Water Quality Special Study Report

U.S. Army Corps of Engineers
Omaha District

Water Quality Conditions Monitored at the Corps' Fort Peck Project in Montana during the 3-Year Period 2004 through 2006

Aerial Photo of Fort Peck Dam, Tailwaters and Lake

Report Number: CENWO-ED-HA/WQSS/Fort Peck/2007

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(Report Number: CENWO-ED-HA/WQSS/Fort Peck/2007)

Prepared by:

Water Quality Unit
Water Control and Water Quality Section
Hydrologic Engineering Branch
Engineering Division
Omaha District
U.S. Army Corps of Engineers

March 2007

For Information Regarding This Document Please Contact:

U.S. Army Corps of Engineers, Omaha District

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (Corps) Fort Peck Project consists of Fort Peck Dam and Fort Peck Reservoir. Fort Peck Dam is located on the Missouri River in northeastern Montana, 17 miles southeast of Glasgow, Montana. The reservoir and dam are authorized for the uses of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Habitat for one endangered species, pallid sturgeon (*Scaphirhynchus albus*), occurs in the Missouri River upstream and downstream of Fort Peck Reservoir. Recreation at Fort Peck Reservoir is of great economic importance to the State of Montana, especially with respect to the reservoir's fishery. Fort Peck Reservoir currently maintains a "two-story" fishery that is comprised of warmwater and coldwater species. The ability of the reservoir to maintain a "two-story" fishery is due to the reservoir's thermal stratification in the summer into a colder bottom region and warmer surface region.

Water quality monitoring was conducted at the Fort Peck Project by the Omaha District over the 3-year period of 2004 through 2006. The water quality monitoring conducted included: 1) continuing long-term, fixed-station monitoring in the reservoir at a near-dam deepwater location; 2) continuous monitoring (i.e., hourly) of water quality conditions in the powerhouse of water discharged through Fort Peck Dam; and 3) intensive water quality surveys in 2004, 2005, and 2006. The results of this monitoring were used to assess the existing water quality conditions of Fort Peck Reservoir.

Overall, the existing water quality conditions monitored in Fort Peck Reservoir were good. Water quality conditions in Fort Peck Reservoir vary along its length, and strong thermal stratification occurs in the deeper area of the reservoir during the summer. Water quality monitoring indicates that the reservoir is mesotrophic. Diatoms dominated the phytoplankton community of Fort Peck Reservoir, and only minor "blooms" of cyanobacteria were observed.

The water discharged through Fort Peck Dam exhibited good water quality. The temperature of the discharge water is reflective of the current deep-water withdrawal from Fort Peck Reservoir; it remains "cold" throughout most of the year. Temperatures of discharged water monitored in late-spring/early-summer remained below 14°C. Water temperatures approached 18°C in late-summer/early-fall as thermal stratification in Fort Peck Reservoir erodes as fall turn-over approaches. A late-spring/early-summer water temperature of 18°C in the Missouri River at Frazer Rapids (approximately 25 miles downstream of Fort peck Dam) has been identified as critical for pallid sturgeon spawning and recruitment in that reach of the river.

Inflow temperatures of the Missouri River to Fort Peck Reservoir are generally warmer than the outflow temperatures of Fort Peck Dam during the months of March through August. Outflow temperatures of the Fort Peck Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the months of September through February. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Fort Peck Dam outflow temperature.

The Omaha District is currently pursuing the application of the Corps' CE-QUAL-W2 (Version 3.2) hydrodynamic and water quality model to Fort Peck Reservoir. CE-QUAL-W2 is an extremely powerful tool to aid in addressing reservoir water quality management issues. Application of the CE-QUAL-W2 model will allow the Corps to better understand how the operation of the Fort Peck Project affects the water quality of Fort Peck Reservoir and the Missouri River below Fort Peck Dam. It is almost a certainty that water quality issues at the Fort Peck Project will remain important in the future.

1 INTRODUCTION

1.1 RECENT WATER QUALITY MONITORING AT THE CORPS' FORT PECK PROJECT

Water quality monitoring conducted by the Omaha District at the Fort Peck Project over the past 3 years included 1) continuing long-term, fixed-station monitoring in the reservoir at a near-dam deepwater location; 2) continuous monitoring (i.e., hourly) of water quality conditions in the powerhouse of water discharged through Fort Peck Dam; and 3) intensive water quality surveys in 2004, 2005, and 2006. The continuing long-term, fixed-station monitoring consisted of monthly (i.e., May through September) field measurements and sample collection. The monitoring in the Fort Peck powerhouse was on water drawn from the penstocks prior to passing through the dam's turbines. The intensive surveys included monitoring at five additional in-reservoir sites and monitoring of the Missouri and Musselshell Rivers and the Big Dry Creek inflows to the reservoir. This report presents the findings of the water quality monitoring conducted by the Omaha District at the Fort Peck Project during the period 2004 though 2006.

1.2 MISSOURI RIVER MAINSTEM SYSTEM

The Missouri River Mainstem System (Mainstem System) is comprised of six dams and reservoirs constructed by the U.S. Army Corps of Engineers (Corps) on the Missouri River and the free-flowing Missouri River downstream of the project dams. The six reservoirs impounded by the dams contain about 73.3 million acre-feet (MAF) of storage capacity and, at normal pool, an aggregate water surface area of about 1 million acres. The six dams and reservoirs in an upstream to downstream order are: Fort Peck Dam and Reservoir (Montana), Garrison Dam and Reservoir (North Dakota), Oahe Dam (South Dakota) and Oahe Reservoir (North and South Dakota), Big Bend Dam and Reservoir (South Dakota), Fort Randall Dam and Reservoir (South Dakota), and Gavins Point Dam and Reservoir (South Dakota and Nebraska). The water in storage at the all Mainstem System reservoirs at the end of 2006 (i.e., December 2006) was 34.36 MAF, which is 47 percent of the total system storage volume. Several years of drought conditions in the upper Missouri River Basin have reduced the water stored in the Mainstem System reservoirs to record low levels.

1.2.1 REGULATION OF THE MAINSTEM SYSTEM

The Mainstem System is a hydraulically and electrically integrated system that is regulated to obtain the optimum fulfillment of the multipurpose benefits for which the dams and reservoirs were authorized and constructed. The Congressionally authorized purposes of the Mainstem System are flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife (including threatened and endangered species). The Mainstem System is operated under the guidelines described in the Missouri River Mainstem System Master Water Control Manual, (Master Manual) (USACE-RCC, 2004). The Master Manual details regulation for all authorized purposes as well as emergency regulation procedures in accordance with the authorized purposes.

Mainstem System regulation is, in many ways, a repetitive annual cycle that begins in late winter with the onset of snowmelt. The annual melting of mountain and plains snowpacks along with spring and summer rainfall produces the annual runoff into the Mainstem System. In a typical year, mountain snowpack, plains snowpack, and rainfall events, respectively, contribute 50, 25, and 25% of the annual runoff to the Mainstem System. After reaching a peak, usually during July, the amount of water stored in the Mainstem System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the Mainstem System, with the higher levels of flow from mid-March to late November, followed by low rates of winter discharge from late November until mid-March, after which the cycle repeats.

To maximize the service to all the authorized purposes, given the physical and authorization limitations of the Mainstem System, the total storage available is divided into four regulation zones that are applied to the individual reservoirs. These four regulation zones are: 1) Exclusive Flood Control Zone, 2) Annual Flood Control and Multiple Use Zone, 3) Carryover Multiple Use Zone, and 4) Permanent Pool Zone.

1.2.1.1 Exclusive Flood Control Zone

Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each Mainstem System reservoir is reserved for use to meet the flood control requirements. This storage space is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. The Exclusive Flood Control Zone encompasses 4.7 MAF and represents the upper 6 percent of the total Mainstem System storage volume. This zone, from 73.3 MAF down to 68.7 MAF, is normally empty. The four largest reservoirs, Fort Peck, Garrison, Oahe, and Fort Randall, contain 97 percent of the total storage reserved for the Exclusive Flood Control Zone.

1.2.1.2 Annual Flood Control and Multiple Use Zone

An upper "normal operating zone" is reserved annually for the capture and retention of runoff (normal and flood) and for annual multiple-purpose regulation of this impounded water. The Mainstem System storage capacity in this zone is 11.7 MAF and represents 16 percent of the total system storage volume. This storage zone, which extends from 68.7 MAF down to 57.0 MAF, will normally be evacuated to the base of this zone by March 1 to provide adequate storage capacity for capturing runoff during the next flood season. On an annual basis, water will be impounded in this zone, as required to achieve the Mainstem System flood control purpose, and also be stored in the interest of general water conservation to serve all the other authorized purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on water from the system. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit release rates during the December through March period.

1.2.1.3 Carryover Multiple Use Zone

The Carryover Multiple Use Zone is the largest storage zone extending from 57.0 MAF down to 18.0 MAF and represents 53 percent of the total system storage volume. Serving the authorized purposes during an extended drought is an important regulation objective of the Mainstem System. The Carryover Multiple Use Zone provides a storage reserve to support authorized purposes during drought conditions. Providing this storage is the primary reason the upper three reservoirs of the Mainstem System are so large compared to other Federal water resource projects. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the Mainstem System because of its role in supporting authorized purposes during critical dry periods when the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only the reservoirs at Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger reservoirs (Fort Peck, Garrison, and Oahe) provide water to the Mainstem System during drought periods to provide for authorized purposes. The storage space assigned to this zone in Fort Randall Reservoir serves a different purpose. It is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of Fort Randall Reservoir during the winter months. During drought periods, the three smaller projects (i.e., Fort Randall, Big Bend, and Gavins Point) reservoir levels are maintained at the same elevation they would be at if runoff conditions were normal.

1.2.1.4 <u>Permanent Pool Zone</u>

The Permanent Pool Zone is the bottom zone that is intended to be permanently filled with water. The zone provides for future sediment storage capacity and maintenance of minimum pool levels for power heads, irrigation diversions, water supply, recreation, water quality, and fish and wildlife. A drawdown into this zone is generally not scheduled except in unusual conditions. The Mainstem System storage capacity in this storage zone is 18.0 MAF and represents 25 percent of the total storage volume. The Permanent Pool Zone extends from 18.0 MAF down to 0 MAF.

1.2.2 WATER CONTROL PLAN FOR THE MAINSTEM SYSTEM

Variations in runoff into the Mainstem System necessitates varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood periods are the plains snowmelt and rainfall period extending from late February through April, and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period extends from mid-December through February. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck and Garrison Dam releases and the peaking capacity of Oahe and Big Bend Dams. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The normal 8-month navigation season extends from April 1 through November 30, during which time Mainstem System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary, depending on the need to conserve or evacuate storage volumes with downstream ice conditions permitting. Releases and pool fluctuations for fish spawning management generally occur from April 1 through June. Two threatened and endangered bird species, piping plover (*Charadrius melodus*) and least tern (*Sterna antillarum*), nest on “sandbar” areas from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All these factors will affect the timing and magnitude of Mainstem System releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power. These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation.

1.3 DESCRIPTION OF THE FORT PECK PROJECT

Fort Peck Dam and Reservoir are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Habitat for one endangered species, pallid sturgeon (*Scaphirhynchus albus*), occurs in the Missouri River upstream and downstream of the reservoir.

1.3.1 FORT PECK DAM AND POWERPLANT

Fort Peck Dam is located on the Missouri River at river mile (RM) 1771.5 in northeastern Montana, 17 miles southeast of Glasgow, Montana. Construction of the Fort Peck project was initiated in 1933, and embankment closure was made in 1937. The Fort Peck Dam embankment is nearly 4 miles long (excluding the spillway) and rises over 250 feet above the original streambed. Fort Peck Dam remains the largest dam embankment in the United States (126 million cubic yards of fill), the second largest volume embankment in the world, and the largest "hydraulic fill" dam in the world. The concrete spillway is over 1 mile long and is located in a natural saddle of the reservoir rim about 3 miles east of the dam. In 1943, the first hydropower unit of the three units in the first powerplant went on line, and the third unit became operational in 1951. Construction of a second powerplant began in the late 1950's and the two units of this plant became operational in 1961. The five generating units at Fort Peck Dam produce an annual average 1.09 million mega-watt hours of electricity, valued in excess of $10 million in revenue.

The Fort Peck Dam outlet works consists of a submerged intake structure and four concrete diversion tunnels, varying in length from 5,700 to 7,200 feet, that extend through the east abutment of the dam. The submerged intake structure, at the upstream end of the tunnels, is approximately 517 feet in length, 57 feet in width (at top), and 65 feet in height (i.e., crest elevation 2095 ft-msl). It is divided into four individual water intake chambers by three 15-foot thick concrete cross walls and equipped with removable steel trash racks. The intake floor of the tunnel portals is at elevation 2030 ft-msl. Tunnels 1 and 2 have steel liners downstream of the control shafts to supply flows to powerplants 1 and 2 respectively. Tunnels 3 and 4 were designed for emergency flood releases and have not been used in recent years.

1.3.2 FORT PECK RESERVOIR

The closing of Fort Peck Dam in 1937 resulted in the formation of Fort Peck Reservoir. The Permanent Pool Zone (inactive storage) of the reservoir was initially filled (elevation 2150) in April 1942 and the Carryover Multiple Use Zone (elevation 2234) first filled 5 years later in 1947. Drought conditions during the late 1950's, combined with withdrawals to provide water for the initial fill of the other Mainstem System projects, resulted in a drawdown of the reservoir level to elevation 2167.4 ft-msl in early 1956, followed by a generally slow increase in pool elevation. The Carryover Multiple Use Zone was finally refilled in June 1964. Generally, the reservoir has remained filled from that time with the exception of the droughts of 1987 to 1993 and 2000 to date. Exclusive flood control storage space was first used in 1969 and then again in 1970, 1975, 1976, 1979, 1996, and 1997. In 1975, a maximum reservoir level of 2251.6 ft-msl, 1.6 feet above the top of the Exclusive Flood Control Zone, occurred. Due to ongoing drought conditions, the reservoir, at the end of December 2006, was 34.5 feet below the pool elevation of 2234 ft-msl, which is the top of the Carryover Multiple Use Zone.

When full, Fort Peck Reservoir is 134 miles long, covers 246,000 acres, and has 1,520 miles of shoreline. Table 1.1 summarizes how the surface area, volume, mean depth, and retention time of Fort Peck Reservoir vary with pool elevations. Major inflows to Fort Peck Reservoir are the Missouri River, Musselshell River, and Big Dry Creek. The reservoir is used as a water supply by the town of Fort Peck, Montana and by numerous individual cabins in the area. The water supply for the town of Fort Peck is obtained from a 10-inch raw water line that taps into the penstock to Unit 3. Cooling water for the individual units in the Fort Peck powerplant is drawn from the water going through the units. Fort Peck Reservoir is an important recreational resource and a major visitor destination in Montana.

Table 1.1. Surface area, volume, mean depth, and retention time of Fort Peck Reservoir at different pool elevations.

Pool Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
2250	245,898	18,687,731	76.0	2.72
2245	238,094	17,474,394	73.4	2.54
2240	226,691	16,309,409	71.9	2.37
2235	214,031	15,208,569	71.1	2.21
2230	200,563	14,169,579	70.6	2.06
2225	187,984	13,202,148	70.2	1.92
2220	179,404	12,236,952	68.2	1.78
2215	172,112	11,407,020	66.3	1.66
2210	164,592	10,565,907	64.2	1.54
2205	157,232	9,761,001	62.1	1.42
2200	149,653	8,993,723	60.1	1.31
2195	142,016	8,264,516	58.2	1.20
2190	134,099	7,573,749	56.5	1.10
2185	126,382	6,923,345	54.8	1.01
2180	119,809	6,309,129	52.7	0.92
2175	113,166	5,725,330	50.6	0.83
2170	104,794	5,178,658	49.4	0.75
2165	96,624	4,677,236	48.4	0.68
2160	90,348	4,211,053	46.6	0.61

Average Annual Inflow (1967 through 2006) = 7.32 Million Acre-Feet
Average Annual Outflow: (1967 through 2006) = 6.82 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 2250-2246 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 2246-2234 ft-msl), Carryover Multiple Use Zone (elev. 2234-2160 ft-msl), and Permanent Pool Zone (elev. 2160-2030 ft-msl).

1.3.3 MISSOURI RIVER DOWNSTREAM OF FORT PECK DAM

The Missouri River from Fort Peck Dam flows in an easterly direction for about 204 miles in an unchannelized river before entering the headwaters of Garrison Reservoir near Williston, North Dakota. Major tributaries include the Milk, Poplar, and Yellowstone Rivers. The Yellowstone River enters the Missouri River just upstream of the Garrison Reservoir delta and influences only a short segment of the Fort Peck reach. The reach of the Missouri River from Fort Peck Dam to Garrison Reservoir has been identified as a priority area for the recovery of the endangered pallid sturgeon. Water supply intakes for several municipalities are located on this reach. The water supply intakes for the Fort Peck National Fish Hatchery and the town of Glasgow, MT are located in the Fort Peck Dam tailwaters area. The water supply intake manifold for the Fort Peck National Fish Hatchery is located in the dredge cuts just downstream of the dam, and the water supply intake for the town of Glasgow is located in the Nelson dredge approximately 3 miles downstream of the dam.

Releases of water from Fort Peck Dam into the Missouri River average about 10,000 cfs, with slightly more in wet years and slightly less in drought years. Channel capacity below Fort Peck Dam is approximately 35,000 cfs. Daily winter releases are generally 10,000 to 13,000 cfs during "normal" water years. Full hydropower capacity is 15,000 cfs. During 1975, a significant flood year, releases averaged 35,000 cfs in July. Minimum hourly releases, particularly during fish spawning, have been requested from Fort Peck. Although a year-round instantaneous minimum release of 3,000 cfs has been established to protect the trout fishery located in the dredge cuts immediately downstream of Fort Peck Dam, an attempt is made to keep releases above 4,000 cfs.

1.4 WATER QUALITY MANAGEMENT CONCERNS AT THE FORT PECK PROJECT

1.4.1 APPLICABLE WATER QUALITY STANDARDS

1.4.1.1 Fort Peck Reservoir

The State of Montana has assigned Fort Peck Reservoir a B-3 classification in the State's water quality standards. As such, the reservoir is to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. Although not assigned, a coldwater fishery currently exists in Fort Peck Reservoir, and coldwater aquatic life would seemingly be protected under the anti-degradation provisions of the State of Montana's water quality standards and the Federal Clean Water Act (CWA).

1.4.1.2 Missouri River Downstream of Fort Peck Dam

The Missouri River downstream of Fort Peck Dam has been assigned, in the State of Montana's water quality standards, a B-2 classification from the dam to the confluence of the Milk River and a B-3 classification from the Milk River confluence to the Montana/North Dakota state line. Both B-2 and B-3 waters are to be maintained suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; waterfowl and furbearers; and agricultural and industrial water supply. In addition, B-2 waters are to maintain growth and marginal propagation of salmonid fishes and associated aquatic life, and B-3 waters are to maintain growth and propagation of non-salmonid fishes and associated aquatic life.

1.4.2 FEDERAL CLEAN WATER ACT SECTION 303(D) IMPAIRED WATER BODY LISTINGS

1.4.2.1 Fort Peck Reservoir

Pursuant to Section 303(d) of the Federal CWA, Montana has placed Fort Peck Reservoir on the state's list of impaired waters citing impairment to the uses of drinking water supply and primary contact recreation due to the pollutants of lead, mercury, metals, and noxious aquatic plants. The identified sources of these pollutants are agriculture, resource extraction, abandoned mining, atmospheric deposition, debris, and bottom deposits. The State of Montana has also issued a fish consumption advisory for Fort Peck Reservoir due to mercury concerns.

1.4.2.2 Missouri River Downstream of Fort Peck Dam

The Missouri River downstream of Fort Peck Dam has been placed on the State of Montana's list of impaired waters citing impairment to the uses of aquatic life support, coldwater fishery – trout, and warmwater fishery due to the stressors of flow alteration, riparian degradation, thermal modifications, and other habitat alterations. The identified probable sources of these stressors are flow regulation/modification and hydromodification. No fish consumption advisory has been issued for the Missouri River downstream of Fort Peck Dam by the State of Montana.

1.4.3 MAINTENANCE OF A "TWO-STORY" RECREATIONAL FISHERY IN FORT PECK RESERVOIR

Recreation at Fort Peck Reservoir is of great economic importance to the State of Montana, especially with respect to the reservoir's fishery. Fort Peck Reservoir currently maintains a "two-story" fishery in that the reservoir fishery is comprised of warmwater and coldwater species. The ability of the reservoir to maintain a "two-story" fishery is due to the reservoir's thermal stratification in the summer into a colder bottom region and warmer surface region. Warmwater species present in the reservoir that are recreationally important include walleye (*Sander vitreus*), sauger (*Sander canadensis*), northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), catfish (*Ictalurus spp.*), and yellow perch (*Perca flavescens*). Coldwater species present in the reservoir that are recreationally important include chinook salmon (*Oncorhynchus tshawytscha*) and lake trout (*Salvelinus namaycush*). Chinook salmon are maintained in the reservoir through regular stocking. A primary forage fish utilized by all sport fishes in the reservoir is the lake cisco (*Coregonus artedii*) – a coldwater species. Since it is a primary forage fish in Fort Peck Reservoir, fluctuations in the cisco population can have a ripple effect throughout the reservoir's entire recreational sport fishery. The recent pool-level drawdowns of Fort Peck Reservoir, due to the ongoing drought conditions in the interior western United States have reduced the amount of coldwater habitat available in Fort Peck Reservoir.

Two water quality parameters, temperature and dissolved oxygen, are of prime importance regarding the maintenance of coldwater fishery habitat in Fort Peck Reservoir. As the pool level of Fort Peck Reservoir falls, the amount of coldwater habitat available at lower reservoir depths during summer thermal stratification is reduced. During summer thermal stratification, the reservoir also experiences degradation of dissolved oxygen at lower reservoir depths as accumulated organic matter is decomposed. The situation could be of most concern later in the summer when the reduced volume of colder water combined with the degradation of dissolved oxygen in the deeper water of the reservoir act together to possibly limit the coldwater habitat volume.

1.4.4 WATER QUALITY FOR THE ENHANCEMENT OF PALLID STURGEON POPULATIONS IN THE MISSOURI RIVER DOWNSTREAM OF FORT PECK DAM

One of the few remaining populations of pallid sturgeon occurs in the Missouri River between Fort Peck Dam and the headwaters of Garrison Reservoir. Individuals in this population also inhabit the lower Yellowstone River. As such, this reach of the Missouri River has been identified as a priority recovery area for the pallid sturgeon (USFWS, 1993). It is hypothesized that the building and operation of Fort Peck Dam and Reservoir have adversely impacted the pallid sturgeon in this reach of the Missouri River by regulating flows, lowering water temperatures, reducing sediment and nutrient transport, and increasing water clarity.

Historically, the lower Missouri River in Montana was a turbid, warmwater environment with seasonally fluctuating flows. The sediment and turbidity of the water through these cycles contributed significantly to the evolution of the pallid sturgeon. The fish adapted to highly turbid and low visibility environments by physiologically evolving to enhance their ability to capture prey and avoid capture as juveniles and larvae in this low visibility environment. It is also believed that the pallid sturgeon adapted by developing spawning cues based on historical conditions in the river. The fish requires a spawning cue of suitable magnitude, duration, and timing to complete this life cycle element. It is believed that increasing flow and water temperature in the late spring is a primary factor for pallid sturgeon to initiate spawning.

Water temperature is believed to be a controlling factor on the pallid sturgeon in this reach of the Missouri River in regards to spawning cues and larval survival during the summer. Because Fort Peck Dam has a deepwater withdrawal from the reservoir, water temperature in the Missouri River downstream of the dam are appreciably colder than “pre-dam” conditions. A water temperature of around 18°C (64.4°F) is believed necessary to initiate a spawning response in pallid sturgeon. Additionally, a dramatic decline in water temperatures after spawning can affect larval pallid sturgeon development and likely adversely affect the production and availability of suitable forage (i.e., plankton and other invertebrate species) for the juvenile pallid sturgeon throughout the summer. Low water temperatures may induce mortality in young pallid sturgeon. With this in mind, a late-spring/early-summer water temperature of 18°C in the Missouri River at Frazer Rapids (approximately 25 miles downstream of Fort peck Dam) has been identified as critical for pallid sturgeon spawning and recruitment in this reach of the river.

Fort Peck Reservoir is trapping sediment that historically moved down the Missouri River through the reach downstream of the dam. It is also believed that the current colder water temperatures in the river are likely suppressing production of plankton and other invertebrate organisms that contribute to turbidity of the water. The resulting clearer water is believed to adversely affect young pallid sturgeon by making them more vulnerable to sight-feeding predators and increasing competition for food by sight-adapted predators. In addition, adult fish may be adversely affected by the increased ability of prey to avoid capture in clearer water.

2 WATER QUALITY MONITORING CONSIDERATIONS

2.1 WATER QUALITY MONITORING OBJECTIVES

2.1.1 General Monitoring Objectives

The Omaha District has identified four purposes and 12 general monitoring objectives for surface water quality monitoring to facilitate implementation of the District's Water Quality Management Program (USACE, 2007). The water quality monitoring conducted at the Fort Peck Project over the 3-year period, 2004 through 2006, was implemented to address 6 of the 12 identified monitoring objectives. The six general water quality monitoring objectives that were addressed are:

- Characterize the spatial and temporal distribution of surface water quality conditions at District projects.
- Identify pollutants and their sources that are affecting surface water quality and the aquatic environment at District projects.
- Determine if surface water quality conditions at District projects or attributable to District operations or reservoir regulation (i.e., downstream conditions resulting from reservoir discharges) meet applicable Federal, Tribal, and State water quality standards.
- Determine if surface water quality conditions at District projects or attributable to District operations or reservoir regulation are improving, degrading, or staying the same over time.
- Apply water quality models to assess surface water quality conditions at District projects.
- Collect the information needed to design, engineer, and implement measures or modifications at District projects to enhance surface water quality and the aquatic environment.

2.1.2 Specific Monitoring Objectives

In addition to the six general water quality monitoring objectives, one specific monitoring objective was identified for the intensive water quality surveys of Fort Peck Reservoir:

1) Collect the information needed to allow application and "full calibration" of the Version 3.2 CE-QUAL-W2 hydrodynamic and water quality model to Fort Peck Reservoir.

2.2 LIMNOLOGICAL CONSIDERATIONS

2.2.1 Vertical and Longitudinal Water Quality Gradients

The annual temperature distribution represents one of the most important limnological processes occurring within a reservoir. Thermal variation in a reservoir results in temperature-induced density stratification, and an understanding of the thermal regime is essential to water quality assessment. Deep, temperate-zone lakes typically completely mix from the surface to the bottom twice a year (i.e., dimictic). Temperature-zone dimictic lakes exhibit thermally-induced density stratification in the summer and winter months that is separated by periods of "turnover" in the spring and fall (i.e., Fort Peck Reservoir). This stratification typically occurs through the interaction of wind and solar insolation at the reservoir surface and creates density gradients that can influence reservoir water quality. During the summer, solar insolation has its highest intensity and the reservoir becomes stratified into three zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion.

<u>Epilimnion</u>: The epilimnion is the upper zone that consists of the less dense, warmer water in the reservoir. It is fairly turbulent since its thickness is determined by the turbulent kinetic energy inputs (e.g., wind, convection, etc.), and a relatively uniform temperature distribution throughout this zone is maintained.

Metalimnion: The metalimnion is the middle zone that represents the transition from warm surface water to cooler bottom water. There is a distinct temperature gradient through the metalimnion. The metalimnion contains the thermocline that is the plane or surface of maximum temperature rate change.

Hypolimnion: The hypolimnion is the bottom zone of the more dense, colder water that is relatively quiescent. Bottom withdrawal or fluctuating water levels in reservoirs, however, may significantly increase hypolimnetic mixing.

Long, dendritic reservoirs with tributary inflows located a considerable distance from the outflow and unidirectional flow from headwater to dam (i.e., Fort Peck Reservoir) develop gradients in space and time (USACE, 1987). Although these gradients are continuous from headwater to dam, three characteristic zones result: a riverine zone, a zone of transition, and a lacustrine zone (USACE, 1987).

Riverine Zone: The riverine zone is relatively narrow and well mixed, and although water current velocities are decreasing, advective forces are still sufficient to transport significant quantities of suspended particles such as silts, clays, and organic particulate. Light penetration in this zone is minimal and may be the limiting factor that controls primary productivity in the water column. The decomposition of tributary organic loadings often creates a significant oxygen demand, but an aerobic environment is maintained because the riverine zone is generally shallow and well mixed. Longitudinal dispersion may be an important process in this zone.

Zone of Transition: Significant sedimentation occurs through the transition zone, with a subsequent increase in light penetration. Light penetration may increase gradually or abruptly, depending on the flow regime. At some point within the mixed layer of the zone of transition, a compensation point between the production and decomposition of organic matter should be reached. Beyond this point, production of organic matter within the reservoir mixed layer should begin to dominate.

Lacustrine Zone: The lacustrine zone is characteristic of a lake system. Sedimentation of inorganic particulate is low; light penetration is sufficient to promote primary production, with nutrient levels the limiting factor; and production of organic matter exceeds decomposition within the mixed layer. Entrainment of metalimnetic and hypolimnetic water, particulate, and nutrients may occur through internal waves or wind mixing during the passage of large weather fronts. Hypolimnetic mixing may be more extensive in reservoirs than "natural" lakes because of bottom withdrawal. In addition, an intake structure may simultaneously remove water from the hypolimnion and metalimnion.

When tributary inflow enters a reservoir, it displaces the reservoir water. If there is no density difference between the inflow and reservoir waters, the inflow moves as a density current in the form of overflows, interflows, or underflows. Internal mixing is the term used to describe mixing within a reservoir from such factors as wind, Langmuir circulation, convection, Kelvin-Helmholtz instabilities, and outflow (USACE, 1987).

2.2.2 Chemical Characteristics of Reservoir Processes

2.2.2.1 Constituents

Some of the most important chemical constituents in reservoir waters that affect water quality are needed by aquatic organisms for survival. These include oxygen, carbon, nitrogen, and phosphorus. Other important constituents are silica, manganese, iron, and sulfur.

Dissolved oxygen: Oxygen is a fundamental chemical constituent of water bodies that is essential to the survival of aquatic organisms and is one of the most important indicators of reservoir water quality conditions. The distribution of dissolved oxygen (DO) in reservoirs is a result of dynamic transfer processes from the atmospheric and photosynthetic sources to consumptive uses by the aquatic biota. The resulting distribution of DO in the reservoir water strongly affects the solubility of many inorganic chemical constituents. Often, water quality control or management approaches are formulated to maintain an aerobic or oxic (i.e., oxygen-containing) environment. Oxygen is produced by aquatic plants (phytoplankton and macrophytes) and is consumed by aquatic plants, other biological organisms, and chemical oxidations. In reservoirs, the DO demand may be divided into two separate but highly interactive fractions: sediment oxygen demand (SOD) and water column oxygen demand.

Sediment oxygen demand: The SOD is typically highest in the upstream area of the reservoir just below the headwater. This is an area of transition from riverine to lake characteristics. It is relatively shallow but stratifies. The loading and sedimentation of organic matter is high in this transition area and, during stratification, the hypolimnetic DO to satisfy this demand can be depleted. If anoxic conditions develop, they generally do so in this area of the reservoir and progressively move toward the dam during the stratification period. The SOD is relatively independent of DO when DO concentrations in the water column are greater than 3 to 4 mg/l, but becomes limited by the rate of oxygen supply to the sediments.

Water column oxygen demand: A characteristic of many reservoirs is a metalimnetic minimum in DO concentrations or negative heterograde oxygen curve (Figure 2.1). Density interflows not only transport oxygen-demanding material into the metalimnion, but can also entrain reduced chemicals from the upstream anoxic area and create additional oxygen demand. Organic matter and organisms from the mixed layer settle at slower rates in the metalimnion because of increased viscosity due to lower temperatures. Since this labile organic matter remains in the metalimnion for a longer time period, decomposition occurs over a longer time, exerting a high oxygen demand. Metalimnetic oxygen depletion is an important process in deep reservoirs. A hypolimnetic oxygen demand generally starts at the sediment/water interface unless underflows contribute organic matter that exerts a significant oxygen demand. In addition to metalimnetic DO depletion, hypolimnetic DO depletion also is important in shallow, stratified reservoirs since there is a smaller hypolimnetic volume of oxygen to satisfy oxygen demands than in deep reservoirs.

Dissolved oxygen distribution: Two basic types of vertical DO distribution may occur in the water column: an orthograde and clinograde DO distribution (Figure 2.1). In the orthograde distribution, DO concentration is a function primarily of temperature, since DO consumption is limited. The clinograde DO profile is representative of more productive, nutrient-rich reservoirs where the hypolimnetic DO concentration progressively decreases during stratification and can occur during both summer and winter stratification periods.

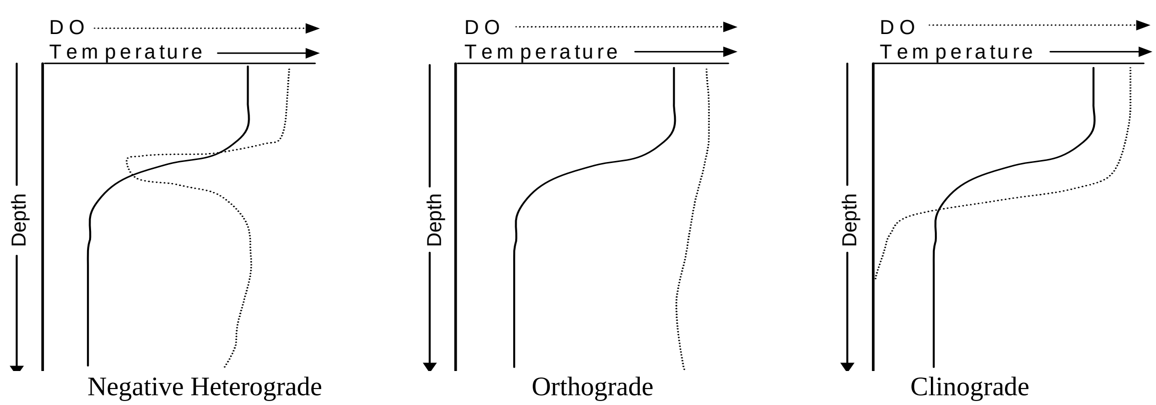

Figure 2.1. Vertical dissolved oxygen concentrations possible in thermally stratified reservoirs.

Inorganic carbon: Inorganic carbon represents the basic building block for the production of organic matter by plants. Inorganic carbon can also regulate the pH and buffering capacity or alkalinity of aquatic systems. Inorganic carbon exists in a dynamic equilibrium in three major forms: carbon dioxide (CO_2), bicarbonate ions (HCO_3), and carbonate ions (CO_3). Carbon dioxide is readily soluble in water and some CO_2 remains in a gaseous form, but the majority of the CO_2 forms carbonic acid that dissociates rapidly into HCO_3 and CO_3 ions. This dissociation results in a weakly alkaline system (i.e., pH $\approx$ 7.1 or 7.2). There is an inverse relationship between pH and CO_2. The pH increases when aquatic plants (phytoplankton or macrophytes) remove CO_2 from the water to form organic matter through photosynthesis during the day. During the night when aquatic plants respire and release CO_2, the pH decreases. The extent of this pH change provides an indication of the buffering capacity of the system. Weakly buffered systems with low alkalinities (i.e., <500 microequivalents per liter) experience larger shifts in pH than well-buffered systems (i.e., >1,000 microequivalents per liter).

Nitrogen: Nitrogen is important in the formulation of plant and animal protein. Nitrogen, similar to carbon, also has a gaseous form. Many species of cyanobacteria can use or fix elemental or gaseous N_2 as a nitrogen source. The most common forms of nitrogen in aquatic systems are ammonia (NH_3-N), nitrite (NO_2-N), and nitrate (NO_3-N). All three forms are transported in water in a dissolved phase. Ammonia results primarily from the decomposition of organic matter. Nitrite is primarily an intermediate compound in the oxidation or nitrification of ammonia to nitrate, while nitrate is the stable oxidation state of nitrogen and represents the other primary inorganic nitrogen form besides NH_3 used by aquatic plants.

Phosphorus: Phosphorus is used by both plants and animals to form enzymes and vitamins and to store energy in organic matter. Phosphorus has received considerable attention as the nutrient controlling algal production and densities and associated water quality problems. The reasons for this emphasis are: phosphorus tends to limit plant growth more than the other major nutrients; phosphorus does not have a gaseous phase and ultimately originates from the weathering of rocks; removal of phosphorus from point sources can reduce the growth of aquatic plants; and the technology for removing phosphorus is more advanced and less expensive than nitrogen removal. Phosphorus is generally expressed in terms of the chemical procedures used for measurement: total phosphorus, particulate phosphorus, dissolved or filterable phosphorus, and soluble reactive phosphorus. Phosphorus is a very reactive element; it reacts with many cations such as iron and calcium and is readily sorbed on particulate matter such as clays, carbonates, and inorganic colloids. Since phosphorus exists in a particulate phase, sedimentation represents a continuous loss from the water column to the sediment. Sediment phosphorus, then, may exhibit longitudinal gradients in reservoirs similar to sediment silt/clay gradients. Phosphorus contributions from sediment under anoxic conditions and macrophyte decomposition are considered internal phosphorus sources or loads, are in a chemical form available for plankton uptake and use, and can represent a major portion of the phosphorus budget.

Silica: Silica is an essential component of diatom algal frustules or cell walls. Silica uptake by diatoms can markedly reduce silica concentrations in the epilimnion and initiate a seasonal succession of diatom species. When silica concentrations decrease below 0.5 mg/l, diatoms generally are no longer competitive with other phytoplankton species.

Other nutrients: Iron, manganese, and sulfur concentrations generally are adequate to satisfy plant nutrient requirements. Oxidized iron (III) and manganese (IV) are quite insoluble in water and occur in low concentrations under aerobic conditions. Under aerobic conditions, sulfur usually is present as sulfate.

2.2.2.2 Anaerobic (Anoxic) Conditions

When dissolved oxygen concentrations in the hypolimnion are reduced to approximately 2 to 3 mg/l, the oxygen regime at the sediment/water interface is generally considered anoxic, and anaerobic processes begin to occur in the sediment interstitial water. Nitrate reduction to ammonium and/or N_2O or N_2 (denitrification) is considered to be the first phase of the anaerobic process and places the system in a slightly reduced electrochemical state. Ammonium-nitrogen begins to accumulate in the hypolimnetic water. The presence of nitrate prevents the production of additional reduced forms such as manganese (II), iron (II), or sulfide species. Denitrification probably serves as the main mechanism for removing nitrate from the hypolimnion. Following the reduction or denitrification of nitrate, manganese species are reduced from insoluble forms (i.e., Mn (IV)) to soluble manganous forms (i.e.,Mn (II)), which diffuse into the overlying water column. Nitrate reduction is an important step in anaerobic processes since the presence of nitrate in the water column will inhibit manganese reduction. As the electrochemical potential of the system becomes further reduced, iron is reduced from the insoluble ferric (III) form to the soluble ferrous (II) form, and begins to diffuse into the overlying water column. Phosphorus, in many instances, is also transported in a complexed form with insoluble ferric (III) species so the reduction and solubilization of iron also result in the release and solubilization of phosphorus into the water column. The sediments may serve as a major phosphorus source during anoxic periods and a phosphorus sink during aerobic periods. During this period of anaerobiosis, microorganisms also are decomposing organic matter into lower molecular weight acids and alcohols such as acetic, fulvic, humic, and citric acids and methanol. These compounds may also serve as trihalomethane precursors (low-molecular weight organic compounds in water; i.e., methane, formate acetate), which, when subject to chlorination during water treatment, form trihalomethanes, or THMs (carcinogens). As the system becomes further reduced, sulfate is reduced to sulfide, which begins to appear in the water column. Sulfide will readily combine with soluble reduced iron (II), however, to form insoluble ferrous sulfide, which precipitates out of solution. If the sulfate is reduced to sulfide and the electrochemical potential is strongly reducing, methane formation from the reduced organic acids and alcohols may occur. Consequently, water samples from anoxic depths will exhibit these chemical characteristics.

Anaerobic processes are generally initiated in the upstream portion of the hypolimnion where organic loading from the inflow is relatively high and the volume of the hypolimnion is minimal, so oxygen depletion occurs rapidly. Anaerobic conditions are generally initiated at the sediment/water interface and gradually diffuse into the overlying water column and downstream toward the dam. Anoxic conditions may also develop in a deep pocket near the dam due to decomposition of autochthonous organic matter settling to the bottom. This anoxic pocket, in addition to expanding vertically into the water column, may also move upstream and eventually meet the anoxic zone moving downstream.

Anoxic conditions are generally associated with the hypolimnion, but anoxic conditions may occur in the metalimnion. The metalimnion may become anoxic due to microbial respiration and decomposition of plankton settling into the metalimnion, microbial metabolism of organic matter entering as an interflow, or through entrainment of anoxic hypolimnetic water from upper reservoir reaches.

2.2.3 BIOLOGICAL CHARACTERISTICS AND PROCESSES

2.2.3.1 Microbiological

The microorganisms associated with reservoirs may be categorized as pathogenic or nonpathogenic. Pathogenic microorganisms are of a concern from a human health standpoint and may limit recreational and other uses of reservoirs. Nonpathogenic microorganisms are important in that they often serve as decomposers of organic matter and are a major source of carbon and energy for a reservoir. Microorganisms generally inhabit all zones of the reservoir as well as all layers. Seasonally high concentrations of bacteria will occur during the warmer months, but they can be diluted by high discharges. Anaerobic conditions enhance growth of certain bacteria while aeration facilitates the use of bacterial food sources. Microorganisms, bacteria in particular, are responsible for mobilization of contaminants from sediments.

2.2.3.2 **Photosynthesis**

Oxygen is a by-product of aquatic plant photosynthesis, which represents a major source of oxygen for reservoirs during the growing season. Oxygen solubility is less during the period of higher water temperatures, and diffusion may also be less if wind speeds are lower during the summer than in the spring or fall. Biological activity and oxygen demand typically are high during thermal stratification, so photosynthesis may represent a major source of oxygen during this period. Oxygen supersaturation in the euphotic zone can occur during periods of high photosynthesis.

2.2.3.3 **Plankton**

Phytoplankton influence dissolved oxygen and suspended solids concentrations, transparency, taste and odor, aesthetics, and other factors that affect reservoir uses and water quality objectives. Phytoplankton are a primary source of organic matter production and form the base of the autochthonous food web in many reservoirs since fluctuating water levels may limit macrophyte and periphyton production. Phytoplankton can be generally grouped as diatoms, green algae, cyanobacteria, or cryptomonad algae. Chlorophyll *a* represents a common variable used to estimate phytoplankton biomass.

Seasonal succession of phytoplankton species is a natural occurrence in reservoirs. The spring assemblage is usually dominated by diatoms and cryptomonads. Silica depletion in the photic zone and increased settling as viscosity decreases because of increased temperatures usually result in green algae succeeding the diatoms. Decreases in nitrogen or a decreased competitive advantage for carbon at higher pH may result in cyanobacteria succeeding the green algae during summer and fall. Diatoms generally return in the fall, but cyanobacteria, greens, or diatoms may cause algae blooms following fall turnover when hypolimnetic nutrients are mixed throughout the water column. The general pattern of seasonal succession of phytoplankton is fairly constant from year to year. However, hydrologic variability, such as increased mixing and delay in the onset of stratification during cool, wet spring periods, can maintain diatoms longer in the spring and shift or modify the successional pattern of algae in reservoirs.

Phytoplankton grazers can reduce the abundance of algae and alter their successional patterns. Some phytoplankton species are consumed and assimilated more readily and are preferentially selected by consumers. Single-celled diatom and green algae species are readily consumed by zooplankton, while filamentous cyanobacteria are avoided by zooplankters. Altering the fish population can result in a change in the zooplankton population that can affect the phytoplankton population.

2.2.3.4 **Organic Carbon and Detritus**

Total organic carbon (TOC) is composed of dissolved organic carbon (DOC) and particulate organic carbon (POC). Detritus represents that portion of the POC that is nonliving. Nearly all the TOC of natural waters consists of DOC and detritus, or dead POC. The processes of decomposition and consumption of TOC are important in reservoirs and can have a significant affect on water quality.

DOC and POC are decomposed by microbial organisms. This decomposition exerts an oxygen demand that can remove dissolved oxygen from the water column. During stratification, the metalimnion and hypolimnion become relatively isolated from sources of dissolved oxygen, and depletion can occur through organic decomposition. There are two major sources of this organic matter: allochthonous (i.e., produced outside the reservoir and transported in) and autochthonous (i.e., produced within the reservoir). Allochthonous organic carbon in small streams may be relatively refractory since it consists of decaying terrestrial vegetation that has washed or fallen into the stream. Larger rivers, however, may contribute substantial quantities of riverine algae or periphyton that decompose rapidly and can exert a significant oxygen demand. Autochthonous sources include dead plankton settling from the mixed layers and macrophyte fragments and periphyton transported from the littoral zone. These sources are also rapidly decomposed.

POC and DOC absorbed onto sediment particles may serve as a major food source for aquatic organisms. The majority of the phytoplankton production enters the detritus food web with a minority being grazed by primary consumers (USACE, 1987). While autochthonous production is important in reservoirs, typically as much as three times the autochthonous production may be contributed by allochthonous material (USACE, 1987).

2.2.4 BOTTOM WITHDRAWAL RESERVOIRS

Bottom withdrawal structures are located near the deepest part of a reservoir. Bottom withdrawal removes hypolimnetic water and nutrients and may promote movement of interflows or underflow into the hypolimnion. They release coldwaters from the deep portion of the reservoir; however, these waters may be anoxic during periods of stratification. Bottom outlets can cause density interflows or underflows (e.g., flow laden with sediment or dissolved solids) through the reservoir and generally provide little or no direct control over release water quality.

The outlet works at Fort Peck Dam utilize a “near-bottom” withdrawal from Fort Peck Reservoir. The submerged intake structure is approximately 517 feet in length, 57 feet in width (at top), and 65 feet in height (i.e., water is drawn into the intake structure at 65 feet above the reservoir bottom). The crest elevation of the submerged intake structure is 2095 ft-msl. This withdrawal elevation would be at a depth of 139 feet when the reservoir is at the top of the Carryover Multiple Use Zone (i.e., elevation 2234 ft-msl).

2.3 APPLICATION OF THE CE-QUAL-W2 WATER QUALITY MODEL TO THE MISSOURI RIVER MAINSTEM SYSTEM PROJECTS

Water quality data must be applied to understand and manage water resources effectively. Application of appropriate mathematical models promotes efficient and effective use of data. Models are powerful tools for guiding project operations, refining water quality sampling programs, planning project modifications, evaluating management scenarios, improving project benefits, and illuminating new or understanding complex phenomena. CE-QUAL-W2 is a “state-of-the-art” water quality model that can greatly facilitate addressing reservoir water quality management issues.

CE-QUAL-W2 is a water quality and hydrodynamic model in two dimensions (longitudinal and vertical) for rivers, estuaries, lakes, reservoirs, and river basin systems. CE-QUAL-W2 models basic physical, chemical, and biological processes such as temperature, nutrient, algae, dissolved oxygen, organic matter, and sediment relationships. Version 1.0 of the model was developed by the Corps’ Water Quality Modeling Group at the Waterways Experiment Station in the late 1980’s. The current model release is Version 3.2 and is supported by the Corps’ Engineer Research and Development Center (ERDC) and Portland State University.

2.3.1 PAST APPLICATION OF THE CE-QUAL-W2 MODEL

Version 2.0 of the CE-QUAL-W2 model was applied to four of the upper Mainstem System Projects in the early 1990's (i.e., Fort Peck, Garrison, Oahe, and Fort Randall). The application of the model was part of the supporting technical documentation of the Environmental Impact Statement (EIS) that was prepared for the Missouri River Master Water Control Manual Review and Update Study. The results of the model application were included as an Appendix to the Review and Update Study – "Volume 7B: Environmental Studies, Reservoir Fisheries, Appendix C – Coldwater Habitat Model, Temperature and Dissolved Oxygen Simulations for the Upper Missouri River Reservoirs" (Cole et. al., 1994). The report (Cole et. al, 1994) provided results of applying the model to the four reservoirs regarding the effects of operational changes on reservoir coldwater fish habitat. This early application of the model represents the best results that could be obtained based on the model version and water quality data available at that time, and it provided predictive capability for coldwater fish habitat regarding two system operational variables of concern – end-of-month stages and monthly average releases.

Although application of the CE-QUAL-W2 (Version 2.0) model met its intended purpose at the time, a lack of available water data placed limitations on its full utilization. These limitations were discussed in the Master Water Control Review and Update Study report (Cole et. al, 1994). The following excerpts are taken from that report:

> *"Typically, dissolved oxygen (DO) is modeled along with a full suite of water quality variables including algal/nutrient interactions. Lack of available algal/nutrient data necessitated a different approach. DO was assumed to be a function of sediment and water column oxygen demands which were adjusted during calibration to reproduce the average DO depletion during summer stratification. The drawback to this approach is that operational changes which might affect algal/nutrient interactions cannot be predicted. Results from this study show only how physical factors relating to changes in reservoir stage and discharge affect DO."*
>
> *"As a result, model predictions during scenario runs represent only how physical factors affect DO and do not include the effects of reservoir operations on algal/nutrient dynamics and their effects on DO. To include algal/nutrient effects would require at least one year's worth of detailed algal/nutrient data for each reservoir that were not and could not be made available during the time frame of this study."*
>
> *"Steps should be taken to obtain a suitable database that can be used to calibrate the entire suite of water quality algorithms in the model. It is almost a certainty that water quality issues will remain important in the future."*

The current version of the CE-QUAL-W2 model (Version 3.2) has incorporated numerous enhancements over the Version 2.0 model that was applied to the four Mainstem System Projects in the early 1990's. These enhancements, among other things, include improvements to the numerical solution scheme, water quality algorithms, two-dimensional modeling of the waterbasin, code efficiencies, and user-model interface. Communication with the author of the past application of the Version 2.0 model to the Mainstem System Projects and current model support personnel indicated that the Omaha District should pursue implementing Version 3.2 of the model (personal communication, Thomas M. Cole, USACE/ERDC).

2.3.2 FUTURE APPLICATION OF THE CE-QUAL-W2 MODEL

As part of its Water Quality Management Program, the Omaha District initiated the application of the CE-QUAL-W2 (Version 3.2) model to the Mainstem System Projects. The District is approaching the model application as an ongoing, iterative process. Data will be collected, and the model will be run and continuously calibrated as new information is gathered. The goal is to have a fully functioning model in place for all the Mainstem System Projects that meets the uncertainty requirements of decision-makers.

The current plan for applying the model to a single project will encompass a 5-year period. During years 1 through 3, an intensive water quality survey will be conducted to collect the water quality data needed to fully calibrate the model. Application and calibration of the model will occur in years 4 and 5. Once the model has been calibrated and "finalized", it will be used to facilitate the development of a Project-Specific Water Quality Report and Water Quality Management Objectives for the project. The current plan is to stagger the application of the model by annually beginning the application process at a different Mainstem System Project. The tentative order for applying the model to the Projects is: 1) Garrison Project, 2) Fort Peck Project, 3) Oahe Project, 4) Fort Randall Project, 5) Big Bend Project, and 6) Gavins Point Project. The 3-year intensive water quality survey was conducted at the Fort Peck Project during 2004 through 2006, and the application and calibration of the model to Fort Peck Reservoir is currently ongoing. Eventually it is hoped that the CE-QUAL-W2 models developed for each of the Projects can be linked and used to make integrated water quality management decisions throughout the Mainstem System.

2.3.3 CURRENT APPLICATION OF THE CE-QUAL-W2 MODEL TO FORT PECK RESERVOIR

The Fort Peck Project is the second Mainstem System Project on which the Version 3.2 CE-QUAL-W2 model is being applied, and its application to Fort Peck Reservoir is currently ongoing. Current application efforts, among other things, have focused on modifying the earlier developed reservoir bathymetry files, refining the calibration of outflow water quality conditions, and activating the model's water quality algorithms. Much more detailed outflow data regarding monitored water quality conditions currently exists to refine the calibration of the model. The water quality algorithms that describe the nutrient/algae/dissolved oxygen interactions are being calibrated. The goals are to have the model mechanistically determine reservoir dissolved oxygen levels and to use the model's predictive capabilities to evaluate factors influencing the occurrence of dissolved oxygen in Fort Peck Reservoir. A Water Quality Special Report will be prepared at a future date describing the application and calibration of the CE-QUAL-W2 Version 3.2 model to Fort Peck Reservoir.

3 DATA COLLECTION METHODS

3.1 DATA COLLECTION DESIGN

3.1.1 MONITORING LOCATIONS

The Omaha District collected water quality data at 10 locations at the Fort Peck Project during the period 2004 through 2006. Of the 10 locations, 6 were located in Fort Peck Reservoir, 3 were located on the major tributary inflows to the reservoir (i.e., Missouri River, Musselshell River, and Big Dry Creek), and 1 was located in the Fort Peck Dam powerhouse. Table 3.1 describes the monitoring locations in greater detail, and Figure 3.1 shows their locations.

3.1.2 MONITORING STATION TYPES

The monitoring stations where water quality data were collected during the period 2004 through 2006 were categorized into three types: 1) reservoir, 2) inflow, and 3) outflow (Table 3.1). All of the reservoir stations were meant to represent "deepwater" pelagic conditions and were established at the deepest part of the reservoir with regards to the area being monitored. The six reservoir monitoring stations were oriented along two longitudinal axes – the old Missouri River and Big Dry Creek channels. Four reservoir stations (i.e., L1 through L4) were approximately equally spaced along the old Missouri River channel from near the dam to Hell Creek Bay, a distance of approximately 33 miles (Figure 3.1). Two reservoir stations (i.e., L5 and L6) were located on the old Big Dry Creek channel – one near the old Missouri River channel and the other near Rock Creek Bay (Figure 3.1). The three inflow stations were located on the Missouri River, Musselshell River, and Big Dry Creek just upstream of their confluence with Fort Peck Reservoir (Figure 3.1). The single outflow station was located in the Fort Peck Dam powerhouse. Water quality data collected at this station consisted of monitoring the quality of the water being discharged through the dam's penstocks. Depending on pool elevation, the monitoring stations are believed to be associated with the following zones: Lacustrine Zone (L1, L2, L3, L5, OF1), Zone of Transition (L4, L6), and Riverine Zone (NF1).

Table 3.1. Location and description of monitoring stations that were sampled by the Omaha District for water quality at the Fort Peck Project during the period 2004 through 2006.

Station Number	Station Alias	Name	Location	Station Type	Latitude	Longitude
FTPNFMORR1	NF1	Missouri River near Landusky, MT	At US Highway 191 bridge crossing south of Landusky, MT	Inflow	-----	-----
FTPNFMSLR1	NF2	Musselshell River at Mosby, MT	At MT Highway 200 bridge crossing at Mosby, MT	Inflow	-----	-----
FTPNFBDCK1	NF3	Big Dry Creek near Jordan, MT	At County Rd 462 bridge crossing east of Jordan, MT	Inflow	-----	-----
FTPPP1	OF1	Fort Peck Powerhouse	In powerhouse – water drawn from raw water supply loop	Outflow	-----	-----
FTPLK1772A	L1	Fort Peck Reservoir – Near Dam	Reservoir, Deepwater	Reservoir	N47 59'02.97" (N47.984167)	W106 25'09.22" (W106.419233)
FTPLK1778DW	L2	Fort Peck Reservoir: Skunk Coulee Bay	Reservoir, Deepwater	Reservoir	N47 53'53.40" (N47.898167)	W106 31'28.19" (W106.524500)
FTPLK1789DW	L3	Fort Peck Reservoir: The Pines Recreation Area	Reservoir, Deepwater	Reservoir	N47 47'33.08" (N47.792517)	W106 38'00.26" (W106.63340)
FTPLK1805DW	L4	Fort Peck Reservoir: Hell Creek Bay	Reservoir, Deepwater	Reservoir	N47 40'48.68" (N47.680183)	W106 52'45.47 (W106.879283)
FTPLKBDCA01	L5	Fort Peck Reservoir: Lower Big Dry Creek Arm	Reservoir, Deepwater	Reservoir	N47 54'25.85" (N47.907183)	W106 24'54.87" (106.415233)
FTPLKBDCA02	L6	Fort Peck Reservoir: Rock Creek Bay	Reservoir, Deepwater	Reservoir	N47 44'40.10" (N47.744497)	W106 17'42.90" (W106.295250)

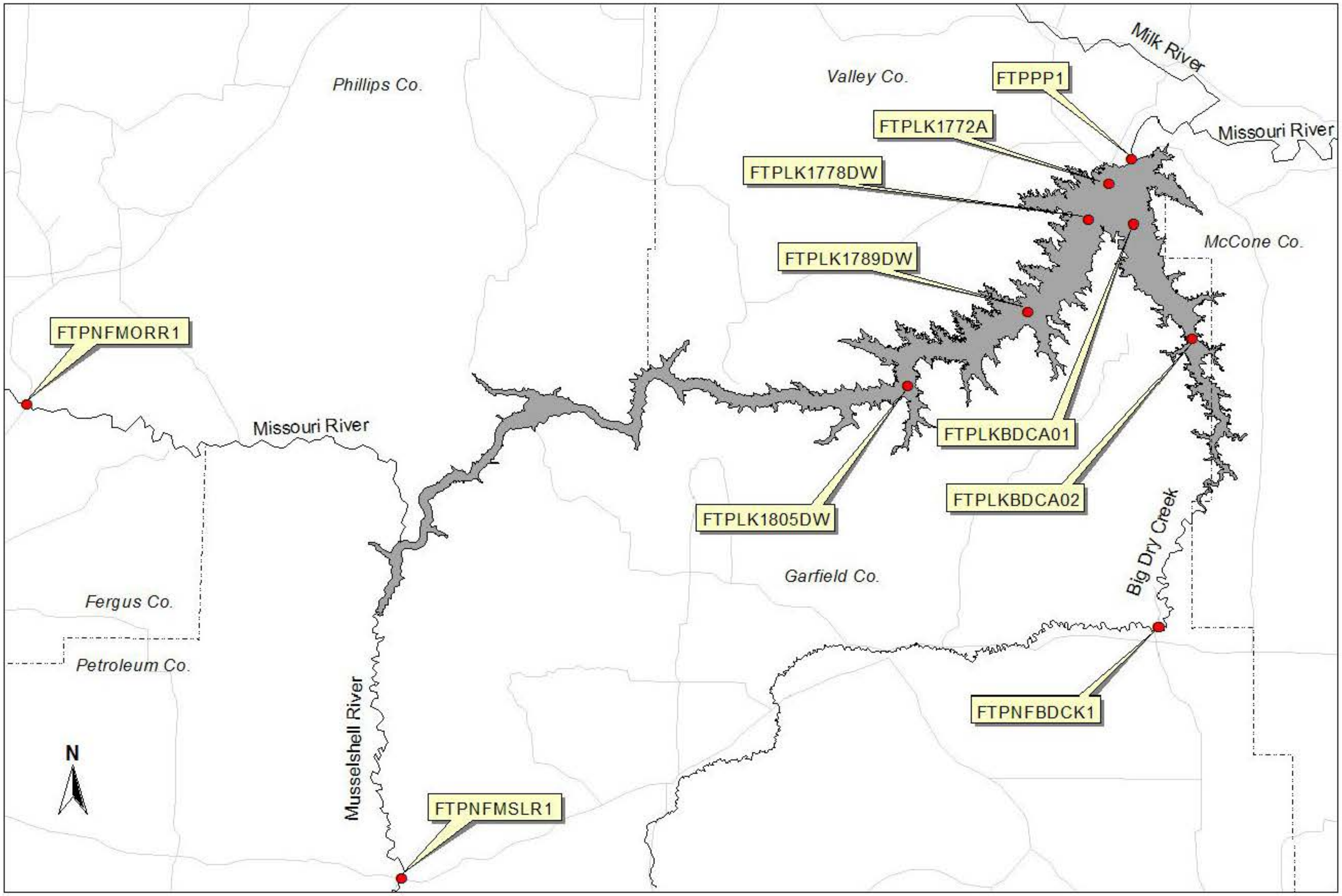

Figure 3.1. Location of sites where water quality monitoring was conducted by the Omaha District at the Fort Peck Project during the period 2004 through 2006.

3.1.3 MEASUREMENTS, SAMPLE TYPES, AND COLLECTION FREQUENCY

3.1.3.1 Reservoir Monitoring Stations

Monitoring at the reservoir monitoring stations consisted of field measurements and collection of discrete-depth "grab" samples for laboratory analysis. Field measurements and grab samples were collected monthly during the period May through September. Two depth-discrete grab samples, near-surface (i.e., ½ the measured Secchi depth) and near-bottom (i.e., within 2 meters of the reservoir bottom), were collected.

3.1.3.2 Inflow Monitoring Stations

Monitoring at these three stations (i.e., NF1, NF2, and NF3) consisted of field measurements and collection of grab samples. A near-surface grab sample was collected from near the bank in an area of faster current. Monitoring at the Missouri River (site NF1) occurred monthly during the period May through September in 2004, 2005, and 2006. Monitoring on the Musselshell River (site NF2) and Big Dry Creek (site NF3) was conducted monthly during the period May through July in 2004. Monitoring of these sites was discontinued in 2005 due to the relative low-flow conditions present in these streams compared to the Missouri River inflow.

Through an agreement with the U.S. Geological Survey (USGS), a water temperature monitoring probe was added to the USGS's gage on the Missouri River near Landusky, Montana (i.e. site NF1). Beginning in October 2004, hourly water temperature measurements were recorded at the site.

3.1.3.3 Outflow Monitoring Station

Monitoring at the Fort Peck powerhouse consisted of year-round hourly logging of water quality conditions and monthly collection of grab samples from a "flow-chamber" drawing water from the "raw-water" supply line. The raw-water supply line is a 10-inch pipe that intersects and draws water from near the end of tunnel 1 in the dam. The water continuously running through the flow-chamber was tapped off the raw-water supply line and traveled 40 feet through a ¾-inch plastic pipe to the flow-chamber. The hourly measurements logged included water temperature, dissolved oxygen, pH, and conductivity. The monthly grab samples where collected from the water flowing into the flow-chamber.

3.1.4 PARAMETERS MEASURED AND ANALYZED

3.1.4.1 Water Quality Parameters

The water quality parameters that were measured and analyzed at the various monitoring stations are given in Table 3.2.

3.1.4.2 Explanatory Variables

Explanatory variables that were quantified included inflow discharge, outflow discharge, and reservoir pool elevation. Inflow discharge at station NF1 was taken as the recorded discharge at the USGS gage (06115200) on the Missouri River near Landusky, MT. Inflow discharge at station NF2 was determined from the USGS gage (06130500) on the Musselshell River at Mosby, MT. Inflow discharge at station NF3 was determined from the USGS gage (06131000) on Big Dry Creek near Van Norman, MT. Outflow discharge from Fort Peck Dam and the pool elevation of Fort Peck Reservoir were obtained from Fort Peck Project records.

Table 3.2. Parameters measured and analyzed at the various monitoring stations.

Parameter	L1, L2, L3, L4, L5, L6	NF1, NF2, NF3	OF1
Dissolved Solids, Total	✓	✓	✓
Organic Carbon, Total (TOC)	✓	✓	✓
Orthophosphorus, Dissolved	✓	✓	✓
Phosphorus, Total	✓	✓	✓
Dissolved Phosphorus, Total	✓	✓	✓
Nitrate-Nitrite as N, Total	✓	✓	✓
Ammonia as N, Total	✓	✓	✓
Kjeldahl Nitrogen, Total	✓	✓	✓
Suspended Solids, Total	✓	✓	✓
Alkalinity	✓	✓	✓
Sulfate	✓	✓	✓
Chlorophyll a	✓		
Phytoplankton Biomass and Taxa Identification	✓		
Iron, Total and Dissolved	✓	✓	✓
Manganese, Total and Dissolved	✓	✓	✓
Metals and Hardness	✓		
Pesticide Scan	✓		
Microcystins	✓		
Secchi Depth/Transparency	✓		
Field Measurements (Hydrolab)**	✓ (Depth Profile)	✓ (Near Surface)	
Continuous Monitoring ("Hydrolab")***			✓

Note: Not all parameters were monitored at all the sites indicated.
** Hydrolab field measurements included: water temperature, dissolved oxygen (mg/l and % saturation), pH, conductivity, ORP, turbidity, and chlorophyll *a*. Depth profile measurements taken at 1-meter intervals from the reservoir surface to the bottom.
*** Continuous monitored parameters include temperature, dissolved oxygen (mg/l and % saturation) pH, and conductivity.

3.2 WATER QUALITY MEASUREMENT AND SAMPLING METHODS

3.2.1 FIELD MEASUREMENTS

Depth-profile and surface measurements for water temperature, dissolved oxygen (mg/l and % saturation), pH, conductivity, Oxidation-Reduction potential (ORP), turbidity, and chlorophyll *a* were taken using a "Hydrolab". Profile measurements were taken at 1-meter intervals. The Hydrolab was operated as specified in the USACE – Water Quality Unit's Standard Operating Procedures (SOPs) Number WQ-21201, "Using a Hydrolab 4, 4a, and 5 to Directly Measure Water Quality" (USACE, 2006). Secchi transparency was measured in accordance with the USACE – Water Quality Unit's SOP Number WQ-21202, "Determining Secchi Depth" (USACE, 2004b).

3.2.2 WATER QUALITY SAMPLE COLLECTION AND ANALYSIS

All water quality samples were collected in accordance with the USACE – Water Quality Unit's SOP Number WQ-21101, "Collection of Surface Water Samples" (USACE, 2003). Surface grab samples were collected by dipping a rinsed plastic churn bucket just below the surface (i.e., approximately 6 inches below the surface). Depth-discrete grab samples were collected with a Kemmerer sampler that was lowered to the desired sampling depth, triggered, and retrieved to the boat.

3.3 ANALYTICAL METHODS

All collected water quality samples were delivered to the Corps' Engineer Research and Development Center (ERDC), Environmental Chemistry Branch Laboratory in Omaha, Nebraska for laboratory analysis. The analytical methods, detection limits, and reporting limits for the analysis of the collected water quality samples are given in Table 3.3. Analysis of the collected plankton samples was done by an outside laboratory under contract to the ERDC Omaha Laboratory.

Table 3.3. Methods, detection limits, and reporting limits for analyses conducted by the Corps' Environmental Chemistry Branch Laboratory.

Analyte	Method	Detection Limit	Reporting Limit
Alkalinity, Total	EPA - 310.2	7 mg/l	20 mg/l
Nitrate/Nitrite, Total as N	EPA - 353.2	0.02 mg/l	0.1 mg/l
Ammonia, Total as N	EPA - 350.1	0.01 mg/l	0.1 mg/l
Kjeldahl Nitrogen, Total as N	EPA - 351.2	0.1 mg/l	0.2 mg/l
Phosphorus, Total as P	EPA - 365.4	0.01 mg/l	0.02 mg/l
Phosphorus, Total Dissolved	EPA - 365.4	0.01 mg/l	0.02 mg/l
Orthophosphorus	EPA - 300.0 / 365.1	0.01 mg/l	0.03 mg/l
Sulfate, Total	EPA - 300.0 / 375.2	0.01 mg/l / 6 mg/l	0.1 mg/l / 20 mg/l
Dissolved Solids, Total	EPA - 160.1	5 mg/l	10 mg/l
Suspended Solids, Total	EPA - 160.2	4 mg/l	10 mg/l
Organic Carbon, Total (TOC)	EPA - 9060	0.05 mg/l	0.25 mg/l
Organic Carbon, Dissolved (DOC)	EPA - 9060	0.05 mg/l	0.25 mg/l
Dissolved Metals:	EPA - 6010B		
Antimony		6 ug/l	20 ug/l
Arsenic		3 ug/l	15 ug/l
Beryllium		0.5 ug/l	2 ug/l
Cadmium		0.5 ug/l	2.5 ug/l
Calcium		100 ug/l	300 ug/l
Chromium III		2 ug/l	10 ug/l
Copper		2 ug/l	10 ug/l
Nickel		3 ug/l	10 ug/l
Lead		2 ug/l	10 ug/l
Magnesium		40 ug/l	120 ug/l
Silver		1 ug/l	5 ug/l
Thallium		6 ug/l	30 ug/l
Zinc		3 ug/l	10 ug/l
Mercury, dissolved and total	EPA - 7470A	0.02 ug/l	0.1 ug/l
Iron and Manganese, total and dissolved	EPA - 6010B	40 ug/l	120 ug/l
Selenium, total	EPA - 6010B	4 ug/l	20 ug/l
Silica, Total and Dissolved	EPA - 6010B	20 ug/l	100 ug/l
Chlorophyll *a*	SM - 10200H2	1 ug/l	3 ug/l
Pesticide scan*:	EPA - 507	0.05 ug/l	0.1 ug/l
Immunoassay – Herbicides (Alachlor, Atrazine, Metolachlor)	Rapid Assay	0.05ug/l	0.1 ug/l
Immunoassay – Microcystins	Rapid Assay	0.2 ug/l	1 ug/l

* Pesticide scan included: Acetochlor, Alachlor, Atrazine, Benfluralin, Butylate, Chlorpyrifos, Cyanazine, Cycloate, EPTC, Hexazinone, Isopropalin, Metolachlor, Metribuzin, Molinate, Oxadiazon, Oxyfluorfen, Pebulate, Pendimethalin, Profluralin, Prometon, Propachlor, Propazine, Simazine, Trifluralin, Vernolate.

4 DATA ASSESSMENT METHODS

4.1 EXISTING WATER QUALITY (2004 THROUGH 2006)

4.1.1 GENERAL WATER QUALITY CONDITIONS

Statistical analyses were performed on the water quality monitoring data collected at reservoir, inflow, and outflow sites during the period 2004 through 2006. Descriptive statistics (i.e., mean, median, minimum, maximum) were calculated to describe central tendencies and the range of observations. Where appropriate, monitoring results were compared to defined water quality standards criteria for the State of Montana.

Spatial variation of selected water quality parameters in Fort Peck Reservoir was evaluated. Longitudinal contour plots were constructed for water temperature, dissolved oxygen, and turbidity to display likely conditions in Fort Peck Reservoir from its upper reaches to Fort Peck Dam. The longitudinal contour plots were constructed using the "Hydrologic Information Plotting Program" included in the "Data Management and Analysis System for Lakes, Estuaries, and Rivers" (DASLER-X) software developed by HydroGeoLogic, Inc. (Hydrogeologic Inc., 2005). Secchi depth measurements collected along Fort Peck Reservoir were evaluated and are displayed using a box plot. The variation of nutrient concentrations with depth were evaluated at site L1 by comparing near-surface and near-bottom collected samples.

The phytoplankton community was evaluated based on collected grab samples. A listing of taxa occurrence, to the species level where possible, was compiled. The frequency of occurrence of a taxon was determined based on the number of samples in which the taxon was present out of the total phytoplankton samples collected. Frequency of occurrence was quantified as follows: Rare – taxon present in 1 to 4 samples, Occasional – taxon present in 5 to 10 samples, and Common – taxon present in more than 10 samples. The relative abundance of a taxon was determined based on the taxon biovolume as a percent of the total sample biovolume. Relative abundance was quantified as follows: Very Low – taxon biovolume < 1%, Low – taxon biovolum 1 to 5%, Medium – taxon biovolume 5 to 10%, and High – taxon biovolume > 10%.

4.1.2 TROPHIC STATUS

Reservoirs are commonly classified or grouped by trophic or nutrient status. The natural progression of reservoirs through time is from an oligotrophic (i.e., low nutrient/low productivity) through a mesotrophic (i.e., intermediate nutrient/intermediate productivity) to a eutrophic (i.e., high nutrient/high productivity) condition. The prefixes "ultra" and "hyper" are sometimes added to oligotrophic or eutrophic, respectively, as additional degrees of trophic status. The tendency toward the eutrophic, or nutrient-rich, status is common to all impounded waters. The eutrophication, or enrichment process, can adversely impact water quality conditions in reservoirs (e.g., increased occurrence of algal blooms, noxious odors, and fish kills; reduced water clarity; reduced hypolimnetic dissolved oxygen concentrations; etc.). Eutrophication of reservoirs can be accelerated by nutrient additions through cultural activities (e.g., point-source discharges and nonpoint sources such as runoff from cropland, livestock facilities, urban areas, etc.).

A Trophic State Index (TSI) can be calculated as described by Carlson (1977). TSI values are determined from Secchi disk transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters are converted to an index number ranging from 0 to 100 according to the following equations:

$$TSI(\text{Secchi Depth}) = TSI(SD) = 10[6 - (\ln SD/\ln 2)]$$

$$TSI(\text{Chlorophyll } a) = TSI(Chl) = 10[6 - ((2.04-0.68 \ln Chl)/\ln 2)]$$

$$TSI(\text{Total Phosphorus}) = TSI(TP) = 10[6 - (\ln (48/TP)/\ln 2)]$$

Accurate TSI values from total phosphorus depend on the assumptions that phosphorus is the major limiting factor for algal growth and that the concentrations of all forms of phosphorus present are a function of algal biomass. Accurate TSI values from Secchi disk transparency depend on the assumption that water clarity is primarily limited by phytoplankton biomass. Carlson indicates that the chlorophyll TSI value may be a better indicator of a lake's trophic condition during mid-summer when algal productivity is at its maximum, while the total phosphorus TSI value may be a better indicator in the spring and fall when algal biomass is below its potential maximum. Calculation of TSI values from data collected from a lake's epilimnion during summer stratification provide the best agreement between all of the index parameters and facilitate comparisons between lakes. Care should be taken if a TSI average score is calculated from the three individual parameter TSI values. If significant differences exist between parameter TSI values, the calculated average value may not be indicative of the trophic condition estimated by the individual parameter values. With this in mind, a TSI average value [TSI(Avg)] calculated as the average of the three individually determined TSI values [i.e., TSI(SD), TSI(Chl), and TSI(TP)] is used by the Omaha District as an overall indicator of a reservoir's trophic state. The Omaha District uses the criteria defined in Table 4.1 for determining reservoir trophic status from TSI values.

Table 4.1. Reservoir trophic status based on calculated Trophic State Index (TSI) values.

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

In addition to classifying lakes, the TSI can serve as an internal check on the assumptions about the relationships among various components of a lake's ecosystem. Carlson states that that the three TSI parameters, when transformed to the trophic scale, should have similar values. Any divergence from this value by one or more of the parameters may provide insights into a lake's water quality dynamics (e.g., is the lake phosphorus limited, is water clarity limited by algae or nonalgal particulate matter, etc.)

Existing trophic conditions were assessed for Fort Peck Reservoir based on the monitoring conducted during the 2004 through 2006 period. The data evaluated consisted of Secchi depth measurements and total phosphorus and chlorophyll *a* analytical results obtained at the reservoir sites L1, L2, L3, L4, L5, and L6. TSI values were calculated and compared to the above criteria.

4.1.3 TIME-SERIES PLOTS OF FLOW, WATER TEMPERATURE, AND DISSOLVED OXYGEN OF WATER DISCHARGED THROUGH FORT PECK DAM

Time series plots were prepared for conditions measured at the Fort Peck Dam powerhouse during the 2004 through 2006 period. Discharge was plotted with hourly temperature and dissolved oxygen measurements. Plots were for measurements taken from the "raw water" supply line.

4.2 ESTIMATING THE OCCURRENCE OF COLDWATER HABITATS IN FORT PECK RESERVOIR

4.2.1 COLDWATER HABITAT CRITERIA – WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen levels are primary water quality factors that determine the suitability of water for coldwater aquatic life. Water quality standards for the protection of aquatic life (i.e., water temperature and dissolved oxygen criteria) usually include different levels of protection based on habitat types, life stages (i.e., eggs, fry, juvenile, and adults), and acute and chronic effects. To protect waters for growth and marginal propagation of salmonid fishes and associated aquatic life, the State of Montana has promulgated the following numeric water quality standards criteria for water temperature and dissolved oxygen: water temperature ≤ 67°F (19.4°C), and dissolved oxygen ≥ 5.0 mg/l.

4.2.2 DEFINITION OF COLDWATER HABITAT TYPES FOR FORT PECK RESERVOIR

For evaluating the coldwater habitat present in Fort Peck Reservoir, two types of coldwater habitat were defined for use in this report based on water temperature and dissolved oxygen concentrations (Table 4.2). Coldwater habitat is defined as water having a temperature of ≤ 19.4°C and a dissolved oxygen concentration of ≥ 5.0 mg/l. Optimal coldwater habitat is defined as water having a temperature of ≤ 15°C and a dissolved oxygen concentration of ≥ 5.0 mg/l.

Table 4.2. Coldwater habitat types defined for evaluation of temperature and dissolved oxygen conditions in Fort Peck Reservoir.

Habitat Type	Water Temperature Criteria	Dissolved Oxygen Criteria
Coldwater	≤ 19.4°C	≥ 5.0 mg/l
Optimal Coldwater	≤ 15°C	≥ 5.0 mg/l

4.2.3 VOLUME ESTIMATION OF COLDWATER HABITATS IN FORT PECK RESERVOIR

The reservoir was divided into six regions represented by the six reservoir monitoring sites (i.e., L1, L2, L3, L4, L5, and L6). Region 1 was defined as the portion of Fort Peck Reservoir from the dam to the confluence of the Big Dry Creek arm of the reservoir (i.e., RM 1772 to RM1778) and was represented by station L1. Region 2 was defined as the portion of the mainstem branch of the reservoir from RM1778 to RM1784 and was represented by station L2. Region 3 was defined as the portion of the mainstem branch of the reservoir from RM1784 to RM1797 and was represented by station L3. Region 4 was defined as the portion of the mainstem branch of the reservoir upstream from RM1797 and was represented by station L4. Region 5 was defined as the portion of Big Dry Creek arm of the reservoir from its confluence with the mainstem branch to RM7 and was represented by station L5. Region 6 was defined as the portion of the Big Dry Creek arm of the reservoir upstream from RM7 and was represented by station L6. Table 4.3 gives an elevation-volume relationship that was established for each of the six regions of the reservoir. The elevation-volume relationship was based on the bathymetry grids developed by the Corps in an earlier application of the CE-QUAL-W2 Hydrodynamic and Water Quality Model to Fort Peck Reservoir (Cole et. al., 1994).

Measured water temperature and dissolved oxygen concentration depth-profiles at each of the six reservoir sites were used to estimate the volume of coldwater habitat in each the six defined reservoir regions represented by the appropriate station. Water temperature and dissolved oxygen concentration depth-profiles measured at monitoring stations L1 through L6 were compared to Table 4.3, and linear interpolation was used to estimate the volume of water in that reservoir region that met the defined coldwater habitat criteria defined in Table 4.2.

Table 4.3. Estimation of "regional" volumes (acre-feet) in Fort Peck Reservoir based on pool elevations.

Reservoir Elevation	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Sum Volume*	Corps Volume**
2250	3,645,242	1,762,211	3,679,361	5,599,247	2,329,118	989,777	18,007,956	18,687,731
2240	3,293,871	1,610,315	3,279,463	4,746,414	2,082,359	778,827	15,791,249	16,309,409
2230	2,959,412	1,460,716	2,899,301	3,958,490	1,844,918	594,463	13,717,301	14,169,579
2220	2,652,462	1,319,175	2,550,146	3,265,999	1,623,316	457,221	11,868,318	12,236,952
2210	2,362,572	1,182,508	2,221,117	2,638,279	1,411,342	347,812	10,163,630	10,565,907
2200	2,097,400	1,053,079	1,918,732	2,088,050	1,213,732	256,668	8,627,661	8,993,723
2190	1,852,195	930,295	1,639,236	1,609,499	1,030,528	184,649	7,246,402	7,573,749
2180	1,625,875	813,719	1,381,877	1,206,178	860,617	128,250	6,016,515	6,309,129
2170	1,416,991	704,106	1,147,289	882,552	701,710	82,185	4,934,832	5,178,658
2160	1,222,009	600,430	932,856	627,419	553,269	41,885	3,977,869	4,211,053
2150	1,040,653	503,749	741,136	426,471	418,401	14,166	3,144,578	3,362,492
2140	874,425	414,305	570,697	261,474	297,067	802	2,418,771	2,613,376
2130	723,615	332,541	420,255	129,080	190,344	0	1,795,834	1,955,609
2120	584,018	257,395	284,697	41,484	103,350	0	1,271,045	1,410,784
2110	461,870	191,006	169,657	6,757	48,735	0	878,027	990,681
2100	349,269	128,506	74,747	0	15,322	0	567,844	663,076
2090	254,318	76,604	21,591	0	0	0	352,513	413,557
2080	166,686	32,725	0	0	0	0	199,411	236,456
2070	90,619	6,133	0	0	0	0	96,752	103,630
2060	34,072	0	0	0	0	0	34,072	35,551
2050	11,320	0	0	0	0	0	11,320	11,057
2040	1,500	0	0	0	0	0	1,500	1,052
2030	0	0	0	0	0	0	0	0

* Total reservoir volume based on summing estimated regional reservoir volumes.
** Total reservoir volume from Corps Area-Capacity Tables based on 1986 survey.

5 FORT PECK RESERVOIR WATER QUALITY CONDITIONS

5.1 EXISTING WATER QUALITY CONDITIONS – 2004 THROUGH 2006

5.1.1 STATISTICAL SUMMARY AND WATER QUALITY STANDARDS ATTAINMENT

Tables 5.1 through 5.7 summarize the water quality conditions that were monitored in Fort Peck Reservoir during 2004 through 2006 at monitoring locations L1, L2, L3, L4, L5, and L6. These results indicate no major water quality concerns.

5.1.2 WATER TEMPERATURE

5.1.2.1 Annual Temperature Regime

The water temperature regime of Fort Peck Reservoir can be described by an annual cycle consisting of eight thermal periods: 1) winter ice cover, 2) spring turnover, 3) spring isothermal conditions, 4) late-spring/early-summer warming, 5) mid-summer maximum thermal stratification, 6) late-summer/early-fall cooling, 7) fall turnover, and 8) fall isothermal conditions leading to winter ice cover. During the winter ice-cover period, Fort Peck Reservoir will be inversely stratified from the surface to the bottom as the more dense water (i.e., 4°C) settles to the bottom. When the ice cover melts in the spring, the reservoir will become isothermal at about 4°C, and complete mixing of the reservoir volume will occur as spring turnover takes place. As the reservoir gradually warms in the spring, isothermal conditions (>4°C) will occur as long as sufficient energy is present to completely mix the reservoir water column. As the reservoir continues to warm in late spring and early summer, thermal stratification will occur, and the hypolimnion will become established. At some point in mid-summer, the reservoir will reach maximum thermal stratification (i.e., maximum temperature difference between water at the reservoir surface and bottom), and a distinct thermocline will be present. As the reservoir begins to cool in late summer, the epilimnion will expand downward, pushing the thermocline deeper, and the hypolimnetic volume of colder water will decrease. The reservoir will continue to cool until it becomes isothermal and mixing occurs through the entire water column and fall turnover occurs. As the reservoir continues to cool, temperatures will remain relatively isothermal until it cools to 4°C. Ice cover will then be established, and the annual thermal cycle of Fort Peck Reservoir will be completed.

Table 5.1. Summary of monthly (May through September) water quality conditions monitored in Fort Peck Reservoir near Fort Peck Dam at monitoring station FTPLK1772A (L1) during the period 2004 through 2006.

	Monitoring Results*						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean****	**Median**	**Min.**	**Max.**	**State WQS Criteria*****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	15	2202.9	2203.1	2199.4	2206.2	-----	-----	-----
Water Temperature (C)	0.1	754	12.9	12.0	5.7	25.5	≤ 26.7[1] ≤ 19.4[1] ≤ 15.0[1]	0 71 212	0% 9% 28%
Dissolved Oxygen (mg/l)	0.1	754	8.8	8.9	5.0	10.8	≥ 6.0[2] ≥ 5.0[2] ≥ 4.0[2] ≥ 3.0[2]	16 1 0 0	2% <1% 0% 0%
Dissolved Oxygen (% Sat.)	0.1	754	86.5	90.0	48.7	107.4	-----	-----	-----
Specific Conductance (umho/cm)	1	754	490	493	364	549	-----	-----	-----
pH (S.U.)	0.1	706	8.2	8.1	7.5	8.7	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	753	6.6	3.3	0.1	33.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	754	393	387	298	526	-----	-----	-----
Secchi Depth (in)	1	15	135	144	56	216	-----	-----	-----
Alkalinity, Total (mg/l)	7	35	159	160	134	180	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	37	0.07	0.03	n.d.	0.24	4.64[3,4] 2.1[3,5]	0 0	0% 0%
Carbon, Total Organic (mg/l)	0.05	35	2.4	2.4	2.2	3.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	14	-----	5.5	n.d.	10.0	-----	-----	-----
Chloride (mg/l)	0.02	12	7.6	7.6	7.4	8.1	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab	1	15	-----	n.d.	n.d.	2	-----	-----	-----
Chlorophyll *a* (ug/l) – Field	1	753	-----	n.d.	n.d.	4.7	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	23	339	340	260	420	-----	-----	-----
Iron, Dissolved (ug/l)	40	25	-----	n.d.	n.d.	50	1,000[5]	0	0%
Iron, Total (ug/l)	40	25	76	60	n.d.	184	1,000[5]	0	0%
Kjeldahl N, Total (mg/l)	0.1	37	0.3	0.2	n.d.	0.6	-----	-----	-----
Manganese, Dissolved (ug/l)	1	25	-----	n.d.	n.d.	12.0	50[6]	0	0%
Manganese, Total (ug/l)	1	25	6.4	4.0	2.0	27.0	50[6]	0	0%
Nitrate-Nitrite N, Total (mg/l)	0.02	37	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	37	0.07	0.04	n.d.	0.66	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	37	-----	0.02	n.d.	0.32	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	37	-----	n.d.	n.d.	0.02	-----	-----	-----
Silica, Dissolved (ug/l)	20	5	3,008	2,973	2,786	3,227	-----	-----	-----
Silica, Total (ug/l)	20	5	3,190	3,033	2,942	3,618	-----	-----	-----
Sulfate (mg/l)	0.1	33	120	120	37	130	-----	-----	-----
Suspended Solids, Total (mg/l)	4	37	-----	n.d.	n.d.	8	-----	-----	-----
Alachlor (ug/l)	0.05	10	-----	n.d.	n.d.	n.d.	≤2	0	0%
Atrazine, Total (ug/l)	0.05	10	-----	n.d.	n.d.	0.07	≤3	0	0%
Metolachlor (ug/l)	0.05	10	-----	n.d.	n.d.	0.07	≤100	0	0%
Microcystins (ug/l)	0.05	9	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F). The temperature criterion for a B-2 use, which is not assigned to Fort Peck Reservoir, is 19.4 C (67 F). The temperature criterion of 15 C is given for reference only.

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

(3) Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.1 and 12.0, respectively.

(4) Acute criterion for aquatic life.

(5) Chronic criterion for aquatic life.

(6) Secondary Maximum Contaminant Level based on aesthetic properties.

Table 5.2. Summary of annual (May and August) water quality conditions monitored in Fort Peck Reservoir near Fort Peck Dam at monitoring station FTPLK1772A (L1) during the period 2004 through 2006.

	Monitoring Results*						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean****	**Median**	**Min.**	**Max.**	**State WQS Criteria*****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Hardness, Dissolved (mg/l)	0.4	4	204	205	199	206	-----	-----	-----
Antimony, Dissolved (ug/l)	20	1	-----	n.d.	n.d.	n.d.	5.6(3)	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	3.2	n.d.	3.5	340(1) 150(2) 10(3)	0 0 0	0% 0% 0%
Beryllium, Dissolved (ug/l)	4	1	-----	n.d.	n.d.	n.d.	4(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	4.4(1) 0.5(2) 5(3)	0 0 0	0% 0% 0%
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	34	3,246(1) 155(2)	0 0	0% 0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	27.5(1) 17.2(2) 1,300(3)	0 0 0	0% 0% 0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	204(1) 7.9(2) 15(3)	0 0 0	0% 0% 0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.7(1) 0.91(2) 0.05(3)	0 0 0	0% 0% 0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	861(1) 96(2) 100(3)	0 0 0	0% 0% 0%
Selenium, Total (ug/l)	4	3	-----	n.d.	n.d.	n.d.	20(1) 5(2) 50(3)	0 0 0	0% 0% 0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	13.9(1) 100(3)	0 0	0% 0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	220(1,2) 2,000(3)	0 0	0% 0%
Pesticide Scan (ug/l)****	0.05	2	-----	n.d.	n.d.	n.d.	*****	-----	-----

n.d. = Not detected.

* Pesticide scan run on May near-surface samples and metals analyses run on August near-surface samples.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.

*** (1) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based – criteria listed are based on a median hardness value of 205.)

(2) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based – criteria listed are based on a median hardness value of 205.)

(3) Human health criterion for surface waters.

**** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides do not have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Table 5.3. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir near Skunk Coulee Bay at monitoring station FTPLK1778DW (L2) during the period 2004 through 2006.

Parameter	Monitoring Results*						Water Quality Standards Attainment		
	Detection Limit	**No. of Obs.**	**Mean****	**Median**	**Min.**	**Max.**	**State WQS Criteria*****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	12	2203.0	2202.9	2199.9	2206.2	-----	-----	-----
Water Temperature (C)	0.1	498	15.0	14.6	8.5	26.3	≤ 26.7(1) ≤ 19.4(1) ≤ 15.0(1)	0 85 197	0% 18% 42%
Dissolved Oxygen (mg/l)	0.1	468	8.3	8.4	5.7	10.0	≥ 6.0(2) ≥ 5.0(2) ≥ 4.0(2) ≥ 3.0(2)	16 0 0 0	3% 0% 0% 0%
Dissolved Oxygen (% Sat.)	0.1	468	86.5	90.9	57.1	106.5	-----	-----	-----
Specific Conductance (umho/cm)	1	468	497	493	422	545	-----	-----	-----
pH (S.U.)	0.1	430	8.2	8.3	7.4	8.7	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	468	5.7	2.5	0.1	27.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	468	381	361	284	534	-----	-----	-----
Secchi Depth (in)	1	12	148	132	102	250	-----	-----	-----

* Results are a combination of all sampling depths.

** The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F). The temperature criterion for a B-2 use, which is not assigned to Fort Peck Reservoir, is 19.4 C (67 F). The temperature criterion of 15 C is given for reference only.

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

Table 5.4. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir near The Pines Recreation Area at monitoring station FTPLK1789DW (L3) during the period 2004 through 2006.

Parameter	Monitoring Results*						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean**	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	2203.0	2202.9	2199.9	2206.2	-----	-----	-----
Water Temperature (C)	0.1	413	15.4	15.0	8.9	24.4	≤ 26.7[1] ≤ 19.4[1] ≤ 15.0[1]	0 78 199	0% 19% 48%
Dissolved Oxygen (mg/l)	0.1	413	8.0	8.3	2.2	9.7	≥ 6.0[2] ≥ 5.0[2] ≥ 4.0[2] ≥ 3.0[2]	46 13 1 1	11% 3% <1% <1%
Dissolved Oxygen (% Sat.)	0.1	413	83.7	89.0	20.7	107.1	-----	-----	-----
Specific Conductance (umho/cm)	1	413	494	490	416	559	-----	-----	-----
pH (S.U.)	0.1	379	8.2	8.3	6.9	8.8	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	412	6.8	3.3	0.1	40.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	413	370	344	136	528	-----	-----	-----
Secchi Depth (in)	1	12	118	114	78	156	-----	-----	-----
Alkalinity, Total (mg/l)	7	30	158	160	140	174	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	30	-----	0.04	n.d.	0.23	3.15[3,4] 1.46[3,5]	0 0	0% 0%
Carbon, Total Organic (mg/l)	0.05	30	2.4	2.4	2.2	2.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	6.9	5.5	4.0	12.0	-----	-----	-----
Chloride (mg/l)	0.02	8	7.5	7.5	7.3	7.8	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab	1	12	-----	1	n.d.	4	-----	-----	-----
Chlorophyll *a* (ug/l) – Field	1	412	-----	n.d.	n.d.	7.2	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	30	348	345	297	478	-----	-----	-----
Iron, Dissolved (ug/l)	40	17	-----	n.d.	n.d.	n.d.	1,000[5]	0	0%
Iron, Total (ug/l)	40	17	137	97	50	359	1,000[5]	0	0%
Kjeldahl N, Total (mg/l)	0.1	30	0.3	0.2	0.2	0.5	-----	-----	-----
Manganese, Dissolved (ug/l)	1	16	-----	1	n.d.	32.0	50[6]	0	0%
Manganese, Total (ug/l)	1	17	14	6	3	56	50[6]	1	6%
Nitrate-Nitrite N, Total (mg/l)	0.02	30	-----	n.d.	n.d.	0.57	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	30	0.05	0.04	n.d.	0.23	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	30	-----	0.02	n.d.	0.06	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	30	-----	n.d.	n.d.	0.05	-----	-----	-----
Silica, Dissolved (ug/l)	20	9	3,453	3,395	2,923	3,892	-----	-----	-----
Silica, Total (ug/l)	20	9	3,816	3,904	3,089	4,657	-----	-----	-----
Sulfate (mg/l)	0.1	30	119	120	104	130	-----	-----	-----
Suspended Solids, Total (mg/l)	4	30	-----	n.d.	n.d.	10.0	-----	-----	-----
Microcystins (ug/l)	0.05	7	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F). The temperature criterion for a B-2 use, which is not assigned to Fort Peck Reservoir, is 19.4 C (67 F). The temperature criterion of 15 C is given for reference only.

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

(3) Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.3 and 15.0, respectively.

(4) Acute criterion for aquatic life.

(5) Chronic criterion for aquatic life.

(6) Secondary Maximum Contaminant Level based on aesthetic properties.

Table 5.5. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir near Hell Creek Bay at monitoring station FTPLK1805DW (L4) during the period 2004 through 2006.

	Monitoring Results*						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean****	**Median**	**Min.**	**Max.**	**State WQS Criteria*****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	9	2203.2	2202.6	2201.6	2206.2	-----	-----	-----
Water Temperature (C)	0.1	217	16.6	17.0	9.5	24.1	≤ 26.7[1] ≤ 19.4[1] ≤ 15.0[1]	0 56 158	0% 26% 73%
Dissolved Oxygen (mg/l)	0.1	217	8.0	8.5	3.5	9.9	≥ 6.0[2] ≥ 5.0[2] ≥ 4.0[2] ≥ 3.0[2]	21 13 1 0	10% 6% <1% 0%
Dissolved Oxygen (% Sat.)	0.1	217	85.6	89.5	35.3	108.4	-----	-----	-----
Specific Conductance (umho/cm)	1	217	479	481	413	528	-----	-----	-----
pH (S.U.)	0.1	193	8.3	8.4	7.3	8.7	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	216	7.6	6.0	0.3	31.4	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	217	376	360	304	508	-----	-----	-----
Secchi Depth (in)	1	9	84	76	46	120	-----	-----	-----
Alkalinity, Total (mg/l)	7	20	158	160	140	170	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	20	-----	0.04	n.d.	0.21	2.59[3,4] 1.10[3,5]	0 0	0% 0%
Carbon, Total Organic (mg/l)	0.05	20	2.6	2.6	2.4	3.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	6	-----	n.d.	n.d.	8.0	-----	-----	-----
Chloride (mg/l)	0.02	6	17.9	7.5	7.3	70.0	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab	1	9	3	1	1	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field	1	216	-----	n.d.	n.d.	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	20	347	350	294	422	-----	-----	-----
Iron, Dissolved (ug/l)	40	17	-----	n.d.	n.d.	n.d.	1,000[5]	0	0%
Iron, Total (ug/l)	40	13	154	131	60	242	1,000[5]	0	0%
Kjeldahl N, Total (mg/l)	0.1	20	0.3	0.3	0.2	0.5	-----	-----	-----
Manganese, Dissolved (ug/l)	1	13	2.4	1.0	n.d.	7.0	50[6]	0	0%
Manganese, Total (ug/l)	1	13	9.0	6.0	2.0	19.0	50[6]	0	0%
Nitrate-Nitrite N, Total (mg/l)	0.02	20	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	20	0.07	0.04	n.d.	0.34	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	20	-----	0.02	n.d.	0.24	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	20	-----	n.d.	n.d.	0.23	-----	-----	-----
Silica, Dissolved (ug/l)	20	7	3,589	3,617	3,130	4,113	-----	-----	-----
Silica, Total (ug/l)	20	7	3,917	3,748	3,405	4,547	-----	-----	-----
Sulfate (mg/l)	0.1	20	114	120	93	140	-----	-----	-----
Suspended Solids, Total (mg/l)	4	20	-----	n.d.	n.d.	12.0	-----	-----	-----
Microcystins (ug/l)	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F). The temperature criterion for a B-2 use, which is not assigned to Fort Peck Reservoir, is 19.4 C (67 F). The temperature criterion of 15 C is given for reference only.

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

(3) Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.4 and 17.0, respectively.

(4) Acute criterion for aquatic life.

(5) Chronic criterion for aquatic life.

(6) Secondary Maximum Contaminant Level based on aesthetic properties.

Table 5.6. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir in the lower Big Dry Creek arm of the reservoir at monitoring station FTPLKBDCA01 (L5) during the period 2004 through 2006.

	Monitoring Results*						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean****	**Median**	**Min.**	**Max.**	**State WQS Criteria*****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	12	2203.0	2202.9	2199.9	2206.2	-----	-----	-----
Water Temperature (C)	0.1	471	15.0	14.5	8.7	25.4	≤ 26.7(1) ≤ 19.4(1) ≤ 15.0(1)	0 82 210	0% 17% 45%
Dissolved Oxygen (mg/l)	0.1	471	8.4	8.4	5.6	10.0	≥ 6.0(2) ≥ 5.0(2) ≥ 4.0(2) ≥ 3.0(2)	18 0 0 0	4% 0% 0% 0%
Dissolved Oxygen (% Sat.)	0.1	471	86.9	91.1	55.1	110.6	-----	-----	-----
Specific Conductance (umho/cm)	1	470	501	496	350	550	-----	-----	-----
pH (S.U.)	0.1	471	8.3	8.3	7.6	9.0	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	471	6.0	2.4	0.1	45.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	471	382	363	301	507	-----	-----	-----
Secchi Depth (in)	1	12	152	159	76	240	-----	-----	-----

* Results are a combination of all sampling depths.

** The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F). The temperature criterion for a B-2 use, which is not assigned to Fort Peck Reservoir, is 19.4 C (67 F). The temperature criterion of 15 C is given for reference only.

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

Table 5.7. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir in the Big Dry Creek arm near Rock Creek Bay at monitoring station FTPLKBDCA02 (L6) during the period 2004 through 2006.

Parameter	Monitoring Results*						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean**	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	2203.0	2208.9	2199.9	2206.2	-----	-----	-----
Water Temperature (C)	0.1	205	17.8	17.4	13.1	24.1	≤ 26.7(1) ≤ 19.4(1) ≤ 15.0(1)	0 68 178	0% 33% 87%
Dissolved Oxygen (mg/l)	0.1	205	8.4	8.5	5.6	9.5	≥ 6.0(2) ≥ 5.0(2) ≥ 4.0(2) ≥ 3.0(2)	1 0 0 0	<1% 0% 0% 0%
Dissolved Oxygen (% Sat.)	0.1	205	92.3	94.4	59.9	103.0	-----	-----	-----
Specific Conductance (umho/cm)	1	205	512	507	433	563	-----	-----	-----
pH (S.U.)	0.1	188	8.4	8.5	7.9	8.8	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	204	7.0	4.4	0.2	25.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	205	381	362	304	492	-----	-----	-----
Secchi Depth (in)	1	12	101	98	54	172	-----	-----	-----
Alkalinity, Total (mg/l)	7	22	158	162	140	179	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	22	-----	0.04	n.d.	0.25	2.14(3,4) 0.77(3,5)	0 0	0% 0%
Carbon, Total Organic (mg/l)	0.05	22	2.6	2.5	2.3	2.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	-----	7	n.d.	9	-----	-----	-----
Chloride (mg/l)	0.02	8	7.6	7.5	7.4	7.9	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab	1	12	----	n.d.	n.d.	7.0	-----	-----	-----
Chlorophyll *a* (ug/l) – Field	1	204	-----	n.d.	n.d.	5.4	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	22	367	360	315	479	-----	-----	-----
Iron, Dissolved (ug/l)	40	15	-----	n.d.	n.d.	70	1,000(5)	0	0%
Iron, Total (ug/l)	40	15	128	100	n.d.	277	1,000(5)	0	0%
Kjeldahl N, Total (mg/l)	0.1	22	0.3	0.3	0.2	0.5	-----	-----	-----
Manganese, Dissolved (ug/l)	1	15	-----	2.0	n.d.	5.5	50(6)	0	0%
Manganese, Total (ug/l)	1	15	6.0	6.0	2.0	13.0	50(6)	0	0%
Nitrate-Nitrite N, Total (mg/l)	0.02	22	-----	n.d.	n.d.	0.17	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	21	0.04	0.03	n.d.	0.13	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	22	-----	0.01	n.d.	0.08	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	22	-----	n.d.	n.d.	0.04	-----	-----	-----
Silica, Dissolved (ug/l)	20	7	2,835	2,818	2,554	3,135	-----	-----	-----
Silica, Total (ug/l)	20	7	3,161	3,108	2,908	3,840	-----	-----	-----
Sulfate (mg/l)	0.1	22	129	128	110	180	-----	-----	-----
Suspended Solids, Total (mg/l)	4	22	-----	n.d.	n.d.	10.0	-----	-----	-----
Microcystins (ug/l)	0.05	7	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F). The temperature criterion for a B-2 use, which is not assigned to Fort Peck Reservoir, is 19.4 C (67 F). The temperature criterion of 15 C is given for reference only.

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

(3) Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.5 and 17.4, respectively.

(4) Acute criterion for aquatic life.

(5) Chronic criterion for aquatic life.

(6) Secondary Maximum Contaminant Level based on aesthetic properties.

5.1.2.2 Spatial Variation

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile water temperature measurements taken at reservoir monitoring sites during the period 2004 through 2006 (Plates 1 through 12). The contour plots were constructed along two longitudinal axes – the Missouri River mainstem arm (sites L1, L2, L3, and L4) and the Big Dry Creek arm (sites L5 and L6). As seen in Plates 1 through 12, temperatures in Fort Peck Reservoir vary longitudinally from the dam to the reservoir's upper reaches and vertically from the reservoir surface to the bottom. The near-surface water in the upper reaches of the reservoir warms up sooner in the spring than the near-surface water near the dam (Plates 1, 5, and 9). By mid-summer a strong thermocline becomes established in the lower reaches of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature (Plates 2, 6, and 10). As the near-surface waters of the reservoir cool in the late summer, the thermocline is pushed deeper and these wind-mixed upper waters are fairly uniform in temperature (Plates 4, 8, and 12). The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam where a strong thermocline becomes established during the summer. The shallower upper reaches of Fort Peck Reservoir do not exhibit much vertical variation of temperature during mid to late summer as wind action allows for complete mixing of the water column.

5.1.2.3 Summer Thermal Stratification

Fort Peck Reservoir exhibited significant thermal stratification during the summer of all 3 years (Plates 2, 3, 6, 7, 10, and 11). During maximum stratification in mid-summer, the thermocline in Fort Peck Reservoir in 2004, 2005, and 2006 was at a depth of about 20 meters (65 feet). The depth of the thermocline defines the upper limit of the hypolimnion. Where the corresponding elevation of the thermocline intersects the reservoir bottom defines the longitudinal boundary of the hypolimnion in the upper reaches of Fort Peck Reservoir. During 2004 through 2006, the longitudinal boundary of the hypolimnion in the Missouri River Arm was around River Mile 1830. Taking the slope of the reservoir bottom to be about 1.5 feet/mile along the old Missouri River channel, every foot of elevation increase in the pool elevation would extend the boundary of the hypolimnion about 0.7 mile up the reservoir.

5.1.3 DISSOLVED OXYGEN

5.1.3.1 Spatial Variation

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile dissolved oxygen measurements taken at reservoir monitoring sites during the period 2004 through 2006 (Plates 13 through 24). The contour plots were constructed along two longitudinal axes – the Missouri River mainstem arm (sites L1, L2, L3, and L4) and the Big Dry Creek arm (sites L5 and L6). As seen in Plates 13 through 24, dissolved oxygen concentrations in Fort Peck Reservoir vary longitudinally from the dam to reservoir's upper reaches, and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l first appeared near the reservoir bottom in the middle reaches of the Missouri River Arm in August (Plates 15, 19, and 23). The lowest dissolved oxygen concentrations remained in this area of the reservoir through fall turnover (Plates 16, 20, and 24). Near-bottom dissolved oxygen concentrations near the dam remained above 5 mg/l throughout all 3 years of the monitored period 2004 through 2006. The earlier occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Fort Peck Reservoir is attributed to the increased allochthonous organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with low dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone.

The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the lacustrine zone nearer the dam because of the time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water.

5.1.4 WATER CLARITY

5.1.4.1 Secchi Transparency

Figure 5.1 displays the distribution of the Secchi depth transparencies measured at the six in-reservoir monitoring sites as a box plot (note: the six monitoring sites are oriented in an upstream to downstream direction along the x-axis for both arms of the reservoir). Secchi depth transparency increased in a downstream direction from site L4 to site L1 in the Missouri River Arm and from L6 to L5 in the Big Dry Creek Arm. Downstream of site L3 in the Missouri River Arm, Secchi depth transparency did not show significant longitudinal variation. Under the conditions that were monitored during the 2004 to 2006 period, it appears that sites L4, L3, and L6 were in the vicinity of the boundary between the reservoir's transition and lacustrine zones.

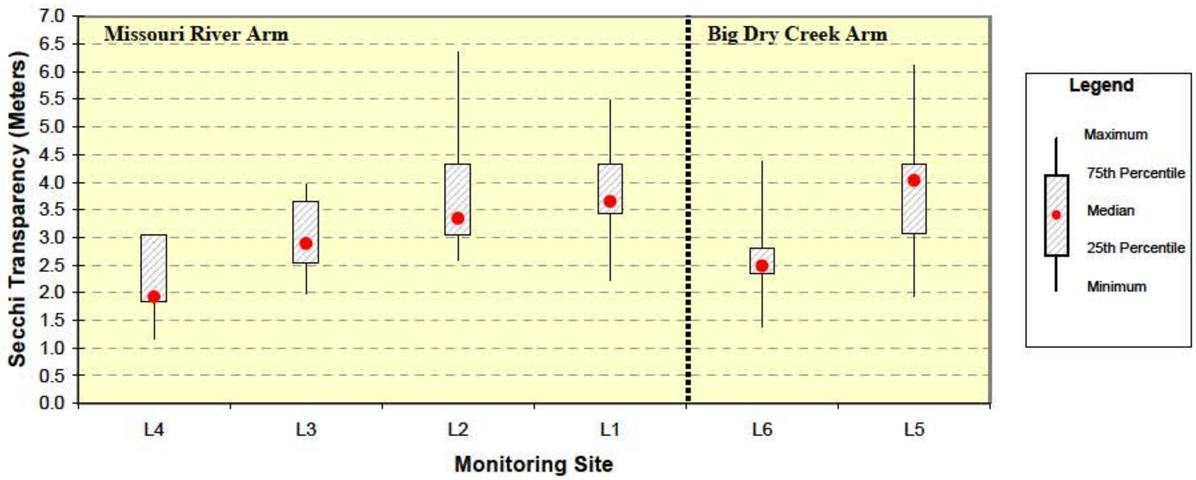

Figure 5.1. Box plot of Secchi transparencies measured at sites L1 through L6 during the period 2004 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction for both arms of the reservoir.)

5.1.4.2 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Given the low chlorophyll *a* concentrations monitored, (Tables 5.1 through 5.7), turbidity in Fort Peck Reservoir is largely due to suspended inorganic material. Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites L1, L2, L3, L4, L5, and L6 during the period 2004 through 2006 (Plates 25 through 36). As seen in Plates 25 through 36, turbidity levels in Fort Peck Reservoir vary longitudinally from the dam to reservoir's upper reaches and vertically from the reservoir surface to the bottom. Turbidity levels are noticeably higher in the upper reaches of the Missouri River Arm of the reservoir as compared to the area near the dam. This is attributed to the turbid conditions of the inflowing Missouri River. It also appears that slight turbidity plumes may move through the reservoir as interflows (Plates 26, 29, 30, 31, and 32).

5.1.5 NUTRIENT CONDITIONS

5.1.5.1 Trophic Status

Trophic State Index (TSI) values for Fort Peck Reservoir were calculated from the monitoring data collected at sites L1, L2, L3, L4, L5, and L6 during the period 2004 through 2006 (Table 5.8). The calculated TSI values indicate that region of Fort Peck Reservoir represented by the monitored sites (i.e., sites L1, L3, L4, and L6) is in a mesotrophic state.

Table 5.8. Mean Trophic State Index (TSI) values calculated for Fort Peck Reservoir at four reservoir monitoring locations based on measured Secchi depth, total phosphorus, and chlorophyll *a* values during the period 2004 through 2006.

Site	No. of Obs.	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
L1	15	43	53	41	46
L3	12	45	54	41	46
L4	9	50	56	45	50
L6	12	47	53	42	47

5.1.5.2 Variation of Nutrient Levels with Reservoir Depth

Depth-discrete nutrient levels were determined based on near-surface and near-bottom samples collected at site L1 during May through September over the period 2004 through 2006 (Table 5.9). Nutrient levels did not vary appreciably with depth.

5.1.5.3 Missouri River Nutrient Flux Conditions

Nutrient flux rates for the Missouri River were calculated based on water quality samples collected near Landusky, Montana (i.e. site NF1) and estimated instantaneous flow conditions at the time of sample collection (Table 5.10). The maximum nutrient flux rates are attributed to greater nonpoint source nutrient loadings associated with runoff conditions.

5.1.6 PHYTOPLANKTON COMMUNITY

Forty-eight individual phytoplankton grab samples were collected from Fort Peck Reservoir at sites L1, L3, L4, and L6 during the period 2004 through 2006. Collected algae included taxa from the following seven taxonomic Divisions: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Euglenophyta (Euglenoid Algae), and Pyrrophyta (Dinoflagellate Algae). Plate 37 summarizes the percent taxa composition by Division, based on biovolume, of the monthly phytoplankton samples. The prevalence of these groups of algae in Fort Peck Reservoir from greatest to least, based on taxa occurrence and abundance, were Bacillariophyta > Chlorophyta/Cryptophyta/Cyanobacteria > Pyrrophyta > Chrysophyta >> Euglenophyta. The diatoms were generally the most prevalent algae throughout the entire sampling period. Plate 38 lists the algal genera/species collected and their frequency of occurrence and relative abundance. No significant concentrations of the microcystins toxin were measured in Fort Peck Reservoir.

Table 5.9. Mean and median depth discrete nutrient concentrations measured at site L1 during the period 2004 through 2006.

Nutrient	Near-Surface (0-2 Meters)	Mid-Depth (10-29 Meters)	Near-Bottom (44-51 Meters)
Kjeldahl N, Total (mg/l)			
• No. of Obs.	15	7	15
• Mean	0.25	0.27	0.27
• Median	0.21	0.26	0.22
Ammonia N, Total (mg/l)			
• No. of Obs.	15	7	15
• Mean	0.06	0.09	0.06
• Median	0.03	0.04	0.03
Nitrate-Nitrite N, Total (mg/)			
• No. of Obs.	15	7	15
• Mean	<0.02	<0.02	<0.02
• Median	<0.02	<0.02	<0.02
Phosphorus, Total (mg/l)			
• No. of Obs.	15	7	15
• Mean	0.08	0.06	0.10
• Median	0.04	0.04	0.04
Phosphorus, Dissolved (mg/l)			
• No. of Obs.	15	7	10
• Mean	0.03	0.02	0.03
• Median	0.02	0.02	0.03
Total Organic Carbon (mg/l)			
• No. of Obs.	14	7	14
• Mean	2.5	2.4	2.4
• Median	2.5	2.4	2.4

Table 5.10. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Landusky, Montana during May through September over the period 2004 through 2006.

Statistic	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	11	11	11	11	10	11
Mean	0.028	0.168	-----	0.084	0.006	0.569
Median	0.027	0.105	n.d.	0.019	0.005	0.457
Minimum	n.d.	0.035	n.d.	0.004	n.d.	0.296
Maximum	0.092	0.795	0.048	0.553	0.016	1.140

n.d. = non-detectable.

Note: Statistics of Missouri River flows used for flux calculations were: mean = 7,059 cfs, median = 6,200 cfs, minimum = 4,040 cfs, and maximum = 12,200 cfs.

5.2 COLDWATER HABITAT IN FORT PECK RESERVOIR

5.2.1 ANNUAL OCCURRENCE OF COLDWATER HABITAT

The occurrence of coldwater habitat in Fort Peck Reservoir is directly dependent on the reservoir's annual thermal regime. Early in the winter ice-cover period, the entire reservoir volume will be supportive of coldwater habitat. As the winter ice-cover period continues, lower dissolved oxygen concentrations may occur near the bottom as organic matter decomposes and reservoir mixing is prevented by ice cover. As dissolved oxygen concentrations in the near-bottom water fall below 5 mg/l, coldwater habitat will not be supported. During the spring isothermal period, water temperatures and dissolved oxygen levels in the entire reservoir volume will be supportive of coldwater habitat. During the early-summer reservoir warming period, coldwater habitat will progressively decrease as water temperatures in the epilimnion become non-supportive of coldwater habitat. During mid-summer when Fort Peck Reservoir is experiencing maximum thermal stratification, water temperatures will only be supportive of coldwater habitat in the hypolimnion. Theoretically, coldwater habitat should remain stable during this period unless degradation of dissolved oxygen concentrations near the reservoir bottom become non-supportive of coldwater habitat. The most critical period for the support of coldwater habitat in Fort Peck Reservoir is when the reservoir begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion will continue to decrease while the expanding epilminion may not yet be cold enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and potentially pinching off coldwater habitat from below. This situation will continue until the epilimnion cools enough to be supportive of coldwater habitat. When fall turnover occurs, dissolved oxygen concentrations at all depths will be near saturation and supportive of coldwater habitat.

5.2.2 INTERACTION OF WATER TEMPERATURE AND DISSOLVED OXYGEN IN DETERMINING THE OCCURRENCE OF COLDWATER HABITAT

The occurrence of coldwater habitat is determined by the interaction of water temperature and dissolved oxygen concentrations as they vary with reservoir depth. The interaction of varying water temperature and dissolved oxygen with depth in determining the occurrence of coldwater habitat at the near-dam, deepwater station (i.e., site L1) is shown in Figure 5.2. Figure 5.2 plots the 19.4°C water temperature and 5 mg/l dissolved oxygen concentration isopleths at station L1 for 2004, 2005, and 2006. It is noted that dissolved oxygen concentrations below 5 mg/l were not measured at site L1 during the monitored period. A dissolved oxygen concentration of 5.0 mg/l was measured near the reservoir bottom on September 22, 2004. Coldwater habitat is represented by the area between the 19.4°C and 5 mg/l isopleths. As shown in Figure 5.2, the increasing depth of 19.4°C water during the summer, resulted in a decline in the occurrence of coldwater habitat at site L1.

5.2.3 OCCURRENCE OF COLDWATER HABITAT DURING THE PERIOD 2004 THROUGH 2006

The volumes of total and optimal coldwater habitat estimated to be present in Fort Peck Reservoir during 2004 to 2006 are given in Plates 39 through 50. Figure 5.3 shows the total reservoir volume and the amount of total and optimal coldwater habitat estimated to have been present in Fort Peck Reservoir during 2004, 2005, and 2006. The estimated total coldwater habitat progressively decreased from June through August and then increased in September/October in all 3 years (Figure 5.3). The estimated optimal coldwater habitat progressively decreased from June through September in 2004 and 2005, and from June through August of 2006, after which it increased in October 2006 (Figure 5.3).

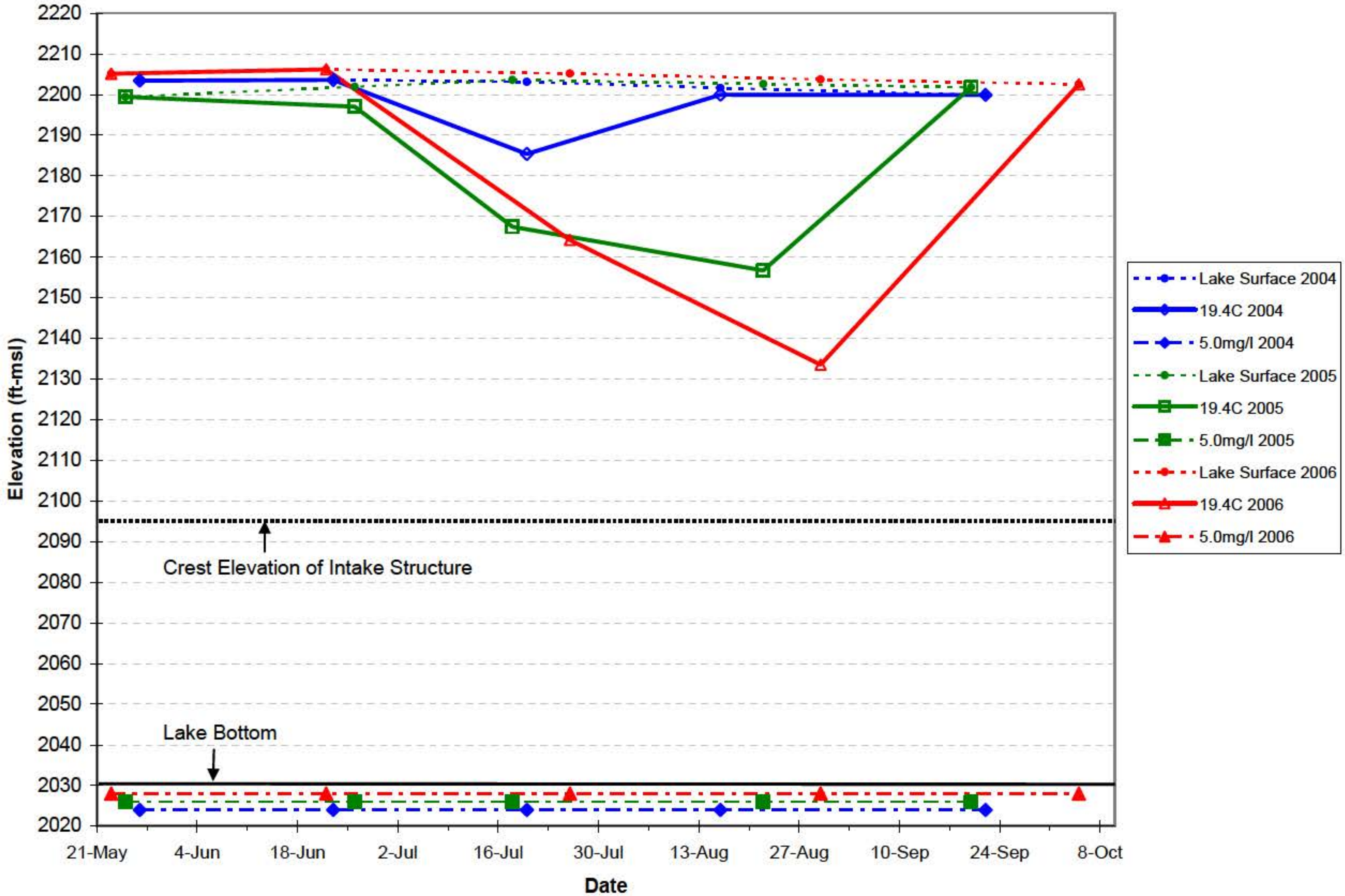

Figure 5.2. Elevation of reservoir surface and 19.4°C water temperature and 5 mg/l dissolved oxygen concentration isopleths by year for station L1.

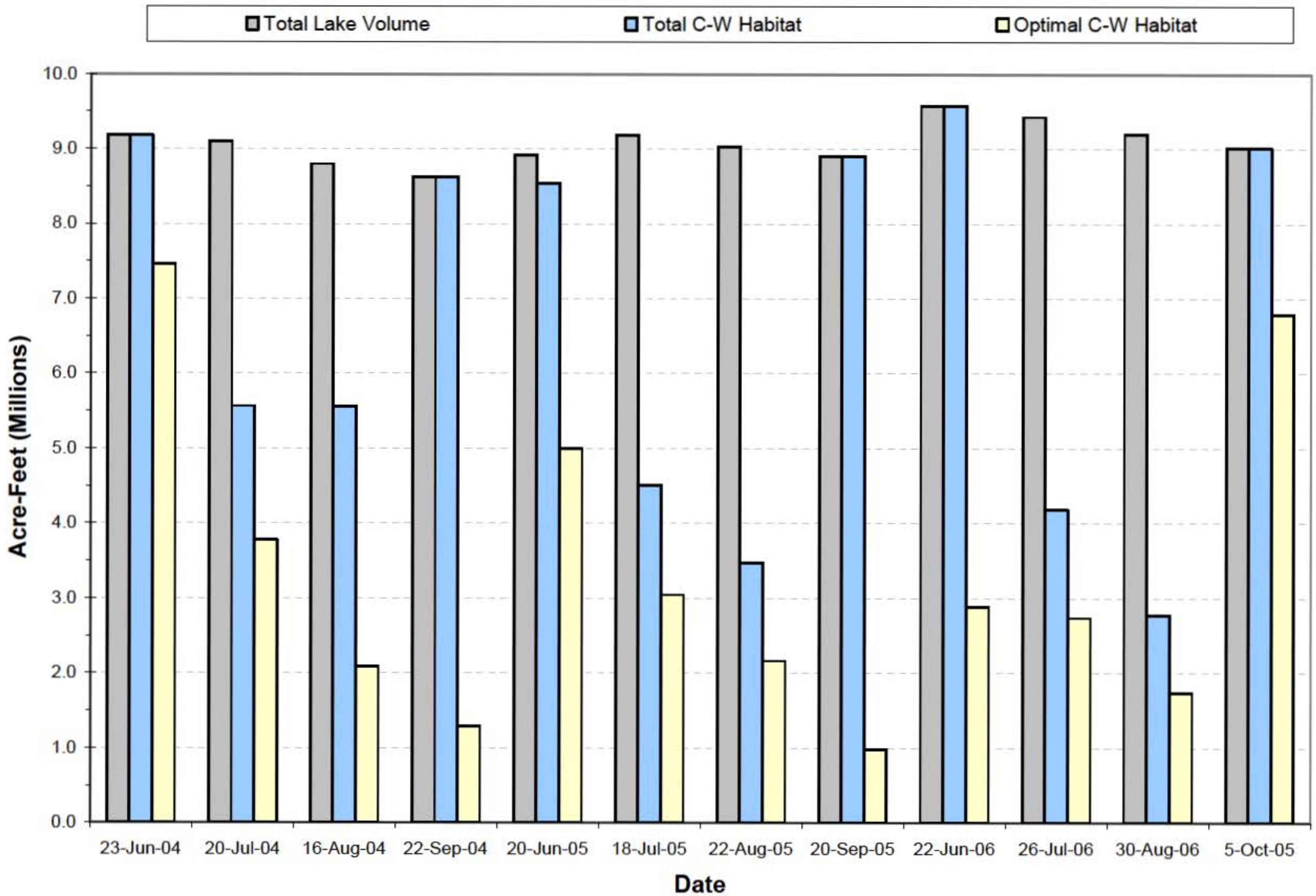

Figure 5.3. Total reservoir volume and the amount of coldwater habitat estimated to be present in Fort Peck Reservoir during 2004, 2005, and 2006.

6 WATER QUALITY CONDITIONS OF INFLOWS TO FORT PECK RESERVOIR

6.1 STATISTICAL SUMMARY AND WATER QUALITY STANDARDS ATTAINMENT

Statistical summaries of water quality conditions monitored at the three inflow sites, based on the collected grab samples, are given in Table 6.1 through 6.3. Table 6.1 summarizes the water quality conditions that were monitored in the Missouri River near Landusky, Montana (site NF1) during the period 2004 through 2006. Table 6.2 summarizes the water quality conditions that were monitored in the Musselshell River at Mosby, Montana (site NF2) during the period 2004 through 2005. Table 6.2 summarizes the water quality conditions that were monitored in Big Dry Creek near Jordan, Montana (site NF3) during 2004. Review of these results indicated no major water quality concerns. However, it is noted that all three sites exhibited very high levels of total iron and manganese. This is believed to be a natural condition associated with the geology and soils of the region.

6.2 CONTINUOUS WATER TEMPERATURE MONITORING OF THE MISSOURI RIVER AT THE USGS GAGING STATION NEAR LANDUSKY, MONTANA

Figures 6.1 and 6.2, respectively, plot water temperature and streamflow for the Missouri River, as recorded at the USGS's Landusky gaging station (USGS Gage Number 06115200) for water years 2005 and 2006.

Table 6.1. Summary of monthly (May through September) water quality conditions monitored in the Missouri River near Landusky, Montana at monitoring Station FTPNFMORR1 (NF1) during the period 2004 through 2006**.**

	Monitoring Results*						Water Quality Standards Attainment		
Parameter	Detection Limit	No. of Obs.	Mean**	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	10	11	7,059	6,200	4,040	12,200	-----	-----	-----
Water Temperature (C)	0.1	11	18.5	18.3	12.8	25.7	≤ 26.7[1]	0	0%
Dissolved Oxygen (mg/l)	0.1	11	8.2	8.2	7.1	9.7	≥ 6.0[2] ≥ 5.0[2] ≥ 4.0[2] ≥ 3.0[2]	0 0 0 0	0% 0% 0% 0%
Dissolved Oxygen (% Sat.)	0.1	11	90.9	89.9	81.2	101.0	-----	-----	-----
Specific Conductance (umho/cm)	1	11	431	430	342	563	-----	-----	-----
pH (S.U.)	0.1	11	8.4	8.4	8.1	8.9	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	11	353	90	1	2,100	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	11	359	356	287	436	-----	-----	-----
Alkalinity, Total (mg/l)	7	11	146	144	120	163	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	11	0.16	0.13	n.d.	0.40	3.88[3,4] 1.0[3,5]	0 0	0% 0%
Carbon, Total Organic (mg/l)	0.05	11	2.8	2.6	2.2	3.4	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	4	7.3	6.5	4.0	12.0	-----	-----	-----
Chloride (mg/l)	0.02	3	6.8	7.3	5.5	7.8	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	10	318	315	255	388	-----	-----	-----
Iron, Dissolved (ug/l)	40	11	-----	n.d.	n.d.	40	1,000[5]	0	0%
Iron, Total (ug/l)	40	11	8,704	3,047	755	50,221	1,000[5]	10	91%
Kjeldahl N, Total (mg/l)	0.1	11	0.7	0.5	0.2	2.3	-----	-----	-----
Manganese, Dissolved (ug/l)	1	10	3.8	2.5	n.d.	12.0	50[6]	0	0%
Manganese, Total (ug/l)	1	11	121	62	23	533	50[6]	6	55%
Nitrate-Nitrite N, Total (mg/l)	0.02	11	-----	n.d.	n.d.	0.15	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	11	0.29	0.13	0.03	1.60	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	10	0.03	0.03	n.d.	0.07	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	11	-----	n.d.	n.d.	0.03	-----	-----	-----
Silica, Dissolved (ug/l)	20	7	4,704	4,831	3,621	5,463	-----	-----	-----
Silica, Total (ug/l)	20	7	15,740	12,144	6,917	30,143	-----	-----	-----
Sulfate (mg/l)	0.1	11	87	83	51	162	-----	-----	-----
Suspended Solids, Total (mg/l)	4	11	342	122	26	2,000	-----	-----	-----
Pesticide Scan (ug/l)	0.05	1	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F).

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

(3) Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.4 and 18 3, respectively.

(4) Acute criterion for aquatic life.

(5) Chronic criterion for aquatic life.

(6) Secondary Maximum Contaminant Level based on aesthetic properties.

Table 6.2. Summary of monthly (May through September) water quality conditions monitored in the Musselshell River at Mosby, Montana at monitoring station FTPNFMSLR1 (NF2) during the period 2004 through 2005.

Parameter	Monitoring Results*						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean**	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	3	122	43	4	319	-----	-----	-----
Water Temperature (C)	0.1	3	20.2	19.0	16.7	25.0	≤ 26.7(1)	0	0%
Dissolved Oxygen (mg/l)	0.1	3	8.0	8.2	7.1	8.7	≥ 6.0(2) ≥ 5.0(2) ≥ 4.0(2) ≥ 3.0(2)	0 0 0 0	0% 0% 0% 0%
Dissolved Oxygen (% Sat.)	0.1	3	92.0	93.2	89.1	93.8	-----	-----	-----
Specific Conductance (umho/cm)	1	3	2,287	2,848	887	3,127	-----	-----	-----
pH (S.U.)	0.1	3	8.4	8.4	8.3	8.5	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	3	220.8	55.7	14.1	592.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	3	342	327	301	398	-----	-----	-----
Alkalinity, Total (mg/l)	7	3	249	240	233	273	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	3	0.21	0.14	0.07	0.41	3.88(3,4) 0.95(3,5)	0 0	0% 0%
Carbon, Total Organic (mg/l)	0.05	3	6.2	6.8	5.0	6.9	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	3	1,847	2,258	764	2,519	-----	-----	-----
Iron, Dissolved (ug/l)	40	3	-----	n.d.	n.d.	n.d.	1,000(5)	0	0%
Iron, Total (ug/l)	40	3	4,528	1,583	427	11,573	1,000(5)	2	67%
Kjeldahl N, Total (mg/l)	0.1	3	0.8	0.6	0.4	1.3	-----	-----	-----
Manganese, Dissolved (ug/l)	1	3	12.2	7.7	2.0	27.0	50(6)	0	0%
Manganese, Total (ug/l)	1	3	132	97	79	220	50(6)	3	100%
Nitrate-Nitrite N, Total (mg/l)	0.02	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	3	0.23	0.07	0.04	0.57	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	3	0.02	0.02	0.01	0.04	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	3	-----	n.d.	n.d.	0.01	-----	-----	-----
Silica, Dissolved (ug/l)	20	3	3,016	3,211	1,323	4,514	-----	-----	-----
Silica, Total (ug/l)	20	3	10,919	4,514	1,323	26,919	-----	-----	-----
Sulfate (mg/l)	0.1	3	670	360	163	1,576	-----	-----	-----
Suspended Solids, Total (mg/l)	4	3	173	95	24	400	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F).

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

(3) Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.4 and 19.0, respectively.

(4) Acute criterion for aquatic life.

(5) Chronic criterion for aquatic life.

(6) Secondary Maximum Contaminant Level based on aesthetic properties.

Table 6.3. Summary of monthly (May through September) water quality conditions monitored in Big Dry Creek near Jordan, Montana at monitoring station FTPNFBDCK1 (NF3) during 2004.

Parameter	Monitoring Results*						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean**	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	0.1	3	3.7	3.0	3.0	5.0	-----	-----	-----
Water Temperature (C)	0.1	3	18.7	17.7	13.1	25.3	≤ 26.7(1)	0	0%
Dissolved Oxygen (mg/l)	0.1	3	8.2	8.0	7.6	8.9	≥ 6.0(2) ≥ 5.0(2) ≥ 4.0(2) ≥ 3.0(2)	0 0 0 0	0% 0% 0% 0%
Dissolved Oxygen (% Sat.)	0.1	3	90.9	88.2	87.7	96.9	-----	-----	-----
Specific Conductance (umho/cm)	1	3	2,357	2,395	1,603	3,072	-----	-----	-----
pH (S.U.)	0.1	3	8.9	8.8	8.8	8.9	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	3	233.9	292.3	66.3	343.2	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	3	325	312	279	385	-----	-----	-----
Alkalinity, Total (mg/l)	7	3	393	375	310	493	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	3	0.26	0.26	0.12	0.41	1.84(3,4) 0.46(3,5)	0 0	0% 0%
Carbon, Total Organic (mg/l)	0.05	3	10.7	11.0	9.0	12.0	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	3	1,652	1,742	1,104	2,111	-----	-----	-----
Iron, Dissolved (ug/l)	40	3	-----	100	n.d.	235	1,000(5)	0	0%
Iron, Total (ug/l)	40	3	4,569	5,657	1,552	6,497	1,000(5)	3	100%
Kjeldahl N, Total (mg/l)	0.1	3	1.1	1.1	0.9	1.3	-----	-----	-----
Manganese, Dissolved (ug/l)	1	3	6.6	8.8	1.0	10.0	50(6)	0	0%
Manganese, Total (ug/l)	1	3	210	181	111	337	50(6)	3	100%
Nitrate-Nitrite N, Total (mg/l)	0.02	3	-----	0.03	n.d.	0.35	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	3	0.22	0.18	0.17	0.30	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	3	0.07	0.06	0.05	0.11	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	3	-----	n.d.	n.d.	0.01	-----	-----	-----
Silica, Dissolved (ug/l)	20	3	1,824	2,140	381	2,952	-----	-----	-----
Silica, Total (ug/l)	20	3	13,441	16,353	4,691	19,280	-----	-----	-----
Sulfate (mg/l)	0.1	3	650	693	167	1,091	-----	-----	-----
Suspended Solids, Total (mg/l)	4	3	134	158	60	184	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** (1) Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F).

(2) 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

(3) Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.8 and 17.7, respectively.

(4) Acute criterion for aquatic life.

(5) Chronic criterion for aquatic life.

(6) Secondary Maximum Contaminant Level based on aesthetic properties.

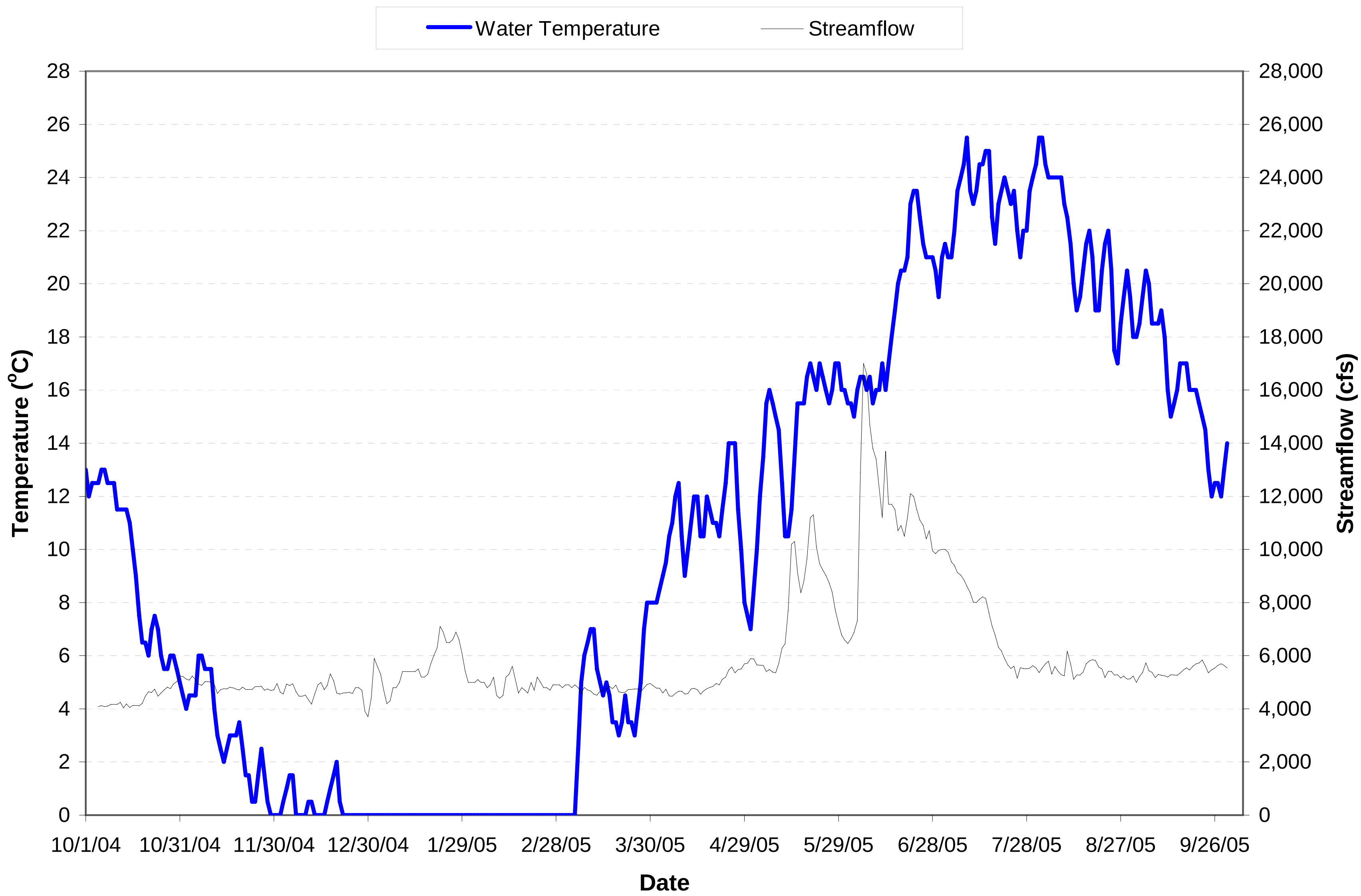

Figure 6.1. Mean daily water temperature and streamflow of the Missouri River at inflow site NF1 for water year 2005 (i.e., October 2004 through September 2005). Means based on hourly measurements recorded at USGS gaging station 06115200.

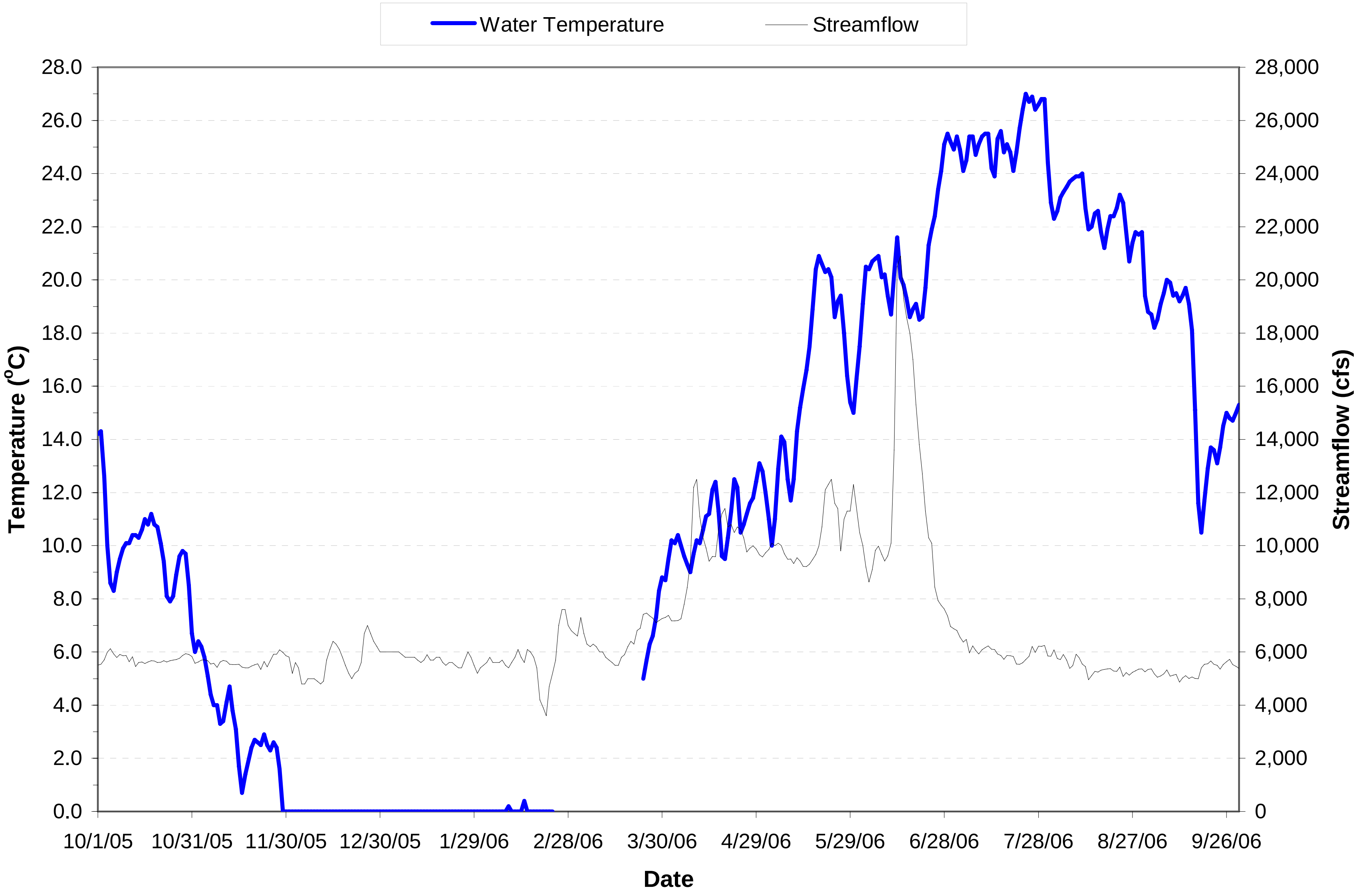

Figure 6.2. Mean daily water temperature and streamflow of the Missouri River at inflow site NF1 for water year 2006 (i.e., October 2005 through September 2006). Means based on hourly measurements recorded at USGS gaging station 06115200. (Gaps in plot indicate missing data).

7 WATER QUALITY CONDITIONS OF THE MISSOURI RIVER DOWNSTREAM OF FORT PECK DAM

7.1 WATER QUALITY CONDITIONS OF WATER DISCHARGED THROUGH FORT PECK DAM

7.1.1 STATISTICAL SUMMARY AND WATER QUALITY STANDARDS ATTAINMENT

Table 7.1 summarizes the water quality conditions that were monitored monthly in the Fort Peck Dam powerplant during the period 2004 through 2006. These results indicate no major water quality standards concerns. However, it is noted that all water temperature measurements are below the 18°C target level for the Missouri River at Frazer Rapids (i.e., approximately 25 miles downstream of Fort Peck Dam) for enhancement of the pallid sturgeon population (see Section 7.3 for additional discussion).

7.1.2 WATER TEMPERATURE

Continuous monitoring of water quality conditions of water drawn from the "raw water supply line" within the Fort Peck powerplant was started on January 1, 2004. Plots of the hourly water temperatures recorded at this site from January 2004 through December 2006 are shown in Plates 51 through 62. Also shown on these plots is the hourly discharge rate of Fort Peck Dam. During the January through March period, water temperatures were fairly stable at around 2°C and exhibited no observable fluctuation with changing dam discharge rates (Plates 51, 55, and 59). From April through June, water temperatures exhibited a steady increase to a maximum of 12° to 14°C at the end of the period, and no direct correlation was observable between discharge rate and temperature (Plates 52, 56, and 60). During the July through September period, water temperatures continued to increase, albeit more slowly, and exhibited large irregular fluctuations (Plates 53, 57, and 61). Discharge rate did not appear to be a dominant factor contributing to the observed temperature fluctuations during this period. The temperature fluctuations in the discharge water during this period could be attributed to irregular movement of the thermocline depth in Fort Peck Reservoir with periodic climatic events. From September through December, water temperatures exhibited a steady decline to below 4°C and little fluctuation with changing dam discharge rates (Plates 54, 58, and 62).

7.1.3 DISSOLVED OXYGEN

Plots of the hourly dissolved oxygen concentrations recorded on water drawn from the "raw water supply line" in the Fort Peck powerplant during 2004 through 2006 are shown in Plates 63 through 74. Also shown on these plots is the hourly discharge rate of Fort Peck Dam. During the January through March period, dissolved oxygen levels were fairly stable at about 12 mg/l (Plates 63, 67, and 71). From April through June, dissolved oxygen levels exhibited a steady decrease to a minimum of about 8 mg/l at the end of the period, and little fluctuation of dissolved oxygen with dam discharge was noted (Plates 64, 68, and 72). During the July through September period, dissolved oxygen levels continued to decrease to a minimum of about 6 mg/l and exhibited some irregular daily variation (Plates 65, 69, and 73). Once the reservoir experienced fall turn-over in late September or early October, dissolved oxygen levels exhibited a steady increase to about 12 mg/l and little daily fluctuation (Plates 66, 70. and 74).

Table 7.1. Summary of monthly (year-round) water quality conditions monitored at the Fort Peck Dam powerplant at monitoring station FTPPP1 (OF1) during the period 2004 through 2006.

	Monitoring Results*						Water Quality Standards Attainment		
Parameter	Detection Limit	No. of Obs.	Mean**	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	27	2201.7	2202.0	2198.3	2206.2	-----	-----	-----
Water Temperature (C)	0.1	27	9.8	10.6	1.4	16.8	≤ 26.7[1]	0	0%
							≤ 19.4[1]	0	0%
							≤ 15.0[1]	4	15%
Dissolved Oxygen (mg/l)	0.1	27	9.6	9.6	6.0	13.8	≥ 6.0[2]	0	0%
							≥ 5.0[2]	0	0%
							≥ 4.0[2]	0	0%
							≥ 3.0[2]	0	0%
Dissolved Oxygen (% Sat.)	0.1	27	88.8	91.2	62.7	103.2	-----	-----	-----
Specific Conductance (umho/cm)	1	27	506	511	405	704	-----	-----	-----
pH (S.U.)	0.1	23	8.2	8.2	7.8	8.5	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	5	2.1	2.1	1.8	2.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	10	442	431	342	575	-----	-----	-----
Alkalinity, Total (mg/l)	7	27	162	163	140	180	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	27	0.09	0.03	n.d.	0.51	3.80[3,4]	0	0%
							1.79[3,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	27	2.7	2.4	2.2	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	10	----	5.0	n.d.	9.0	-----	-----	-----
Chloride (mg/l)	0.02	8	8.1	7.6	7.4	10.0	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	27	354	349	306	481	-----	-----	-----
Iron, Dissolved (ug/l)	40	23	-----	n.d.	n.d.	40	1,000[5]	0	0%
Iron, Total (ug/l)	40	26	169	139	n.d.	683	1,000[5]	0	0%
Kjeldahl N, Total (mg/l)	0.1	27	0.4	0.2	n.d.	2.2	-----	-----	-----
Manganese, Dissolved (ug/l)	1	23	-----	1	n.d.	10	50[6]	0	0%
Manganese, Total (ug/l)	1	23	10	7	2	38	50[6]	0	0%
Nitrate-Nitrite N, Total (mg/l)	0.02	27	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	27	0.04	0.03	n.d.	0.14	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.01	17	-----	n.d.	n.d.	0.08	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	27	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	0.1	27	133	128	57	209	-----	-----	-----
Suspended Solids, Total (mg/l)	4	27	----	n.d.	n.d.	80	-----	-----	-----

n.d. = Not detected.

* Results are a combination of all sampling depths.

** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

*** [1] Numeric temperature criterion given in Montana water quality standards for a B-3 use is 26.7 C (80 F). The temperature criterion for a B-2 use, which is not assigned to Fort Peck Reservoir, is 19.4 C (67 F). The temperature criterion of 15 C is given for reference only.

[2] 6.0 = 7-Day Mean for Early Life Stages, 5.0 = 1-Day Minimum for Early Life Stages, 4.0 = 7-Day Mean Minimum for Other Life Stages, 3.0 = 1-Day Minimum for Other Life Stages. Early life stage includes all embryonic and larval stages and all juvenile fish to 30 days following hatching.

[3] Total ammonia criteria pH and temperature dependent – criteria listed are for the median pH and temperature values of 8.2 and 10.6, respectively.

[4] Acute criterion for aquatic life.

[5] Chronic criterion for aquatic life.

[6] Secondary Maximum Contaminant Level based on aesthetic properties.

Table 7.2. Summary of annual (May and August) water quality conditions monitored at the Fort Peck Dam powerplant at monitoring station FTPPP1 (OF1) during the period 2004 through 2006.

Parameter	Monitoring Results*						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean**	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Hardness, Dissolved (mg/l)	0.4	4	208	209	201	213	-----	-----	-----
Antimony, Dissolved (ug/l)	20	2	-----	n.d.	n.d.	n.d.	5.6(3)	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	3.0	340(1) 150(2) 10(3)	0 0 0	0% 0% 0%
Beryllium, Dissolved (ug/l)	4	2	-----	n.d.	n.d.	n.d.	4(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	4.5(1) 0.5(2) 5(3)	0 0 0	0% 0% 0%
Chromium, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	34	3,298(1) 158(2)	0 0	0% 0%
Copper, Dissolved (ug/l)	2	4	-----	3.5.	n.d.	4.0	28.0(1) 17.5(2) 1,300(3)	0 0 0	0% 0% 0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	208(1) 8.1(2) 15(3)	0 0 0	0% 0% 0%
Mercury, Total (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	1.7(1) 0.91(2) 0.05(3)	0 0 0	0% 0% 0%
Nickel, Dissolved (ug/l)	3	5	-----	n.d.	n.d.	n.d.	875(1) 97(2) 100(3)	0 0 0	0% 0% 0%
Selenium, Total (ug/l)	4	4	-----	n.d.	n.d.	n.d.	20(1) 5(2) 50(3)	0 0 0	0% 0% 0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	14.4(1) 100(3)	0 0	0% 0%
Zinc, Dissolved (ug/l)	3	4	6.5	7.0	4.0	8.0	224(1,2) 2,000(3)	0 0	0% 0%
Pesticide Scan (ug/l)****	0.05	2	-----	n.d.	n.d.	n.d.	*****	-----	-----

n.d. = Not detected.
* Pesticide scan run on May near-surface samples and metals analyses run on August near-surface samples.
** Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
*** (1) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based – criteria listed are based on a median hardness value of 209.)
(2) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based – criteria listed are based on a median hardness value of 209.)
(3) Human health criterion for surface waters.
**** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.
***** Some pesticides do not have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

7.2 COMPARISON OF MONITORED INFLOW AND OUTFLOW TEMPERATURES OF THE MISSOURI RIVER AT FORT PECK RESERVOIR

Figures 7.1 and 7.2, respectively, plot the mean daily water temperatures monitored at the Missouri River near Landusky, Montana (site NF1) and the Fort Peck Dam powerplant (site OF1) during the 2005 and 2006 water years (i.e., October through September). Inflow temperatures of the Missouri River to Fort Peck Reservoir are generally warmer than the outflow temperatures of Fort Peck Dam during the period of March through August (Figures 7.1 and 7.2). Outflow temperatures of the Fort Peck Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of September through February (Figures 7.1 and 7.2). A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Fort Peck Dam outflow temperature (Figures 7.1 and 7.2).

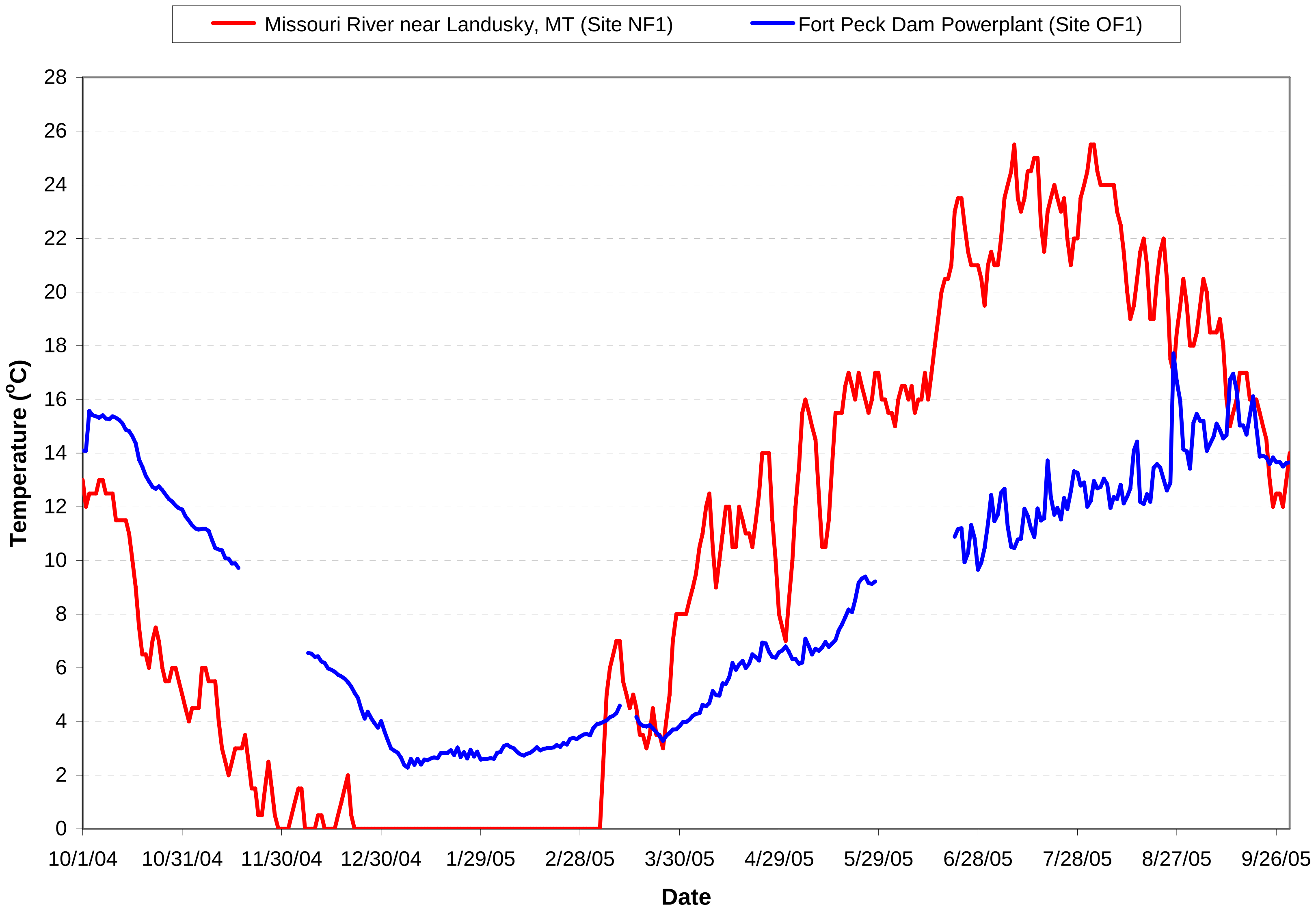

Figure 7.1. Mean daily water temperatures monitored at the Fort Peck powerplant and the Missouri near Landusky, Montana from October 2004 through September 2005. (Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

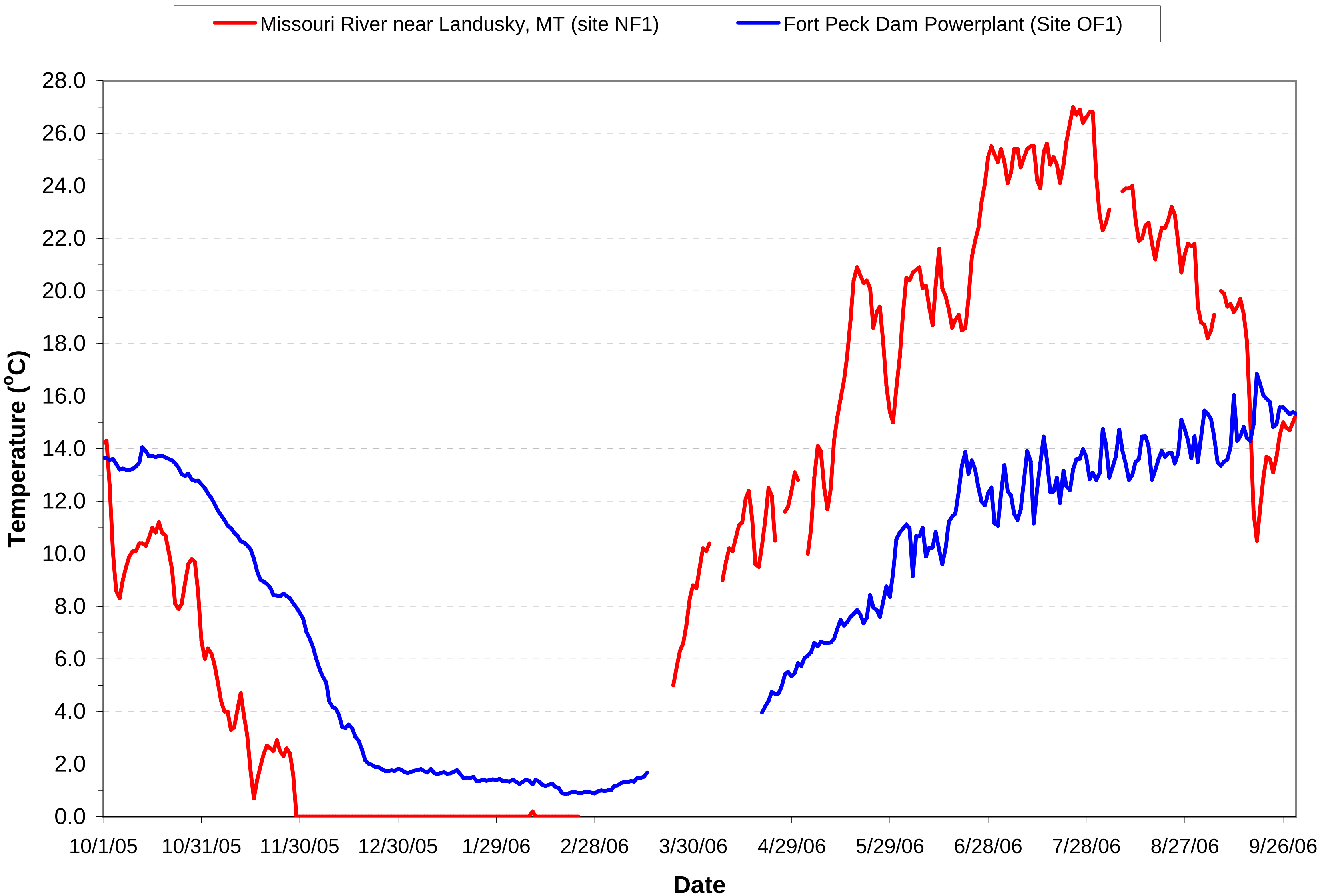

Figure 7.2. Mean daily water temperatures monitored at the Fort Peck powerplant and the Missouri near Landusky, Montana from October 2005 through September 2006. (Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

7.3 WATER TEMPERATURES MEASURED IN THE MISSOURI RIVER DOWNSTREAM OF FORT PECK DAM

Water temperatures have been monitored in the Missouri River downstream of Fort Peck Dam over the past several years as part of a multi-agency effort to study the pallid sturgeon population in the Missouri and Yellowstone Rivers. Two sites on the Missouri River that have been monitored by the USGS under this effort are the Fort Peck Dam tailwaters (i.e., approximately 5 miles downstream of Fort Peck Dam) and Frazer Rapids (approximately 25 miles downstream of Fort Peck Dam). The water temperatures monitored at the Fort Peck Dam powerplant during the period 2004 through 2006 were compared to the Missouri River water temperatures monitored by the USGS at their tailwaters and Frazer Rapids sites. Figures 7.3, 7.4, and 7.5, respectively, plot mean daily water temperatures monitored at the three sites and the mean daily discharge of Fort Peck Dam from May through October during 2004, 2005, and 2006. During the 3 years, water temperatures monitored at the Fort Peck Dam powerplant from June through August were generally 2°C cooler than the water temperatures monitored in the Missouri River at the Fort Peck Dam tailwaters site, and 4°C cooler than the water temperatures monitored in the Missouri River at Frazer Rapids (Figures 7.3 - 7.5).

During early to mid-September of each year, water temperatures monitored at the three sites were somewhat similar. In early September the water temperatures monitored at the Fort Peck Dam powerplant exhibited pronounced warming. This is attributed to the cooling and downward expansion of the epilimnion in Fort Peck Reservoir as “fall turnover” of the reservoir approached. It appears that in early September the downward expanding epilimnion intersected with the upper reaches of “withdrawal zone” of the powerplant intake. This resulted in warmer epilimnetic warmer being captured in the reservoir and discharged through Fort Peck Dam.

During late-September to early October, water temperatures monitored at the Fort Peck powerplant were generally warmer than those monitored in the Missouri River downstream of Fort Peck Dam. This is attributed to the slower heat loss from Fort Peck Reservoir than the Missouri River in early fall. Warmer water from the epilimnion of Fort Peck Reservoir is discharged through Fort Peck Dam that cools as it moves down the Missouri River. It is during this time period that the relationship of warmer water temperatures occurring in the Missouri River at Frazer Rapids and cooler water temperatures occurring at the Fort Peck Dam powerplant reverses (Figures 7.3 - 7.5).

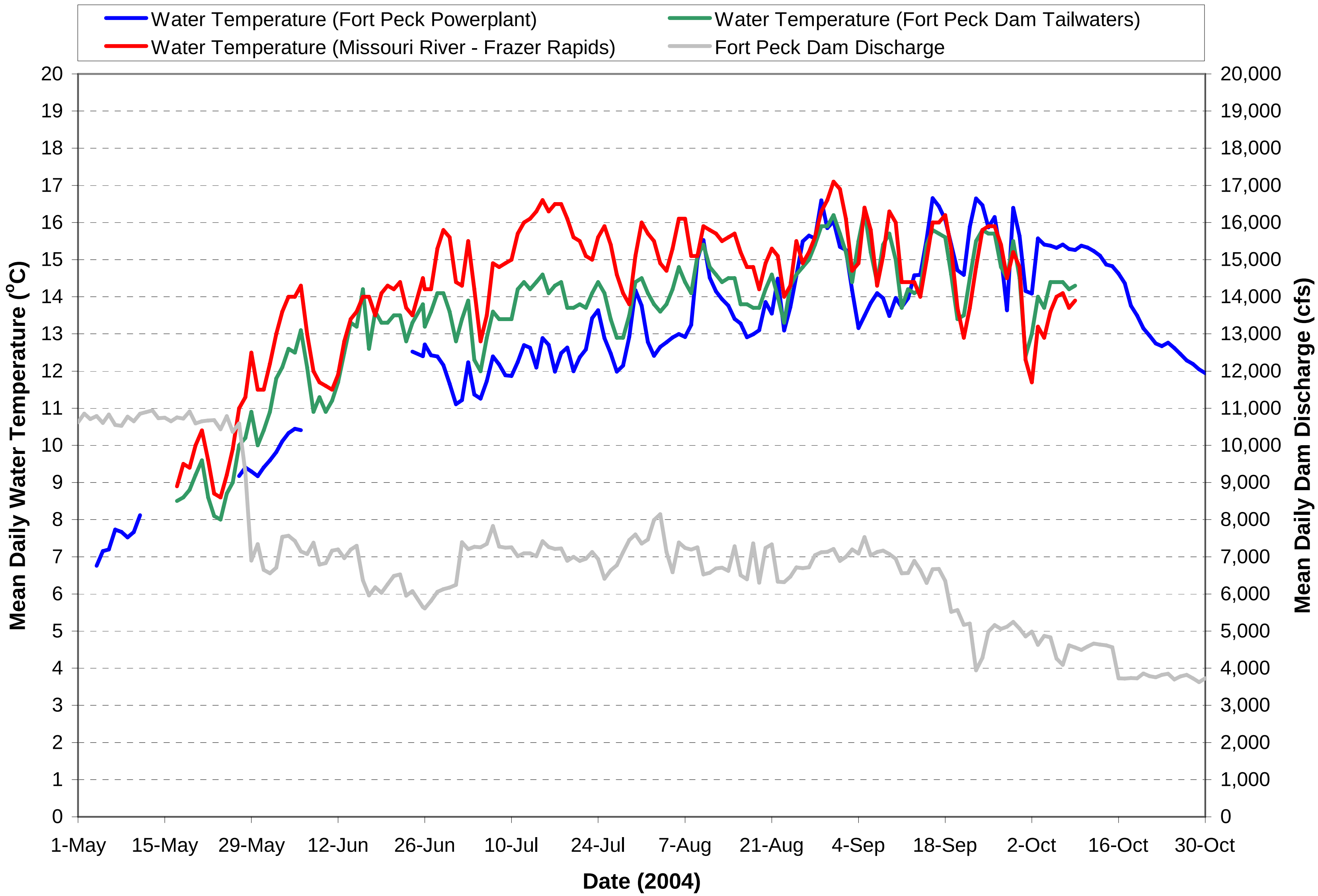

Figure 7.3. Mean daily water temperatures monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2004.

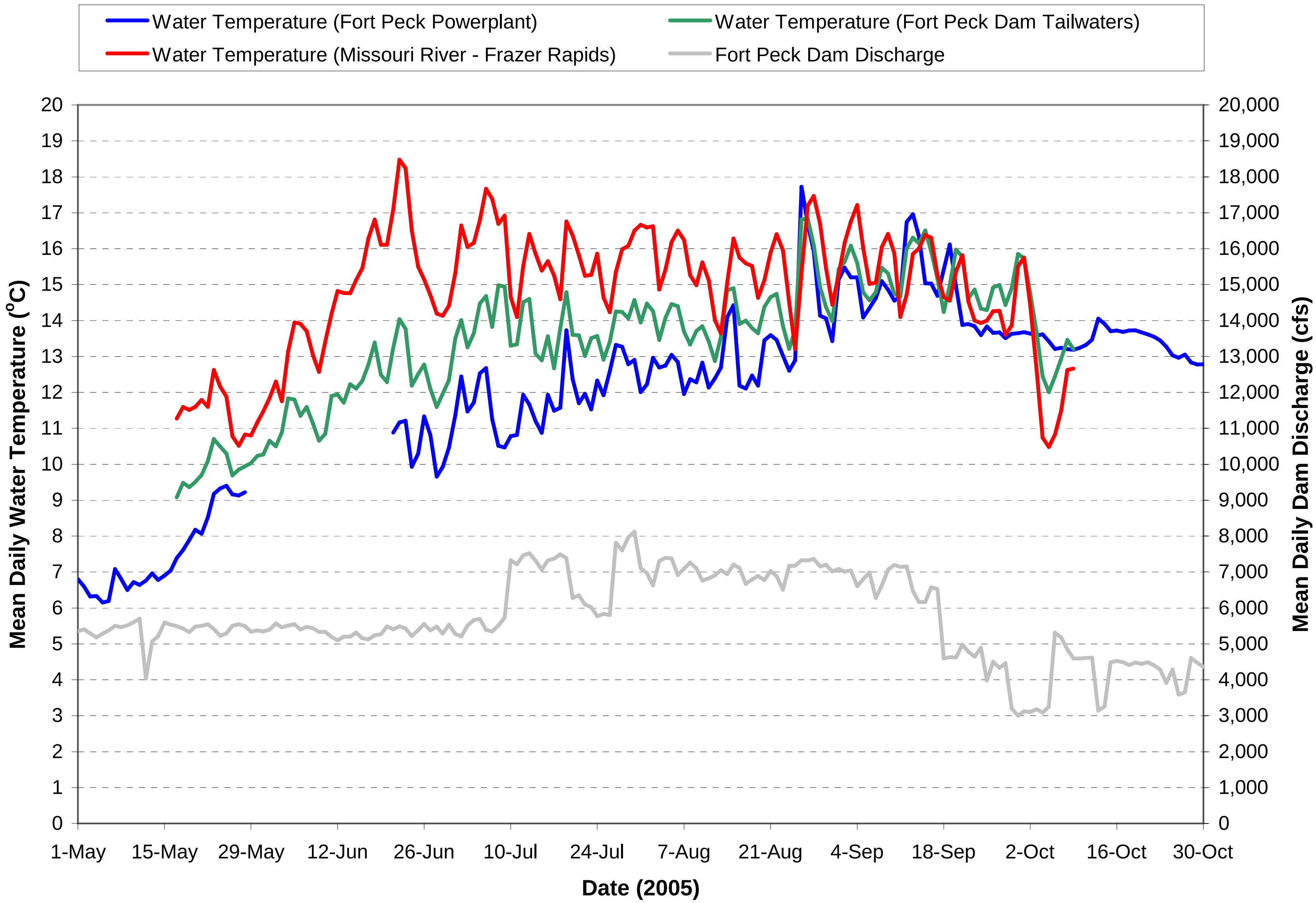

Figure 7.4. Mean daily water temperatures monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2005.

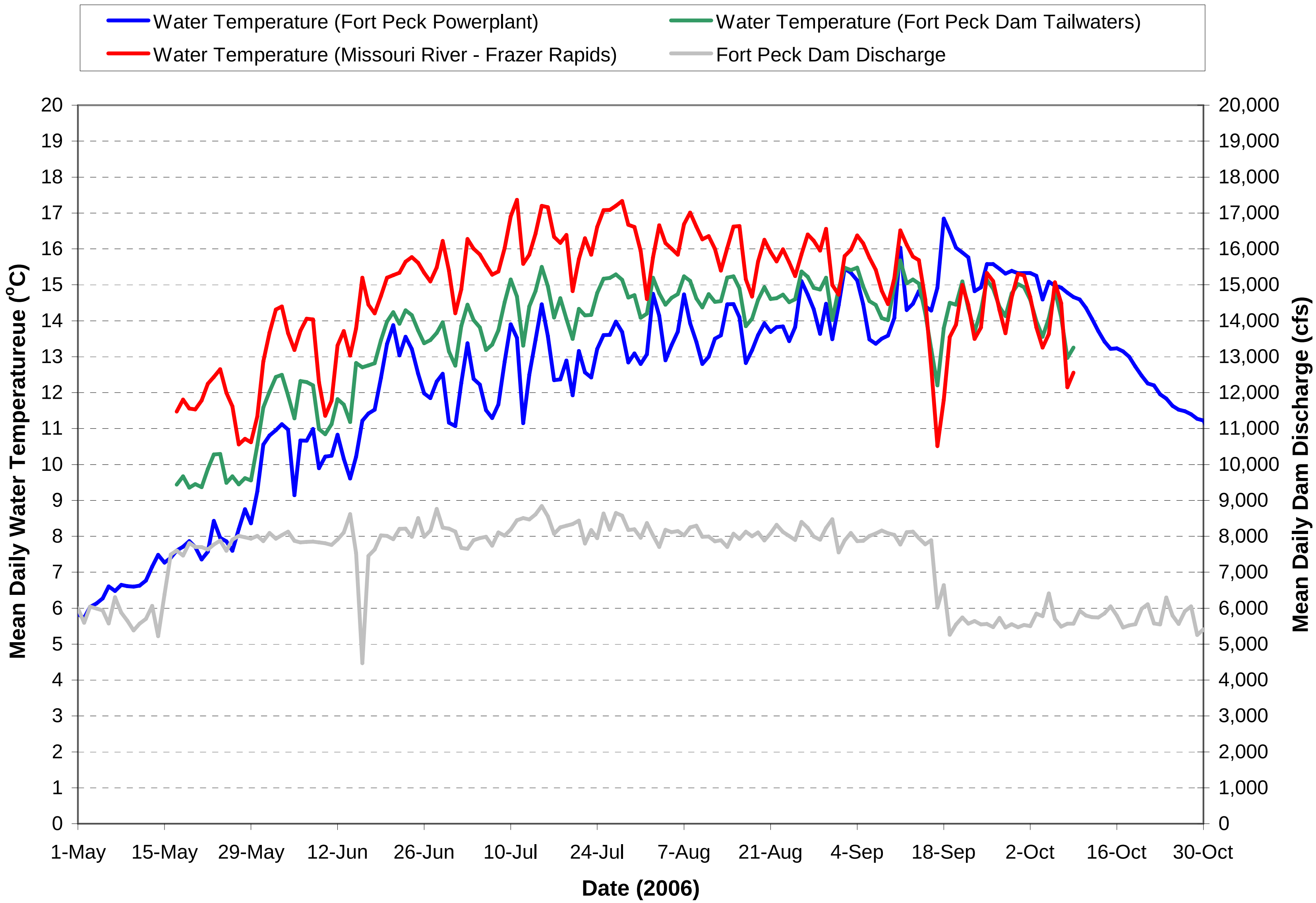

Figure 7.5. Mean daily water temperatures monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2006.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 EXISTING WATER QUALITY CONDITIONS

8.1.1 FORT PECK RESERVOIR

Water quality monitoring of Fort Peck Reservoir during the period of 2004 through 2006 indicated good water quality in the reservoir. Water quality conditions in Fort Peck Reservoir vary along the length of the Missouri River and Big Dry Creek Arms of the reservoir. Strong thermal stratification occurs in the deeper area of the reservoir nearer Fort Peck Dam during the summer. Water quality monitoring indicated that the trophic status of the reservoir is mesotrophic. The phytoplankton community of Fort Peck Reservoir was dominated by diatoms and only minor "blooms" of cyanobacteria occurred.

8.1.2 WATER DISCHARGED THROUGH FORT PECK DAM

Water discharged through Fort Peck Dam exhibited good water quality during the monitored period of 2004 through 2006. The temperature of the discharge water is reflective of the current deep-water withdrawal from Fort Peck Reservoir; it remains "cold" throughout the year. The temperature of the water discharged through Fort Peck Dam in late-spring/early-summer remained below 14°C. Water temperatures approached 18°C in late-summer/early-fall when thermal stratification in Fort Peck Reservoir eroded as fall turn-over approached. A late-spring/early-summer water temperature of 18°C in the Missouri River at Frazer Rapids (approximately 25 miles downstream of Fort peck Dam) has been identified as critical for pallid sturgeon spawning and recruitment in that reach of the river.

8.2 COLDWATER HABITAT IN FORT PECK RESERVOIR

To protect coldwater habitat, Montana's water quality standards state that water temperature should not exceed 19.4°C and dissolved oxygen concentrations should remain above 5 mg/l. For this report, optimal coldwater habitat was defined as water having a temperature ≤15°C and a dissolved oxygen concentration ≥ 5 mg/l. During the 3-year period 2004 through 2006, coldwater habitat ranged from the entire reservoir volume (i.e., > 9 million acre-ft) to a low of about 2.7 million acre-ft (August 2006). The minimum volume of optimal coldwater habitat that was estimated to be present during the period was about 1 million acre-ft (September 2005).

8.3 WATER QUALITY MONITORING RECOMMENDATIONS

Consideration should be given to collecting additional depth profiles for water temperature and dissolved oxygen in the upper reaches of the Missouri River Arm of Fort Peck Reservoir. During the 2004 through 2006 intensive water quality survey, the uppermost site sampled on the Missouri River Arm was the Hell Creek site (i.e., RM1805). Under the pool elevations monitored, the reservoir was still deep enough at this site for thermal stratification to allow a hypolimnion to become established. The lowest dissolved oxygen concentration monitored in the reservoir (i.e., 3.5 mg/l) was measured at this site in August 2005. It is unclear if anoxic conditions (i.e., dissolved oxygen concentrations < 2 to 3 mg/l) occur in hypolimnetic waters upstream from the Hell Creek site. If possible, depth profiles for water temperature and dissolved oxygen should be collected in the Missouri River Arm of Fort Peck Reservoir in the vicinity of RM1825 and RM1845. RM1825 is in the vicinity of the Bone Trail Recreation Area and RM1845 is in the vicinity of the Devils Creek Recreation Area. Fort Peck Reservoir could possibly be accessed from boat ramps at these recreation areas for monitoring at these sites.

9 REFERENCES

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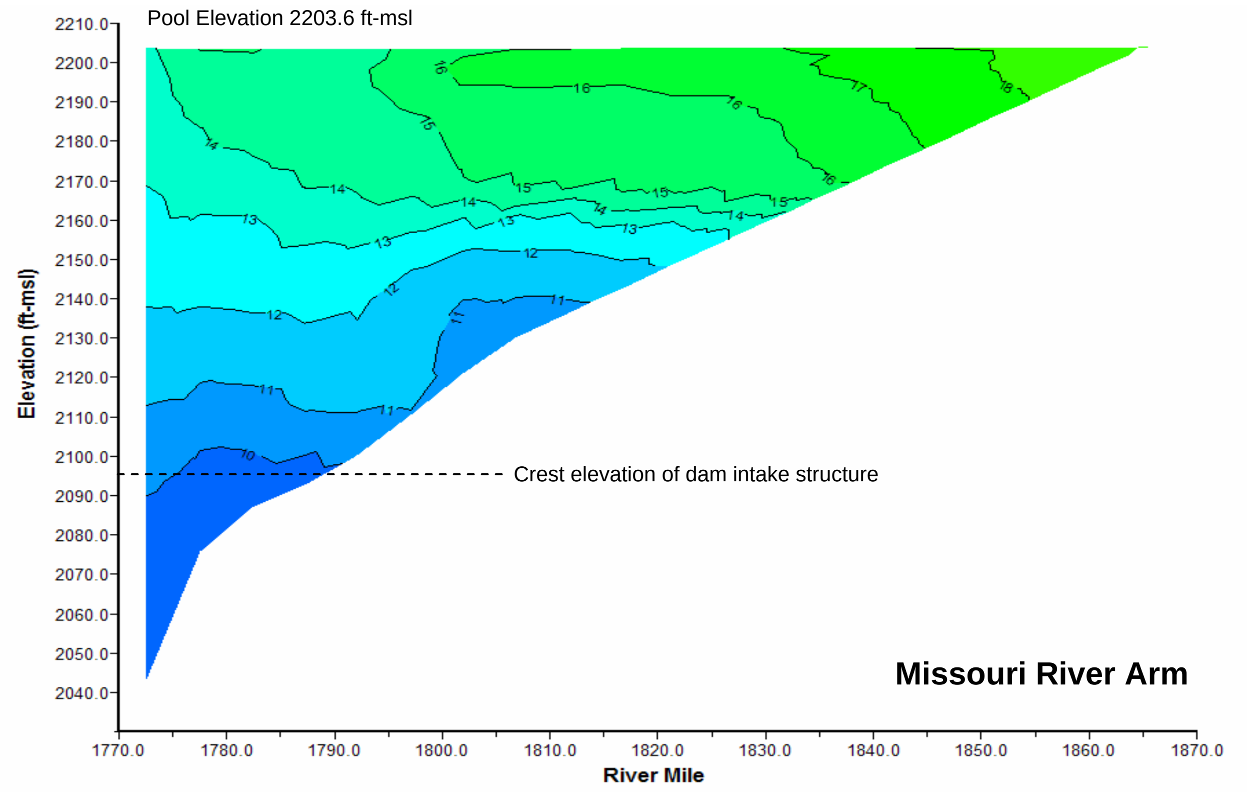
10 PLATES



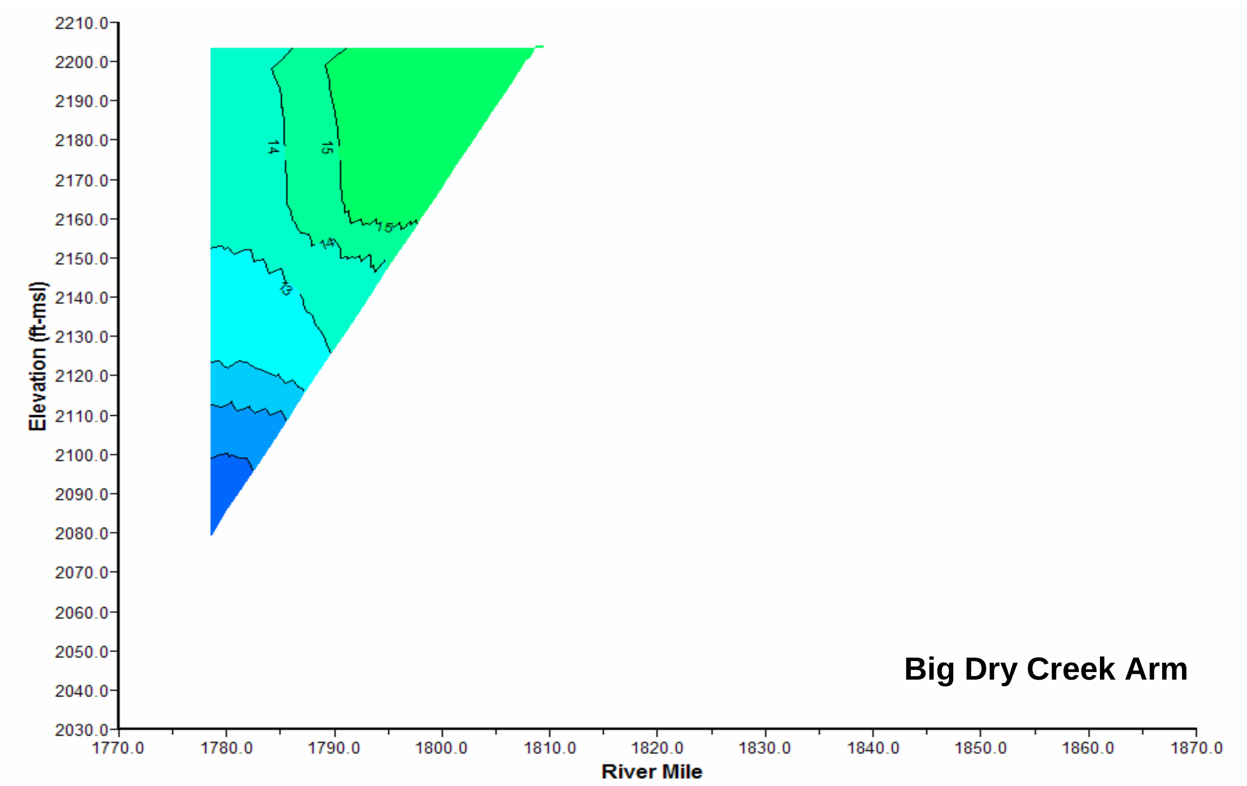


Plate 1. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3,L4, L5, L6, and NF1 on June 23, 2004.

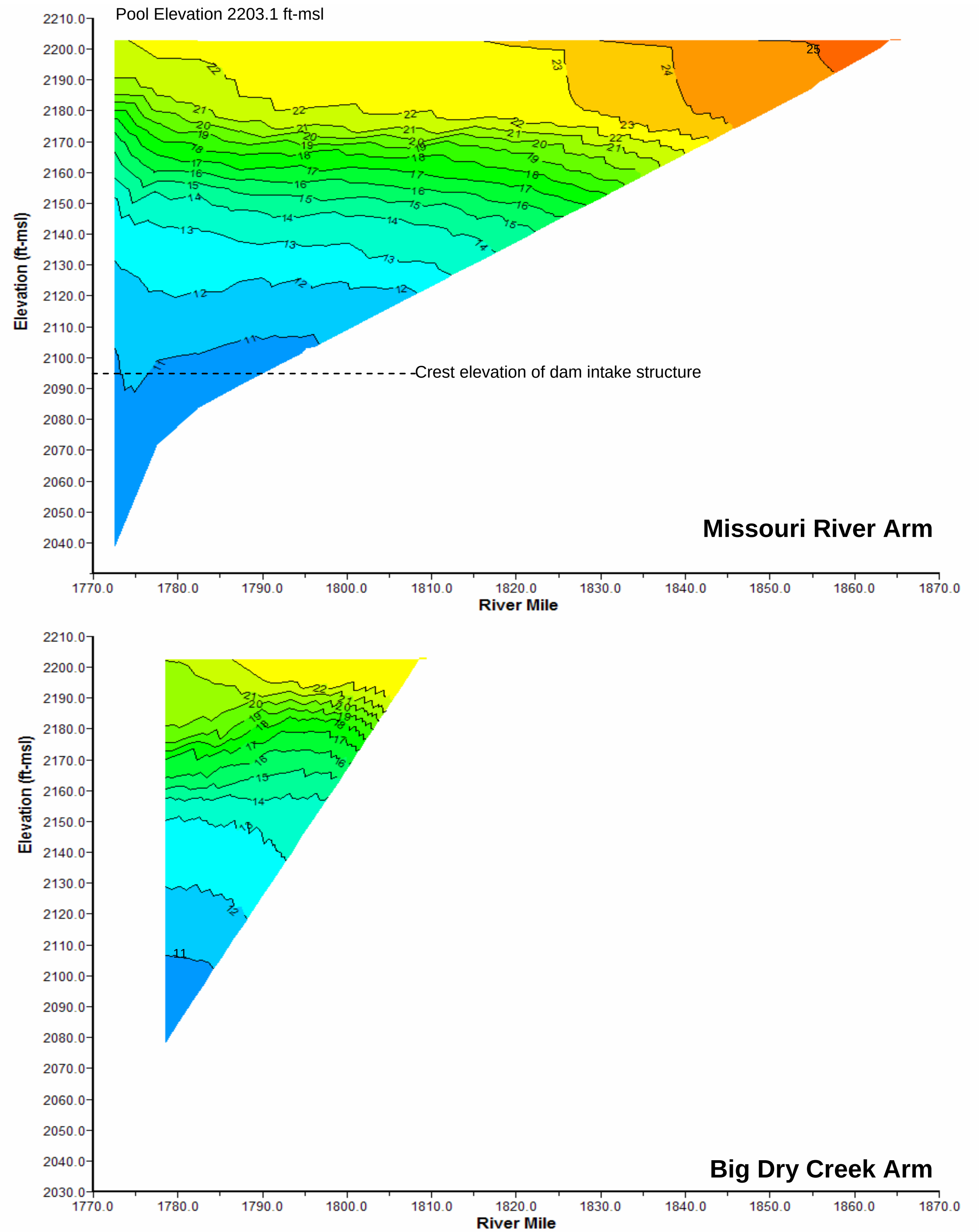


Plate 2. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L5, L6, and NF1 on July 20, 2004.

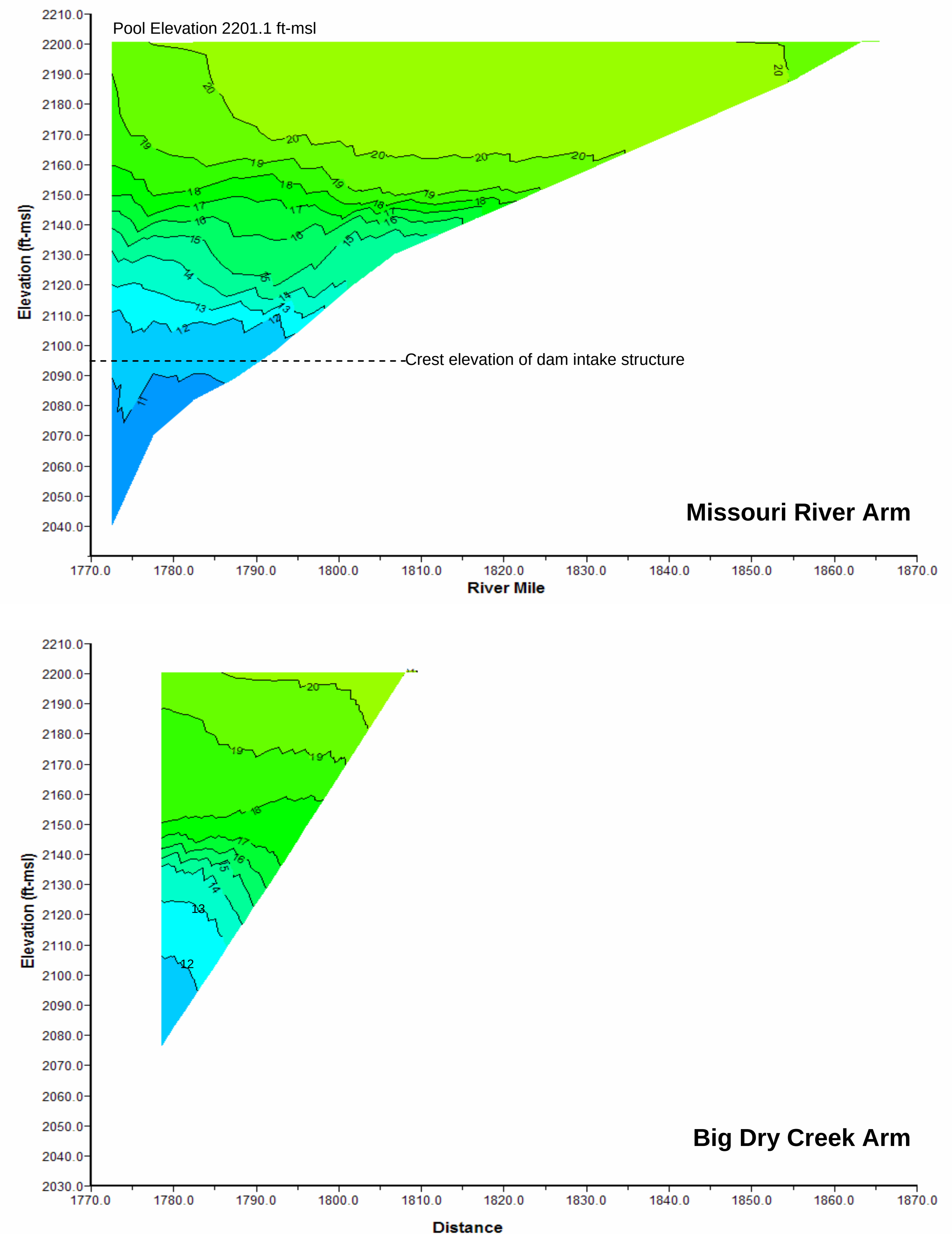
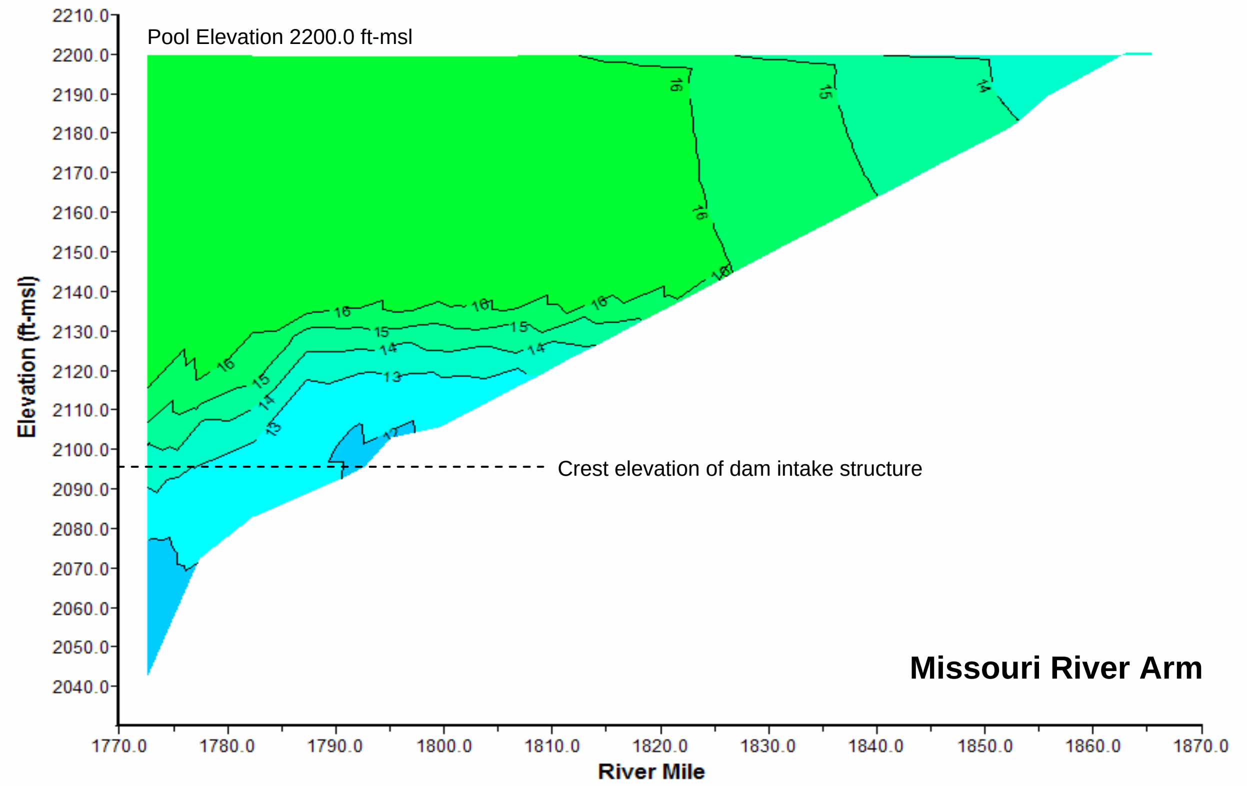


Plate 3. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on August 16, 2004.



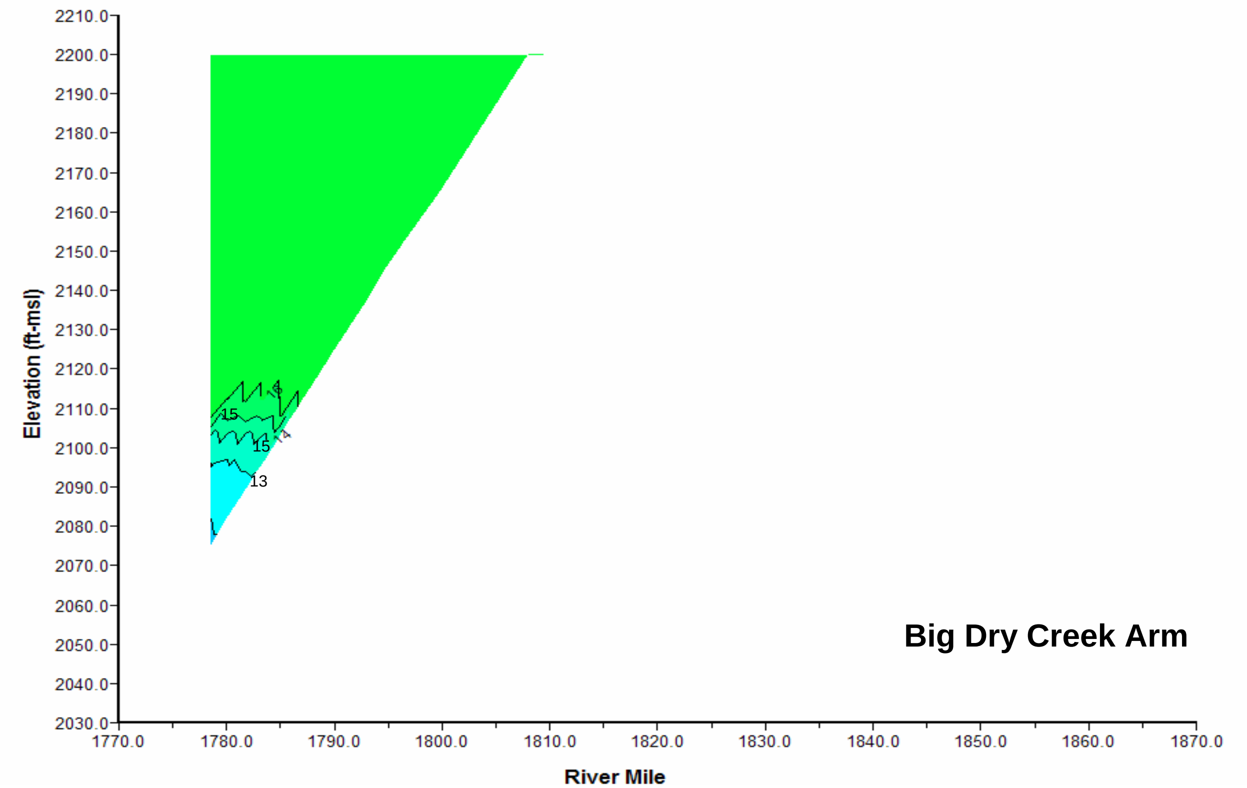


Plate 4. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L5, L6, and NF1 on September 22, 2004.

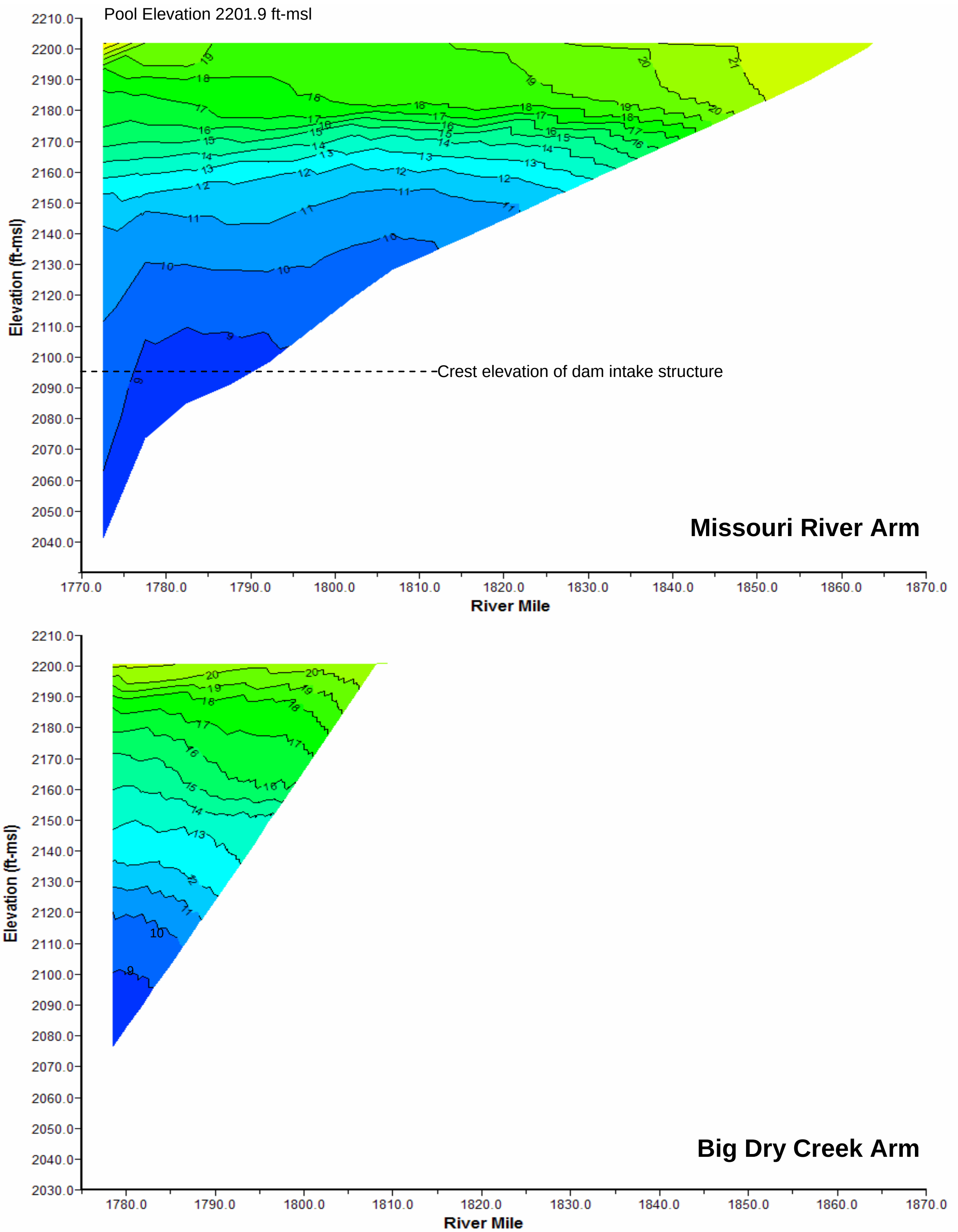


Plate 5. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on June 20, 2005.

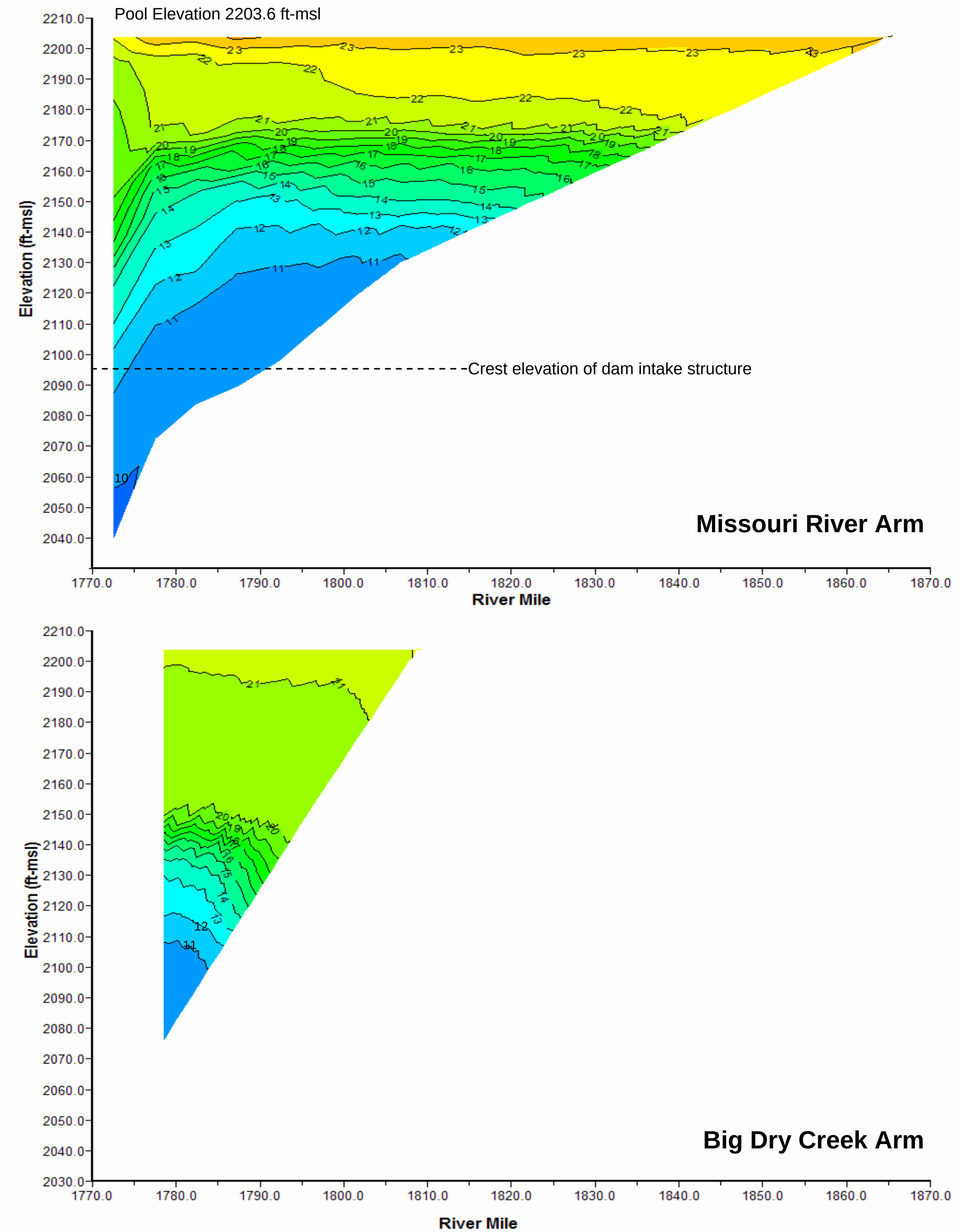


Plate 6. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on July 18, 2005.

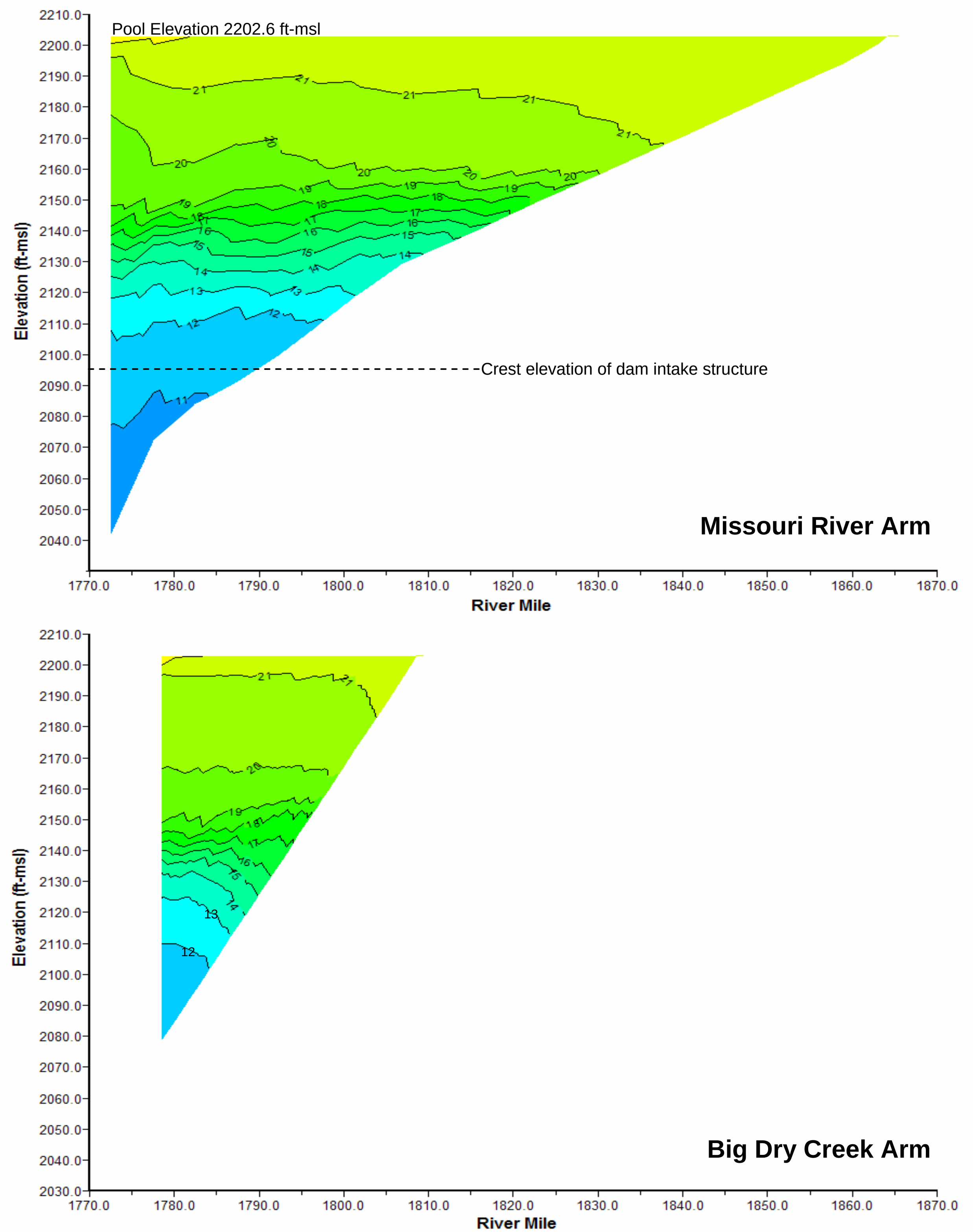


Plate 7. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on August 22, 2005.

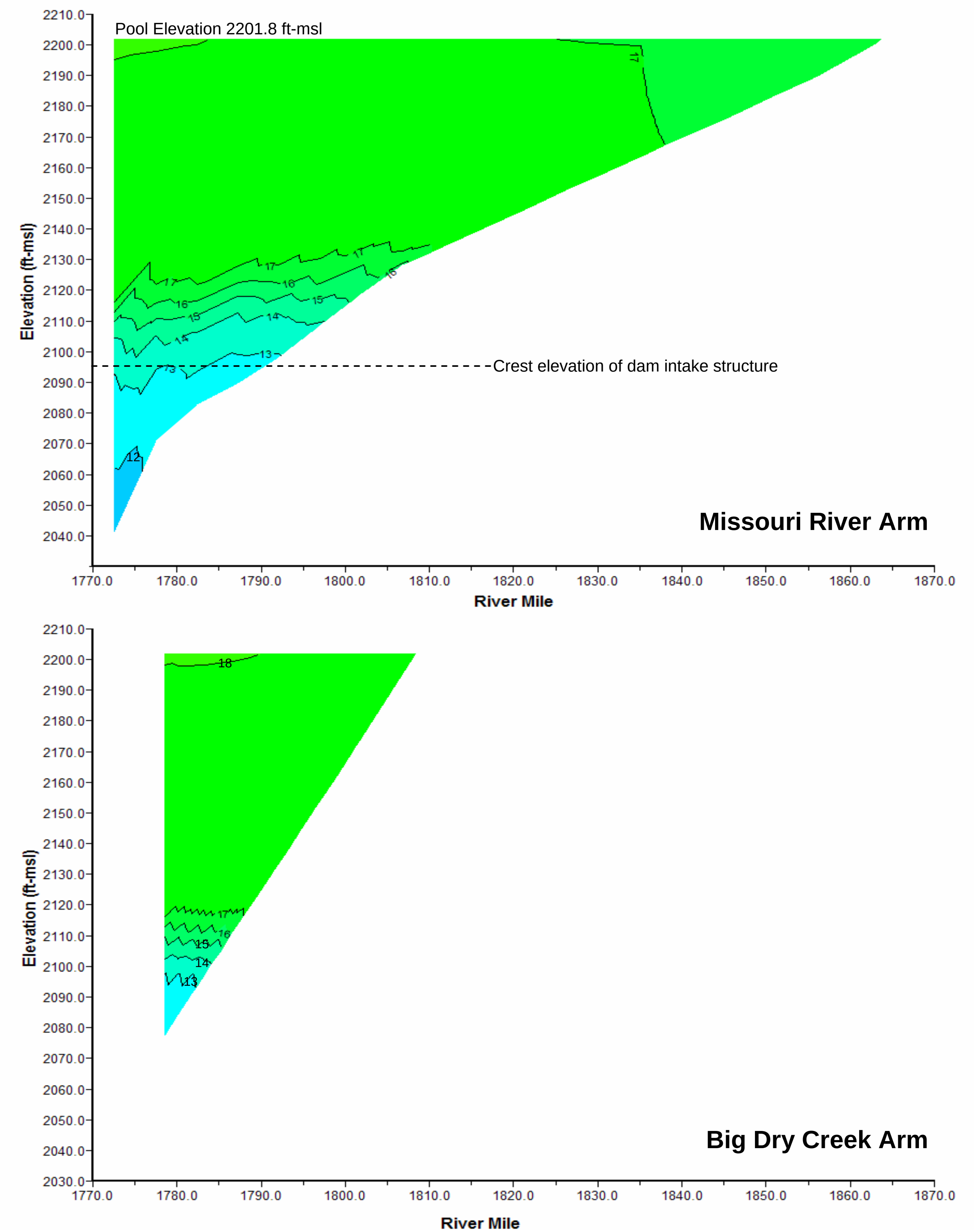


Plate 8. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on September 20, 2005.

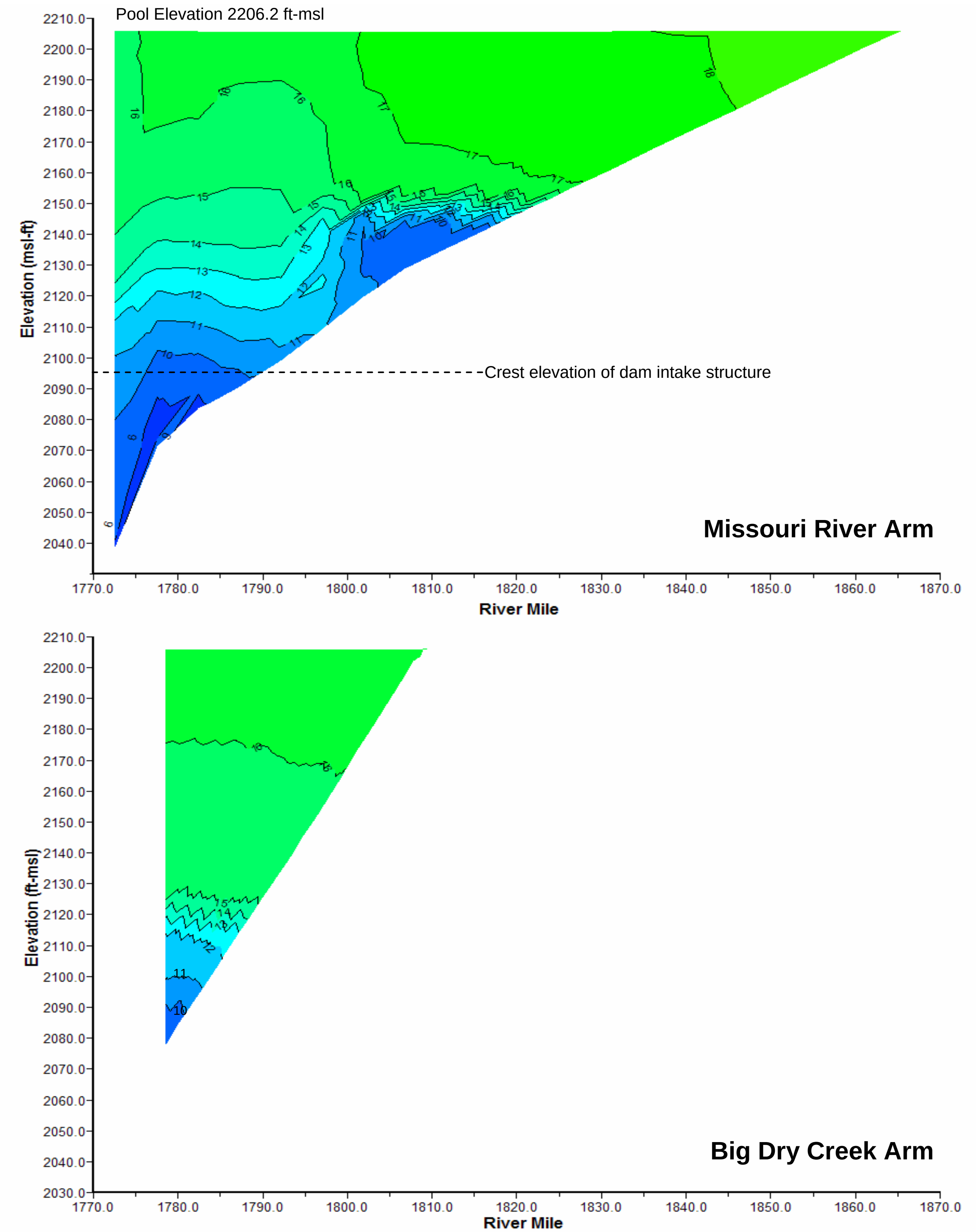


Plate 9. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on June 22, 2006.

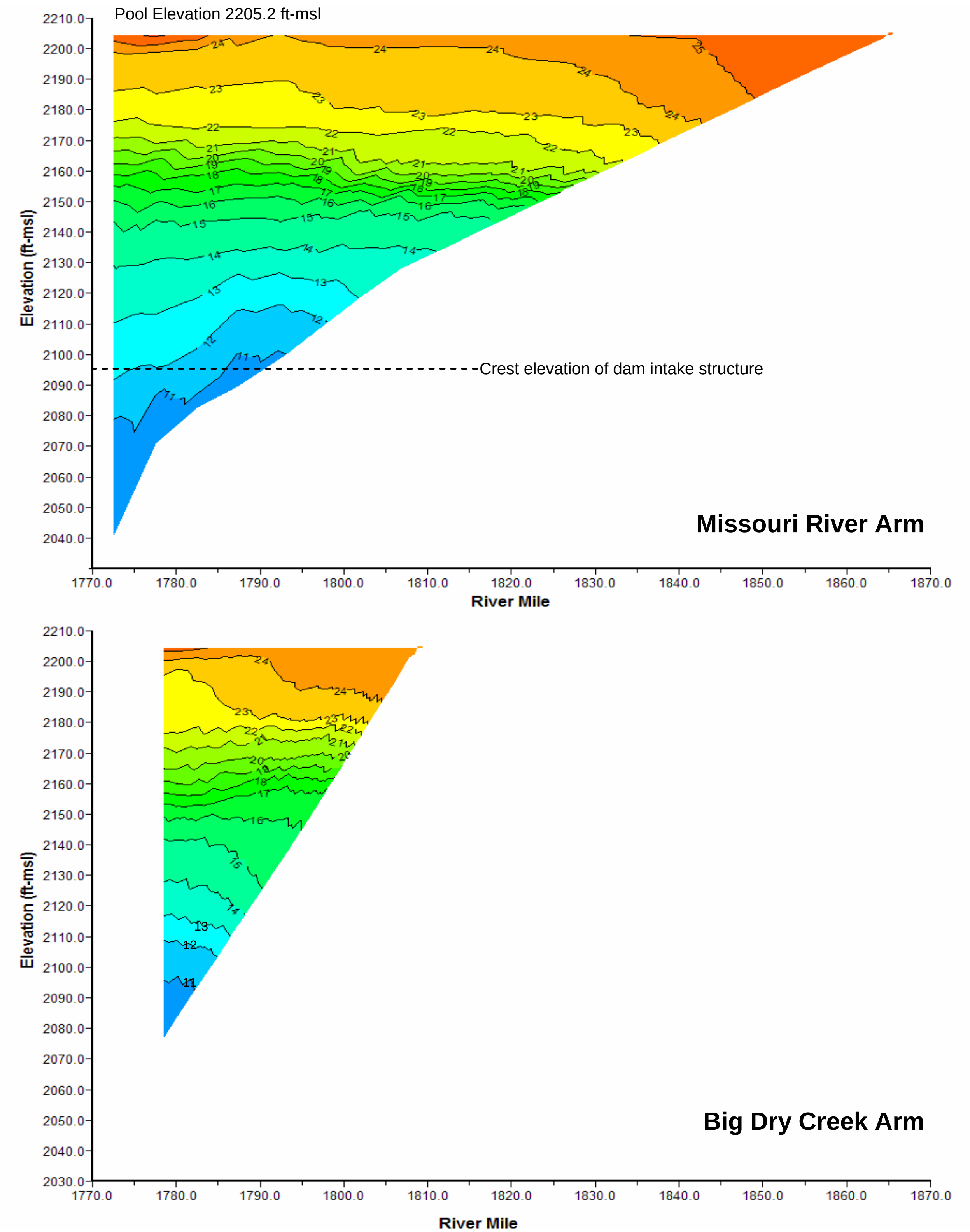


Plate 10. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on July 26, 2006.

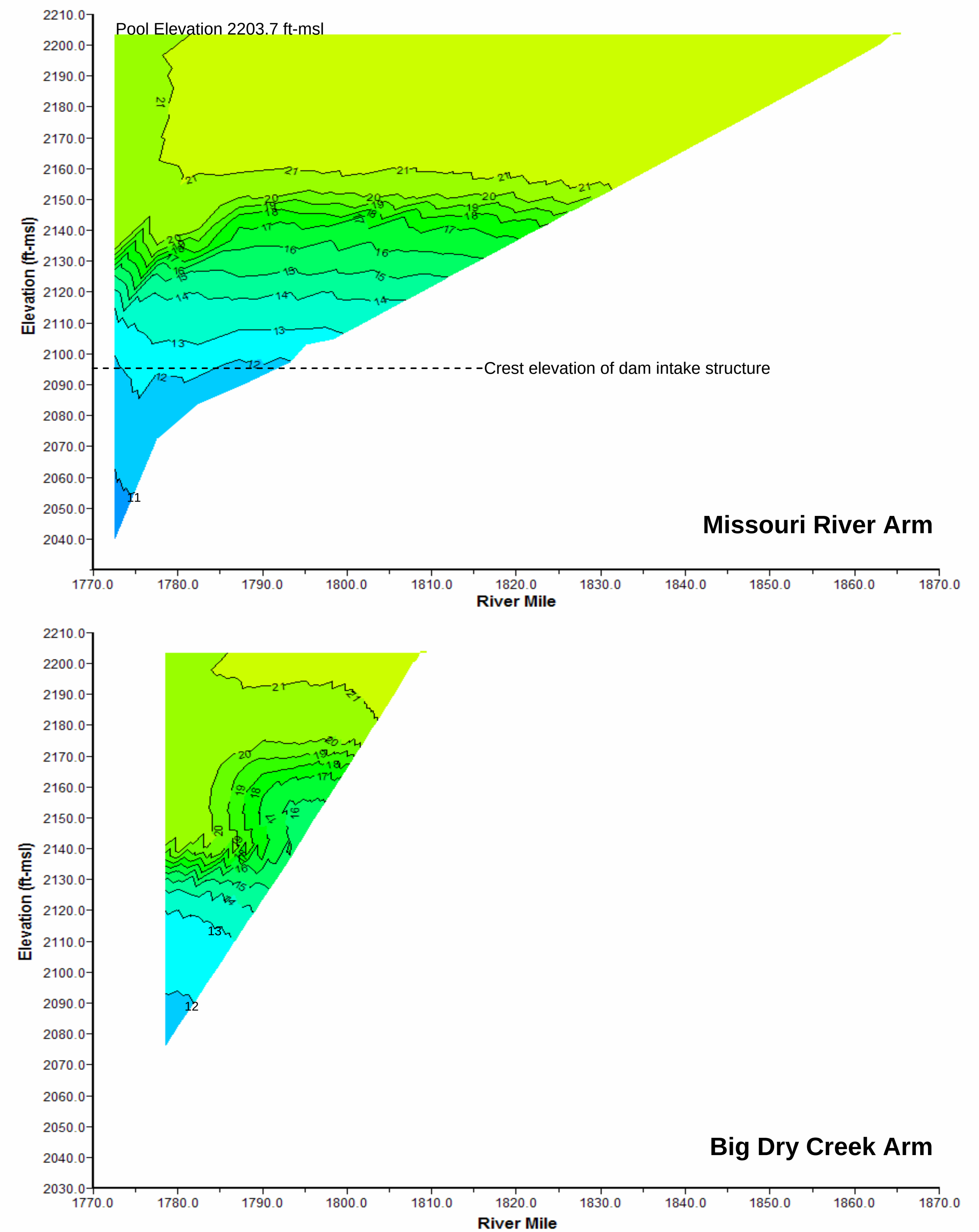
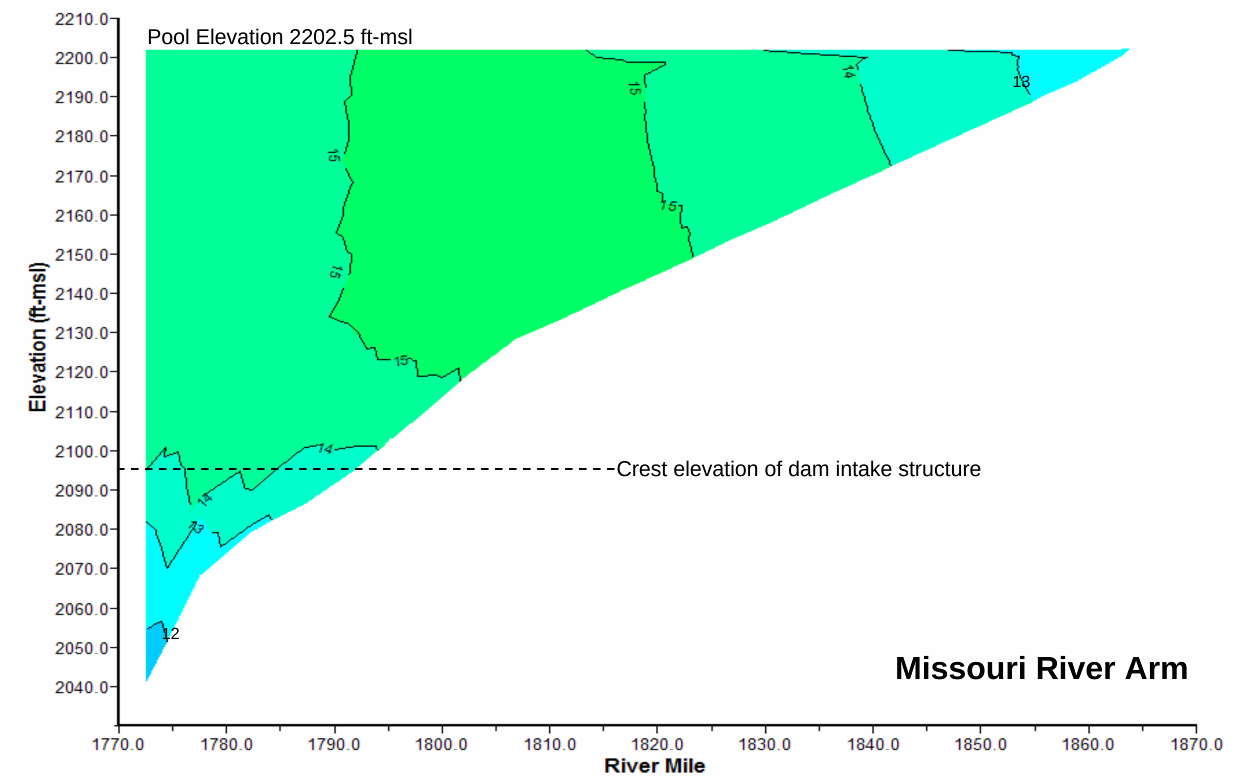


Plate 11. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L5, L6, and NF1 on August 30, 2006.



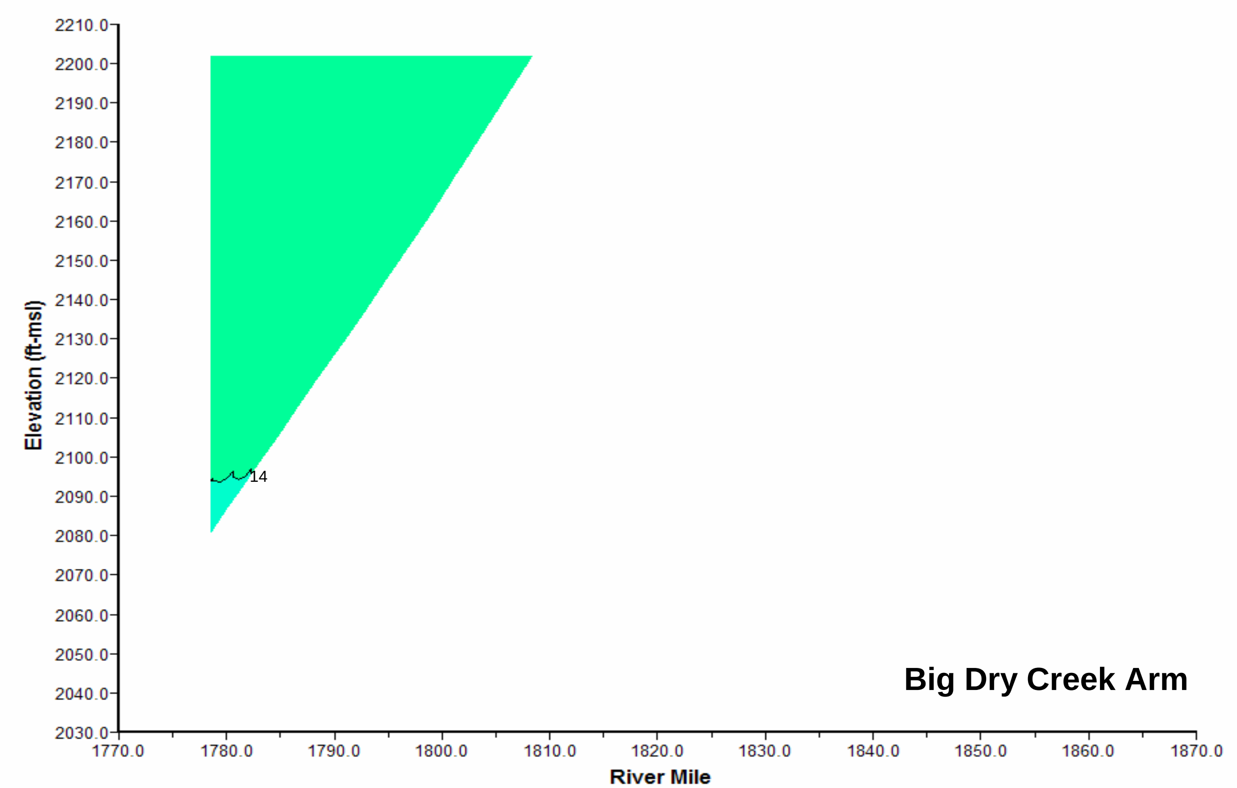


Plate 12. Longitudinal water temperature contour plot of Fort Peck Reservoir based on depth-profile water temperatures monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on October 5, 2006.

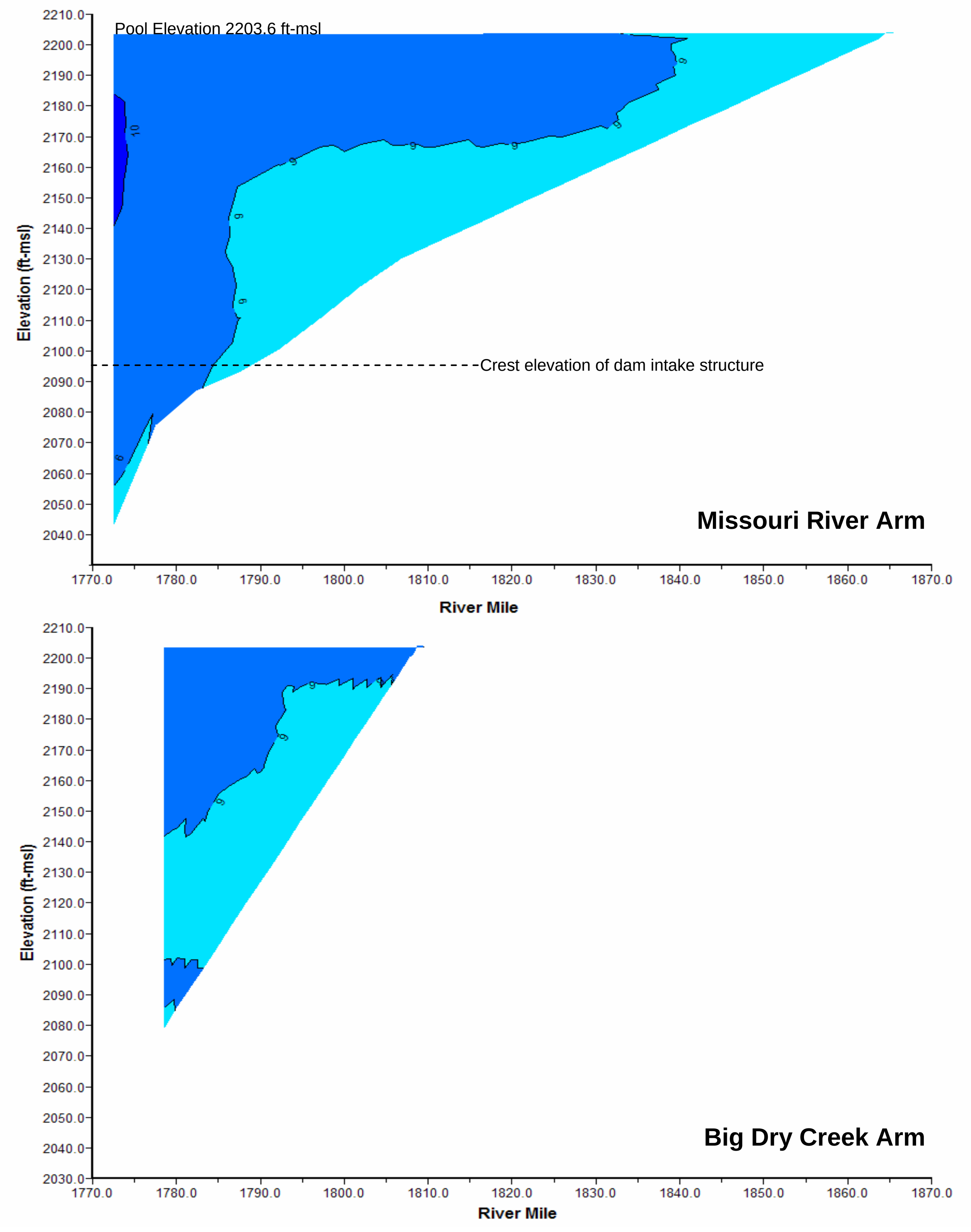
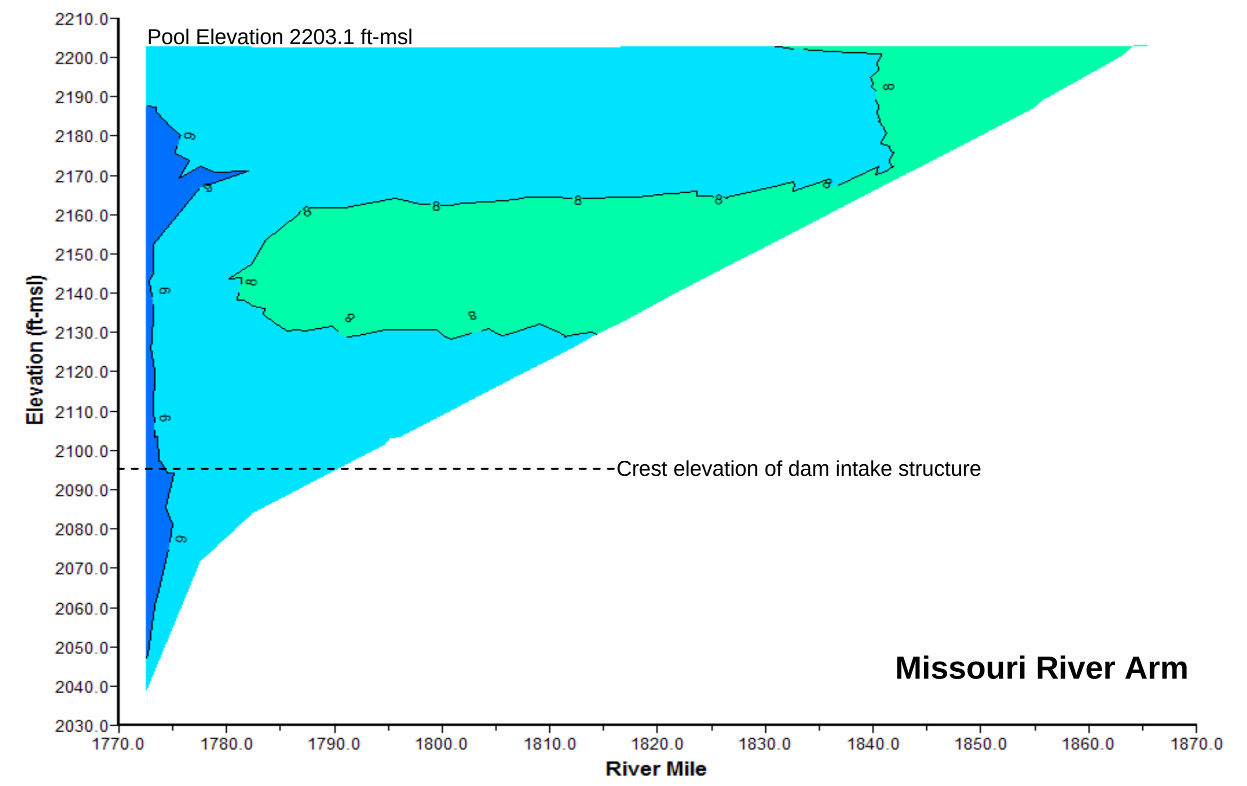


Plate 13. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on June 23, 2004.



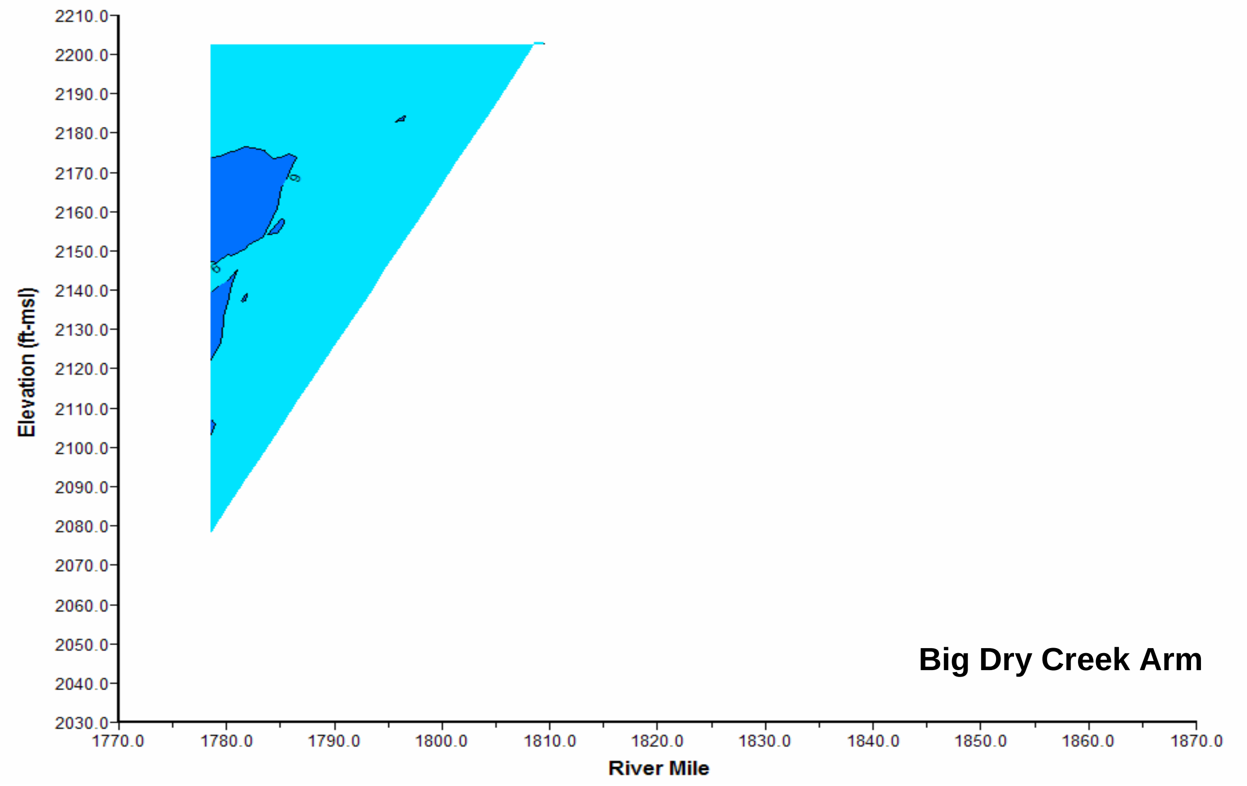
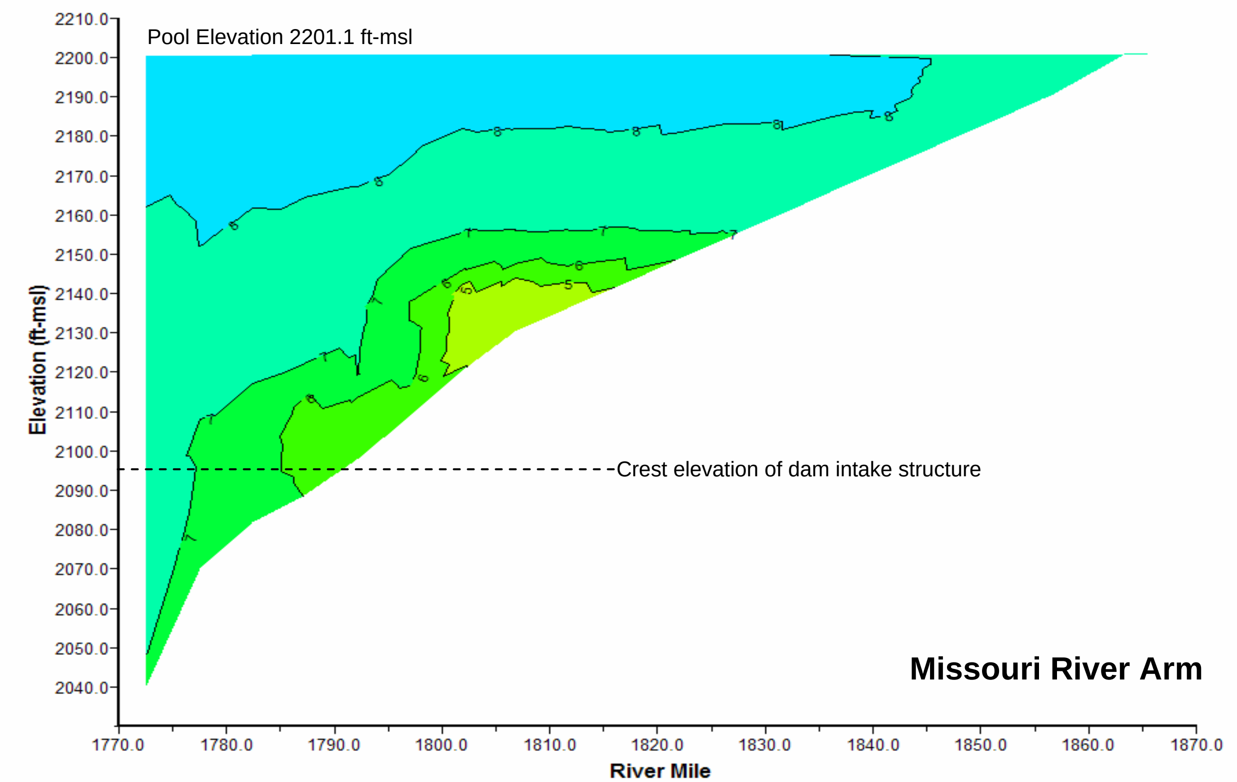


Plate 14. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L5, L6, and NF1 on July 20, 2004.



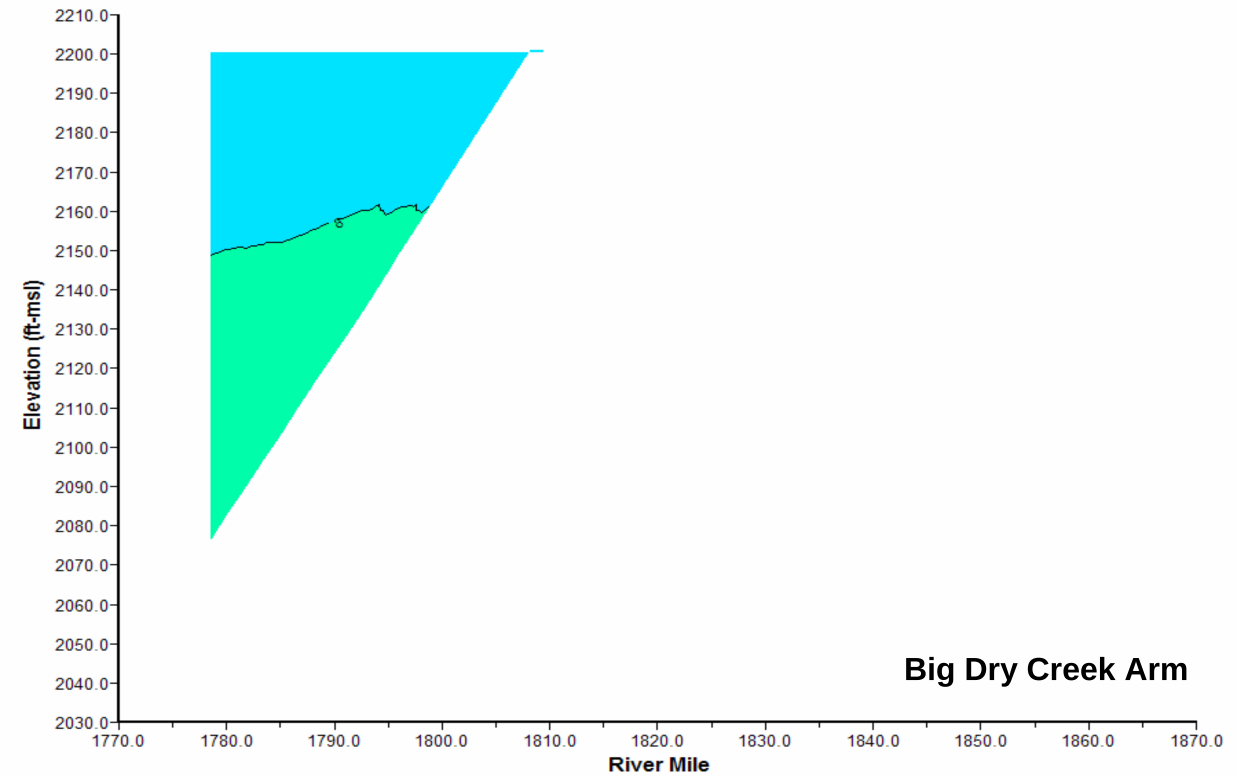


Plate 15. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on August 16, 2004.

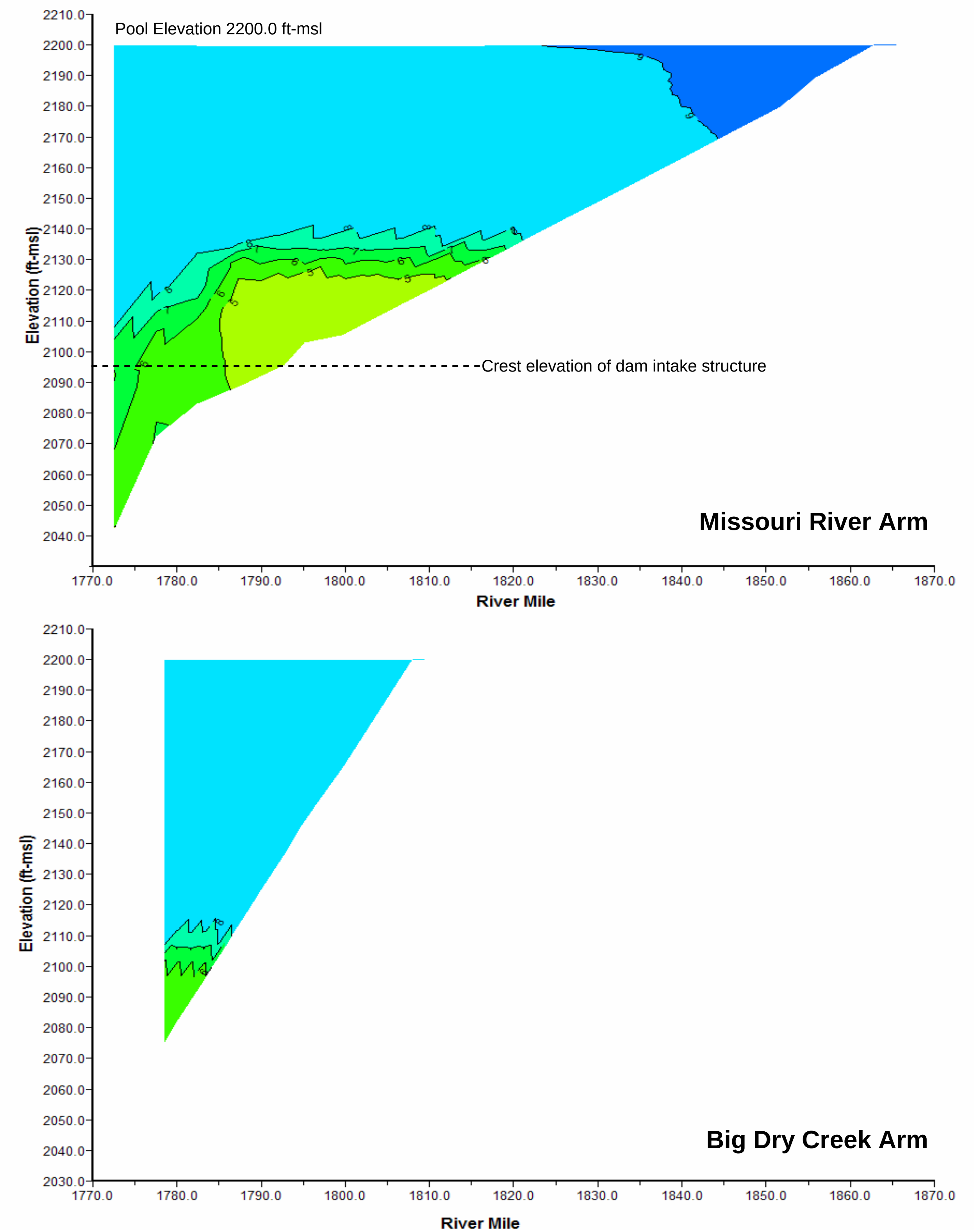


Plate 16. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L5, L6, and NF1 on September 22, 2004.

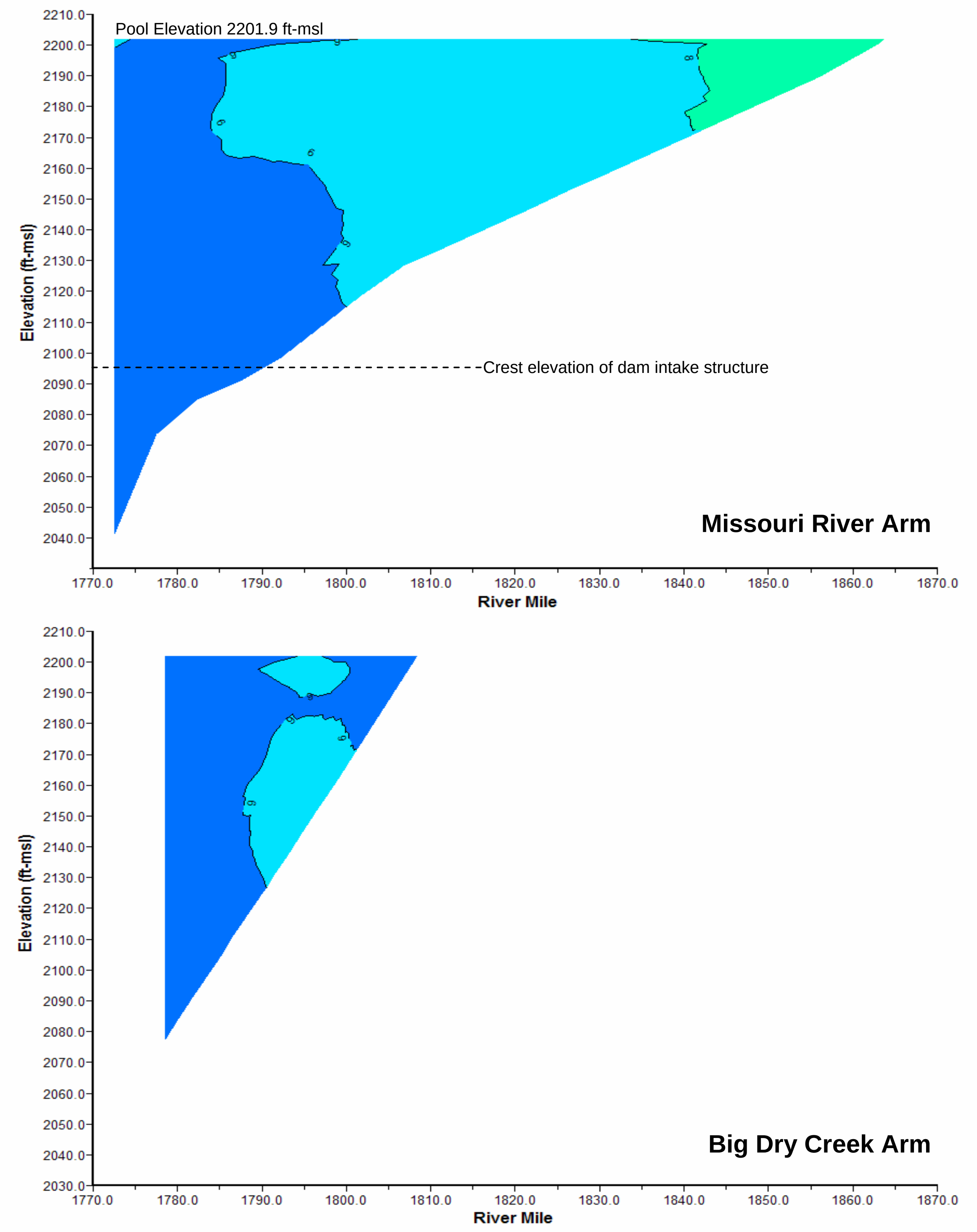


Plate 17. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on June 20, 2005.

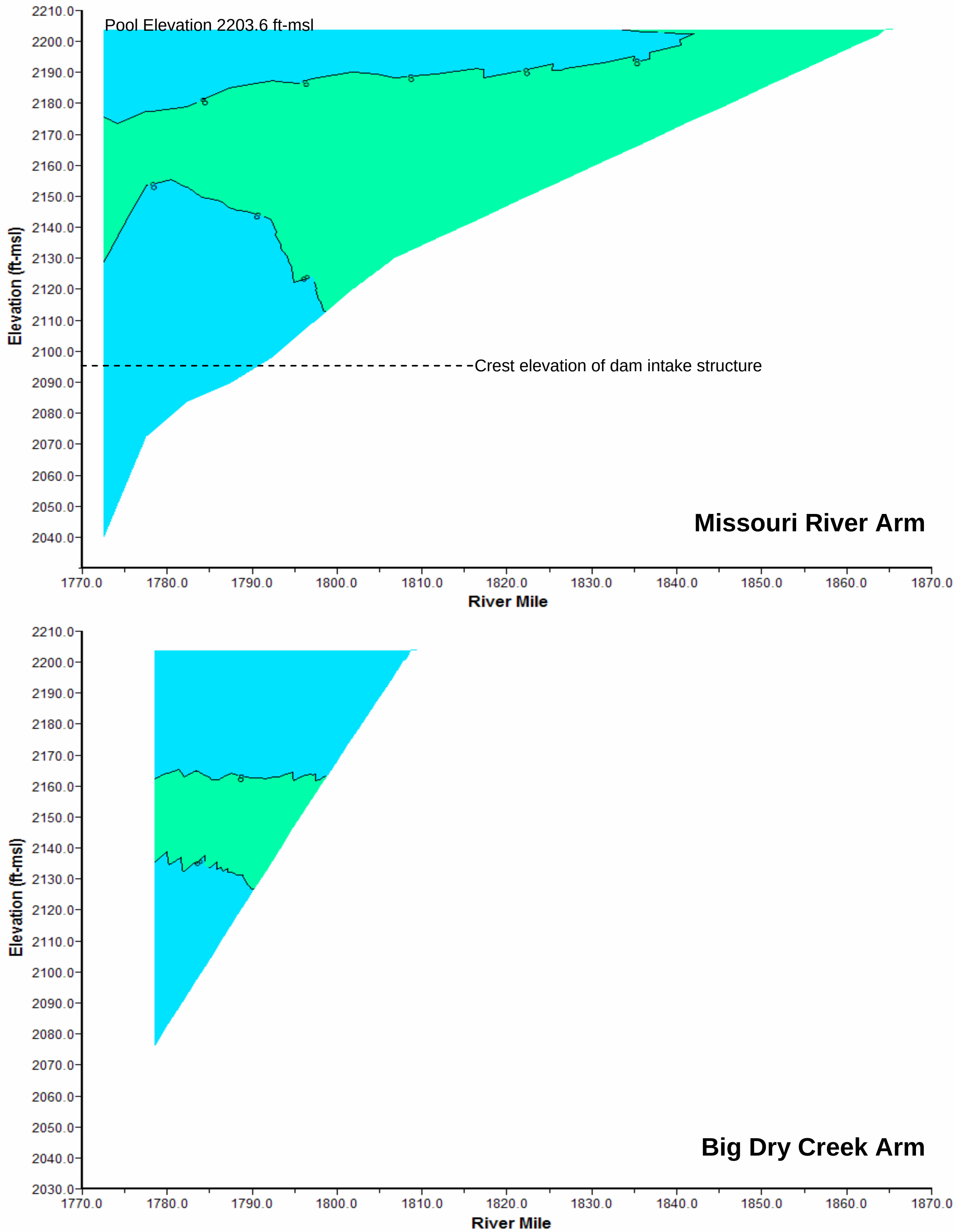


Plate 18. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on July 18, 2005.

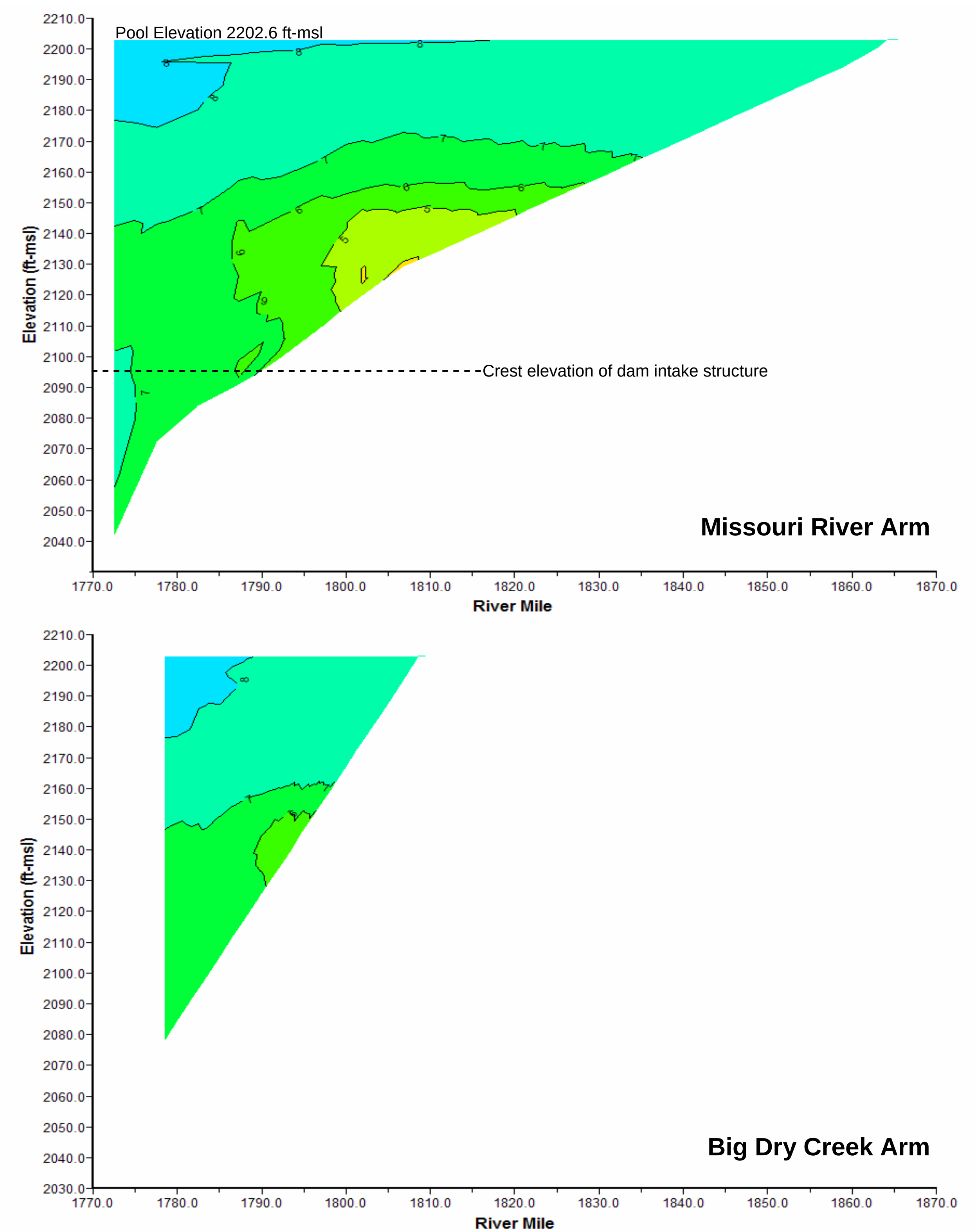


Plate 19. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on August 22, 2005.

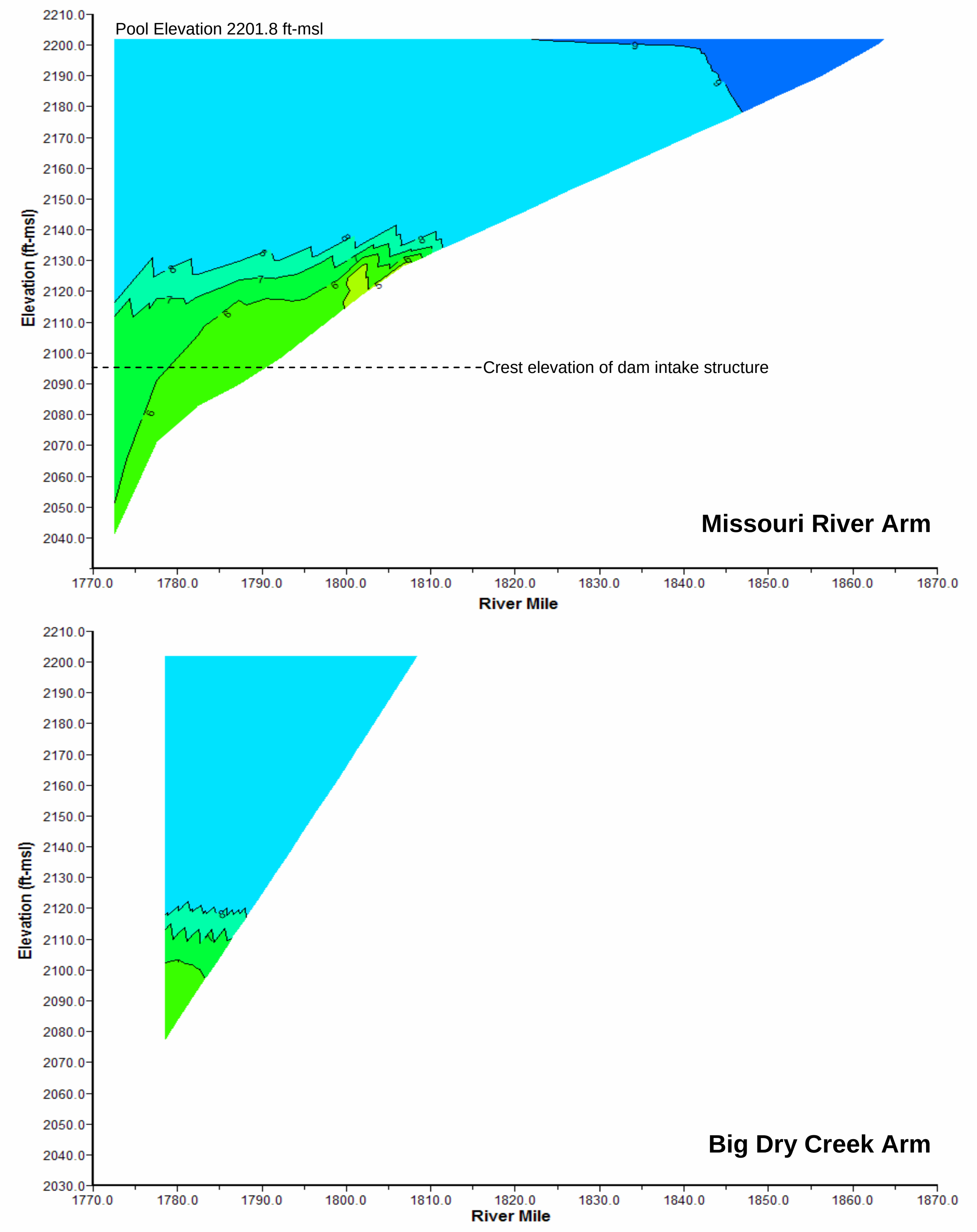


Plate 20. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on September 20, 2005.

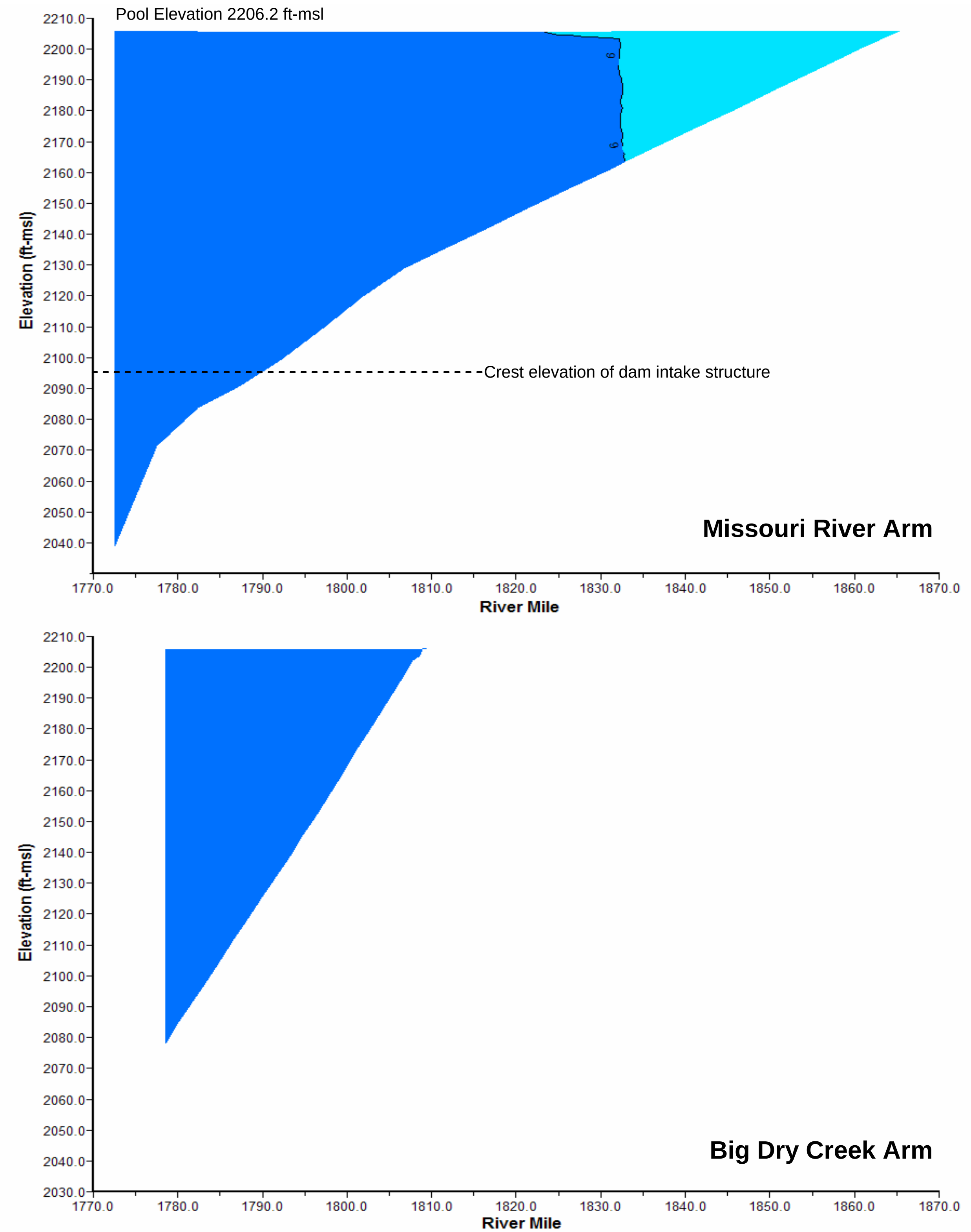


Plate 21. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on June 22, 2006.

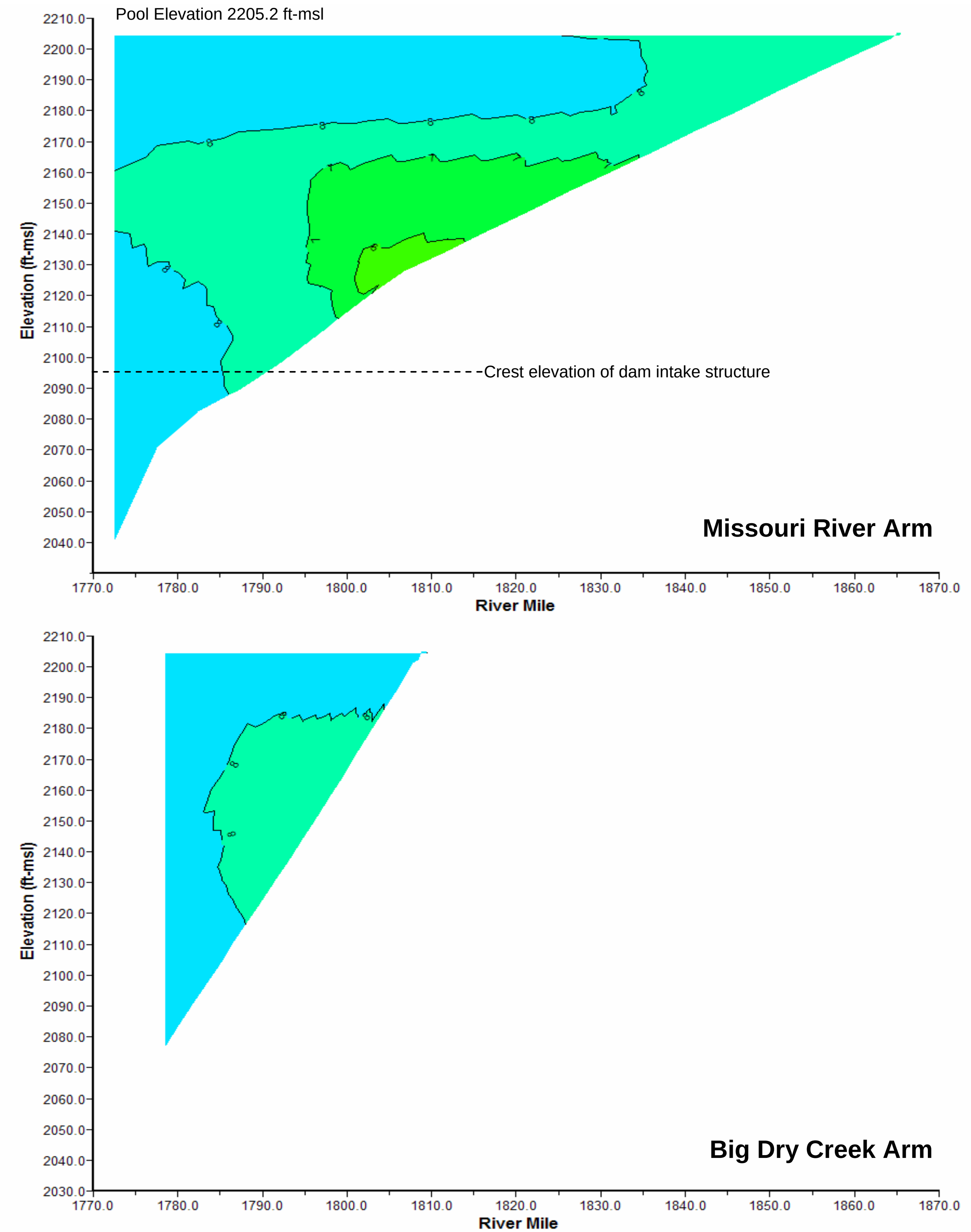


Plate 22. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on July 26, 2006.

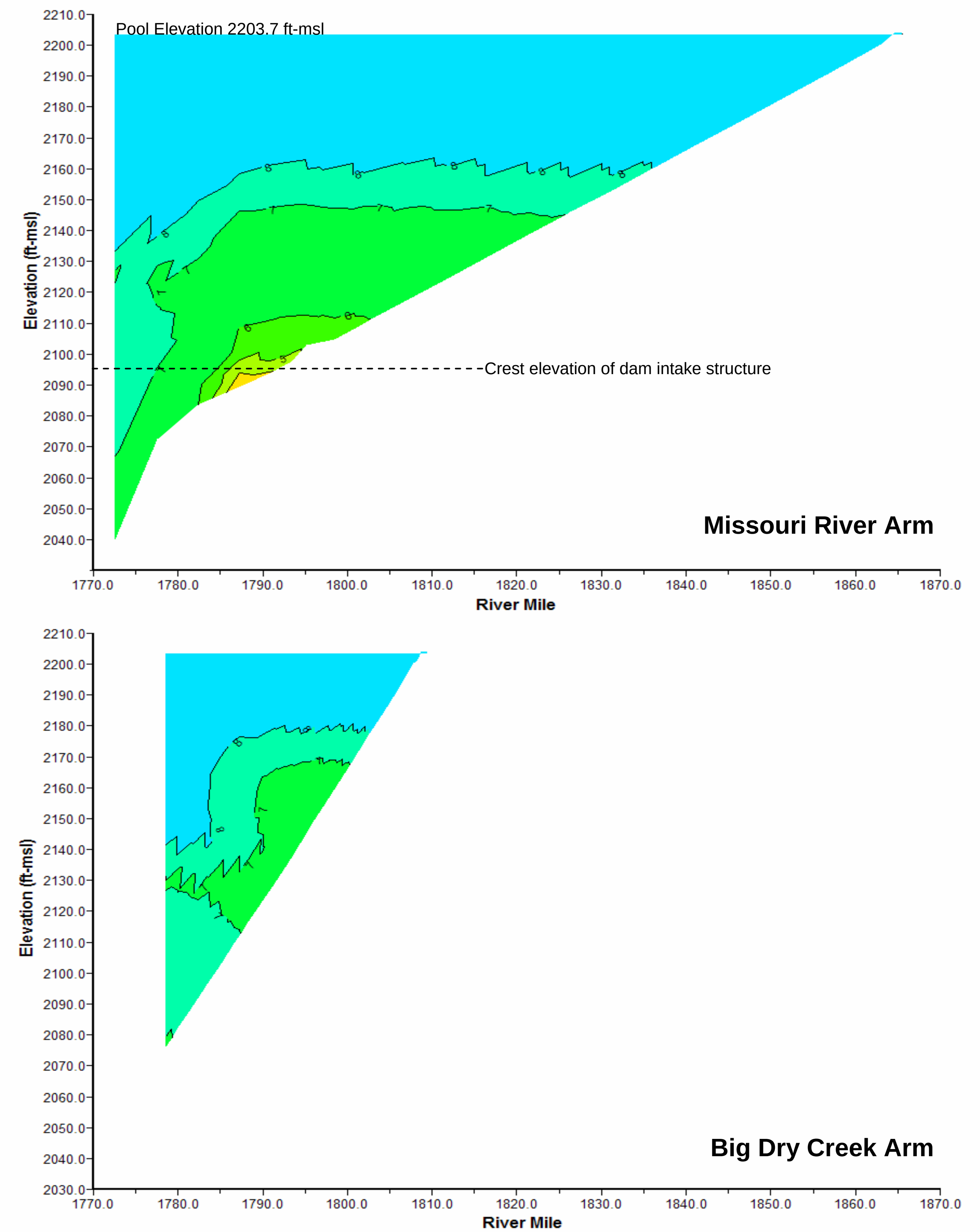


Plate 23. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L5, L6, and NF1 on August 30, 2006.

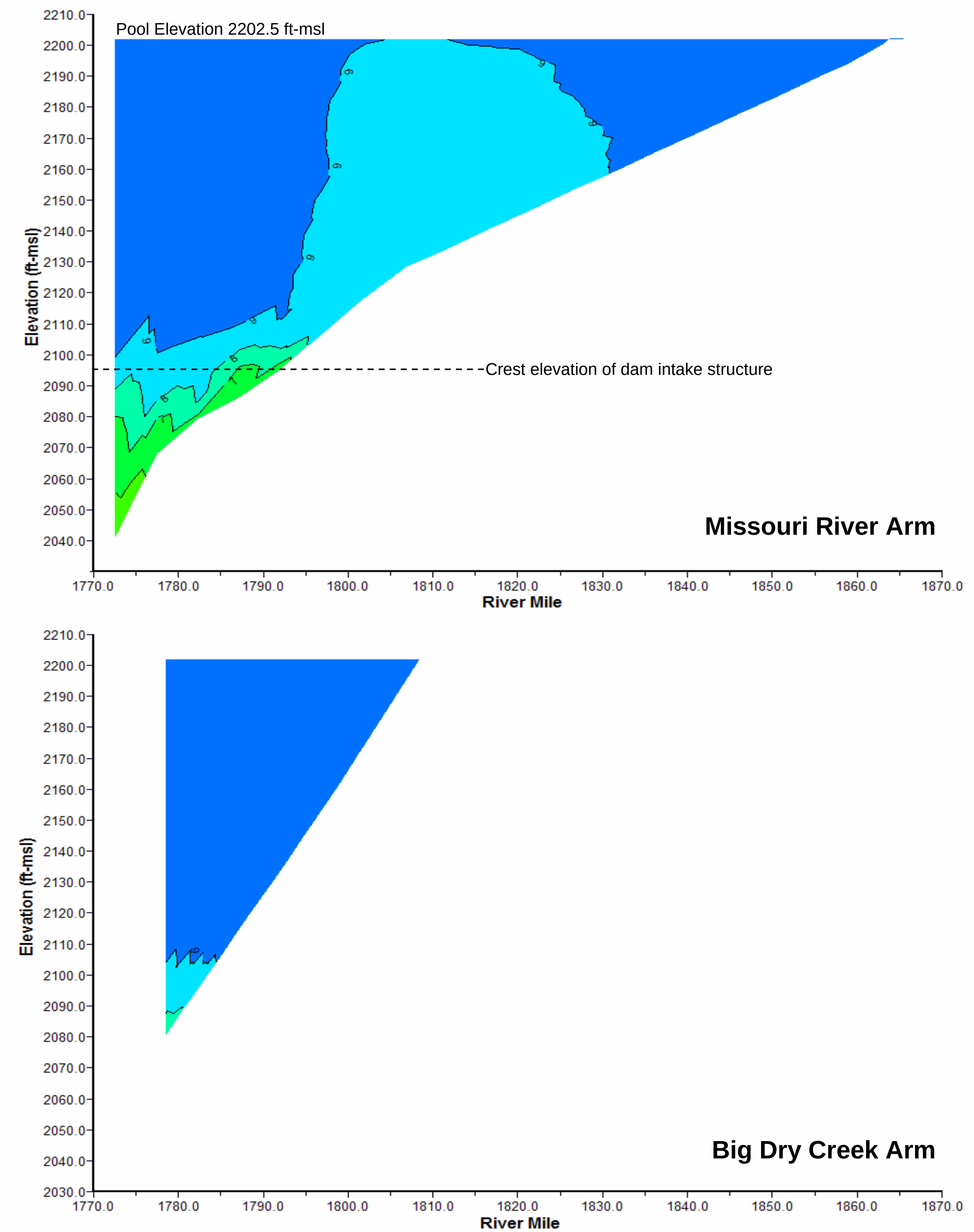


Plate 24. Longitudinal dissolved oxygen contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on October 5, 2006.

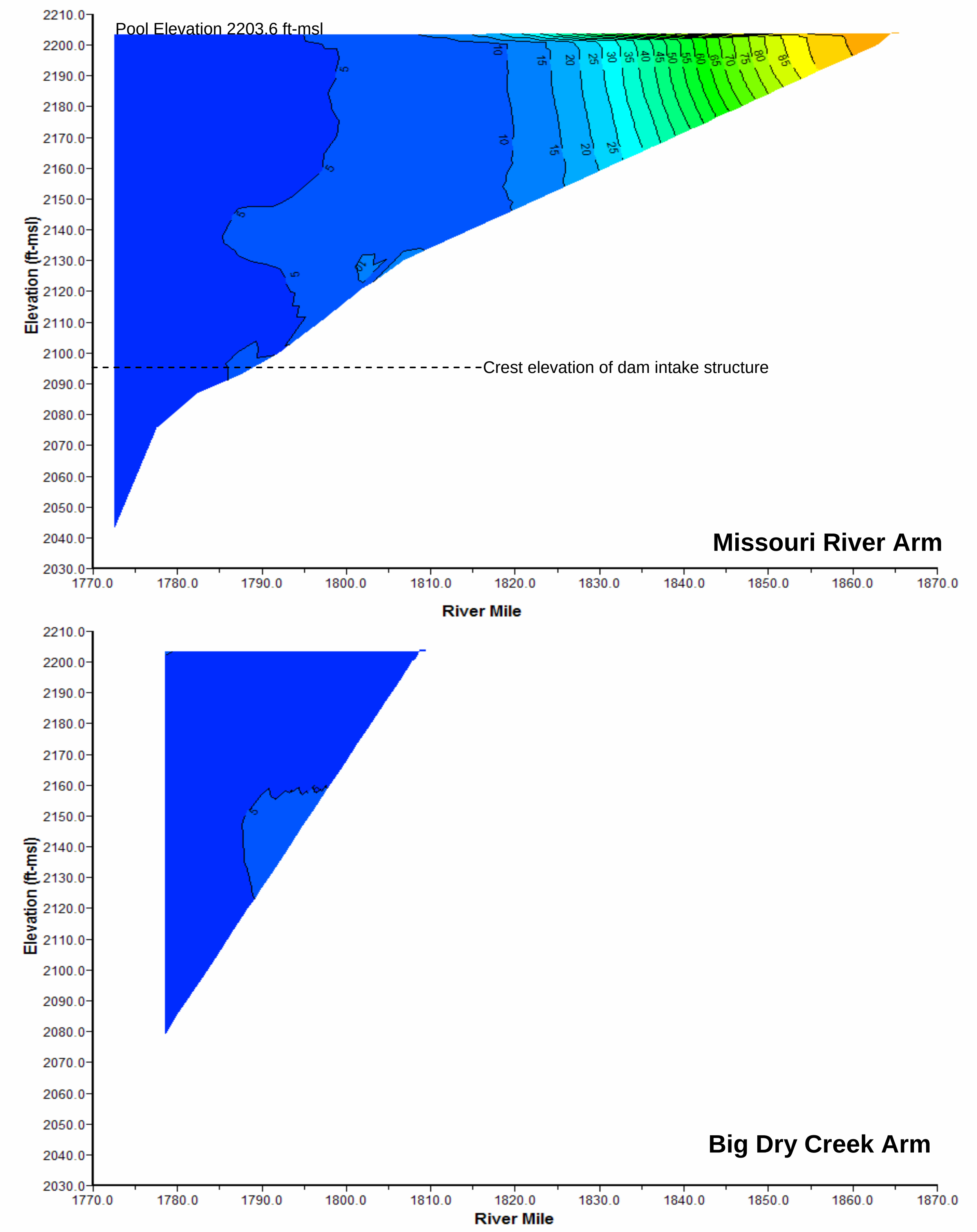


Plate 25. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3,L4, L5, L6, and NF1 on June 23, 2004.

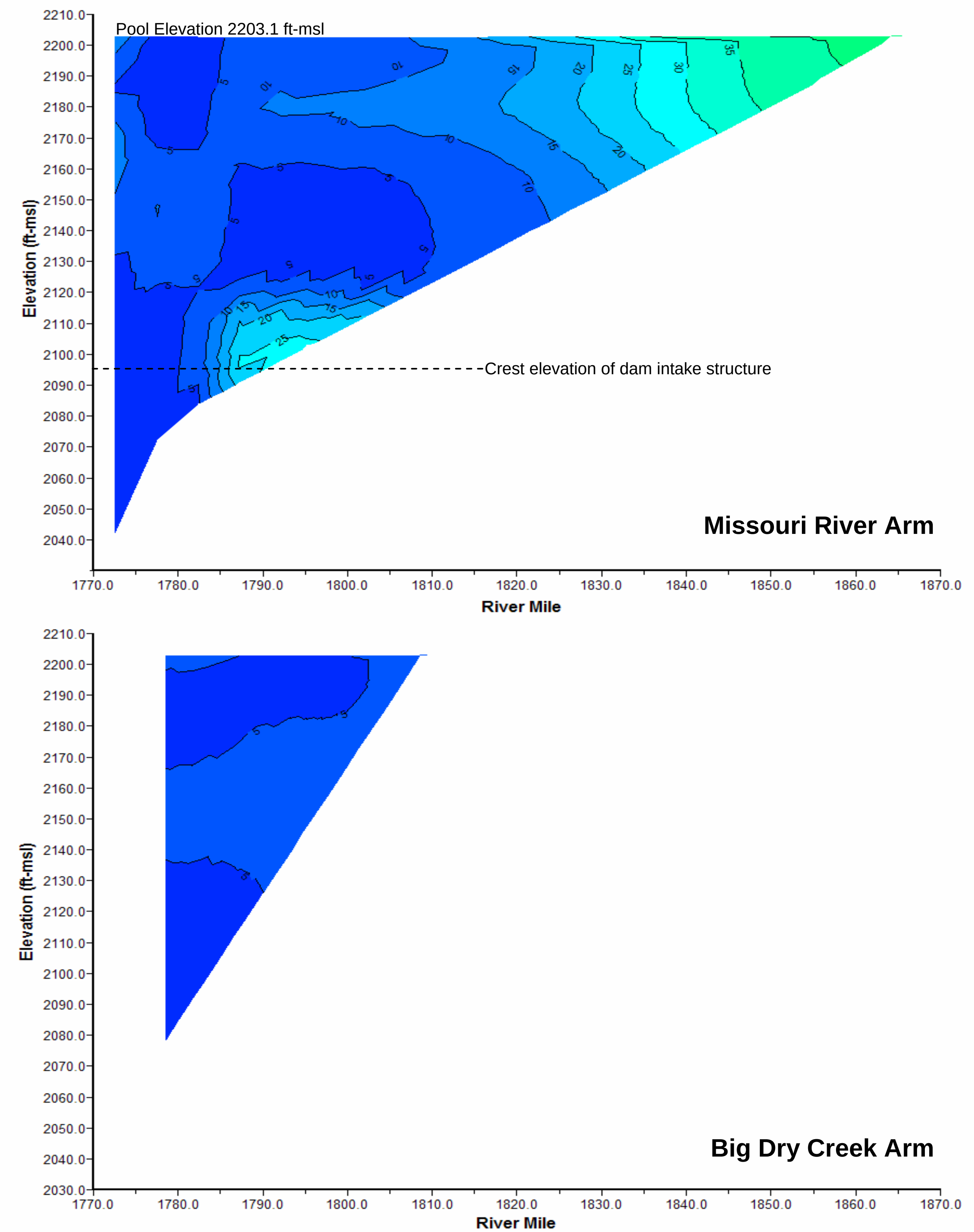


Plate 26. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L5, L6, and NF1 on July 20, 2004.

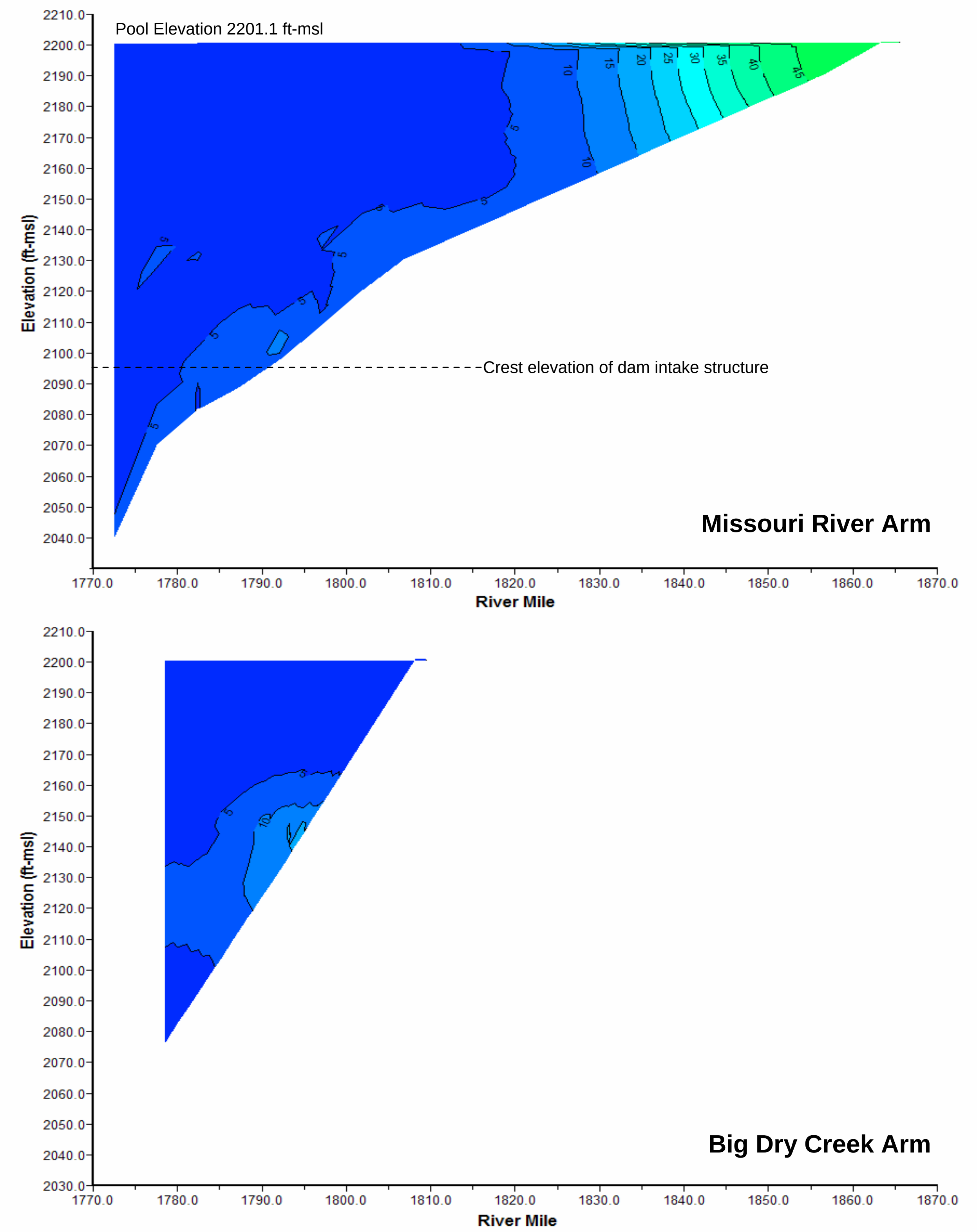


Plate 27. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on August 16, 2004.

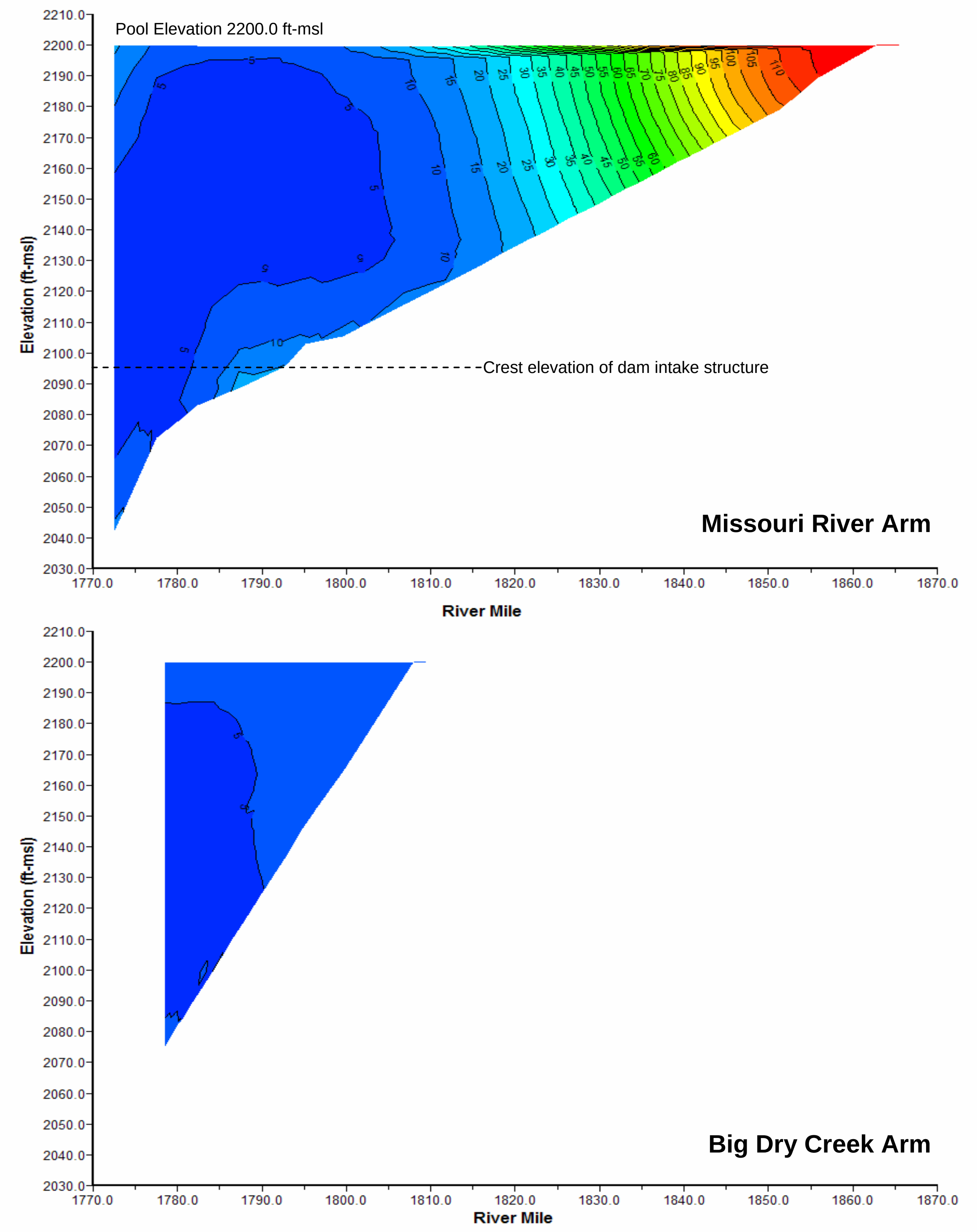
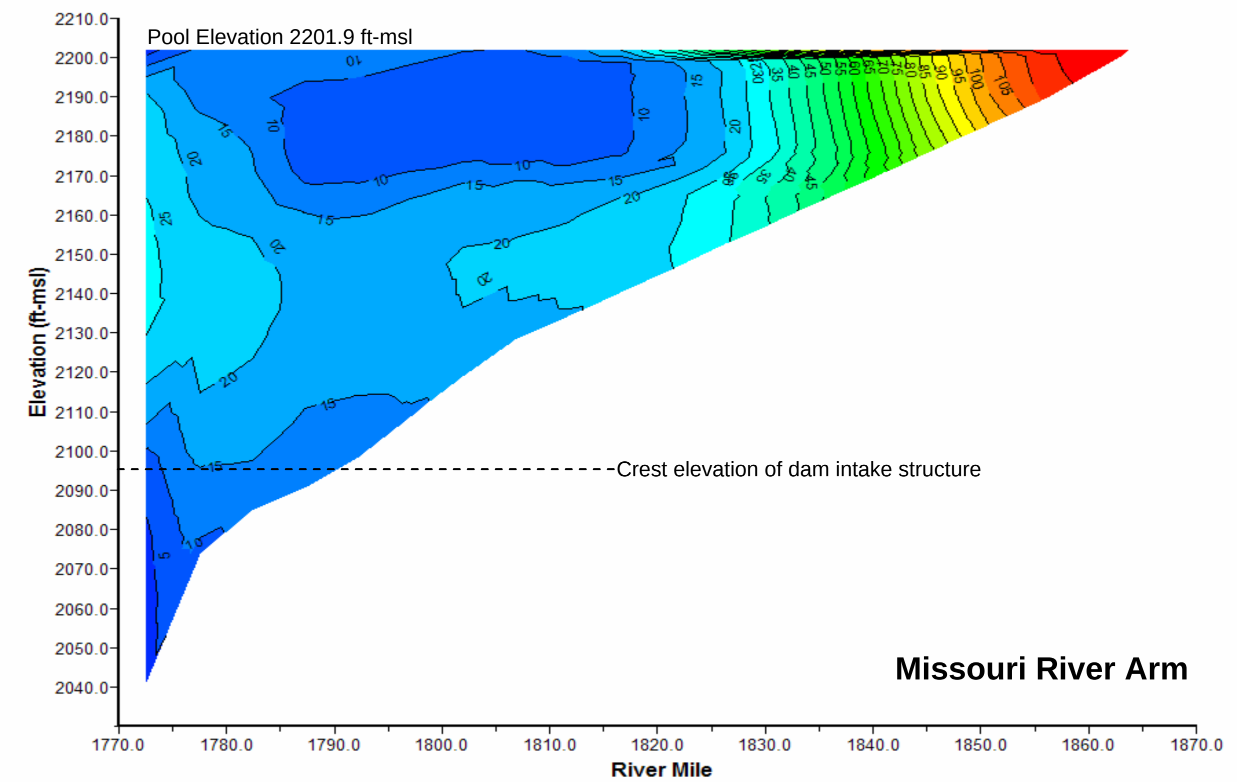


Plate 28. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L5, L6, and NF1 on September 22, 2004.



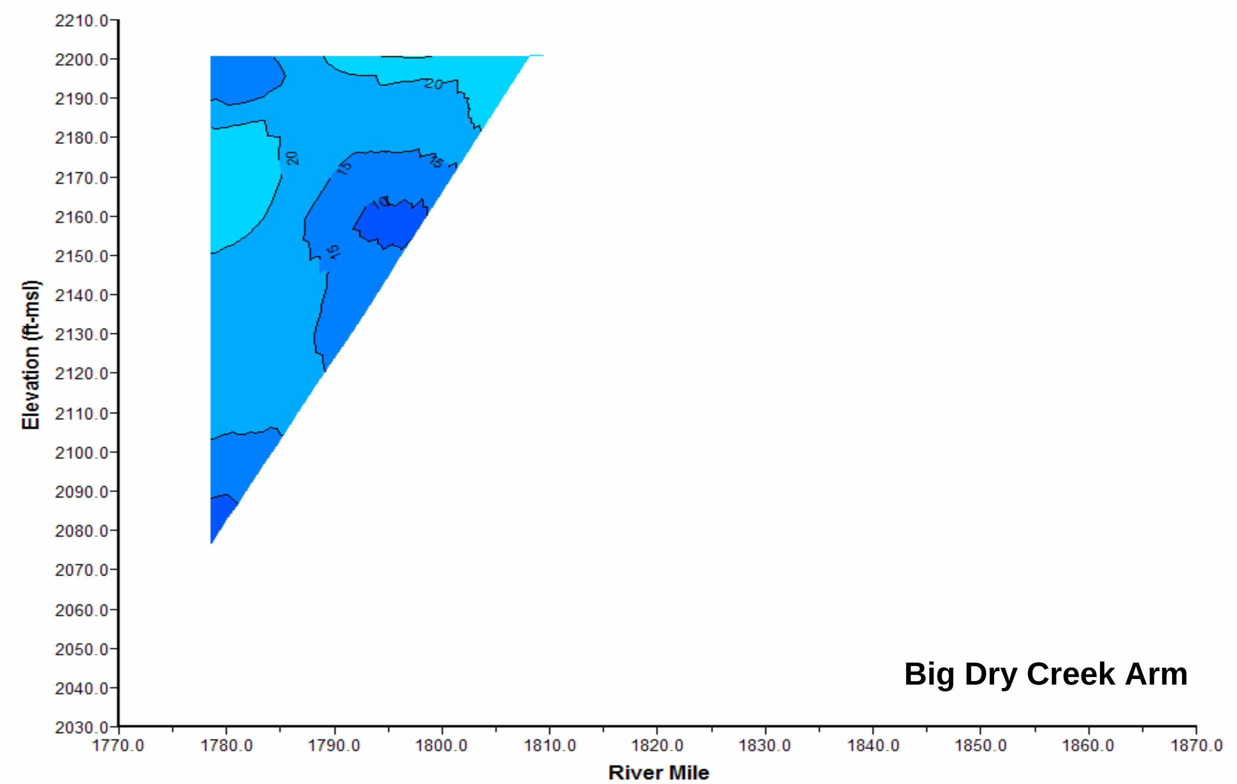


Plate 29. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on June 20, 2005.

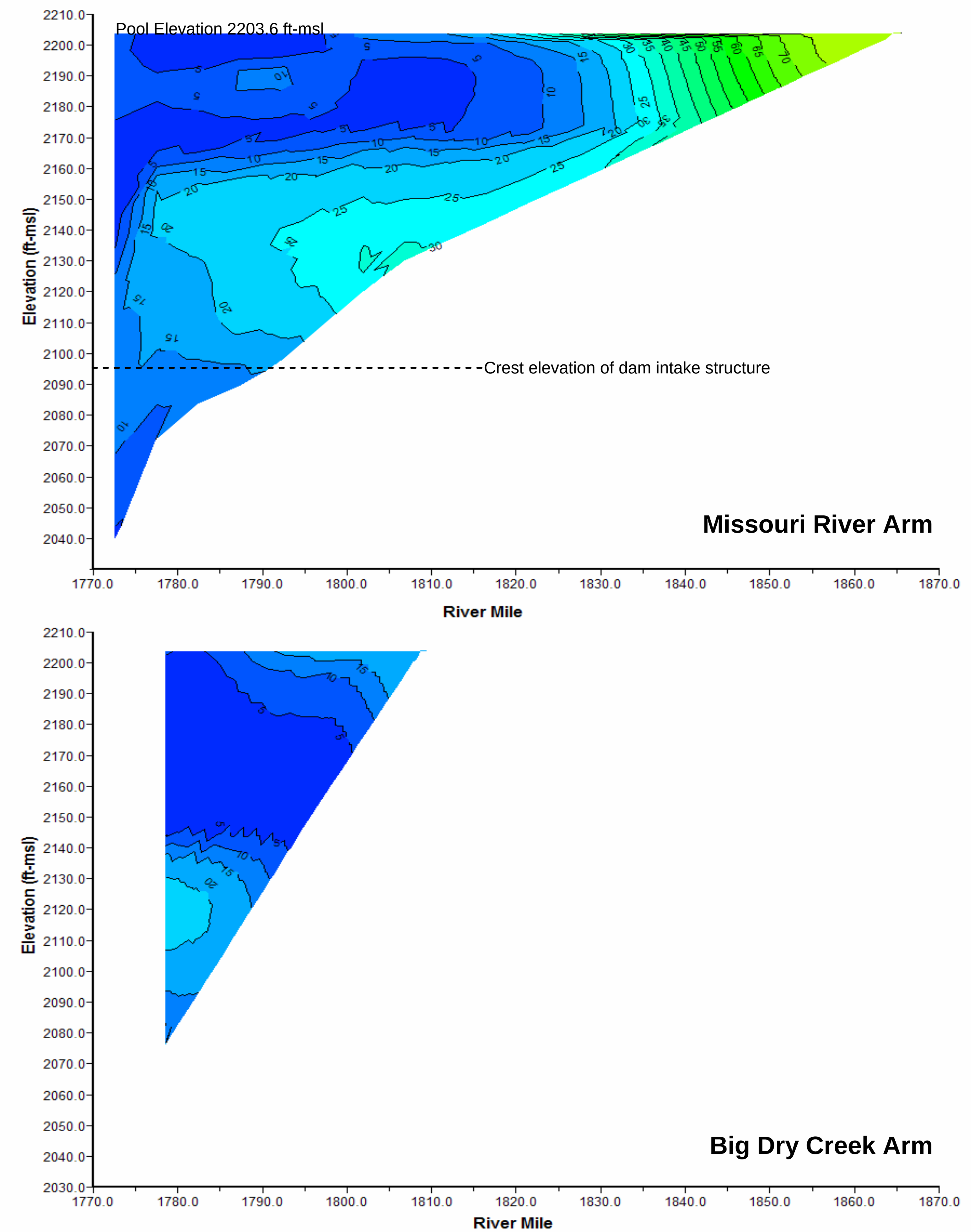


Plate 30. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on July 18, 2005.

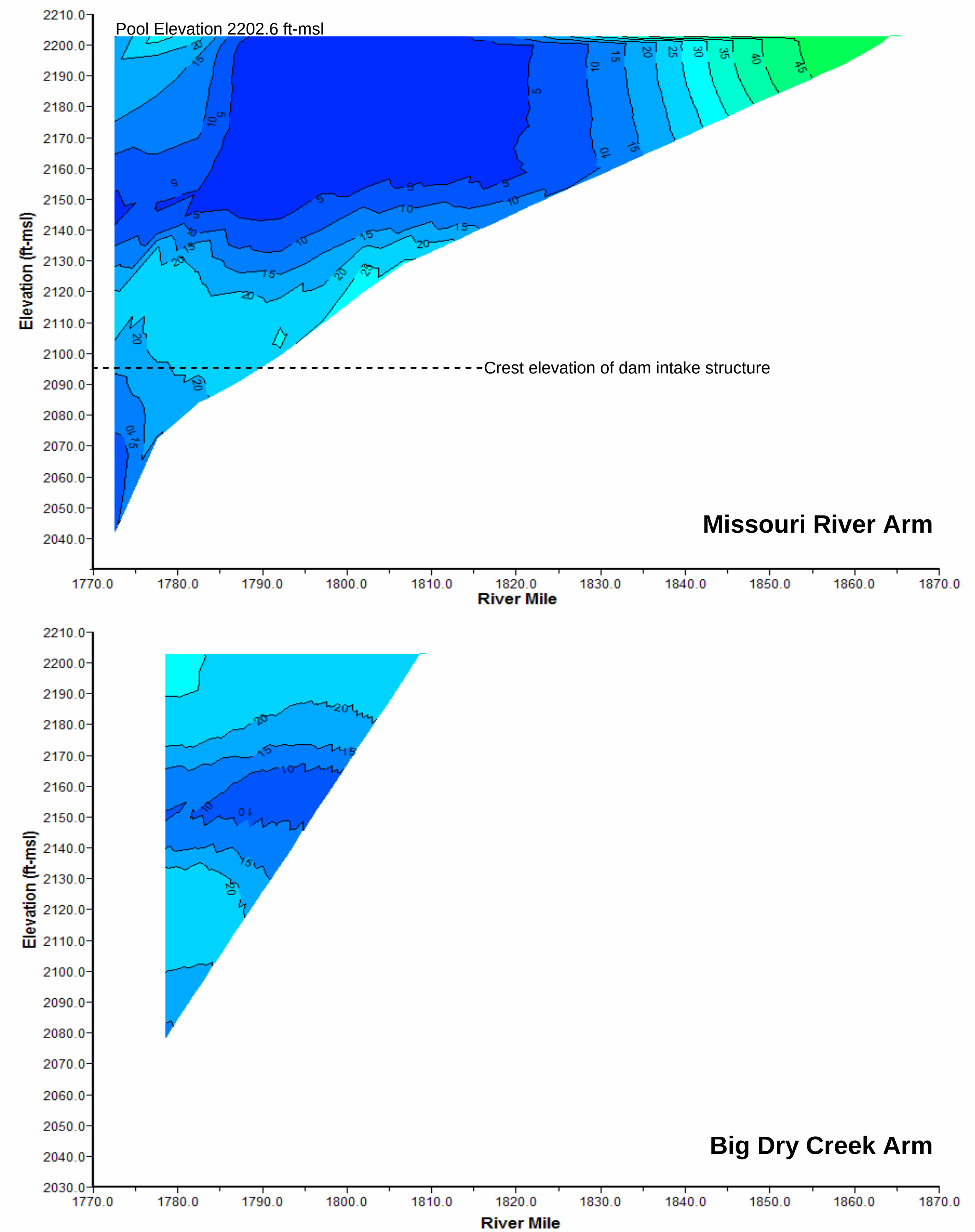


Plate 31. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on August 22, 2005.

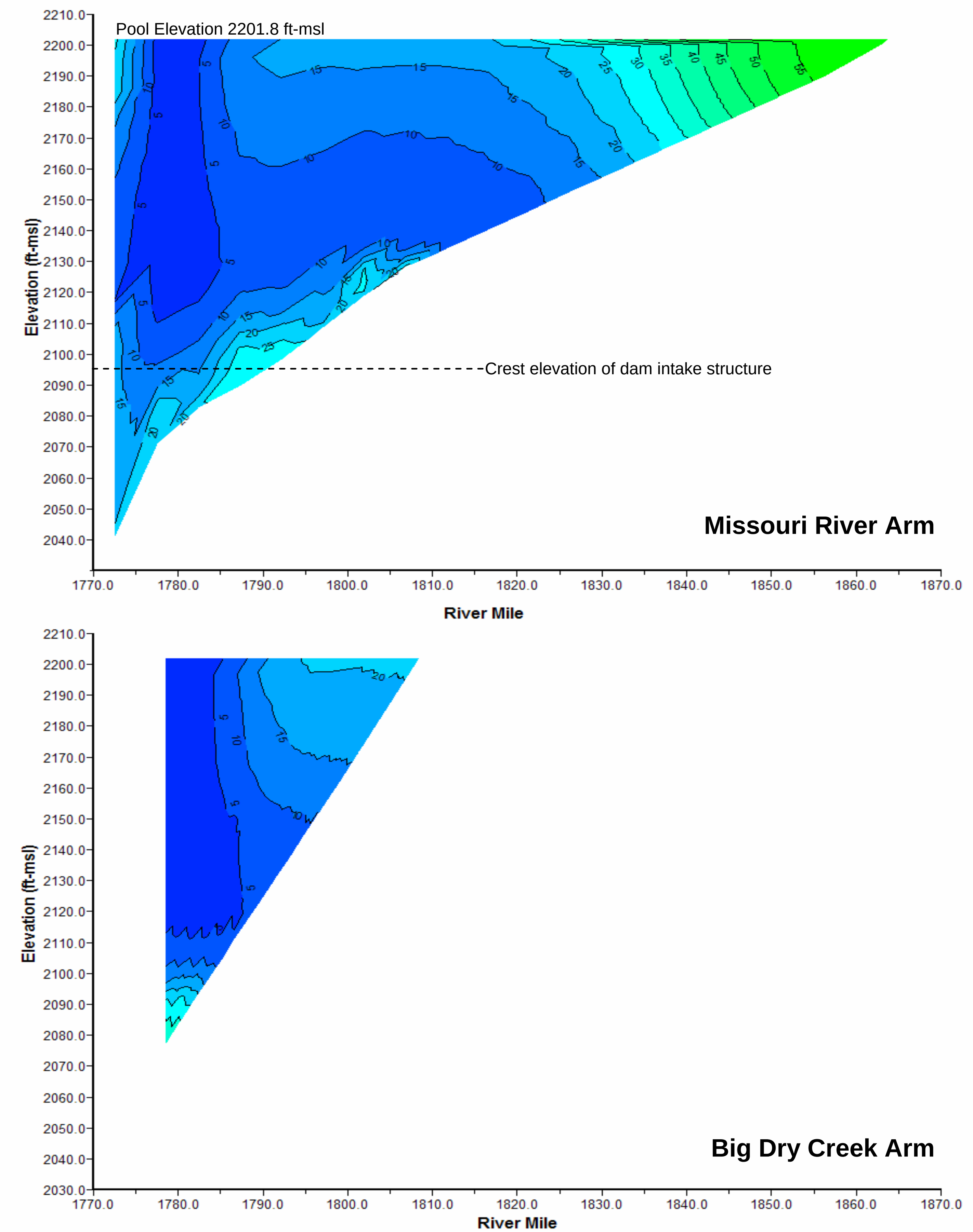


Plate 32. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on September 20, 2005.

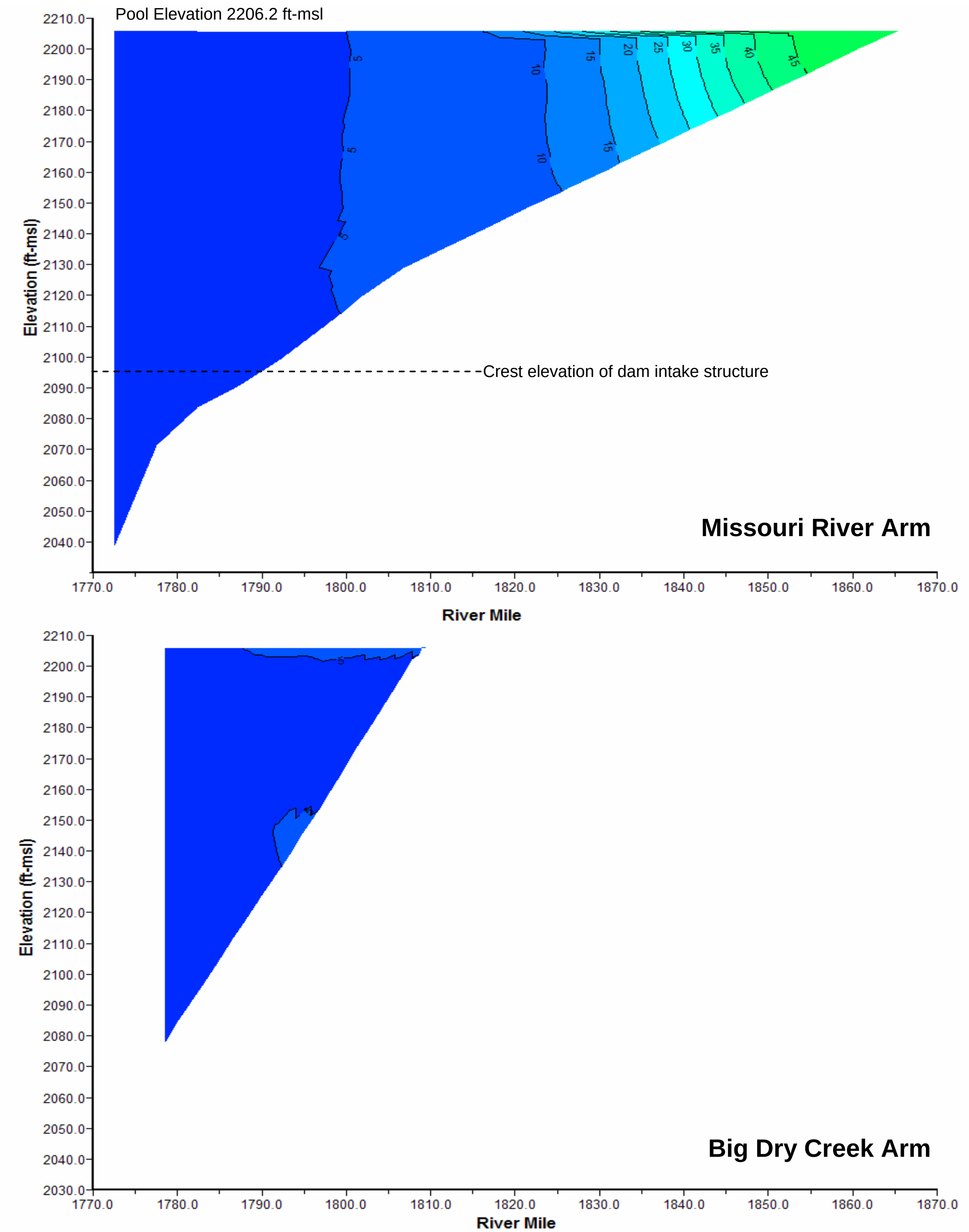
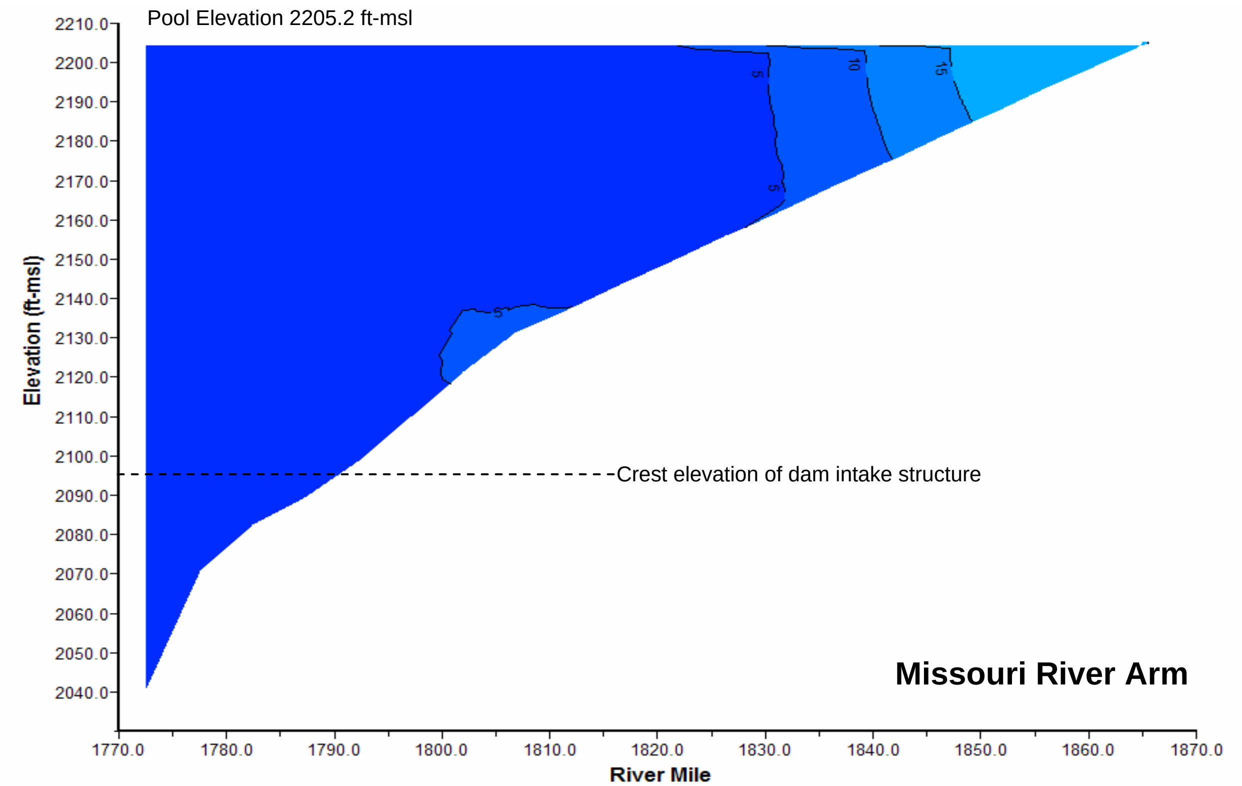


Plate 33. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on June 22, 2006.



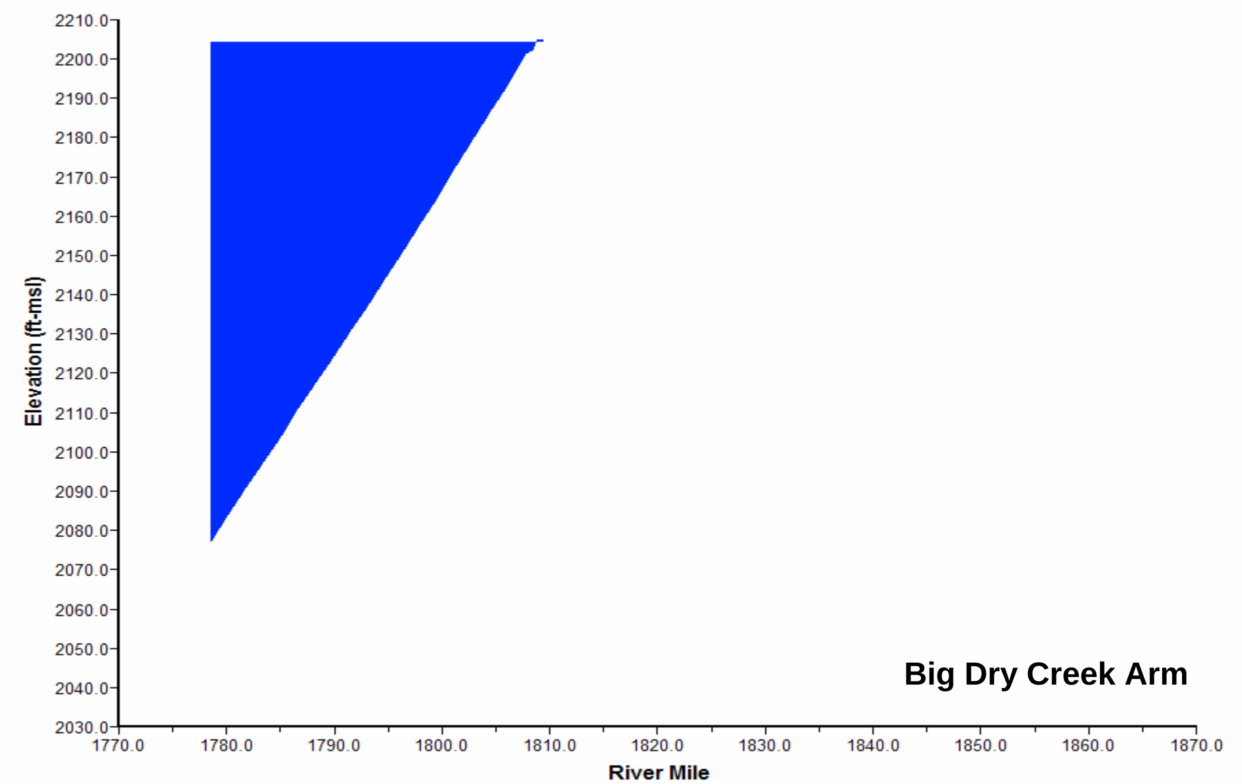


Plate 34. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on July 26, 2006.

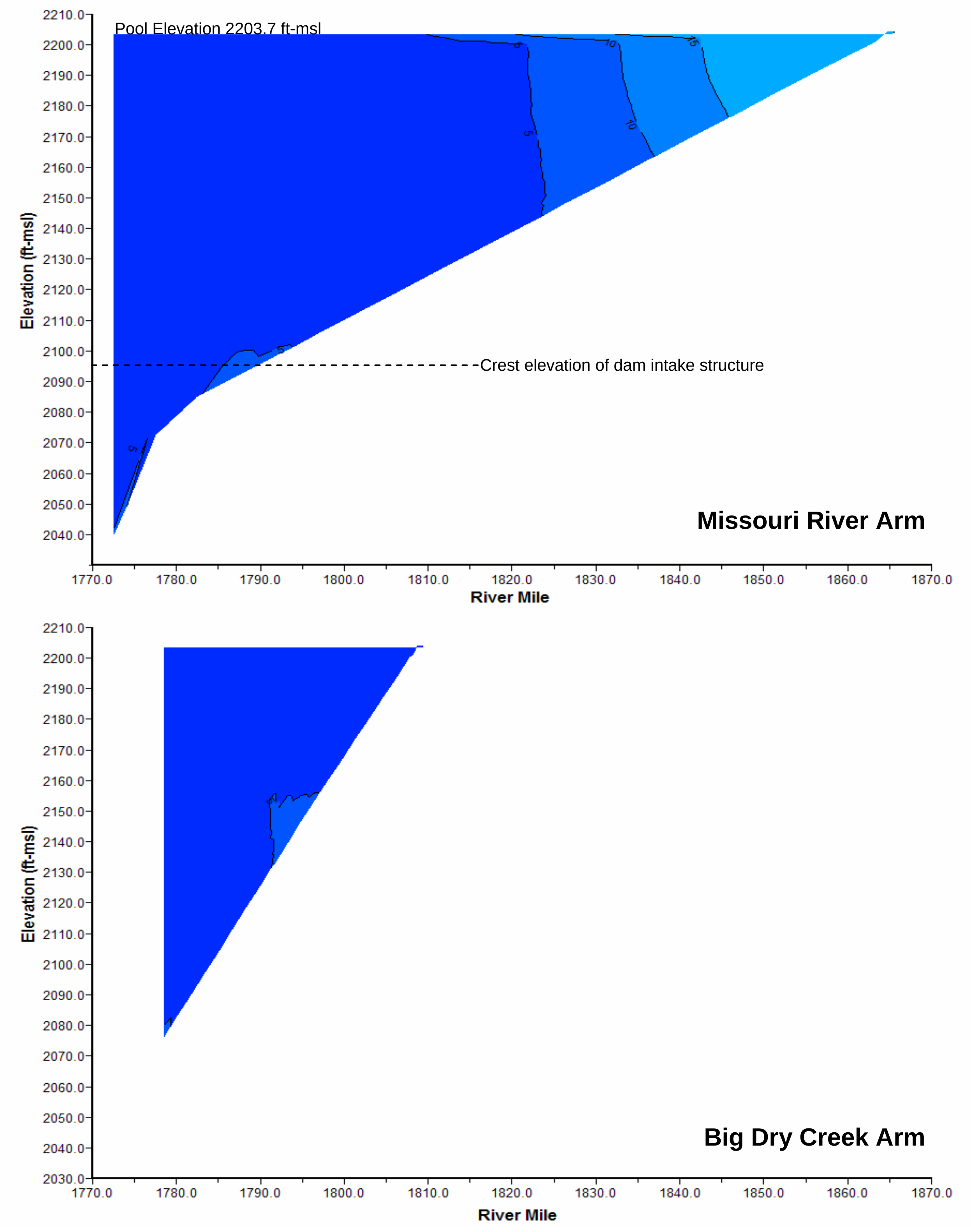


Plate 35. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L5, L6, and NF1 on August 30, 2006.

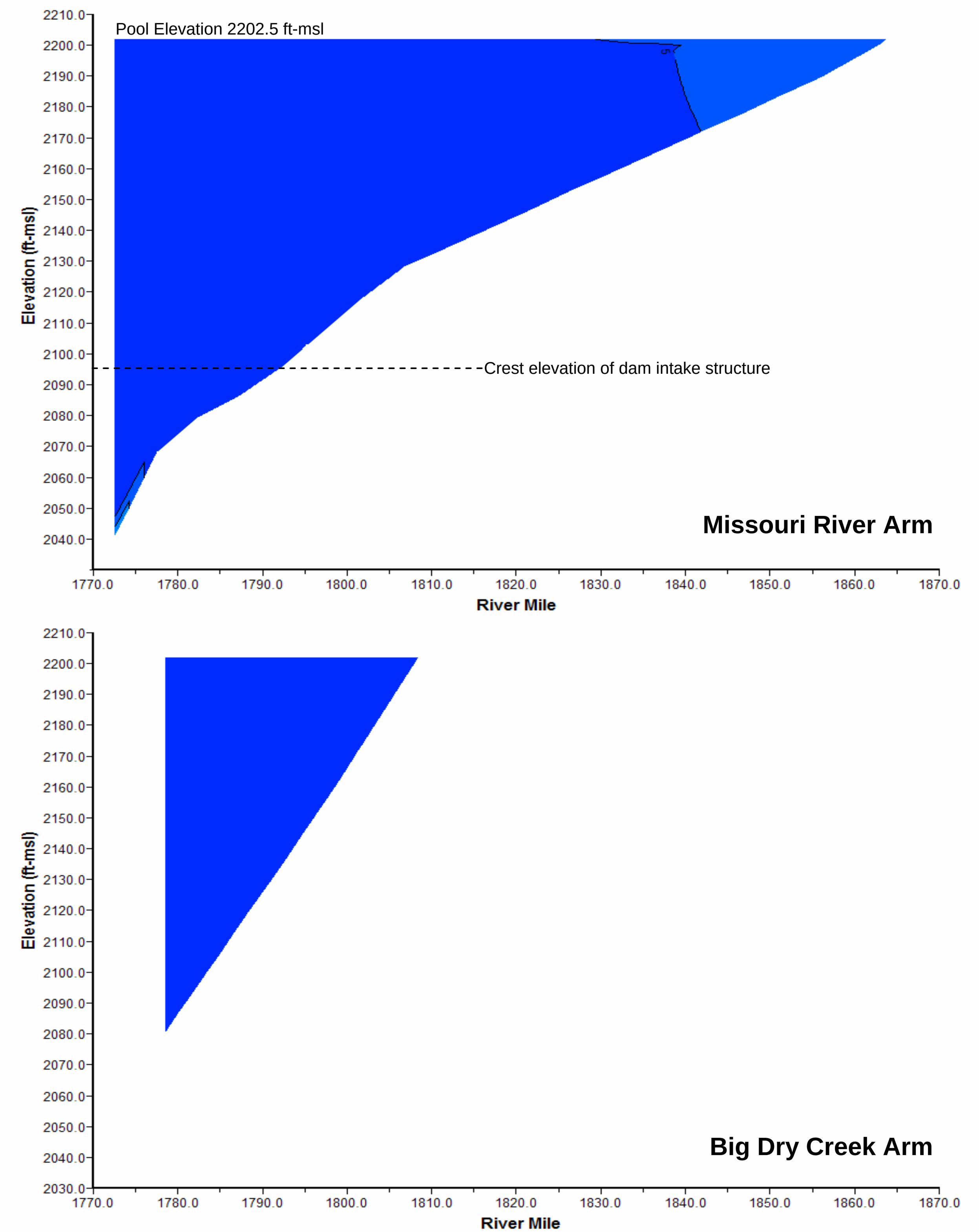


Plate 36. Longitudinal turbidity contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites L1, L2, L3, L4, L5, L6, and NF1 on October 5, 2006.

Plate 37. Phytoplankton total biovolume and percent taxa composition at the Division level based on biovolume for individual grab samples collected in Fort Peck Reservoir at sites L1, L3, L4, and L6 during the period 2004 through 2006.

Site	Date	Biovolume (um^3)	Bacillariophyta	Chlorophyta	Chrysophyta	Cryptophyta	Cyanobacteria	Euglenophyta	Pyrrophyta
L1	May 2004	785,288	2%	-----	-----	57%	41%	-----	-----
L1	June 2004	5,099,022	21%	-----	-----	65%	13%	-----	-----
L1	July 2004	106,065,880	100%	-----	-----	<1%	<1%	-----	-----
L1	Aug 2004	47,445,369	93%	<1%	-----	5%	2%	-----	-----
L1	Sep 2004	47,026,614	66%	10%	-----	9%	9%	-----	5%
L1	May 2005	515,757,980	92%	<1%	7%	-----	-----	-----	-----
L1	June 2005	46,921,234	90%	<1%	-----	-----	1%	-----	9%
L1	July 2005	156,655,118	79%	1%	-----	7%	2%	-----	11%
L1	Aug 2005	329,301,346	46%	1%	1%	5%	18%	-----	30%
L1	Sep 2005	138,703,298	38%	8%	-----	<1%	5%	-----	47%
L1	May 2006	38,868,068	99%	1%	-----	-----	-----	<1%	-----
L1	June 2006	106,214,930	89%	2%	<1%	<1%	8%	<1%	-----
L1	July 2006	99,703,362	25%	1%	3%	1%	34%	1%	35%
L1	Aug 2006	146,573,753	85%	5%	-----	3%	7%	-----	-----
L1	Sep 2006	187,114,896	95%	<1%	-----	4%	1%	-----	-----
L3	June 2004	10,901,692	74%	7%	-----	2%	17%	-----	-----
L3	July 2004	86,045,868	53%	-----	-----	8%	<1%	-----	38%
L3	Aug 2004	118,170,922	86%	-----	-----	11%	<1%	-----	3%
L3	Sep 2004	137,015,326	89%	-----	-----	6%	3%	-----	1%
L3	June 2005	230,426,294	93%	1%	4%	2%	<1%	-----	-----
L3	July 2005	117,389,092	51%	6%	-----	7%	35%	-----	-----
L3	Aug 2005	238,094,698	63%	4%	4%	7%	21%	-----	<1%
L3	Sep 2005	239,001,877	64%	1%	<1%	4%	6%	-----	25%
L3	June 2006	209,290,886	91%	3%	2%	1%	3%	1%	-----
L3	July 2006	102,150,924	37%	4%	11%	1%	22%	-----	25%
L3	Aug 2006	229,259,901	70%	6%	-----	5%	19%	-----	-----
L3	Sep 2006	176,892,532	88%	3%	1%	6%	2%	-----	-----

Plate 37. Continued.

Site	Date	Biovolume (um^3)	Bacillariophyta	Chlorophyta	Chrysophyta	Cryptophyta	Cyanobacteria	Euglenophyta	Pyrrophyta
L4	June 2004	40,330,085	73%	-----	-----	25%	1%	-----	1%
L4	Aug 2004	77,071,993	53%	-----	-----	9%	25%	-----	12%
L4	June 2005	1,065,980,294	97%	1%	2%	<1%	<1%	-----	-----
L4	July 2005	56,454,155	62%	1%	-----	27%	6%	-----	4%
L4	Aug 2005	104,295,158	36%	14%	-----	12%	37%	-----	<1%
L4	Sep 2005	224,860,040	56%	9%	5%	15%	6%	-----	8%
L4	June 2006	462,062,083	94%	2%	1%	2%	-----	<1%	-----
L4	July 2006	339,425,190	19%	10%	3%	22%	43%	-----	3%
L4	Sep 2006	342,710,099	72%	10%	1%	7%	10%	-----	<1%
L6	June 2004	8,899,939	67%	-----	-----	10%	23%	-----	-----
L6	July 2004	50,170,334	73%	-----	2%	15%	<1%	-----	10%
L6	Aug 2004	56,170,047	77%	<1%	-----	8%	14%	-----	1%
L6	Sep 2004	259,164,480	83%	1%	<1%	6%	2%	-----	8%
L6	June 2005	135,109,593	31%	2%	64%	1%	2%	-----	-----
L6	July 2005	60,324,919	47%	3%	---	43%	8%	-----	-----
L6	Aug 2005	155,331,963	41%	10%	3%	-----	30%	-----	16%
L6	Sep 2005	95,486,617	60%	6%	-----	10%	16%	-----	9%
L6	June 2006	91,137,918	91%	1%	-----	-----	2%	6%	-----
L6	July 2006	73,204,385	11%	7%	-----	4%	67%	-----	11%
L6	Aug 2006	86,290,748	60%	5%	-----	14%	21%	-----	-----
L6	Sep 2006	105,358,293	65%	1%	-----	12%	21%	-----	<1%

Plate 38. Listing of phytoplankton taxa collected in Fort Peck Reservoir at sites L1, L3, L4, and L6 during the period 2004 through 2006.

Division	Genus/Species	Frequency of Occurrence*	Relative Abundance**
Bacillariophyta	*Achnanthes spp.*	Rare	Very Low
Bacillariophyta	*Achnanthidium spp.*	Occasional	Very Low
Bacillariophyta	*Actinocyclus normanii*	Rare	Very Low
Bacillariophyta	*Amphora spp.*	Rare	Very Low
Bacillariophyta	*Asterionella formossa*	Common	High
Bacillariophyta	*Aulacoseira spp.*	Common	High
Bacillariophyta	*Aulacoseira granulata*	Common	High
Bacillariophyta	*Aulacoseira islandica*	Common	High
Bacillariophyta	*Cocconeis placentula*	Rare	Very Low
Bacillariophyta	*Cyclostephanos dubius*	Rare	Low
Bacillariophyta	*Cyclotella spp.*	Common	Medium
Bacillariophyta	*Cyclotella ocellata*	Occasional	Very Low
Bacillariophyta	*Cyclotella stelligera*	Rare	Low
Bacillariophyta	*Cymatopleura solea*	Rare	Low
Bacillariophyta	*Cymbella spp.*	Occasional	Very Low
Bacillariophyta	*Diatoma vulgare*	Rare	Low
Bacillariophyta	*Diploneis spp.*	Rare	Very Low
Bacillariophyta	*Eunotia spp.*	Rare	Low
Bacillariophyta	*Fragilaria spp.*	Common	High
Bacillariophyta	*Fragilaria capucina*	Rare	Low
Bacillariophyta	*Fragilaria crotonensis*	Common	High
Bacillariophyta	*Gomphonema gracile*	Rare	Low
Bacillariophyta	*Gomphonema minuta*	Rare	Very Low
Bacillariophyta	*Gyrosigma spp.*	Rare	Very Low
Bacillariophyta	*Mastogloia spp.*	Rare	Very Low
Bacillariophyta	*Melosira varians*	Rare	High
Bacillariophyta	*Navicula spp.*	Common	Low
Bacillariophyta	*Nitzschia spp.*	Occasional	Very Low
Bacillariophyta	*Nitzschia acicularis*	Rare	Very Low
Bacillariophyta	*Nitzschia inconspicua*	Rare	Very Low
Bacillariophyta	*Nitzachia lorenziana*	Rare	Very Low
Bacillariophyta	*Rhopalodia gibba*	Rare	Low
Bacillariophyta	*Stephanodiscus spp.*	Common	Medium
Bacillariophyta	*Stephanodiscus hantzschii*	Common	Medium
Bacillariophyta	*Stephanodiscus niagarea*	Occasional	Medium
Bacillariophyta	*Surirella ovata*	Rare	Very Low
Bacillariophyta	*Synedra spp.*	Common	Low
Bacillariophyta	*Tabellaria fenestrata*	Occasional	Low
Chlorophyta	*Ankistrodesmus falcatus*	Occasional	Very Low
Chlorophyta	*Asterococcus superbus*	Rare	Low
Chlorophyta	*Bracteacoccus spp.*	Rare	Very Low
Chlorophyta	*Characium spp.*	Rare	Very Low
Chlorophyta	*Chlamydomonas spp.*	Common	Low
Chlorophyta	*Chlorella vulgaris*	Rare	Very Low
Chlorophyta	*Closteriopsis longissima*	Rare	Low
Chlorophyta	*Closterium spp.*	Rare	Very Low
Chlorophyta	*Closterium gracile*	Rare	Very Low
Chlorophyta	*Coelastrum microsporum*	Rare	Low
Chlorophyta	*Cosmarium spp.*	Occasional	Very Low
Chlorophyta	*Crucigenia spp.*	Rare	Very Low
Chlorophyta	*Crucigenia apiculata*	Rare	Very Low
Chlorophyta	*Crucigenia crucifera*	Rare	Very Low
Chlorophyta	*Crucigenia irregularis*	Rare	Very Low

Plate 38. (Continued).

Division	Genus/Species	Frequency of Occurrence*	Relative Abundance**
Chlorophyta	*Crucigenia tetrapedia*	Rare	Very Low
Chlorophyta	*Dictyosphaerium pulchellum*	Rare	Low
Chlorophyta	*Elakatothrix gelatinosa*	Rare	Very Low
Chlorophyta	*Euastrum spp.*	Rare	Very Low
Chlorophyta	*Gloeocystis vesiculosa*	Common	Very Low
Chlorophyta	*Golenkinia paucispina*	Rare	Very Low
Chlorophyta	*Golenkinia radiata*	Rare	Very Low
Chlorophyta	*Gonium pectorale*	Rare	Very Low
Chlorophyta	*Gonium sociale*	Rare	Very Low
Chlorophyta	*Monoraphidium capricornutum*	Rare	Very Low
Chlorophyta	*Oocystis spp.*	Occasional	Low
Chlorophyta	*Pandorina morum*	Rare	Low
Chlorophyta	*Pediastrum boryanum*	Rare	Very Low
Chlorophyta	*Pediastrum duplex*	Rare	Medium
Chlorophyta	*Pediastrum simplex*	Rare	Very Low
Chlorophyta	*Planktosphaeria gelatinosa*	Rare	Very Low
Chlorophyta	*Quadrigula spp.*	Occasional	Very Low
Chlorophyta	*Quadrigula lacustris*	Occasional	Very Low
Chlorophyta	*Scenedesmus balatonicus*	Rare	Very Low
Chlorophyta	*Scenedesmus bijuga*	Rare	Very Low
Chlorophyta	*Scenedesmus quadricauda*	Common	Very Low
Chlorophyta	*Schizochlamydella spp.*	Rare	Low
Chlorophyta	*Schroederia spp.*	Rare	Very Low
Chlorophyta	*Selenastrum spp.*	Rare	Very Low
Chlorophyta	*Sorastrum americanum*	Rare	Very Low
Chlorophyta	*Sphaerocystis schroeteri*	Rare	Very Low
Chlorophyta	*Spondylomorum spp.*	Rare	Very Low
Chlorophyta	*Staurastrum spp.*	Occasional	Low
Chlorophyta	*Stichococcus bacillaris*	Rare	Very Low
Chlorophyta	*Tetraedon spp.*	Occasional	Very Low
Chlorophyta	*Tetraedon limnetica*	Rare	Very Low
Chlorophyta	*Tetraedon minimum*	Occasional	Very Low
Chlorophyta	*Ulothrix spp.*	Rare	Very Low
Chrysophyta	*Dinobryon bavaricum*	Occasional	Low
Chrysophyta	*Dinobryon divergens*	Occasional	Low
Chrysophyta	*Dinobryon sertularia*	Rare	Low
Chrysophyta	*Mallomonas spp.*	Occasional	Low
Chrysophyta	*Mallomonas producta*	Rare	Low
Chrysophyta	*Mallomonas tonsurata*	Rare	Low
Cryptophyta	*Cryptomonas spp.*	Common	Medium
Cryptophyta	*Rhodomonas minuta*	Common	High
Cyanobacteria	*Anabaena spp.*	Common	Medium
Cyanobacteria	*Anabaena catenula.*	Rare	Very Low
Cyanobacteria	*Anabaena circinalis*	Rare	Low
Cyanobacteria	*Anabaena flos-aquae*	Rare	Low
Cyanobacteria	*Anabaena helicoidea*	Rare	High
Cyanobacteria	*Anabaena macrospora*	Rare	Very Low
Cyanobacteria	*Anabaena spiroides*	Rare	Medium
Cyanobacteria	*Anabaenopsis spp.*	Occasional	Low
Cyanobacteria	*Anabaenopsis tanganyikae*	Rare	Low
Cyanobacteria	*Aphanizomenon spp.*	Common	Medium
Cyanobacteria	*Aphanocapsa spp.*	Common	Low
Cyanobacteria	*Aphanocapsa delicatissima.*	Occasional	Low

Plate 38. (Continued).

Division	Genus/Species	Frequency of Occurrence*	Relative Abundance**
Cyanobacteria	*Aphanothece spp.*	Occasional	Low
Cyanobacteria	*Aphanothece stagnina*	Rare	Very Low
Cyanobacteria	*Chroococcus spp.*	Rare	Very Low
Cyanobacteria	*Chroococcus minutus*	Rare	Very Low
Cyanobacteria	*Coelosphaerium kuetzingianum*	Rare	Very Low
Cyanobacteria	*Cylindrospermopsis spp.*	Occasional	High
Cyanobacteria	*Gomphosphaeria aponina*	Rare	Very Low
Cyanobacteria	*Gomphosphaeria lacustris*	Rare	Very Low
Cyanobacteria	*Merismopedia spp.*	Occasional	Very Low
Cyanobacteria	*Merismopedia elegans*	Rare	Very Low
Cyanobacteria	*Merismopedia tenuissima*	Rare	Very Low
Cyanobacteria	*Microcystis spp.*	Rare	Very Low
Cyanobacteria	*Microcystis aeruginosa*	Rare	Very Low
Cyanobacteria	*Oscillatoria spp.*	Rare	Low
Cyanobacteria	*Pseudanabaena spp.*	Occasional	Low
Cyanobacteria	*Pseudanabaena limnetica*	Rare	Very Low
Cyanobacteria	*Synechococcus spp.*	Occasional	Very Low
Cyanobacteria	*Trichormus variabilis*	Rare	Very Low
Euglenophyta	*Eulgena spp.*	Occasional	Very Low
Euglenophyta	*Phacus spp.*	Rare	Low
Euglenophyta	*Phacus acuminatus*	Rare	Medium
Pyrrophyta	*Ceratium hirundinella*	Common	High
Pyrrophyta	*Glenodinium spp.*	Rare	Medium
Pyrrophyta	*Peridinium spp.*	Common	Medium
Pyrrophyta	*Peridinium inconspicuum*	Rare	Medium

* Frequency of occurrence based on the number of samples where the taxa were present:
Present in 1 to 4 samples = Rare.
Present in 5 to 10 samples = Occasional.
Present in 11 or more samples = Common.
Note: A total of 48 phytoplankton samples were collected.

** Relative abundance based on the percent biovolume of the individual taxa of the total sample biovolume:
Taxa biovolume <1% of total sample biolvolume = Very Low.
Taxa biovolume 1 to 5% of total sample biolvolume = Low.
Taxa biovolume 5 to 10% of total sample biolvolume = Medium.
Taxa biovolume >10% of total sample biolvolume = High.

Plate 39. Estimate of coldwater habitats present in Fort Peck Reservoir on June 23, 2004 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Elevation (ft-msl) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Volume (acre-ft) of Water ≤ 19.4°C	2,192,862	1,099,673	2,027,591	2,286,132	1,284,872	289,480	9,180,610
Depth (meters) of 15°C Water	Surface	Surface	Surface	11	Surface	14.2	
Elevation (msl) of 15°C Water	Surface	Surface	Surface	2167.5	Surface	2157.0	
Volume (acre-ft) of Water ≤ 15°C	2,192,862	1,099,673	2,027,591	818,769	1,284,872	33,569	7,457,336
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,192,862	1,099,673	2,027,591	2,286,132	1,284,872	289,480	9,180,610
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	Surface to Bottom	Surface to Bottom	Surface to Bottom	2167.5 to Bottom	Surface to Bottom	2157.0 to Bottom	Surface to Bottom
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2,192,862	1,099,673	2,027,591	818,769	1,284,872	33,569	7,457,336

Note: Pool elevation on June 23, 2004 = 2203.6 ft-msl. Approximate reservoir volume on June 23, 2004 = 9,180,610 acre-feet.

Plate 40. Estimate of coldwater habitats present in Fort Peck Reservoir on July 20, 2004 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	5.3	8.3	9.9	10.0*	7.9	5.0	
Elevation (ft-msl) of 19.4°C Water	2185.7	2175.9	2170.9	2170.3	2177.2	2186.7	
Volume (acre-ft) of Water ≤ 19.4°C	1,754,877	768,778	1,168,402	892,261	816,123	166,037	5,566,478
Depth (meters) of 15°C Water	11.0	13.9	15.5	16.0*	13.0	11.3	
Elevation (msl) of 15°C Water	2167.0	2157.5	2152.2	2150.6	2160.4	2166.0	
Volume (acre-ft) of Water ≤ 15°C	1,358,496	576,260	783,314	438,528	559,207	66,065	3,781,870
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0*	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2185.7 to Bottom	2175.9 to Bottom	2170.9 to Bottom	2170.3 to Bottom	2177.2 to Bottom	2186.7 to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	1,754,877	768,778	1,168,402	892,261	816,123	166,037	5,566,478
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2167.0 to Bottom	2157.5 to Bottom	2152.2 to Bottom	2150.6 to Bottom	2160.4 to Bottom	2166.0 to Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	1,358,496	576,260	783,314	438,528	559,207	66,065	3,781,870

* Estimated.

Note: Pool elevation on July 20, 2004 = 2203.1 ft-msl. Approximate reservoir volume on July 20, 2004 = 9,103,811 acre-feet.

Plate 41. Estimate of coldwater habitats present in Fort Peck Reservoir on August 16, 2004 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	1.0	8.5	11.5	15.1	1.3	5.0	
Elevation (ft-msl) of 19.4°C Water	2197.8	2173.2	2163.4	2151.6	2196.8	2184.7	
Volume (acre-ft) of Water ≤ 19.4°C	2,043,455	739,182	1,005,763	458,623	1,155,107	154,758	5,556,888
Depth (meters) of 15°C Water	19.3	19.5	24.0	18.9	18.8	Bottom	
Elevation (msl) of 15°C Water	2137.8	2137.1	2122.4	2139.1	2139.4	Bottom	
Volume (acre-ft) of Water ≤ 15°C	841,247	390,593	317,231	249,559	290,664	0	2,089,294
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2197.8 to Bottom	2173.2 to Bottom	2163.4 to Bottom	2151.6 to Bottom	2196.8 to Bottom	2184.7 to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,043,455	739,182	1,005,763	458,623	1,155,107	154,758	5,556,888
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2137.8 to Bottom	2137.1 to Bottom	2122.4 to Bottom	2139.1 to Bottom	2139.4 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	841,247	390,593	317,231	249,559	290,664	0	2,089,294

Note: Pool elevation on August 16, 2004 = 2201.1 ft-msl. Approximate reservoir volume on August 16, 2004 = 8,796,618 acre-feet.

Plate 42. Estimate of coldwater habitats present in Fort Peck Reservoir on September 22, 2004 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	**Region 2**	**Region 3**	**Region 4**	**Region 5**	**Region 6**	**Total (acre-ft)**
Depth (meters) of 19.4°C Water	Surface	Surface	Surface	Surface*	Surface	Surface	
Elevation (ft-msl) of 19.4°C Water	Surface	Surface	Surface	Surface*	Surface	Surface	
Volume (acre-ft) of Water ≤ 19.4°C	2,097,400	1,053,079	1,918,732	2,088,050	1,213,732	256,668	8,627,661
Depth (meters) of 15°C Water	28.5	26.8	20.9	20.0*	28.5	Bottom	
Elevation (msl) of 15°C Water	2106.5	2112.1	2131.4	2134.4	2106.5	Bottom	
Volume (acre-ft) of Water ≤ 15°C	422,460	204,948	441,317	187,333	37,040	0	1,293,098
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,097,400	1,053,079	1,918,732	2,088,050	1,213,732	256,668	8,627,661
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2106.5 to Bottom	2112.1 to Bottom	2131.4 to Bottom	2134.4 to Bottom	2106.5 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	422,460	204,948	441,317	187,333	37,040	0	1,293,098

* Estimated.

Note: Pool elevation on September 22, 2004 = 2200.0 ft-msl. Approximate reservoir volume on September 22, 2004 = 8,627,661 acre-feet.

Plate 43. Estimate of coldwater habitats present in Fort Peck Reservoir on June 20, 2005 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	1.6	2.0	Surface	Surface	1.8	2.0	
Elevation (ft-msl) of 19.4°C Water	2196.7	2195.3	2201.9	2201.9	2196.0	2195.3	
Volume (acre-ft) of Water ≤ 19.4°C	2,016,482	995,371	1,976,185	2,192,594	1,140,450	222,819	8,543,901
Depth (meters) of 15°C Water	10.3	9.9	9.8	8.4	9.2	13.5	
Elevation (msl) of 15°C Water	2168.1	2169.4	2169.7	2174.3	2171.7	2157.6	
Volume (acre-ft) of Water ≤ 15°C	1,379,944	697,885	1,140,856	1,021,711	728,724	35,232	5,004,352
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2196.7 to Bottom	2195.3 to Bottom	Surface to Bottom	Surface to Bottom	2196.0 to Bottom	2195.3 to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,016,482	995,371	1,976,185	2,192,594	1,140,450	222,819	8,543,901
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2168.1 to Bottom	2169,4 to Bottom	2169.7 to Bottom	2174.3 to Bottom	2171.7 to Bottom	2157.6 to Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	1,379,944	697,885	1,140,856	1,021,711	728,724	35,232	5,004,352

* Estimated.

Note: Pool elevation on June 20, 2005 = 2201.9 ft-msl. Approximate reservoir volume on June 20, 2005 = 8,919,495 acre-feet.

Plate 44. Estimate of coldwater habitats present in Fort Peck Reservoir on July 18, 2005 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	11.0	11.1	10.3	9.7	17.3	Bottom	
Elevation (ft-msl) of 19.4°C Water	2167.5	2167.2	2169.8	2171.8	2146.8	Bottom	
Volume (acre-ft) of Water ≤ 19.4°C	1,368,246	675,077	1,143,000	940,805	379,574	0	4,506,702
Depth (meters) of 15°C Water	22.3	14.5	13.6	14.5	19.5	Bottom	
Elevation (msl) of 15°C Water	2130.4	2156.0	2159.0	2156.0	2139.6	Bottom	
Volume (acre-ft) of Water ≤ 15°C	729,647	561,758	913,684	547,040	292,798	0	3,044,927
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2167.5 to Bottom	2167.2 to Bottom	2169.8 to Bottom	2171.8 to Bottom	2146.8 to Bottom	Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	1,368,246	675,077	1,143,000	940,805	379,574	0	4,506,702
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2130.4 to Bottom	2156.0 to Bottom	2159.0 to Bottom	2156.0 to Bottom	2139.6 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	729,647	561,758	913,684	547,040	292,798	0	3,044,927

* Estimated.

Note: Pool elevation on July 18, 2005 = 2203.6 ft-msl. Approximate reservoir volume on July 18, 2005 = 9,180,610 acre-feet.

Plate 45. Estimate of coldwater habitats present in Fort Peck Reservoir on August 22, 2005 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	14.0	17.1	14.2	14.4	16.0	14.1	
Elevation (ft-msl) of 19.4°C Water	2156.7	2146.5	2156.0	2155.4	2150.1	2156.3	
Volume (acre-ft) of Water ≤ 19.4°C	1,162,162	472,444	856,168	534,983	419,750	31,629	3,477,136
Depth (meters) of 15°C Water	22.3	20.0	21.6	19.0	20.0	Bottom	
Elevation (msl) of 15°C Water	2129.4	2137.0	2131.7	2140.3	2137.0	Bottom	
Volume (acre-ft) of Water ≤ 15°C	715,239	389,776	525,564	266,424	265,050	0	2,162,053
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2156.7 to Bottom	2146.5 to Bottom	2156.0 to Bottom	2155.4 to Bottom	2150.1 to Bottom	2156.3 to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	1,162,162	472,444	856,168	534,983	419,750	31,629	3,477,136
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2129.4 to Bottom	2137.0 to Bottom	2131.7 to Bottom	2140.3 to Bottom	2137.0 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	715,239	389,776	525,564	266,424	265,050	0	2,162,053

* Estimated.

Note: Pool elevation on August 22, 2005 = 2202.6 ft-msl. Approximate reservoir volume on August 22, 2005 = 9,027,013 acre-feet.

Plate 46. Estimate of coldwater habitats present in Fort Peck Reservoir on September 20, 2005 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Elevation (ft-msl) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Volume (acre-ft) of Water ≤ 19.4°C	2,145,131	1,076,376	1,973,161	2,187,091	1,249,302	273,074	8,904,135
Depth (meters) of 15°C Water	27.8	27.6	25.5	Bottom	28.2	Bottom	
Elevation (msl) of 15°C Water	2110.6	2111.2	2118.1	Bottom	2109.3	Bottom	
Volume (acre-ft) of Water ≤ 15°C	469,199	198,973	262,839	0	46,396	0	977,407
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,145,131	1,076,376	1,973,161	2,187,091	1,249,302	273,074	8,904,135
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2110.6 to Bottom	2111.2 to Bottom	2118.1 to Bottom	Bottom	2109.3 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	469,199	198,973	262,839	0	46,396	0	977,407

* Estimated.

Note: Pool elevation on September 20, 2005 = 2201.8 ft-msl. Approximate reservoir volume on September 20, 2005 = 8,904,135 acre-feet.

Plate 47. Estimate of coldwater habitats present in Fort Peck Reservoir on June 22, 2006 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Elevation (ft-msl) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Volume (acre-ft) of Water ≤ 19.4°C	2,261,807	1,133,325	2,106,211	2,429,192	1,336,250	313,177	9,579,962
Depth (meters) of 15°C Water	20.0	17.0	14.0	17.2	25.1	Bottom	
Elevation (msl) of 15°C Water	2140.6	2150.4	2160.3	2149.8	2123.8	Bottom	
Volume (acre-ft) of Water ≤ 15°C	884,399	507,616	939,289	418,401	136,408	0	2,886,113
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	Surface to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,261,807	1,133,325	2,106,211	2,429,192	1,336,250	313,177	9,579,962
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2140.6 to Bottom	2150.4 to Bottom	2160.3 to Bottom	2149.8 to Bottom	2123.8 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	884,399	507,616	939,289	418,401	136,408	0	2,886,113

* Estimated.

Note: Pool elevation on June 22, 2006 = 2206.2 ft-msl. Approximate reservoir volume on June 22, 2006 = 9,579,962 acre-feet.

Plate 48. Estimate of coldwater habitats present in Fort Peck Reservoir on July 26, 2006 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	12.6	12.5	12.7	14.5	13.1	11.6	
Elevation (ft-msl) of 19.4°C Water	2163.9	2164.2	2163.5	2157.6	2162.2	2167.1	
Volume (acre-ft) of Water ≤ 19.4°C	1,298,052	643,974	1,007,908	579,191	585,926	70,498	4,185,549
Depth (meters) of 15°C Water	18.8	18.5	18.5	17.7	19.2	Bottom	
Elevation (msl) of 15°C Water	2143.5	2144.5	2144.5	2147.1	2142.2	Bottom	
Volume (acre-ft) of Water ≤ 15°C	932,605	454,555	647,395	378,622	323,760	0	2,736,937
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2164.9 to Bottom	2165.2 to Bottom	2164.5 to Bottom	2158.6 to Bottom	2163.2 to Bottom	2168.1 to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	1,298,052	643,974	1,007,908	579,191	585,926	70,498	4,185,549
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2144.8 to Bottom	2145.5 to Bottom	2145.5 to Bottom	2148.1 to Bottom	2143.2 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	932,605	454,555	647,395	378,622	323,760	0	2,736,937

* Estimated.

Note: Pool elevation on July 26, 2006 = 2205.2 ft-msl. Approximate reservoir volume on July 26, 2006 = 9,426,365 acre-feet.

Plate 49. Estimate of coldwater habitats present in Fort Peck Reservoir on August 30, 2006 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	21.3	21.4	16.6	18.0*	20.3	9.7	
Elevation (ft-msl) of 19.4°C Water	2133.8	2133.5	2149.2	2144.6	2137.1	2171.9	
Volume (acre-ft) of Water ≤ 19.4°C	780,923	570,158	727,501	337,373	266,117	90,937	2,773,009
Depth (meters) of 15°C Water	24.1	23.7	23.7	23.0*	22.5	Bottom	
Elevation (msl) of 15°C Water	2124.6	2125.9	2125.9	2128.2	2129.9	Bottom	
Volume (acre-ft) of Water ≤ 15°C	648,233	420,255	364,676	113,313	189,474	0	1,735,951
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2133.8 to Bottom	2133.5 to Bottom	2149.2 to Bottom	2144.6 to Bottom	2137.1 to Bottom	2171.9 to Bottom	
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	780,923	570,158	727,501	337,373	266,117	90,937	2,773,009
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2124.2 to Bottom	2125.9 to Bottom	2125.9 to Bottom	2128.2 to Bottom	2129.9 to Bottom	Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	648,233	420,255	364,676	113,313	189,474	0	1,735,951

* Estimated.

Note: Pool elevation on August 30, 2006 = 2203.7 ft-msl. Approximate reservoir volume on August 30, 2006 = 9,195,970 acre-feet.

Plate 50. Estimate of coldwater habitats present in Fort Peck Reservoir on October 5, 2006 based on measured water temperature and dissolved oxygen depth-profiles.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total (acre-ft)
Depth (meters) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Elevation (ft-msl) of 19.4°C Water	Surface	Surface	Surface	Surface	Surface	Surface	
Volume (acre-ft) of Water ≤ 19.4°C	2,163,693	1,085,436	1,994,328	2,225,607	1,263,135	279,454	9,011,653
Depth (meters) of 15°C Water	Surface	Surface	Surface	Bottom	Surface	Surface	
Elevation (msl) of 15°C Water	Surface	Surface	Surface	Bottom	Surface	Surface	
Volume (acre-ft) of Water ≤ 15°C	2,163,693	1,085,436	1,994,328	0	1,263,135	279,454	6,786,046
Depth of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Elevation of 5 mg/l DO Water	Bottom	Bottom	Bottom	Bottom*	Bottom	Bottom	
Volume (acre-ft) of Water ≤ 5mg/l DO	0	0	0	0	0	0	0
Thickness of Coldwater Habitat Layer (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,163,693	1,085,436	1,994,328	2,225,607	1,263,135	279,454	9,011,653
Volume (acre-ft) of Coldwater Habitat (i.e., ≤ 19.4°C, and ≥ 5 mg/l DO)	2,163,693	1,085,436	1,994,328	2,225,607	1,263,135	279,454	9,011,653
Thickness of Optimal Coldwater Habitat Layer (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	Surface to Bottom	Surface to Bottom	Surface to Bottom	Bottom	Surface to Bottom	Surface to Bottom	
Volume (acre-ft) of Optimal Coldwater Habitat (i.e., ≤ 15°C, and ≥ 5 mg/l DO)	2,163,693	1,085,436	1,994,328	0	1,263,135	279,454	6,786,046

* Estimated.

Note: Pool elevation on October 5, 2006 = 2202.5 ft-msl. Approximate reservoir volume on October 5, 2006 = 9,011,653 acre-feet.

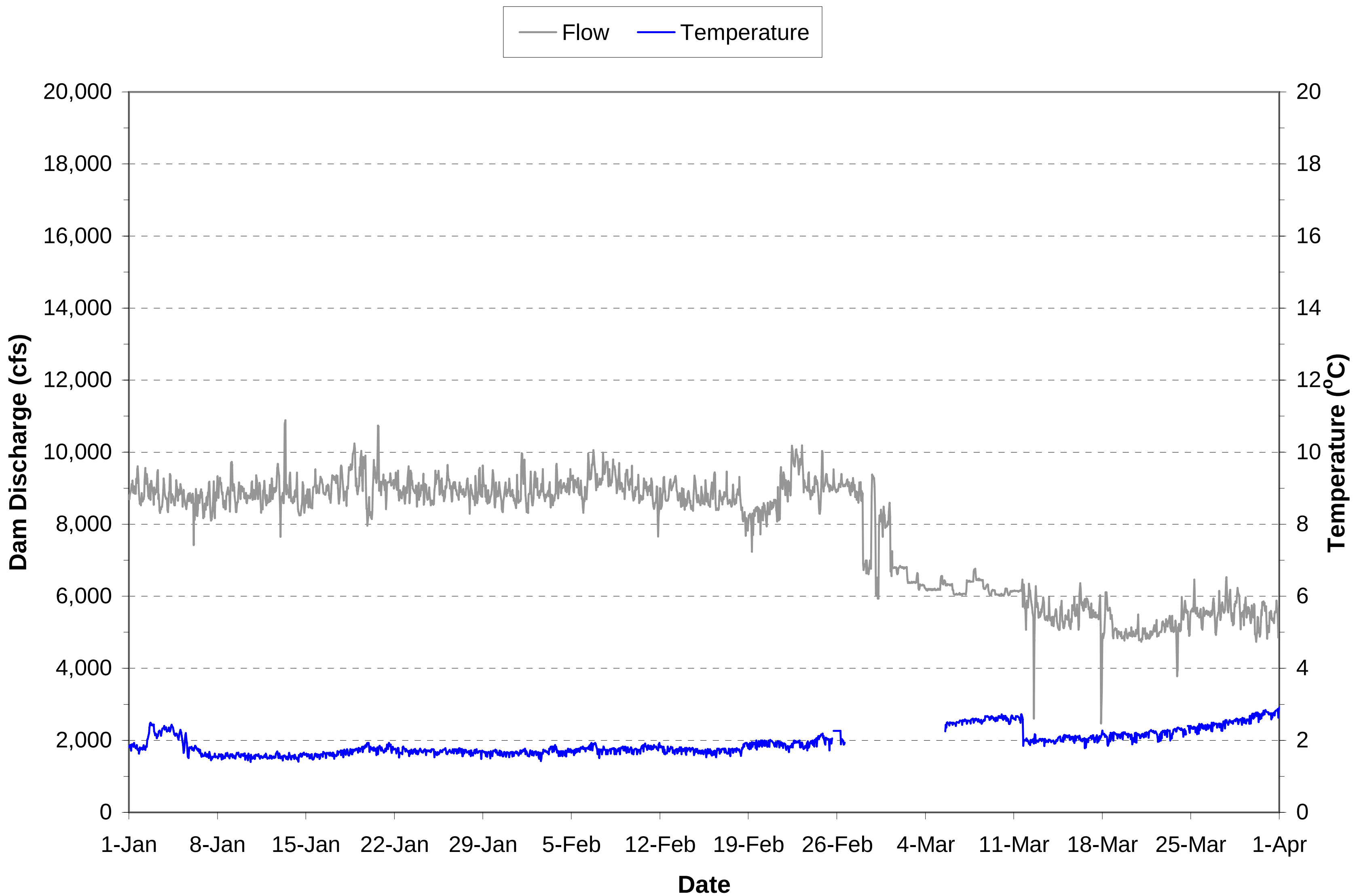


Plate 51. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period January through March 2004**.** (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

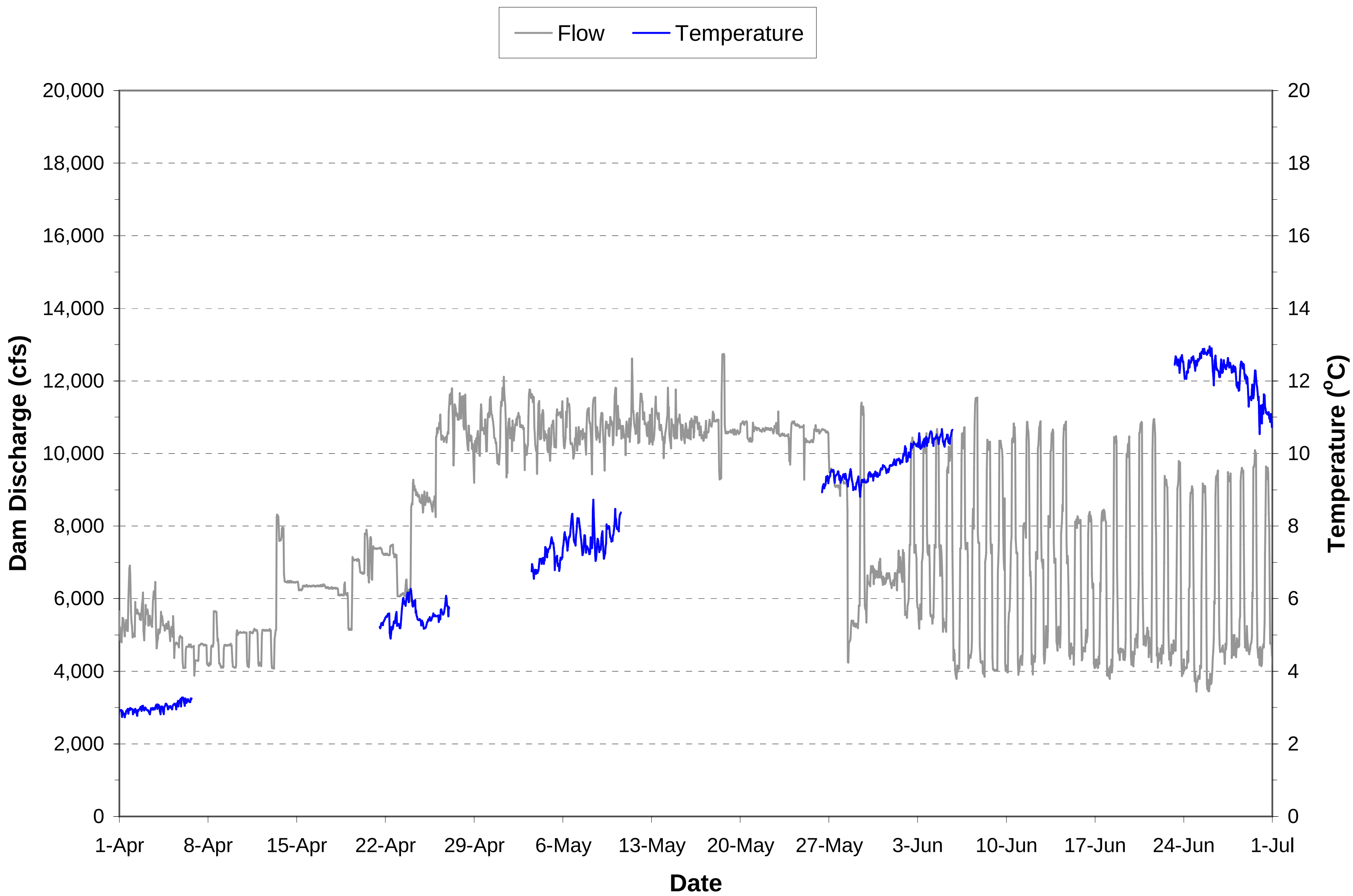


Plate 52. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period April through June 2004. (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

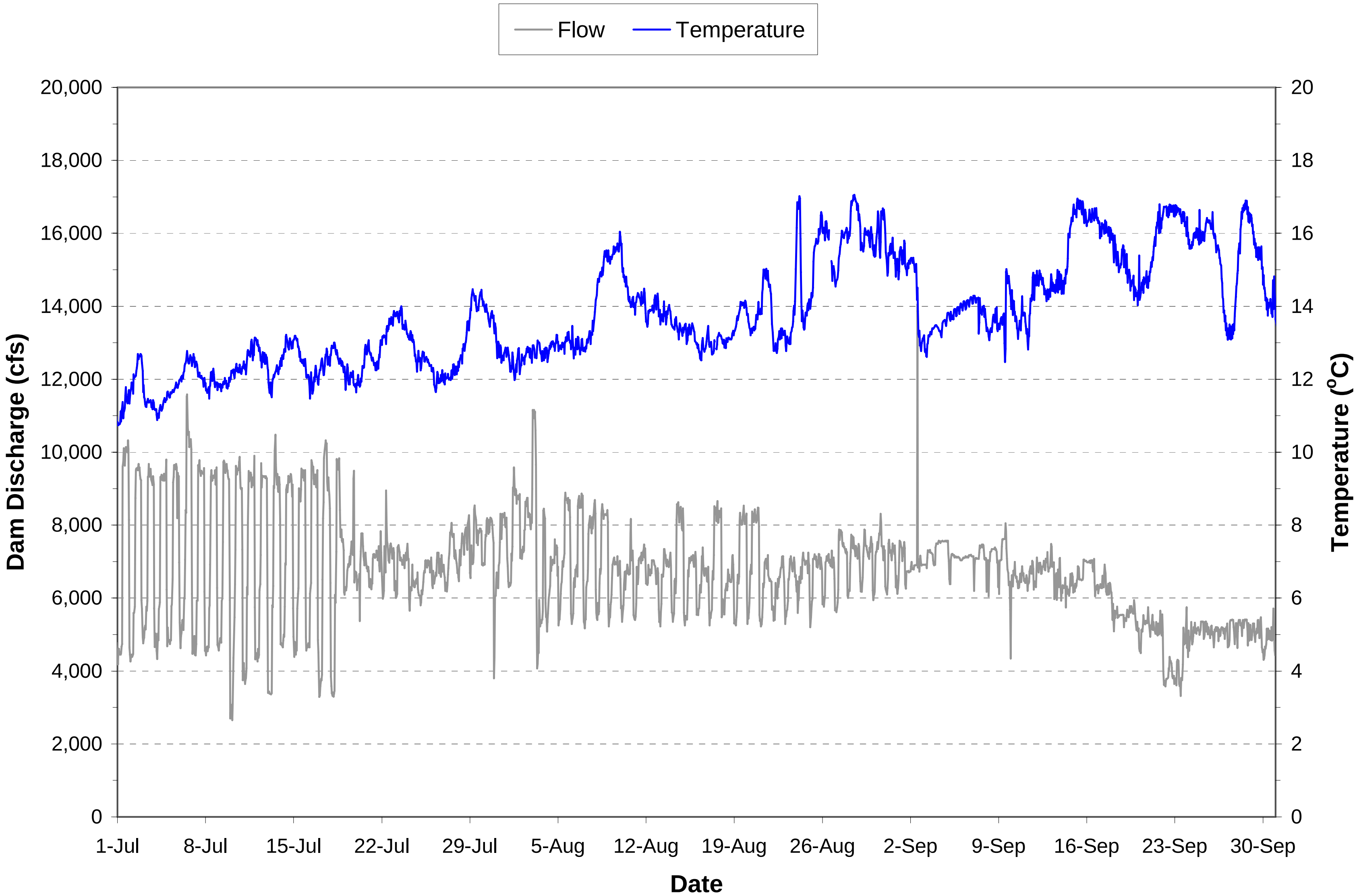


Plate 53. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period July through September 2004.

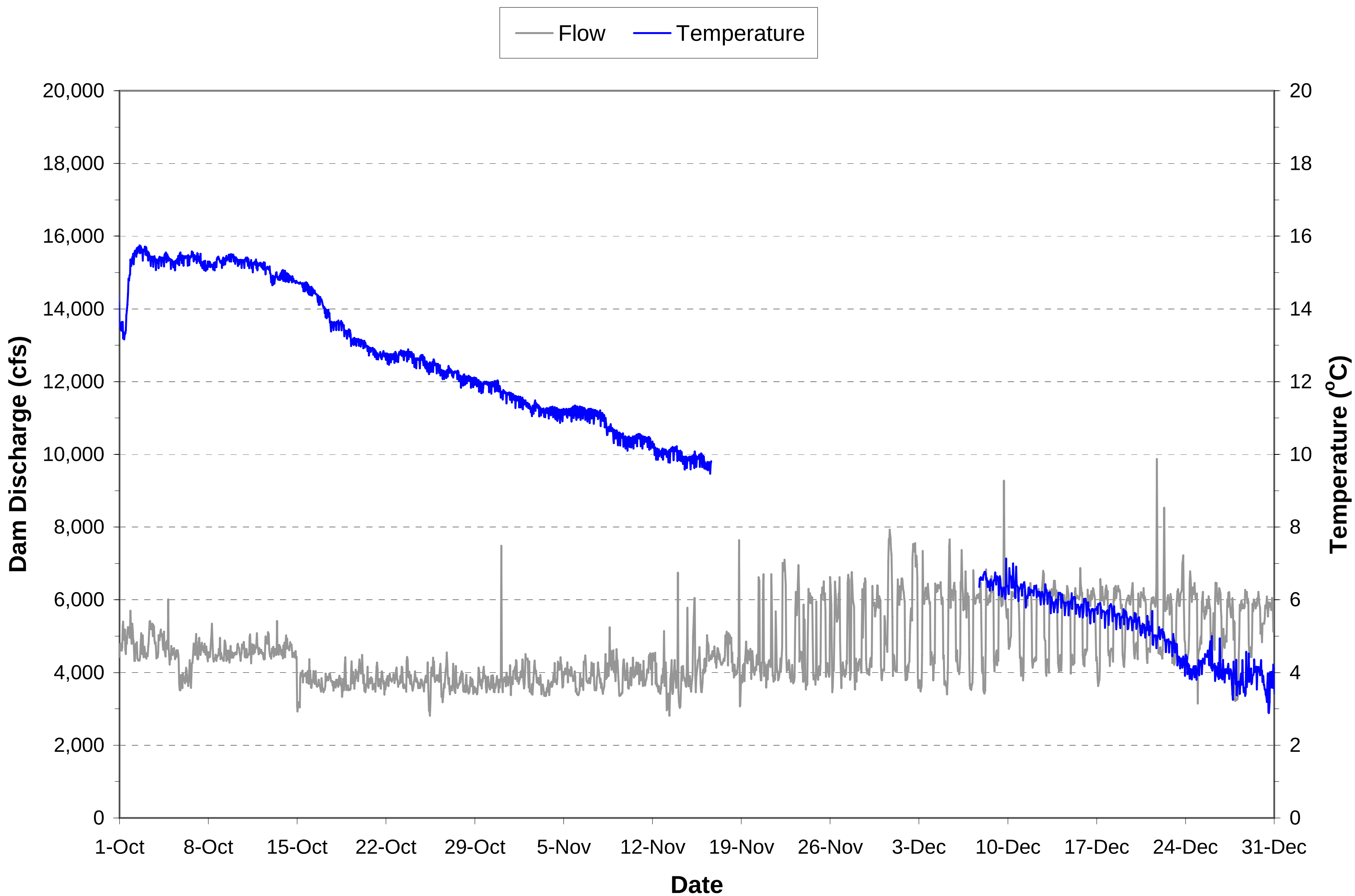


Plate 54. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period October through December 2004. (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

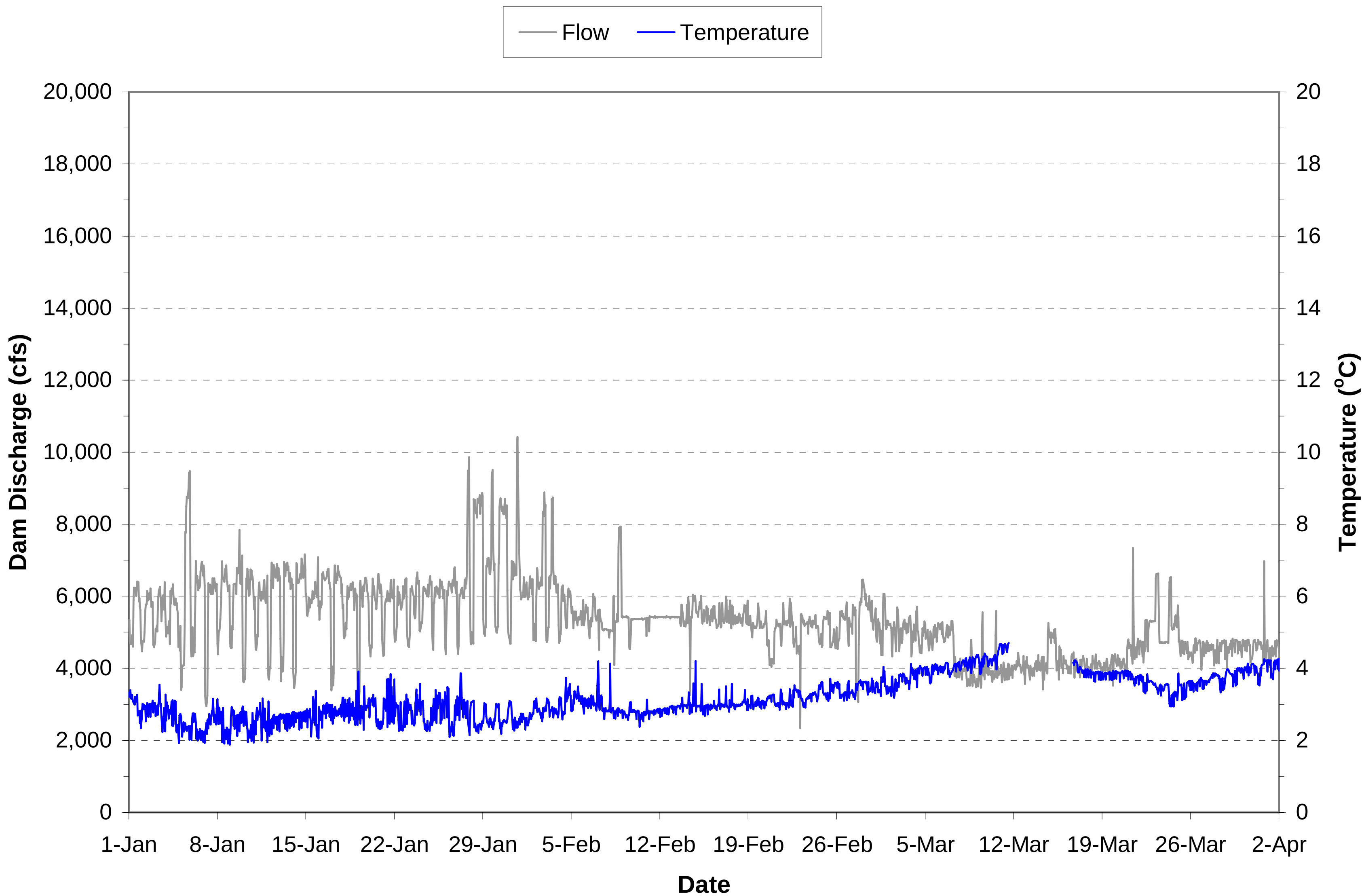


Plate 55. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period January through March 2005. (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

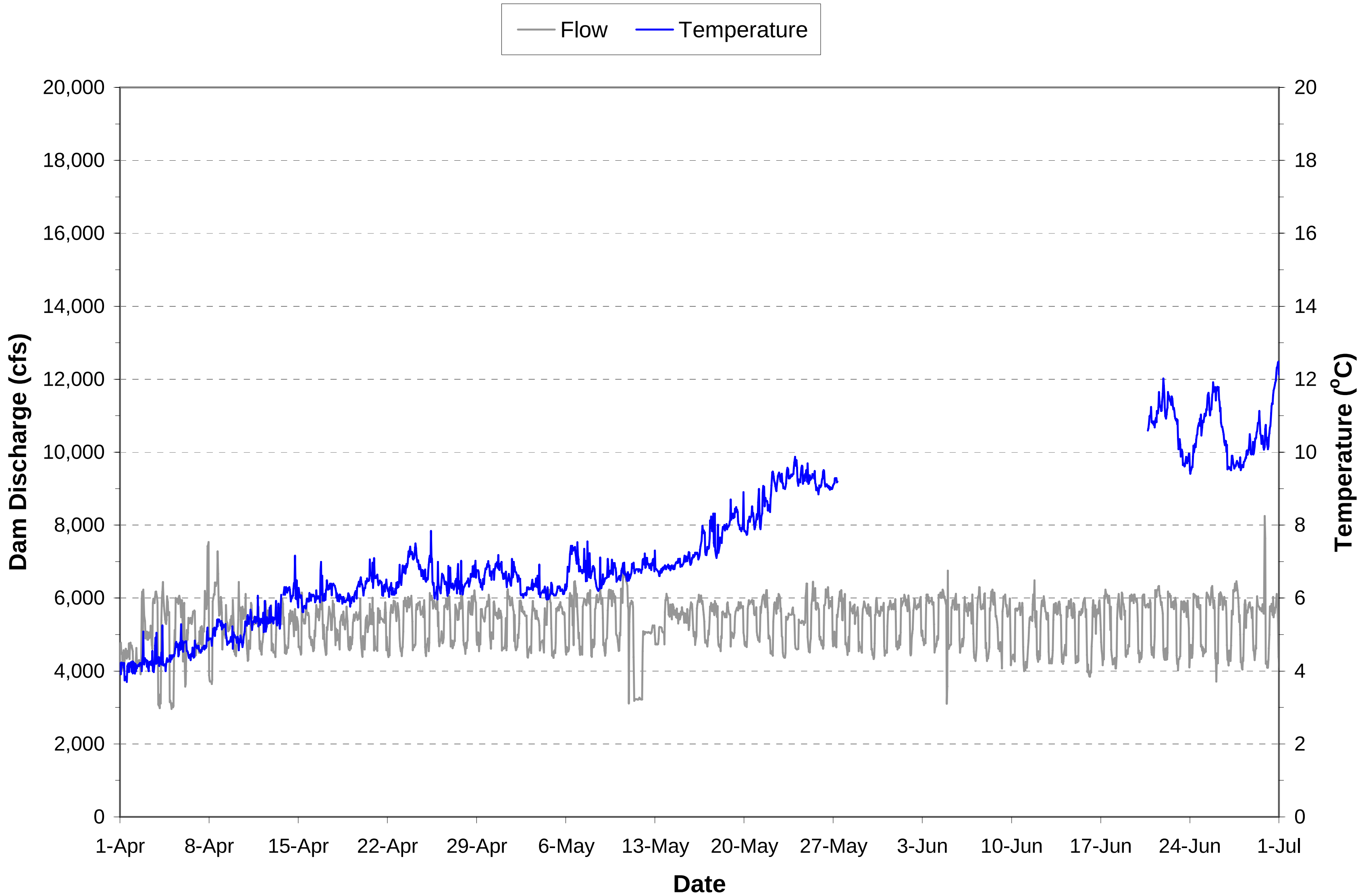


Plate 56. Hourly discharge and water temperature monitored in the “raw water supply line” at the Fort Peck powerhouse during the period April through June 2005. (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

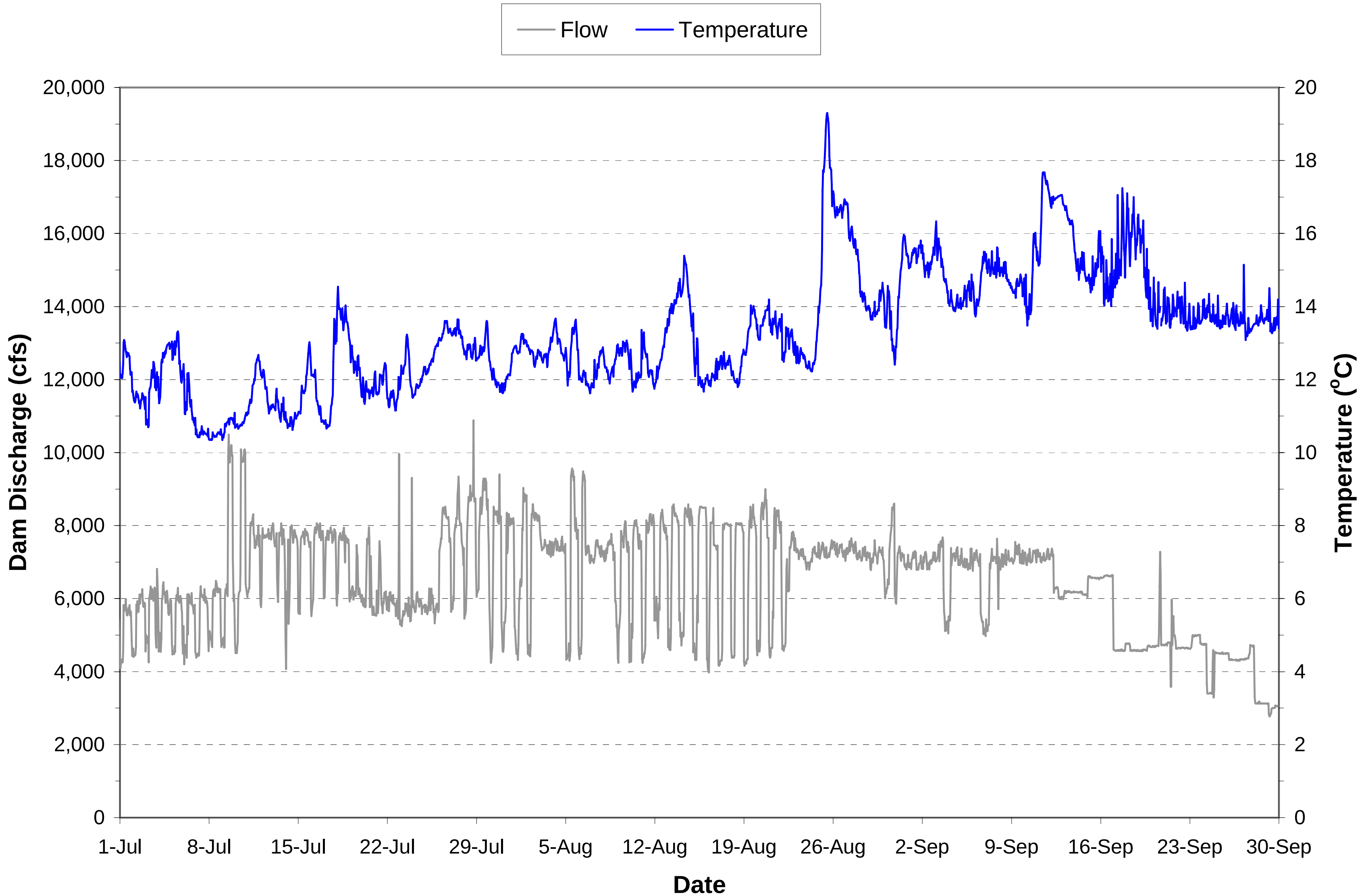


Plate 57. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period July through September 2005.

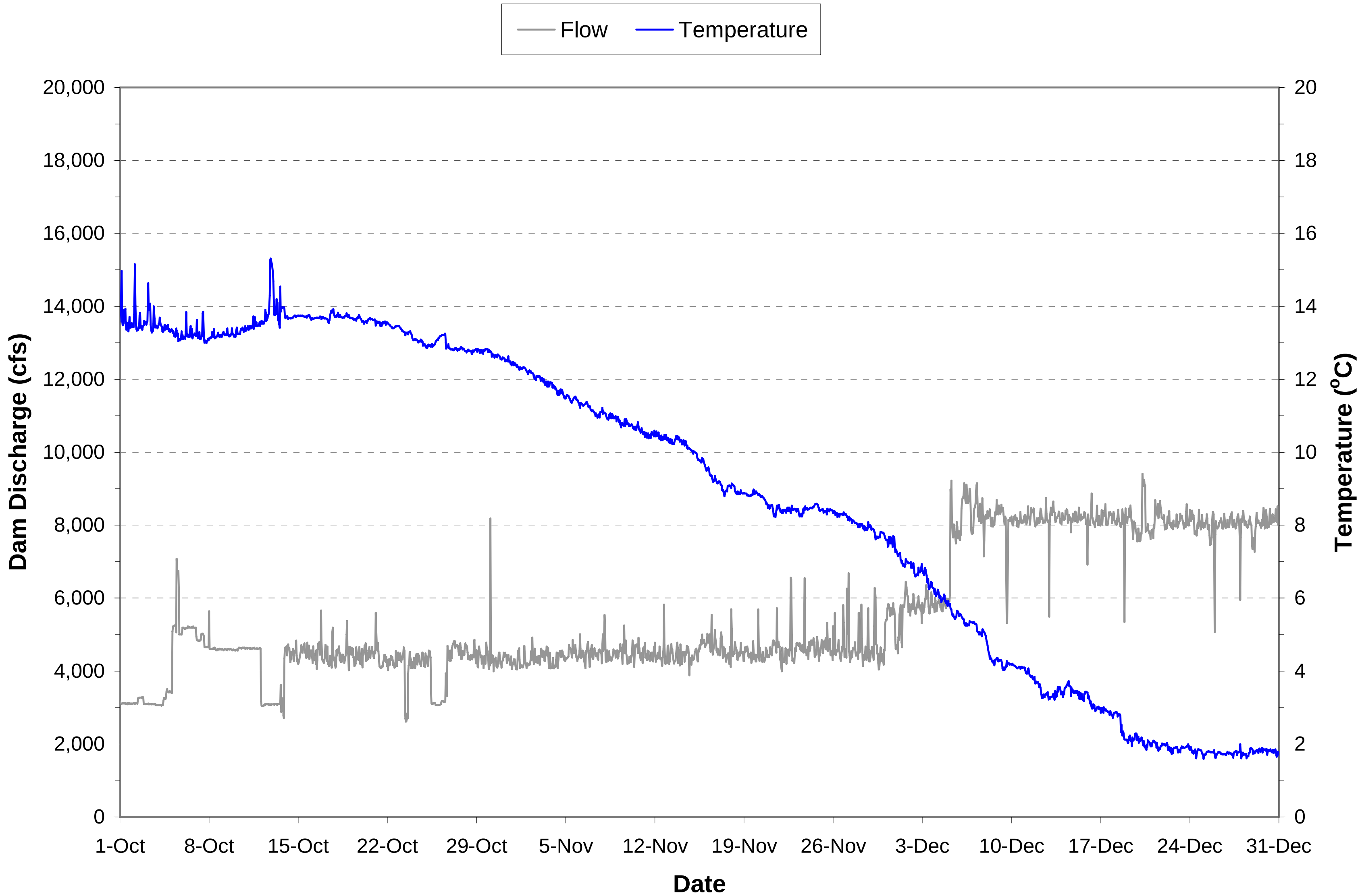


Plate 58. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period October through December 2005.

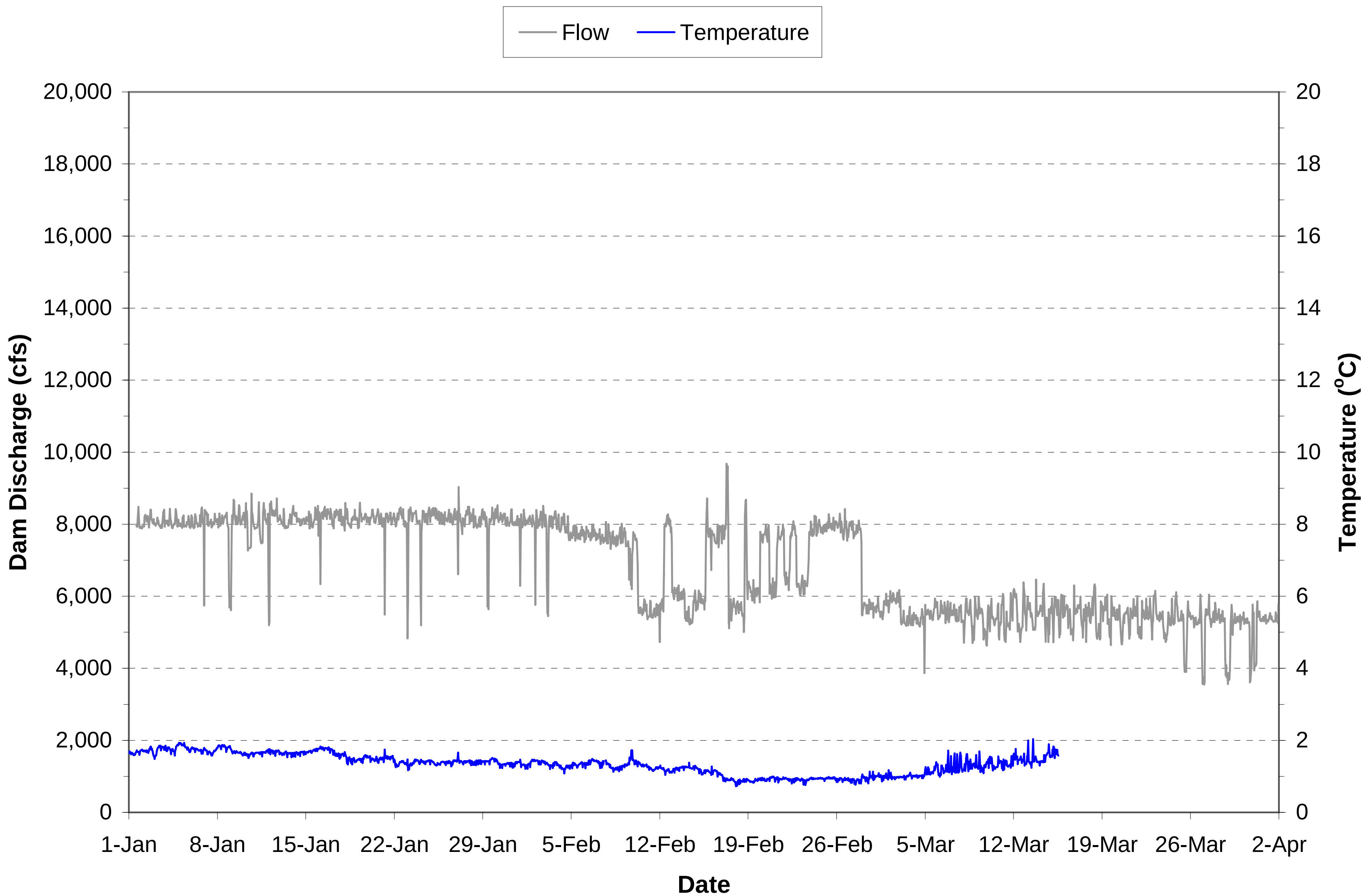


Plate 59. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period January through March 2006. (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

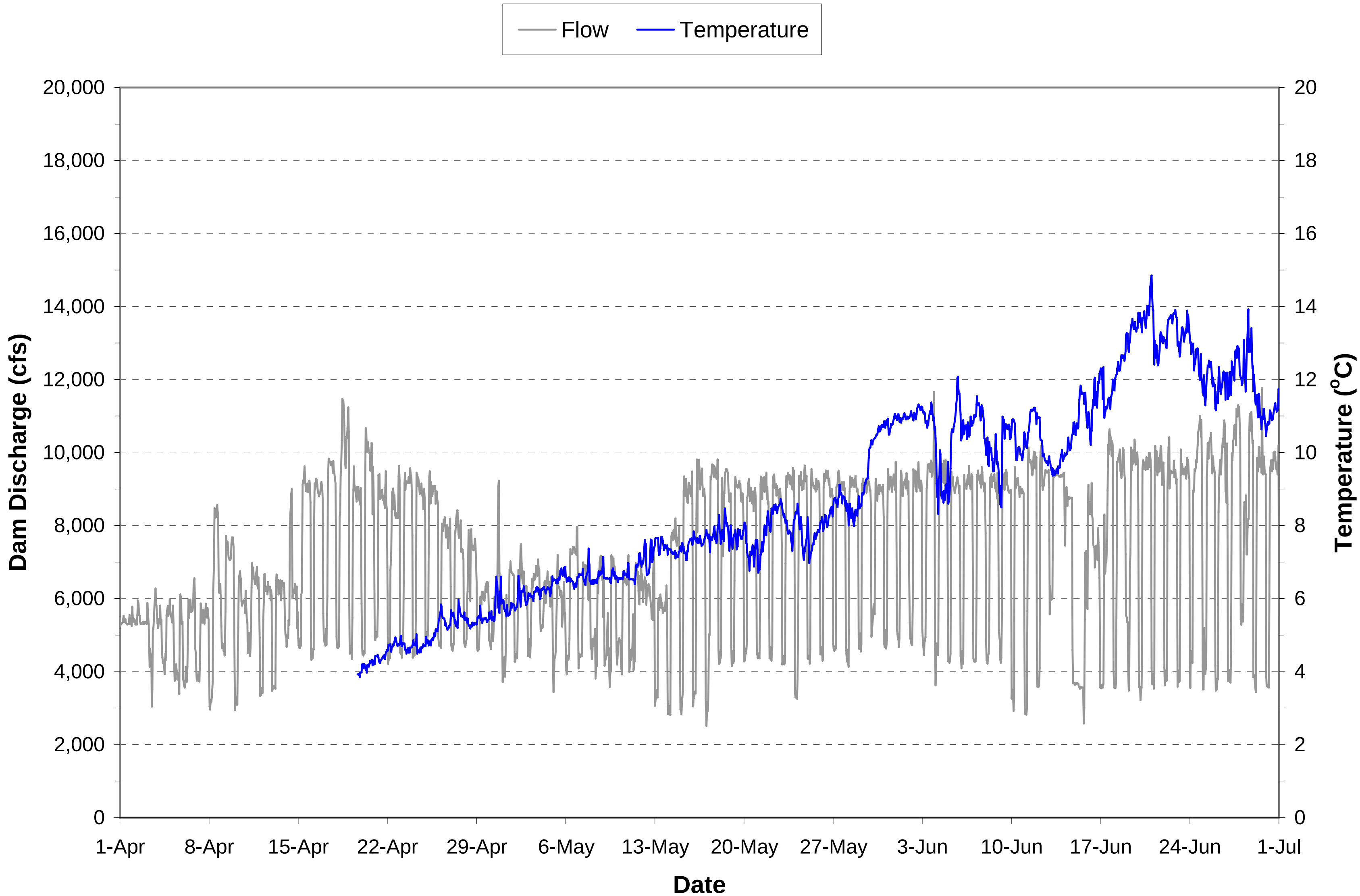


Plate 60. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period April through June 2006. (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

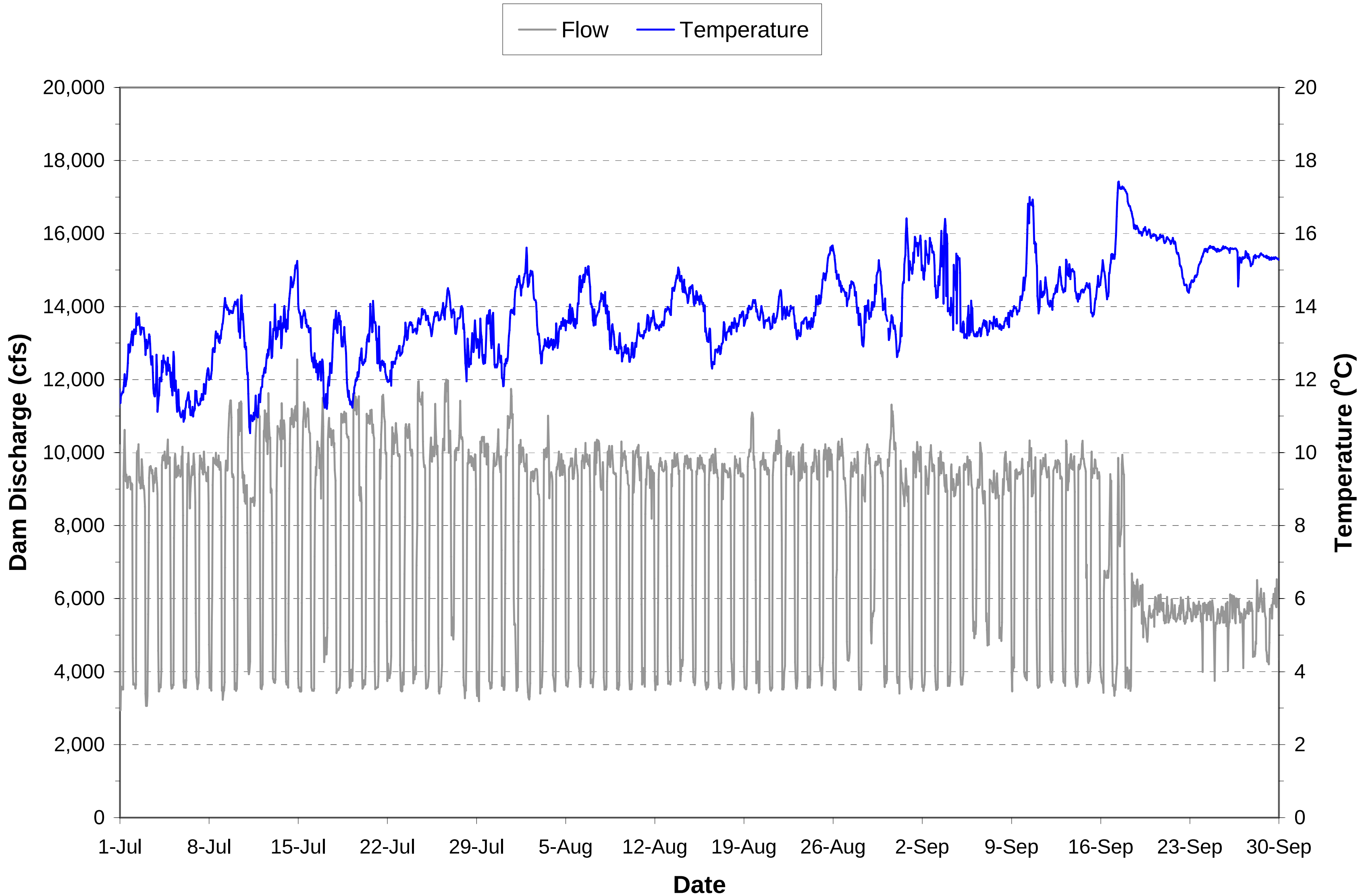


Plate 61. Hourly discharge and water temperature monitored in the “raw water supply line” at the Fort Peck powerhouse during the period July through September 2006.

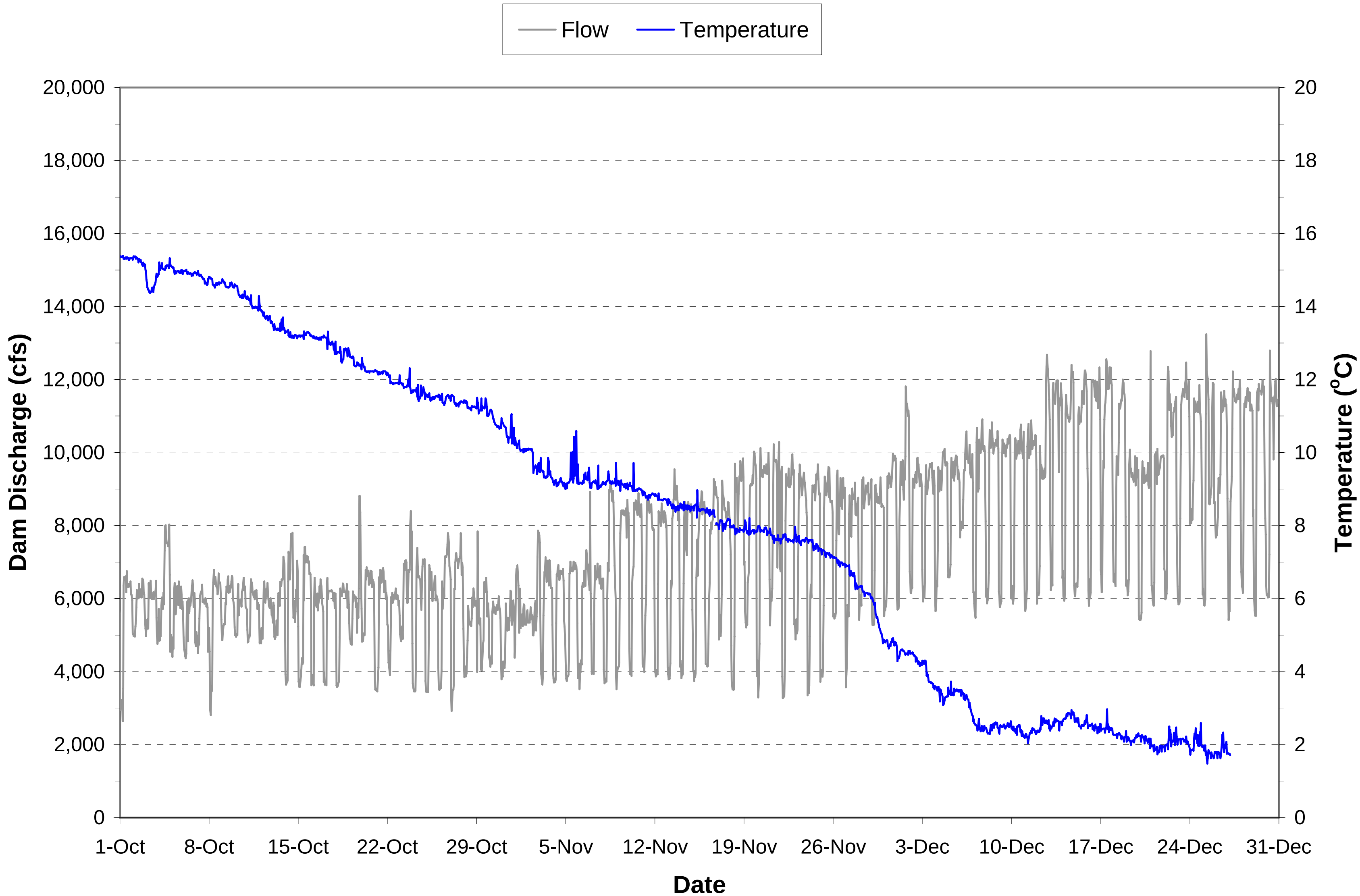


Plate 62. Hourly discharge and water temperature monitored in the "raw water supply line" at the Fort Peck powerhouse during the period October through December 2006. (Note: Gaps in temperature plot are periods when the monitoring equipment was not operational.)

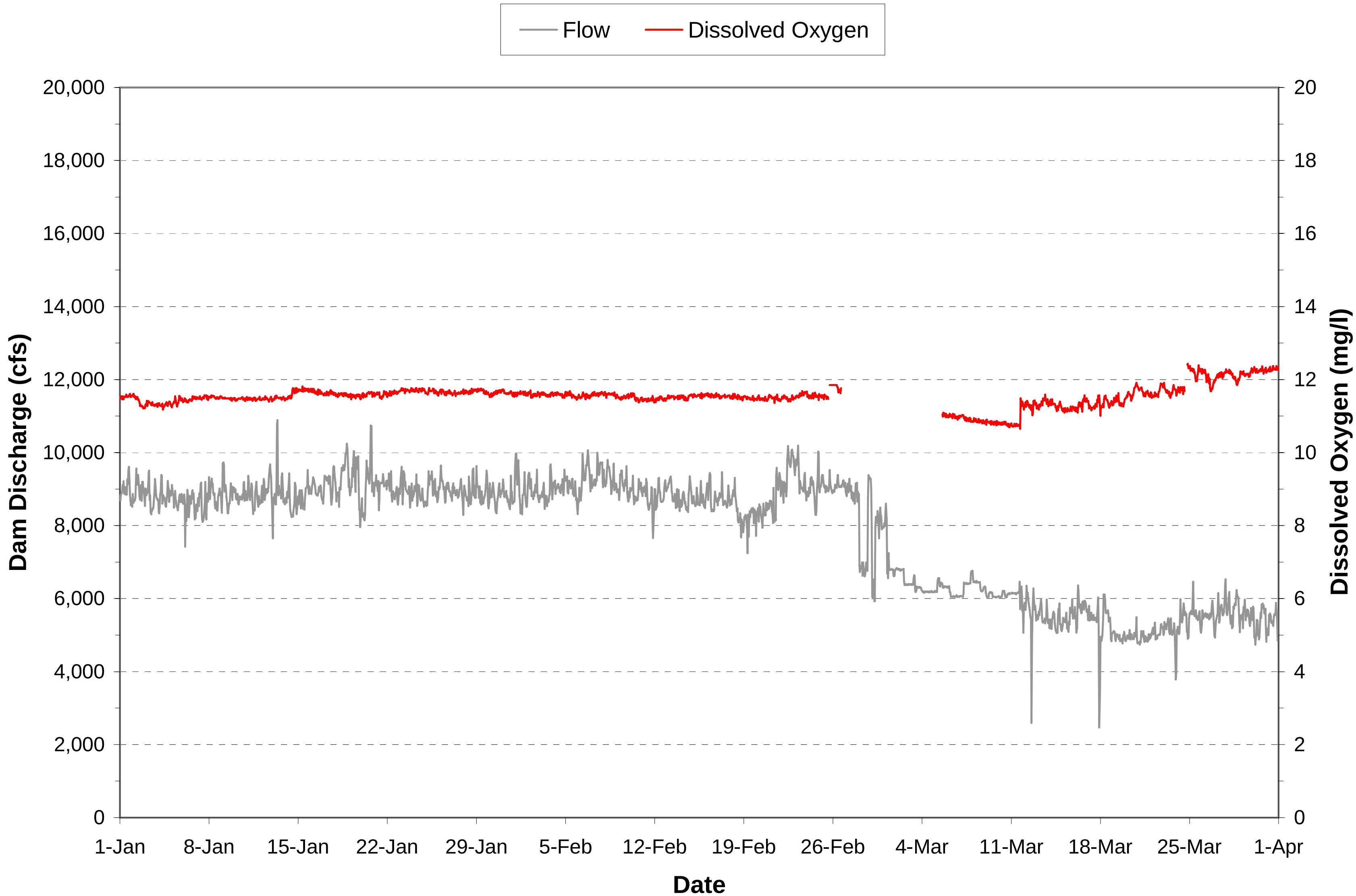


Plate 63. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period January through March 2004. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

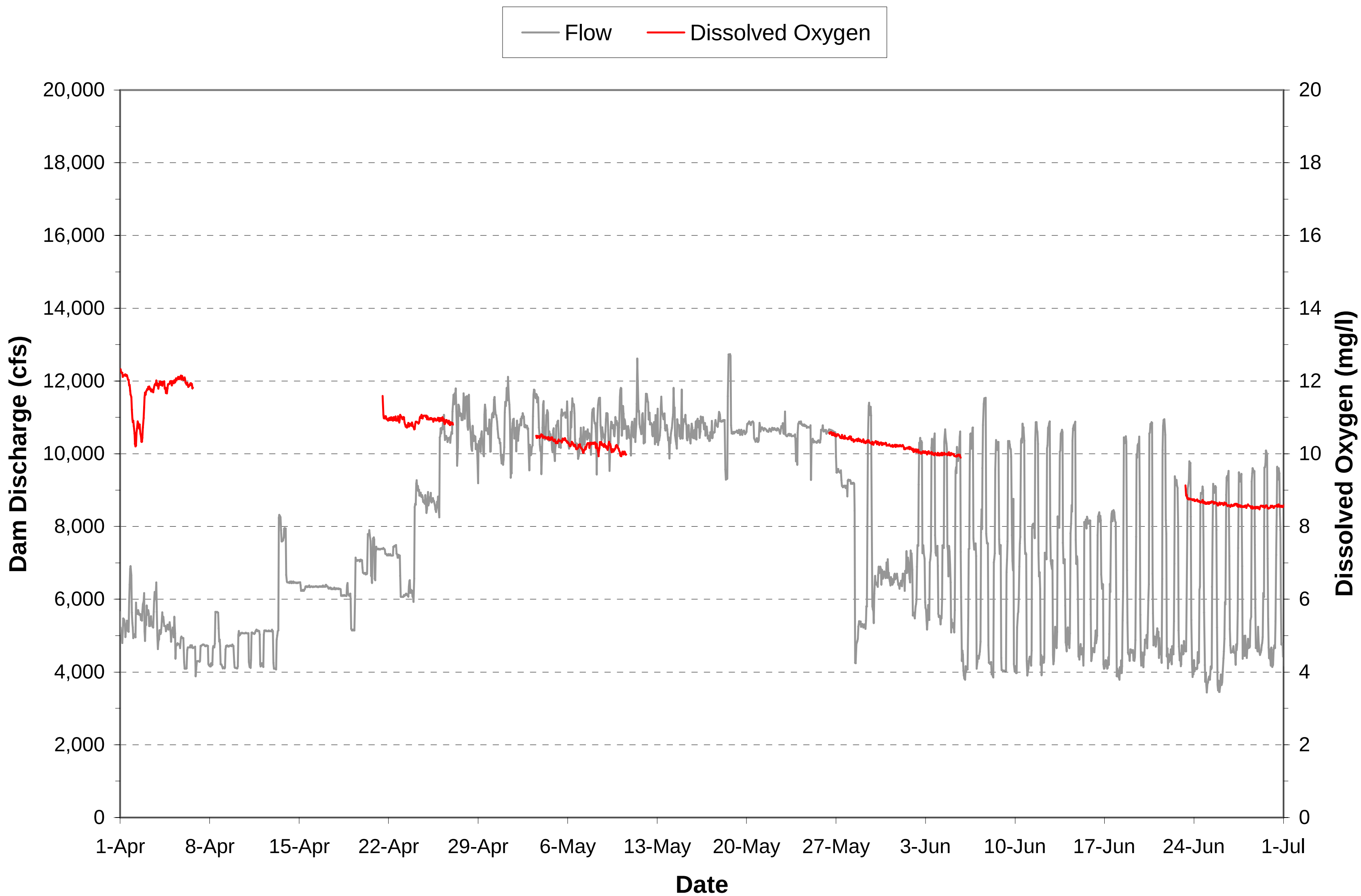


Plate 64. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period April through June 2004. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

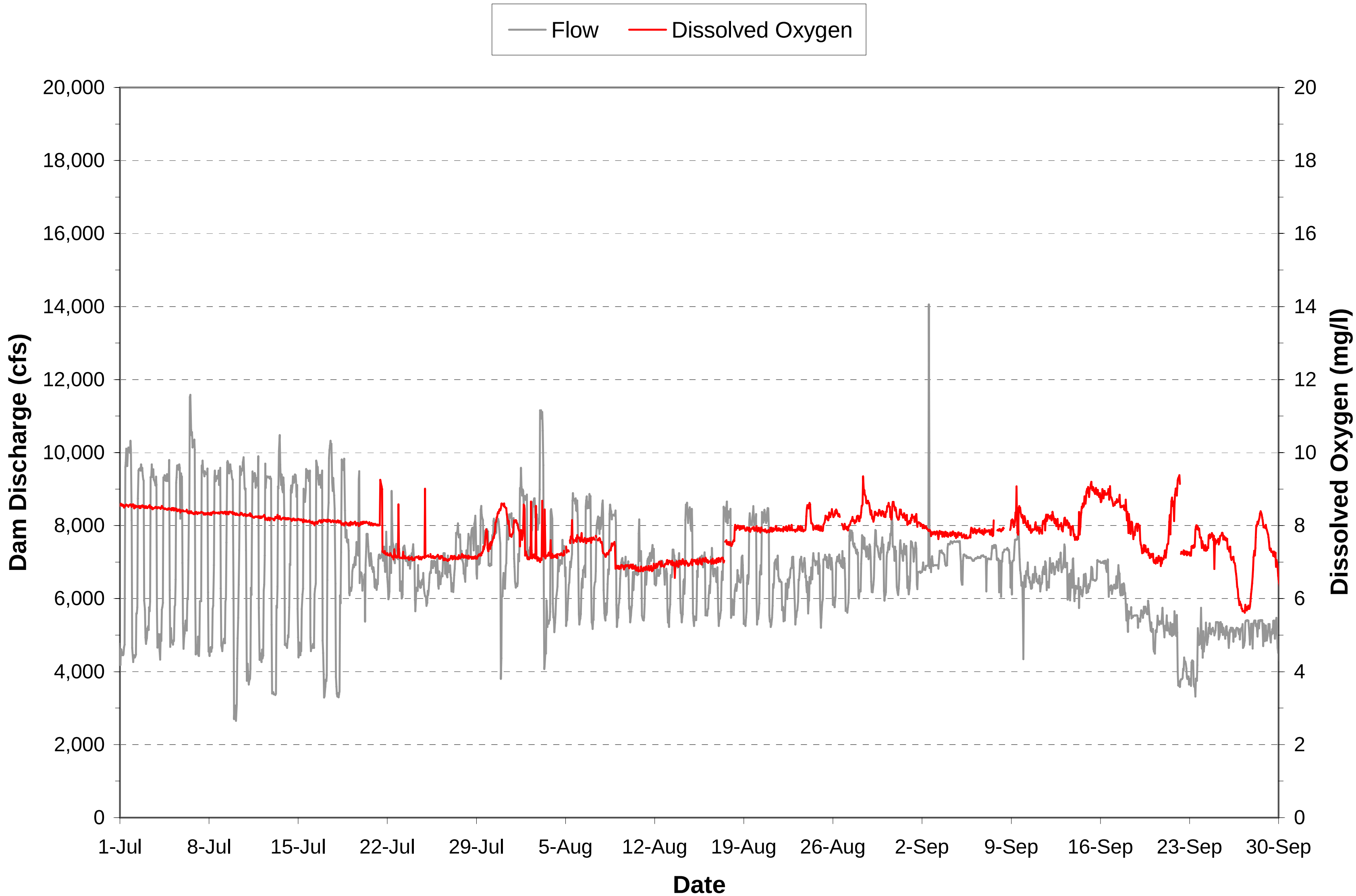


Plate 65. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period July through September 2004. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

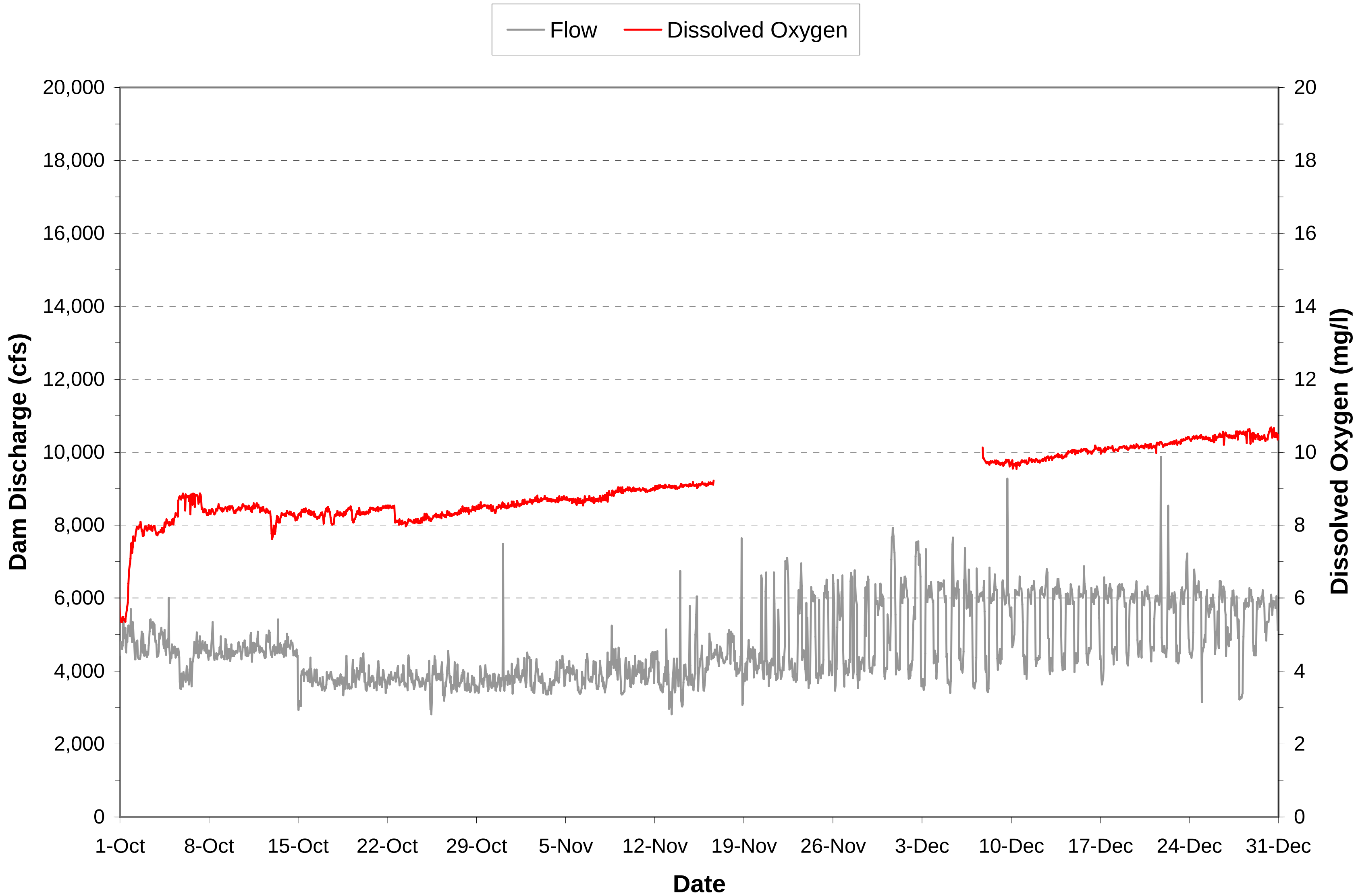


Plate 66. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period October through December 2004. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

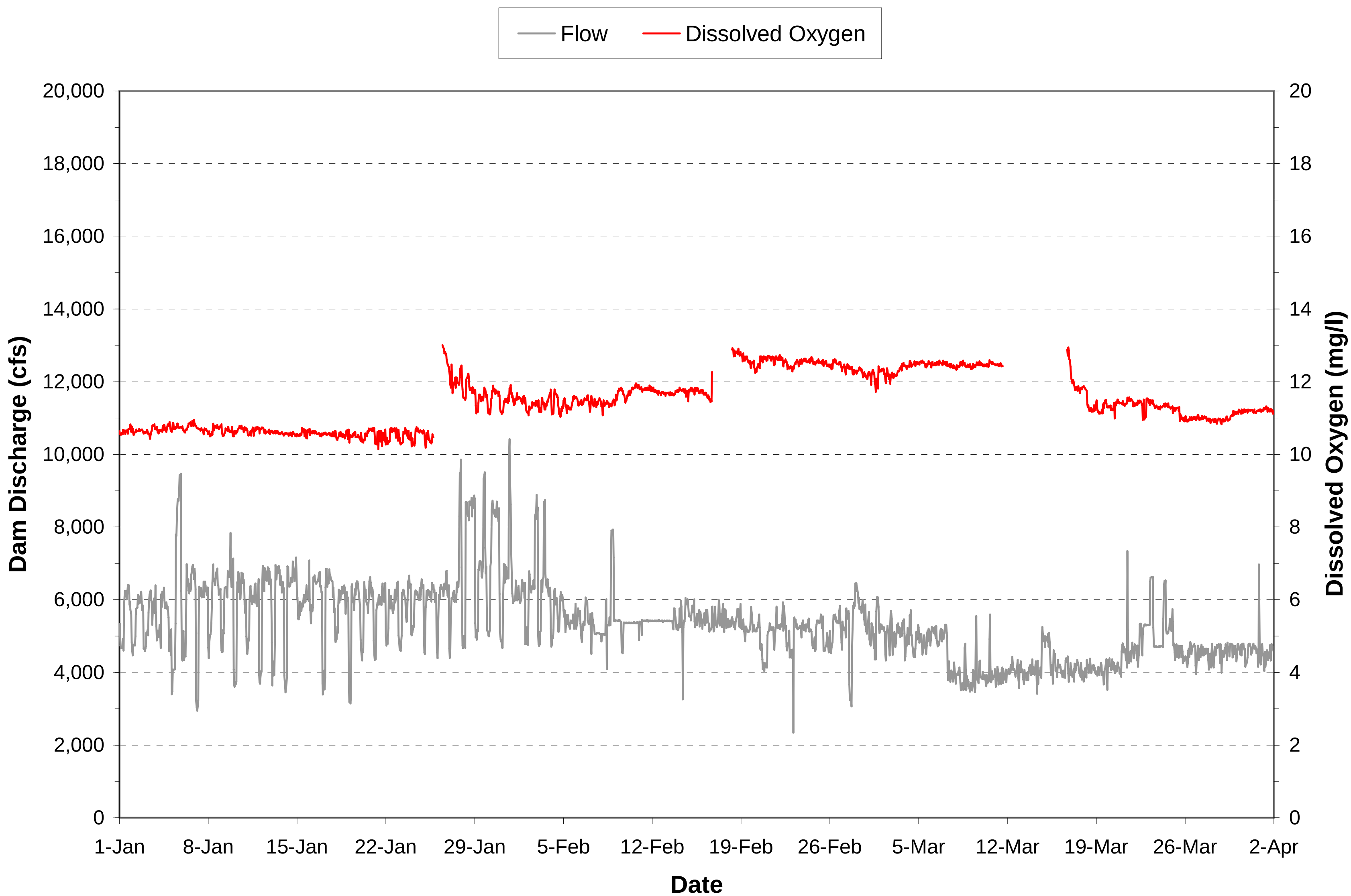


Plate 67. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period January through March 2005. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

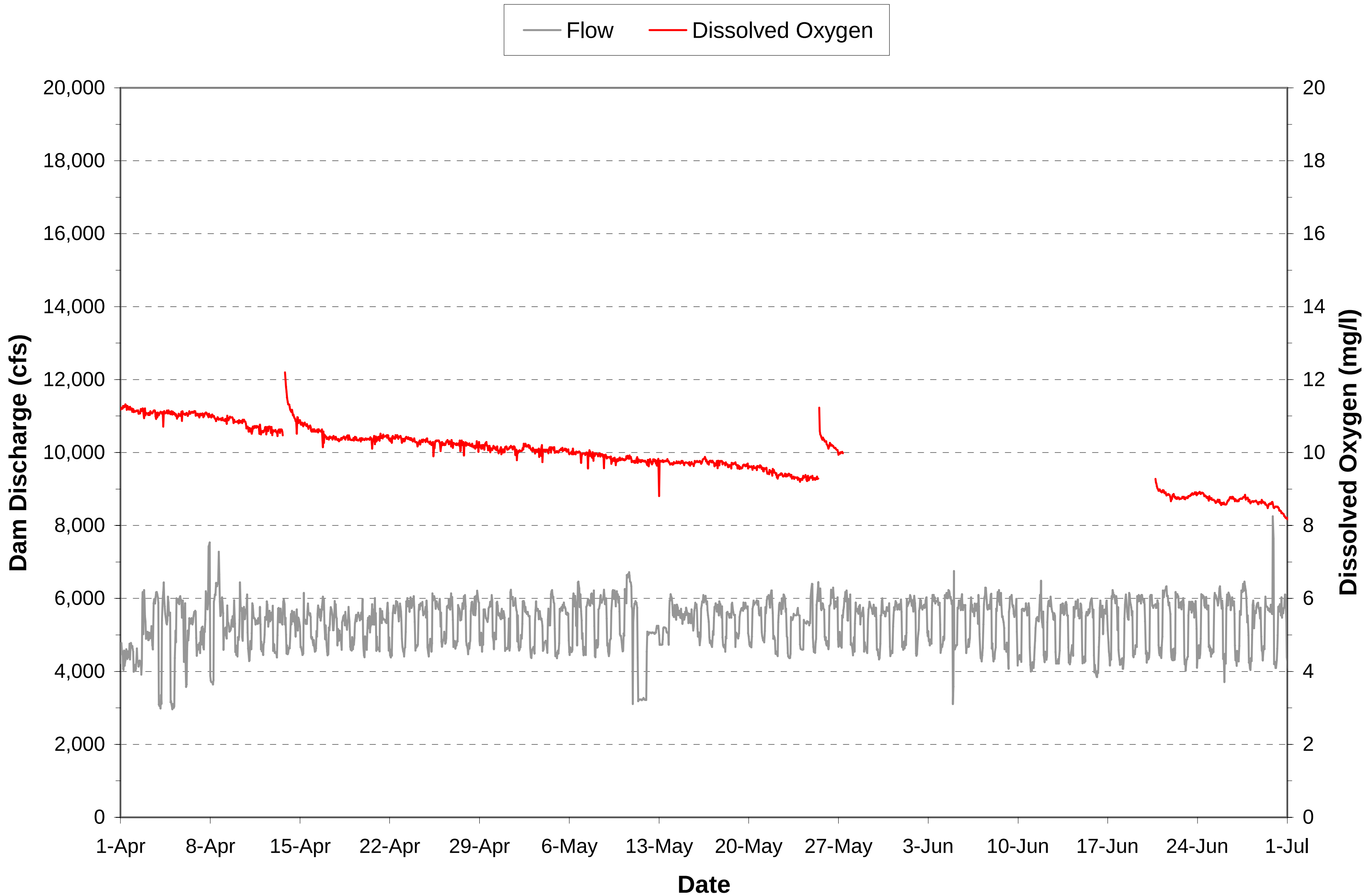


Plate 68. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period April through June 2005. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

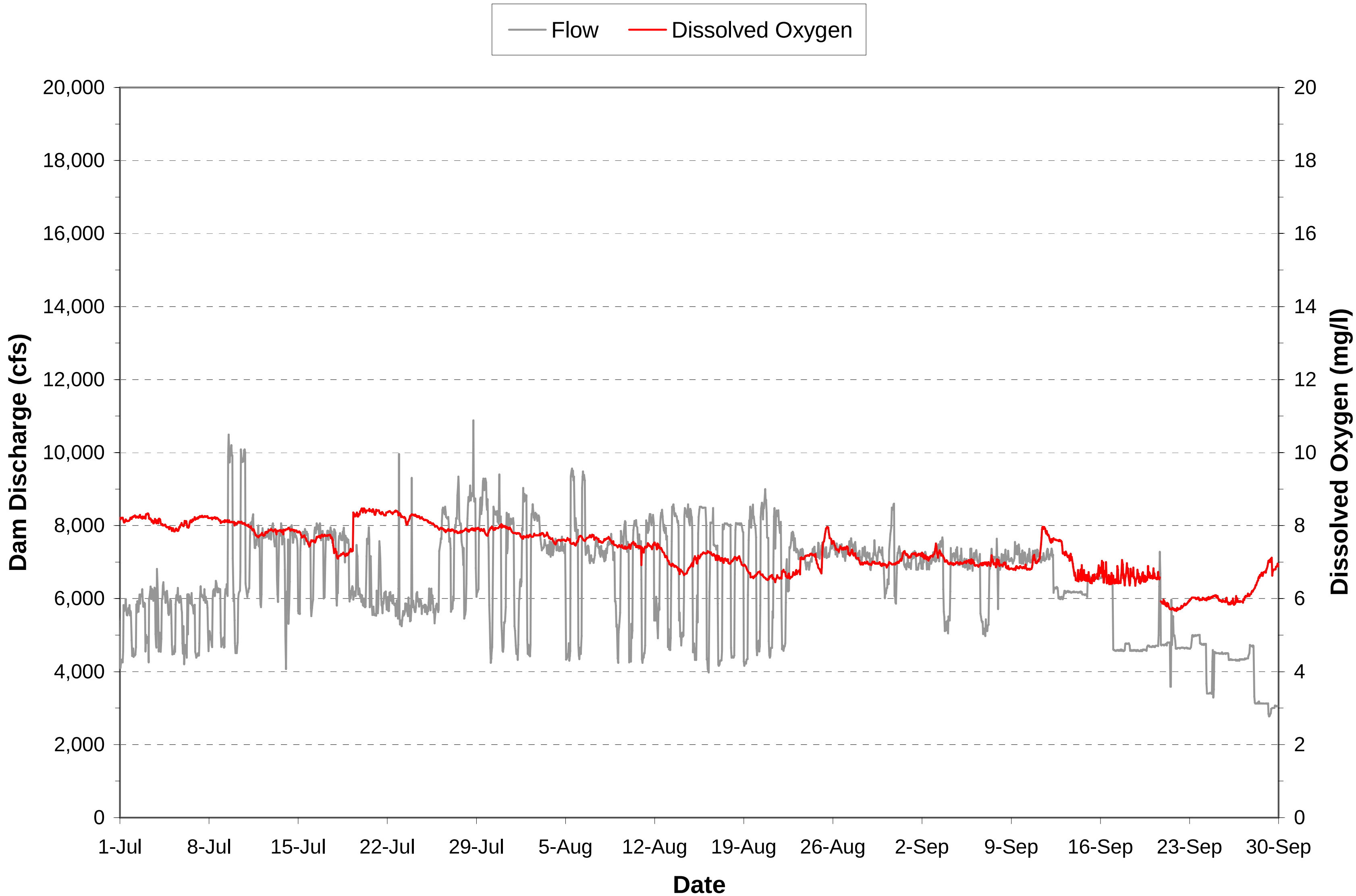


Plate 69. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period July through September 2005. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

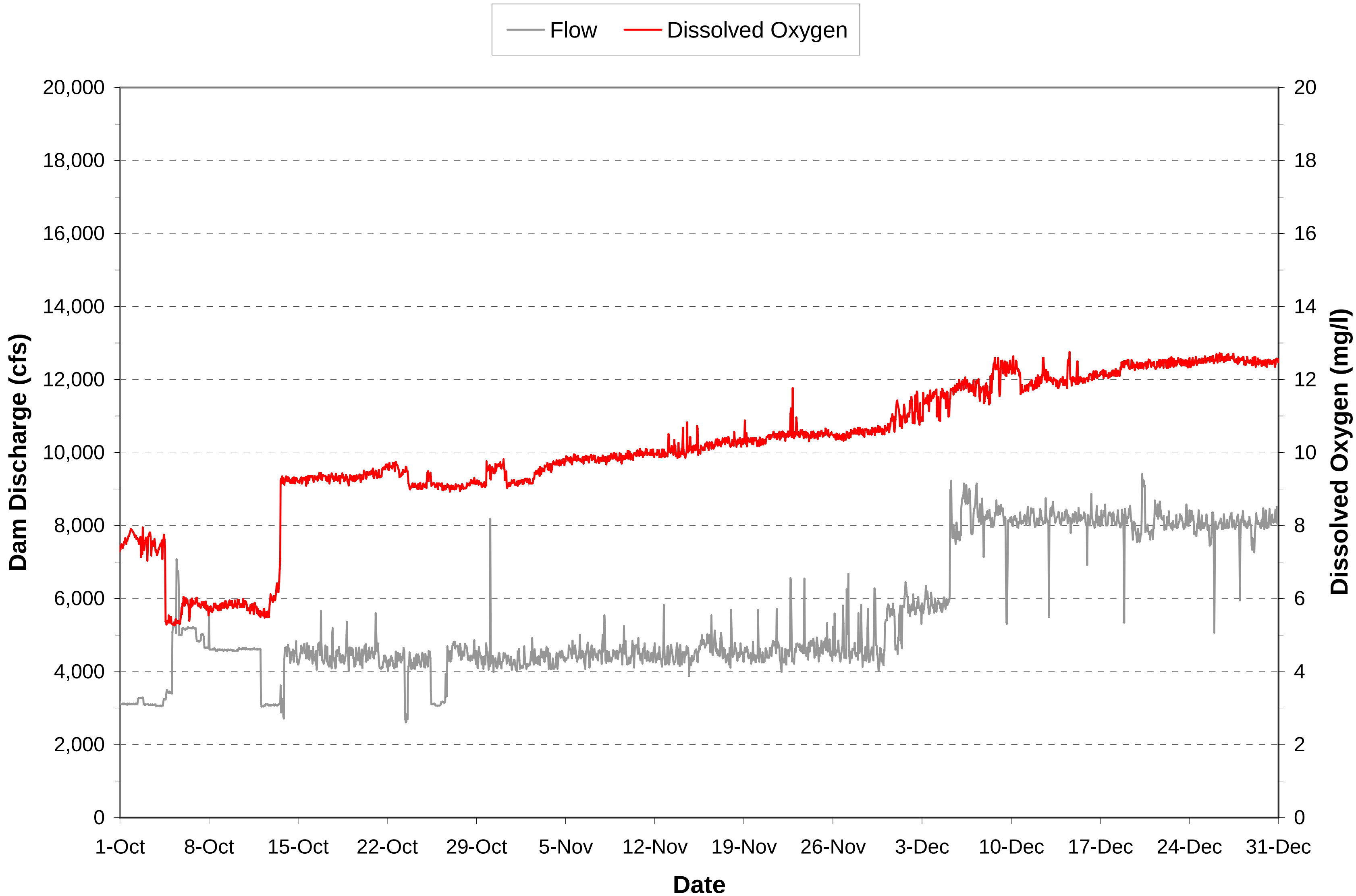


Plate 70. Hourly discharge and dissolved oxygen concentrations monitored in the “raw water supply line” at the Fort Peck powerhouse during the period October through December 2005.

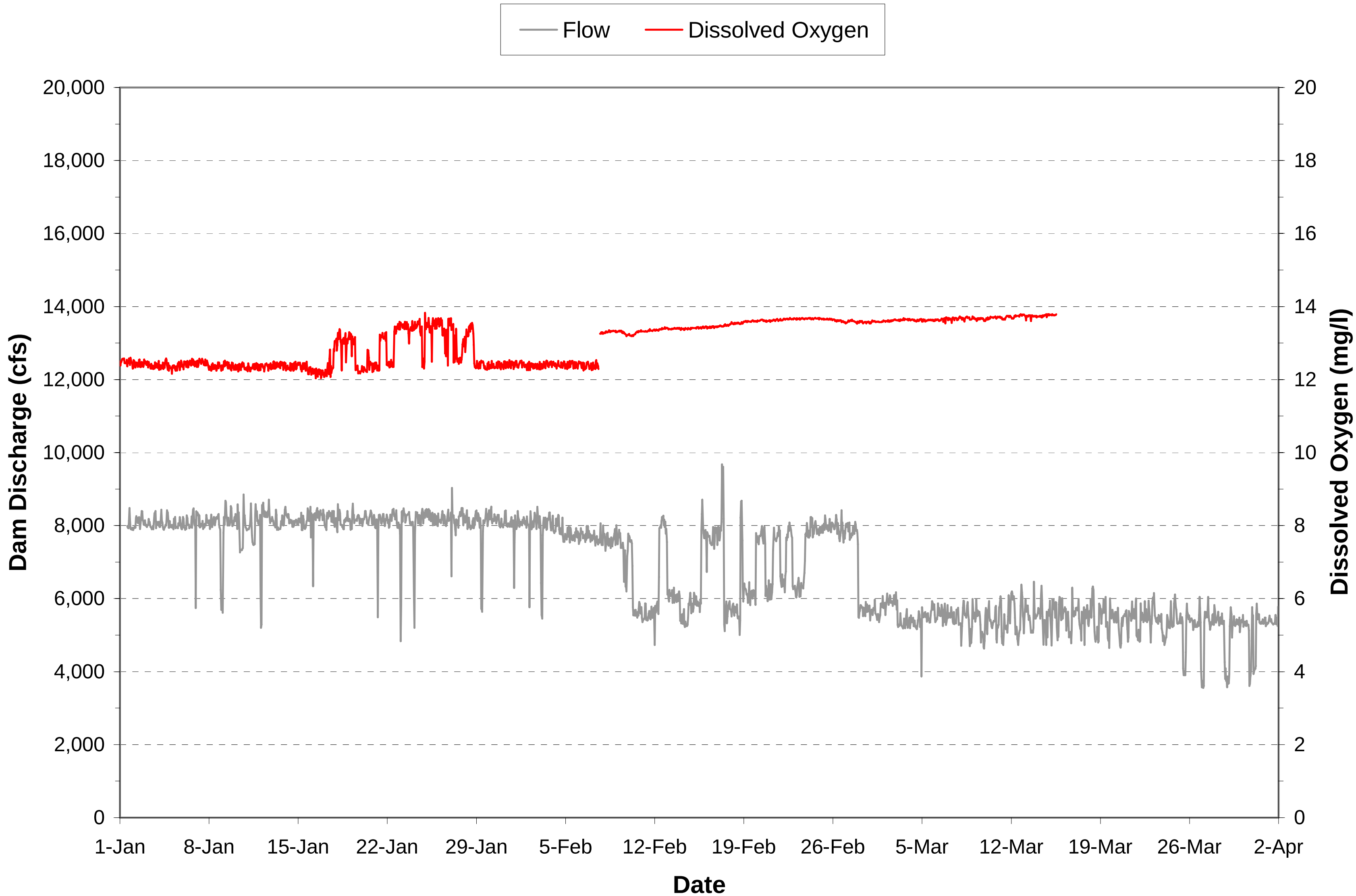


Plate 71. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period January through March 2006. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

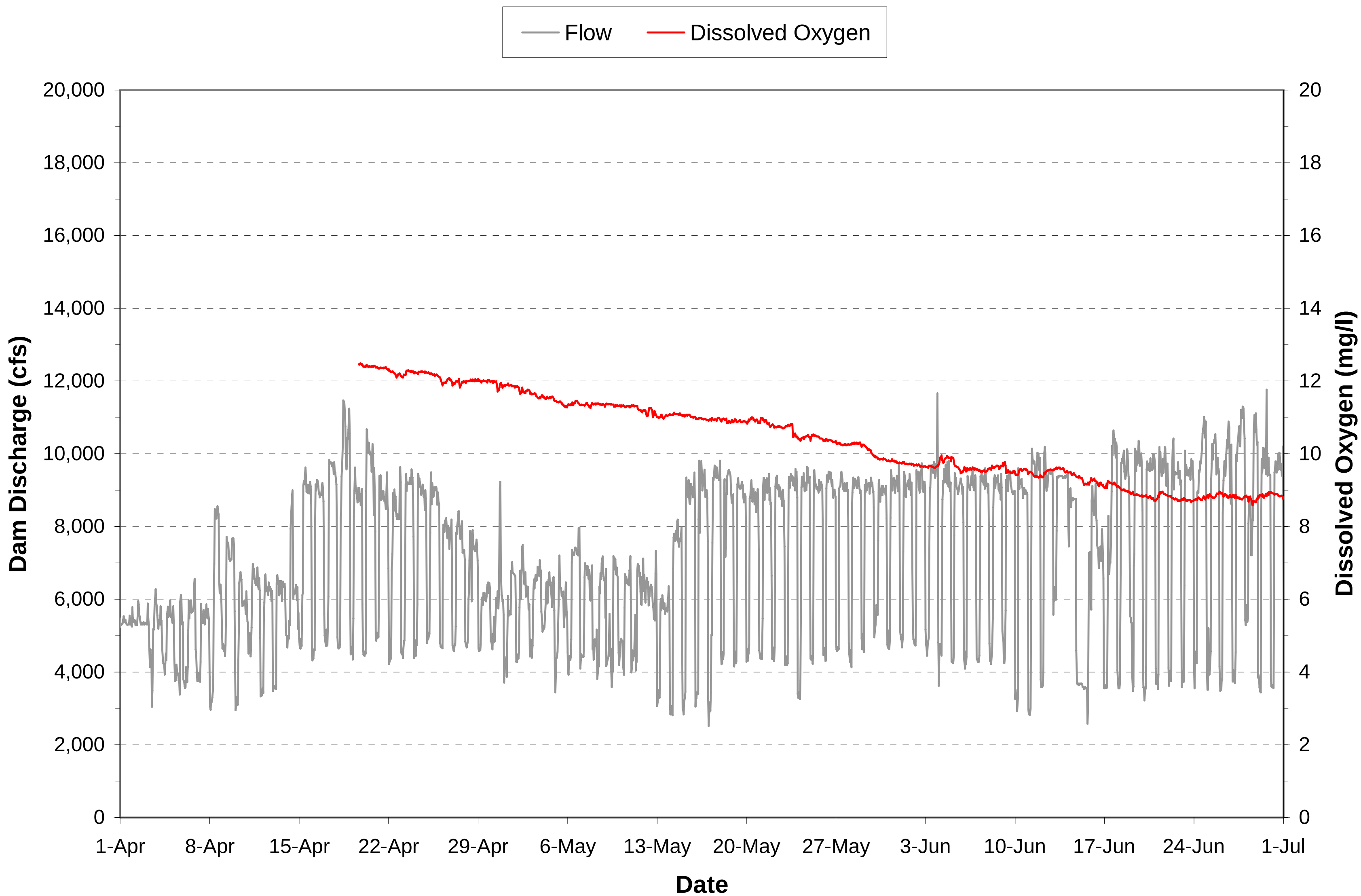


Plate 72. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period April through June 2006. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)

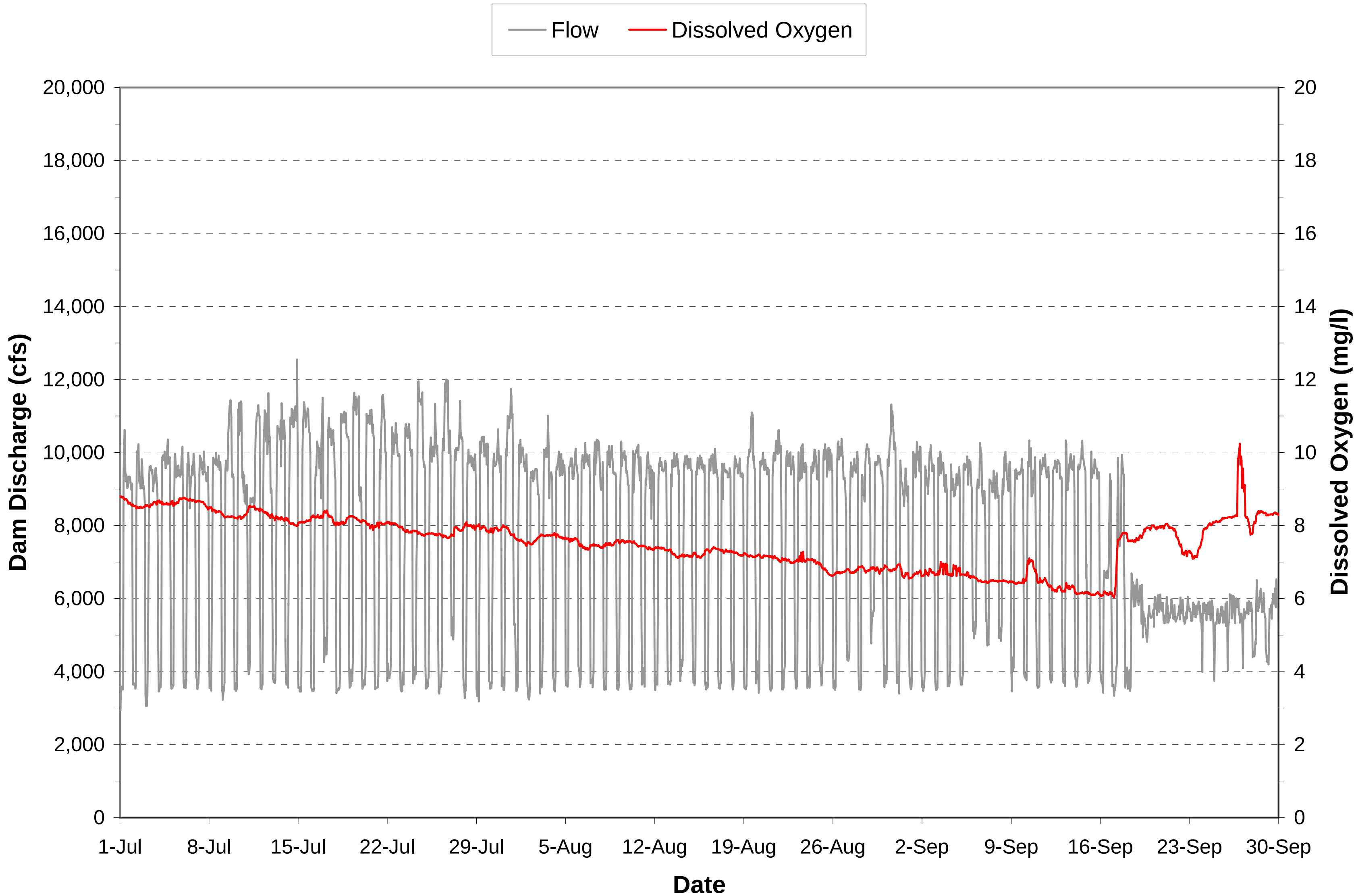


Plate 73. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period July through September 2006.

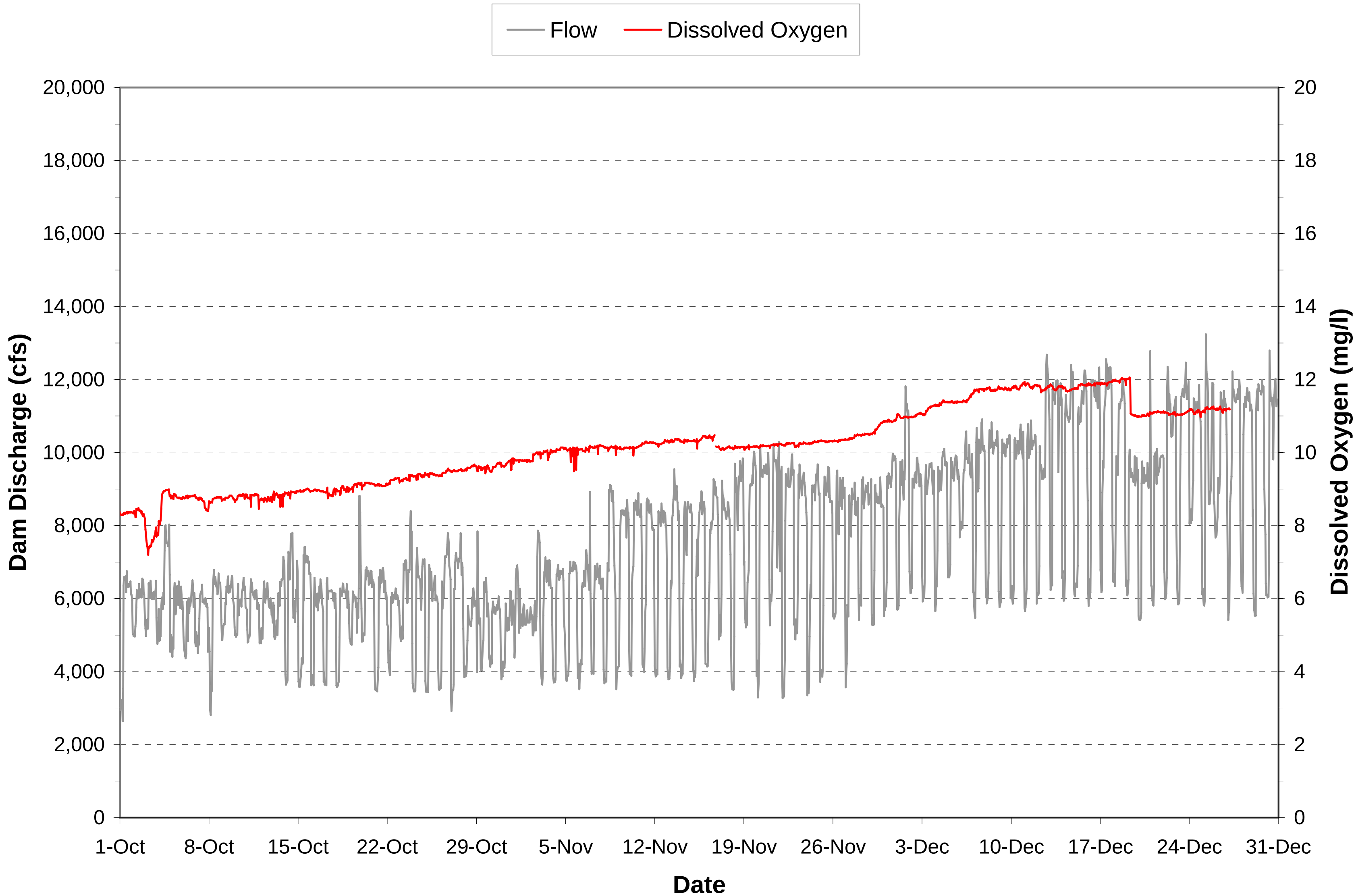


Plate 74. Hourly discharge and dissolved oxygen concentrations monitored in the "raw water supply line" at the Fort Peck powerhouse during the period October through December 2006. (Note: Gaps in dissolved oxygen plot are periods when the monitoring equipment was not operational.)