Chemical and Physical Properties of Lake Sakakawea 1992 - 2000

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Introduction

Lake Sakakawea is the second mainstem reservoir on the Missouri River located in west central North Dakota. It has a surface area of 368,000 acres and volume of 22,700,000 acre feet at full pool. Normal operation at full pool is 1850 feet above sea level. During the summers of 1992 through 1996 the North Dakota Department of Health, Division of Water Quality, Surface Water Program (NDDoH, DWQ, SWP) conducted extensive water quality research on Lake Sakakawea. The purpose of this intensive sampling regime was to assess the effect low water conditions were having on the reservoir.

Drought conditions had affected runoff since the mid-1980's and Lake Sakakawea had been decreasing in level since 1987 (Figure 1). Lake Sakakawea reached its lowest level since filling in May of 1991 with a level of 1815 feet above sea level, 35 feet below normal operation and nearly one-half the total volume.

Sampling consisted of water column temperature and dissolved oxygen profiles and water chemistry analysis. In 1993, chlorophyll-a analysis and phytoplankton identification and enumeration were added to the reservoir sampling. During 1992, emphasis was put on temperature and dissolved oxygen profiles with limited water chemistry analysis. Sampling in 1993 through 1996 focused on both temperature and dissolved oxygen profiles and water chemistry.

Eleven sampling sites were used to evaluate the water quality of Lake Sakakawea (Figure 2). Sampling sites are located from the face of the dam near Riverdale to the upper end of the reservoir near Lewis and Clark State Park. The summers of 1992 and 1993 had been unusually cool following the drought, but, until July 1993, lake levels remained low. During sampling in 1992, Lake Sakakawea water levels were fairly stable at around 1,820 feet above sea level. Lake levels dropped slightly in the winter of 1992-1993 and slowly raised back by June 1993. In July 1993, heavy rains fell across North Dakota and water levels on Lake Sakakawea began to rise. By the end of September 1993, water levels had risen 14 feet.

Methods

Water samples were collected on Lake Sakakawea from early June through September of each sampling year. Samples were collected following the "Standard Operating Procedures for Field Samplers" (NDSDHCL, DWQ, SWP). In 1992, sampling was conducted approximately every other week. Sites in the lower portion of Lake Sakakawea were sampled 12 times between June 8 and September 10. Sites in the upper end of the lake were sampled nine times beginning June 22 through September 11. In 1993-1996, samples were taken five times along the whole lake from June through September. The use of a Magellan, Global Positioning System (GPS) hand-held unit was used to locate each sampling site.

At each site, a temperature and dissolved oxygen profile was taken from the surface to the lake bottom. Measurements were taken every 2 meters until stratification was noticed and then taken each meter. Once through the stratified layer, readings were once again taken at each 2 meters.

The winkler/azide method was used to calibrate the meter twice each day before and after sampling. Water chemistry results were checked by QA/QC procedures outlined in the "Standard Operating Procedures.”

Diagrams of the coldwater habitat were made for each and were taken from the temperature profiles for Lake Sakakawea. Coldwater habitat was defined as water with a temperature below 15 degrees centigrade and dissolved oxygen levels above 5 mg/l. Up to four layers would be possible per month (Figures 3-7). The surface layer, colored red, was the level of the reservoir at the end of the month. Coldwater layer, colored blue, was the start of the coldwater habitat. Coldbot layer, colored green, was the bottom of the coldwater habitat. This took place when the water’s physical variables, temperature or dissolved oxygen were either above 15 degrees centigrade or below 5 mg/l. Bottom was the last variable, colored black, and was the bottom of the lake.

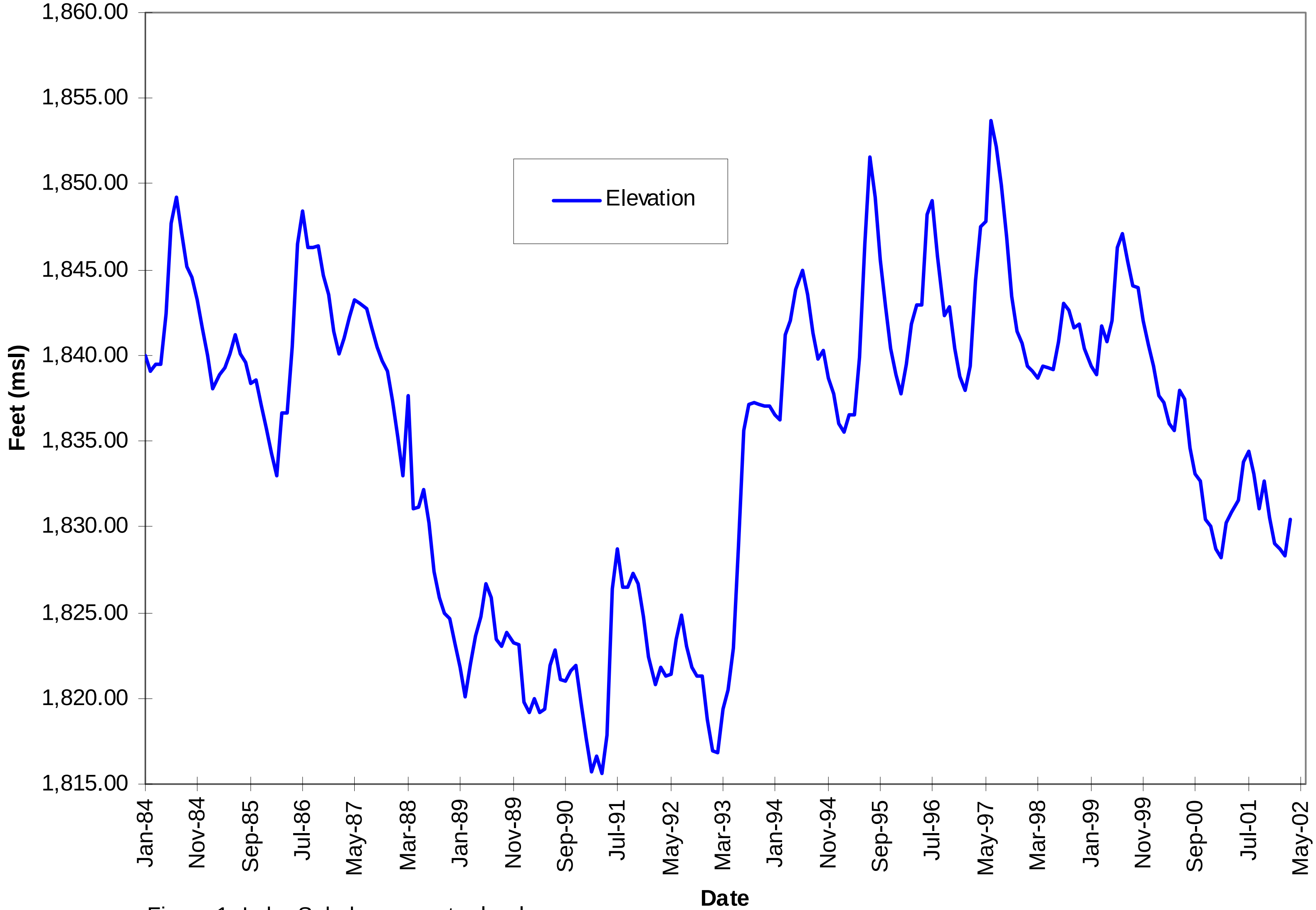

Figure 1. Lake Sakakawea water level

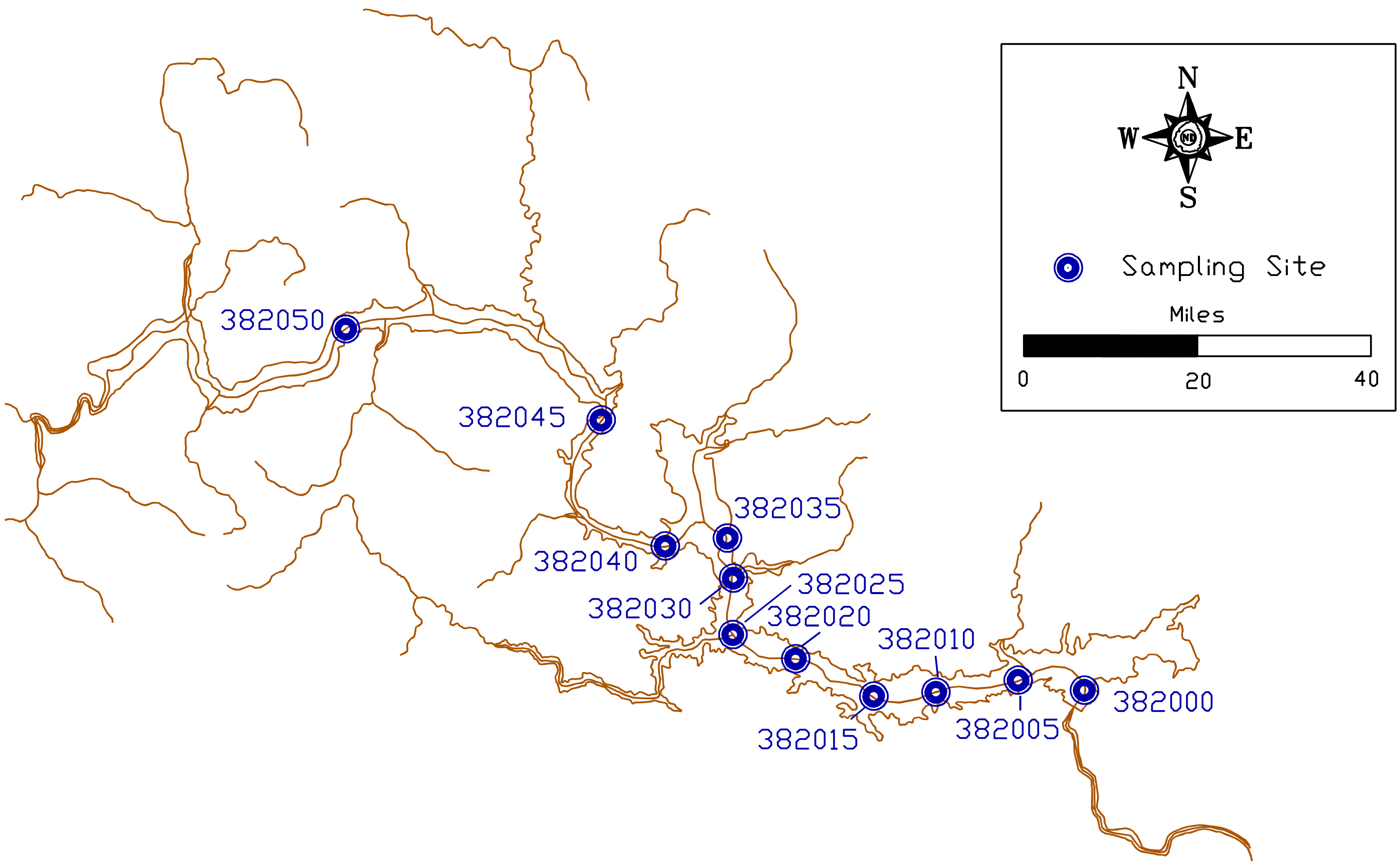

Figure 2. Sampling locations on Lake Sakakawea

Results and Discussion

In July 1993, Lake Sakakawea was influenced by heavy rains and cool temperatures. Water levels were increasing during this time and were at approximately 1,835 feet above sea level by the end of July (Figure 1).

Dissolved Oxygen

Oxygen levels were good in 1992 throughout the water column, ranging up to 10 mg/l. Oxygen levels in the lower four sampling sites(RM 1390-1420) were fairly consistent throughout the water column near 9 mg/l with a drop to 3.8 mg./l in July near Riverdale. The next four sites (RM 1430-1450) measured during this time showed oxygen levels above 8 mg/l in the epilimnion but declined to nearly 5 mg/l in the hypolimnion (Appendix). See Table 1 for site explanation.

Oxygen levels taken in August 1992 ranged between 8 and 9 mg/l in the epilimnion, while levels dropped off drastically at the thermocline. Oxygen levels fell to nearly 4 mg/l near the bottom in the upper sites measured in 1992. The four sites that exhibited temperatures indicative of cold water habitat also displayed oxygen levels above 5 mg/l.

Oxygen levels during July 1993 ranged between 7 and 9.4 mg/l . The dissolved oxygen levels were more stable in the lower reaches of the reservoir, with slight decreases near the bottom. Mid-reservoir and upper reservoir sites generally exhibited a slight decline throughout the profile. As compared to July 1992, oxygen levels in the lower reaches were very similar.

Dissolved oxygen profiles taken during August 1993 also met the criteria for cold water habitat, with all sites and all depths above 5 mg/l. RM 1390 through RM 1445 were very stable throughout the water column, with only small deviations in oxygen levels compared to 1992. Mid to upper sites showed a strong relationship with the thermocline, decreasing in oxygen as depth increased. This compared fairly well to 1992, but the decrease in oxygen was markedly reduced in 1993. This again may be attributed to the large inflow received during July 1993.

The dissolved oxygen profiles for September of both years displayed fairly stable conditions throughout the water column. In 1992, the oxygen profile generally ranged between 8 and 9 mg/l, while 1993 ranged from 9 to 10 mg/l. As displayed in the September temperature profiles, the small stratified area was also noticeable in the oxygen profiles. Oxygen levels declined by nearly 3 mg/l at the same sites during each year.

Dissolved oxygen in June 1994, was also at high levels. By August, however, there were mid reservoir areas that fell below 5 mg/l. In September, this area move closer to Garrison Dam and higher in the water column. Many areas in the mid and upper reaches of the reservoir fell well below the 5 mg/l standard in August and September 1994.

Initially, 1995 oxygen levels were above 10 mg/l at all sites, with the exception of Pouch Point and Lewis and Clark sites. These two sites were still above 8 mg/l oxygen, however. All sites displayed a decrease in oxygen throughout the summer months, with RM1430-RM1438 and RM1449-RM1516 sites falling below 5 mg/l in July, August or September.

During 1996, oxygen levels once again started out relatively high, with all sites having more than 9 mg/l except RM1516, which had levels just above 8 mg/l. Oxygen levels remained high throughout the 1996 sampling season. All sites remained above 5 mg/l at all times, thus meeting one of the criteria for coldwater habitat.

Table 1. Site names, STORET numbers, and river mile (RM).

Name	STORET	Rivermile
Riverdale	382000	1390
Hazen Bay	382005	1400
Beulah Bay	382010	1410
Beaver Bay	382015	1420
Indian Hills	382020	1430
Little Missouri	382025	1438
Deepwater	382030	1444
Van Hook Arm	382035	1449
Pouch Point	382040	1466
Four Bears Bridge	382045	1480
Lewis & Clark State Park	382050	1516

Temperature

In 1992, thermal stratification was evident by the time sampling began in early June (Appendix). Temperatures in early August 1993 showed good stratification, but the range of temperatures was smaller than in 1992. Temperatures in early August 1993 ranged from 13 degrees to 19 degrees C except for site 380050, which was influenced by runoff from the heavy July rains. The excessive runoff also impacted the hypolimnetic formation by slowing the process and also increased the temperatures in the hypolimnion by over 2 degrees C compared to August 1992.

During late August 1993, a stable thermocline had developed. Temperatures in the epilimnion averaged just over 19 degrees C, with temperatures in the hypolimnion ranging from 13 degrees to 17 degrees C.

In 1992, water levels were nearly 30 feet below full pool but were stable throughout the sampling season. June 1992 showed the hypolimnion starting 19 meters below the surface. Due to the stable water conditions, the thermocline formed early with good stratification. In June 1993, very weak stratification was noticed, with the thermocline located near the surface and gradually falling off up reservoir. By July 1992, strong stratification was evident and a reduction in the hypolimnion was seen. Also by this time, cold water habitat was being reduced to the lower sampling sites on the lake. In July 1993, stratification was still very weak. At this time, there was a large hypolimnion in July 1993 compared to the previous year. This was due to good runoff in June and the cool temperatures experienced during sampling.

In August 1992, the hypolimnion was compressed to 30 meters below the surface. By this time, cold water habitat was limited to sites 382000 through 382015 in the lower portions of the reservoir. Stratification was heavy throughout the reservoir, with hypolimnetic temperatures increasing as depth decreased. The hypolimnetic volumes were similar to those in August 1993.

Water temperatures progressively became somewhat cooler from 1993 through 1996. This was due to the large amount of spring runoff received by Lake Sakakawea during these years, bringing the lake close to full pool. Although these temperatures cooled off somewhat, they did follow the same basic patterns each year.

Coldwater Habitat

The amount of coldwater habitat present in Lake Sakakawea in 1988 through 1992 was less than 2 million acre/ft and nearly nonexistent in 1991 (Lee et al 1997). Figure 3 displays the amount of coldwater habitat in Lake Sakakawea for June, August and September 1992. As can be seen, the amount of habitat diminished throughout the summer to almost nothing in September. During 1993, a greater area developed as coldwater habitat. This area was maintained throughout the summer months and through the fall (Figure 4).

Although there was more coldwater habitat during 1994, a problem did develop. During August and September, oxygen levels dropped to below 5 mg/l in some areas of Lake Sakakawea (Figure 5). Those areas designated by a green line (below) were incapable of meeting the definition of coldwater habitat during those months.

Again in 1995, a larger coldwater habitat area developed and was sustained throughout the summer months (Figure 6). Coldwater habitat reached up Lake Sakakawea to RM1455. Figure 7 displays coldwater habitat present in 1996. Once again, the area grew deeper and extended further up the reservoir to RM 1466 in August.

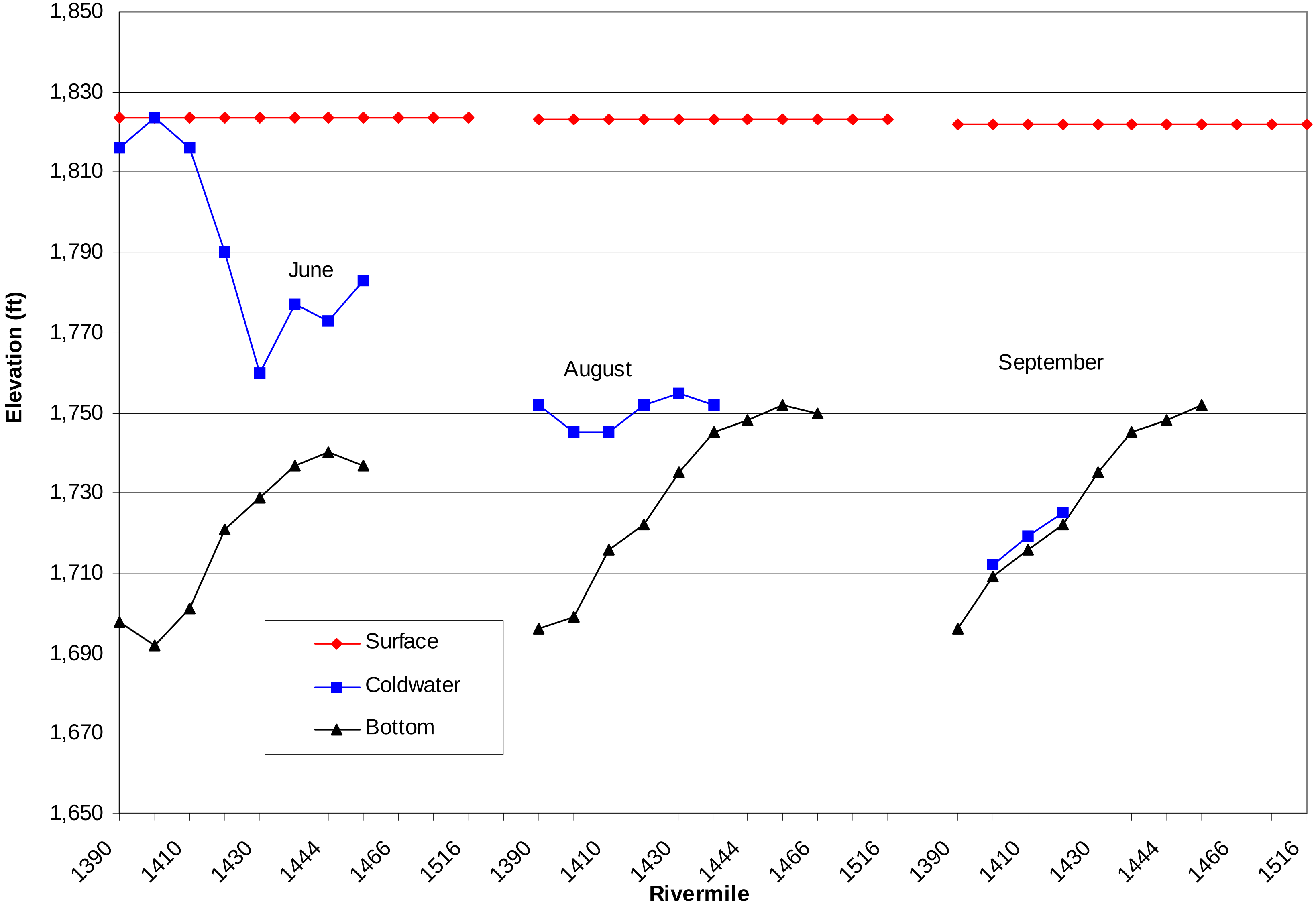

Figure 3. Lake Sakakawea coldwater habitat 1992

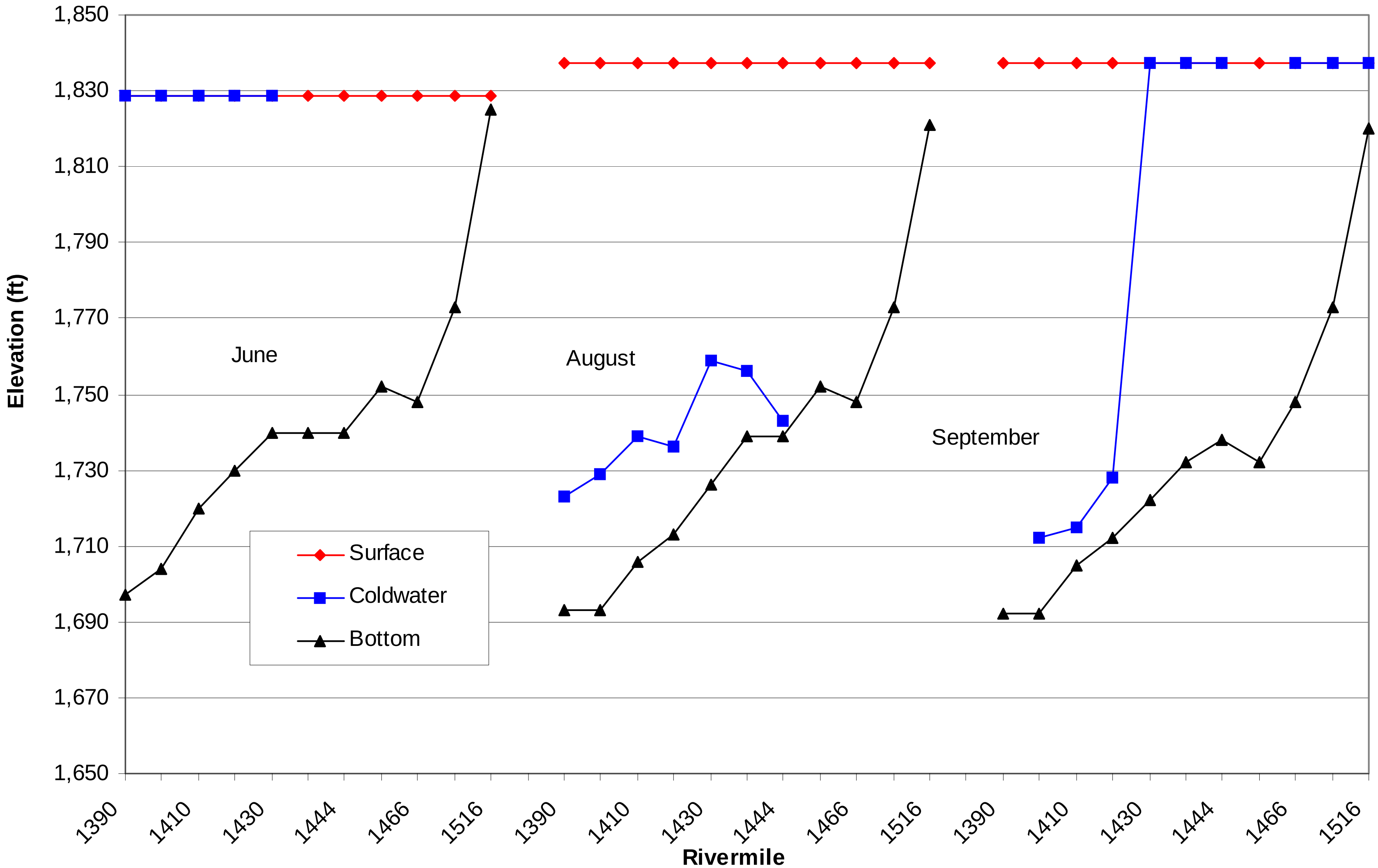

Figure 4. Lake Sakakawea coldwater habitat 1993

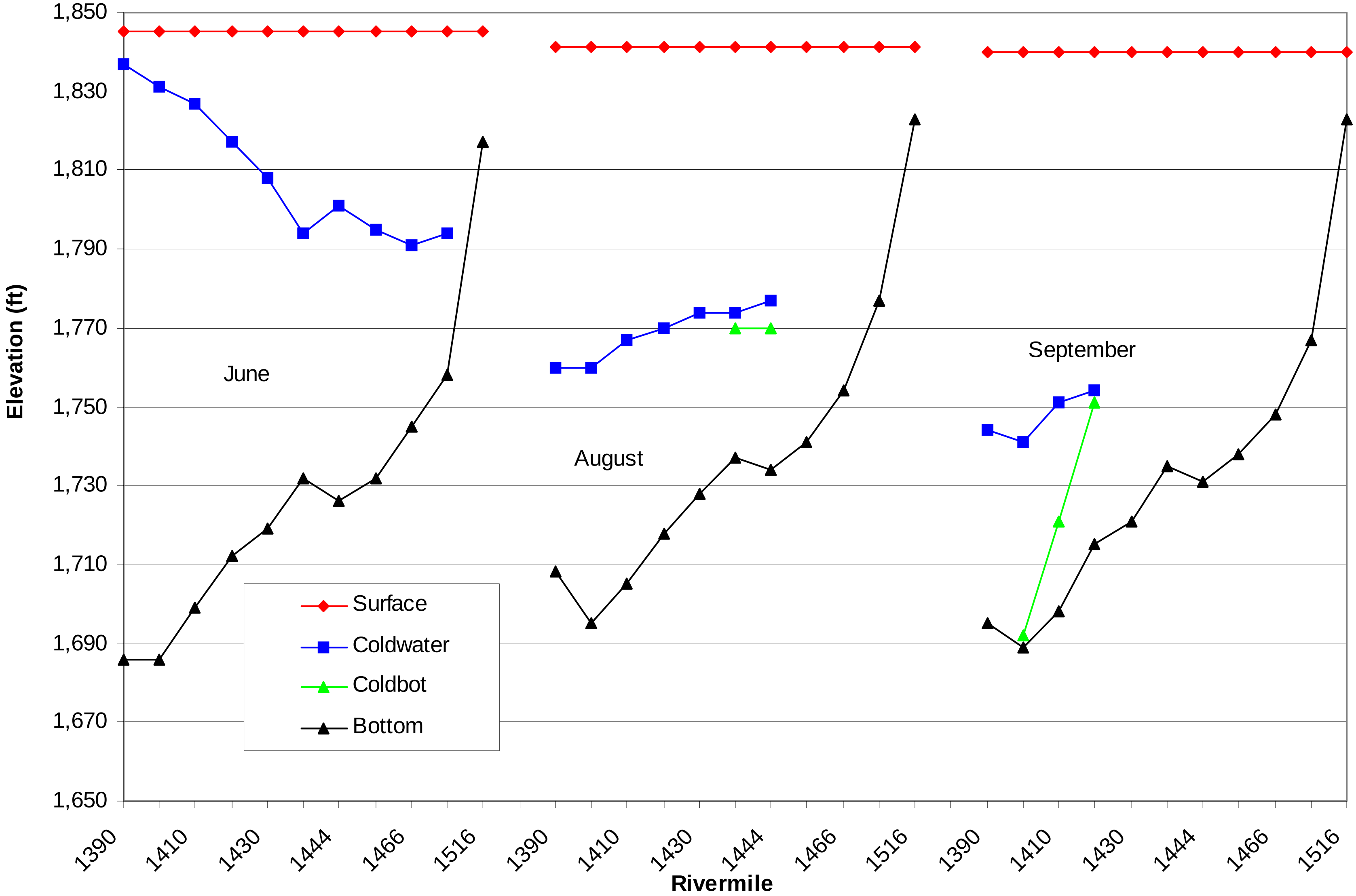

Figure 5. Lake Sakakawea coldwater habitat 1994

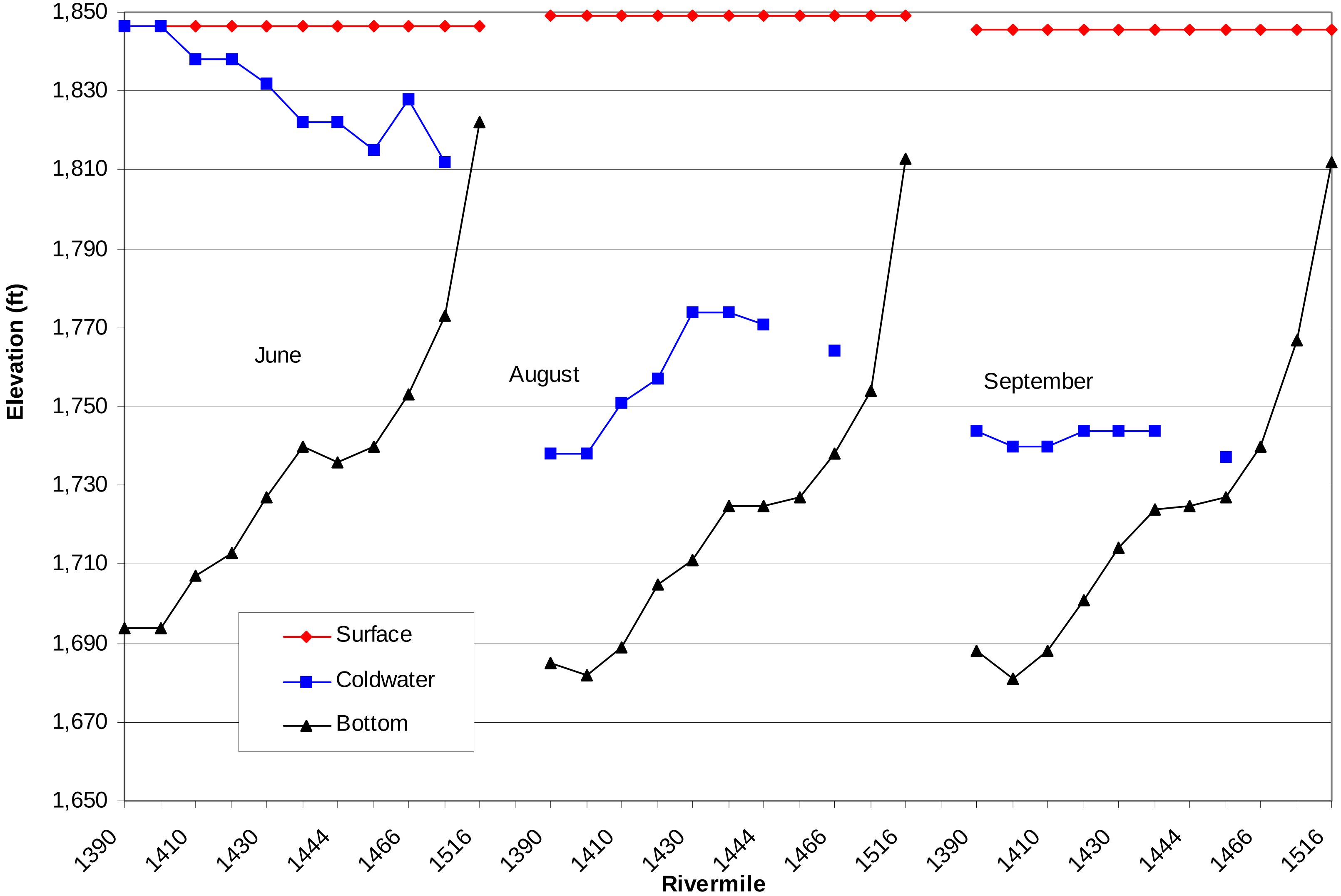

Figure 6. Lake Sakakawea coldwater habitat 1995

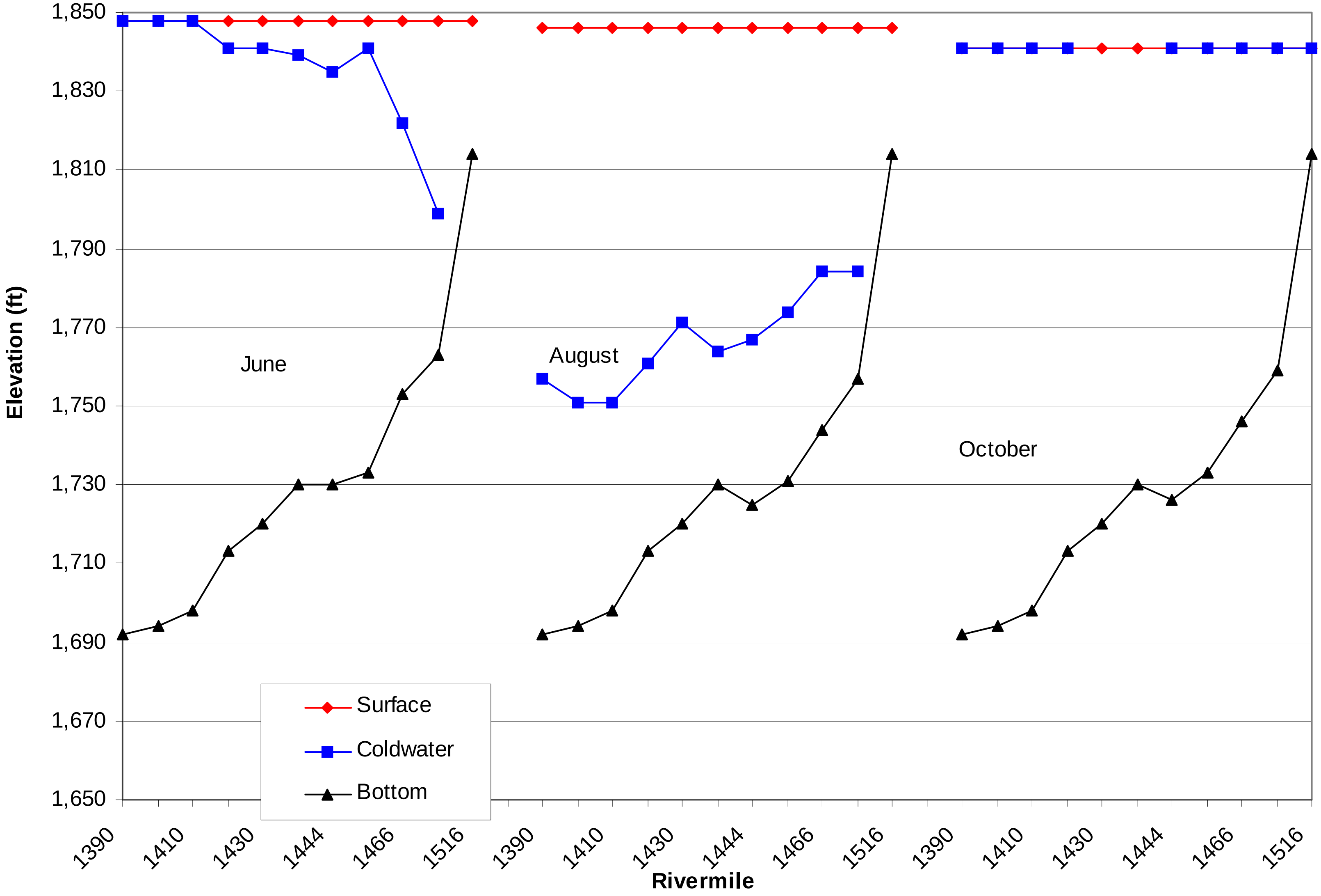

Figure 7. Lake Sakakawea coldwater habitat 1996

Table 2. Lake Sakakawea physical characteristics during the lowest amount of coldwater habitat available 1992-1996 and 1999-2001.

Year	Surface Acres	Volume Acre-ft	NDDH	NDGF	USCOE	Stage feet	Dis-charge cfs
			Coldwater Habitat Acre-feet (million)				
1990	249,665	13,275,410		.065		1821.0	
1991	266,715	14,822,060		0.46	1.81	1826.0	18,000
1992	257,585	14,036,010	.043	1.1	2.80	1823.0	18,130
1993	304,925	17,955,980	1.5	1.47	4.88	1837.1	15,790
1994	325,805	19,216,870	1.8	2.7	5.53	1841.3	18,440
1995	360,505	21,969,270	1.7	1.8	6.72	1849.2	29,760
1996	348,715	20,904,990	3.2	2.5	5.86	1845.8	36,060
1997	352,810	21,255,790		2.3	2.36	1846.9	46,000
1998	335,450	20,256,000			3.63	1842.6	21,900
1999	340,035	20,216,070	1.1	2.0	3.81	1844.1	22,700
2000	292,410	17,061,000		2.2		1834.0	
2001							

Table 2 displays the relationship between surface acres, volume, coldwater habitat, stage (elevation) and discharge. The surface acres, volume, stage and discharge where taken from United States Geological Survey water data reports. The United States Corps of Engineers (USCOE) values were calculated from a model/formula given in the Missouri River Master Manual, Volume 8. North Dakota Game and Fish Department (NDGF) values were obtain via personal communication with Jason Lee, NDGF at Riverdale. The NDGF values were calculated as close to September 1 of each year as possible. The NDDoH values where calculated by determining the lowest amount of coldwater habitat available for each year through actual field measurements and using area-capacity tables developed by the USCOE to estimate the number of acre-feet available.

As can be seen, the estimates varied significantly. Overall, the USCOE estimates tended to be highest, with the NDGF having the second overall highest and the NDDoH giving the lowest estimates of coldwater habitat. Actual field measurements may be closer to the actual amount of coldwater habitat than the USCOE calculated values.

Water Quality

Total dissolved solids (TDS) varied drastically throughout Lake Sakakawea. There was a general increasing trend from 1992 through 1996 at all sites. The range of change varied greatly from site to site. TDS at RM 1390 (face of dam) started off in 1992 just below 400 mg/L and ended in 1996 just above 400 mg/L. Also TDS concentrations did not have wide fluctuations during each year. Further up the reservoir, this pattern did not hold true. At RM 1516 (Lewis and Clark State Park) wide fluctuations occurred between and among years.

Each year, TDS concentrations started out near 250 mg/L and ended over 400 mg/L. During 1994, concentrations started and ended even higher.

Kjeldahl nitrogen and nitrate and nitrite levels followed much the same pattern throughout the reservoir, with one minor exception. The concentration levels remained approximately the same over the project period.

Sulfate, sodium, iron, alkalinity, bicarbonate, carbonate, chromium and selenium all followed the same basic pattern of TDS. A slight, gradual increase in concentration with low variation near the dam and wide ranging variations within each year further upstream. These changes in water quality are to be expected, with the majority of the ions entering the system through the Yellowstone and Missouri rivers and subsequently dropping out by RM 1466 (Pouch Point). This leaves the water with the lowest TDS nearest Garrison Dam.

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Appendix

Variables and Concentrations

Contact the North Dakota Department of Health