and others were analyzed less frequently (*e.g.*, quarterly for nutrients).

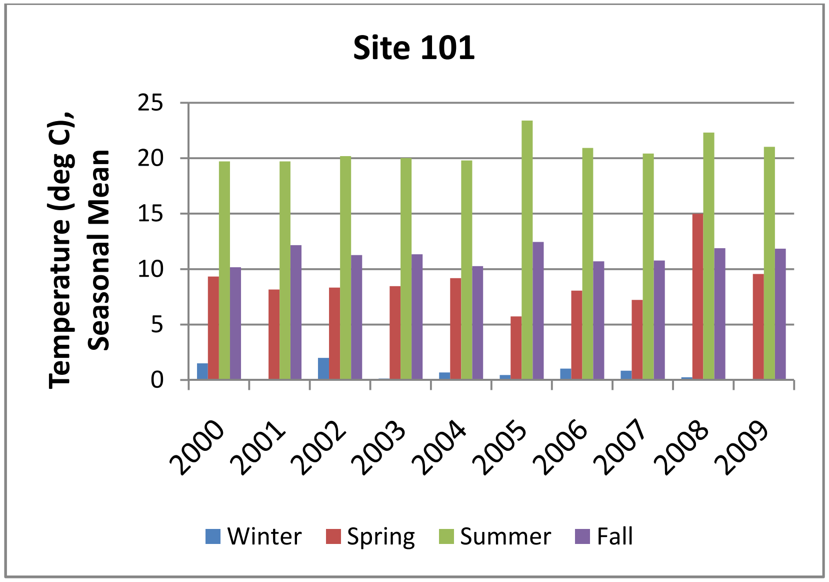
Seasonal mean values were calculated with the seasons divided as follows:

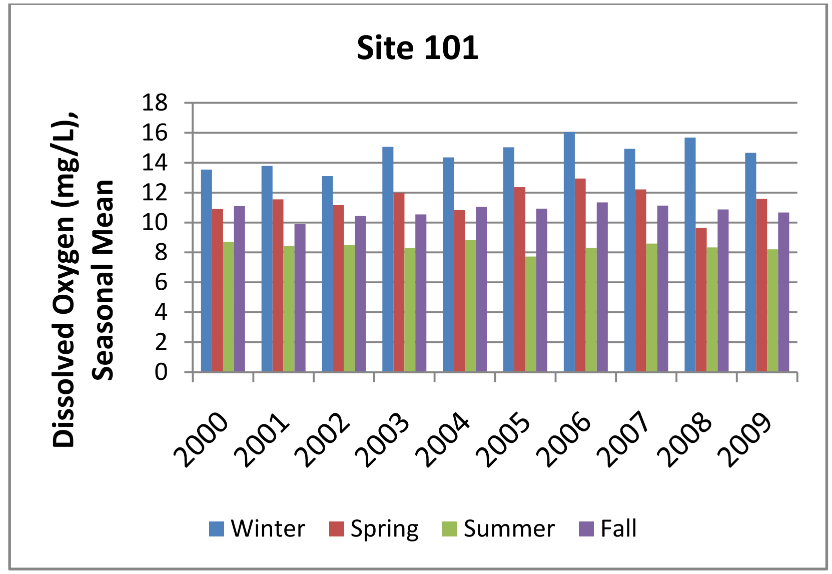
- Winter, December (prior year) through February;
- Spring, March through May;
- Summer, June through August; and
- Fall, September through November.

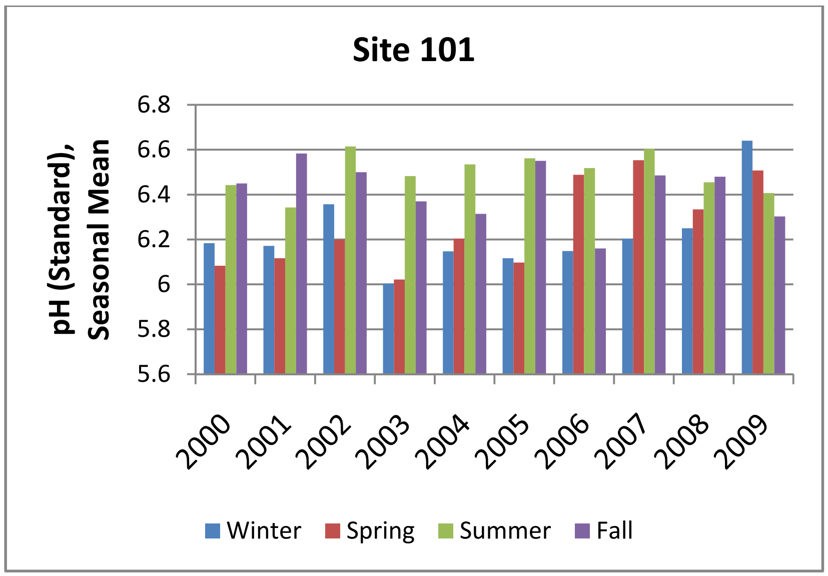
Except for nutrients, the results are presented in barcharts with seasonal means for each year in which data were available. Seasonal means generally represent the average of 5 to 7 sample results for the bacterial and physicochemical sampling parameters.

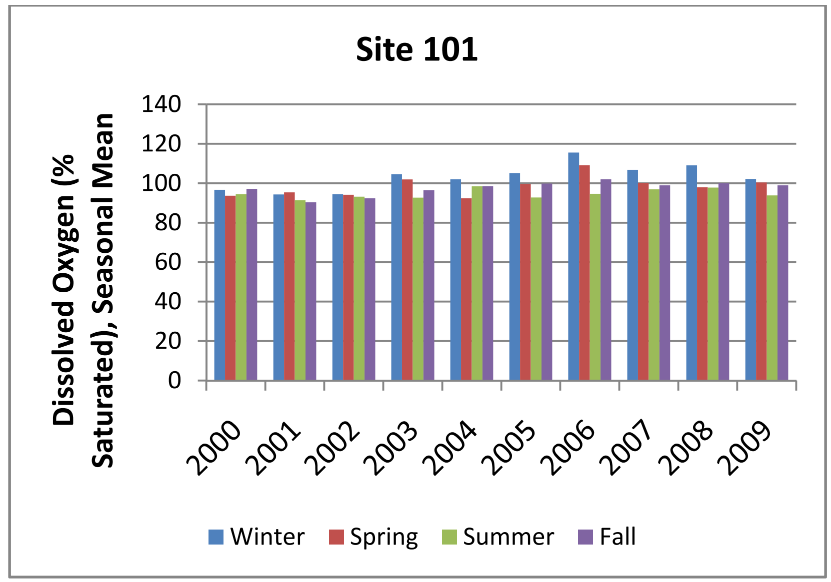
Nutrient monitoring was begun only in 2005 and has been conducted on a quarterly basis for core sites. Because of some earlier inconsistencies or lack of coordination with the laboratory, sometimes 0 to 2 samples were collected per season per year, for a total of 2 to 11 sample results per season over the entire five years of data collection. In this case, nutrient data were grouped by season, disregarding what year samples were taken.

Figure 48. Barcharts of Seasonal Mean Values, Site 101.









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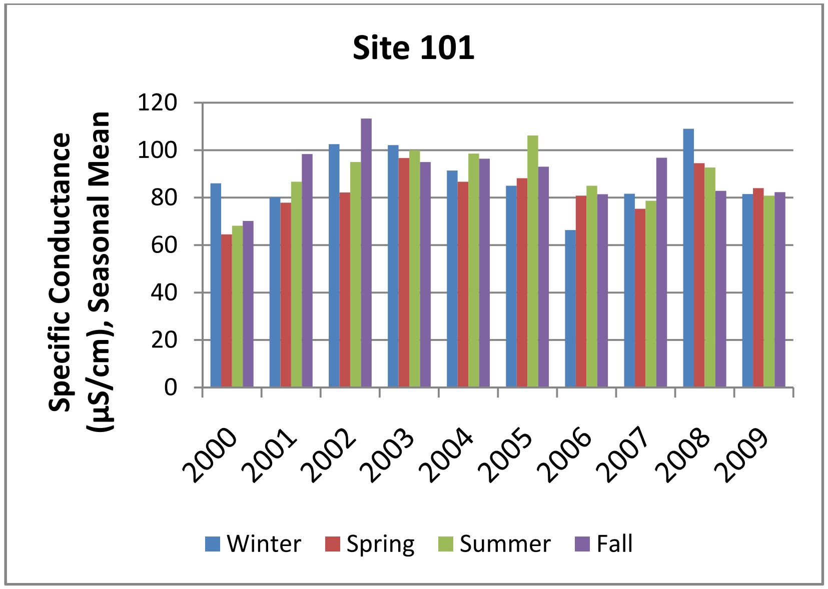

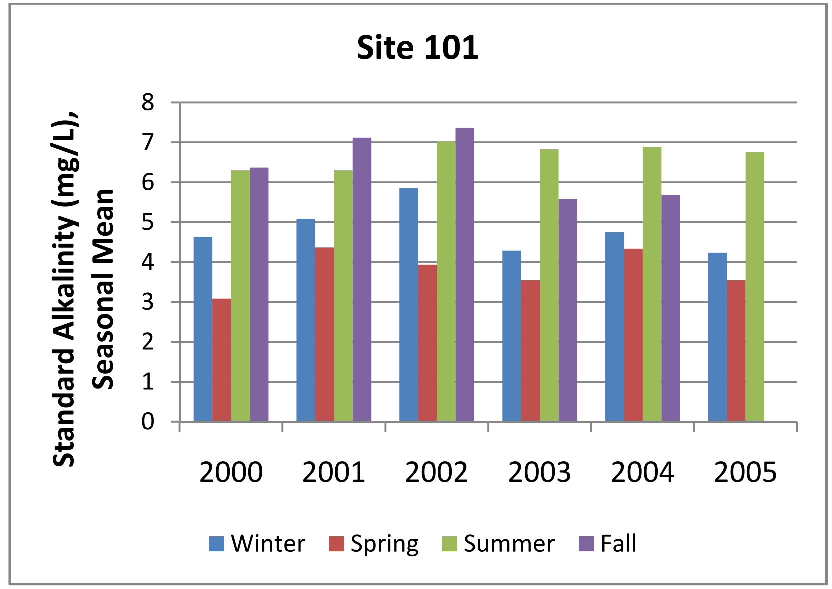

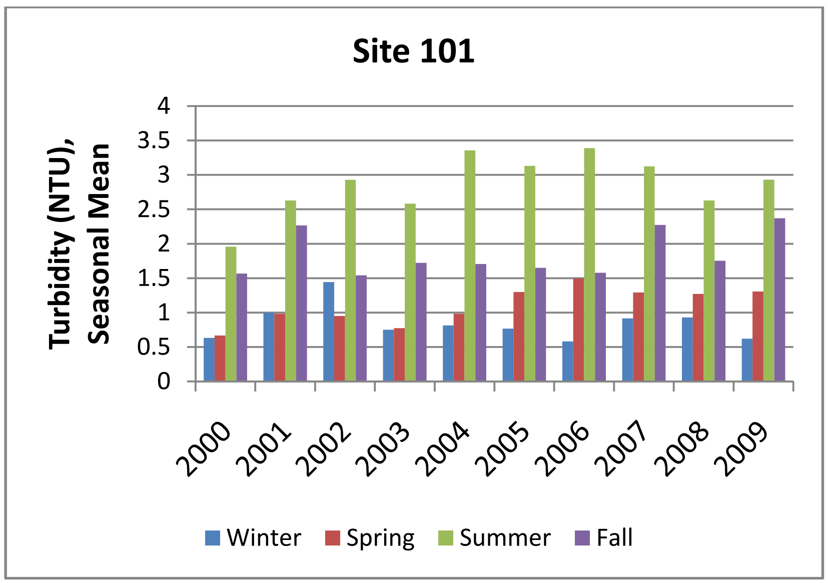

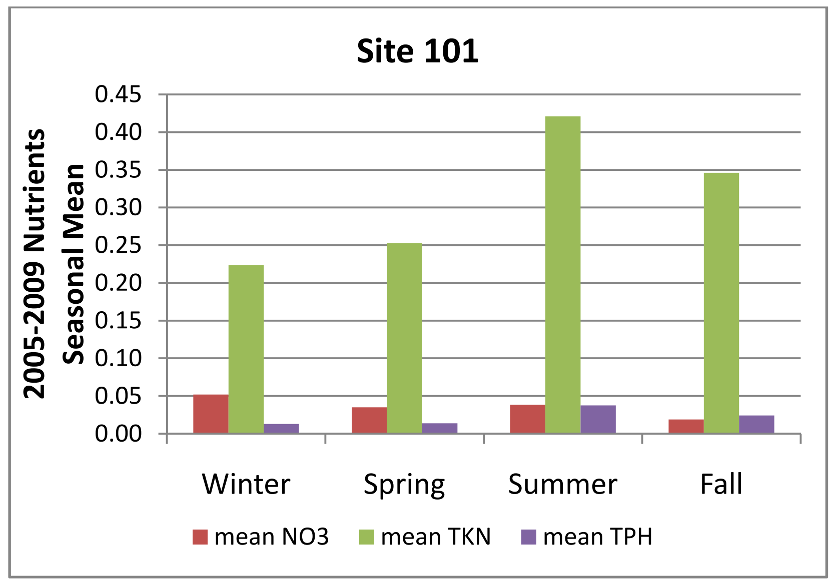

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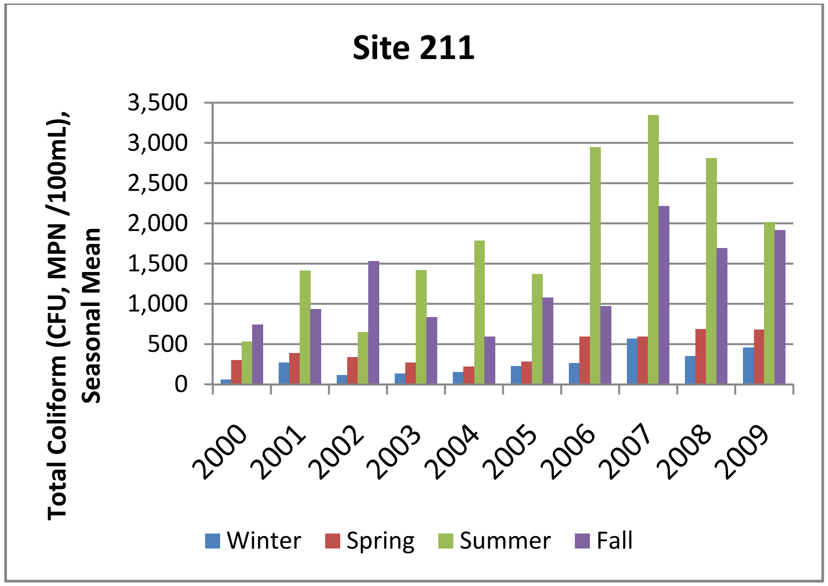
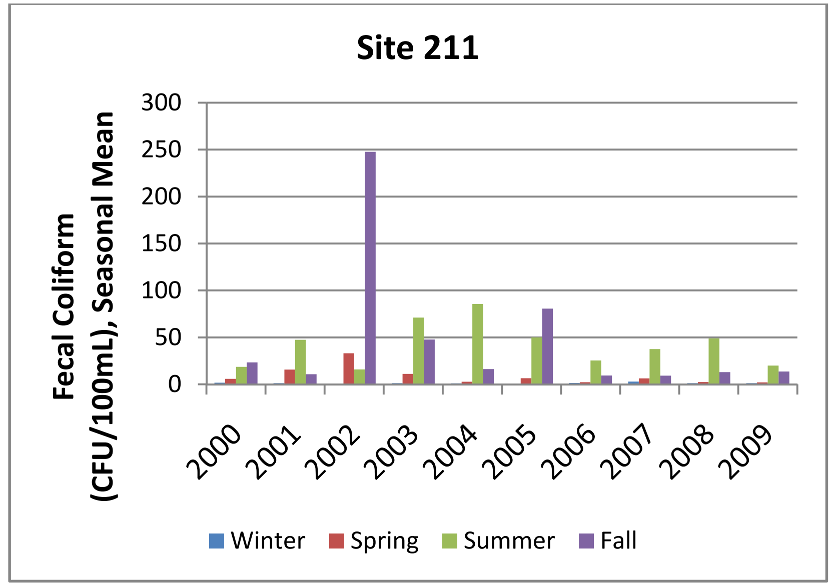
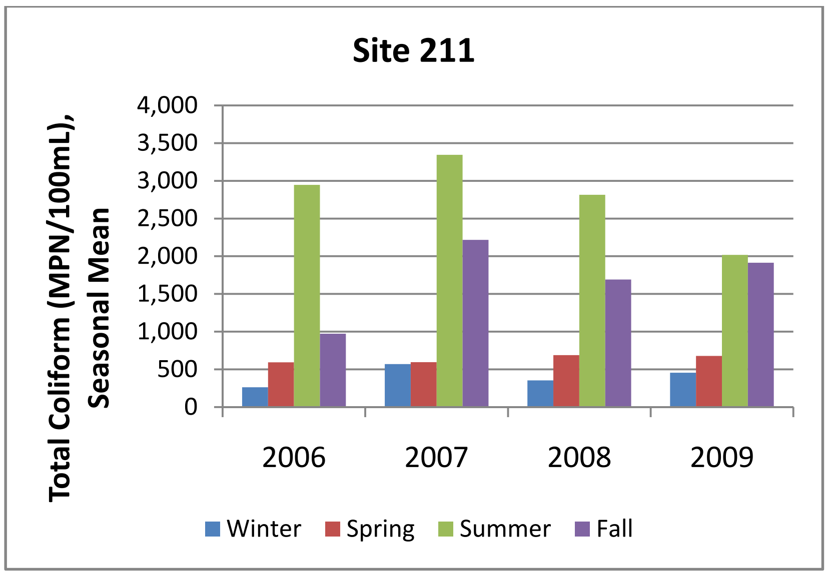






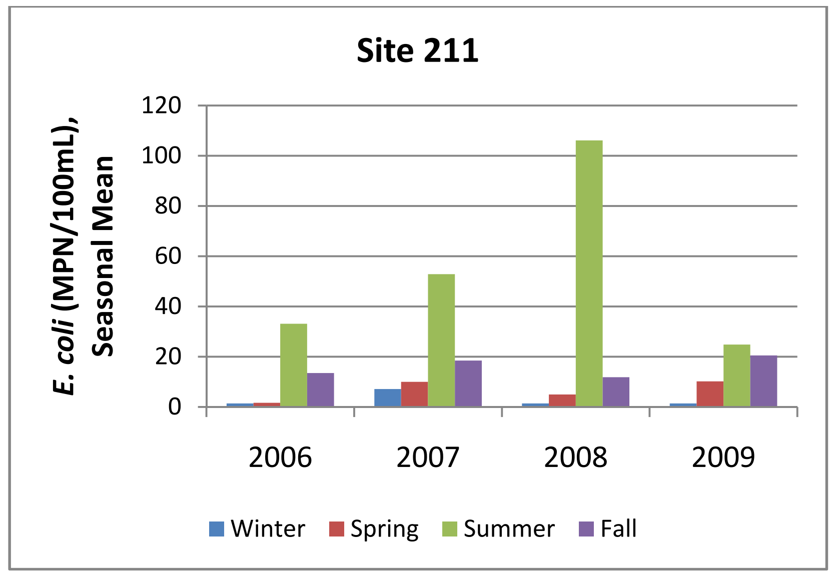
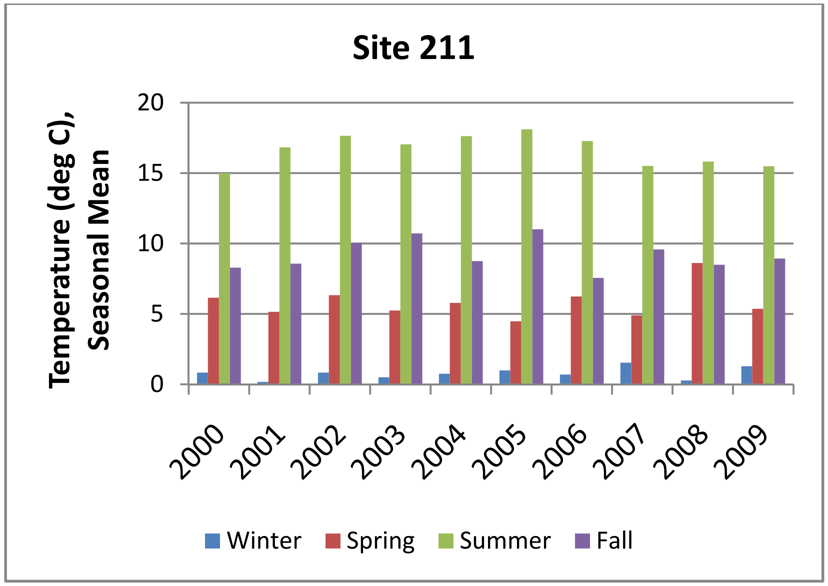
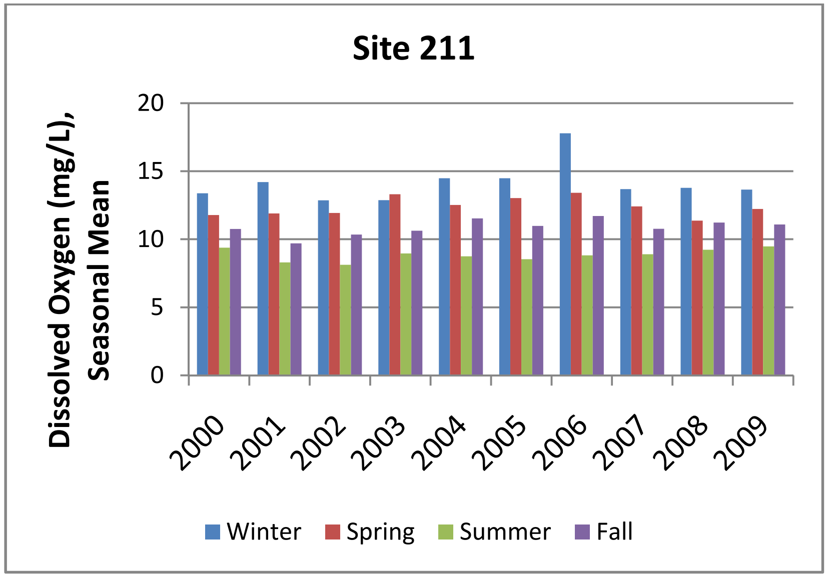
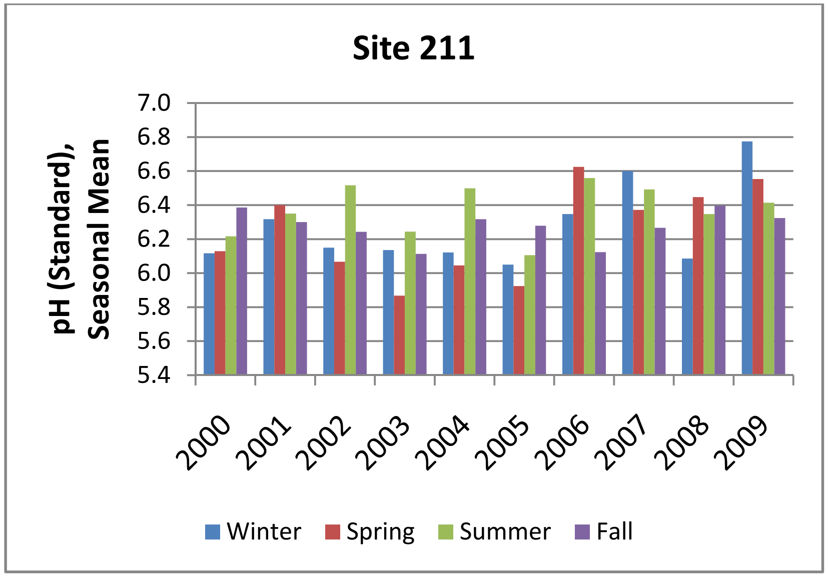
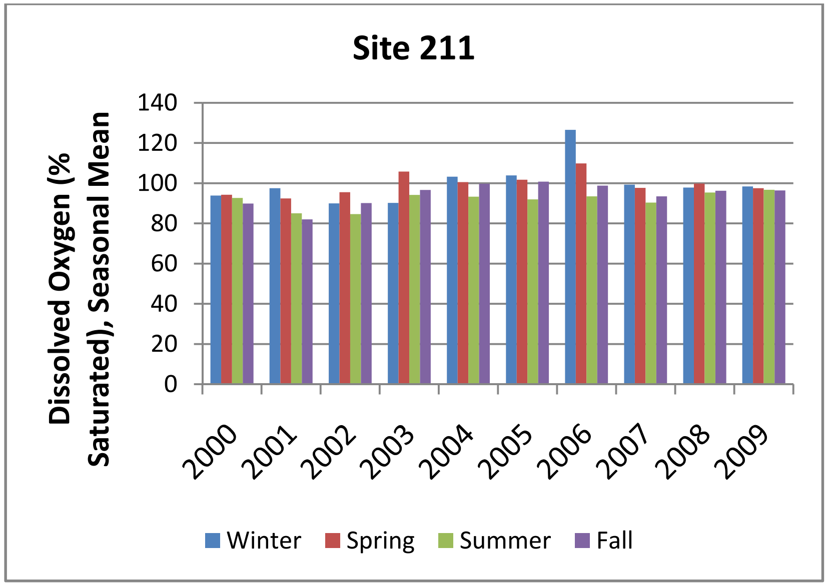


Figure 49. Barcharts of Seasonal Mean Values, Site 211.









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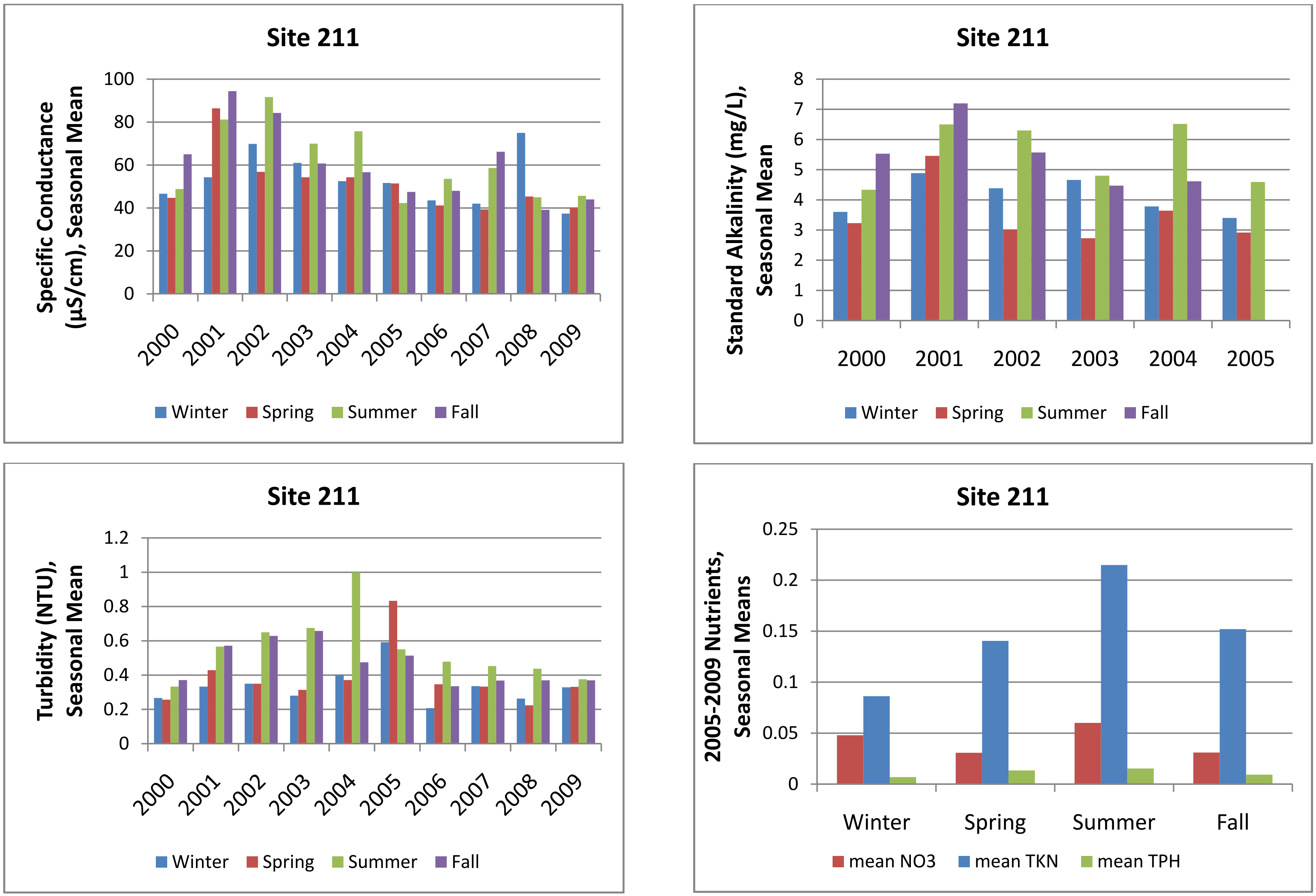

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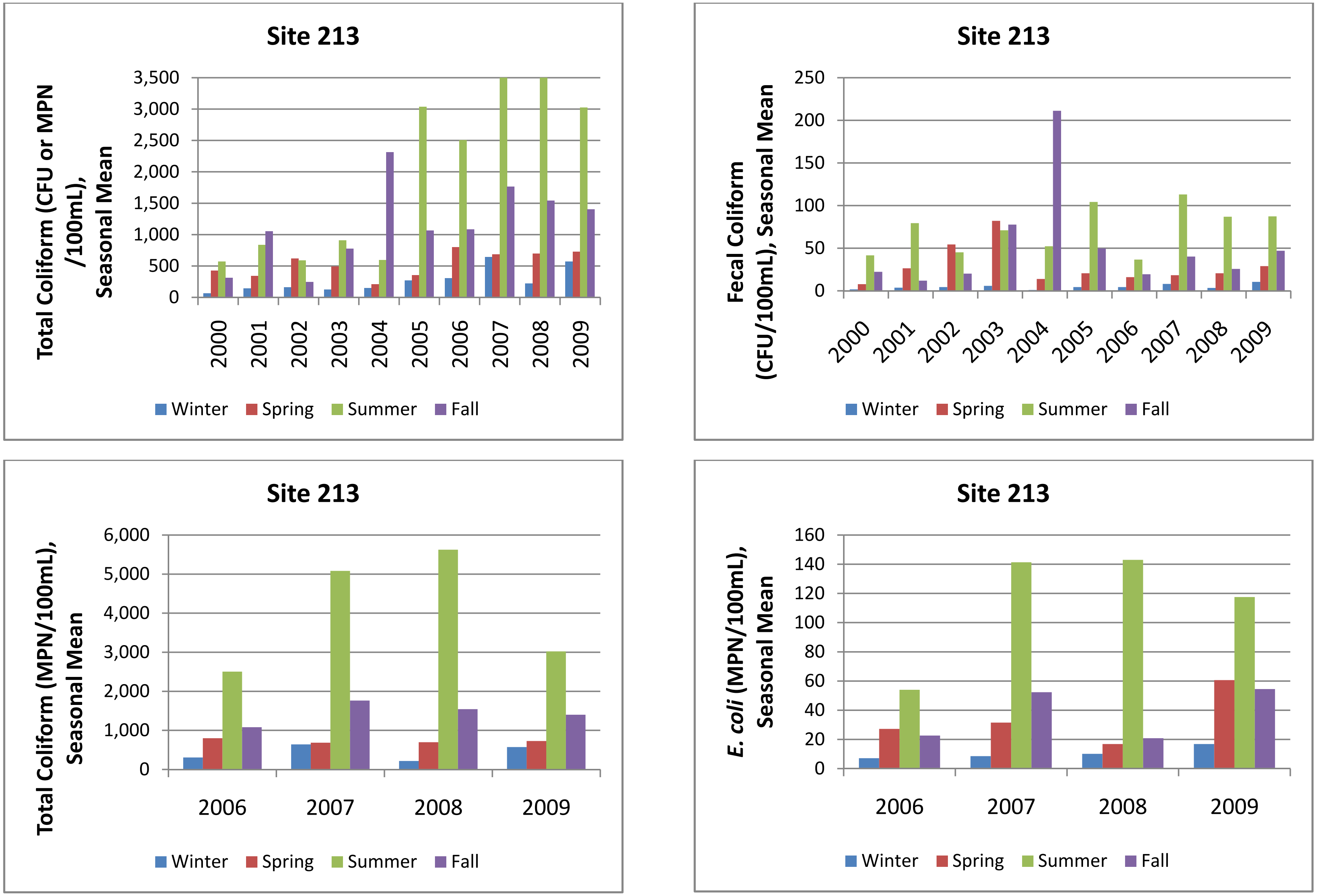
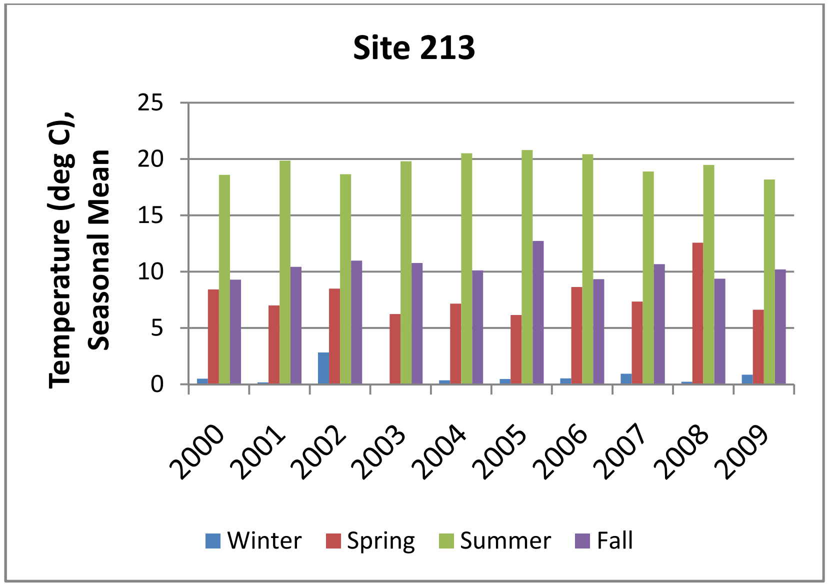
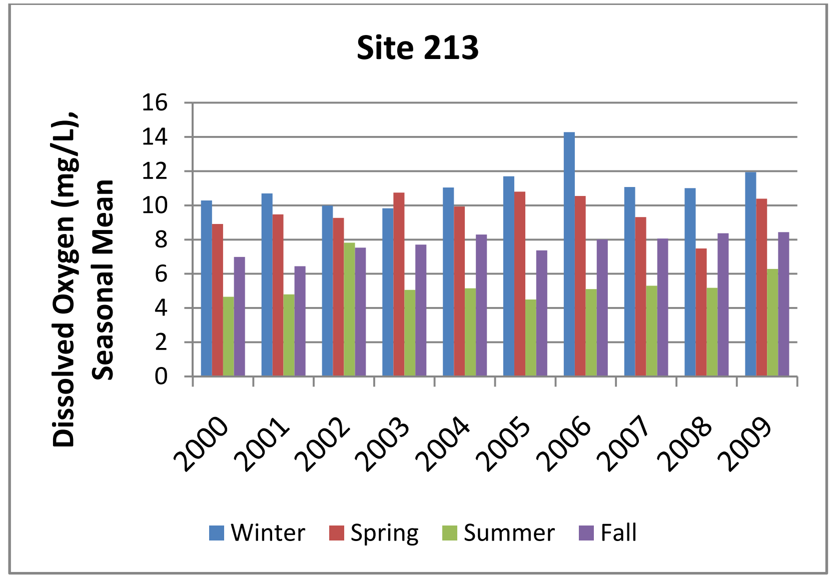
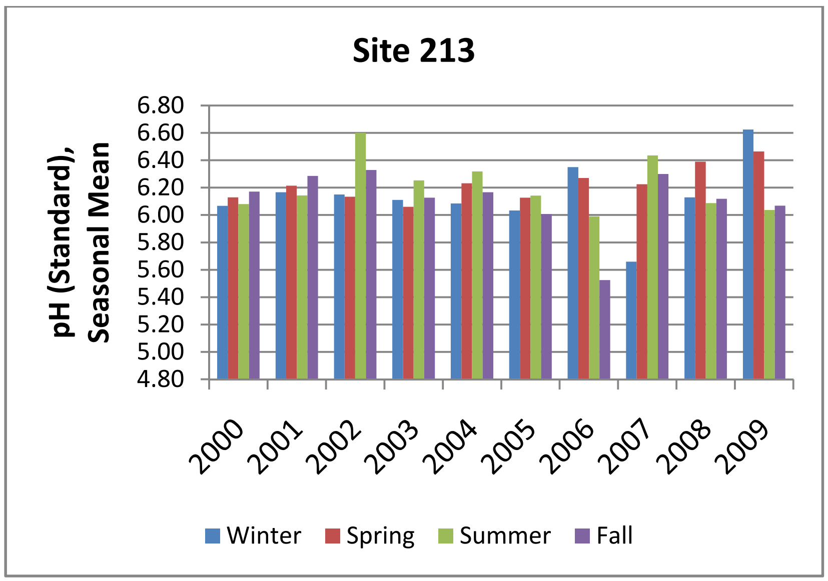
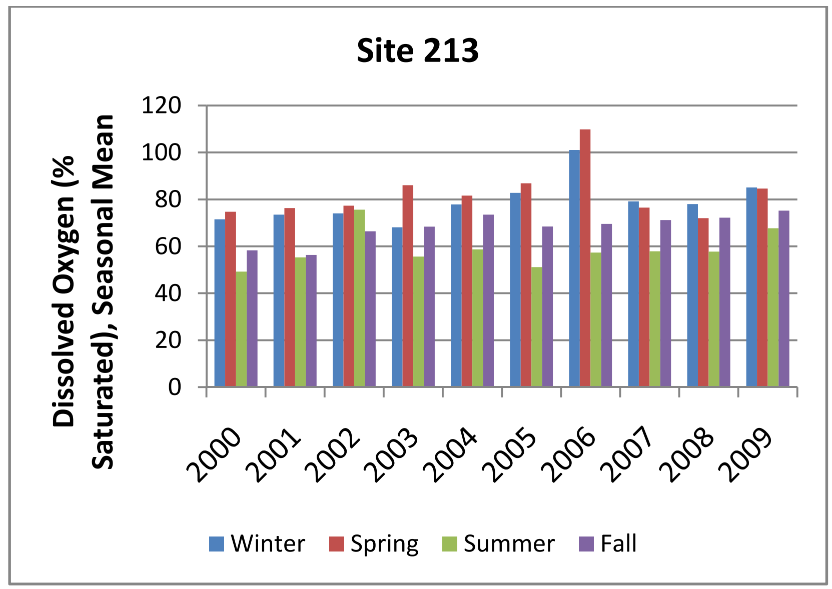


Figure 50. Barcharts of Seasonal Mean Values, Site 213.









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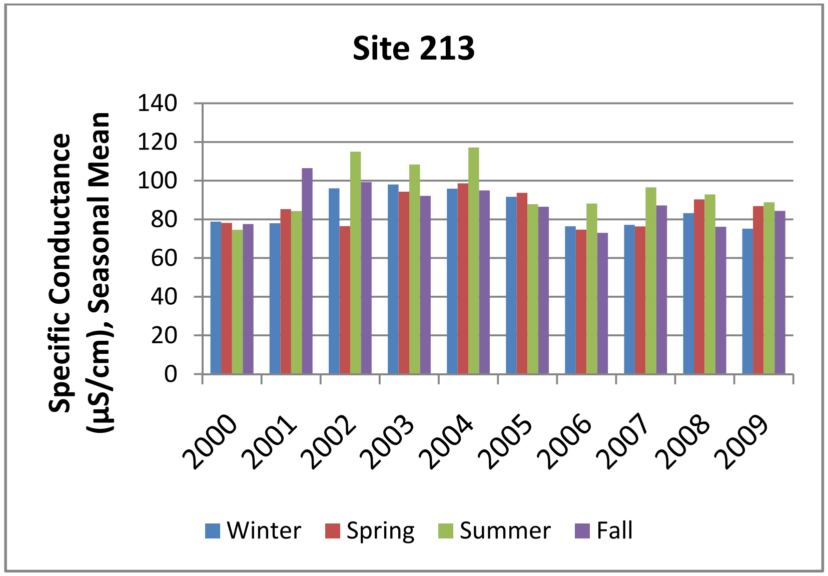

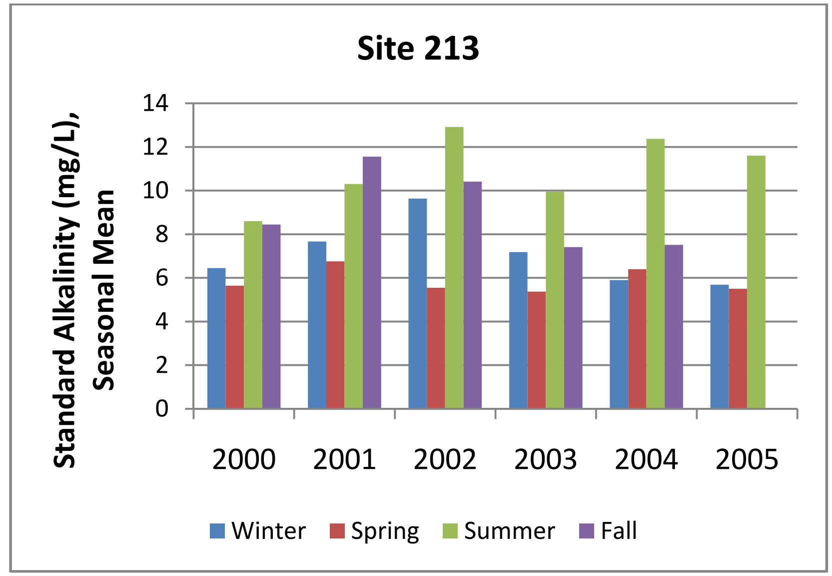

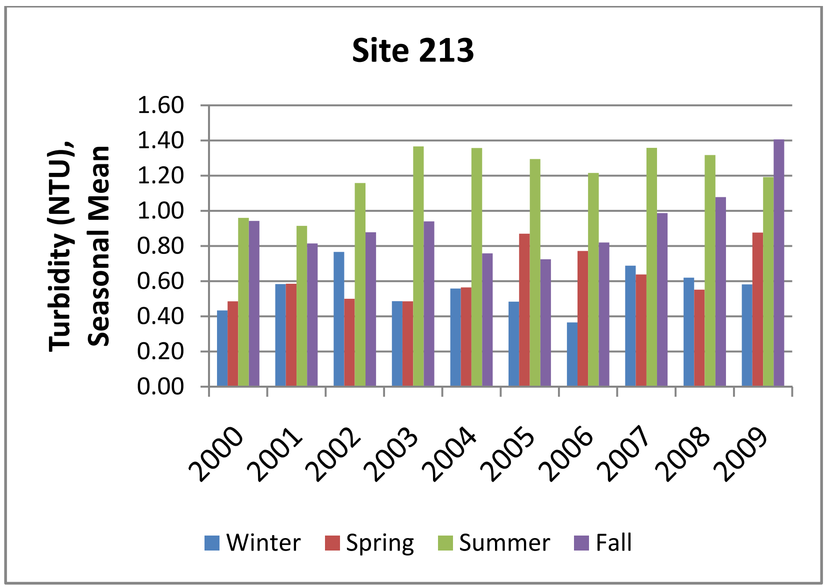

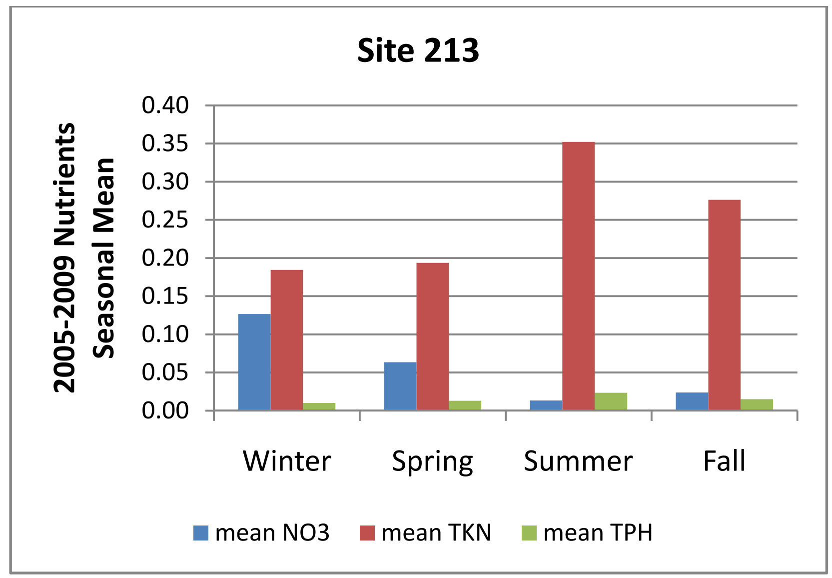

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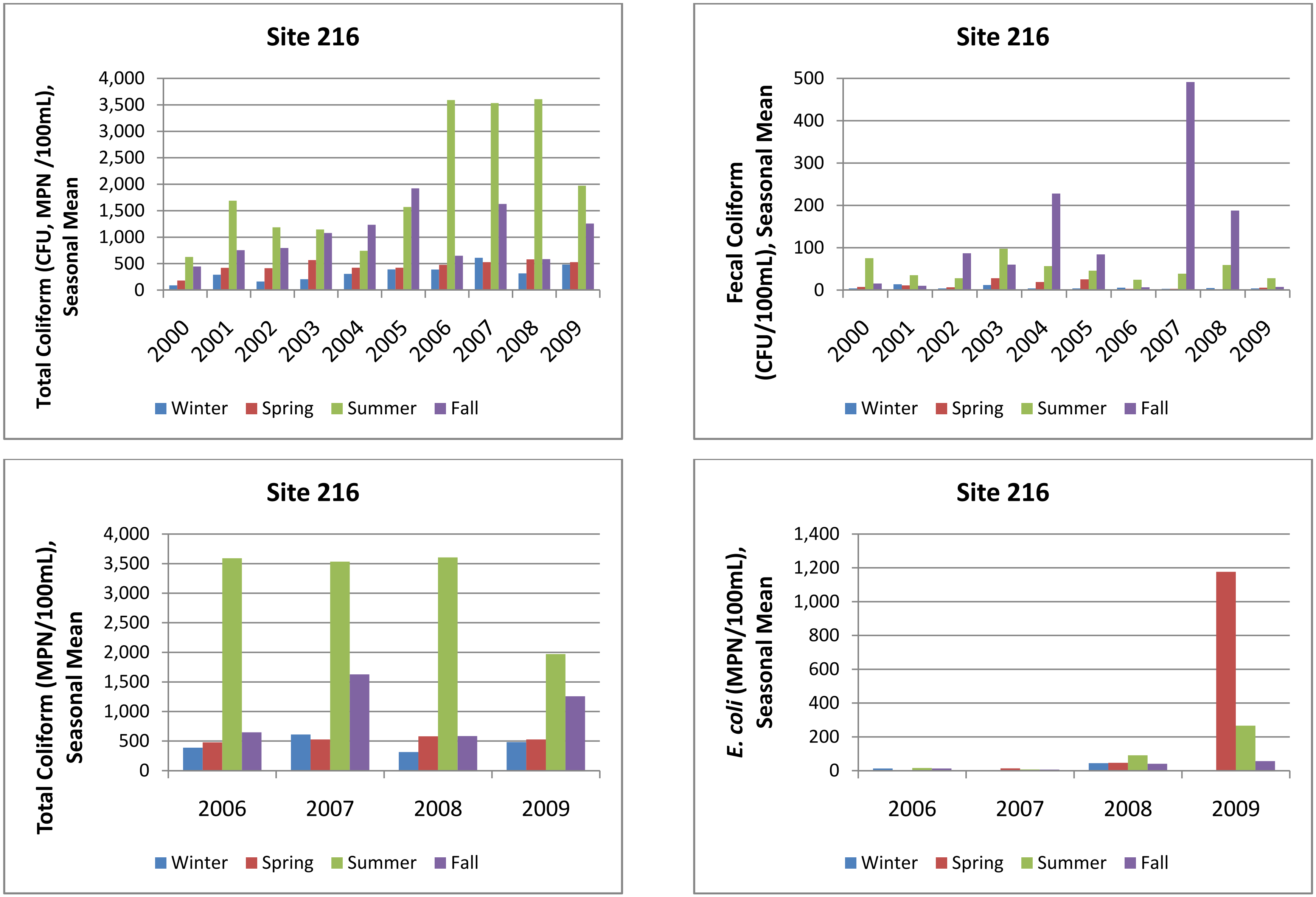
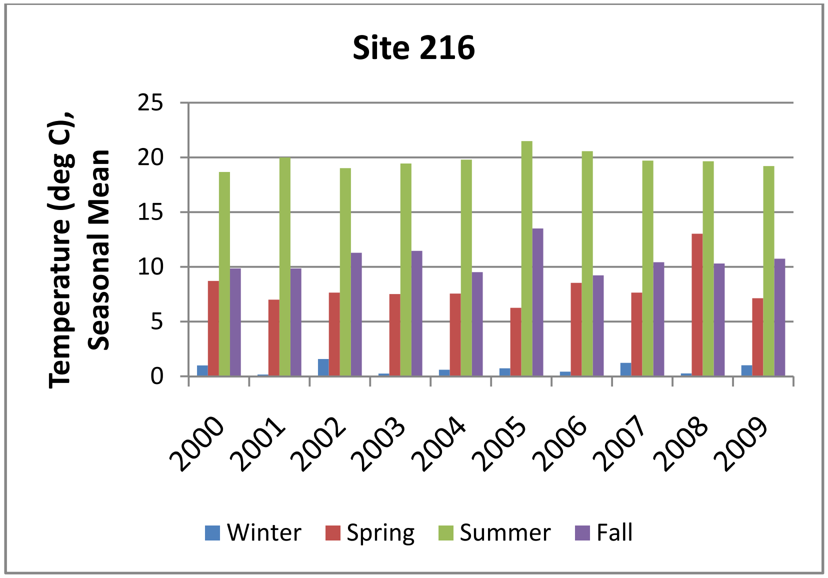
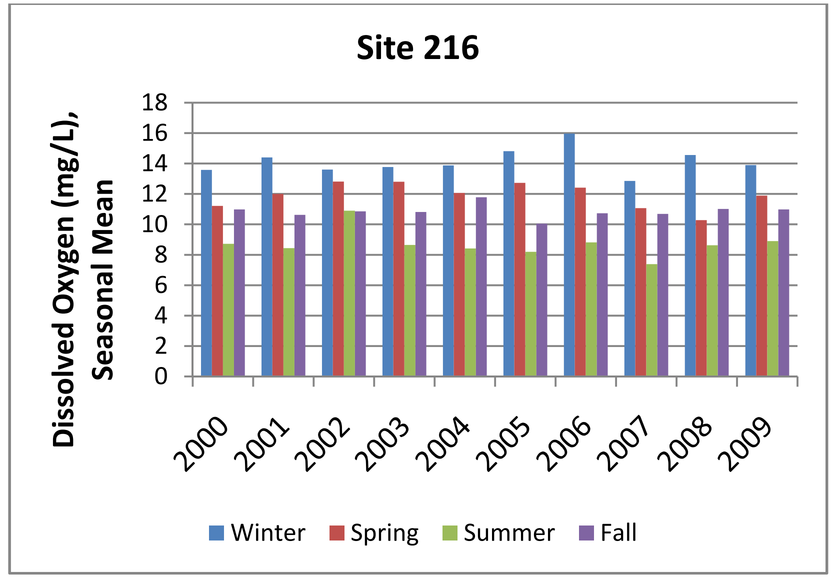
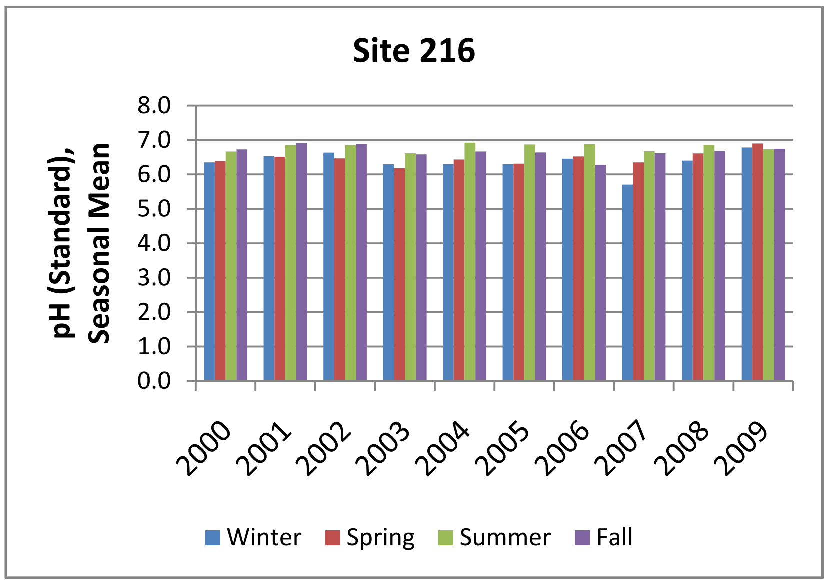
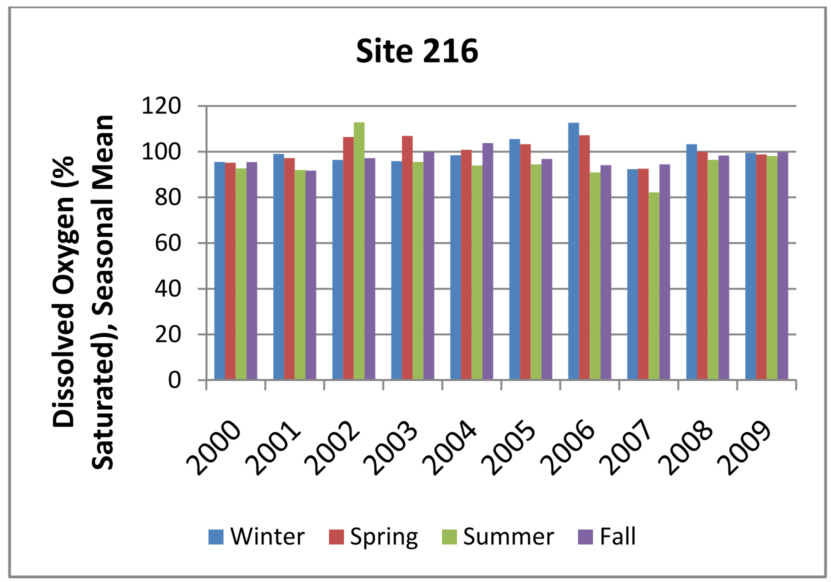


Figure 51. Barcharts of Seasonal Mean Values, Site 216









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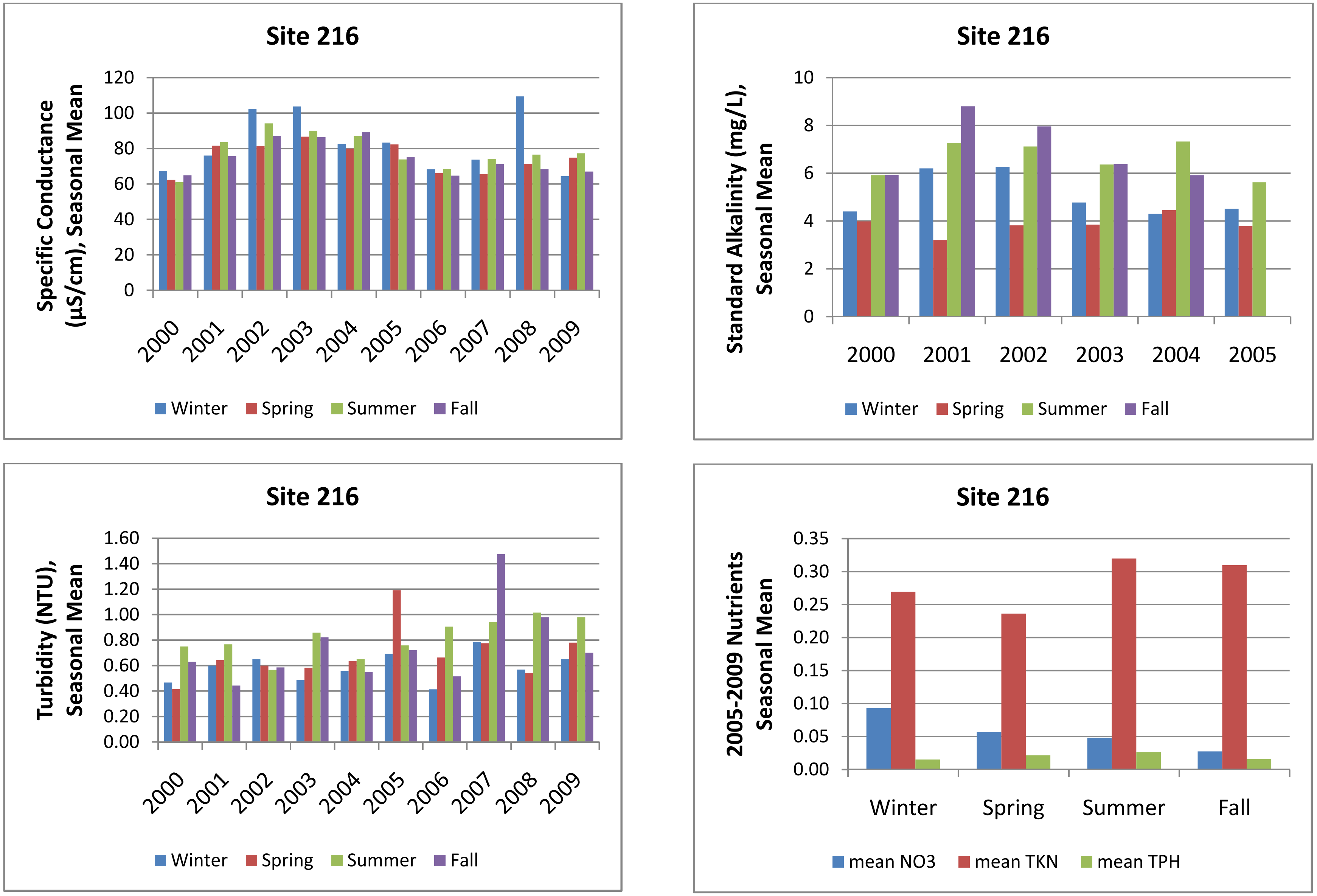


Figure 51 (continued).

4 Additional Analyses for Ware River Intake, Site 101

Water quality samples from Site 101 are collected biweekly (*i.e.*, every two weeks) for bacteria and physicochemical parameters and, since 2005, quarterly for nutrients. Site 101 has also been monitored for natural organic matter by UV_{254} on a weekly basis since 2005, with results shown in **Figure 52**. Data for Site 101 were evaluated to assess whether UV_{254} monitoring could be changed from weekly to biweekly without affecting trend analysis, as discussed below in Section 4.1.

Flow from Ware River may be diverted to Quabbin Reservoir from October 15 to June 15, provided that the river flow at the intake works does not fall below 85 million gallons per day. Water quality during the allowable diversion period (October 15 to June 15) was compared to the water quality during the non-diversion period (June 16 to October 14), as discussed in Section 4.2.

4.1.1.1 Evaluation of UV_{254} Monitoring at Site 101

UV_{254} measures water absorbance of ultraviolet light at a wavelength of 254 nm across 1 centimeter of water. At 254 nm, light is absorbed by organic carbon molecules and complex compounds, such as pesticides. UV_{254} testing is cost-efficient and easy compared to testing total organic carbon (TOC) in water samples, and it serves as an indicator for natural organic matter.

Natural organic matter may react with chlorine during disinfection treatment and form disinfection byproducts, some of which are or may be carcinogenic over a person's lifetime. UV_{254} values over 0.050 cm^{-1} may be a concern for formation of disinfection byproducts (Reckhow, personal communication).

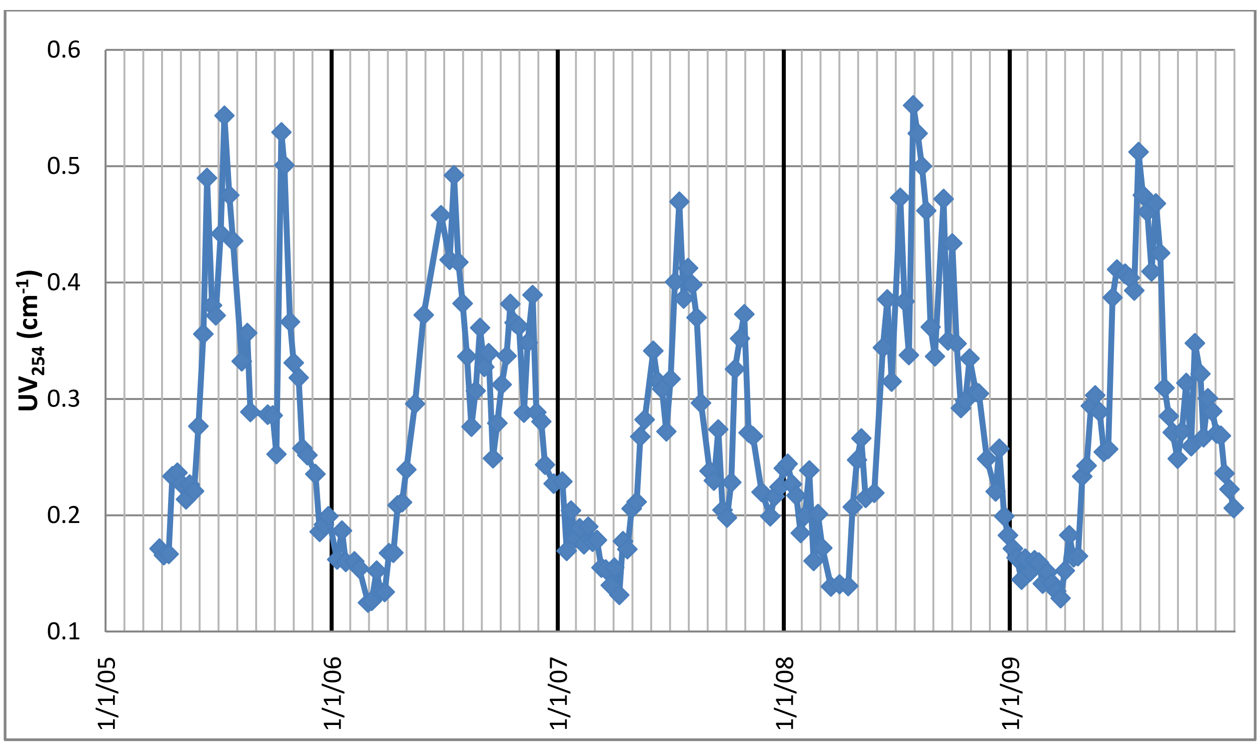


Figure 52. UV_{254} at Site 101, 2005-2009

For Quabbin and Wachusett Reservoirs, absorbance values can range from about 0.02 cm^{-1} for Quabbin Reservoir source water (at the WDF raw water intake) to 0.04-0.08 cm^{-1} for Wachusett Reservoir source water (at the raw water intake for the Carroll water treatment plant in Marlborough, MA). At the three sampling stations in Quabbin Reservoir, values ranged from 0.017-0.031 cm^{-1} at Sites 202 and 206, to 0.025-0.17 cm^{-1} at Den Hill. In the Quabbin and Ware River watersheds, UV_{254} values ranged from 0.023 to 0.66 cm^{-1} in the Quabbin Reservoir watershed and from 0.029 to 0.86 cm^{-1} in the Ware River watershed. Higher values of about 0.500 cm^{-1} are typically found in "colored, or eutrophic waters, or waters from productive wetlands" (Reckhow, personal communication).

UV_{254} at Site 101 ranged from 0.1250 to 0.5522 cm^{-1}, with a median of 0.2676 cm^{-1}. Generally, UV_{254} did not fluctuate dramatically from week to week, but varied seasonally and annually, as shown in **Figure 52**. Seasonal average values of UV_{254} at Site 101 were comparable with other Ware River core sites (See **Table 49** and **Figure 53**). Because seasonal and annual trends have been consistent over five years of monitoring, weekly sampling of UV_{254} at this site is no longer necessary. UV_{254} monitoring may be changed to a biweekly frequency, consistent with the other Ware River tributary sampling sites.

Table 49. Seasonal Average UV_{254} Values at Core Sites, Ware River Watershed

Site	Year	Spring	Summer	Fall	Winter
101	2005	0.214	0.407	0.338	0.182
	2006	0.195	0.383	0.328	0.206
	2007	0.186	0.357	0.265	0.213
	2008	0.194	0.422	0.339	0.176
	2009	0.199	0.404	0.301	0.241
103A	2005	0.188	0.400	0.289	0.153
	2006	0.192	0.346	0.278	0.176
	2007	0.198	0.329	0.261	0.194
	2008	0.159	0.383	0.328	0.160
	2009	0.190	0.379	0.291	0.201
107A	2005	0.313	0.606	0.409	0.249
	2006	0.300	0.543	0.518	0.303
	2007	0.347	0.509	0.388	0.317
	2008	0.250	0.565	0.469	0.266
	2009	0.301	0.532	0.423	0.321
108	2005	0.194	0.405	0.291	0.163
	2006	0.203	0.353	0.308	0.205
	2007	0.186	0.313	0.282	0.204
	2008	0.160	0.361	0.326	0.164
	2009	0.188	0.377	0.262	0.218
121B	2007	0.187	0.259	0.180	0.181
	2008	0.134	0.223	0.307	0.196
	2009	0.140	0.278	0.239	0.209

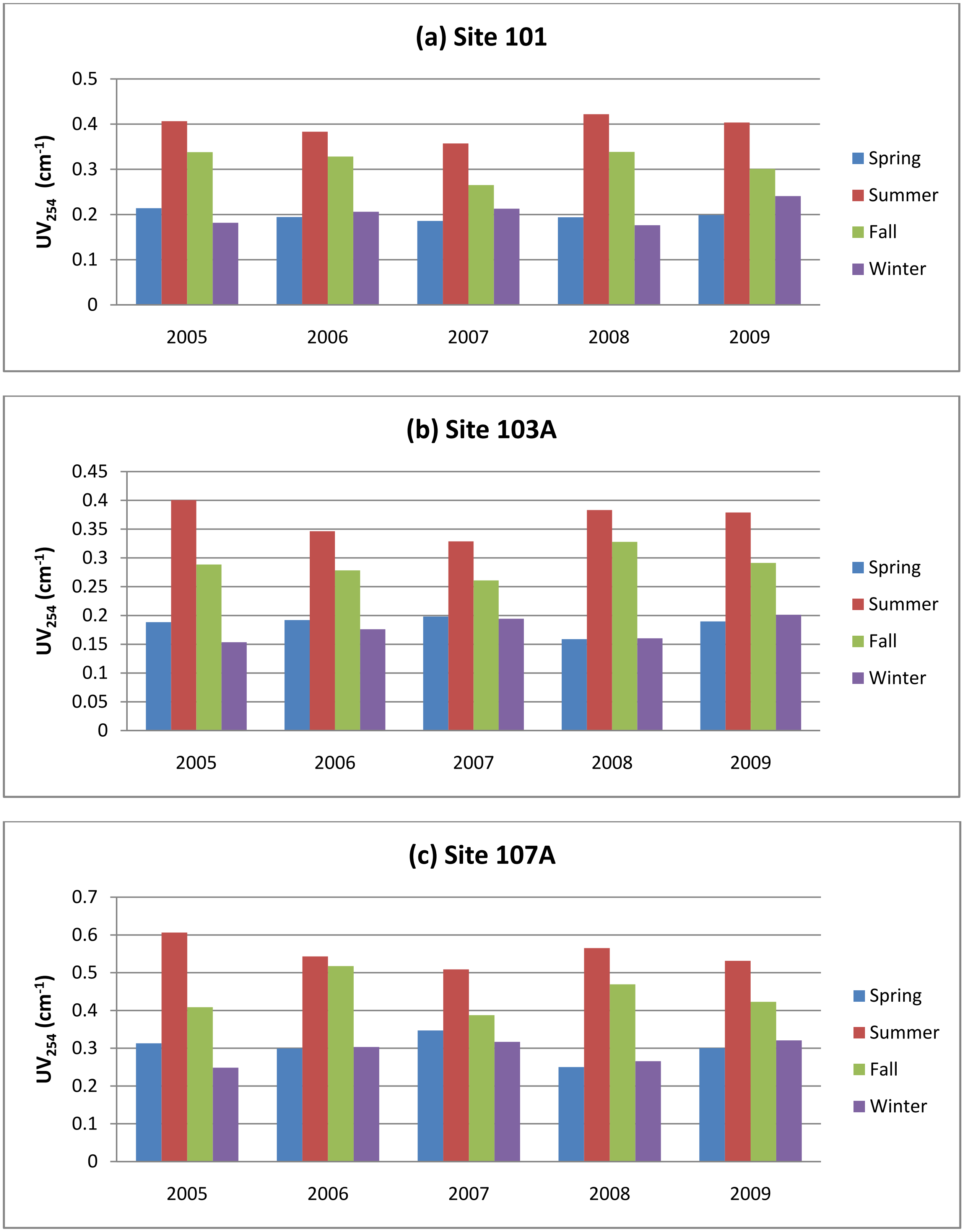
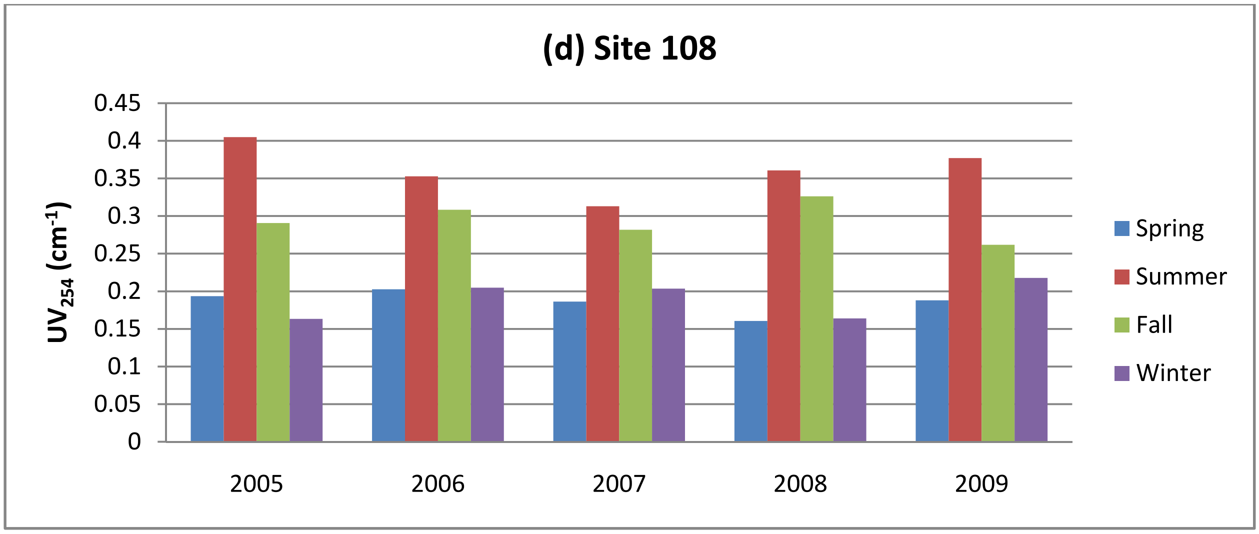


Figure 53. Seasonal Average UV_{254} Values at Core Sites, Ware River Watershed



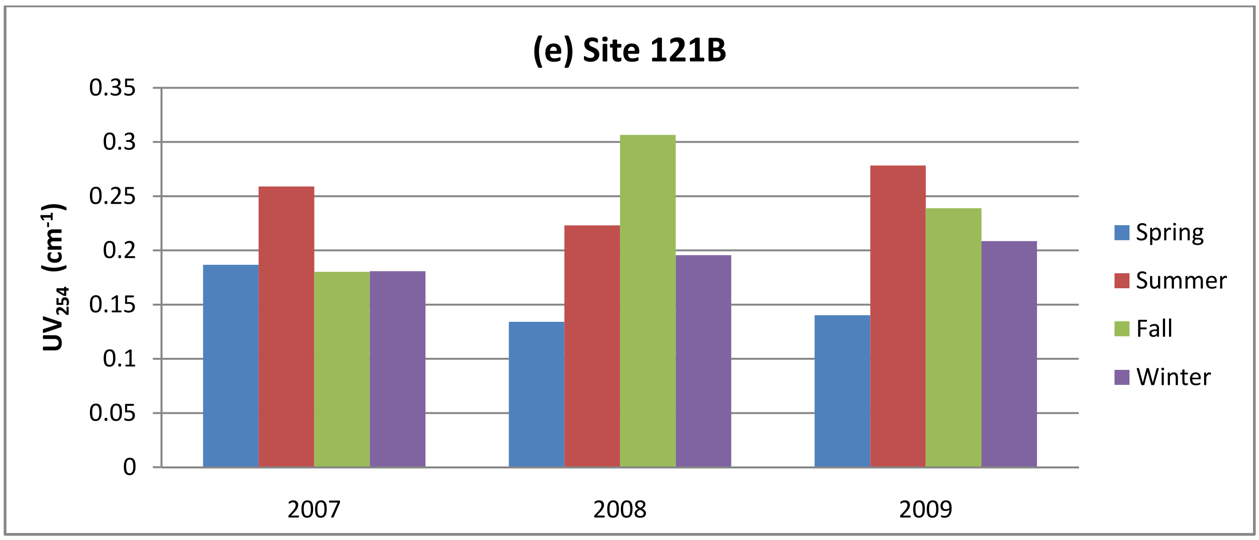


Figure 53 (continued).

It was interesting to note that UV_{254} correlated well with total Kjeldahl nitrogen (TKN) at Site 101, with the coefficient of determination (r^2) as high as 78 percent (see **Figure 54**). This result may not be surprising since both UV_{254} and TKN reflect some measure of organic content and is probably related to the strong influence of wetlands on water quality in the Ware River watershed. A similar analysis on tributaries to Quabbin Reservoir could not be conducted because of insufficient UV_{254} data. In addition, historical TKN data were not useful because of high detection limits (0.6 mg/L) during the 1998-99 monthly monitoring.

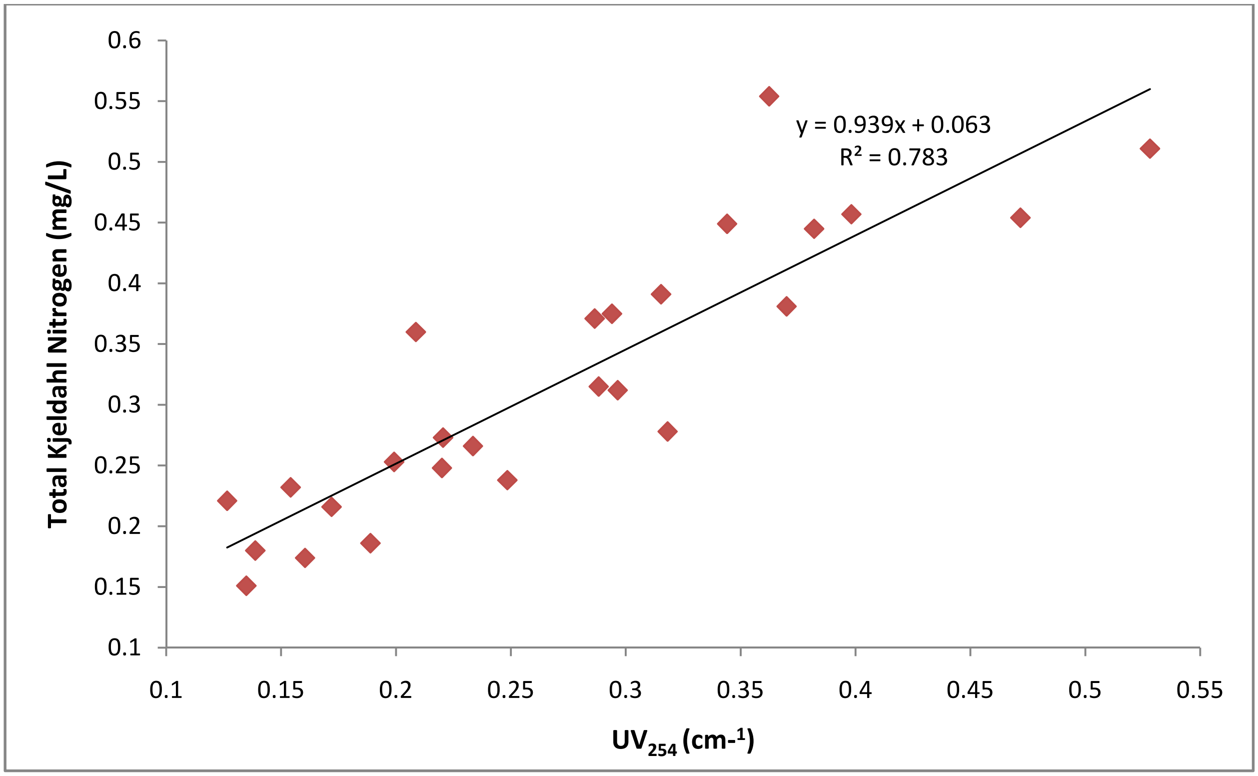


Figure 54. Correlation of UV_{254} and TKN at Site 101, 2005-2009

4.1.1.2 Water Quality during Diversion versus Non-diversion Period

As noted earlier, water from the Ware River may be diverted to Quabbin Reservoir during October 15 to June 15 provided that river flow at the intake works meets a minimum of 85 miilion gallons per day. Water quality was compared between diversion period (October 15 to June 15) and non-diversion period (June 16 to October 14) in a series of boxplots, presented in **Figure 55**.

In general, water quality appears to be slightly better during the diversion period, with overall lower bacterial counts, lower turbidities, and lower nutrient concentrations. Higher bacterial counts and lower dissolved oxygen are generally associated with the warmer temperatures typical of the non-diversion period, which coincides with summer and early fall.

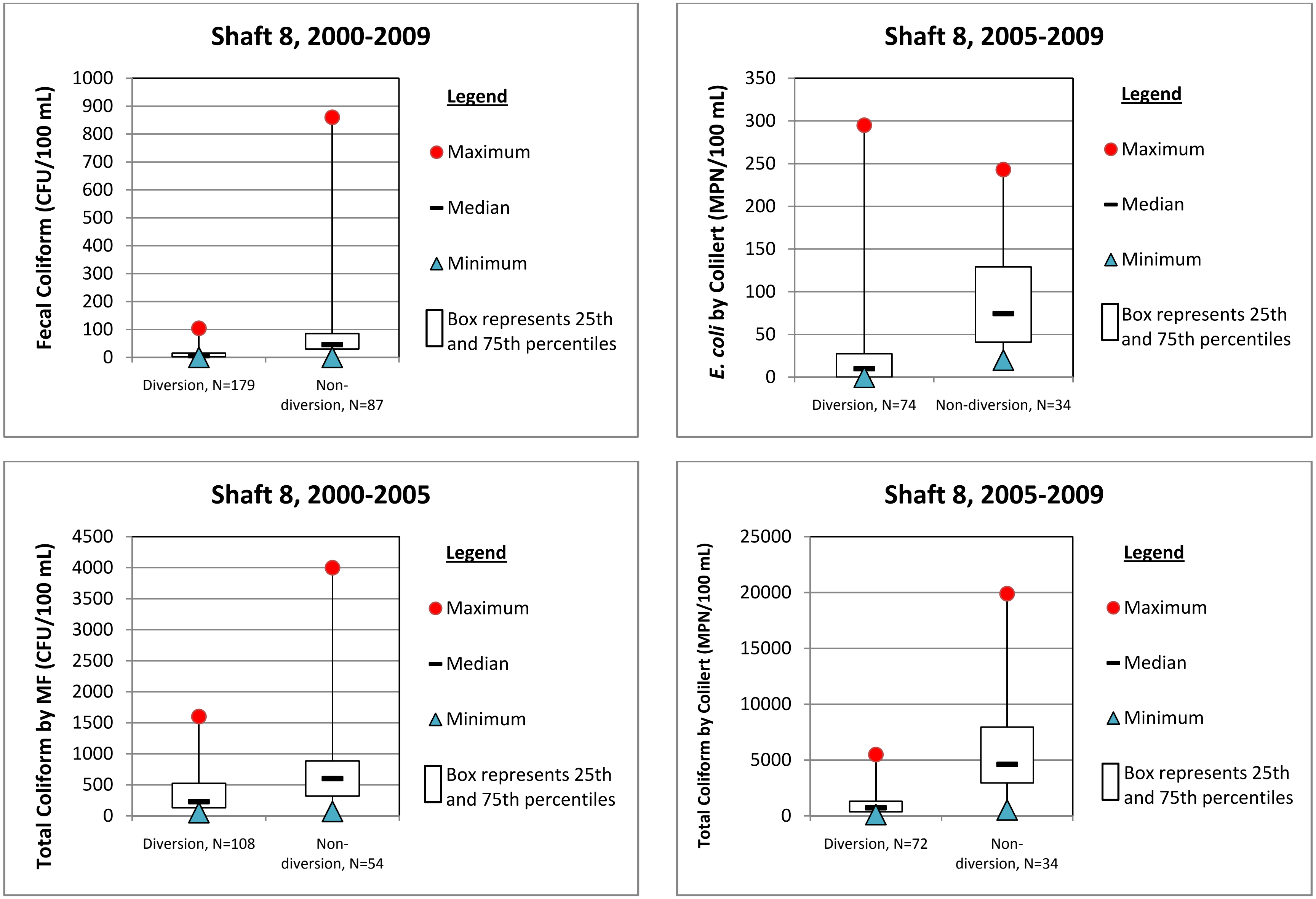


Figure 55. Boxplots of Water Quality Indicators, Diversion versus Non-diversion Period

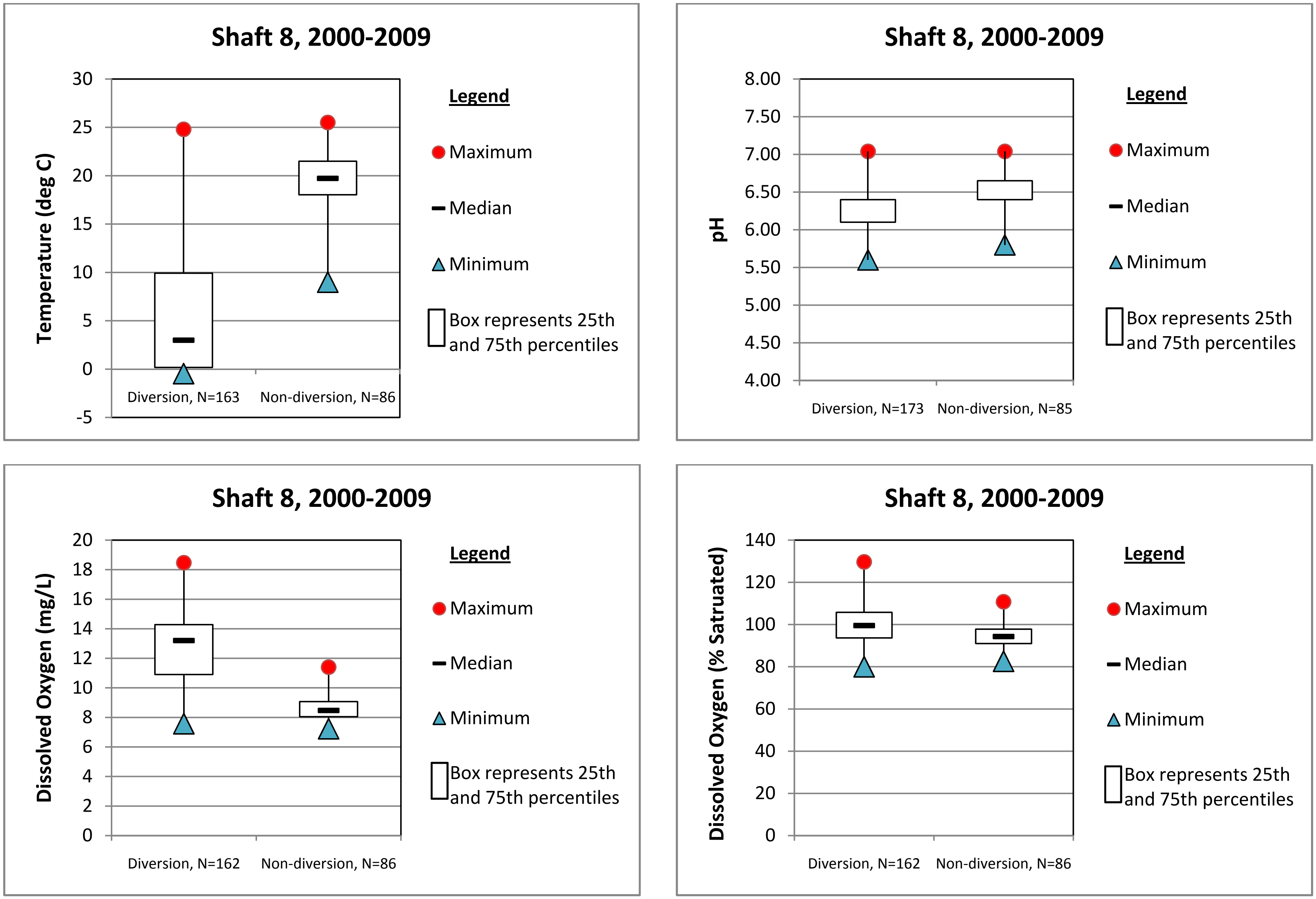


Figure 55 (continued).

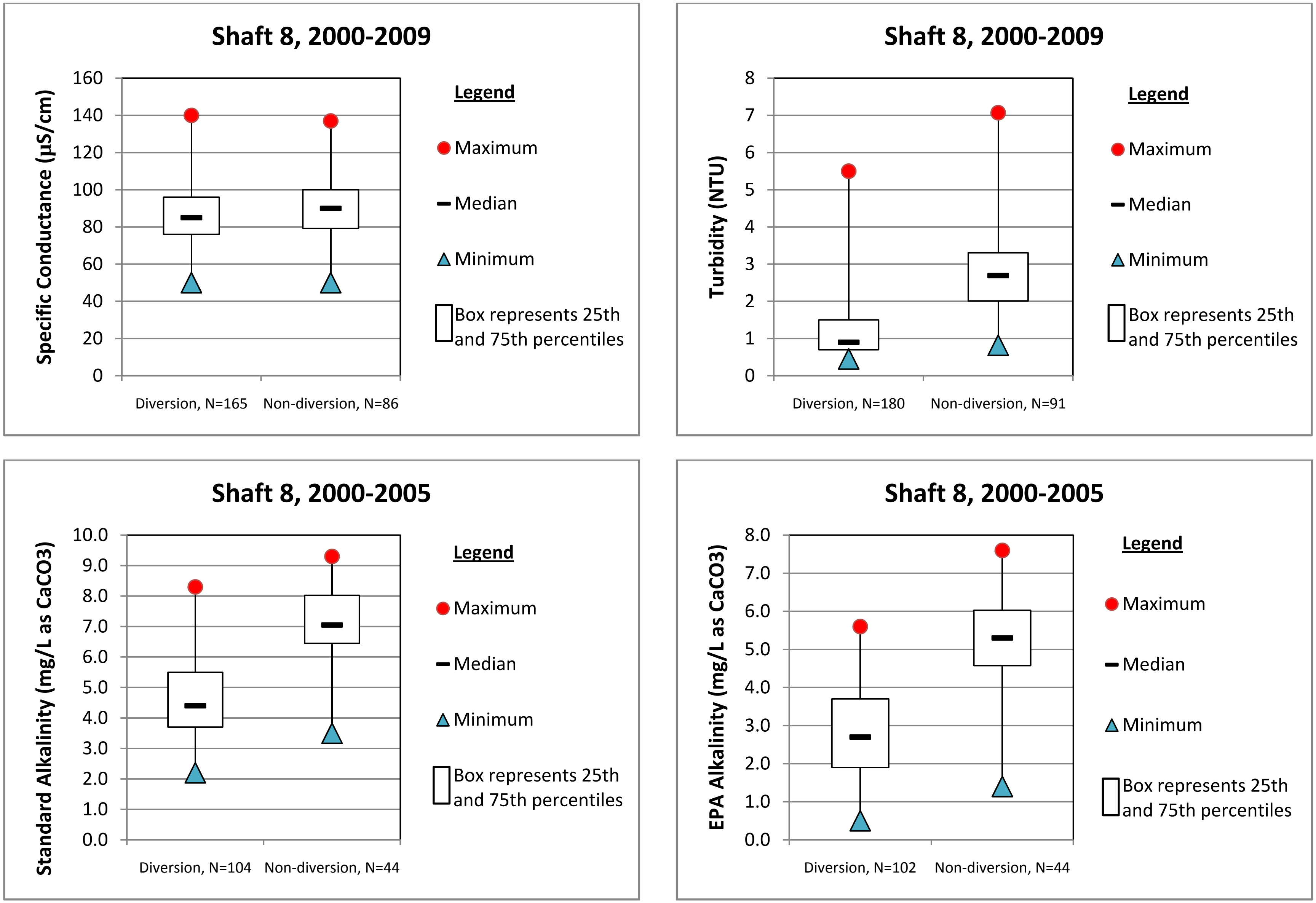


Figure 55 (continued).

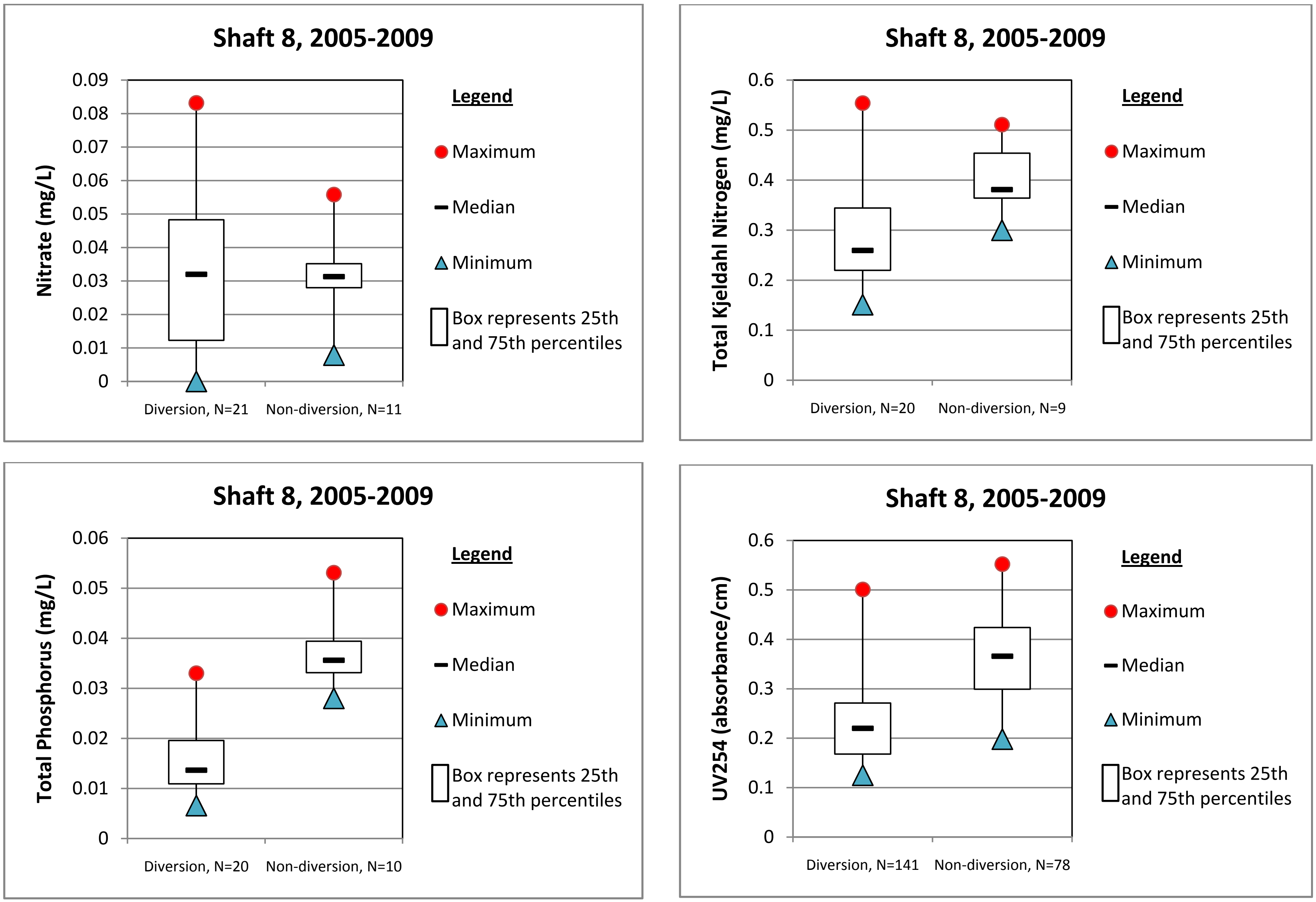


Figure 55 (continued).

5 Recommendations and Conclusions

This report provided an overview of the sampling program for the Quabbin Reservoir and Ware River watersheds between 2000 and 2009. Significant changes were made during this time to reprioritize efforts in the sampling program. The sampling program is expected to follow the general philosophy and goals since 2005 of long-term monitoring at core sites and short-term (1-2 years) monitoring at special EQA sites. Changes in the sampling program will continue to be reviewed annually and coordinated as needed with MWRA.

In addition to summarizing sampling program changes, the purpose of this 10-year data review was to provide range of expected values for the various sampling parameters (*i.e.*, analytes) at all routinely monitored sampling sites. These data summaries will provide a baseline for future monitoring.

Based on the analysis presented here, it is recommended that UV_{254} monitoring at Site 101 be reduced to a biweekly frequency, which would be consistent with other Ware River core sites. UV_{254} monitoring at Quabbin tributary core sites, started in 2009, is recommended to continue on a quarterly basis. Calcium monitoring in tributary and reservoir sites was added in 2010, and further analysis of nutrient dynamics would be worthwhile in evaluating watershed health.

6 Acknowledgements

Yuehlin Lee and Bernadeta Susianti-Kubik prepared this report. Yuehlin was the primary report writer, and Bernadeta produced the sampling station summary tables, all graphs, and summary statistics tables. Bernadeta also evaluated and summarized UV_{254} trends at Site 101. Paul Reyes provided the template needed for preliminary seasonal analysis. Phil Lamothe produced the maps used in this report. Lisa Gustavsen, Peter Deslauriers, and Bob Bishop provided comments on the draft report.

7 References

Department of Conservation and Recreation (DCR). 2004. Water Quality Report: 2003 – Quabbin Reservoir Watershed, Ware River Watershed. DCR, Division of Water Supply Protection, Quabbin Section, Belchertown, Massachusetts.

DCR. 2005. Water Quality Report: 2004 – Quabbin Reservoir Watershed, Ware River Watershed. DCR, Division of Water Supply Protection, Quabbin Section, Belchertown, Massachusetts.

DCR. 2006. Water Quality Report: 2005 – Quabbin Reservoir Watershed, Ware River Watershed. DCR, Division of Water Supply Protection, Quabbin Section, Belchertown, Massachusetts.

Garvey, E.A., Tobiason, J.E., Reckhow, D.A. and Edzwald, J.K. 2001. Natural Organic Matter Fate and Transport in Quabbin Reservoir. Department of Civil and Environmental Engineering, University of Massachusetts, Amherst, Massachusetts.

Metropolitan District Commission (MDC). 2003. Water Quality Report: 2002 – Quabbin Reservoir Watershed, Ware River Watershed. MDC, Division of Watershed Management, Quabbin Section, Belchertown, Massachusetts.

Reckhow, D.A. Professor, Department of Civil and Environmental Engineering, 18 Marston Hall, University of Massachusetts, Amherst, Massachusetts.

Rees, P.L.S., Long, S.C., Baker, R., Bourdeau, D.H., Pei, R., and Barten, P.K. 2006. Development of Event-Based Pathogen Monitoring Strategies for Watersheds. Awwa Research Foundation, Denver, Colorado.

Tobiason, J.E., Long, S.C., Male, J.W., Reckhow, D.A., Garvey, E., Cheek, K., and Spieles, K. 1998. Contaminant Transport Modeling and Water Quality in Quabbin Reservoir – Phase II. Department of Civil and Environmental Engineering, University of Massachusetts, Amherst, Massachusetts.

Worden, D. 2000. Nutrient and Plankton Dynamics in Quabbin Reservoir: Results of the MDC/DWM's 1998-99 Sampling Program. Metropolitan District Commission, Division of Watershed Management.

Worden, D. 2009. Results of 2008 Quarterly Nutrient Sampling at Quabbin Reservoir, memorandum dated February 2, 2009. *In* Water Quality Report: 2008 – Quabbin Reservoir Watershed, Ware River Watershed (Appendix A). DCR, Division of Water Supply Protection, Quabbin Section, Belchertown, Massachusetts.