

**DELAWARE RIVER TAILWATERS TEMPERATURE  
MONITORING, FLEXIBLE FLOW MANAGEMENT  
PROGRAM,**

**June 1, 2011- May 31, 2015**

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Date: April 28, 2016

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**EXECUTIVE SUMMARY**

Overall, the FFMP releases program was effective in maintaining flow and temperature targets in the Upper East Branch, West Branch, and Neversink River tailwater reaches. No thermal stress days were recorded for the Upper East Branch or the West Branch and only 7 in 2012 in the Neversink River. FFMP summer base flows to the West Branch were inadequate in maintaining desirable summer water temperatures in the upper Delaware River but this was also true of all earlier releases programs. Directed releases to meet the Supreme Court mandated Montague flow target continue to exert the greatest influence on summertime temperature and flow conditions on the West Branch and upper Delaware River. Thermal stress days on the Delaware River for the summers of 2011 through 2014 ranged from 0 to 13 at Lordville (RM 321) and 5 to 67 at Callicoon (RM 303).

## INTRODUCTION

The tailwater portions of the West Branch Delaware River (West Branch), East Branch Delaware River (East Branch), Neversink River, and upper reaches of the mainstream Delaware River comprise one of the best wild trout fisheries in New York. Stream flows on these rivers are greatly influenced by releases from three New York City reservoirs: Cannonsville Reservoir on the West Branch, Peptacton Reservoir on the East Branch, and Neversink Reservoir on the Neversink River (Figure 1). These water supply reservoirs were constructed to provide water to New York City.

The volume and timing of releases from these reservoirs were stipulated in the U.S. Supreme Court decrees of 1931 and 1954. Modern reservoir release regulations for the Delaware tailwaters have evolved since 1976, when the New York legislature created Article 15, Title 8 of the New York State Environmental Conservation Law. Regulations (Part 671 of 6NYCRR) were adopted pursuant to the legislation, and the New York regulations were subsequently incorporated into Delaware River Basin statute (DRBC Docket D-77-20-CP). Modifications to reservoir operations must have the unanimous consent of all parties to the Supreme Court decree. These parties are the states of Delaware, New Jersey, New York, Pennsylvania, and New York City. The negotiated releases program currently in effect is called the Flexible Flow Management Program (FFMP) and relies on the Operations Support Tool (OST) developed by NYCDEP to project reservoir inflows, outflows and probability of refill.

The FFMP for the upper Delaware River Tailwaters was initially implemented October 1, 2007, and was scheduled to run through May 31, 2011, a period of 3.7 years. The FFMP has been extended each year since with some minor changes. According to the Decree Parties agreement establishing this program, FFMP was designed to provide safe and reliable supplies of water essential to serve the needs of over 17 million people who depend on water from the City's

Cannonsville, Pepacton and Neversink Reservoirs (City Delaware Basin Reservoirs) and their tailwaters, and the Delaware River; to manage discharges from the City Delaware Basin Reservoirs; to provide flows to help control temperatures in the tailwaters to help sustain cold water fisheries; to assist in mitigating the impacts of flooding; and to provide flows in the main stem and the Delaware Bay to help protect ecological health, support withdrawal and non-withdrawal uses, and repel salinity.

As part of the FFMP agreement, the New York State Department of Environmental Conservation (DEC) monitored the releases program to evaluate its effectiveness in protecting the coldwater ecosystem below the reservoirs. This report summarizes the summer water temperatures observed under the one-year FFMP agreement extensions in effect between June 1, 2011 and May 31, 2015.

## **FLEXIBLE FLOW MANAGEMENT PROGRAM**

FFMP releases are determined by fixed release schedules that depend on season, reservoir storage level, and forecast available water (FAW) estimated by OST. Under normal (L2) and above normal (L1) reservoir storage levels, the applicable releases are determined from a series of schedules labeled 4a-4g which cover a range of FAW from 0 to 100 MGD. The FFMP also contains provisions for spill mitigation applicable under L1 storage levels including a conditional seasonal storage objective (CSSO). Under the CSSO, reservoir storage must be managed to maintain a ten percent void from September 1 through March 15 to reduce the risk of downstream flooding. To adhere to the CSSO, releases may temporarily exceed the scheduled release. The L3, L4, and L5 releases occur when the reservoir system is in drought watch, warning, and emergency, respectively. For more details on reservoir operations under the FFMP, consult the text of the current agreement which is available on the Delaware River Master

home web page (<http://water.usgs.gov/osw/odrm/>). This website also contains a helpful archive of past agreements and court decrees as well as current and archived OST output.

A primary objective of the FFMP was to eliminate “banks” of water that were relied upon in earlier agreements to meet temperature and/or habitat flow targets. These banks proved to be problematic for several reasons. First, meeting temperature and/or flow targets involves combining weather forecasts, current stream conditions, models and experience to predict how much water needs to be released to maintain flow or temperature targets days in advance. This has proven to be very difficult and requires staff to constantly monitor stream conditions. Second, various interested parties have different views on when and how water should be released from a bank, often resulting in pressure on DEC to release water when circumstances may not warrant it. Finally, water in the banks often went unused at the end of the season and therefore did not provide any habitat benefits to the system.

## **THE DELAWARE TAILWATERS**

Water releases from three large New York City water supply reservoirs in the Delaware River basin are critical for maintaining trout populations in approximately 70 miles of downstream tailwaters. Since 2011, the FFMP has classified these waters under four categorical habitat protection levels jointly recommended by NYSDEC and Pennsylvania Fish and Boat Commission in 2010 (Figure 1). Releases from the Neversink Reservoir are intended to maintain trout conditions in 16 miles of Neversink River downstream to Bridgeville. Pepacton Reservoir releases to the East Branch are designed to provide trout habitat for 17 miles downstream to the confluence with the Beaver Kill. From Cannonsville Reservoir on the West Branch, releases are intended to produce trout conditions for the entire 18 miles downstream to Hancock as well as to provide lesser degrees of coldwater habitat protection for the Delaware River between Hancock

and Callicoon. Each of these four rivers are described in greater detail below.

### **East Branch Delaware River**

The East Branch downstream of Pepacton Reservoir flows for 32.1 miles before merging with the West Branch to form the Delaware River (Figure 1). The tailwater reach extends 17 miles downriver from the dam to the confluence with the Beaver Kill. The East branch downstream of the Beaver Kill also supports a wild trout fishery but this reach normally does not receive any thermal benefits from the cold water releases at the Pepacton reservoir dam. The tailwater reach will be referred to as the upper East Branch in this report.

The upper East Branch is a medium size river with an average daily flow of 411 cfs for the 1955-2014 monitoring period at the USGS Harvard gage (USGS website). Stream flows and summer water temperatures in the river are largely dependent on water releases from Pepacton Reservoir. Prior to the FFMP, base releases to the upper East Branch typically ranged from 45 to 95 cfs depending on time of year.

Summer cold water releases are intended to make the upper East Branch suitable for trout throughout its 17.0 mile length. However, the lowermost three miles supports marginal trout habitat as evidenced by the sparse wild trout population. Brown trout are the dominant trout species with brook and rainbow trout present throughout the upper East Branch. The wild trout population in portions of the upper East Branch is supplemented with the stocking of 800 two year old brown trout annually which is equivalent to about 7 older fish per acre in the stocked reach. The two year old fish are stocked in the reach from Downsville to 0.4 miles upstream of the confluence with Beaver Kill.

The trout fishery is managed under a 12 inch size limit and a two fish daily limit throughout the river. The trout season runs from April 1 through October 15. Catch and release

fishing for trout outside the regular trout season is permitted from October 16 through November 30 from Shinhopple Bridge downstream to the mouth at Hancock.

## **West Branch Delaware River**

The West Branch downstream of Cannonsville Reservoir flows for 17.7 miles before merging with the East Branch to form the Delaware River (Figure 1). The upper 10.2 miles is located entirely in New York while the lower 7.5 miles of river forms the state boundary between New York and Pennsylvania. It is a large river with an average daily flow of 875 cfs for the 1964-2014 monitoring period at the USGS Hale Eddy gage (USGS website). Stream flows and summer water temperatures in the river are largely dependent on water releases from Cannonsville Reservoir. Prior to the FFMP, base releases generally ranged from 33 to 325 cfs depending on the time of year. River Master directed releases, which NYC typically makes to the West Branch, can exceed 1400 cfs and are frequent during a dry summer and fall.

Summer cold water releases make the West Branch suitable for trout throughout its 17.7 mile length. Trout populations consist primarily of brown trout with rainbow trout also found throughout the river. Brook trout are rare with rainbow trout more common in the border water reach. The river supports a wild trout fishery that was last stocked in 1994. However, a small number of hatchery brown trout from the Oquaga Creek stocking migrate downstream into the Deposit area of the West Branch.

The trout fishery is managed under a 12 inch size limit and two fish daily limit outside the catch and release only section. The trout season runs from April 1 through October 15. There is a catch and release/artificial only section from Route 17 overpass at Deposit to 2.0 miles downstream. All angling is prohibited from October 16 through March 31 to protect spawning fish in all non-border water sections. Additionally, the NY/PA border section opens on the first Saturday

after April 11 through October 15. Catch and release/artificial only fishing for trout outside the regular trout season is permitted in the NY/PA border section from October 16 through the Friday preceding the first Saturday after April 11.

## **Delaware River**

The Delaware River, below the confluence of the East and West Branches flows for 321 miles before entering the Atlantic Ocean and forms the state boundary between New York and Pennsylvania for the uppermost 74 miles. This very large river has an average annual daily flow of 2,967 cfs for the 1975-2014 monitoring period at the USGS Callicoon gage (USGS website). Summer water temperatures are strongly influenced by the warm East Branch and the volume of cold water being released to the West Branch. At the confluence, the East Branch side of the river can be up to 25°F warmer than the West Branch side of the river. In general, base releases from Cannonsville Reservoir are insufficient in providing consistent cold water benefits to the Delaware River. Large River Master directed releases or thermal releases are required to provide these cold water benefits. Callicoon is considered the downstream end of the tailwaters but, between Callicoon and Hankins, the habitat protection level classification is “miminal” compared to “moderate” between Hankins and Lordville and “good” between Lordville and Hancock. The “excellent” classification does not apply to any portion of the Delaware River below the confluence of the East and West Branches (Figure 1).

The wild trout population is dominated by rainbow trout but brown trout are common. Due to the Delaware River’s large size, fish sampling has been ineffective. The limited sampling undertaken suggests that trout abundance averages 5 to 10 lbs/acre (Sanford 1992; McBride 1995) with warm water fishes such as smallmouth bass and walleye common. The river also supports an American shad fishery in late spring. In recent years, striped bass have been

appearing in the upper river reaches.

The trout fishery is managed under a 14 inch size limit and a one fish daily limit throughout the river. The trout season runs from the first Saturday after April 11 through October 15. Catch and release fishing for trout outside the regular trout season is permitted throughout the river.

No creel survey of the entire trout reach has been conducted on the Delaware River; however, a 2.3 mile reach by Lordville (Figure 1) was last censused in 1999. Fishing pressure on this reach totaled 3,722 hours or 1,149 trips (McBride 2003) which averaged 37 hours/acre, 11 trips/acre, or 500 trips/mile. These anglers averaged 0.32 trout/hour and reportedly creeled no trout (McBride 2003).

Angler's diary cooperators from 2002 through 2007 had average annual trout catch rates ranging from 0.25 to 0.65 fish/h and 0.19 to 0.47 legal ( $\geq 14$  in) fish/h. The six year average catch rate was 0.48 trout/h and 0.31 legal trout/h. The percentage of trout caught that were legal size, 18 in. plus, and 20 in plus averaged 64% (range was 51 to 77%), 19% (range was 11 to 24%) and 4% (range was 2 to 8%). Rainbow trout dominated the catch (61%) followed by wild brown trout (38%), brook trout ( $\leq 1\%$ ), and hatchery brown trout ( $\leq 1\%$ ).

## **Neversink River**

The Neversink River downstream of Neversink Reservoir flows for 40.3 miles before entering the Delaware River at Port Jervis (Figure 1). The tailwater reach extends from the dam downstream 16.3 miles to Bridgeville. Although the trout fishery extends another 14 miles downriver, this reach receives essentially no thermal benefits from the cold water releases at the dam.

It is a small river with an average daily flow of 272 cfs for the 1993-2014 monitoring

period at the USGS Bridgeville gage (USGS website). Stream flows and summer water temperatures in the tailwater reach are largely dependent on water releases from Neversink Reservoir. Prior to the FFMP, base releases to the river ranged from 25 to 53 cfs depending on time of year.

The tailwater reach supports a wild trout population dominated by brown trout. Brook trout are occasionally found while wild rainbow trout are absent. The wild trout population was supplemented with the annual stocking of 6,500 yearling brown trout at an average rate of 116 fish/acre. In 2013 roughly half of the policy was converted to brook trout on an experimental basis, as a section of the tailwater has been documented to exhibit excellent thermal conditions for brook trout throughout the summer. In addition, a private group stocks several thousand 13 to 17 inch and larger brook, brown and rainbow trout annually at one stocking location in the area of Avon Lodge (Angyal 2004).

The tailwater trout fishery is managed under a 9 inch minimum size limit and five fish daily creel limit through much of its 16.3 mile length. The trout season opens April 1 and closes October 15. A special catch and release section is located within the Neversink River Unique Area and owned by the people of the State of New York situated in the Towns of Thompson and Forestburgh and abutting that reach of the Neversink River from its confluence with Mercer Brook south to the Sullivan-Orange County line, except any portion thereof where the right to fish is privately owned.

Trout population studies were conducted at three standardized site 8 to 9 times from 1992 through 2006. Trout density and biomass in the tailwater reach averaged 83 trout/acre (range was 4 to 405 trout/acre) and 40.3 lbs/acre (range was 0.7 to 110.2 lbs/acre). Trout per mile average 181 yearling and older fish/mile (range was 22 to 402 fish/mile) and 121 legal ( $\geq 9$  in) fish/mile

(range was 0 to 339 legal fish/mile). The number of 12 inch and larger trout average 39 fish/mile (range was 0 to 95 fish/mi).

The last angler survey on the Neversink River tailwater was conducted in 2006. In that survey, fishing pressure totaled 11,328 hours or 4,356 trips on the tailwater reach (McBride et al. 2008). Fishing effort averaged 135 hours/acre, 52 trips/acre, or 267 trips/mile. However, angler effort was not evenly distributed. Fishing pressure was lowest on the reach closest to the dam (26 hours/acre) and highest in the Avon Lodge reach at 291 hour/acre. Anglers in 1999 averaged 0.67 trout/hour (range was 0.31 to 0.78 trout/hour) and 0.57 legal ( $\geq 9$  in) trout/hour (range was 0.24 to 0.64 fish/hour). Catch rates of 0.31 trout/hour were lowest near the dam compared to the average of 0.70 trout/hour downstream between Woodbourne and Bridgeville.

## **METHODS**

### **Flow Measurements**

Flow immediately below each reservoir (release or release plus spill) were measured and recorded at USGS gages at Neversink, Downsville, and Stilesville and further downstream at the habitat references sites at Bridgeville, Harvard, and Hale Eddy.

### **Temperature Monitoring**

Thermal data were obtained from eight permanent USGS gages and 21 Onset Optic “Stow Away” thermographs installed and maintained by DEC staff on the upper East Branch, West Branch, Delaware River, and Neversink River. The thermographs have a resolution of 0.2°C and were set to record temperature hourly. Thermographs were placed in the deepest water that personnel could access. All thermographs were encased in a length of heavy pipe and chained to a stake or adjacent rock. Accuracy of the thermographs was checked against a hand held calibrated mercury thermometer. Ideally, thermographs were placed by June 1 and removed by

October 1. However, placement and removal dates were dependent upon suitable flows.

Placement in 2013 occurred after June 25 for the West Branch, East Branch, and upper Delaware River because of unusually high flows in late May and June.

Data analysis involved selecting the highest of the 24 hour recordings as the daily maximum and the mean of the 24 hourly recordings as the daily average. Daily maxima and weekly averages are presented for the summer period and compared to existing regulatory criteria or biological standards developed from the fisheries literature (Elliot 2001)

Thermal stress day observations were used because they permit comparison with water temperature data by site within the same river between years. A thermal stress day occurs when the maximum water temperature equals or exceeds 75°F and/or the water temperature equals or exceeds 72°F for an entire 24 hour period (Sheppard 1983). Although useful for comparative purposes, the thermal stress day criteria defined by Sheppard (1983) was never intended to be used as targets to define favorable temperature conditions for trout (Hulbert 1987).

## **RESULTS**

### **WEST BRANCH**

#### **Air Temperature**

The Deposit weather station in 2011, 2012, 2013 and 2014 recorded a maximum air temperature of 96°F, 92°F, 90 °F, and 87 °F, respectively. Temperatures 90°F or higher occurred on ten days in 2011, five days in 2012, four in 2013, and zero days in 2014. The summer (June 1-Sept. 15) of 2012 was the warmest of the four years that FFMP was in effect. There were 20 days that summer when the air temperature was 85°F or higher compared to 19 in 2011, 13 days in 2013 and 5 days in 2014. The summer of 2014 was coolest with 48 days when the maximum air temperature was 75°F or lower compared to 46 days in 2013, 28 days in 2012 and 20 days in

2011.

## **Peak Flows**

Peak flows at the USGS gage in Hale Eddy in 2011, 2012, 2013, and 2014 were 22,200, 2,070, 4,950 and 8,240 cfs, respectively. The high flow resulted from a combination of hurricane Irene and tropical storm Lee in late August and early September. This peak flow is comparable to the peak flows of 17,500, 21,500, and 43,400 cfs recorded in 2004, 2005 and 2006, respectively. The 2004, 2005, and 2006 peak flow events were ranked fourth, second, and first since Cannonsville Reservoir became operational in 1963. The second ranked flow is now the 2011 event.

## **Spill Mitigation Releases**

Spill mitigation releases, ranging from 149 to 1,508 cfs, were made to the West Branch on 706 days between June 1, 2011 and May 31, 2015 (Table 3).

## **Summer Water Temperatures**

No thermal stress days were reported at any of the 10 West Branch temperature monitoring stations during the 2011-2014 monitoring period (Table 4). The maximum water temperature recorded was 70°F in 2011, 72.3°F in 2012, 66.3°F in 2013, and 67.0°F in 2014. The warmest water temperature generally occurred in the lower reaches of the West Branch except during the period in September of 2011 when extensive spill from Cannonsville Reservoir was occurring due to precipitation associated with two tropical storms. The number of summer (June 1-Sept. 15) days that the West Branch daily maximum water temperature was 70°F or higher totaled one day in 2011, three days in 2012, zero days in 2013, and zero days in 2014.

The longitudinal daily average summer water temperature profiles for the 2011-14 monitoring period at Stilesville, Hale Eddy, and Hancock is illustrated in Figure 2. See

Appendices 1, 2, 3 and 4 for the minima, average, and maxima summer water temperature for each individual temperature monitoring station on the West Branch for the 2011-14 monitoring period. Summer (June 1- Sept. 15) daily average water temperatures were coolest at Stilesville and warmest at Hancock. At Stilesville in 2011, 2012, 2013, and 2014, the highest average summer water temperature recorded was 67.7°F, 48.3°F, 51.4°F and 48.3°F, respectively. The highest summer daily average water temperatures at Hale Eddy was 66.0°F in 2011, 59.3°F in 2012, 60.5°F in 2013, and 58.1°F in 2014. At Hancock in 2011, 2012, 2013, and 2014, the highest daily average summer water temperatures recorded was 65.3°F, 68.2°F, 62.4°F, and 62.7°F, respectively.

During the summer of 2012 & 2014 at Stilesville, the daily average water temperature was less than 50°F for all days. There was nine days in 2011 and one day in 2013 when the daily average summer water temperature at Stilesville was 50°F or higher. The number of days at Hale Eddy where the daily average summer water temperature was above 60°F in 2011, 2012, 2013, and 2014 totaled 6, 0, 1, and 0, respectively. At Hancock, the daily average summer water temperature in 2011, 2012, 2013, and 2014 was 65°F or higher on 2, 9, 0, and 0 days, respectively.

## **Thermal Releases**

Thermal releases were made to the West Branch on two occasions to alleviate thermal stress to trout in the Delaware River. During the summer of 2011, 2012 and 2013, thermal releases were made over a two-three day period each year. Thermal releases ranged from 726 to 1009 cfs in 2011, 579 to 716 cfs in 2012 and 682 to 893 cfs in 2013 (Table 3).

## **UPPER EAST BRANCH**

### **Air Temperature**

The Deposit weather station in 2011, 2012, 2013 and 2014 recorded a maximum air temperature of 96°F, 92°F, 90 °F, and 87 °F, respectively. Temperatures 90°F or higher occurred on ten days in 2011, five days in 2012, four in 2013, and zero days in 2014. The summer (June 1-Sept. 15) of 2012 was the warmest of the four years of FFMP operations summarized. There were 20 days that summer when the air temperature was 85°F or higher compared to 19 days in 2011, 13 days in 2013 and 5 days in 2014. The summer of 2014 was coolest with 48 days when the maximum air temperature was 75°F or lower compared to 46 days in 2013, 28 days in 2012 and 20 days in 2011.

### **Peak Flows**

Peak flows at the USGS gage at Harvard for 2011, 2012, 2013, and 2014 were 17,100, 2,000, 5,220, and 5,470 cfs, respectively. These peak flows were low compared to the peak flow of 20,600, 21,300, and 22,100 cfs recorded in 2004, 2005, and 2006, respectively. The 2004, 2005, and 2006 peak flow events ranked third, second, and first for the 52 year period since 1954.

### **Spill Mitigation Releases**

Spill mitigation releases, ranging from 101 to 718 cfs, were made to the upper East Branch on 720 days between June 1, 2011 and May 31, 2015 (Table 3).

### **Summer Water Temperatures**

No thermal stress days were recorded at any of the seven upper East Branch tailwater temperature monitoring stations during the 2011-14 summer (June 1-Sept 15) monitoring period (Table 4). This is in contrast to the 6, 26, 8 and 0 thermal stress days recorded at Fish's Eddy, which is 4.6 miles downstream of the East Branch temperature monitoring site, on the lower East Branch in 2011, 2012, 2013 and 2014, respectively (Table 4). The maximum summer water

temperature recorded on the Upper East Branch was 73.5°F, 73°F in 2012, 71.8°F in 2013, and 70.4°F in 2014. The number of summer days that the Upper East Branch daily maximum water temperature was 70°F or higher totaled 3 days in 2011, 12 days in 2012, 3 days in 2013, and 2 days in 2014.

The longitudinal daily average summer water temperature profiles for the 2011-14 monitoring period at Downsville, Harvard, East Branch and Fish's Eddy is illustrated in Figure 3. See Appendices 1, 2, 3 and 4 for the daily maxima, average, and minima water temperature for each individual temperature monitoring station on the East Branch for the 2011-14 study period. During most of the summer, average daily summer temperatures (June 1-Sept.15) were coolest at Downsville and warmest at East Branch. However, hurricane Irene and tropical storm Lee turned that profile around in late August to early September with warm water spilling from Pepacton Reservoir. At Downsville in 2011, 2012, 2013, and 2014, the highest average summer daily water temperature recorded was 68.2°F, 51°F, 53.6°F, and 67.8°F, respectively. The highest summer daily average water temperature at Harvard was 67.9°F in 2011, 67.2°F in 2012, 66.2°F in 2013 and 66.4°F in 2014. At the East Branch monitoring station, the highest summer daily average water temperature recorded in 2011, 2012, 2013, and 2014 was 69.9°F, 70.2°F, 69.4°F, and 67.6°F, respectively.

### **Thermal Releases**

No thermal releases were made to the upper East Branch during the FFMP study period.

## **NEVERSINK RIVER**

### **Air Temperature**

The Deposit weather station in 2011, 2012, 2013 and 2014 recorded a maximum air temperature of 96°F, 92°F, 90 °F, and 87 °F, respectively. Temperatures 90°F or higher occurred

on ten days in 2011, five days in 2012, four in 2013, and zero days in 2014. The summer (June 1-Sept. 15) of 2012 was the warmest of the three years that FFMP was in effect. There were 20 days that summer when the air temperature was 85°F or higher compared to 19 days in 2011, 13 days in 2013 and 5 days in 2014. The summer of 2014 was coolest with 48 days when the maximum air temperature was 75°F or lower compared to 46 days in 2013, 28 days in 2012 and 20 in 2011.

### **Peak Flows**

Peak flows at the USGS gage in Bridgeville for 2011, 2012, 2013, and 2014 were 16,800, 4,740, 5,820, and 2,160 cfs, respectively. The peak flow in 2011 is comparable to the record flows of 25,900, 12,500, and 11,100 recorded in 2005, 2006 and 2007. Since the gage was established in 1993, the 2005, 2006, and 2007 peak flows ranked first, second, and third, respectively. The peak flow seen in 2011 will now be ranked second highest.

### **Spill Mitigation Releases**

Spill mitigation releases, ranging from 71 to 198 cfs, were made to the Neversink River on 741 days between June 1, 2011 and May 31, 2015 (Table 3).

### **Water Temperatures**

A total of 7 thermal stress days were recorded at the five Neversink River tailwater temperature monitoring stations during the 2012 summer (June 1-Sept 15) monitoring period (Table 4). Zero thermal stress days were recorded during the 2011, 2013 and 2014 summer. Thermal stress days were recorded at the Fallsburg, Ranch Road bridge and Bridgeville monitoring station in 2012 (Table 4). The maximum water temperatures recorded was 74.8°F in 2011, 77.6°F in 2012, 72.7°F in 2013, and 72.1°F in 2014. The number of summer days that the Neversink River daily maxima water temperature was 70°F or higher totaled 15 days in 2011, 56 days in 2012, 7

days in 2013, and 7 days in 2014.

The longitudinal daily average summer water temperature profiles for the 2011-14 monitoring period at Hasbrouck, Fallsburg, and Bridgeville are illustrated in Figure 4. See Appendices 1, 2, 3 and 4 for the daily maxima, average, and minima water temperature for each individual temperature monitoring station on the Neversink River for the 2011-14 study period. At Hasbrouck in 2011, 2012, 2013, and 2014, the highest daily average summer water temperature recorded was 67.9°F, 59.4°F, 63.2°F, and 67.3°F, respectively. The highest summer daily average water temperature at Fallsburg was 67.7 °F in 2011, 72.8 °F in 2012, 64.2 °F in 2013, and 67.1°F in 2014. At Bridgeville in 2008, 2009, 2010 and 2011, the highest daily average summer water temperature was 71.3°F, 68.3 °F, 67.9°F and 69.6°F, respectively.

### **Thermal Releases**

No thermal releases were made to the Neversink Tailwaters during the FFMP study period.

## **DELAWARE RIVER**

### **Air Temperature**

The Deposit weather station in 2011, 2012, 2013 and 2014 recorded a maximum air temperature of 96°F, 92°F, 90 °F, and 87 °F, respectively. Temperatures 90°F or higher occurred on ten days in 2011, five days in 2012, four in 2013, and zero days in 2014. The summer (June 1-Sept. 15) of 2012 was the warmest of the four years covered by this report. There were 20 days that summer when the air temperature was 85°F or higher compared to 19 days in 2011, 13 days in 2013 and 5 days in 2014. The summer of 2014 was coolest with 48 days when the maximum air temperature was 75°F or lower compared to 46 days in 2013, 28 days in 2012 and 20 in 2011.

### **PEAK FLOWS**

Peak flows at the USGS gage in Callicoon for the 2012, 2013, and 2014 were 30,700,

20,500, and 28,700 cfs, respectively. These peak flows were low compared to the peak flows of 107,000, 114,000, and 144,000 cfs recorded during 2004, 2005, and 2006, respectively. The 2004, 2005, and 2006 peak events ranked third, second, and first since the Callicoon gage was established in 1976.

## **Summer Water Temperatures**

At Lordville (RM 321), there were 3 thermal stress days in 2011, 13 thermal stress days in 2012, 2 in 2013, and 0 in 2014 (Table 4). At Callicoon (RM 303), there were 18 thermal stress days in 2011, 67 in 2012, 13 in 2013, and 5 in 2014 (Table 4). The maximum summer water temperature recorded on the upper Delaware River in 2011, 2012, 2013, and 2014 was 83.8°F, 82.6°F, 82.6°F, and 76.6°F, respectively. The number of summer (June 1-Sept 15), days that the daily maxima water temperature was 70°F or higher was 53 days in 2011, 90 days in 2012, 55 days in 2013, and 66 days in 2014 at Callicoon compare to 17 days in 2011, 71 days in 2012, 13 days in 2013, and 2 days in 2014 at Lordville.

The longitudinal daily average summer water temperature profiles for the 2011-14 monitoring period at Leonards, Abe Lord, and Callicoon are illustrated in Figure 5. See Appendices 1, 2, 3 and 4 for the daily maxima, average, and minima water temperature for each individual temperature monitoring station on the upper Delaware River. Summer daily average water temperatures were coolest at Leonards and warmest at Callicoon. At Leonards in 2011, 2012, 2013, and 2014, the highest average daily summer water temperature was 71.8°F, 74.6°F, 69.5°F, and 67°F, respectively. The highest summer average water temperature at Abe Lord was 75.4°F in 2011, 76.2°F in 2012, 72.6° in 2013, and 70.6°F in 2014. At Callicoon, it was 80.4°F in 2012, 79.5°F in 2012, 79.7°F in 2013, and 73.4°F in 2014. At Leonard's, the average daily water temperature was 70°F or higher for 1 days in 2001, 15 days in 2012 but less than 70°F all

summer in 2013 and 2014. The number of days at Abe Lord where the daily average summer water temperature was 70°F or higher totaled 8 days in 2011, 42 days in 2012, 5 days in 2013, and 1 day in 2014 including 1 day in 2011 and two days in 2012 when the daily average water temperature was 75°F or higher. At Callicoon in 2011, 2012, 2013, and 2014, there were 30, 77, 32, and 27 days when the daily average summer water temperature was 70°F or higher including 6, 30, 6, and 0 days when the average daily water temperature was 75°F or higher.

### **Thermal Releases**

Thermal releases were made to the West Branch on two occasions to alleviate thermal stress to trout in the Delaware River. During the summer of 2012 and 2013, thermal releases were made over a two day period each year. Thermal releases ranged from 386 to 450 cfs in 2012 and 877 to 894 cfs in 2013 (Table 3).

### **Spill Mitigation Releases**

Although spill mitigation releases are not made to the Delaware River, it does benefit from those releases that are made to the upper East Branch and West Branch. Summer spill mitigation releases from the West Branch are most beneficial because of the beneficial impacts to water temperatures. See Table 3 for the seasonal frequency of spill mitigation releases to the West Branch and East Branch.

## **DISCUSSION**

The FFMP is the latest in a sequence of releases programs approved by the Decree Parties over the years. This report covers the first period of time during which the modified FFMP (incorporating the OST and NY-PA habitat protection recommendations) was in effect. Between the 2011 and 2015, the FFMP was renewed annually without significant changes. Therefore, the data reflect the performance of the same releases program under varying

hydrologic conditions. However, the system remained in either L1 (spill mitigation) or L2 (normal operations) for the entire period; the release tables for drought watch were never in effect.

Under normal summer temperatures, the 500-525 cfs summer releases (from release tables 4f-4g) recommended for the West Branch by the NY-PA joint fisheries paper (2010) were sufficient to meet the “good” management objective for the upper mainstem Delaware between Hancock and Lordville as defined in the NY-PA joint fisheries paper. This “good” designation means that opportunities for a coldwater fishery will be maintained. However, elevated water temperatures will occasionally be an issue and the year-round abundance of coldwater species are not expected to be as prevalent as in sections with the “Excellent” protection level such as the West Branch. Summer water temperatures will occasionally exceed a daily maximum of 75°F for short periods and water temperatures greater than 68°F occur more frequently than for sections with “Excellent” protection. It should be noted that the implementation of recommended releases depends on sufficient forecast available water as determined by OST and that, within the range of L2 normal operations, lower estimates of forecast available water result in shifts to lower releases based on tables 4a-4e of the FFMP. Releases were made from these lower tables at times during period covered in this report.

During heat waves 500-525 cfs was insufficient to prevent longer periods where daily maximum water temperatures exceeded 75 degrees at Lordville without further intervention. Figures 6 and 7 show the frequency of summer days that the daily maximum and average water temperature was at least 70°F, 72°F, 75°F, and 80°F at Lordville and Callicoon. It must be pointed out that Cannonsville base releases since 1963 provided minimal thermal benefits to the Delaware River downstream of the confluence of the East and West Branches. Cooling benefits

to the Delaware River only occur when large River Master directed releases are made. Thus it will remain important to distinguish between the influence of directed releases and that of the base releases in evaluating thermal impacts to the mainstem.

The release of available water instead of the retention and management of large “banks” of water is the core premise of the FFMP. However, the experience gained under the FFMP since 2011 suggests that the need to respond to episodes of extraordinary summer heat with a short term pulse of additional cold water will persist if the magnitude and duration of thermally stressful conditions are to be minimized in the reaches managed under the “good” habitat objective. To avoid the difficulties of quickly obtaining unanimous consent of the Decree Parties to address an extraordinary need, the establishment of a small bank of water dedicated to short term relief of thermal stress should be considered.

Despite its inability to maintain suitable summer water temperatures in the upper Delaware River, FFMP was very successful in maintaining suitable summer water temperatures in the West Branch, upper East Branch and Neversink River tailwaters. Average daily summer water temperatures rarely exceeded 70°F and were mostly in the mid to upper 60°F or lower. It was 70°F or higher on the upper East Branch one time in 2012 and 2 in 2010, two times on the Neversink River in 2012 and never on the West Branch. Another indicator for the effectiveness of FFMP was the absence of thermal stress days on the West Branch and upper East Branch throughout this study and for only 7 days in 2012 on the Neversink River (Table 4). In comparison, the number of thermal stress days on the Delaware River ranged from 5 to 67 in 2014 and 2012 with the number of stress days increasing down river (Table 4).

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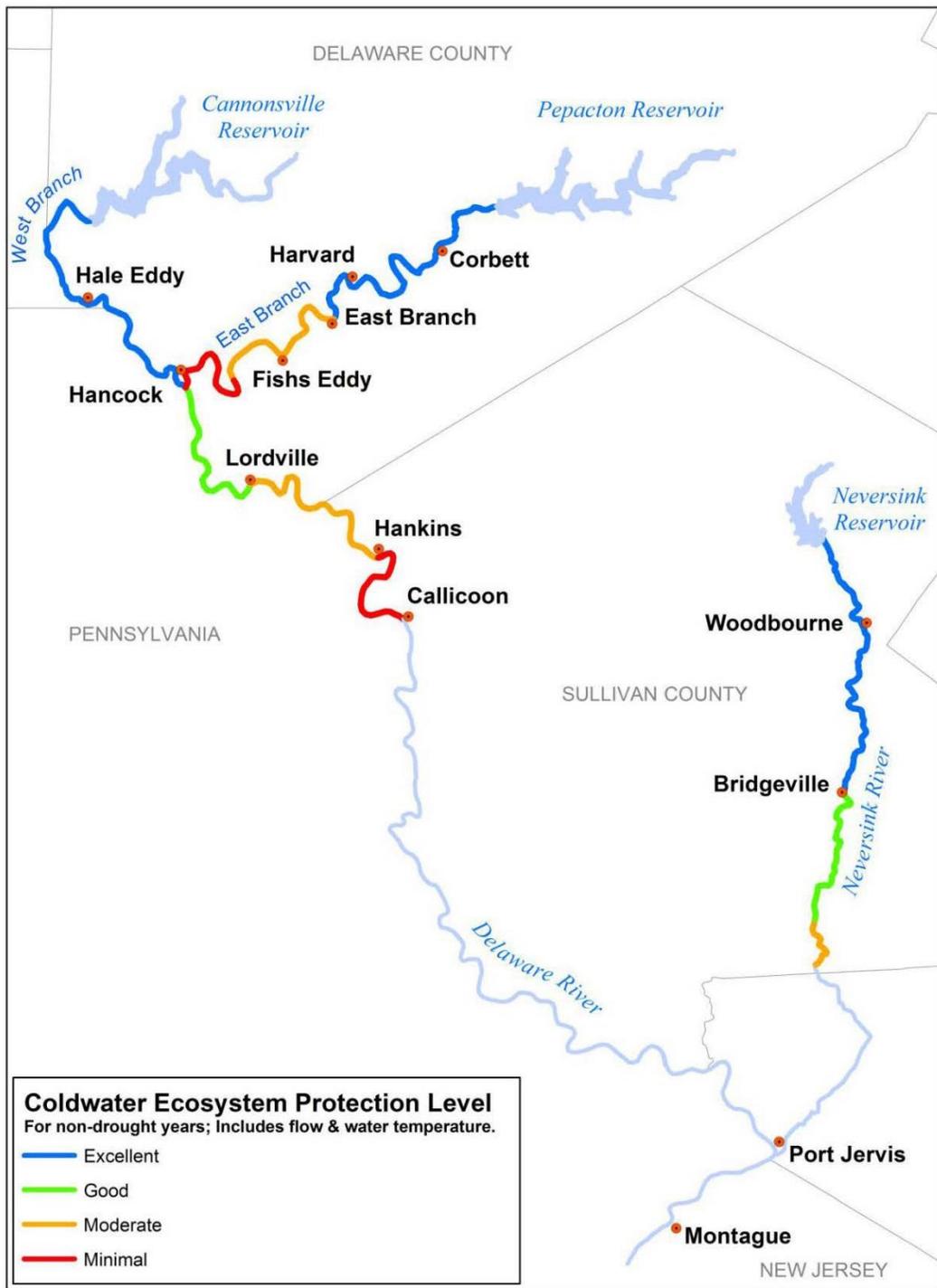
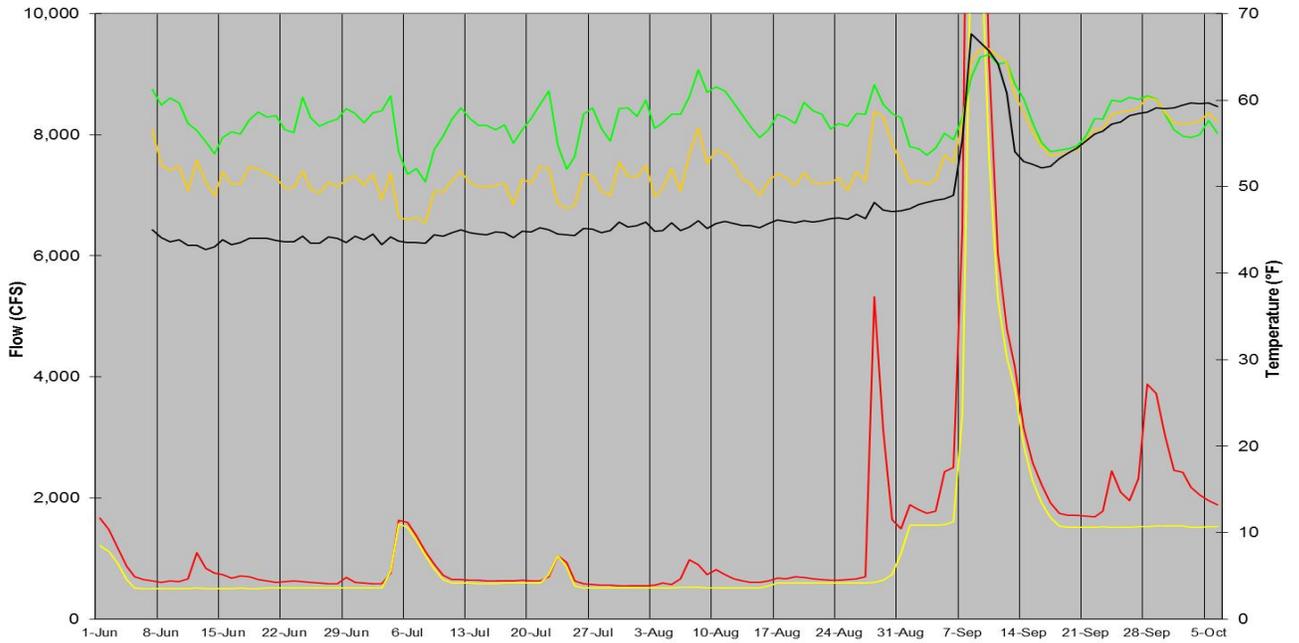


Figure 1: Habitat objectives for the Delaware Tailwaters (NYSDEC & PF&BC, 2010).

2011



2012

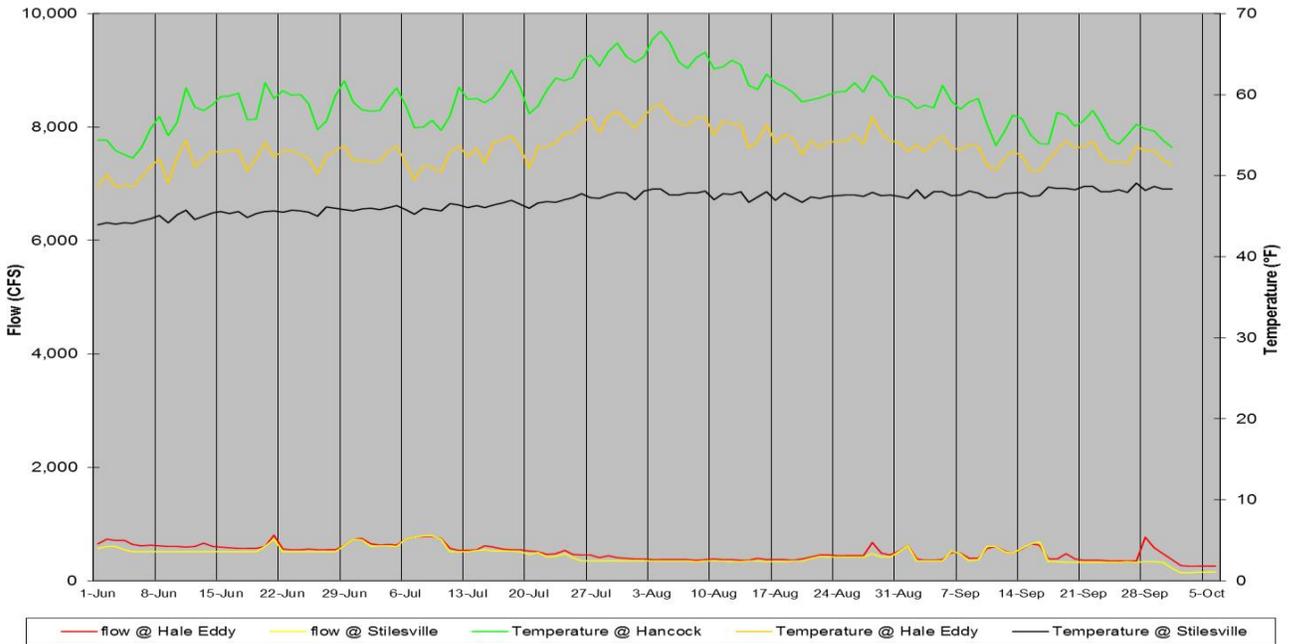
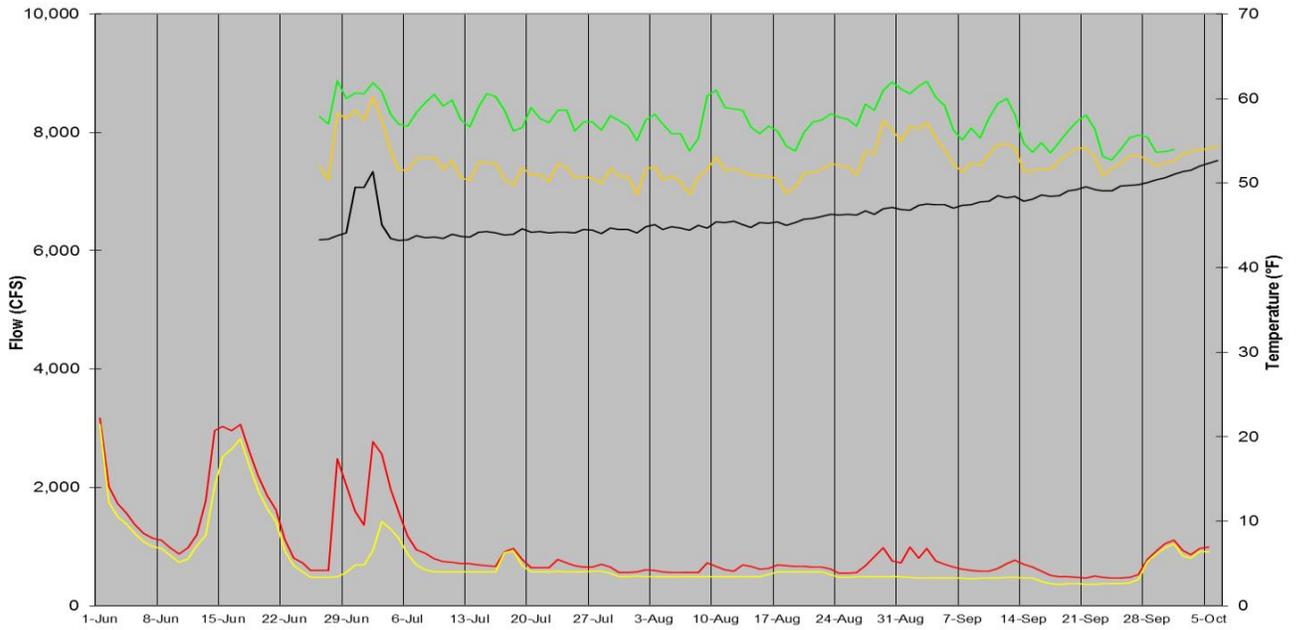


Figure 2: Longitudinal summer daily average water temperature profile on the West Branch at Stilesville, Hale Eddy, and Hancock along with daily average flows at Hale Eddy and Stilesville, 2011-2014.

2013



2014

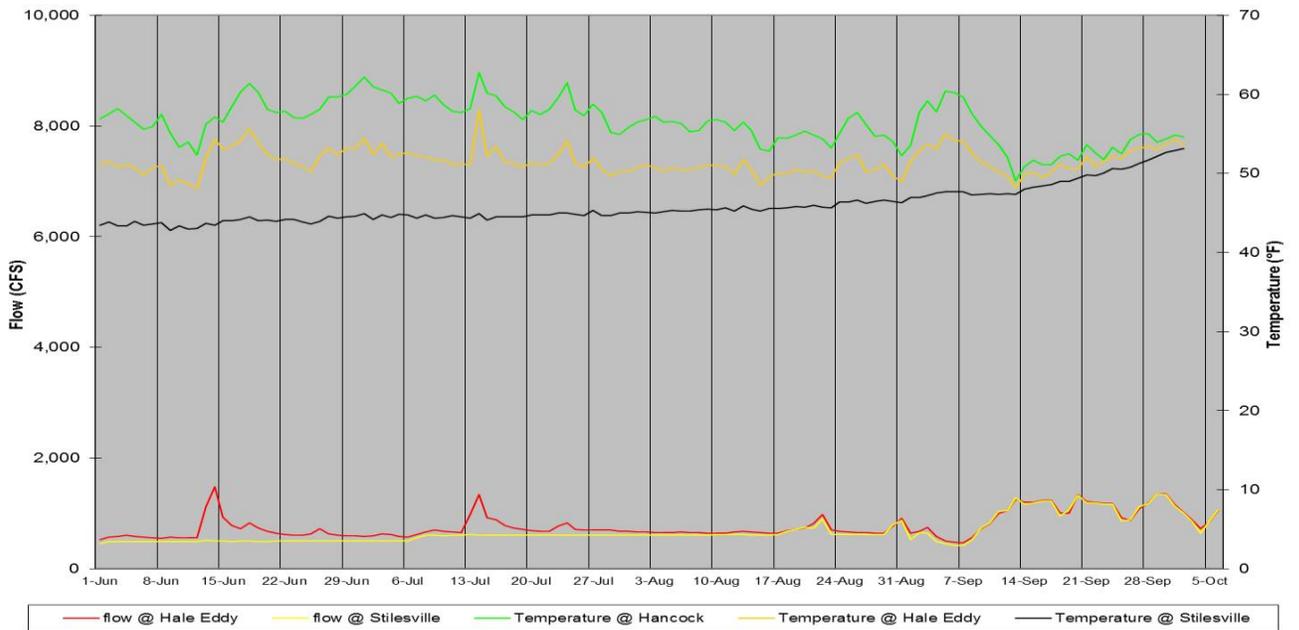


Figure 2 (continued): Longitudinal summer daily average water temperature profile on the West Branch at Stilesville, Hale Eddy, and Hancock along with daily average flows at Hale Eddy and Stilesville, 2011-2014.

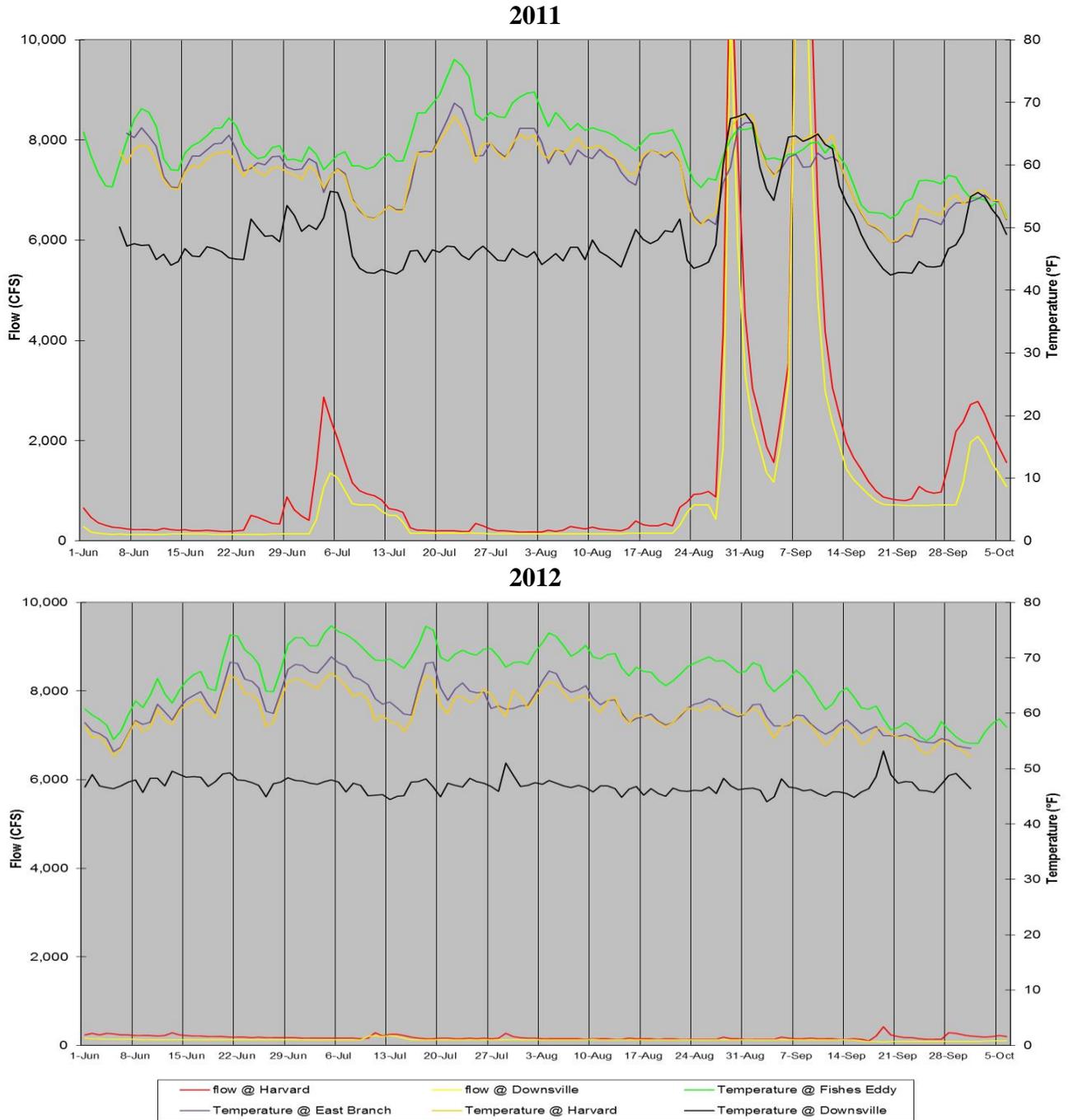


Figure 3: Longitudinal summer daily average water temperature profile on the East Branch at Downsville, Harvard, East Branch, and Fish's Eddy along with daily average flows at Downsville and Harvard, 2011-2014.

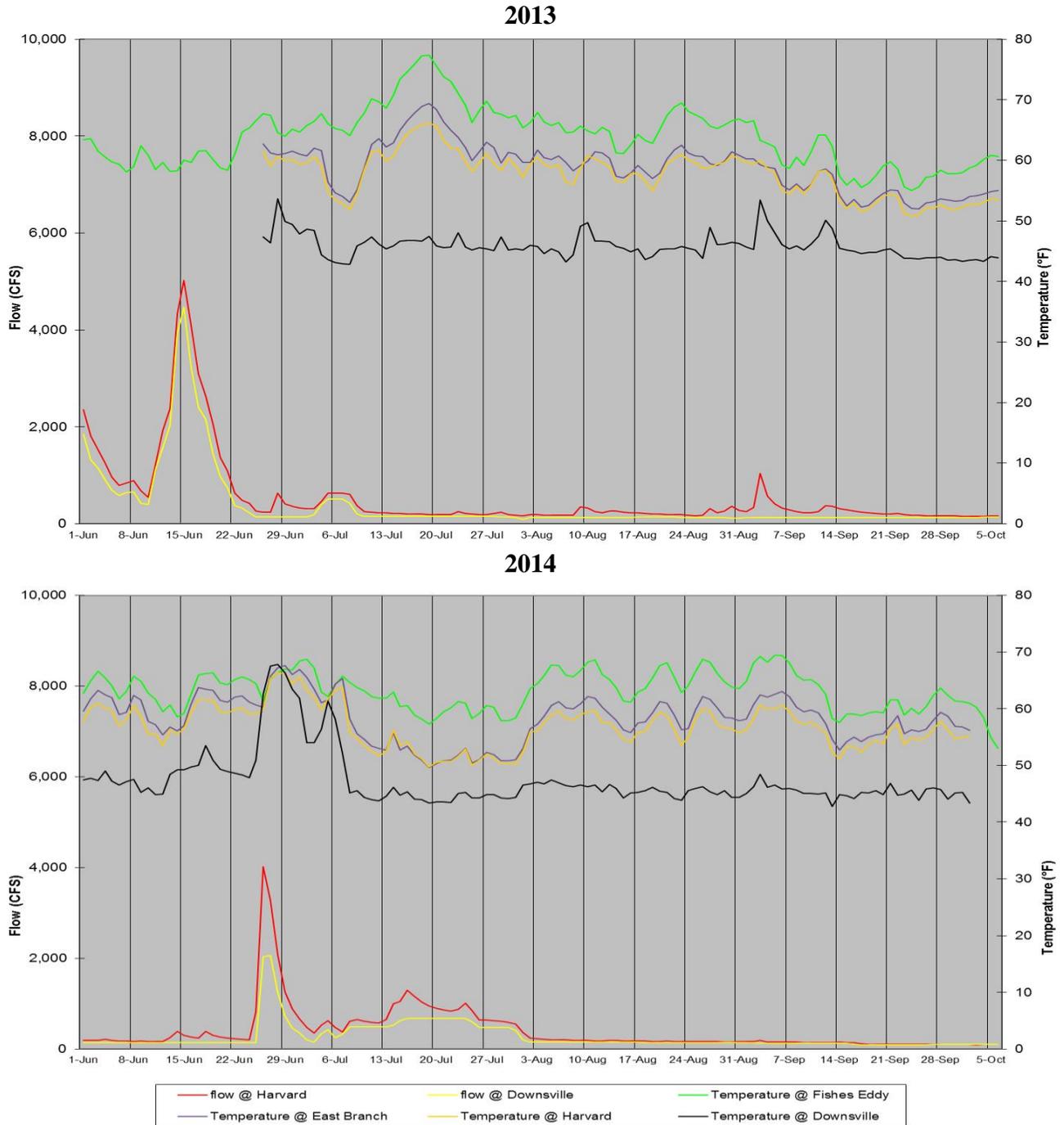


Figure 3(continued): Longitudinal summer daily average water temperature profile on the East Branch at Downsville, Harvard, East Branch, and Fish's Eddy along with daily average flows at Downsville and Harvard, 2011-2014.

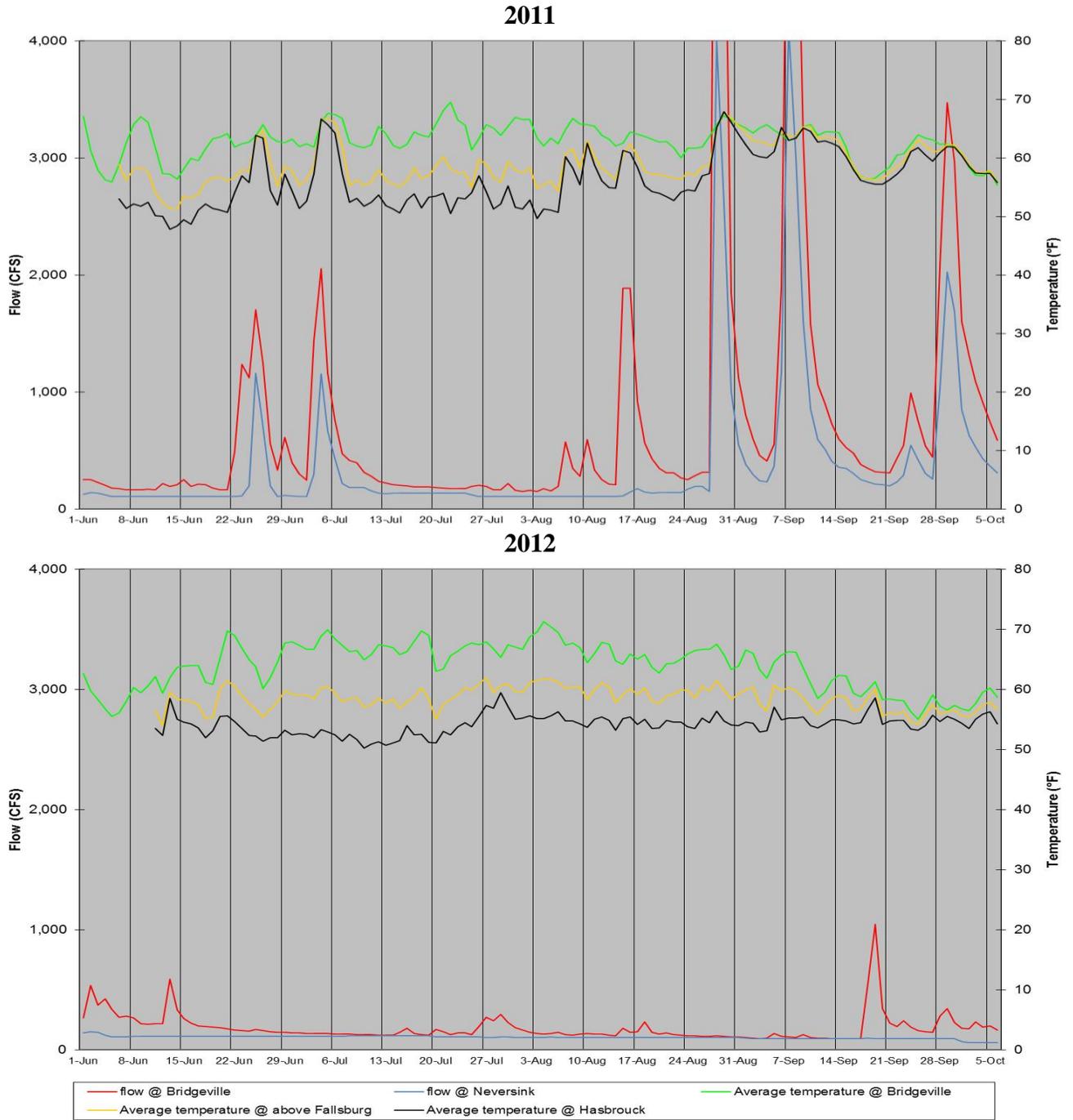


Figure 4: Longitudinal summer average water temperature profile on the Neversink River at Bridgeville, Fallsburg, and Hasbrouck along with daily average flows at Bridgeville and Neversink just below the dam, 2011-2014.

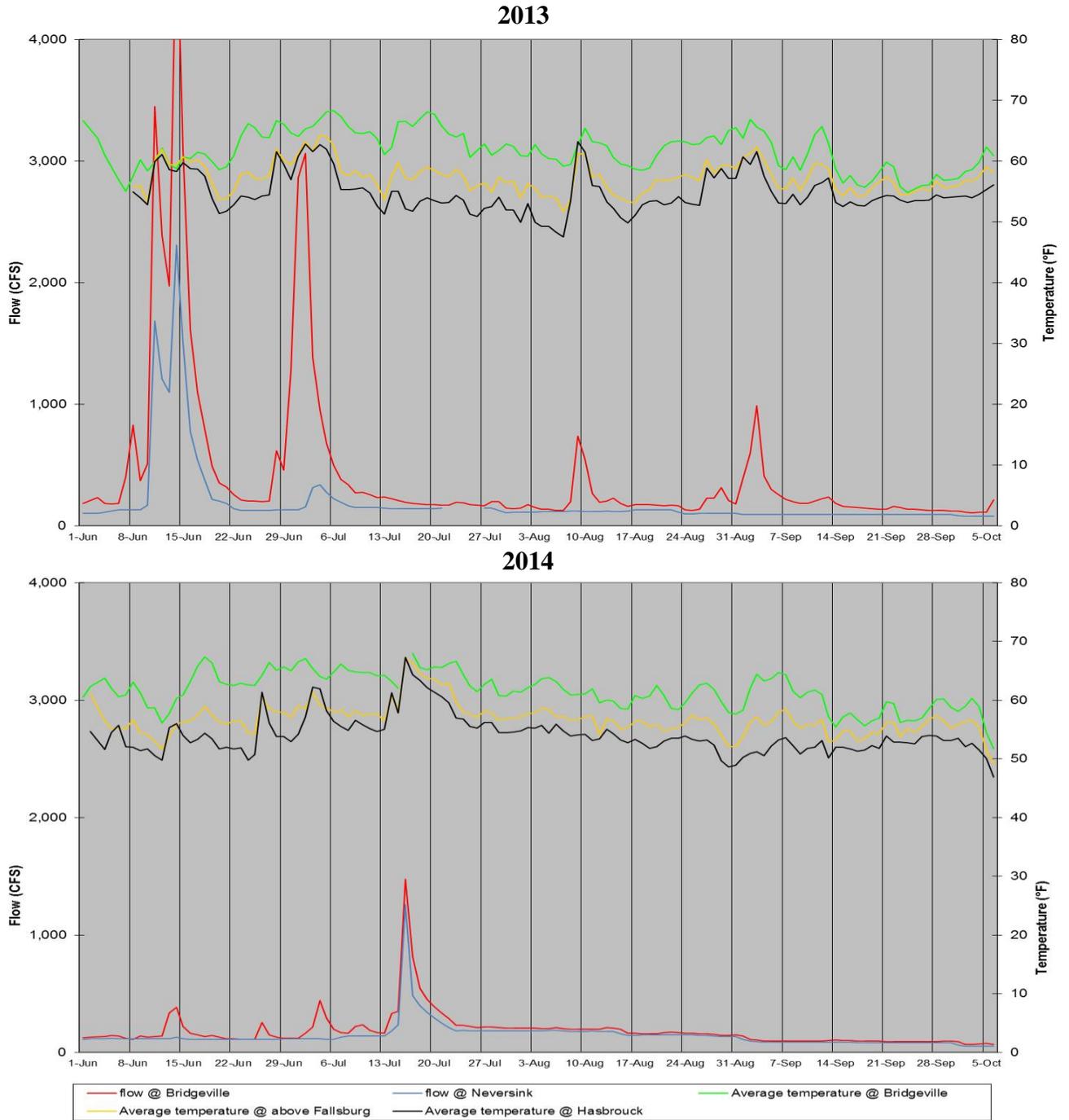


Figure 4 (continued): Longitudinal summer average water temperature profile on the Neversink River at Bridgeville, Fallsburg, and Hasbrouck along with daily average flows at Bridgeville and Neversink just below the dam, 2011-2014.

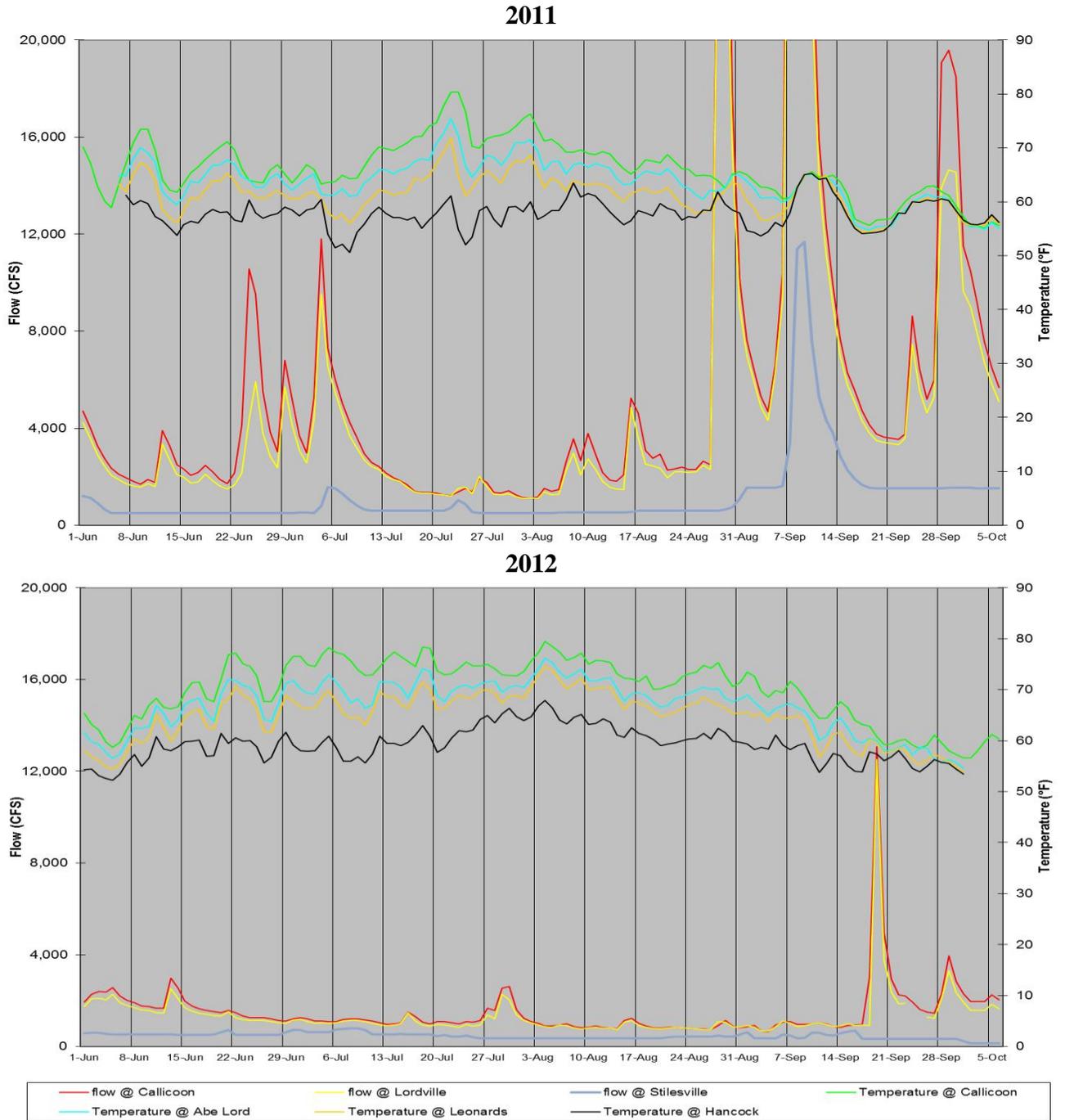


Figure 5: Longitudinal summer daily average temperature profile on the West Branch at Hancock and Leonards Abe Lord, and Callicoon on the Delaware River along with the daily average flows at Stilesville on the West Branch and Lordville and Callicoon on the Delaware River, 2011-2014.

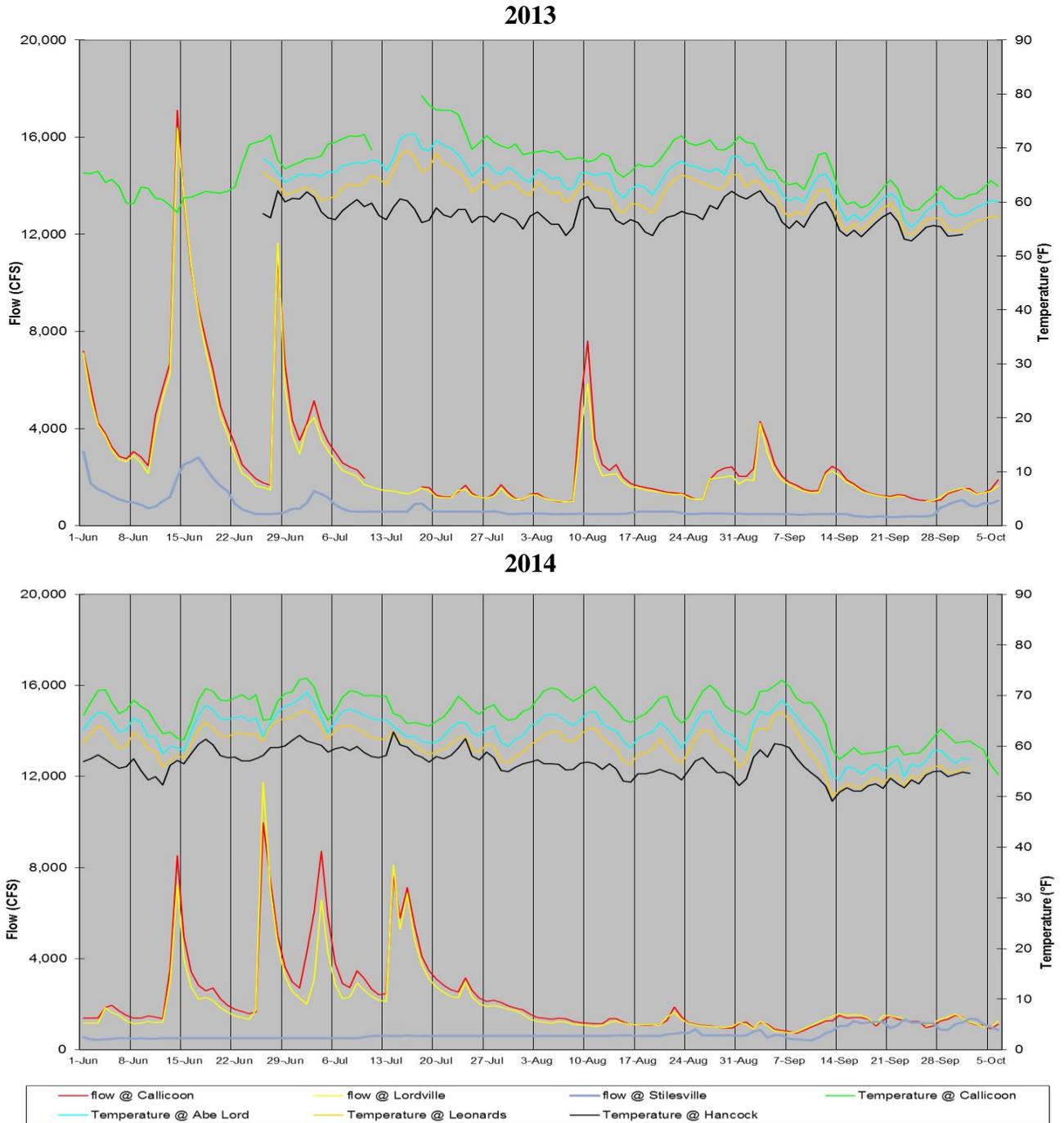


Figure 5 (continued): Longitudinal summer daily average temperature profile on the West Branch at Hancock and Leonards Abe Lord, and Callicoon on the Delaware River along with the daily average flows at Stilesville on the West Branch and Lordville and Callicoon on the Delaware River, 2011-2014.

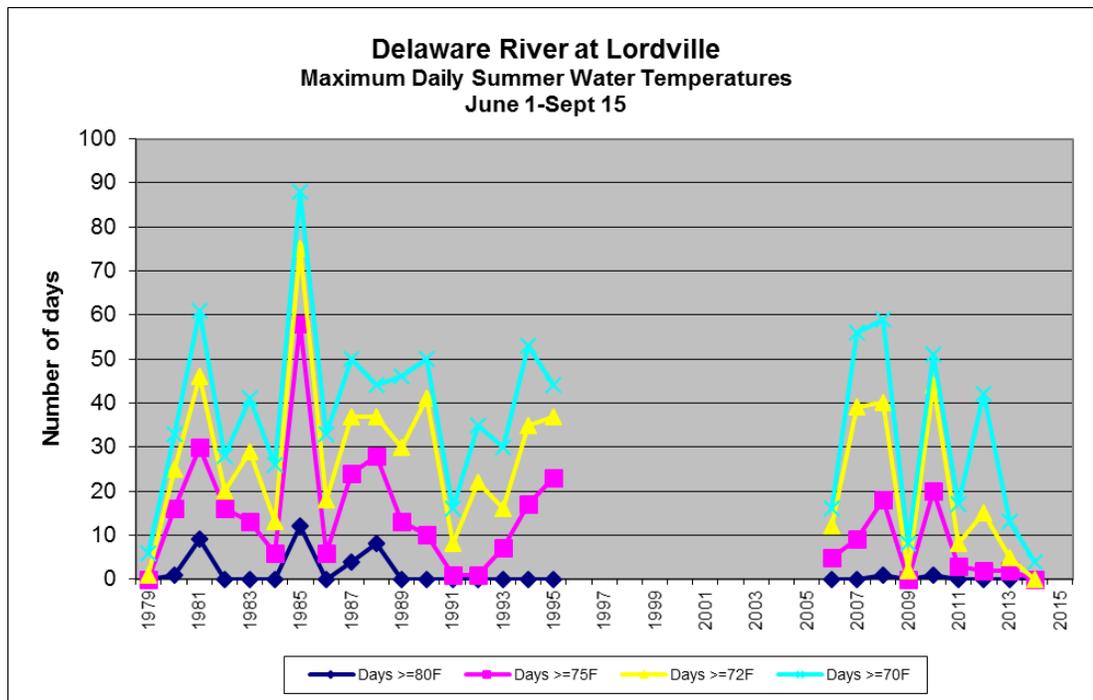
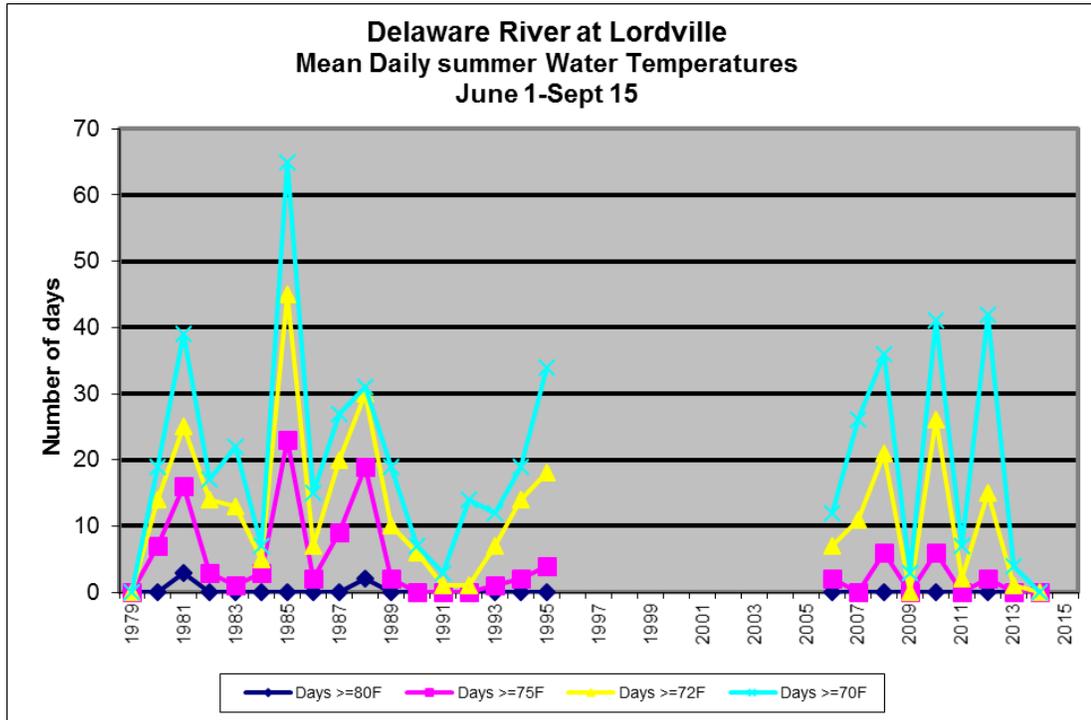


Figure 6: Frequency of average and maximum summer water temperatures for the Delaware River at Lordville, 1979-2014.

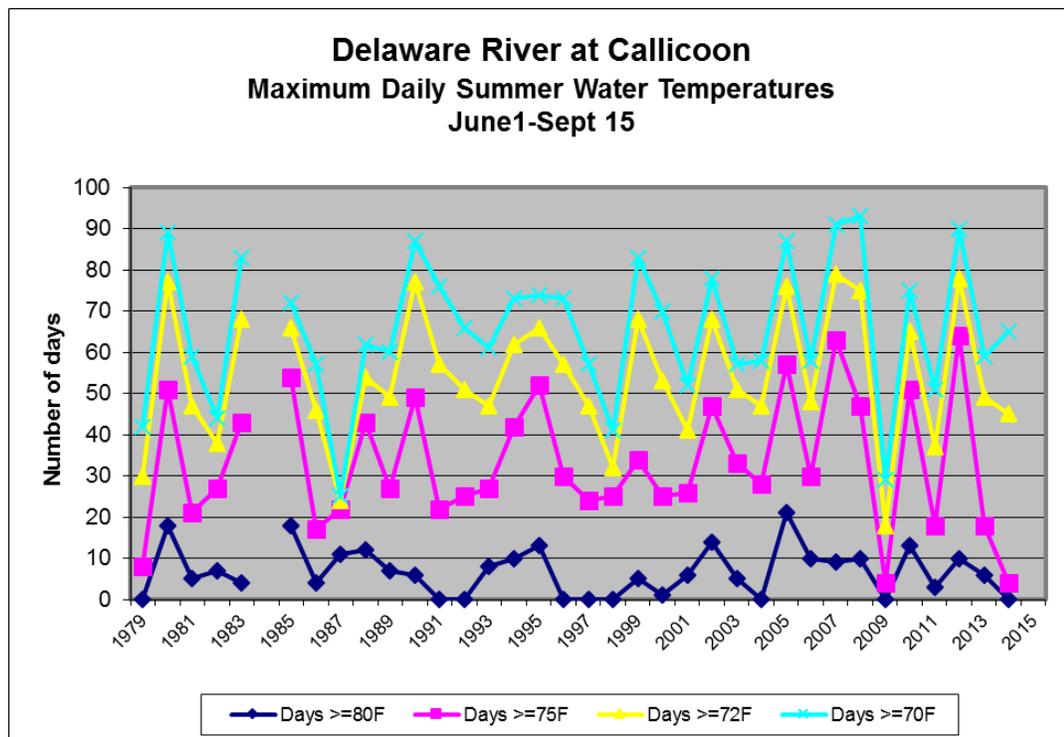
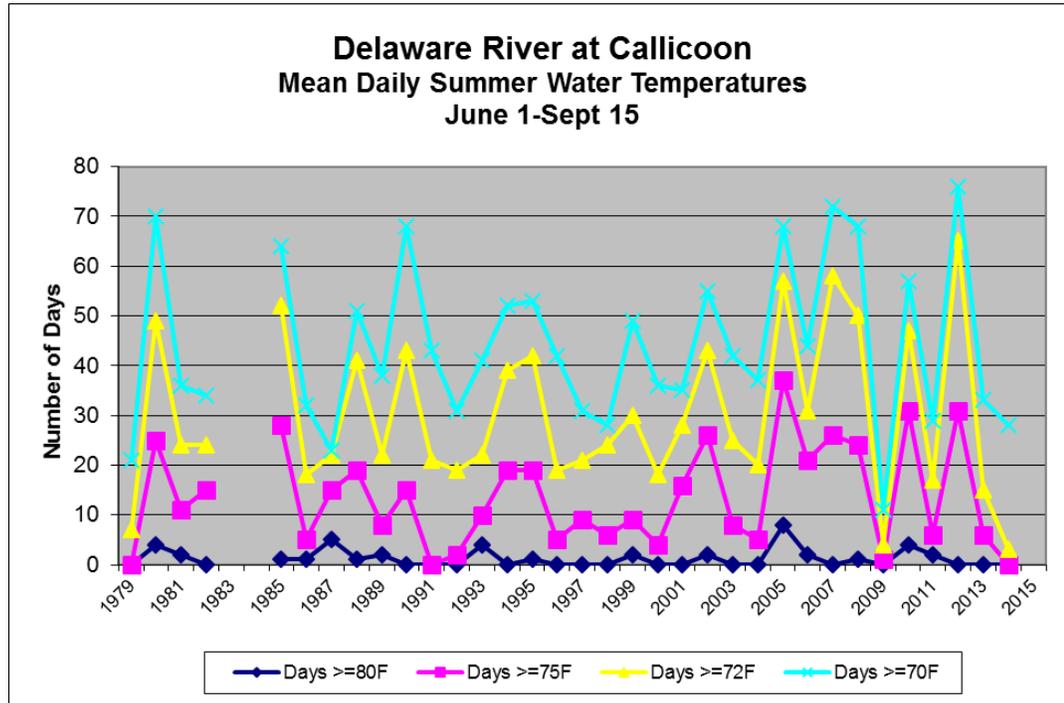


Figure 7: Frequency of average and maximum summer water temperatures for the Delaware River at Callicoon, 1979-2014.

Table 1: Original schedule of FFMP releases (cfs) from Cannonsville, Pepacton, and Neversink Reservoirs with 35 MGD available. Effective date Oct 1, 2007.

Cannonsville Storage Zone	Winter		Spring	Summer			Fall	
	Dec 1 - Mar 31	Apr 1 - Apr 30	May 1 - May 31	Jun 1 - Jun 15	Jun 16 - Jun 30	Jul 1 - Aug 31	Sep 1 - Sep 30	Oct 1 - Nov 30
L1-a	1500	1500	*	*	1500	1500	1500	1500
L1-b	250	*	*	*	*	350	275	250
L1-c	110	110	225	275	275	275	140	110
L2	80	80	215	260	260	260	115	80
L3	70	70	100	175	175	175	95	70
L4	55	55	75	130	130	130	55	60
L5	50	50	50	120	120	120	50	50

Pepacton Storage Zone	Winter		Spring	Summer			Fall	
	Dec 1 - 31-Mar	Apr 1 - 30-Apr	May 1 - 20-May	Jun 1 - 15-Jun	Jun 16 - 30-Jun	Jul 1 - 31-Aug	Sep 1 - 15-Sep	Oct 1 - 30-Nov
L1-a	700	700	*	*	700	700	700	700
L1-b	185	*	*	*	*	250	200	185
L1-c	85	85	120	150	150	150	100	85
L2	65	65	110	140	140	140	85	60
L3	55	55	80	100	100	100	55	55
L4	45	45	50	85	85	85	40	40
L5	40	40	40	80	80	80	30	30

Neversink Storage Zone	Winter		Spring	Summer			Fall	
	Dec 1 - 31-Mar	Apr 1 - 30-Apr	May 1 - 20-May	Jun 1 - 15-Jun	Jun 16 - 30-Jun	Jul 1 - 31-Aug	Sep 1 - 15-Sep	Oct 1 - 30-Nov
L1-a	190	190	*	*	190	190	190	190
L1-b	100	*	*	*	*	125	85	95
L1-c	65	65	90	110	110	110	75	60
L2	45	45	85	100	100	100	70	45
L3	40	40	50	75	75	75	40	40
L4	35	35	40	60	60	60	30	30
L5	30	30	30	55	55	55	25	25

\*Storage zone does not apply during this period. Releases will be made in accordance with zone L1-c.

Table 2: Modified FFMP schedule of releases (cfs) with 35 MGD available from Cannonsville, Pepacton, and Neversink Reservoirs. Effective date June 1, 2011.

Cannonsville Storage Zone	Winter		Spring		Summer			Fall		
	Dec 1 - 31-Mar	Apr 1 - 30-Apr	May 1 - 20-May	May 21 - 31-May	Jun 1 - 15-Jun	Jun 16 - 30-Jun	Jul 1 - 31-Aug	Sep 1 - 15-Sep	Sep 16 - 30-Sep	Oct 1 - 30-Nov
L1-a	1500	1500	*	*	*	1500	1500	1500	1500	1500
L1-b	600	600	*	*	*	*	600	600	600	600
L1-c	175	250	300	375	400	400	400	375	275	175
L2-a	110	175	225	300	325	325	325	300	210	110
L2-b	90	115	175	250	275	275	275	250	150	90

Pepacton Storage Zone	Winter		Spring		Summer			Fall		
	Dec 1 - 31-Mar	Apr 1 - 30-Apr	May 1 - 20-May	May 21 - 31-May	Jun 1 - 15-Jun	Jun 16 - 30-Jun	Jul 1 - 31-Aug	Sep 1 - 15-Sep	Sep 16 - 30-Sep	Oct 1 - 30-Nov
L1-a	700	700	*	*	*	700	700	700	700	700
L1-b	300	300	*	*	*	*	300	300	300	300
L1-c	100	100	110	130	150	150	150	150	125	100
L2	70	70	90	125	140	140	140	125	90	70

Neversink Storage Zone	Winter		Spring		Summer			Fall		
	Dec 1 - 31-Mar	Apr 1 - 30-Apr	May 1 - 20-May	May 21 - 31-May	Jun 1 - 15-Jun	Jun 16 - 30-Jun	Jul 1 - 31-Aug	Sep 1 - 15-Sep	Sep 16 - 30-Sep	Oct 1 - 30-Nov
L1-a	190	190	*	*	*	190	190	190	190	190
L1-b	125	110	*	*	*	*	150	150	150	125
L1-c	75	75	100	100	125	125	125	100	100	75
L2	50	50	70	90	100	100	100	90	75	50

\*Storage zone does not apply during this period. Releases will be made in accordance with zone L1-c.

Table 3: Summary of FFMP thermal mitigation, directed, and spill mitigation releases (CFS) from Cannonsville, Pepacton, and Neversink Reservoirs, 2011-14.

			Thermal Releases				Directed Releases				Spill Mitigation Releases			
			Days	Min	Max	Average	Days	Min	Max	Average	Days	Min	Max	Average
			Made	Release	Release		Made	Release	Release		Made	Release	Release	
<b>Cannonsville Reservoir</b>														
2011	Summer	June									3	0	599	591
2011	Summer	July	3	726	1009	854					21	0	1494	791
2011	Summer	August									16	0	1306	650
2011	Fall	September									26	0	1502	1453
2011	Fall	October									31	223	1508	920
2011	Fall	November									30	223	614	238
2011	Winter	December									31	699	1504	1078
2012	Winter	January									31	226	1497	577
2012	Winter	February									29	224	1501	490
2012	Spring	March									31	176	227	196
2012	Spring	April					1	317	317	317	1	175	175	175
2012	Spring	May									7	517	526	524
2012	Summer	June	2	579	716	648	2	650	712	681	3	596	596	596
2012	Summer	July					24	402	753	555				
2012	Summer	August					5	398	535	444				
2012	Fall	September					12	387	617	507				
2012	Fall	October												
2012	Fall	November									30	149	231	215
2012	Winter	December									16	218	231	227
2013	Winter	January									31	223	227	224
2013	Winter	February									28	224	699	401
2013	Spring	March									31	213	704	444
2013	Spring	April												
2013	Spring	May									3	248	654	384
2013	Summer	June									24	278	1499	783
2013	Summer	July	3	682	893	817					26	520	1204	673
2013	Summer	August									8	511	602	588
2013	Fall	September					5	415	989	724	25	371	480	436
2013	Fall	October					29	260	948	558	2	224	226	225
2013	Fall	November					14	167	712	373				
2013	Winter	December									23	212	227	224
2014	Winter	January									31	224	1507	1120
2014	Winter	February									31	224	879	563
2014	Spring	March									15	207	927	705
2014	Spring	April									25	480	1508	1282
2014	Spring	May									14	469	526	507
2014	Summer	June												
2014	Summer	July									25	597	608	600
2014	Summer	August					9	620	794	707	22	597	605	600
2014	Fall	September									30	402	1321	922
2014	Fall	October					20	158	1199	798				
2014	Fall	November					25	187	1109	685				
2014	Winter	December												
2015	Winter	January												
2015	Winter	February												
2015	Spring	March												
2015	Spring	April												
2015	Spring	May									6	155	330	224





Table 4: Thermal Stress Days\*and maximum water temperatures recorded at monitoring sites on the Delaware River, West Branch, East Branch, and Neversink River Tailwaters, 2011-2014.

Station	miles below dam	2011		2012		2013		2014	
		Days	Max Temp						
<b>Mainstem Delaware</b>									
Leonards	21.1	0	74.5	4	78.0	0	72.5	0	70.4
USGS @ Lordville	27.5	3	78.3	13	78.8	2	75.2	0	70.5
Abe Lord	28.7	3	79.2	18	79.4	3	75.9	0	72.5
Kellams Bridge	36.6	5	80.1	34	80.5	7	78.1	0	72.9
USGS @ Callicoon	46.2	18	83.8	67	82.6	13	82.6	5	76.6
<b>West Br Delaware</b>									
USGS @ Stilesville	1.4	0	70.0	0	54.1	0	66.4	0	61.7
Stilesville	1.7	0	68.0	0	52.5	0	56.0	0	53.9
Men's Club	4.7	0	67.0	0	64.9	0	61.5	0	59.4
Hale Eddy near USGS	8.6	0	67.0	0	65.6	0	64.9	0	62.2
USGS @ Hale Eddy	8.6	0	68.4	0	64.8	0	64.9	0	61.9
Roods Ck	10.3	0	67.0	0	66.3	0	64.9	0	63.5
Balls Eddy	13.6	0	67.0	0	69.0	0	64.9	0	64.2
Hancock near USGS	17.0	0	67.0	0	71.8	0	65.6	0	66.3
USGS @ Hancock	17.0	0	70.0	0	72.3	0	65.8	0	66.6
Shehawken	17.9	0	67.0	0	71.8	0	66.3	0	67.0
<b>East Br Delaware</b>									
Downsville	2.2	0	69.7	0	59.4	0	62.9	0	70.4
Shinhopple	8.2	0	69.7	0	62.9	0	60.8	0	70.4
Terry's Campsite	11.0	0	69.7	0	68.3	0	67.0	0	70.4
Deutch's Flat	12.4	0	69.7	0	70.4	0	68.3	0	70.4
Harvard near USGS	14.3	0	73.5	0	72.5	0	71.1	0	69.0
USGS @ Harvard	14.3	0	72.7	0	73.0	0	71.4	0	69.8
EastBranch	17.0	0	72.6	0	72.5	0	71.8	0	69.7
USGS @ Fishes Eddy	21.6	6	81.3	26	79.9	8	81.7	0	73.4
Hancock(Fireman's Park)	31.2	15	84.9	54	83.0	14	84.4	5	75.9
<b>Neversink</b>									
Hasbrouck	2.8	0	70.2	0	62.5	0	66.4	0	69.7
Woodbourne	6.0	0	70.2	0	63.2	0	66.9	0	70.5
Just abv Fallsburg	8.4	0	69.8	2	75.6	0	68.3	0	71.4
Ranch Rd. bridge	11.9	0	70.6	2	77.6	0	69.6	0	71.6
USGS @ Bridgeville	16.2	0	74.8	3	76.8	0	72.7	0	72.1

\*Stress days are defined as any day the highest water temperature at the site was equal to or greater than 75F or the average temperature was equal to or greater than 72F over a 24 h period. In most cases, both events were true.

Table 5: Annual count of thermal stress days at selected USGS Gages representative of habitat protection program protection levels under FFMP 2011-2014.

<b>Gage</b>	<b>FFMP Protection Level</b>	<b>2011</b>	<b>Max Consecutive</b>	<b>2012</b>	<b>Max Consecutive</b>	<b>2013</b>	<b>Max Consecutive</b>	<b>2014</b>	<b>Max Consecutive</b>
<b>Harvard</b>	Excellent	0	-	0	-	0	-	0	-
<b>Hancock</b>	Excellent/Good	0	-	0	-	0	-	0	-
<b>Bridgeville</b>	Excellent/Good	0	-	3	-	0	-	0	-
<b>Lordville</b>	Good/Moderate	3	3	13	8	2	2	0	-
<b>Callicoon</b>	Minimal	18	6	67	32	13	6	5	2

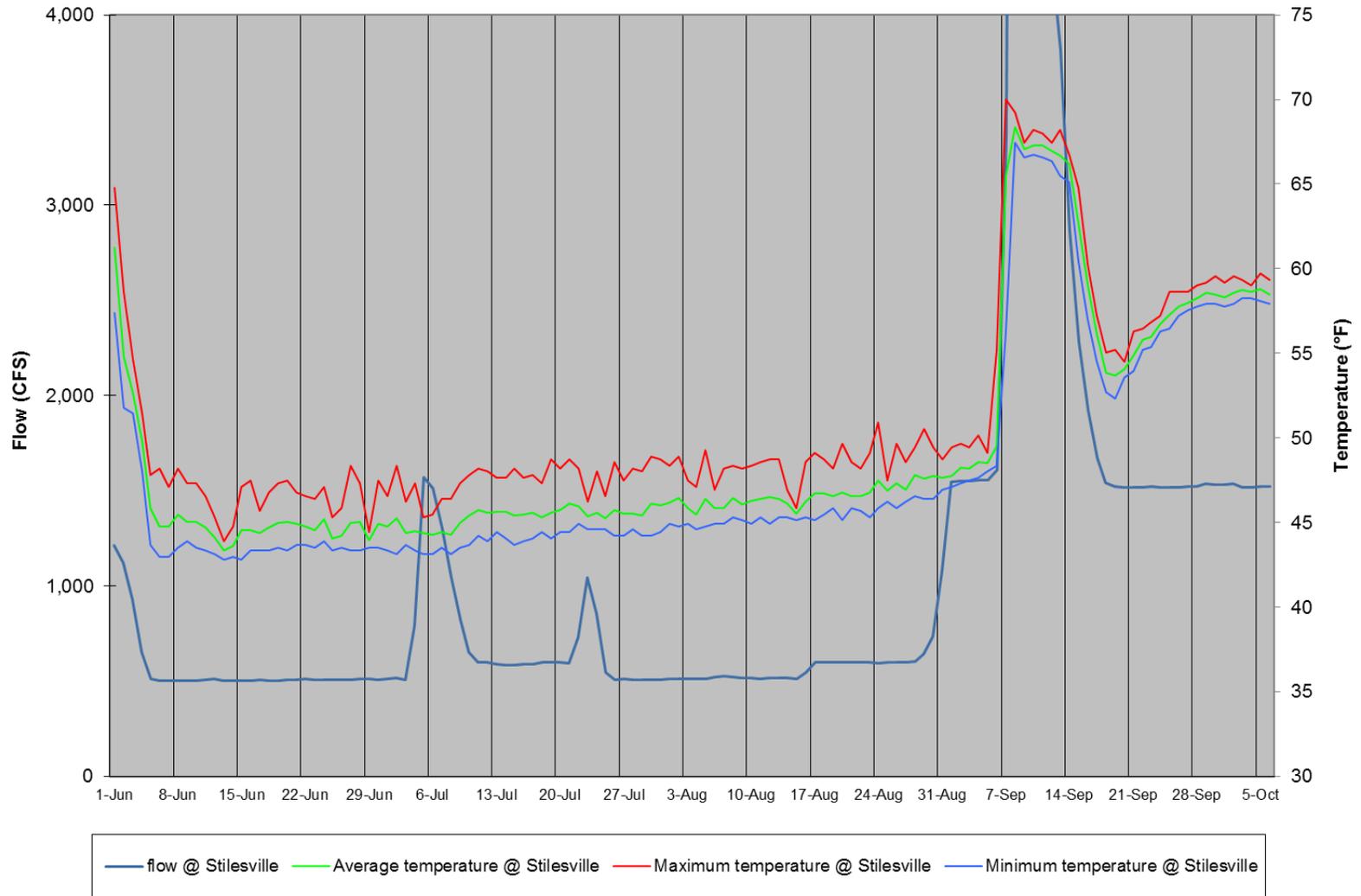
## Appendix 1:

### UPPER DELAWARE TAILWATERS

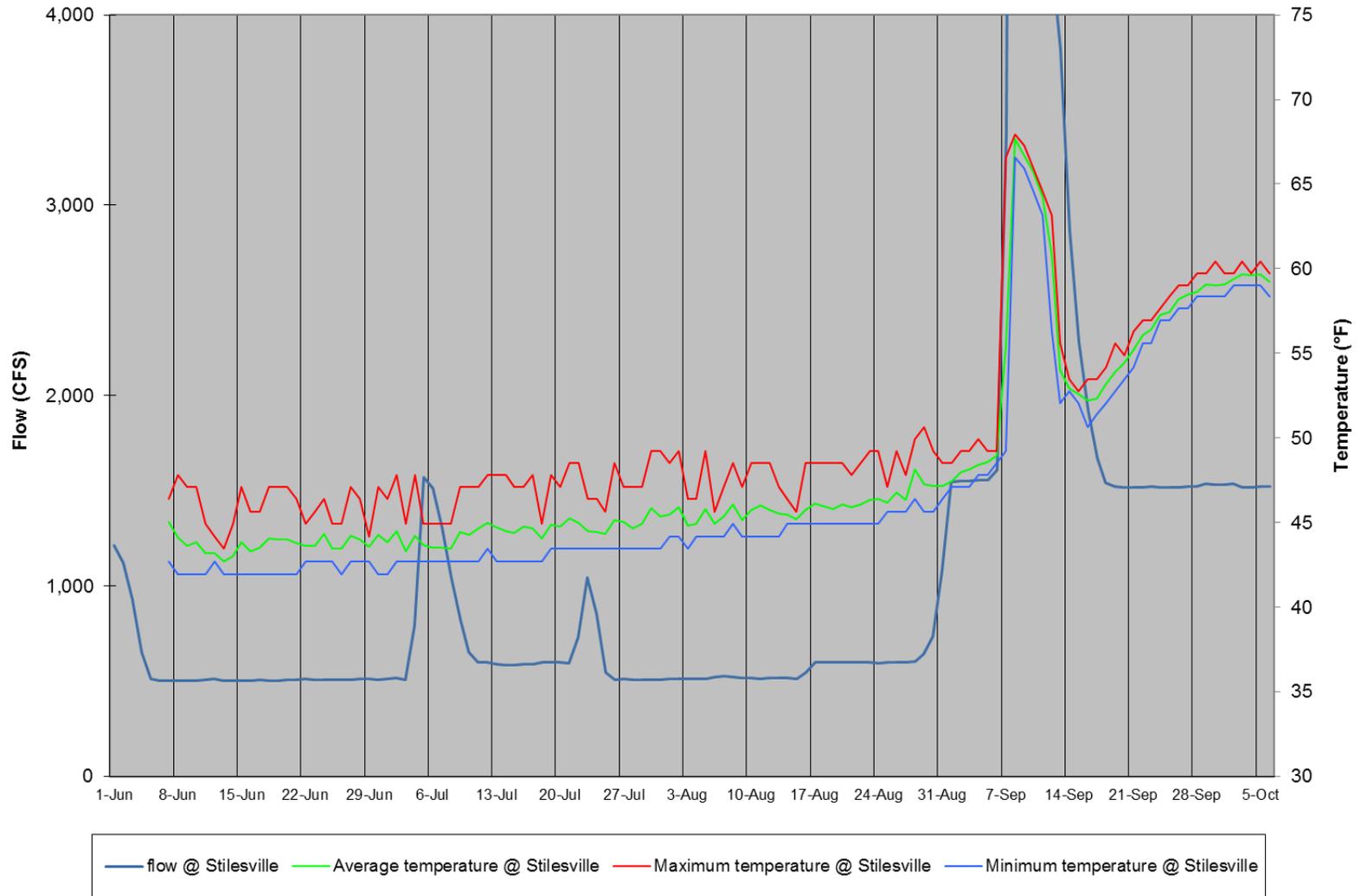
Maxima, minima, and average summer water temperature profile for each temperature monitoring site, 2011

West Branch: Appendices 1A to 1J East Branch: Appendices 1K to 1S Neversink River:  
Appendices 1T to 1X  
Delaware River: Appendices 1Y to 1CC

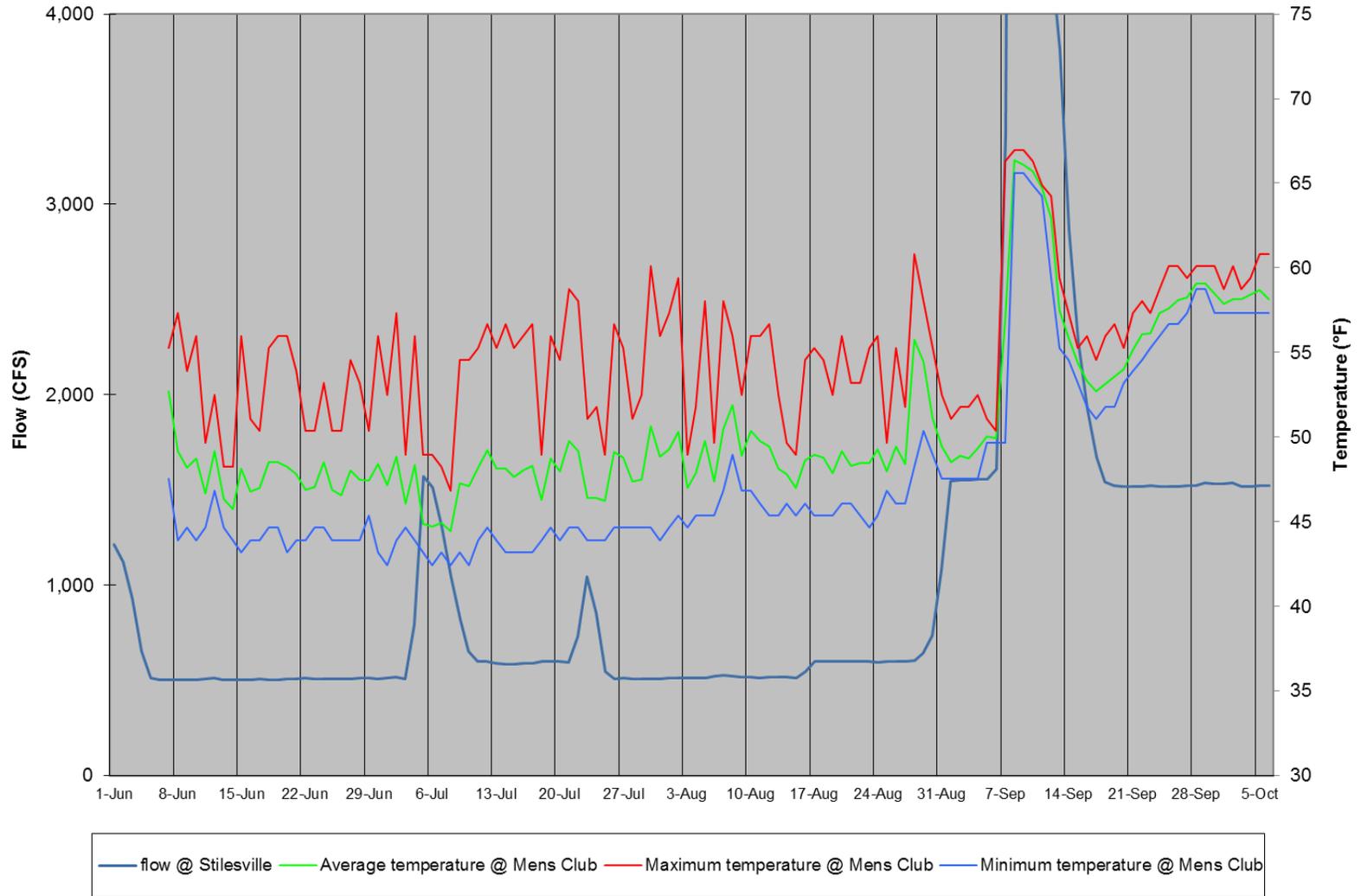
**Appendix 1A. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Stilesville, along with daily average flows at Stilesville, 2011.**



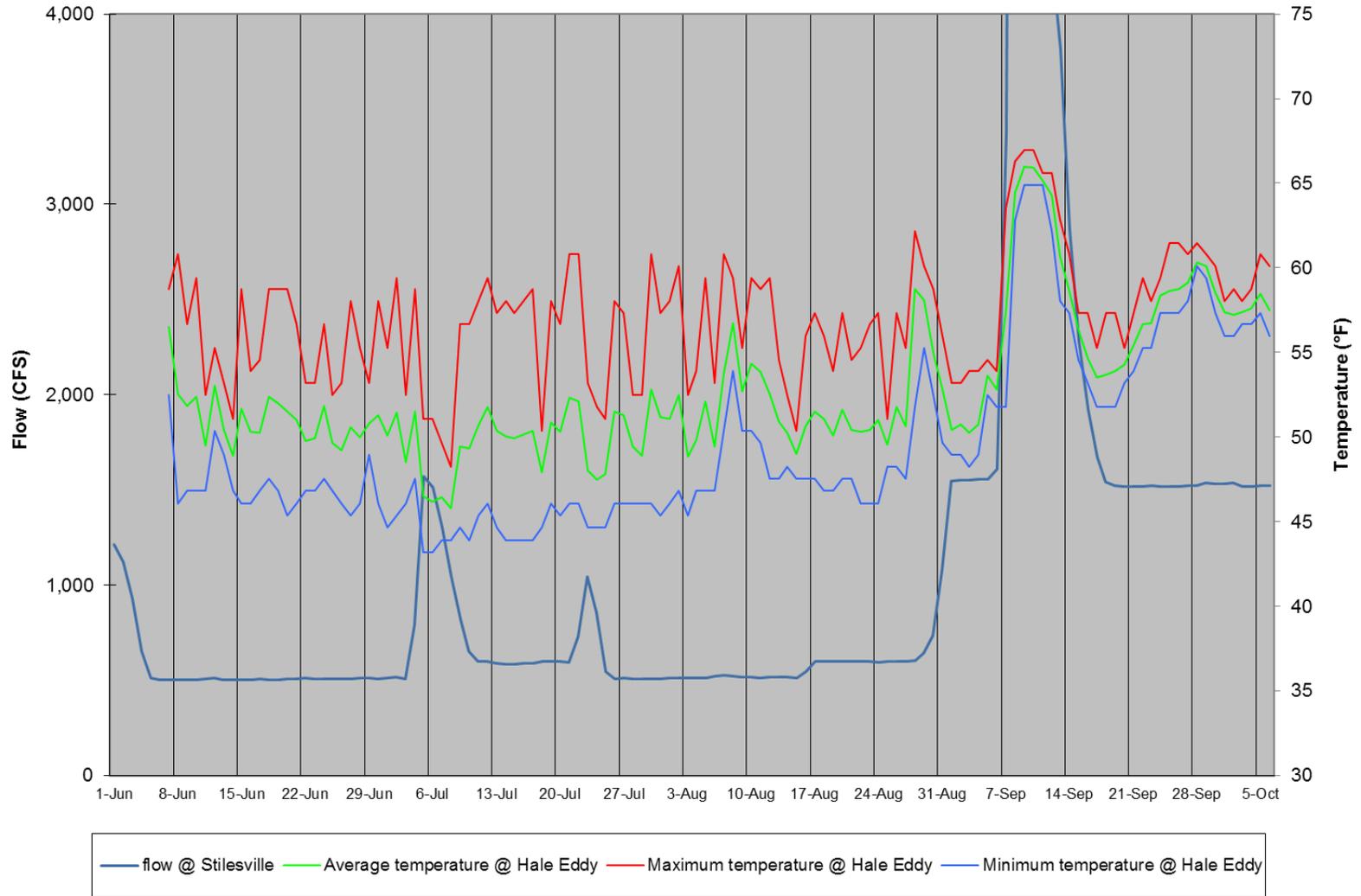
**Appendix 1B. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Stilesville, along with daily average flows at Stilesville, 2011.**



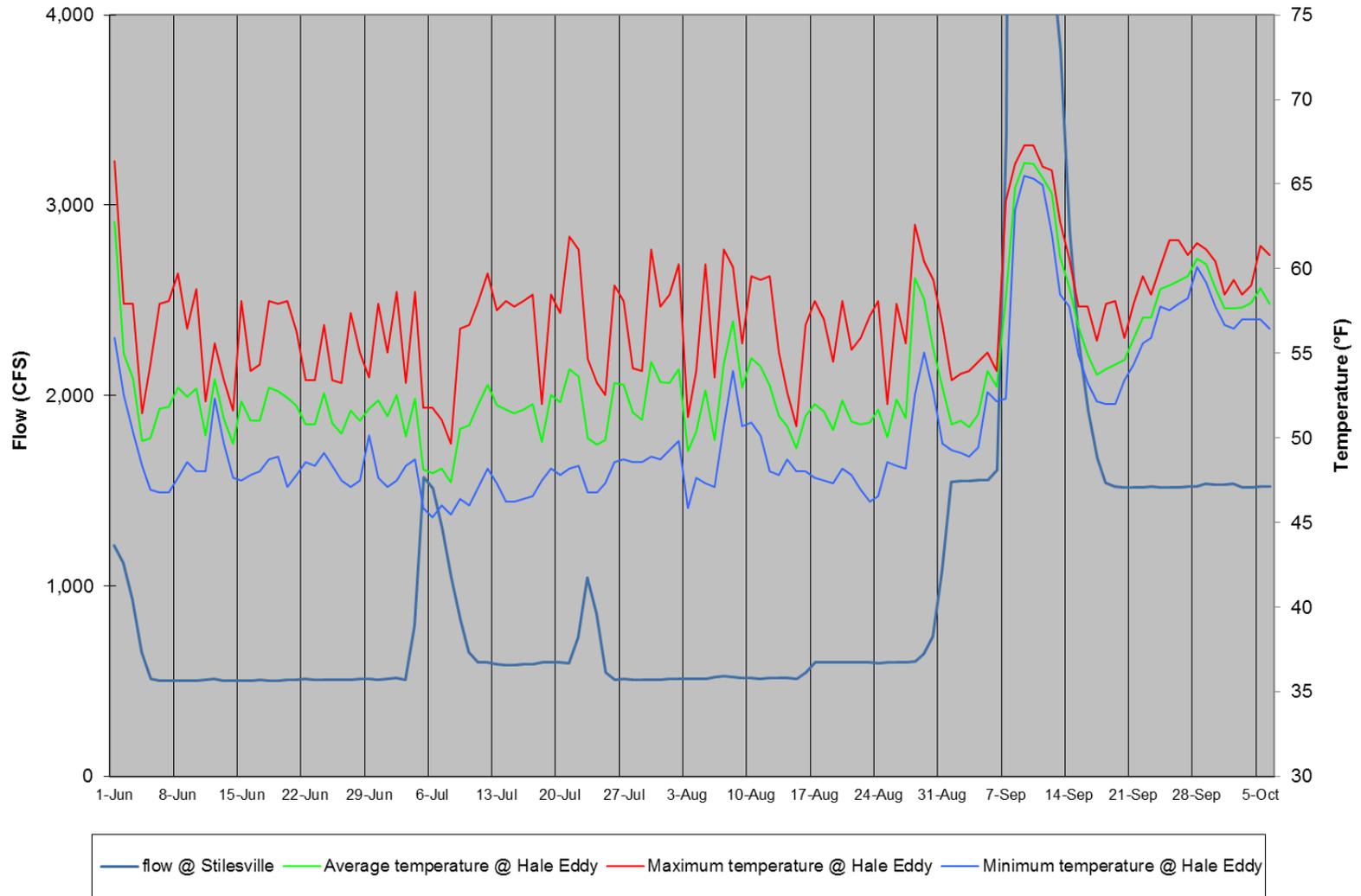
**Appendix 1C. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Men's Club, along with daily average flows at Stilesville, 2011.**



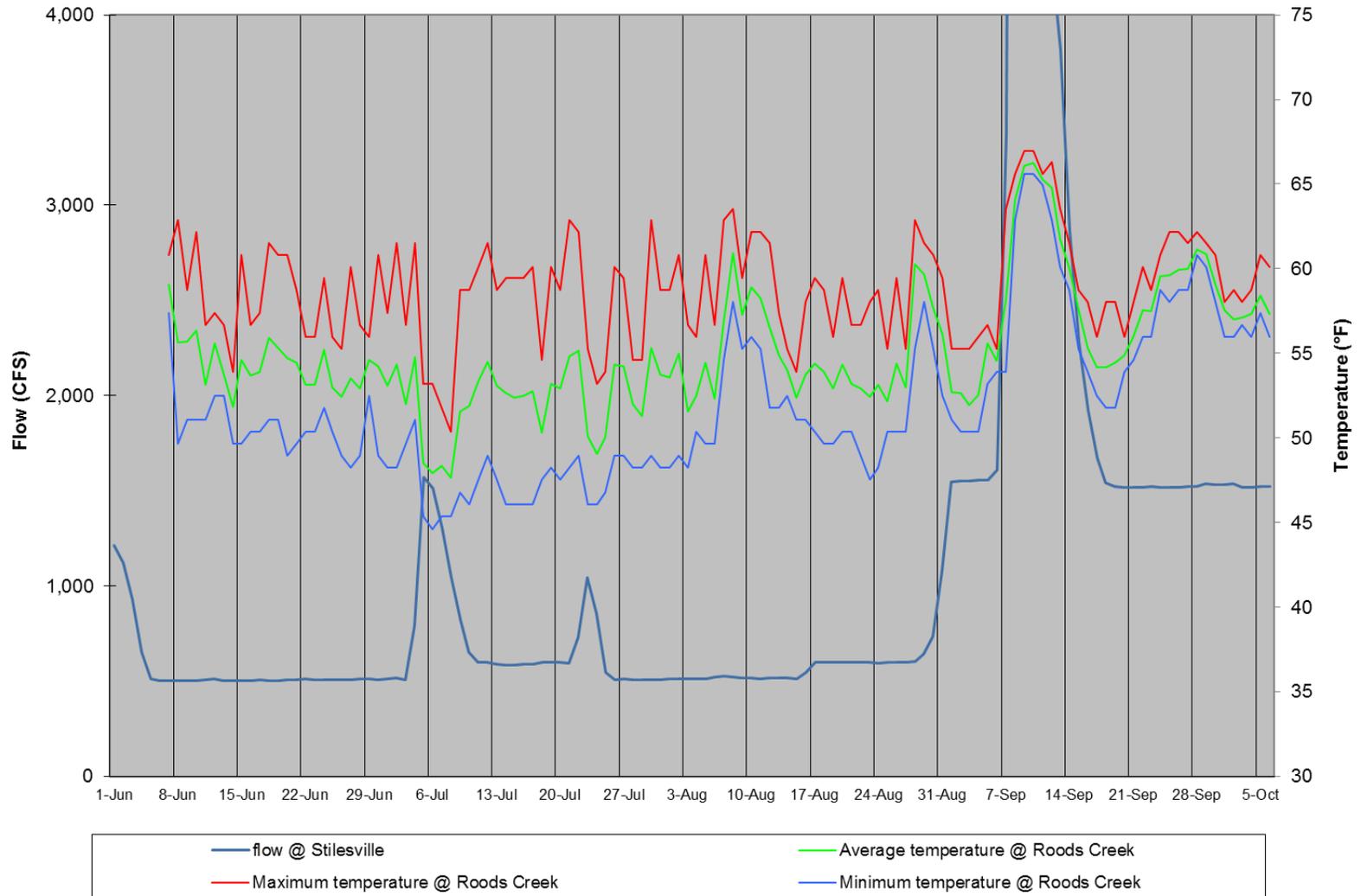
Appendix 1D. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2011.



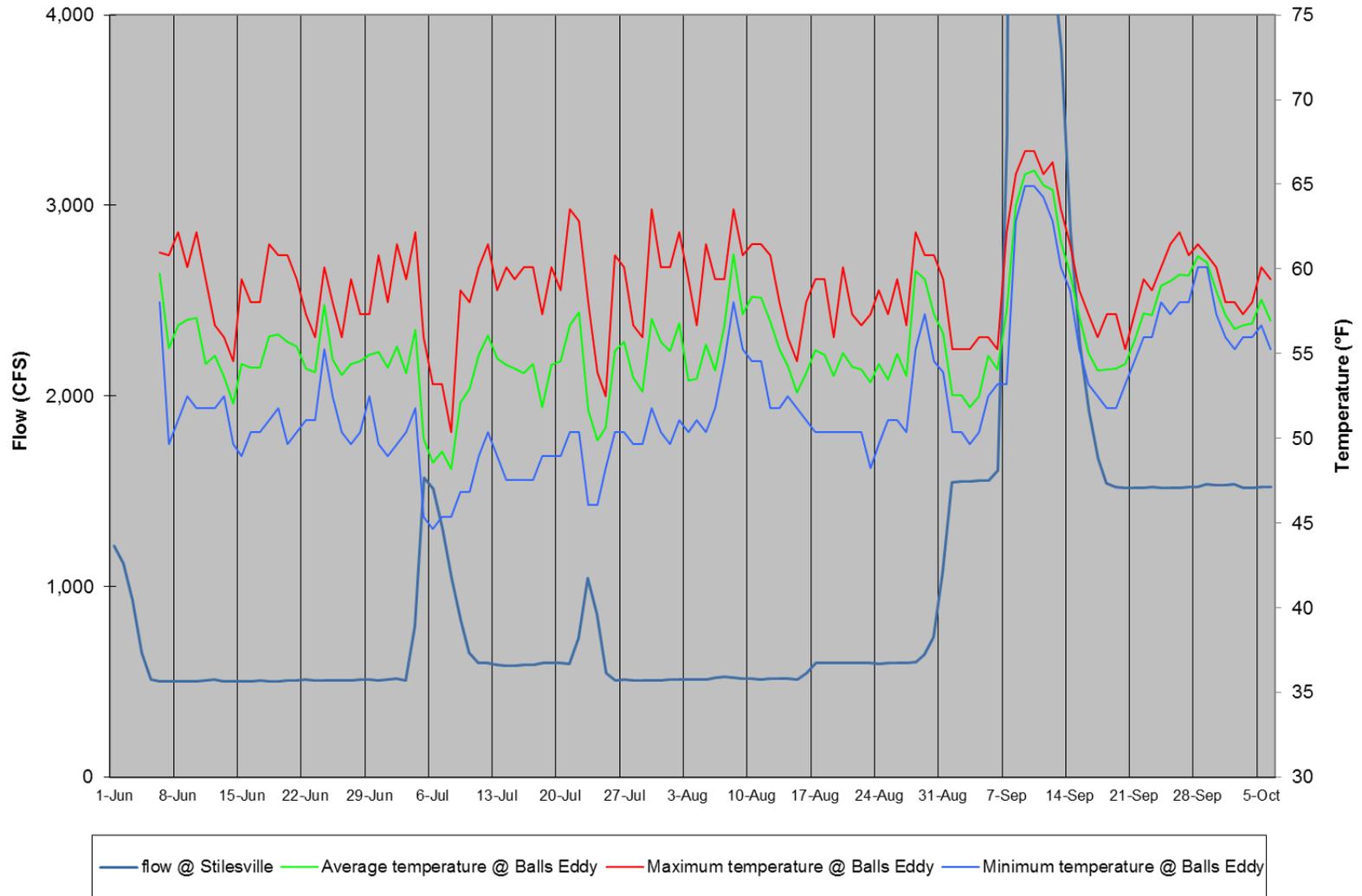
Appendix 1E. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2011.



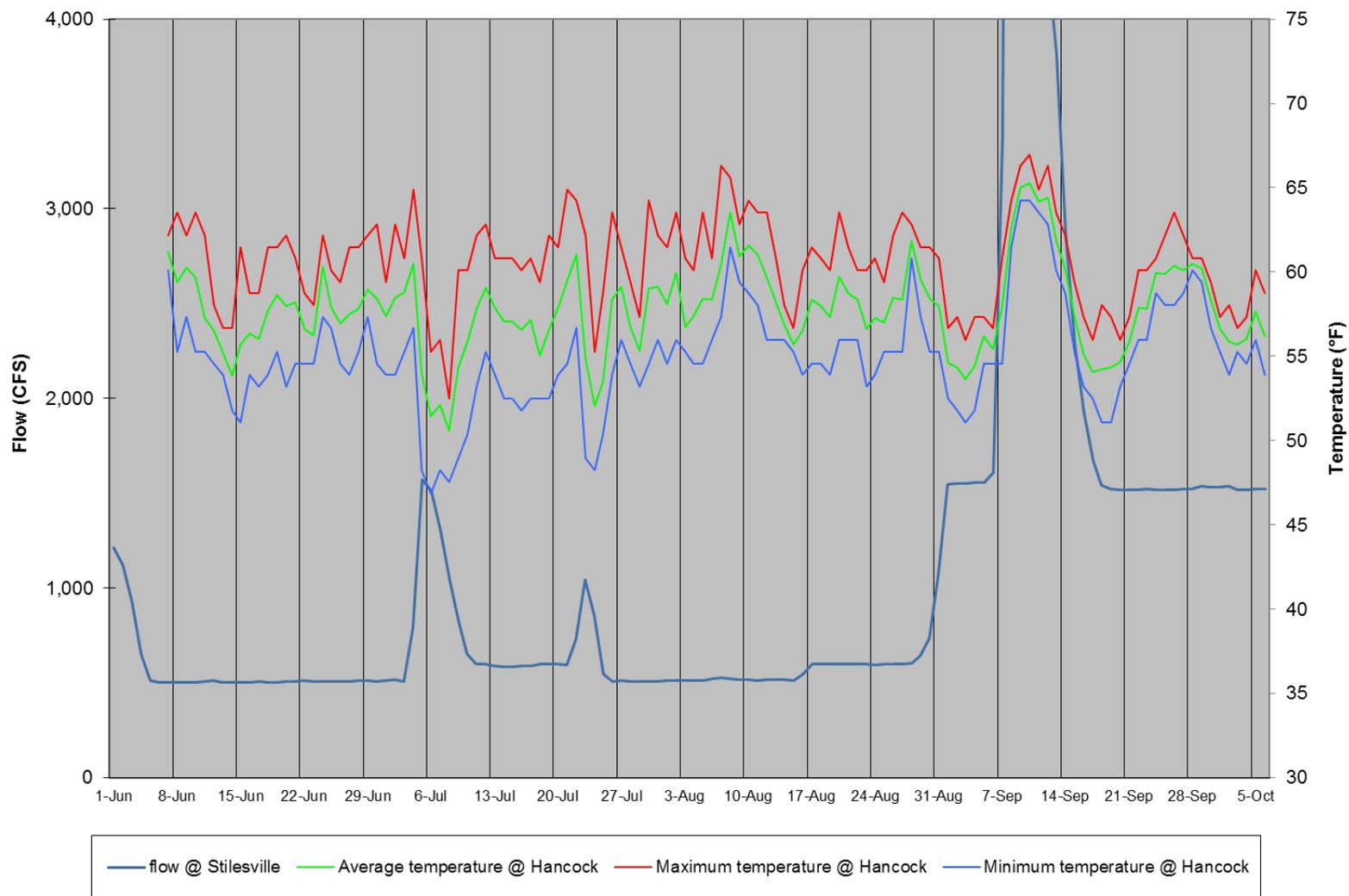
**Appendix 1F. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Roods Creek, along with daily average flows at Stilesville, 2011.**



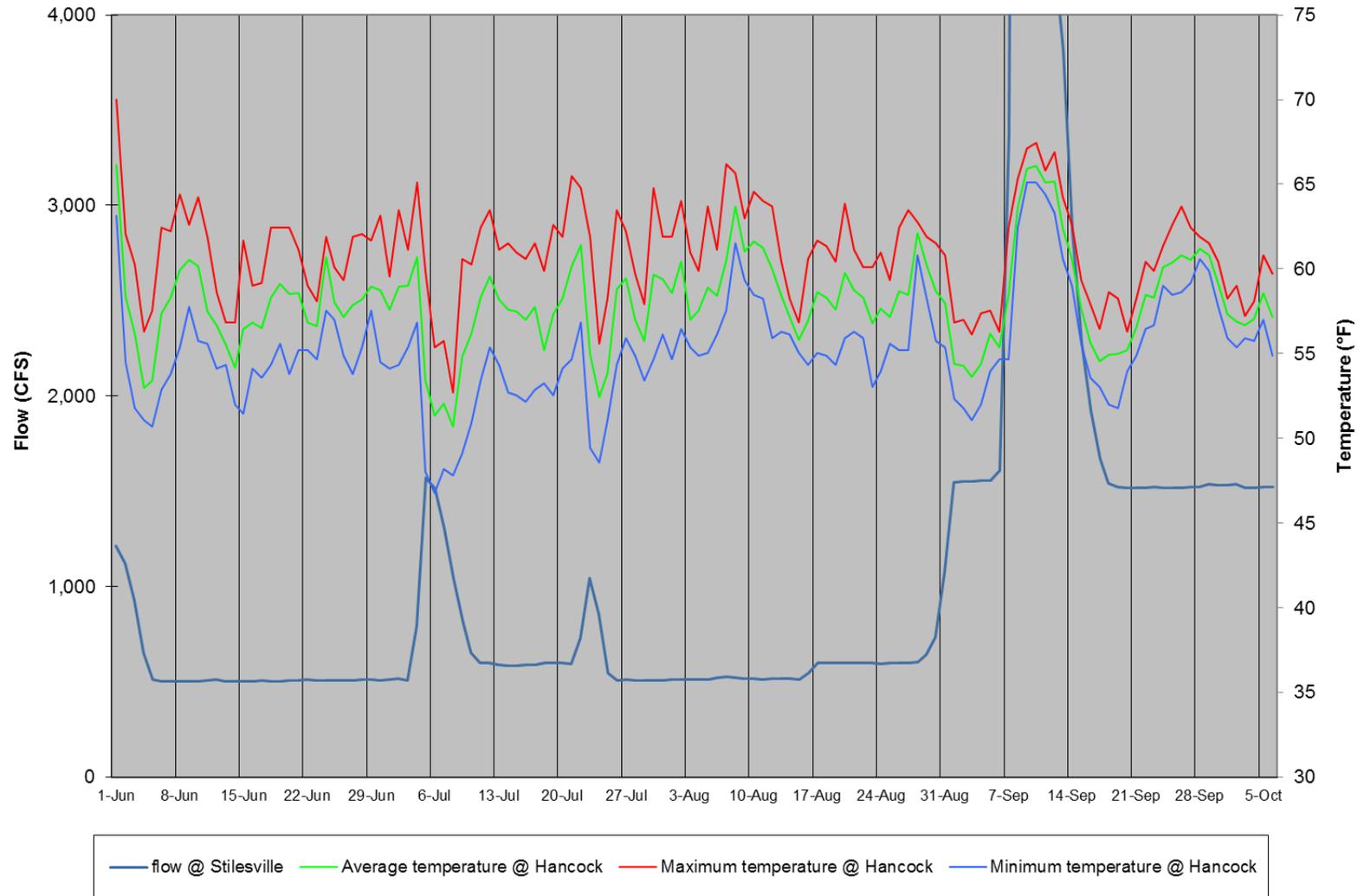
**Appendix 1G. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Balls Eddy, along with daily average flows at Stilesville, 2011.**



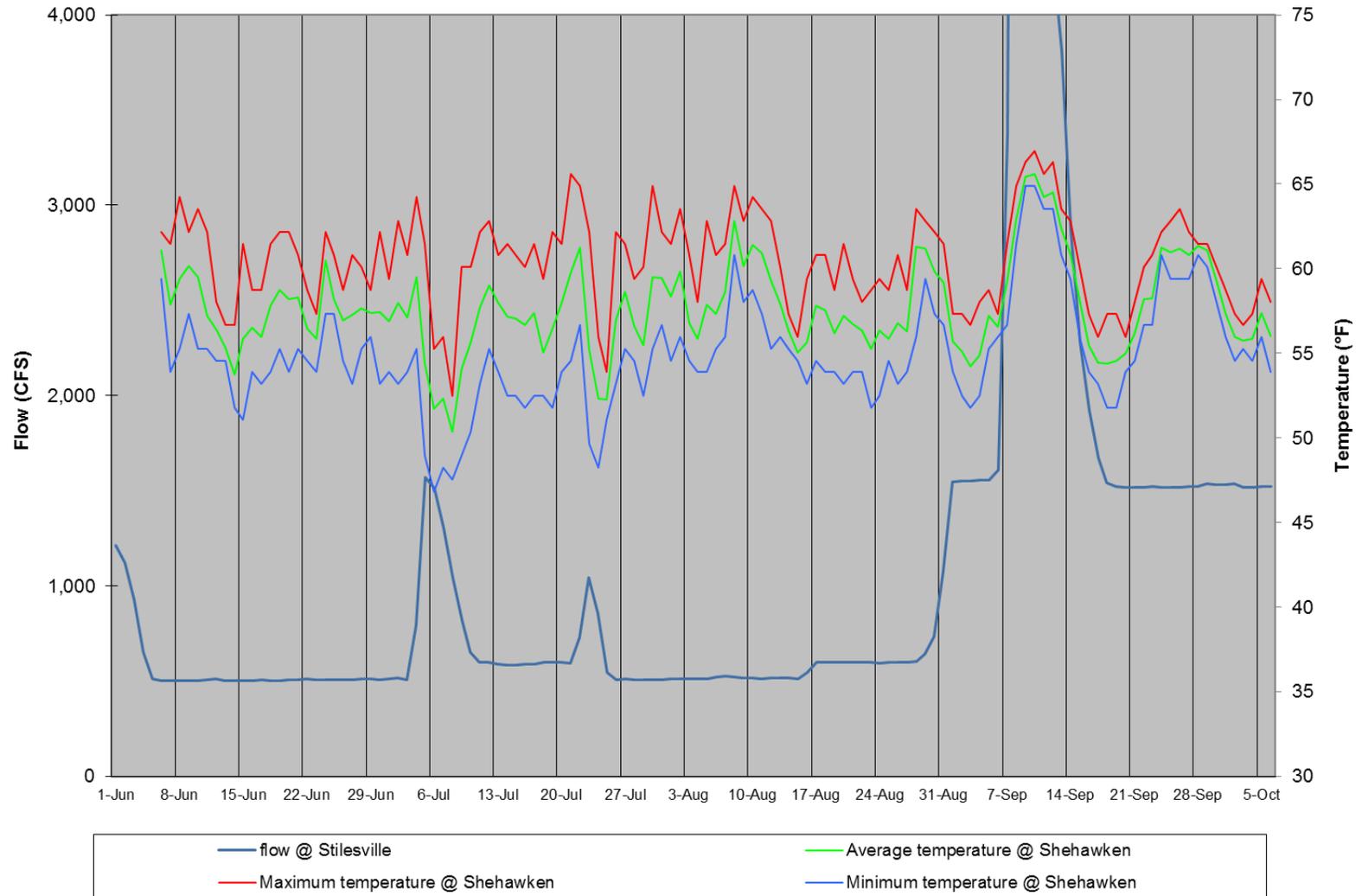
**Appendix 1H. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hancock, along with daily average flows at Stilesville, 2011.**



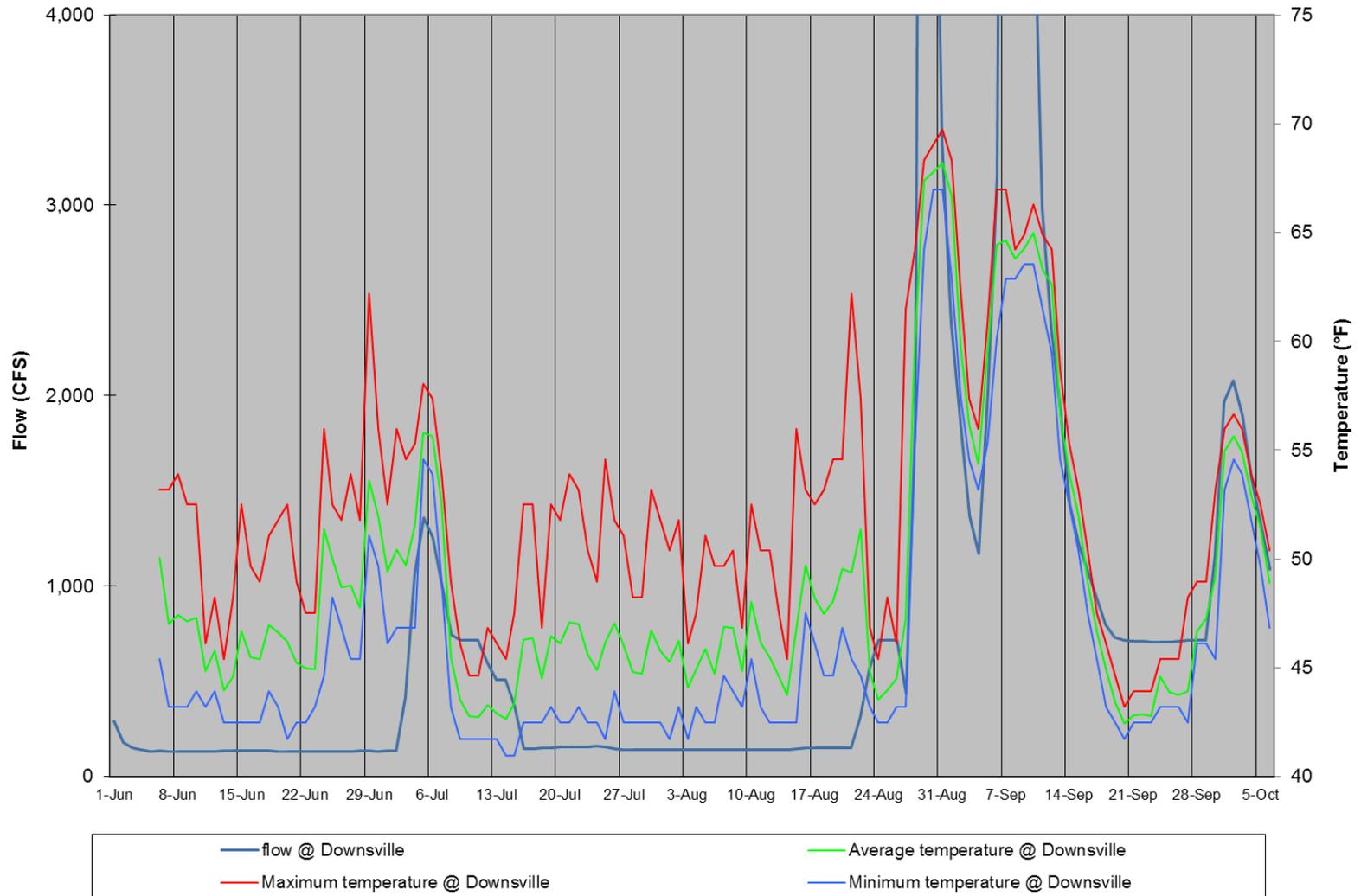
**Appendix 11. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hancock, along with daily average flows at Stilesville, 2011.**



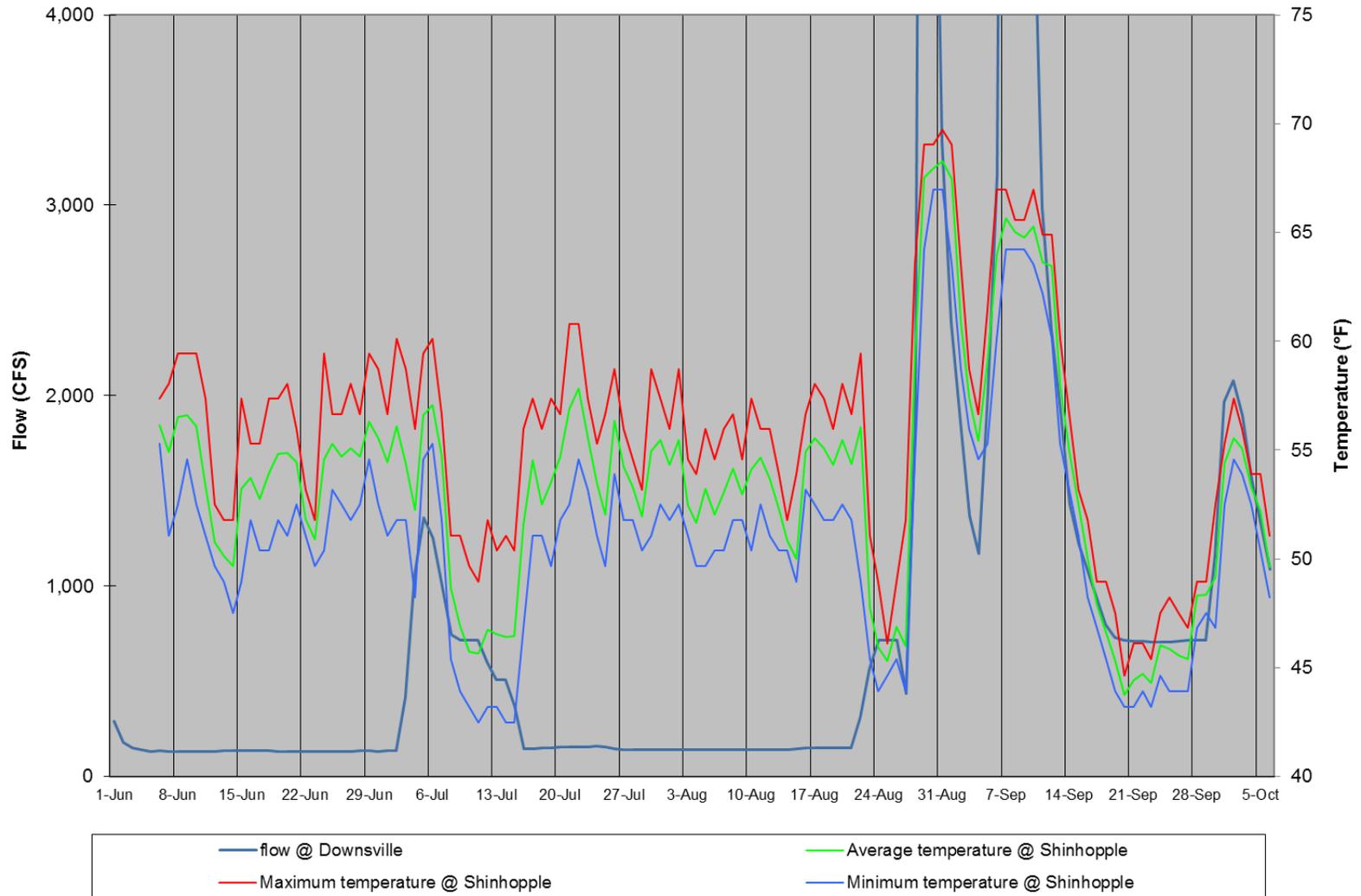
**Appendix 1J. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Shehawken, along with daily average flows at Stilesville, 2011.**



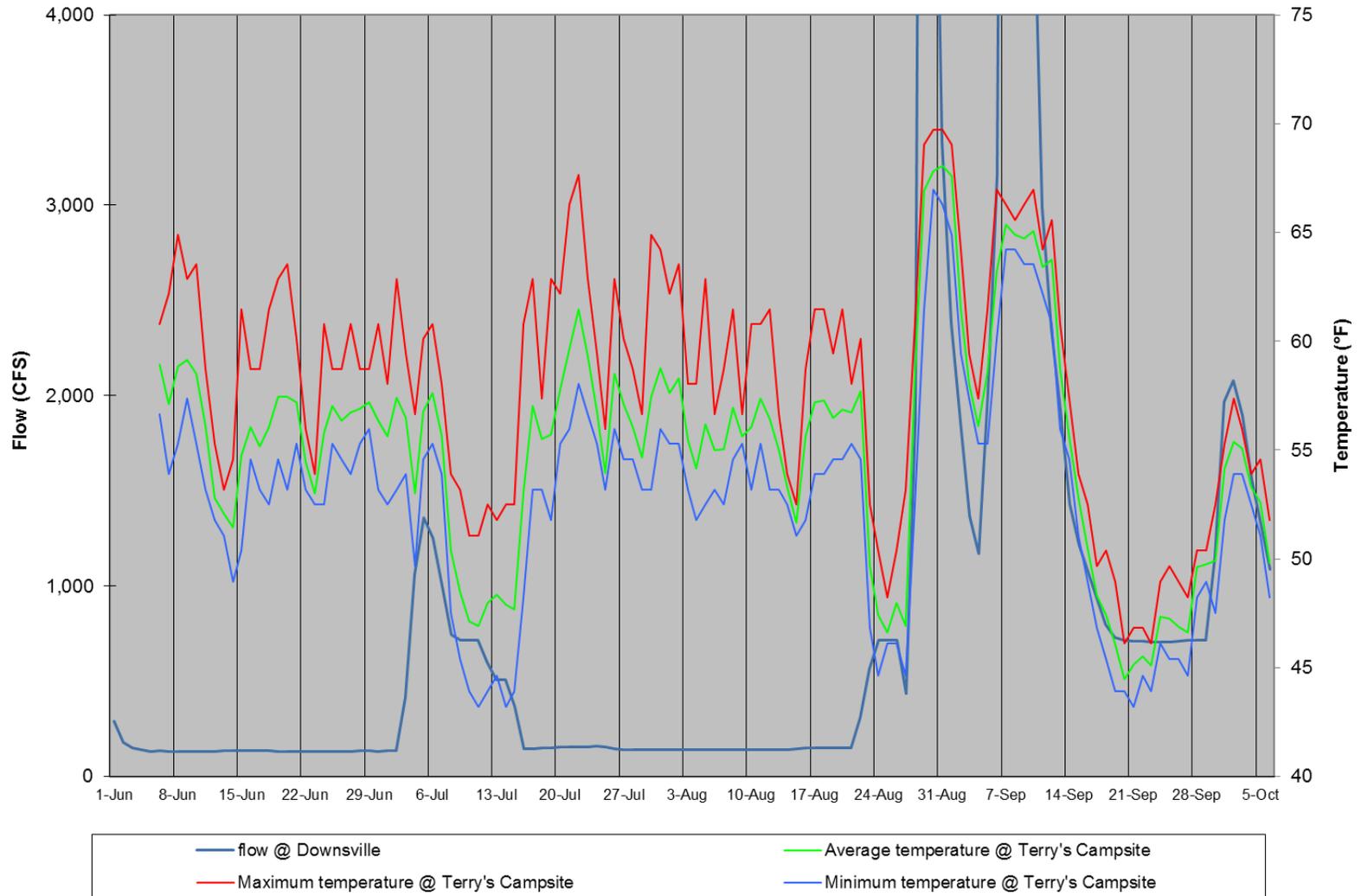
**Appendix 1K. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Downsville, along with daily average flows at Downsville, 2011.**



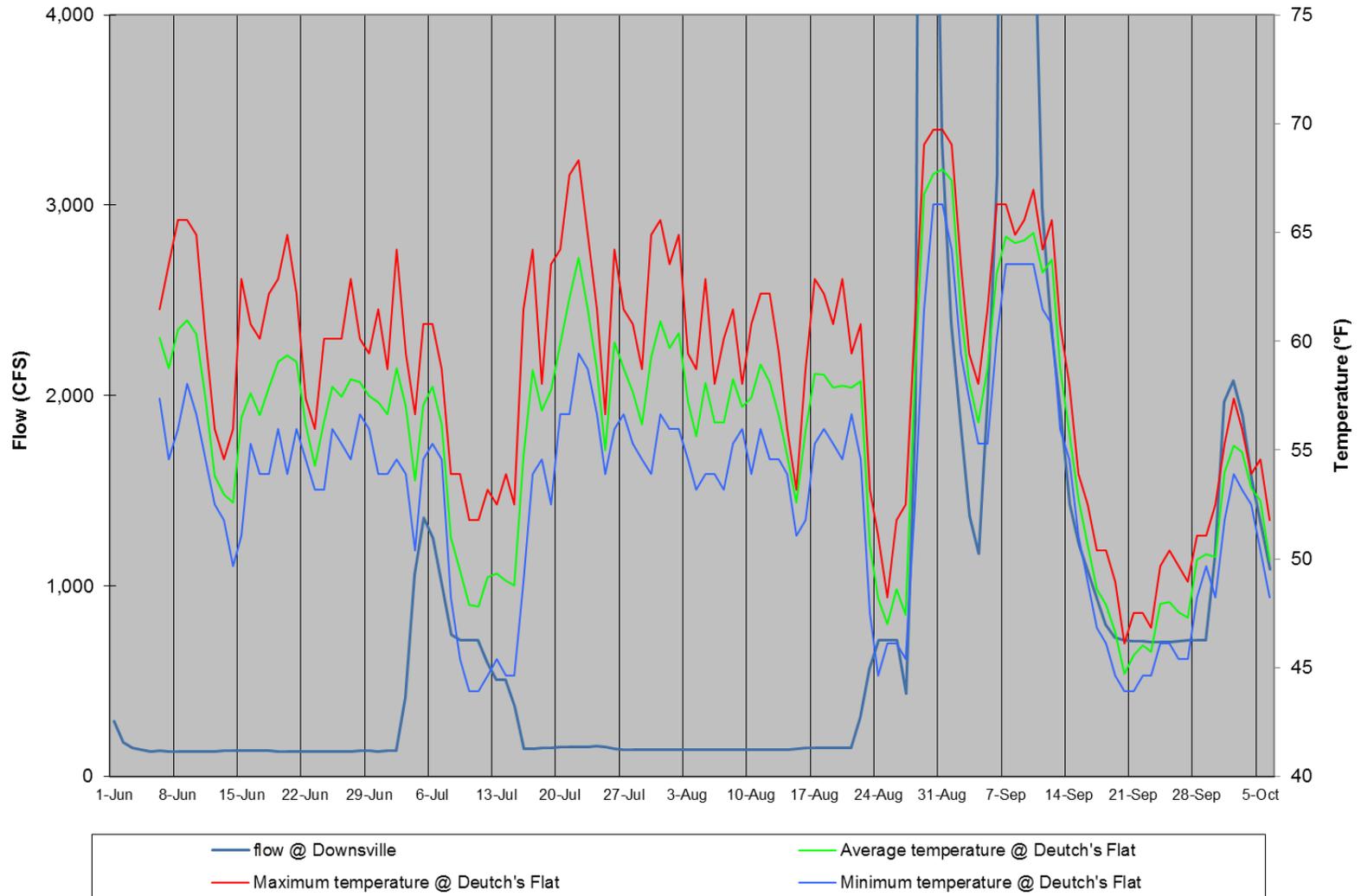
**Appendix 1L. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Shinhopple, along with daily average flows at Downsville, 2011.**



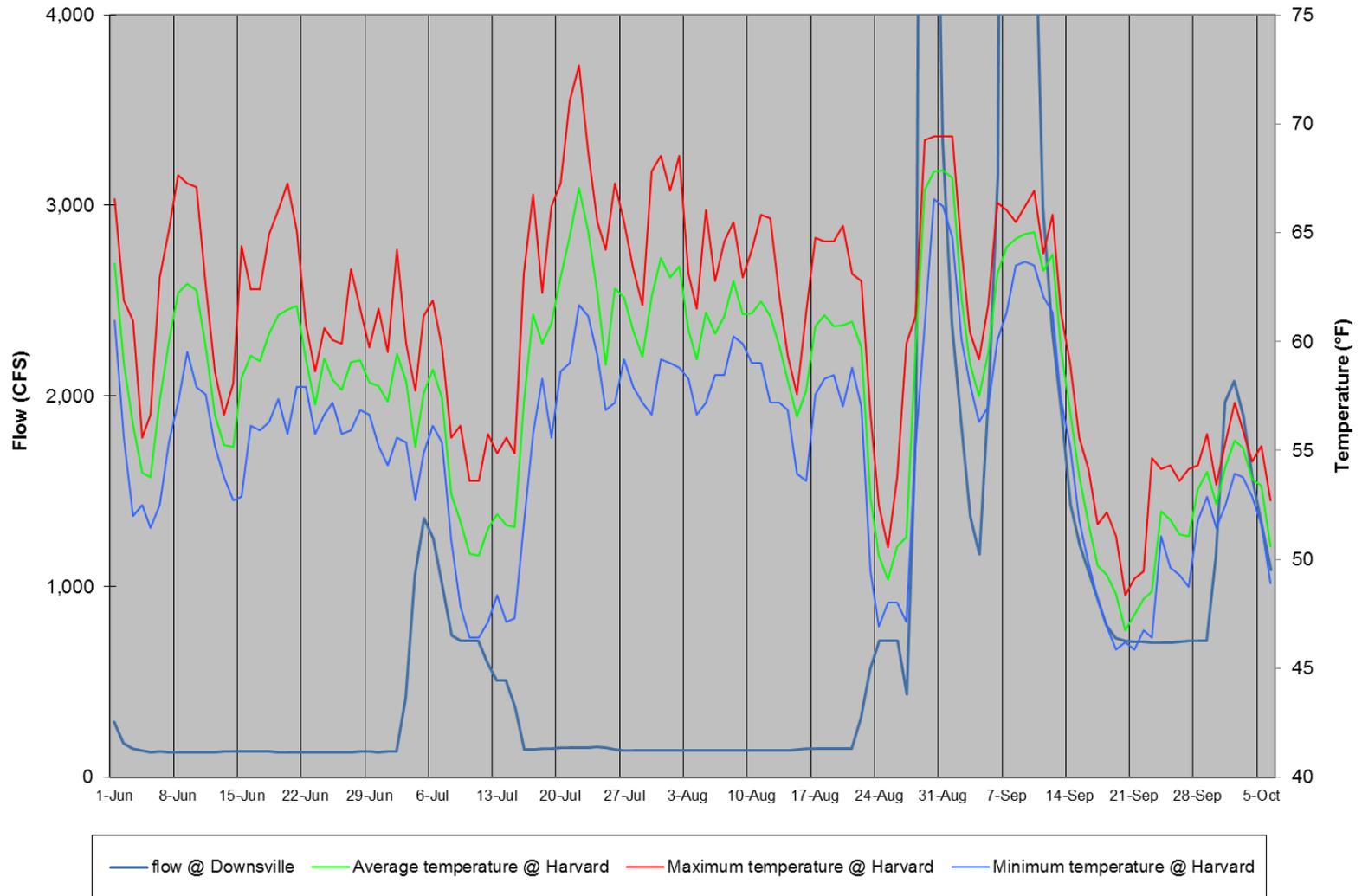
**Appendix 1M. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Terry's Campsite, along with daily average flows at Downsville, 2011.**



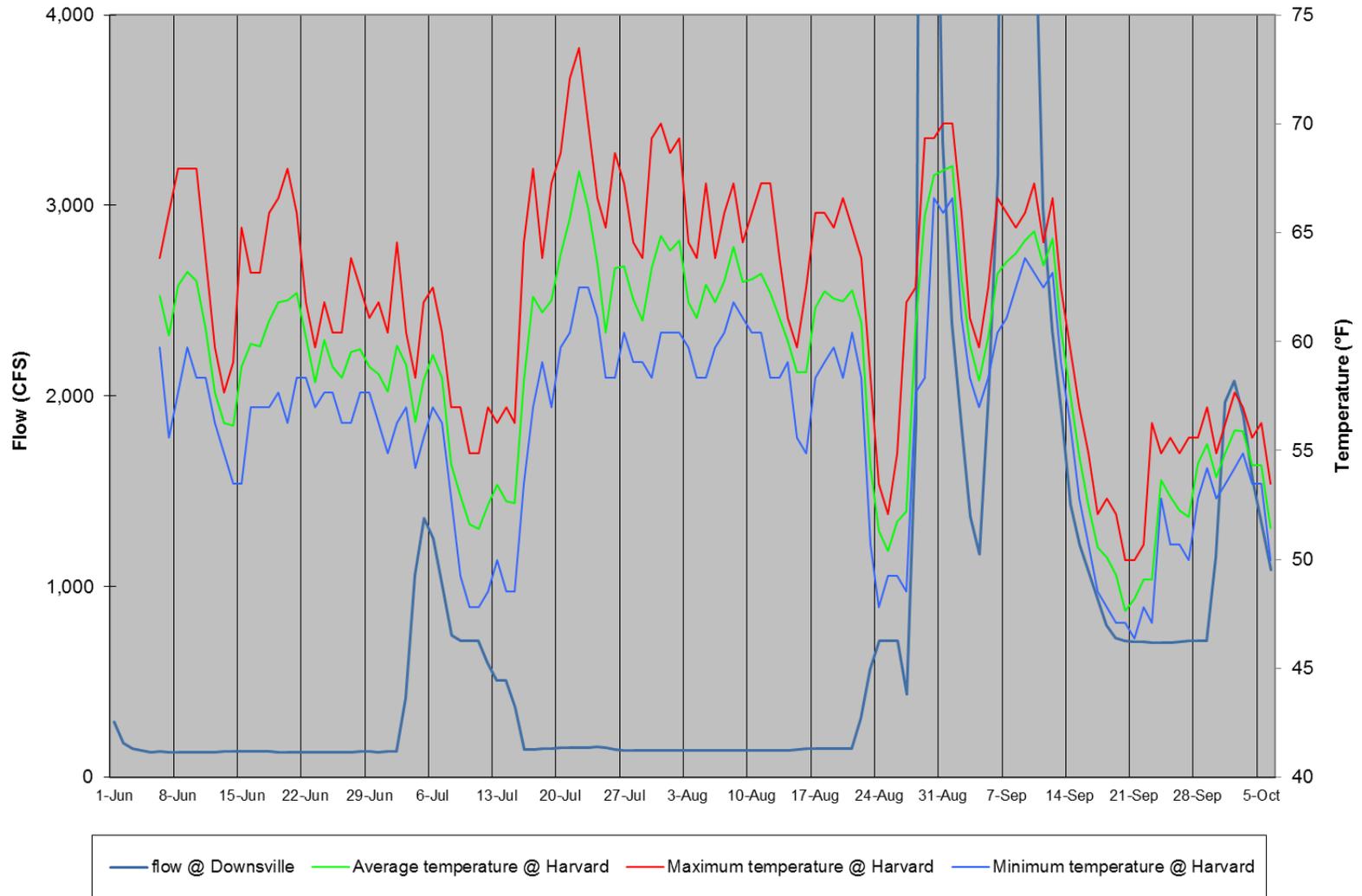
**Appendix 1N. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Deutch's Flat, along with daily average flows at Downsville, 2011.**



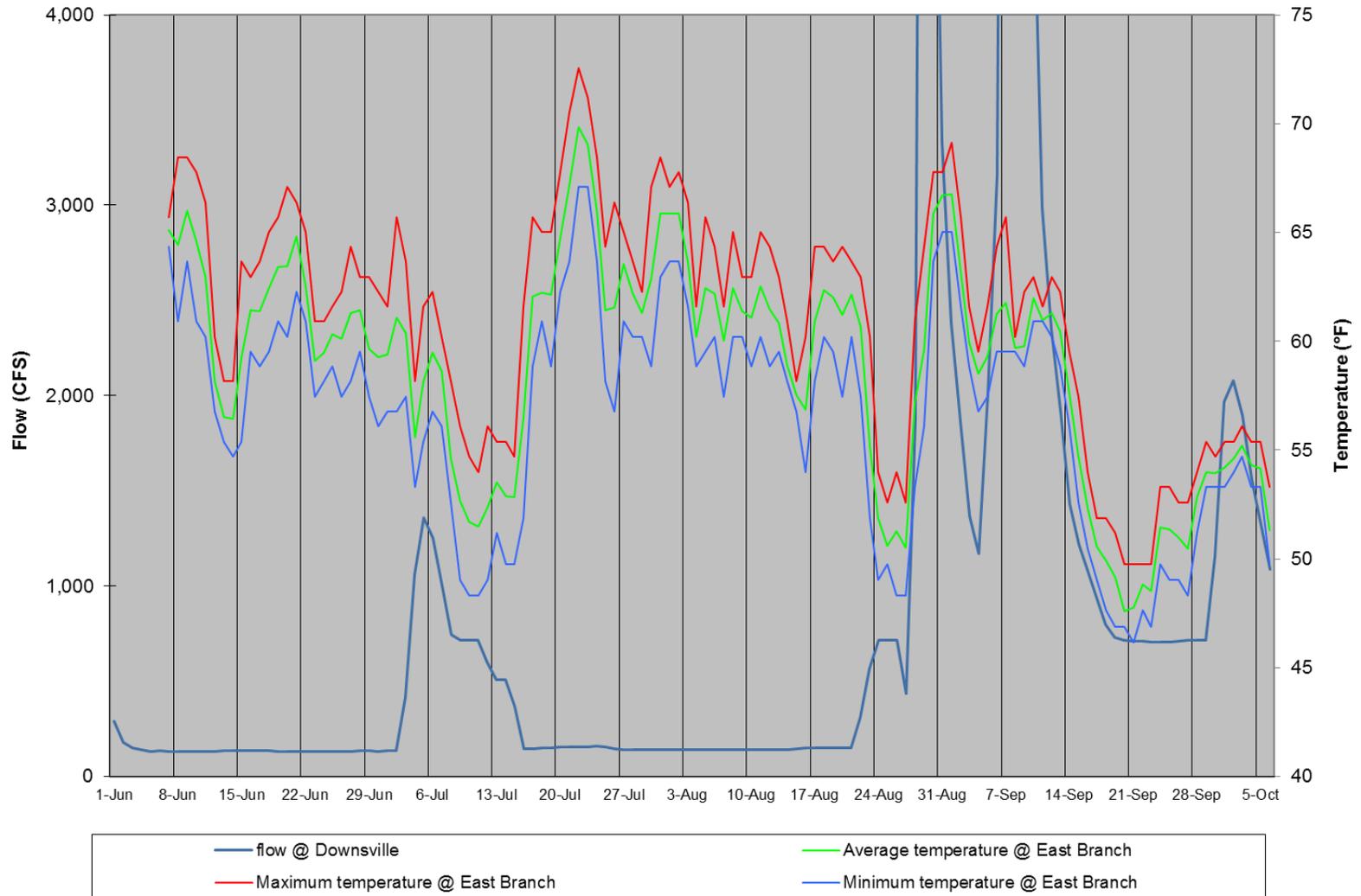
**Appendix 10. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Harvard, along with daily average flows at Downsville, 2011.**



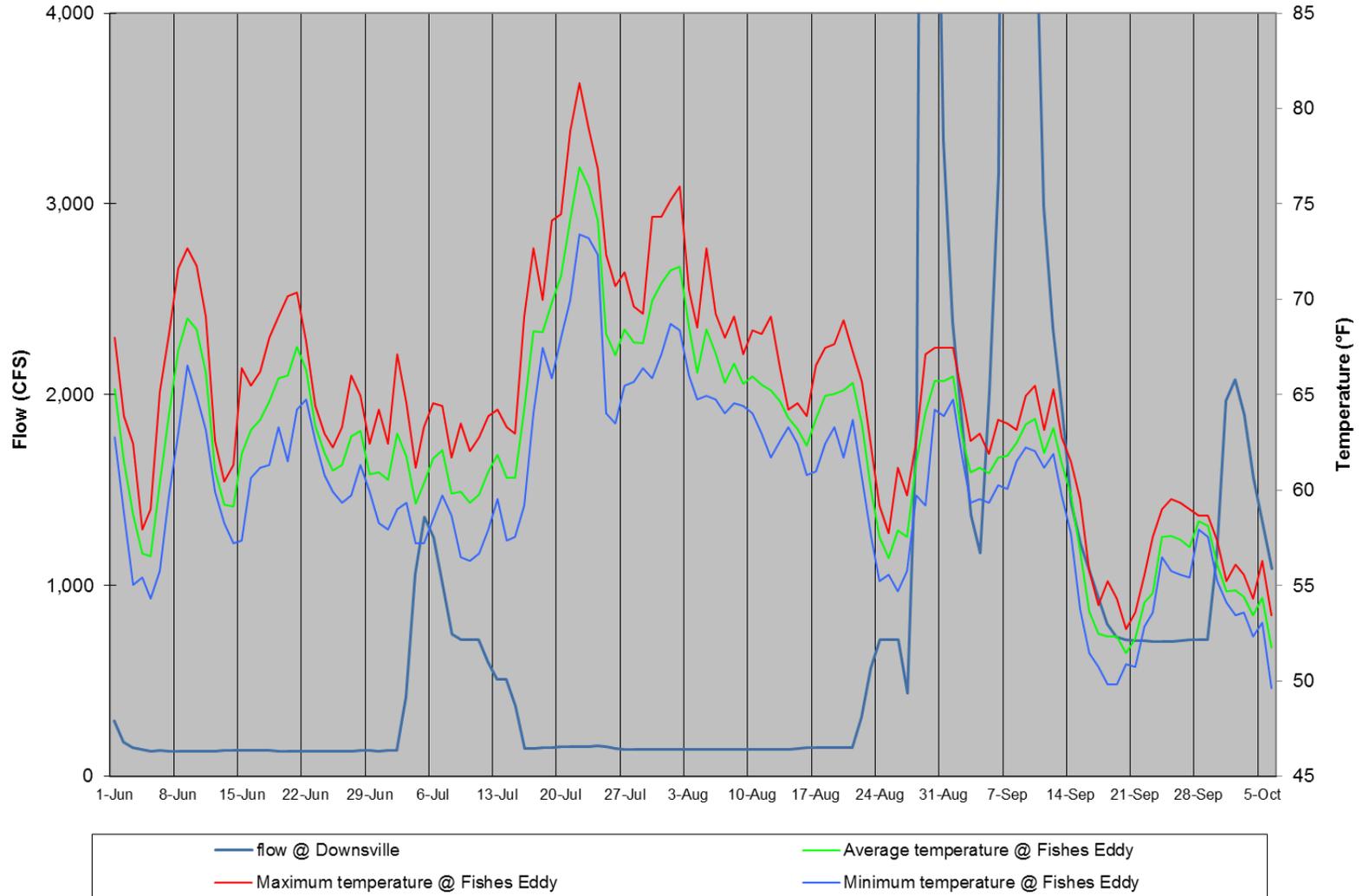
**Appendix 1P. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Harvard, along with daily average flows at Downsville, 2011.**



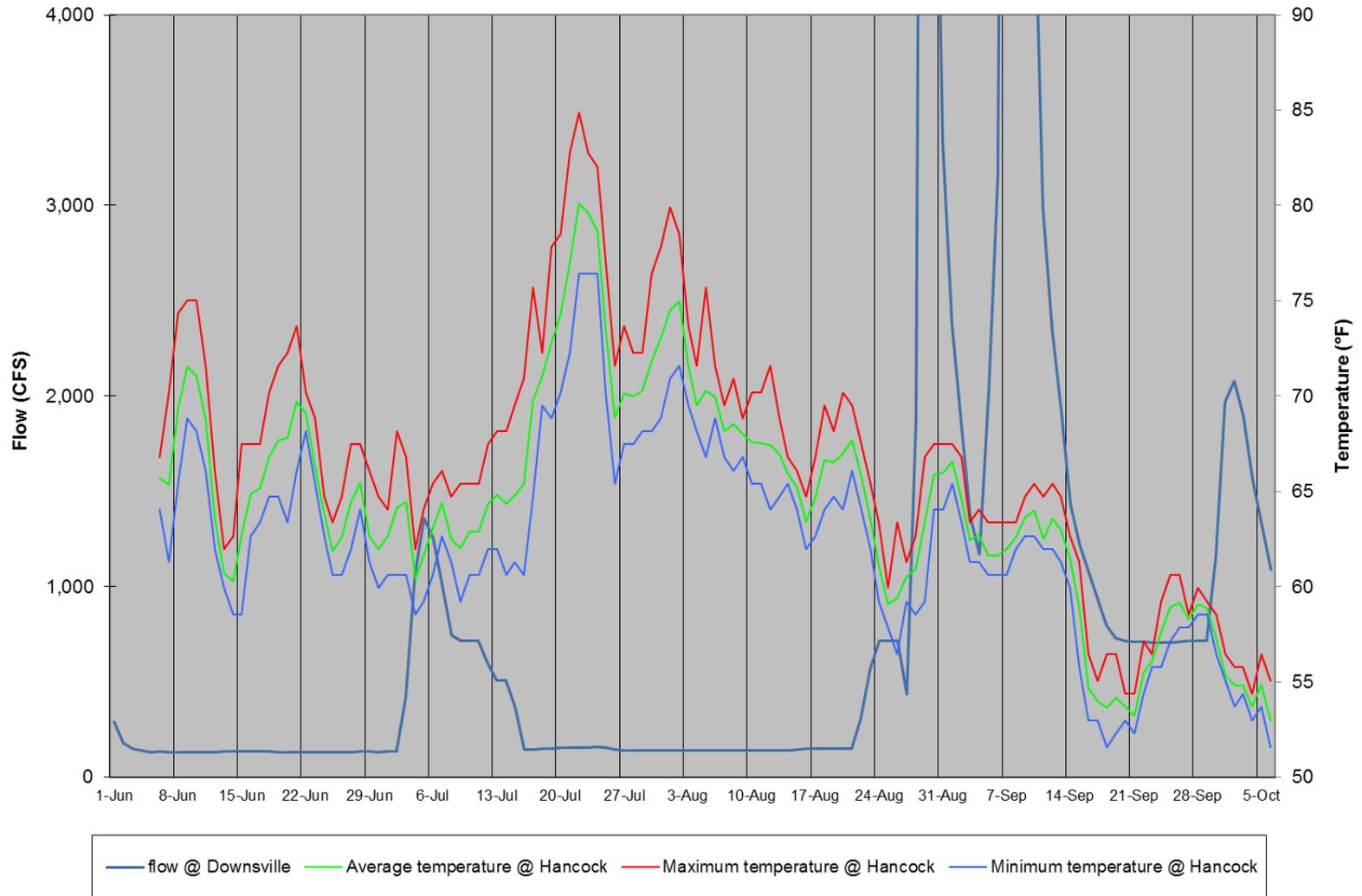
**Appendix 1Q. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at East Branch, along with daily average flows at Downsville, 2011.**



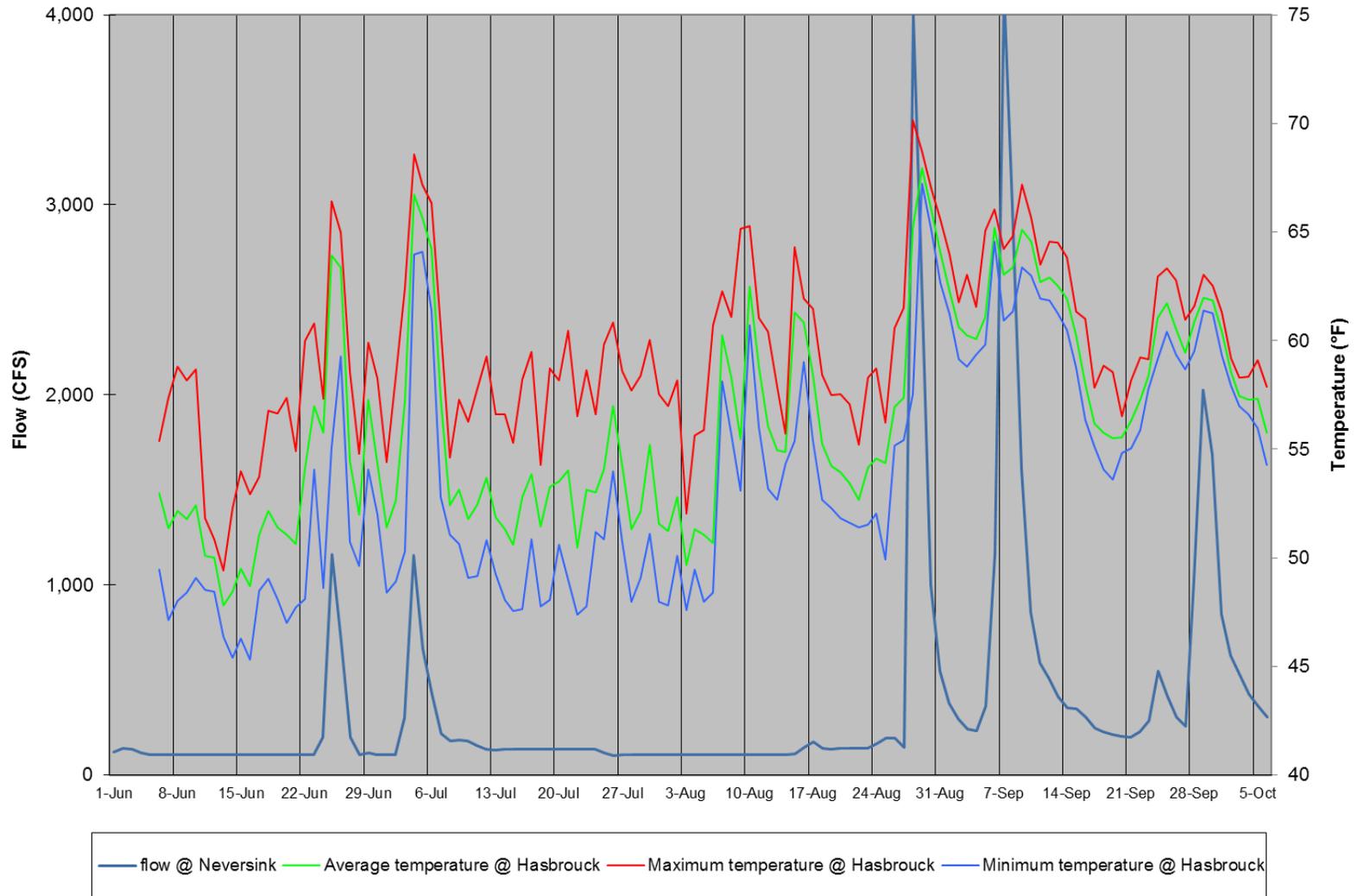
**Appendix 1R. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Fishes Eddy, along with daily average flows at Downsville, 2011.**



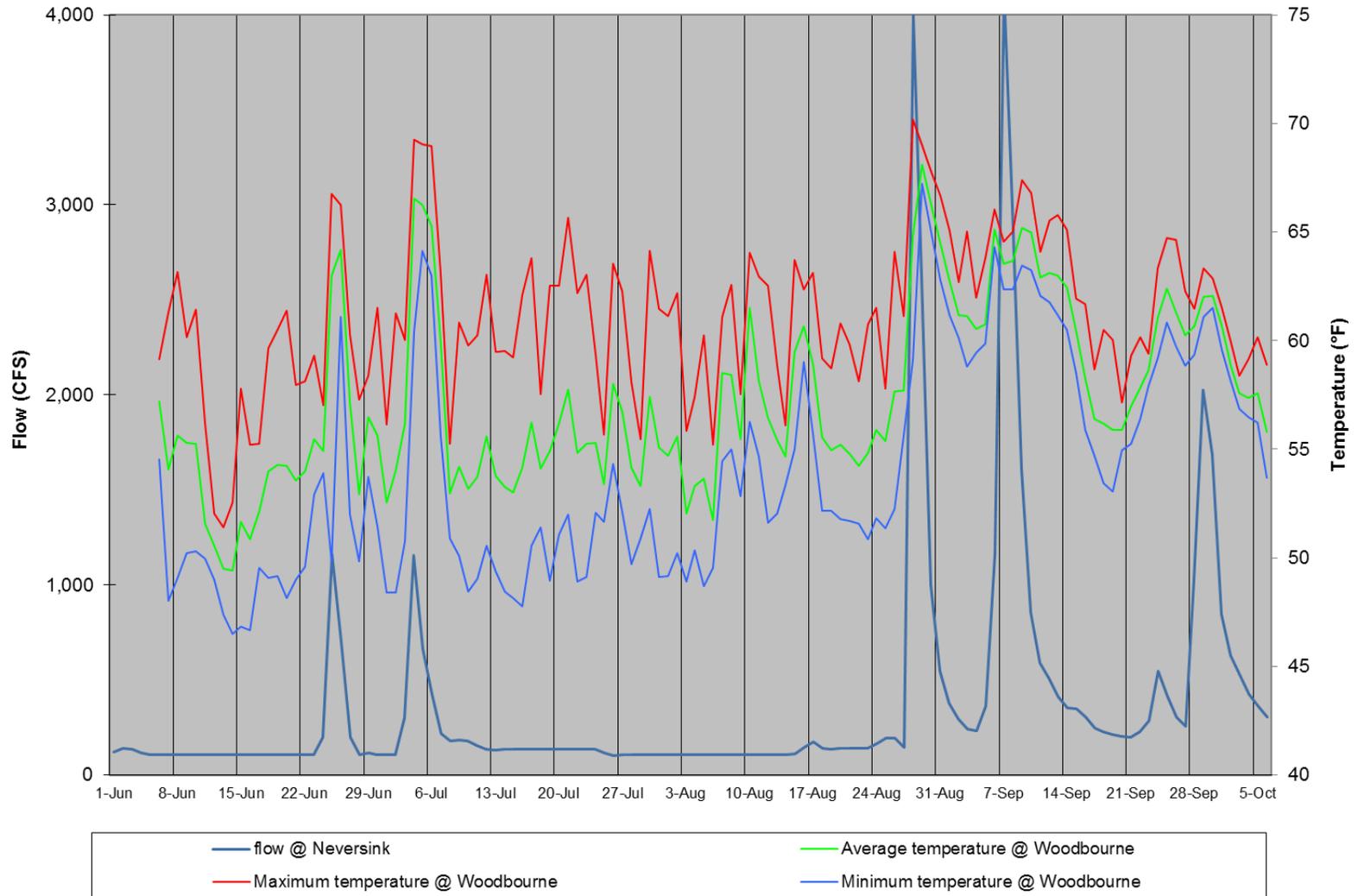
**Appendix 1S. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Hancock, along with daily average flows at Downsville, 2011.**



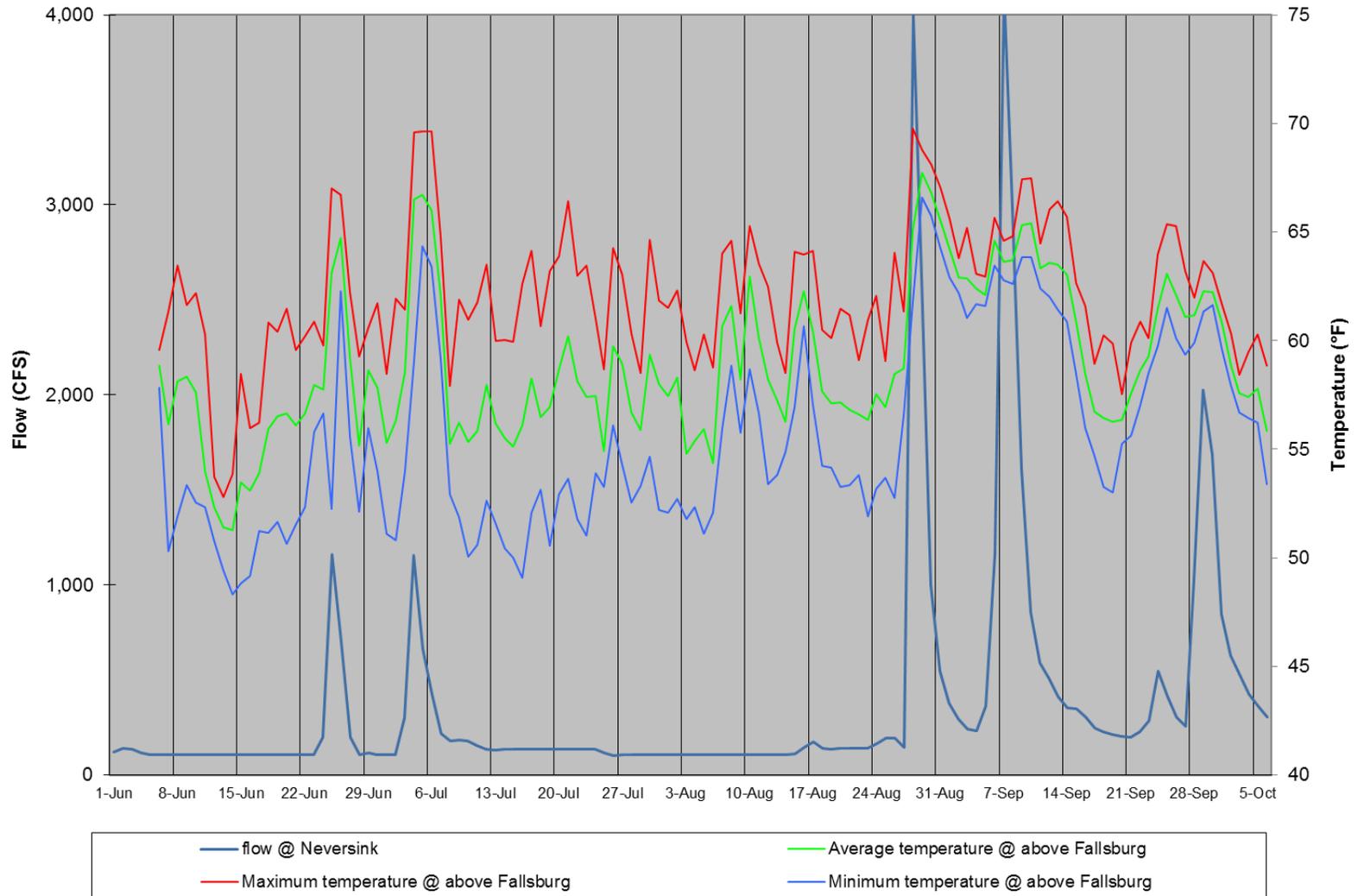
**Appendix 1T. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Hasbrouck, along with daily average flows at Neversink, 2011.**



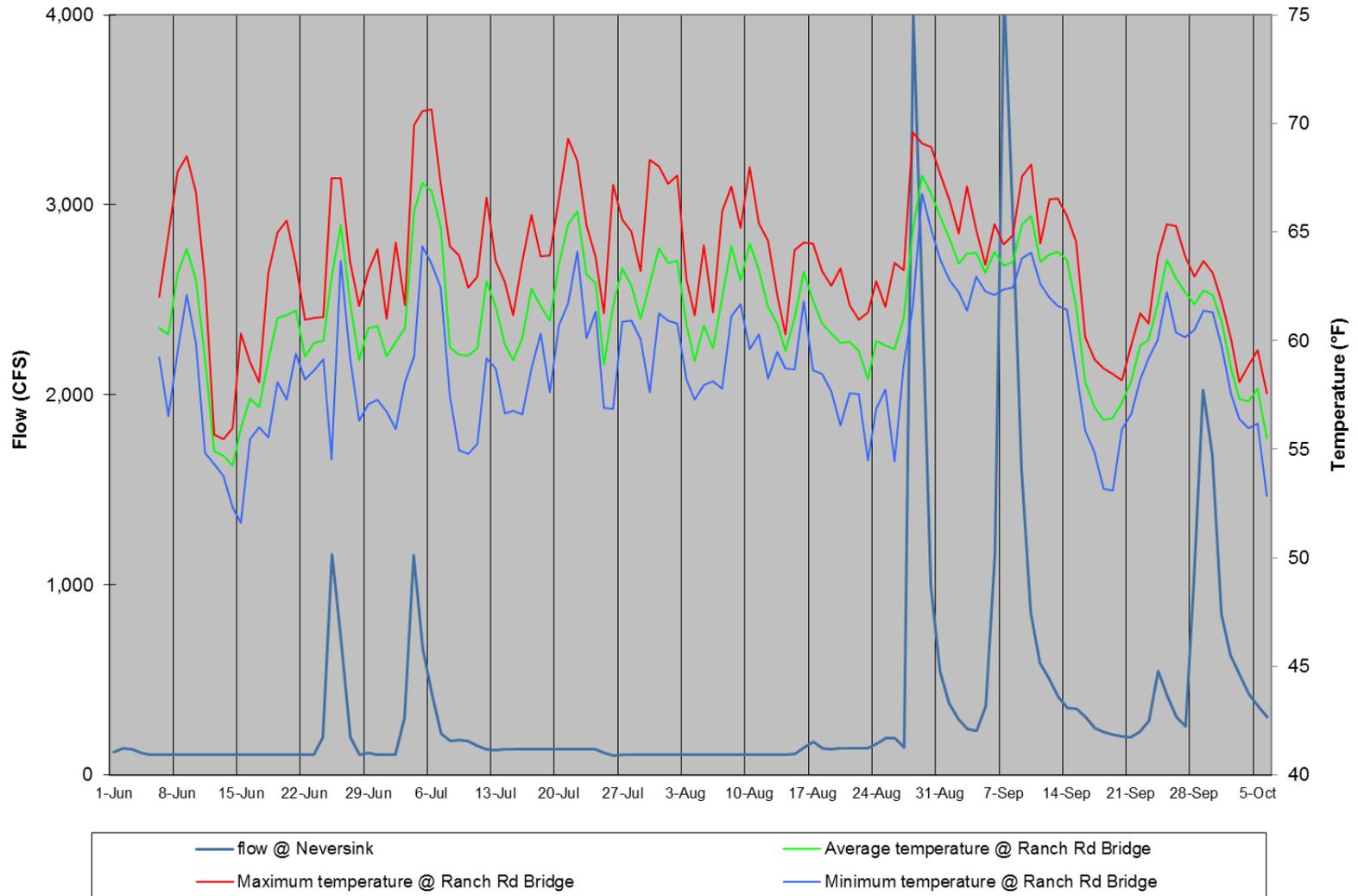
**Appendix 1U. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Woodbourne, along with daily average flows at Neversink, 2011.**



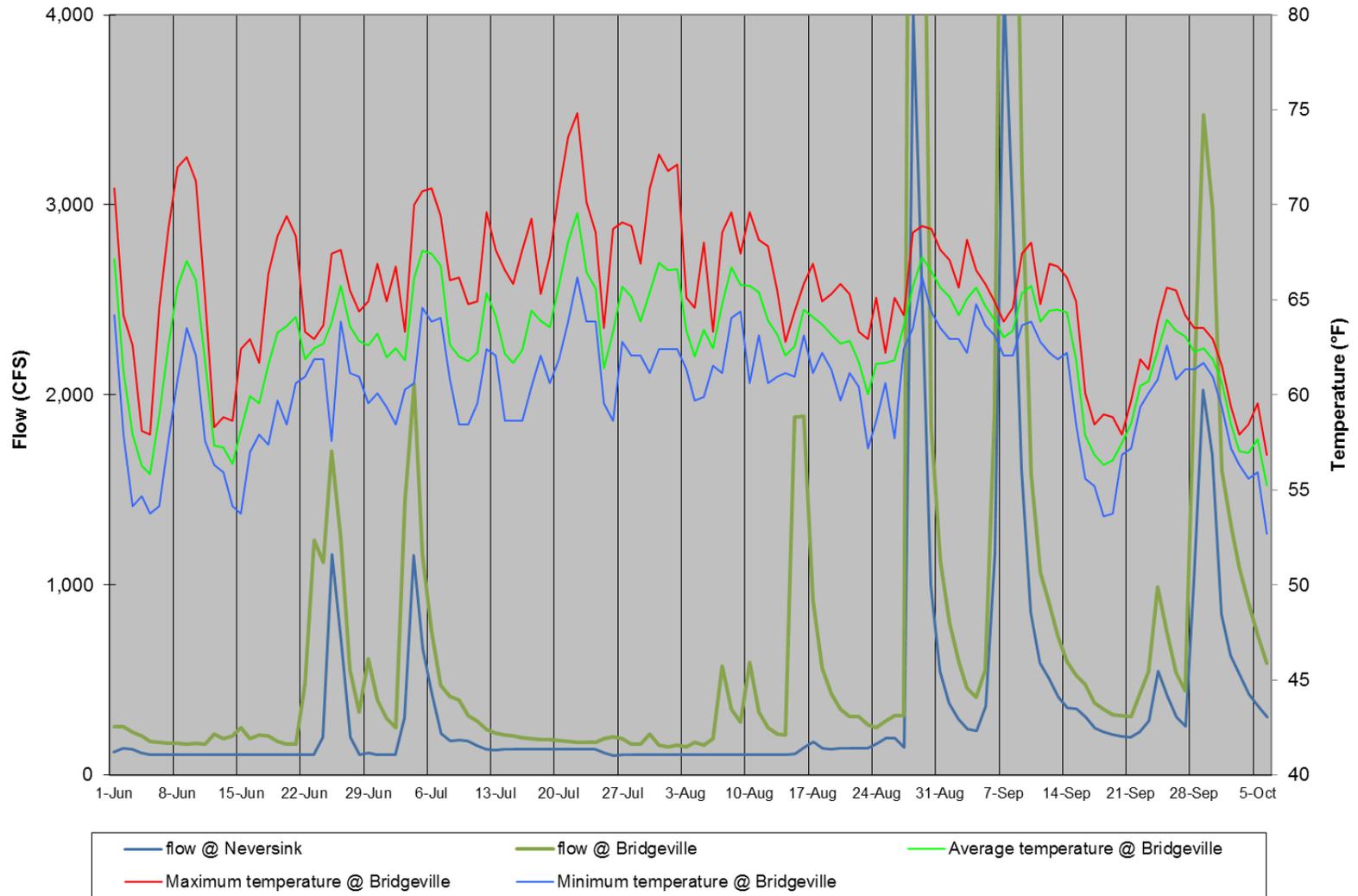
**Appendix 1V. Summer daily average, maximum, and minimum water temperature profiles on the Neversink just above Fallsburg, along with daily average flows at Neversink, 2011.**



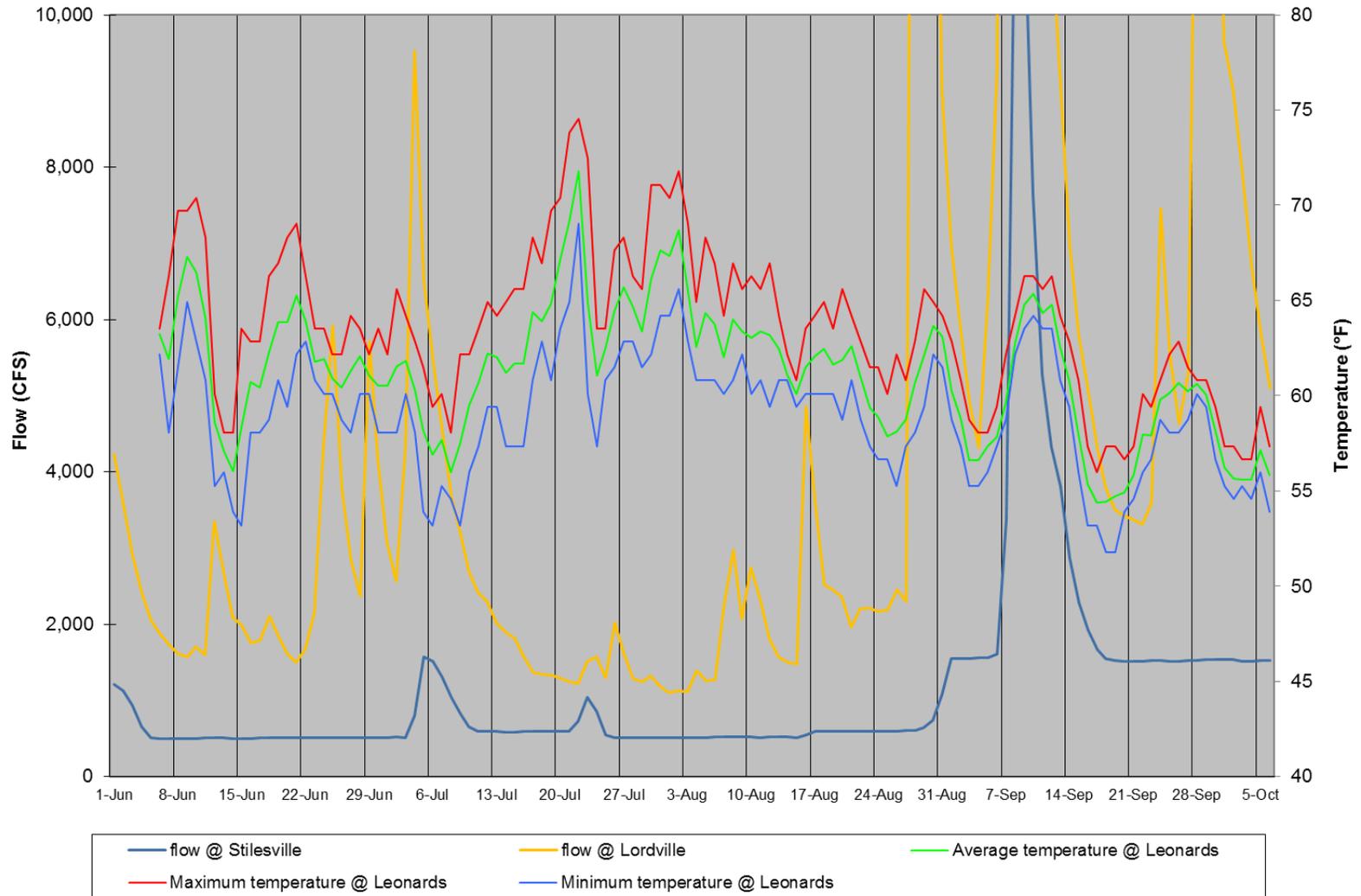
**Appendix 1W. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Ranch Rd bridge, along with daily average flows at Neversink, 2011.**



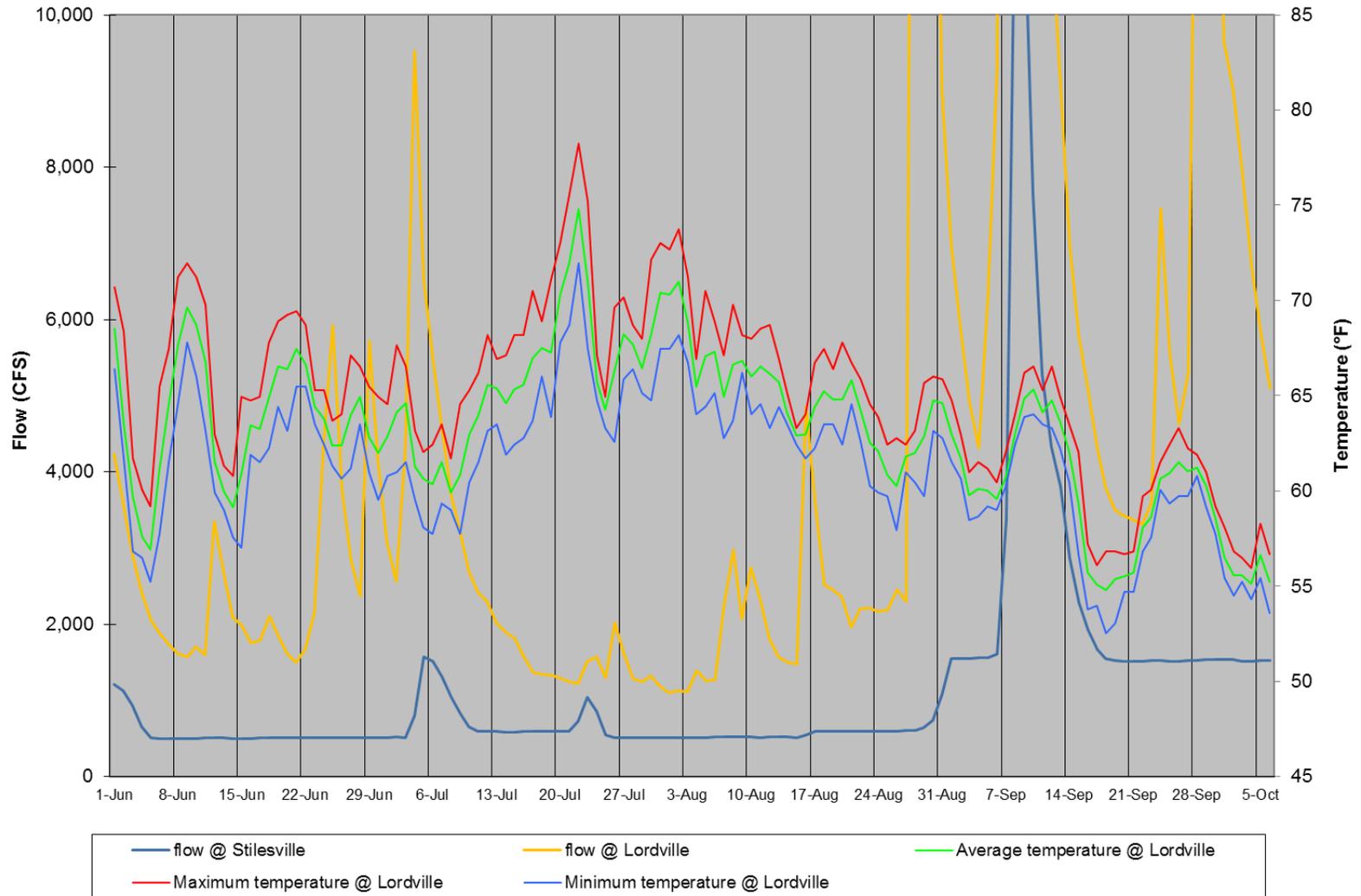
**Appendix 1X. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Bridgeville, along with daily average flows at Bridgeville & Neversink, 2011.**



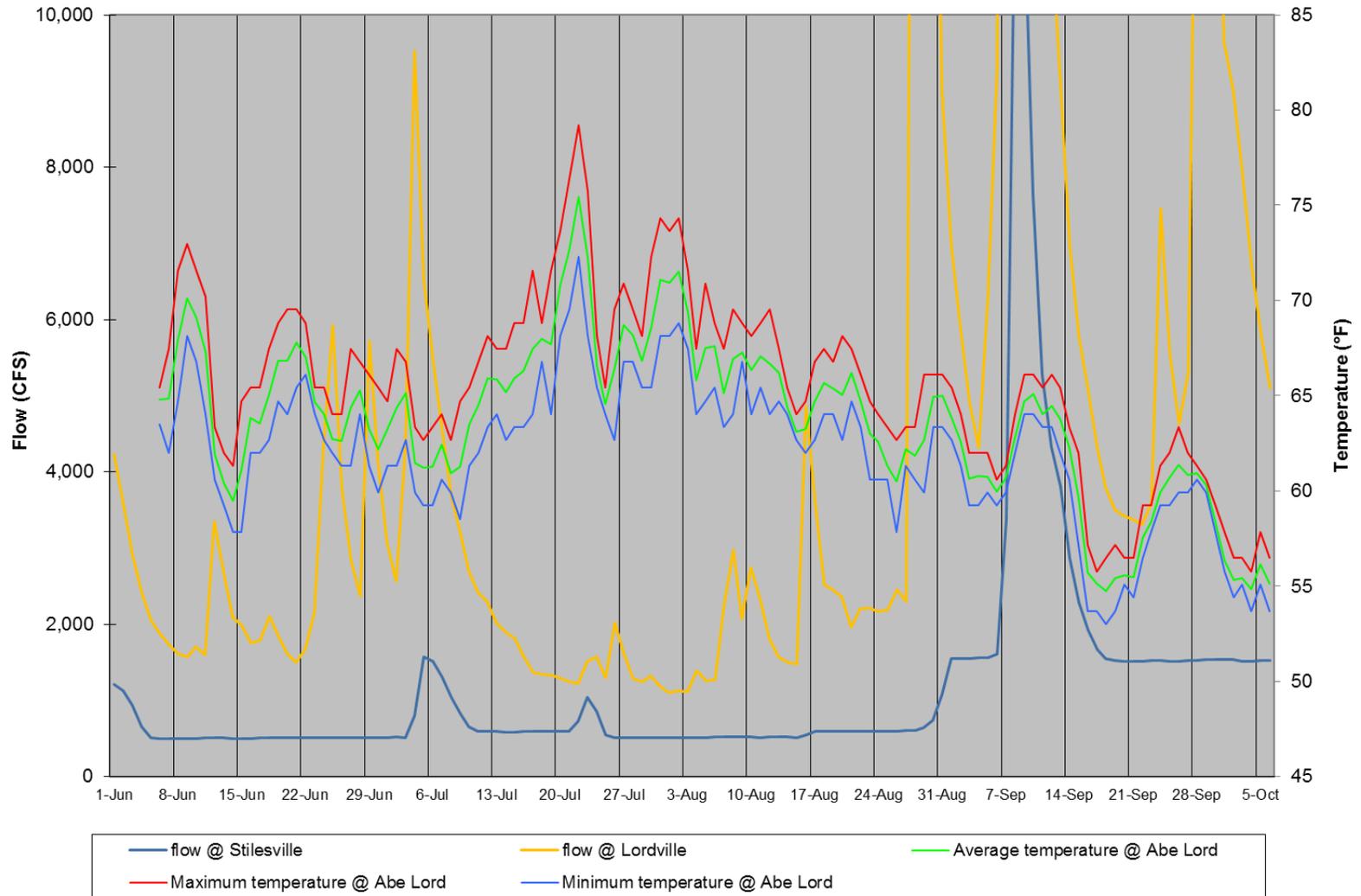
**Appendix 1Y. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Leonards, along with daily average flows at Stilesville on the West Branch and Lordville, 2011.**



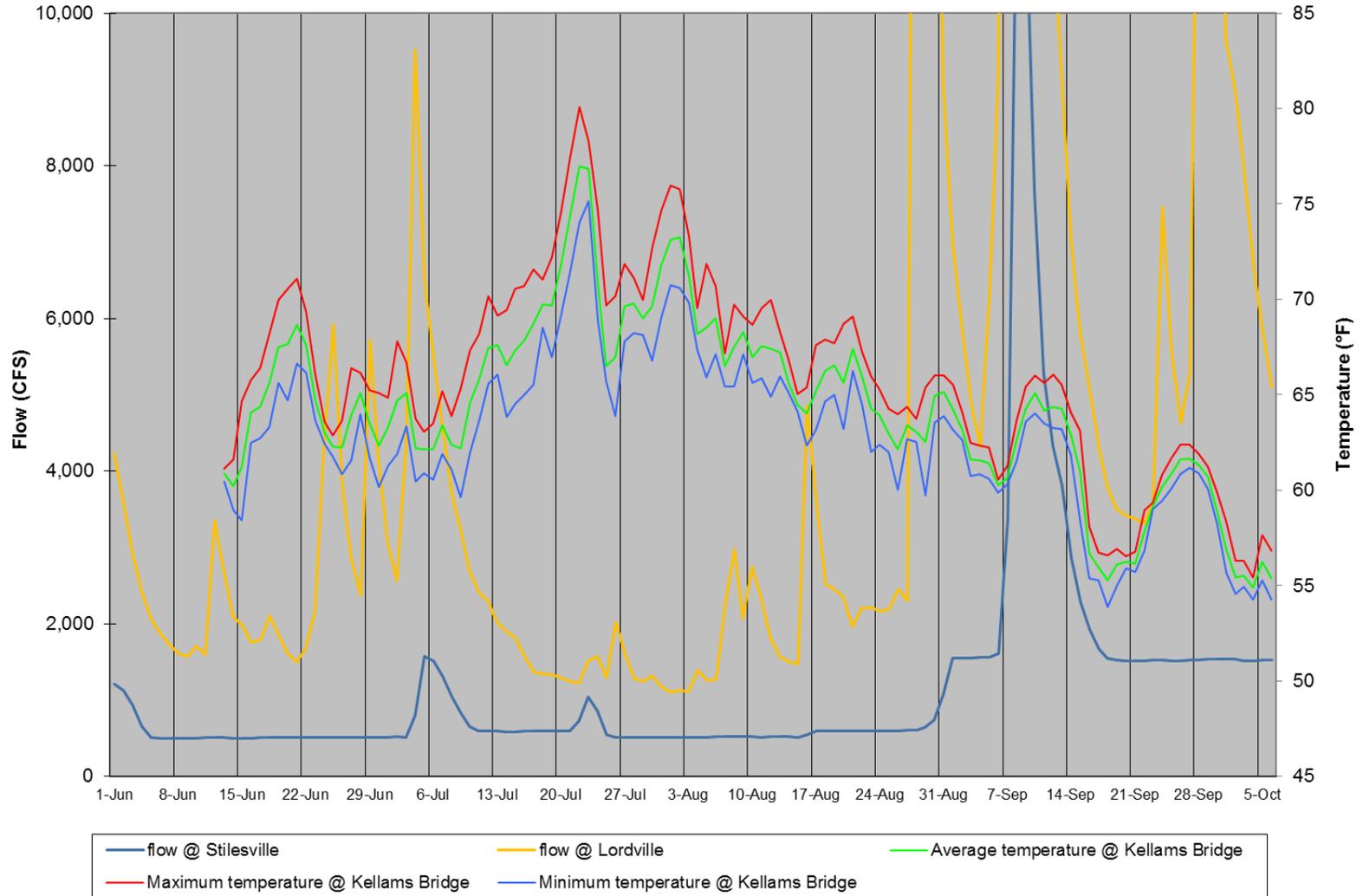
**Appendix 1Z. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Lordville, along with daily average flows at Stilesville on the West Branch and Lordville, 2011.**



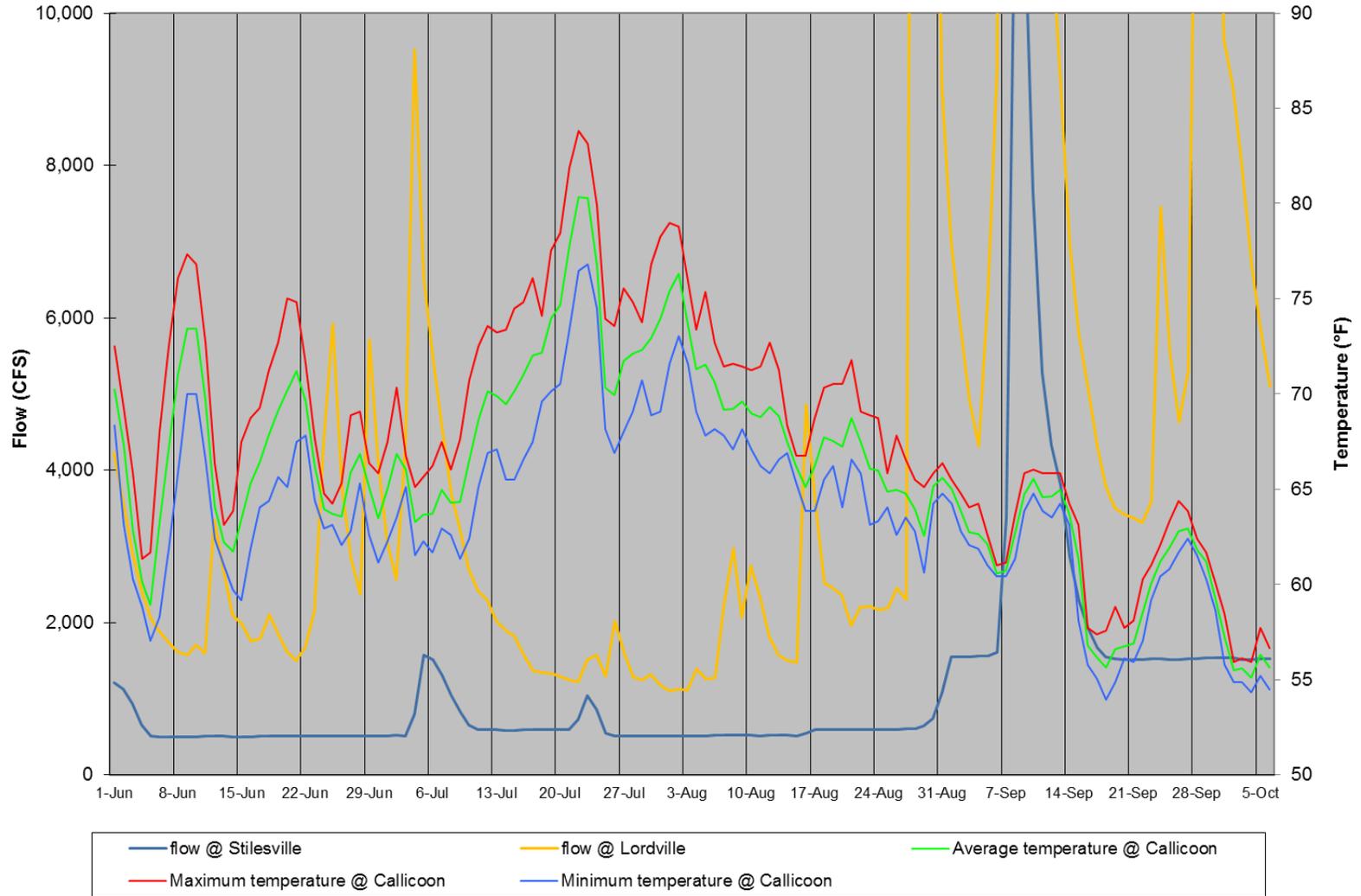
**Appendix 1AA. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Abe Lord, along with daily average flows at Stilesville on the West Branch and Lordville, 2011.**



**Appendix 1BB. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Kellams Bridge, along with daily average flows at Stilesville on the West Branch and Lordville, 2011.**



**Appendix 1CC. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Callicoon, along with daily average flows at Stilesville on the West Branch and Lordville, 2011.**



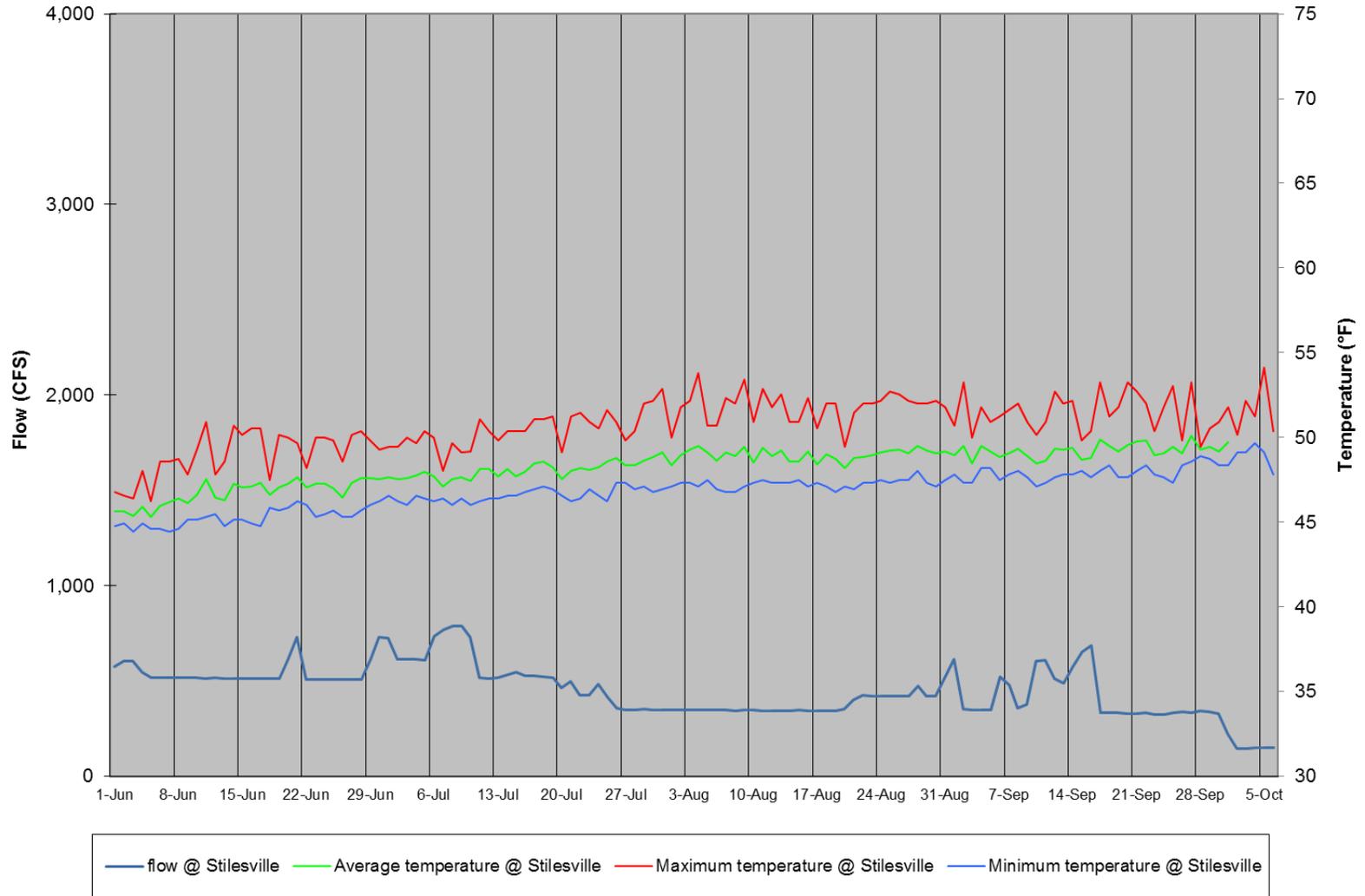
## Appendix 2:

### UPPER DELAWARE TAILWATERS

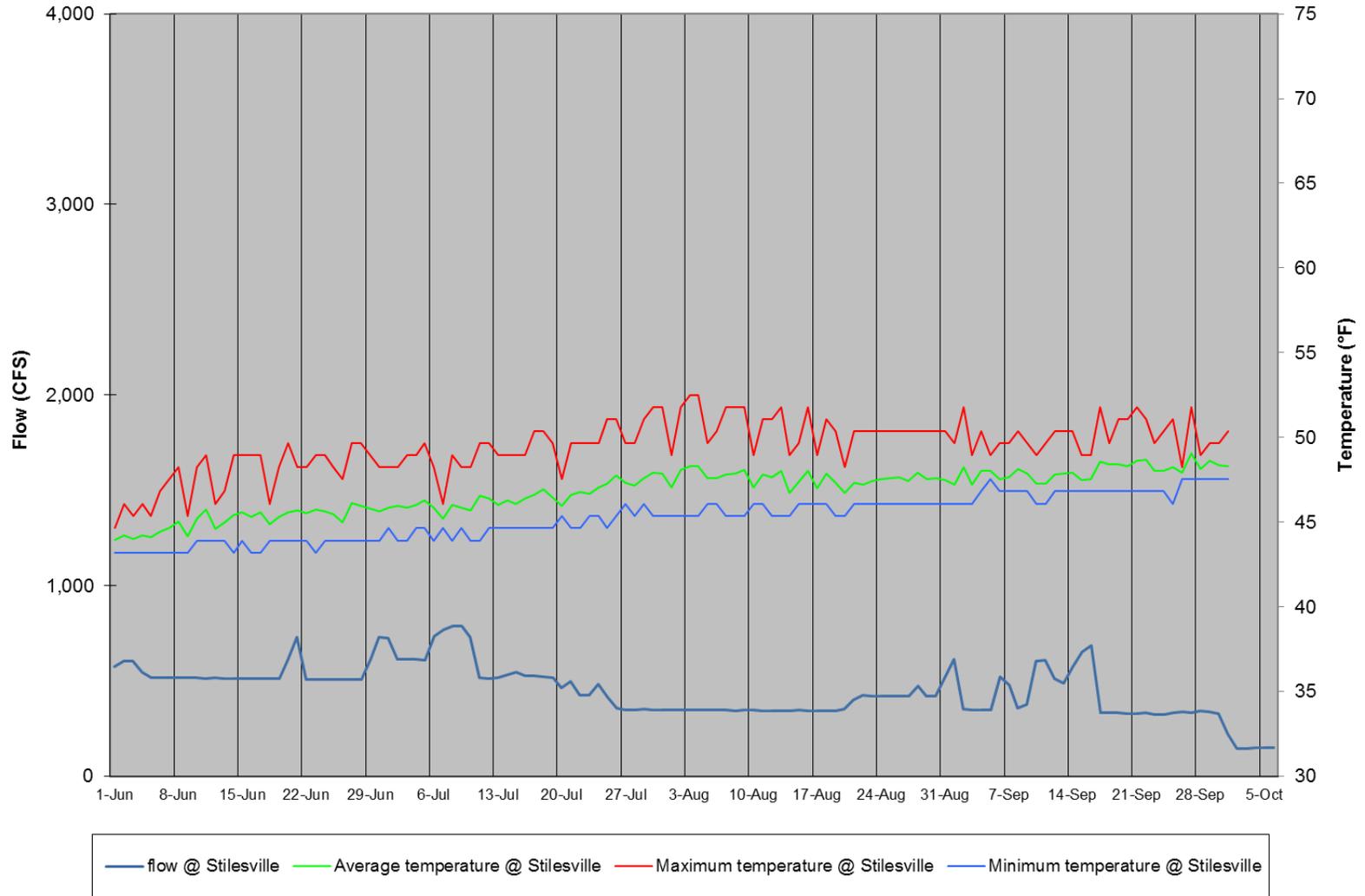
Maxima, minima, and average summer water temperature profile for each temperature monitoring site, 2012

West Branch: Appendices 2A to 2J East Branch: Appendices 2K to 2S Neversink River:  
Appendices 2T to 2X  
Delaware River: Appendices 2Y to 2CC

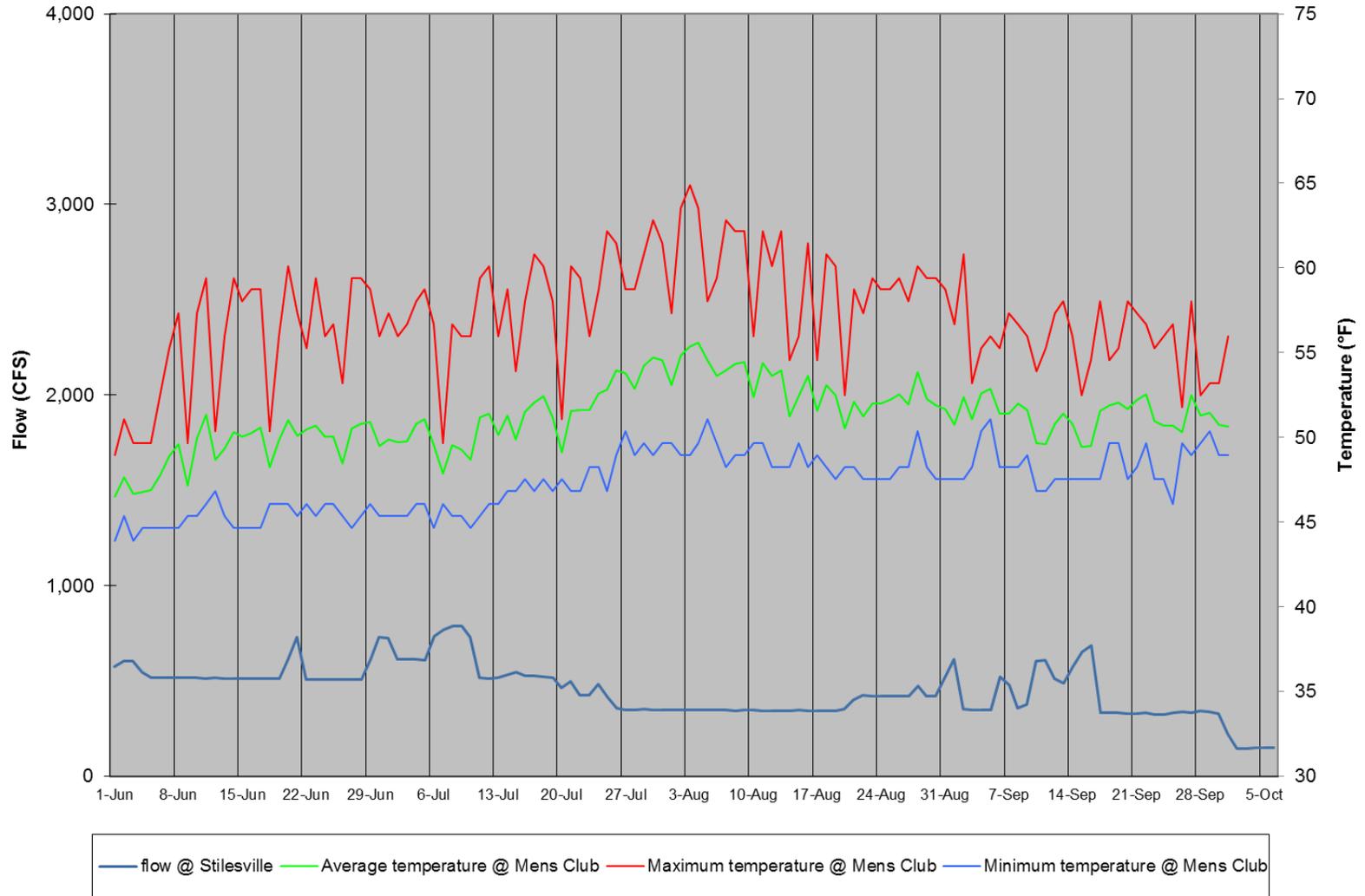
**Appendix 2A. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Stilesville, along with daily average flows at Stilesville, 2012.**



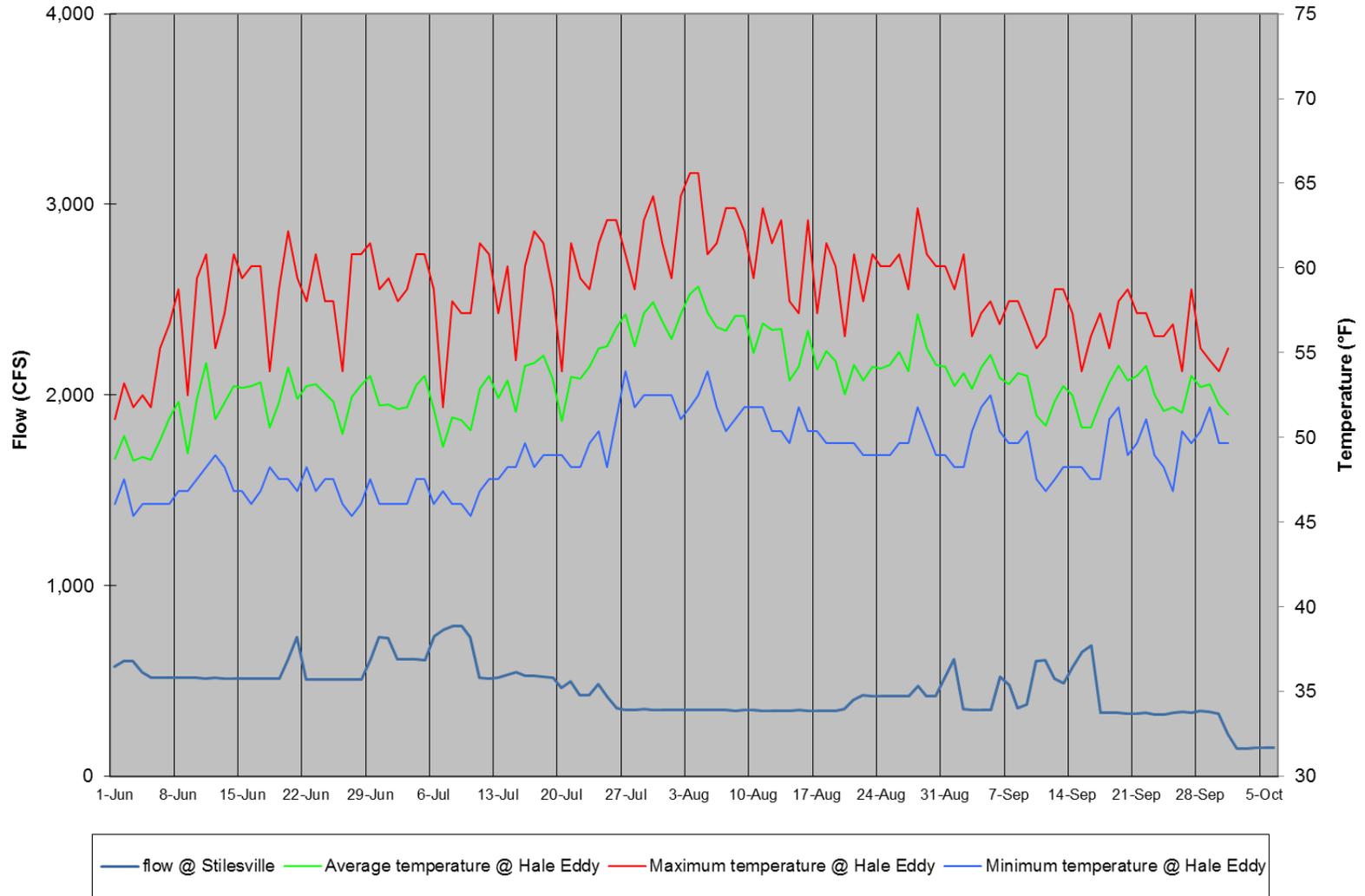
**Appendix 2B. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Stilesville, along with daily average flows at Stilesville, 2012.**



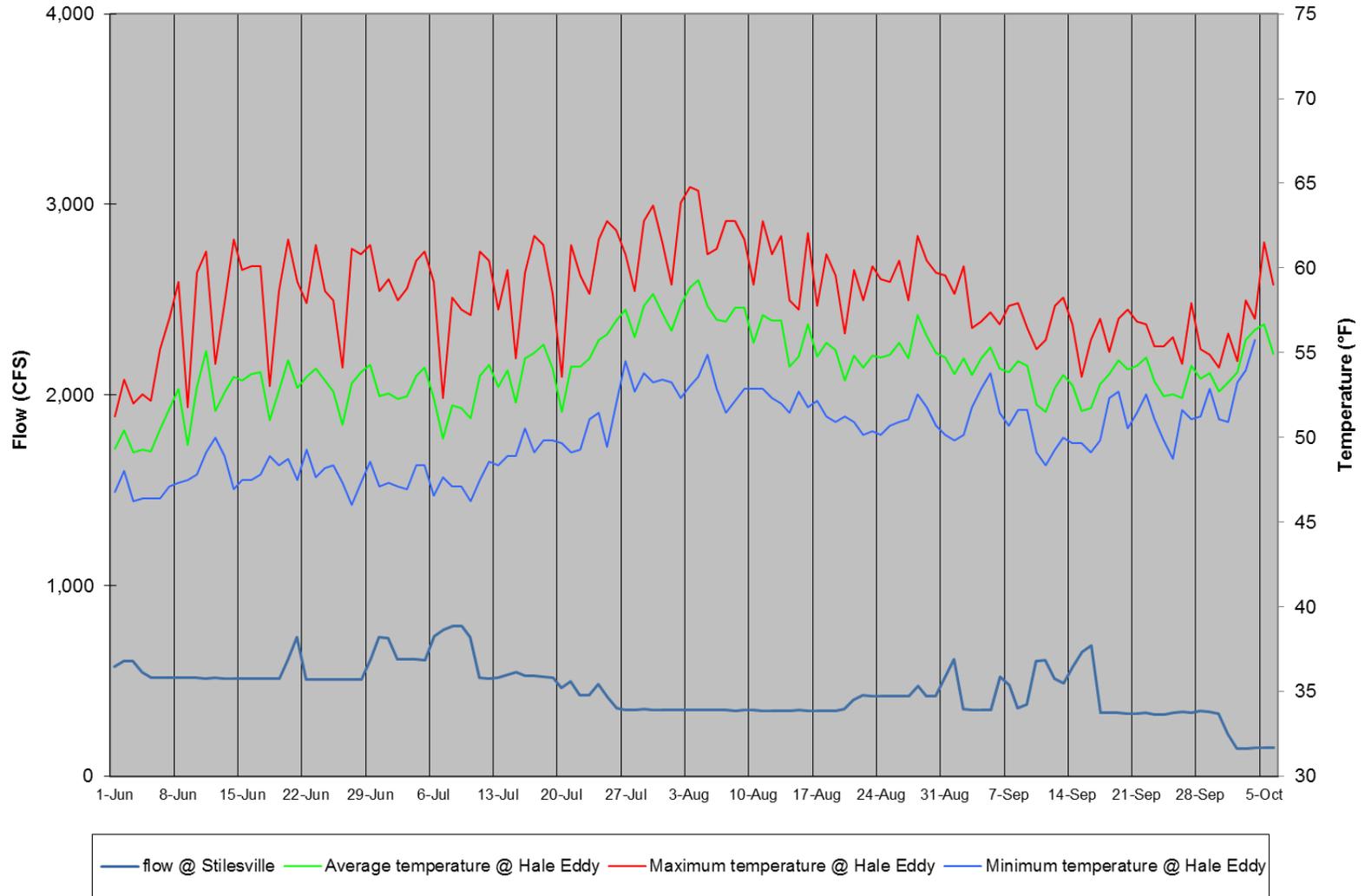
**Appendix 2C. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Men's Club, along with daily average flows at Stilesville, 2012.**



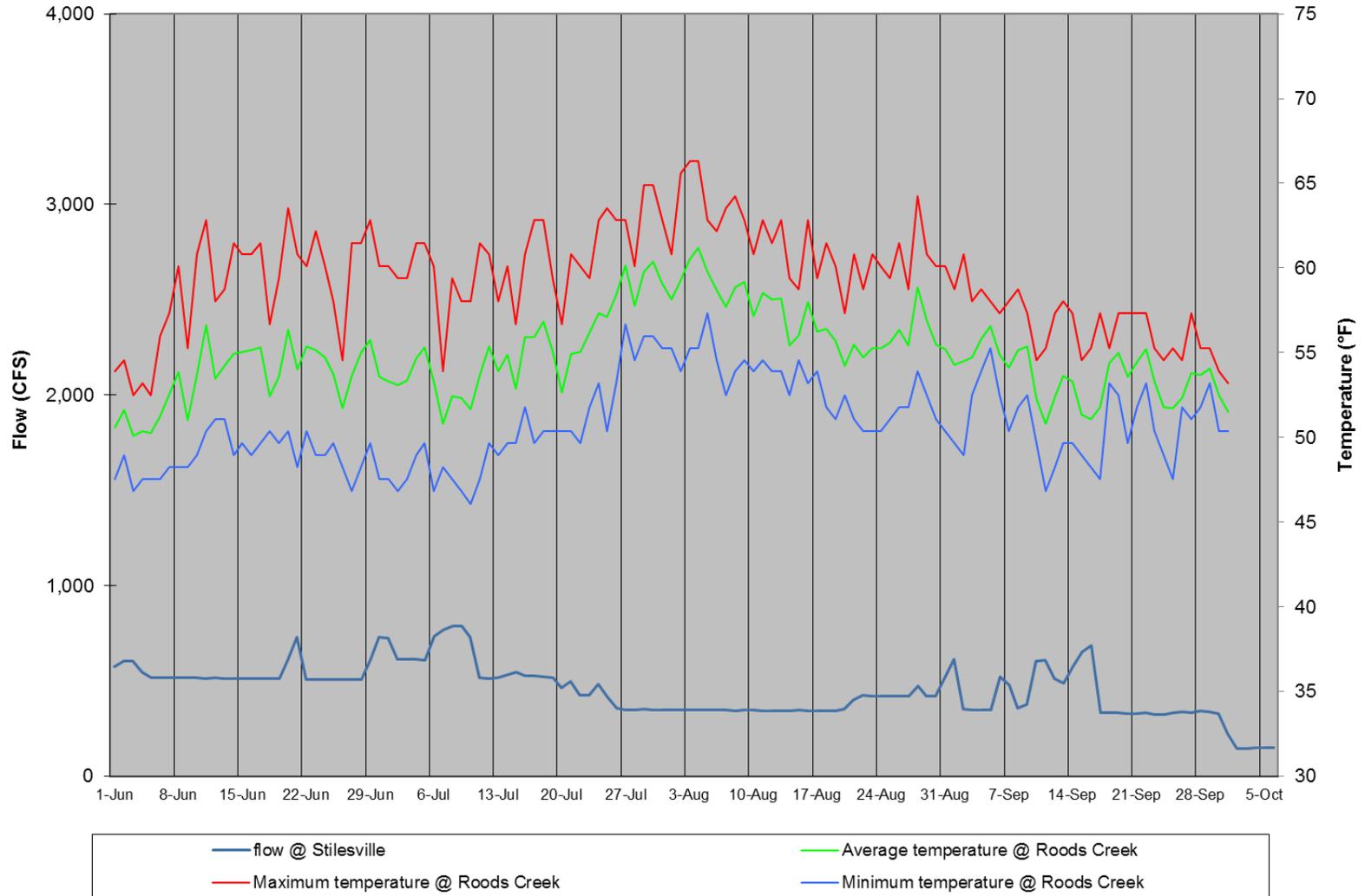
**Appendix 2D. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2012.**



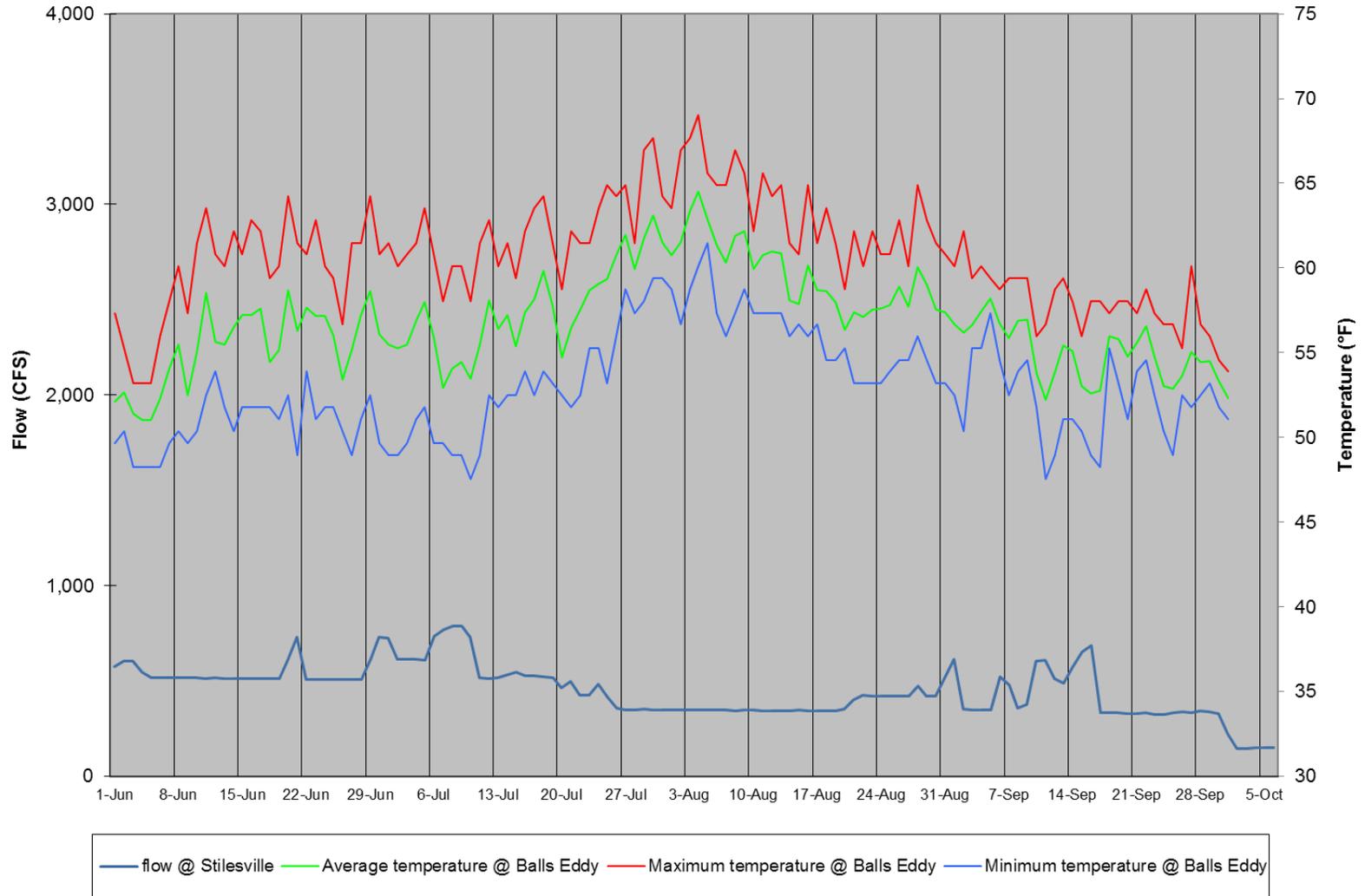
**Appendix 2E. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2012.**



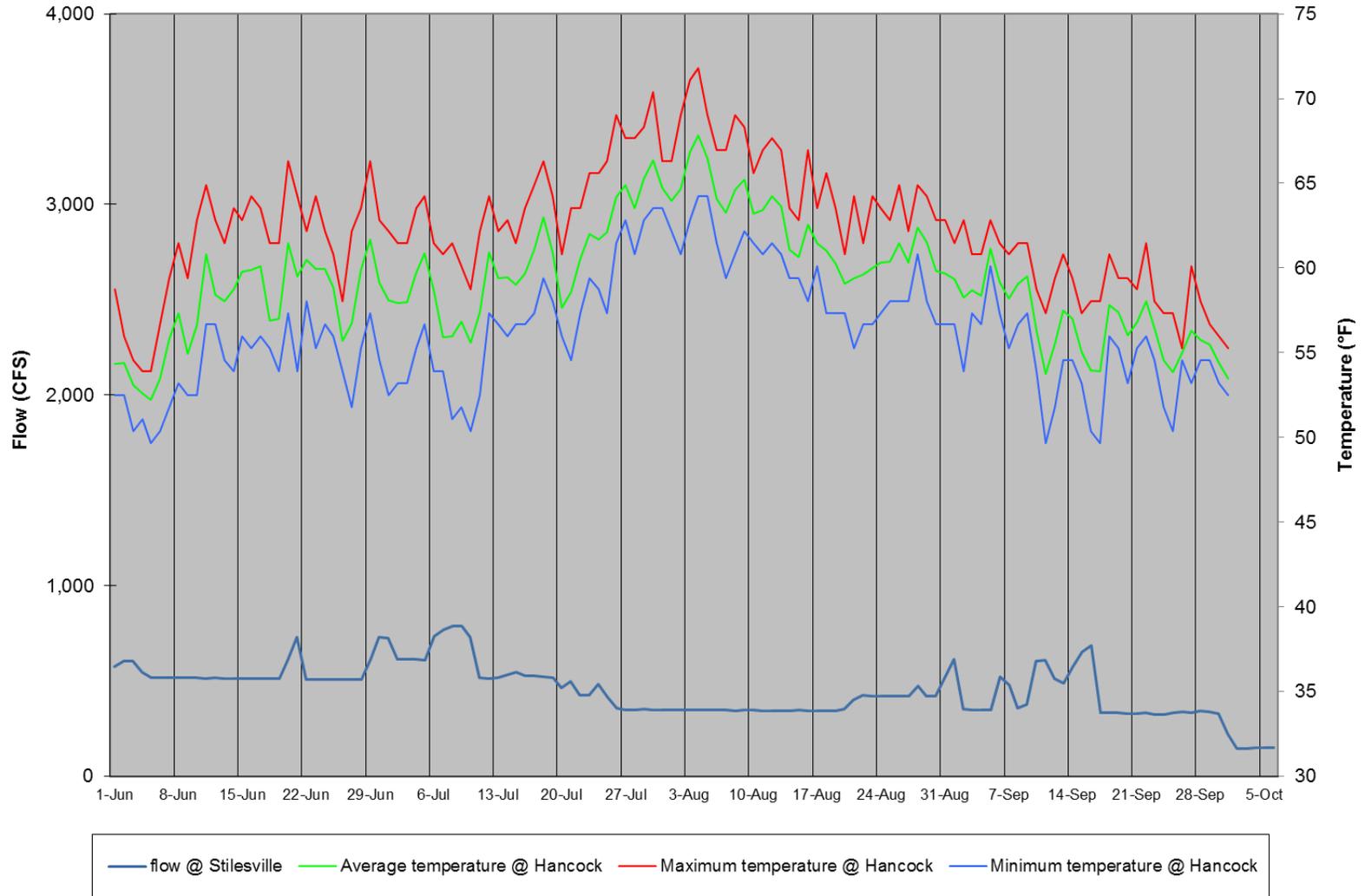
**Appendix 2F. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Roods Creek, along with daily average flows at Stilesville, 2012.**



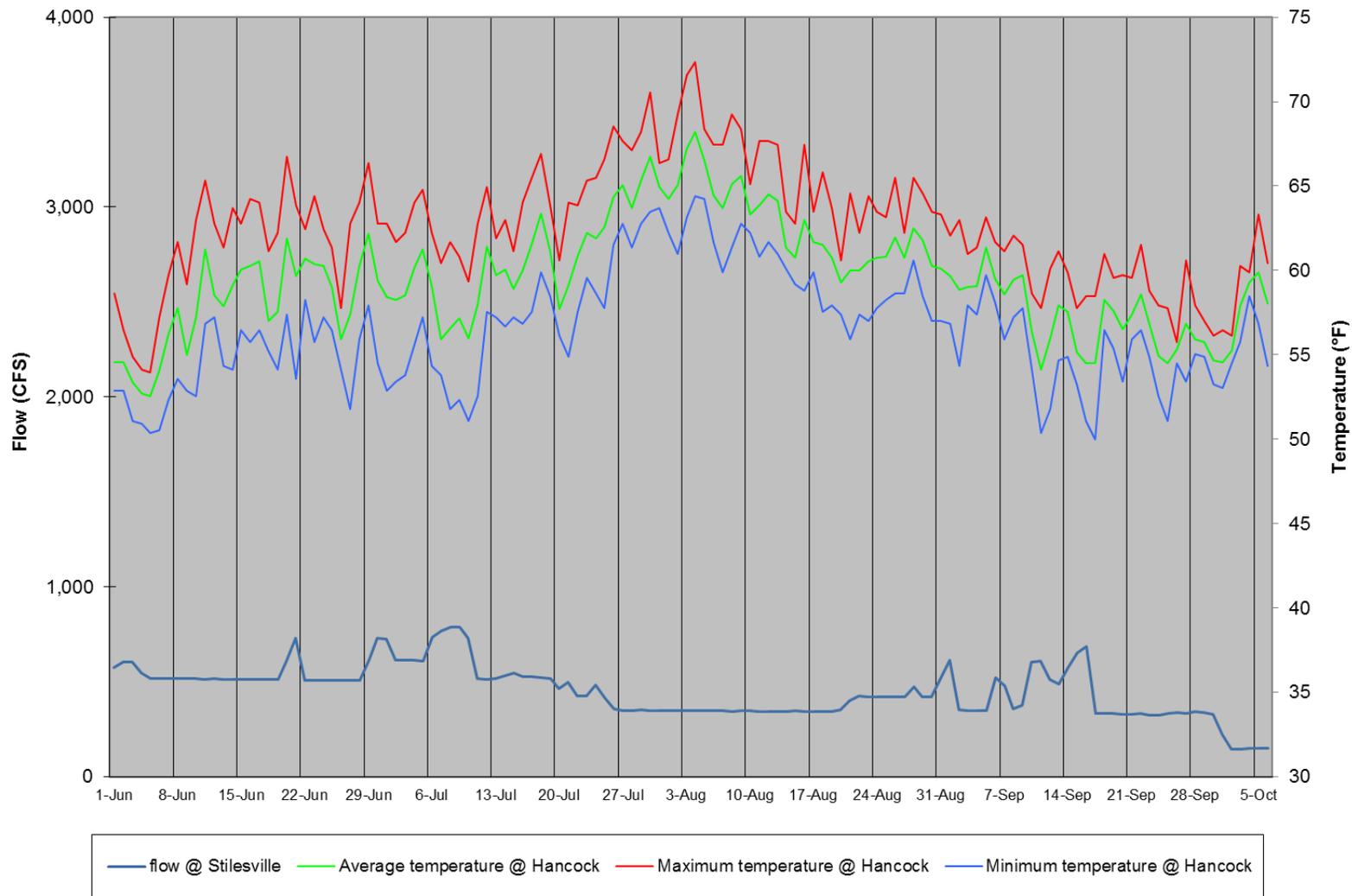
**Appendix 2G. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Balls Eddy, along with daily average flows at Stilesville, 2012.**



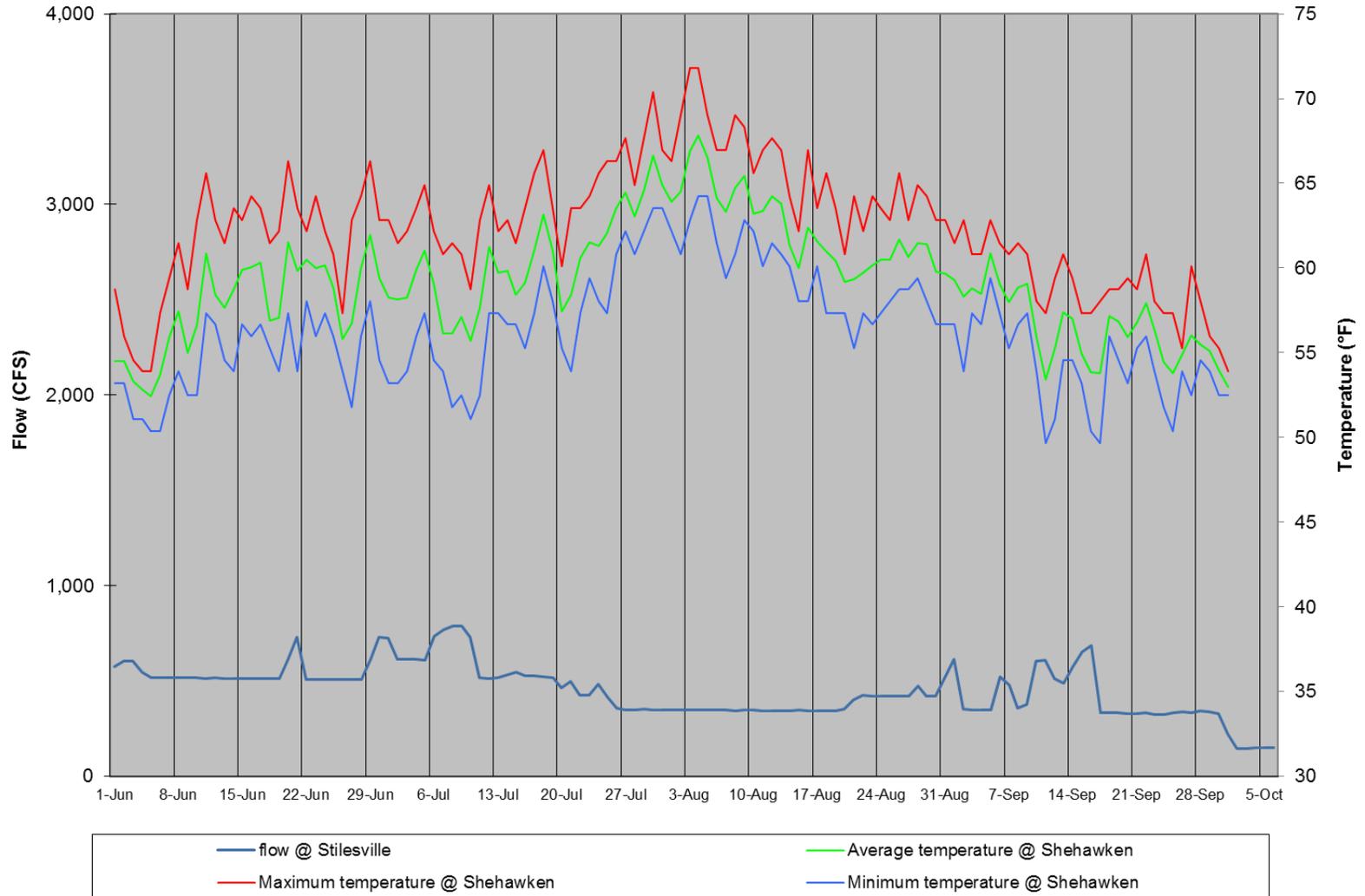
**Appendix 2H. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hancock, along with daily average flows at Stilesville, 2012.**



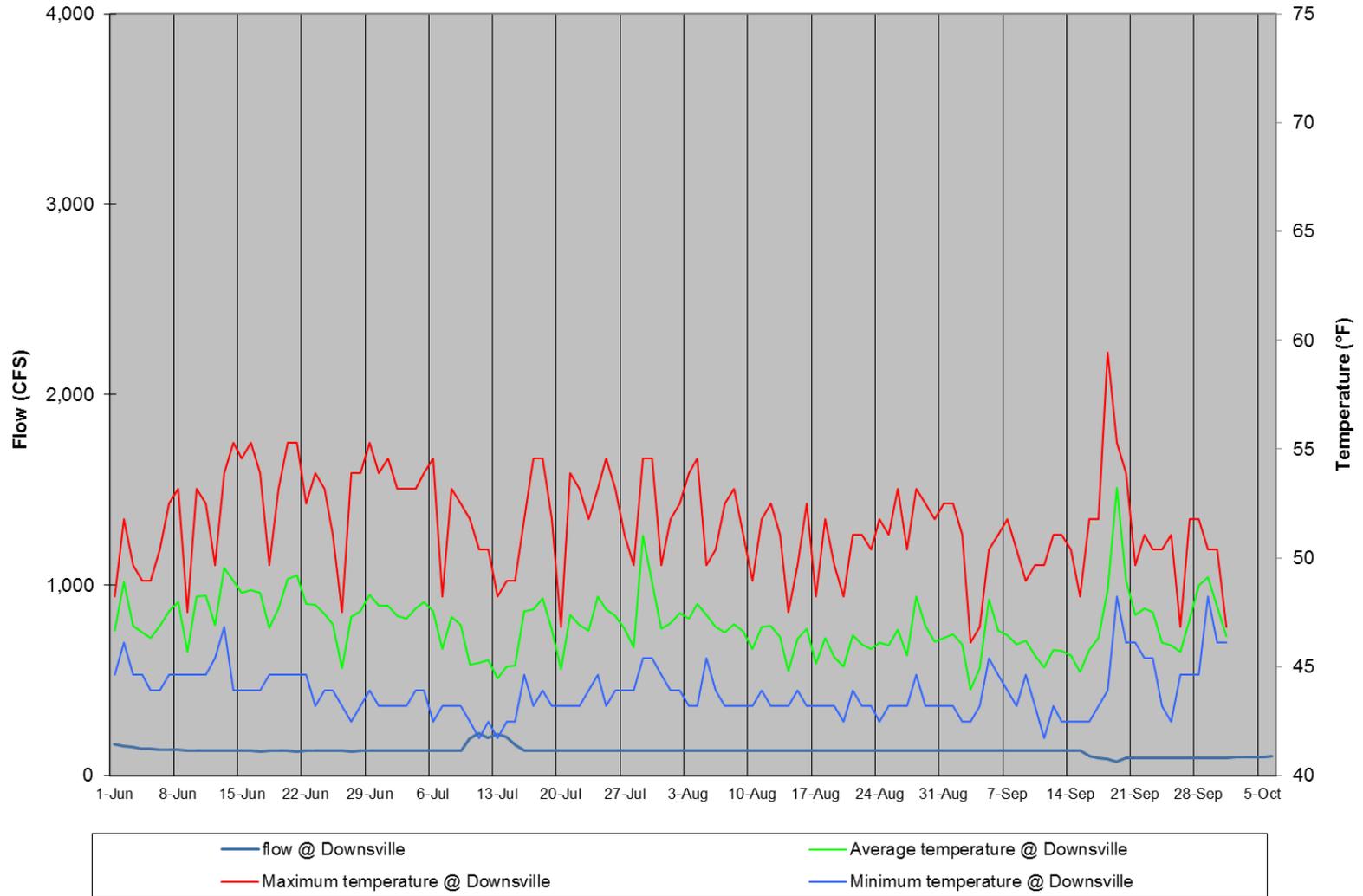
**Appendix 2I. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hancock, along with daily average flows at Stilesville, 2012.**



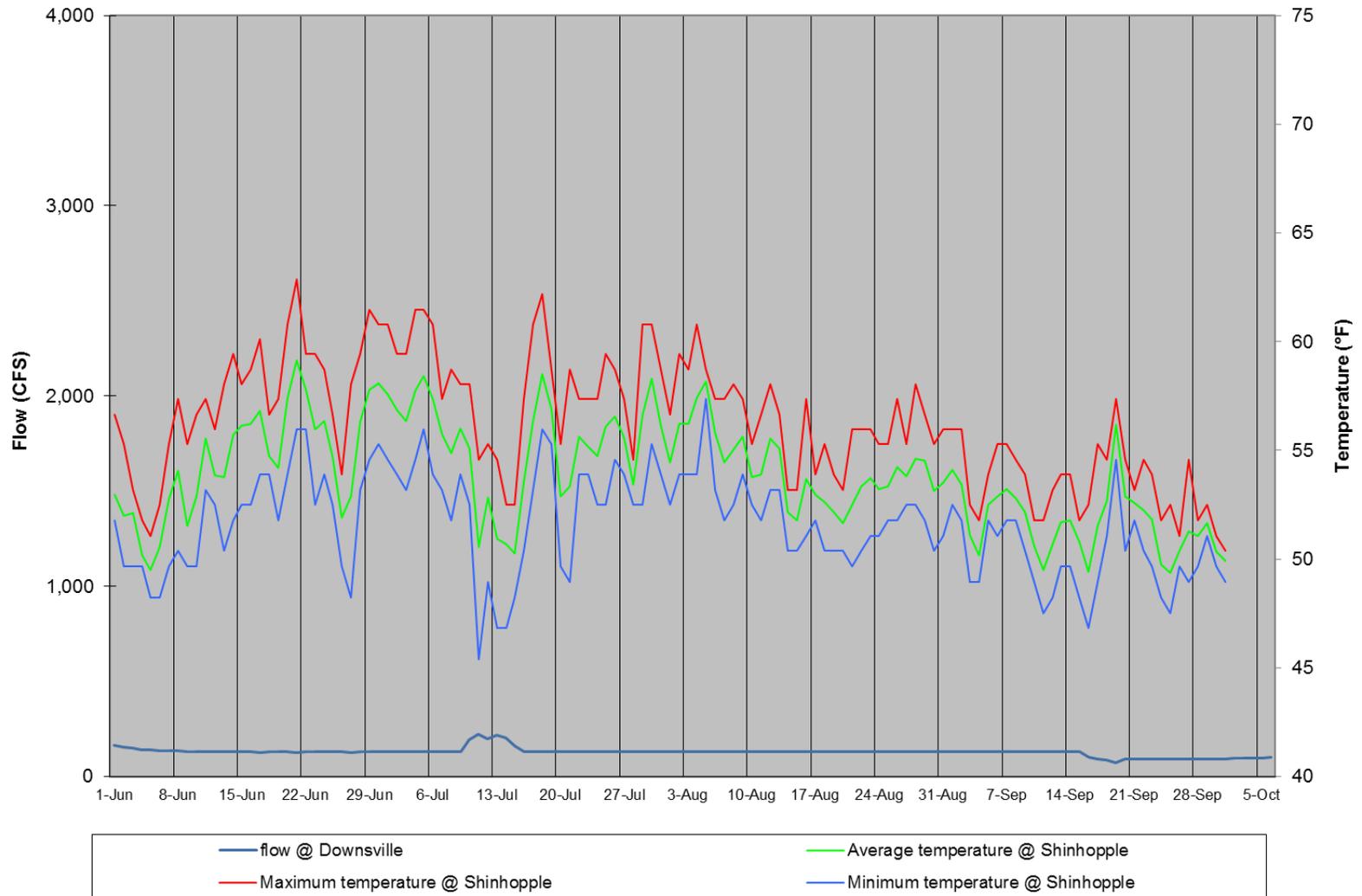
**Appendix 2J. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Shehawken, along with daily average flows at Stilesville, 2012.**



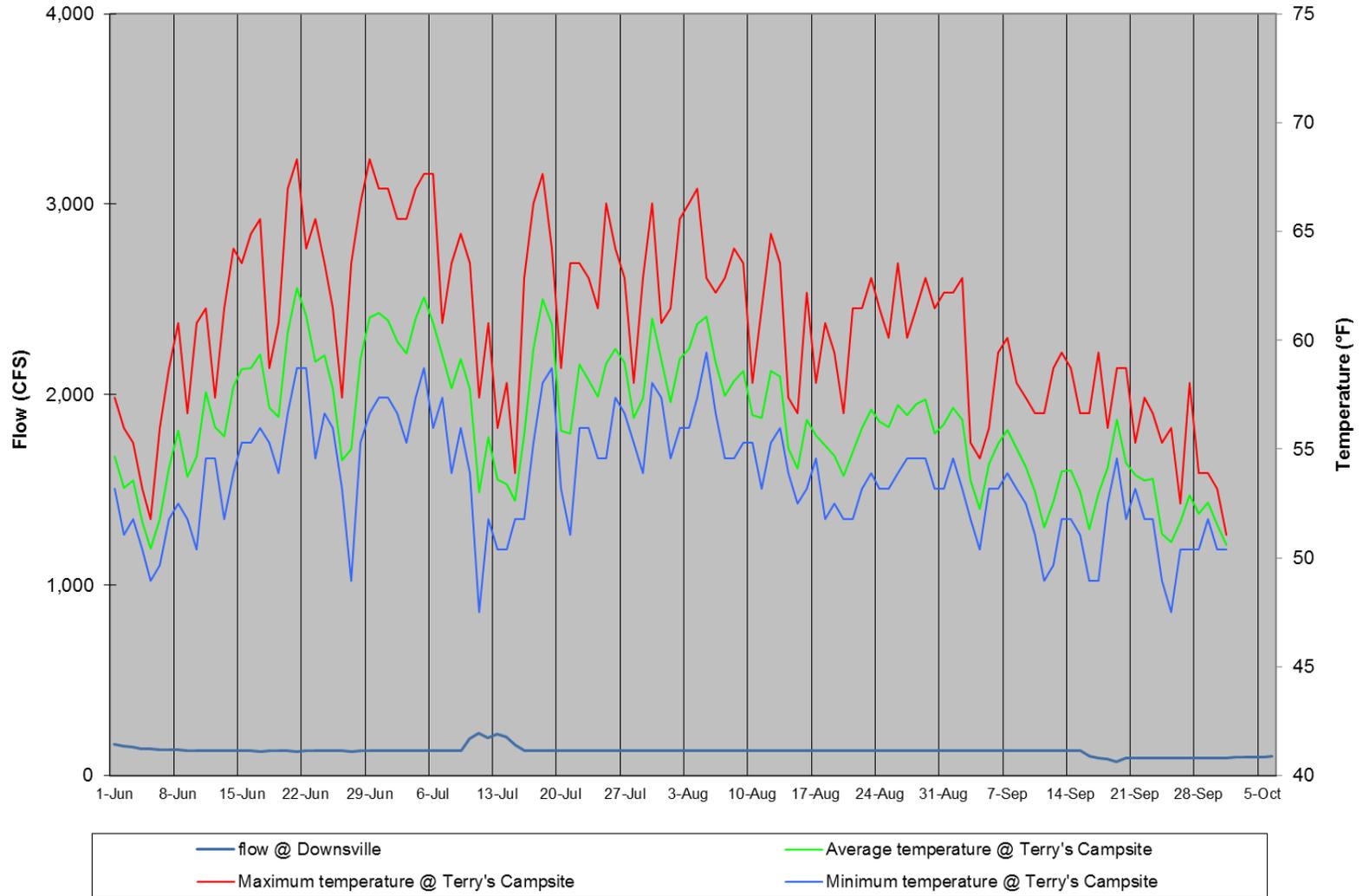
**Appendix 2K. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Downsville, along with daily average flows at Downsville, 2012.**



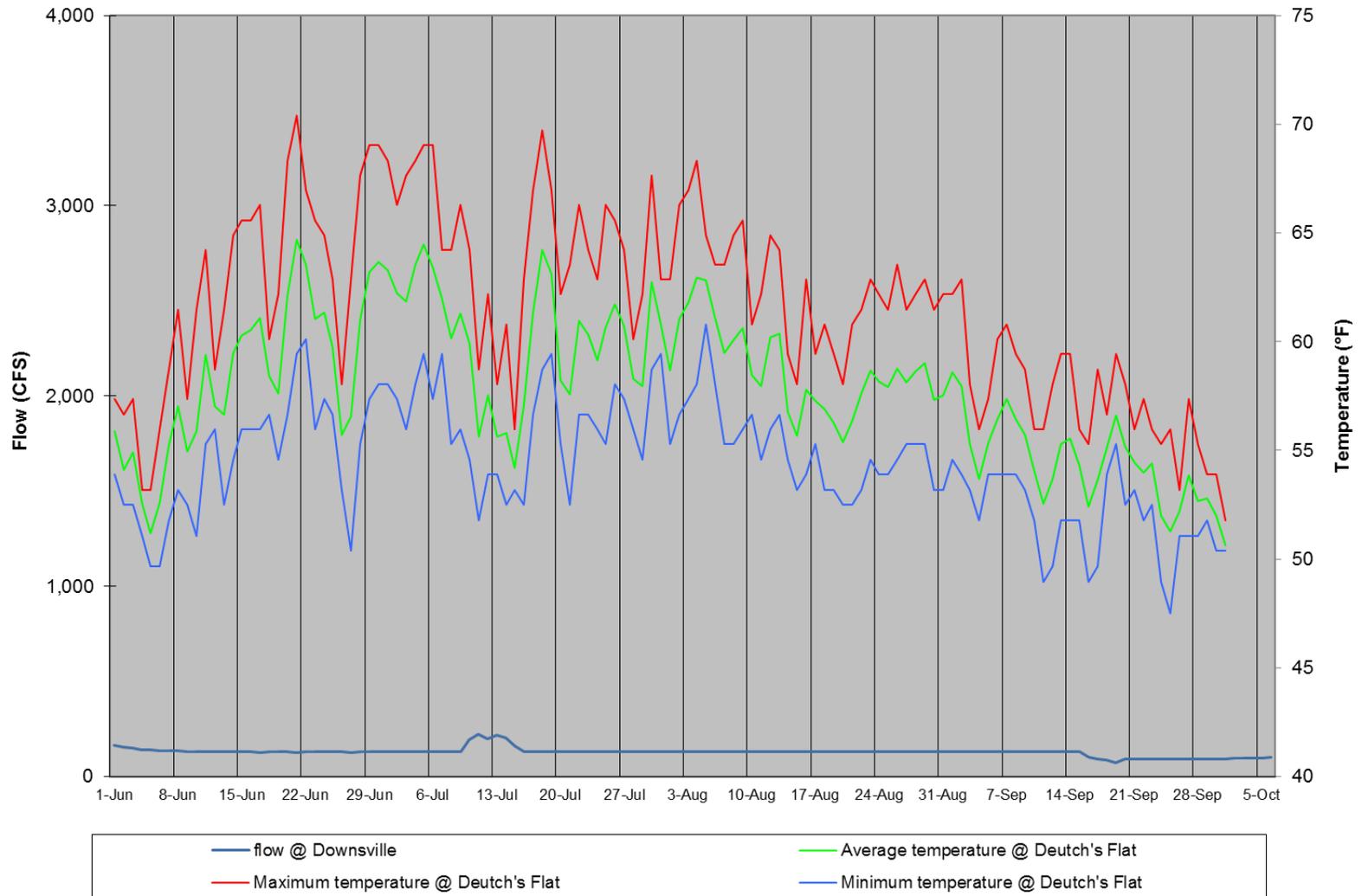
**Appendix 2L. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Shinhopple, along with daily average flows at Downsville, 2012.**



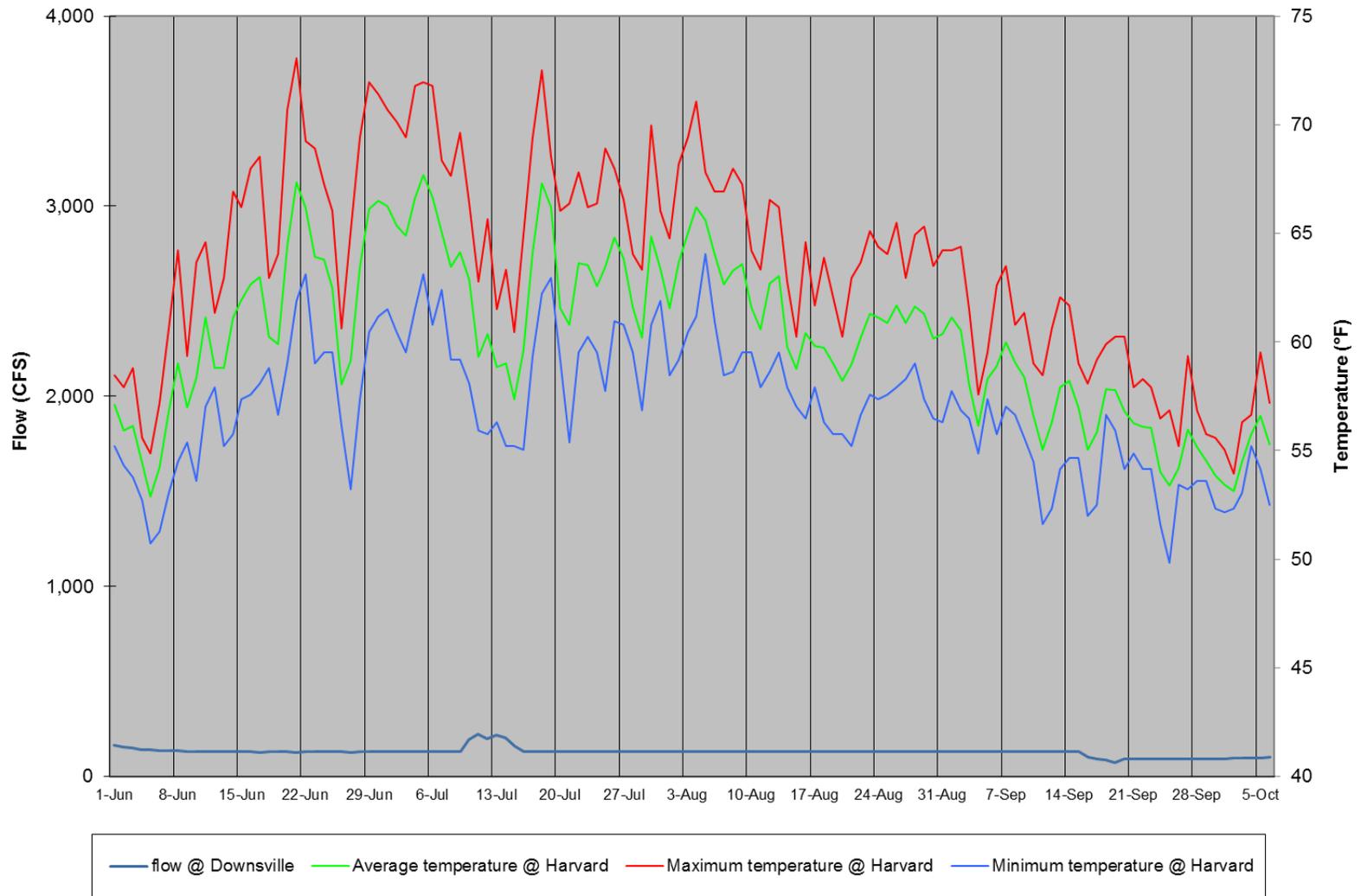
**Appendix 2M. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Terry's Campsite, along with daily average flows at Downsville, 2012.**



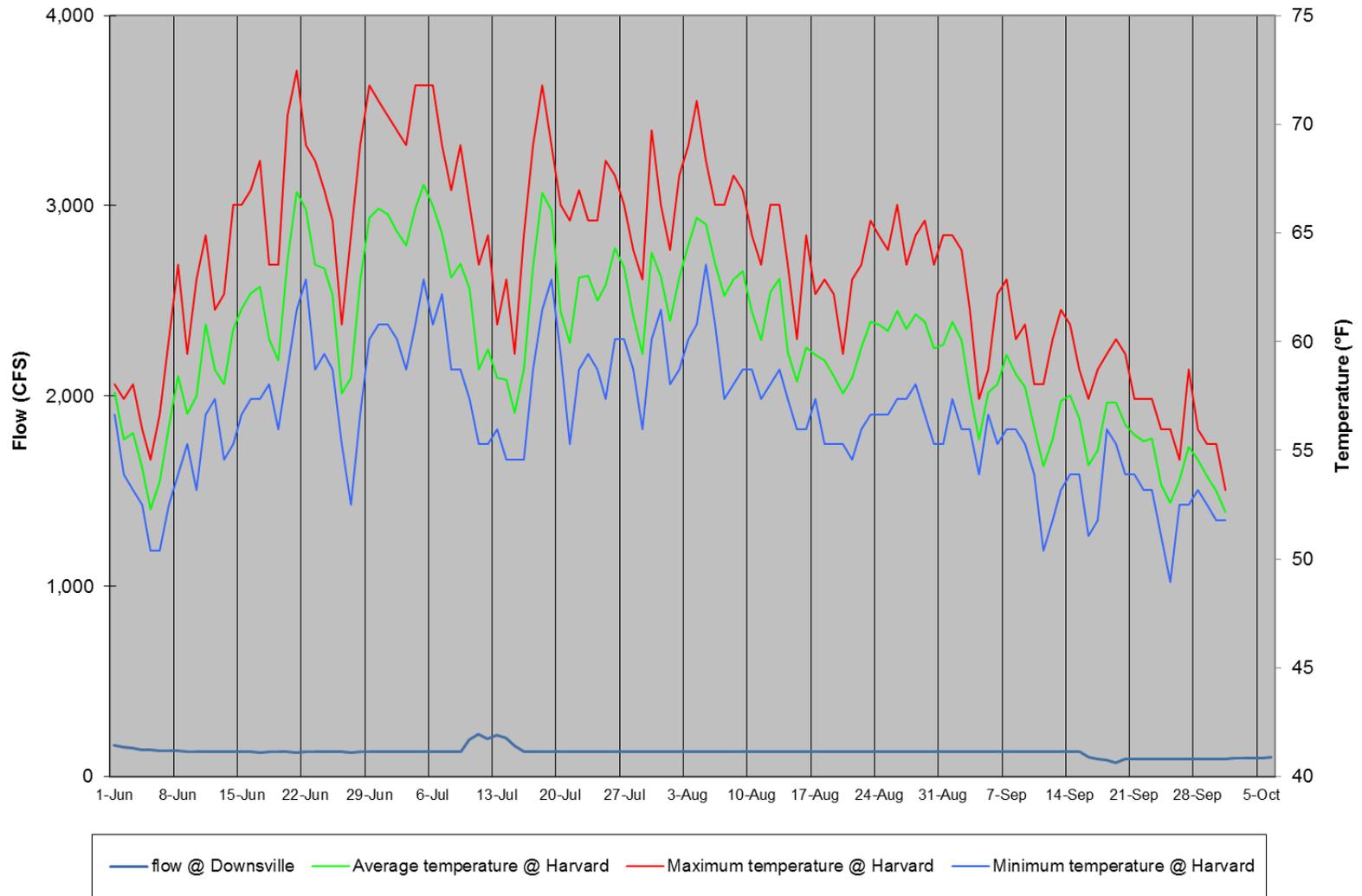
**Appendix 2N. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Deutch's Flat, along with daily average flows at Downsville, 2012.**



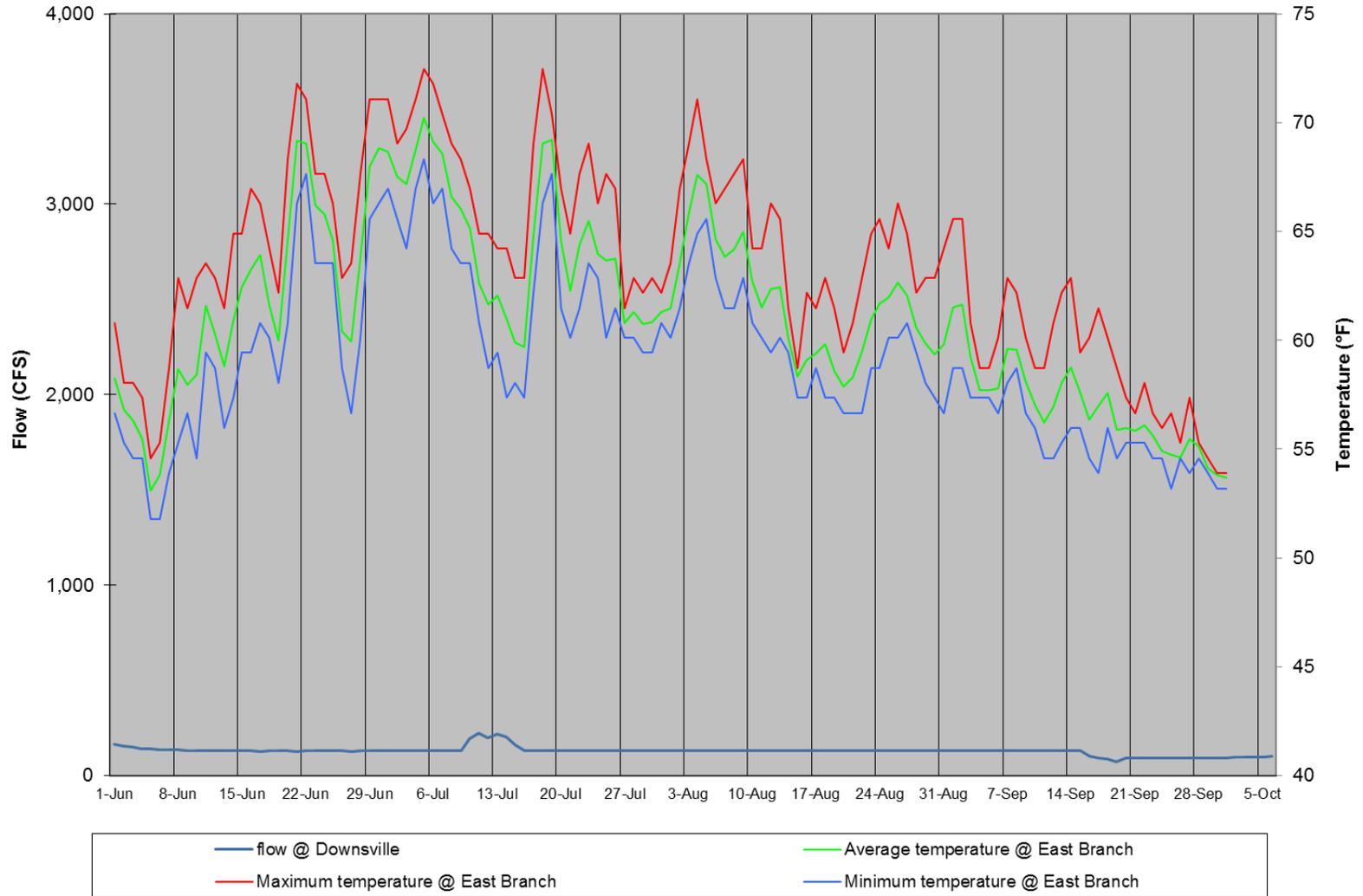
**Appendix 20. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Harvard, along with daily average flows at Downsville, 2012.**



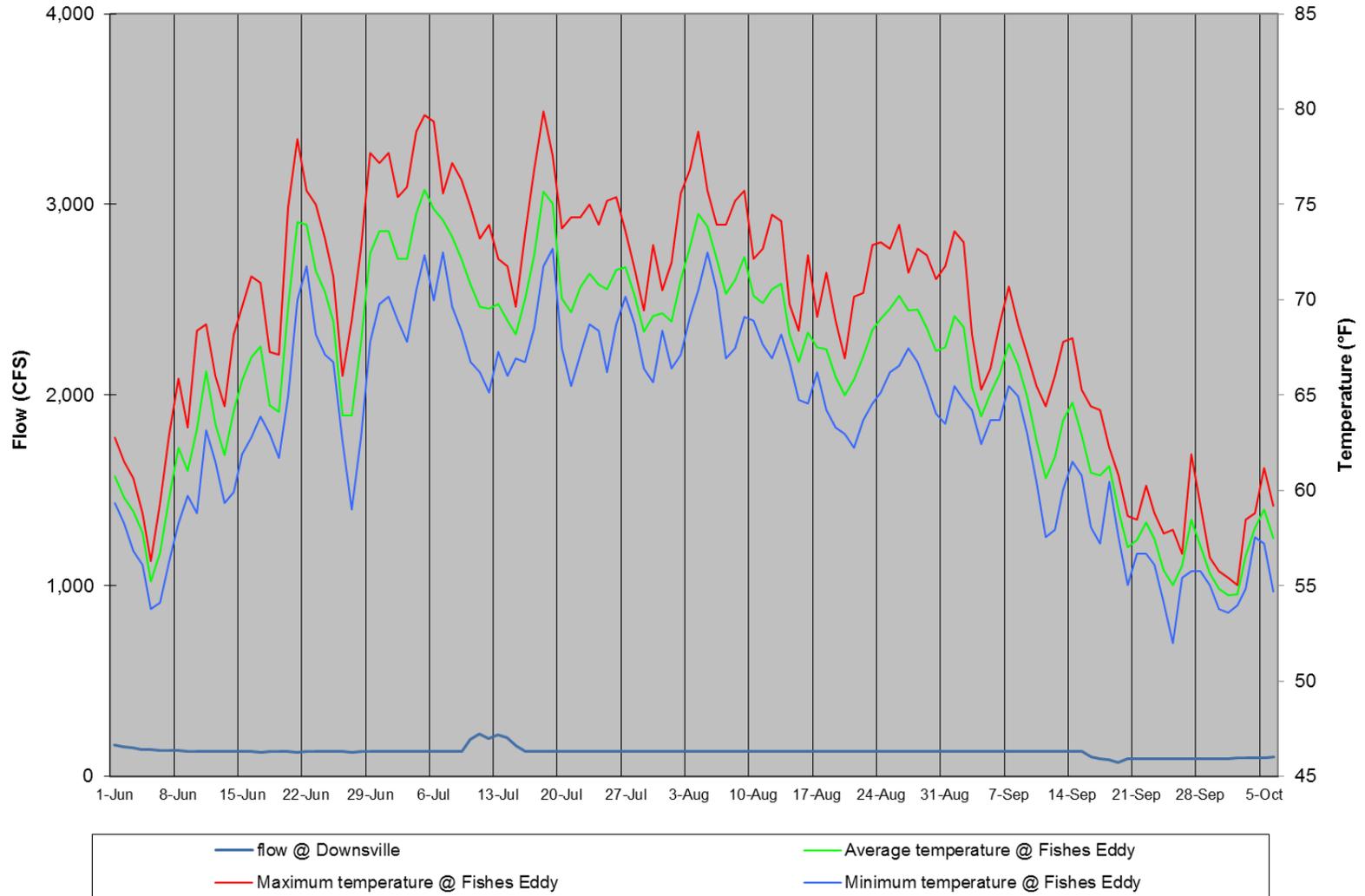
**Appendix 2P. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Harvard, along with daily average flows at Downsville, 2012.**



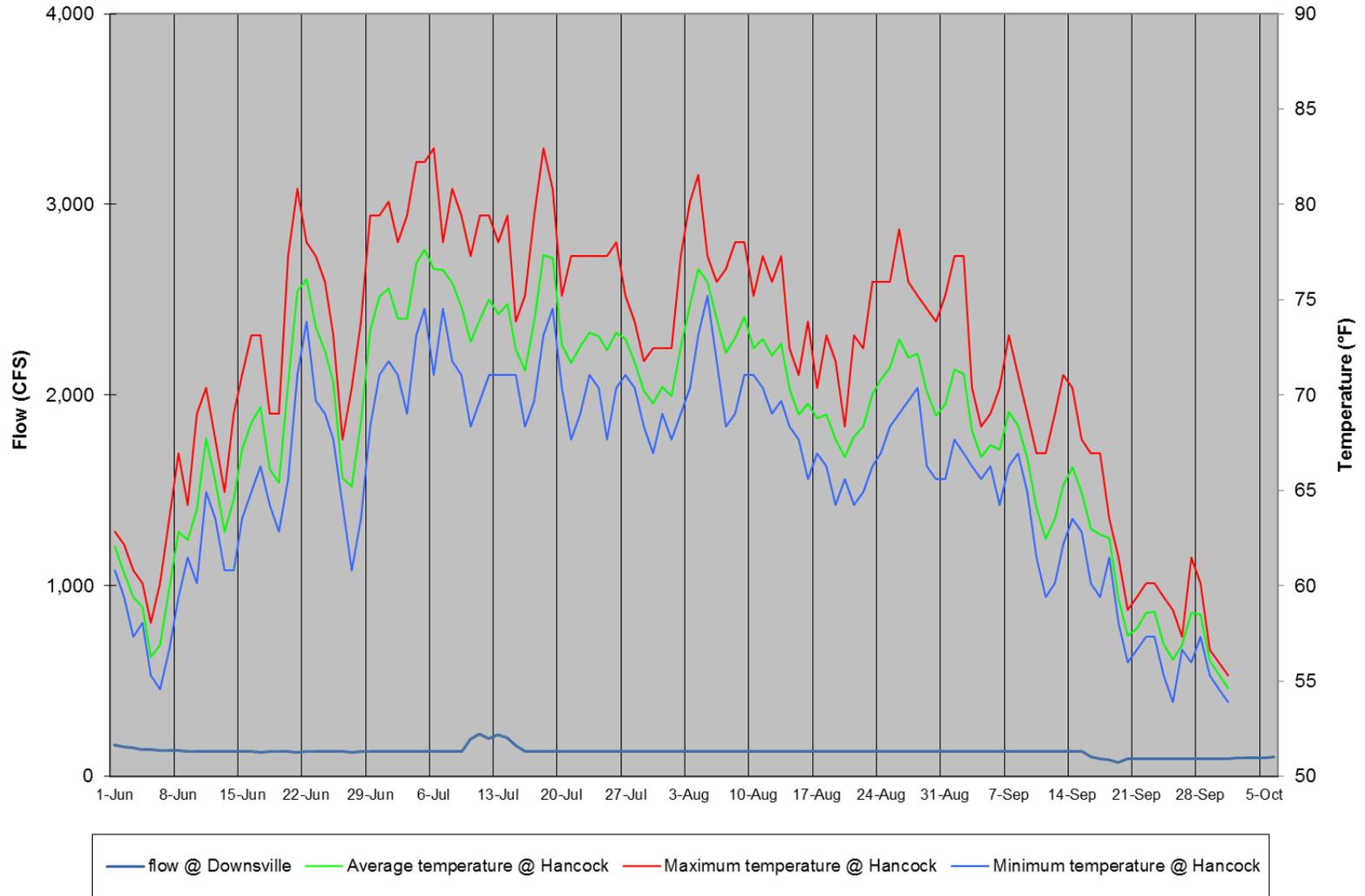
**Appendix 2Q. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at East Branch, along with daily average flows at Downsville, 2012.**



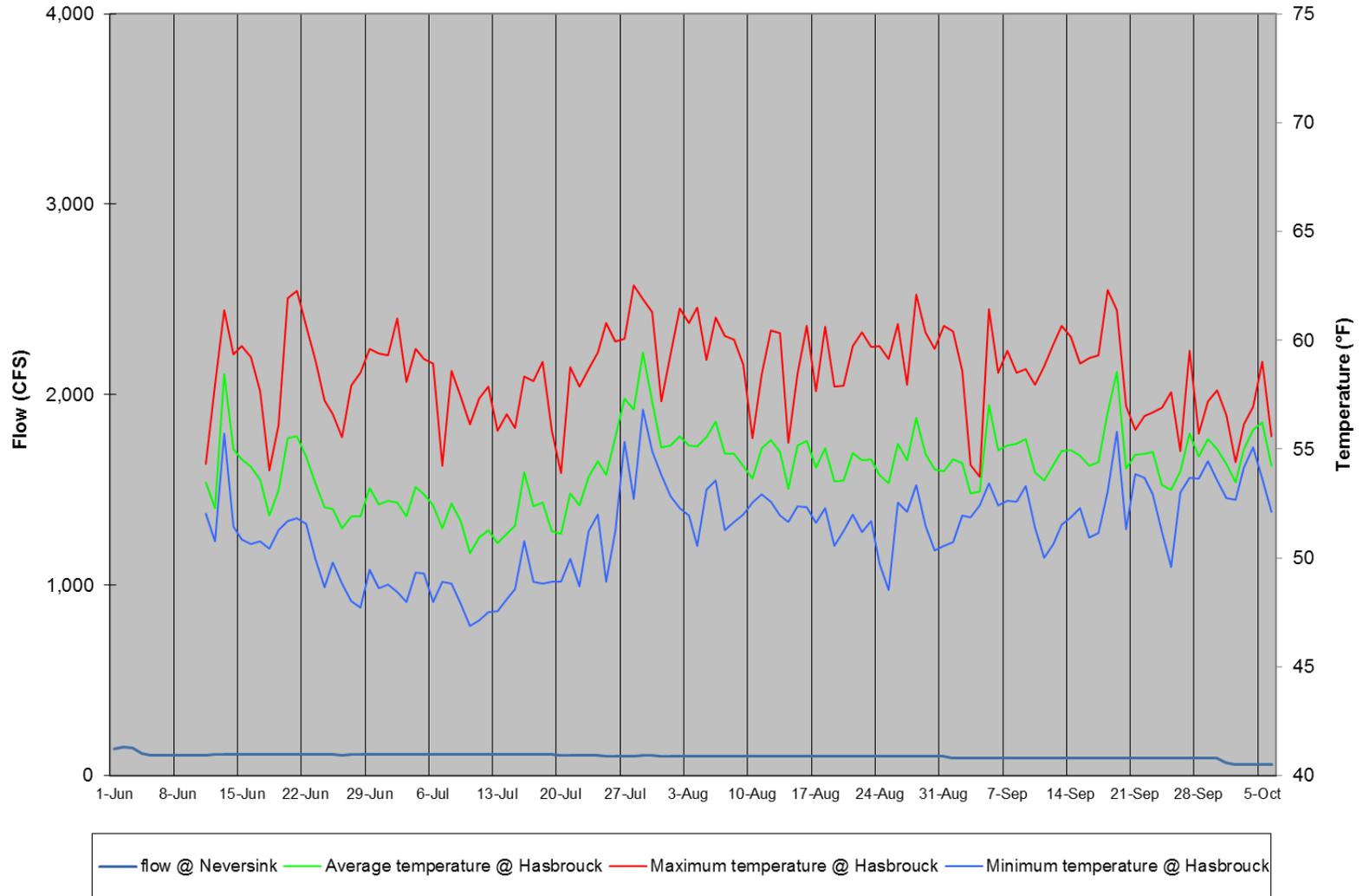
**Appendix 2R. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Fishes Eddy, along with daily average flows at Downsville, 2012.**



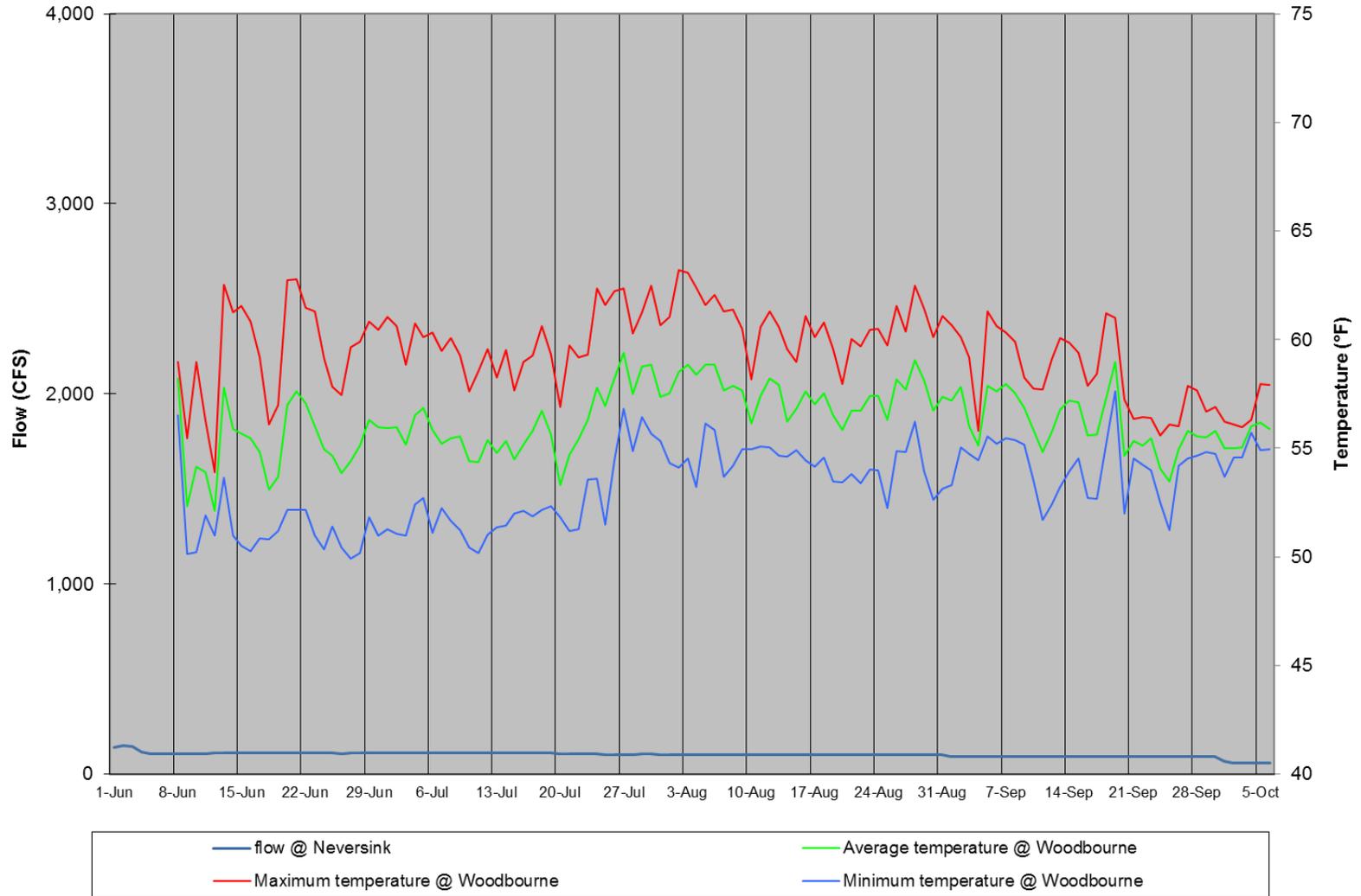
**Appendix 2S. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Hancock, along with daily average flows at Downsville, 2012.**



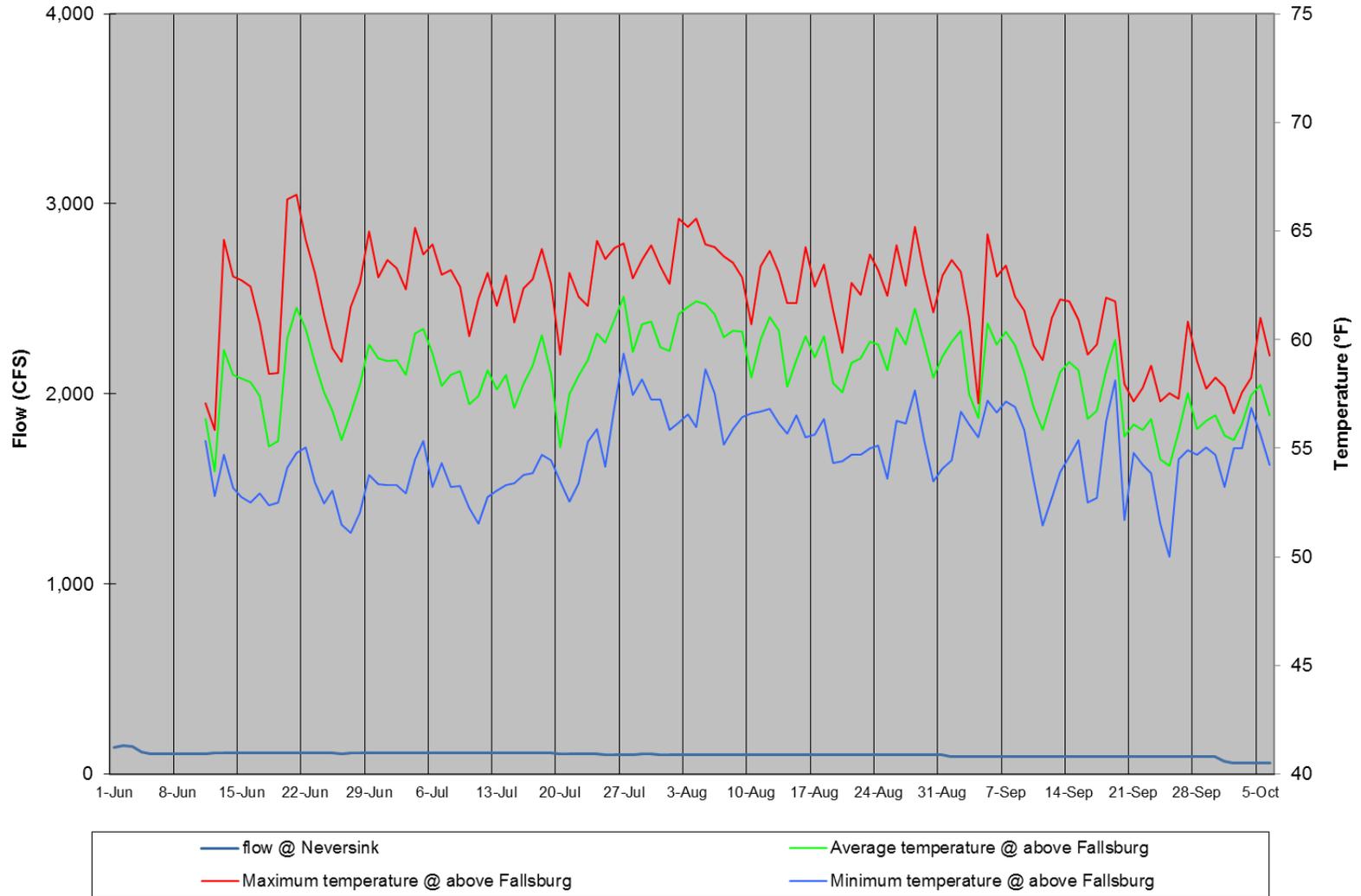
**Appendix 2T. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Hasbrouck, along with daily average flows at Neversink, 2012.**



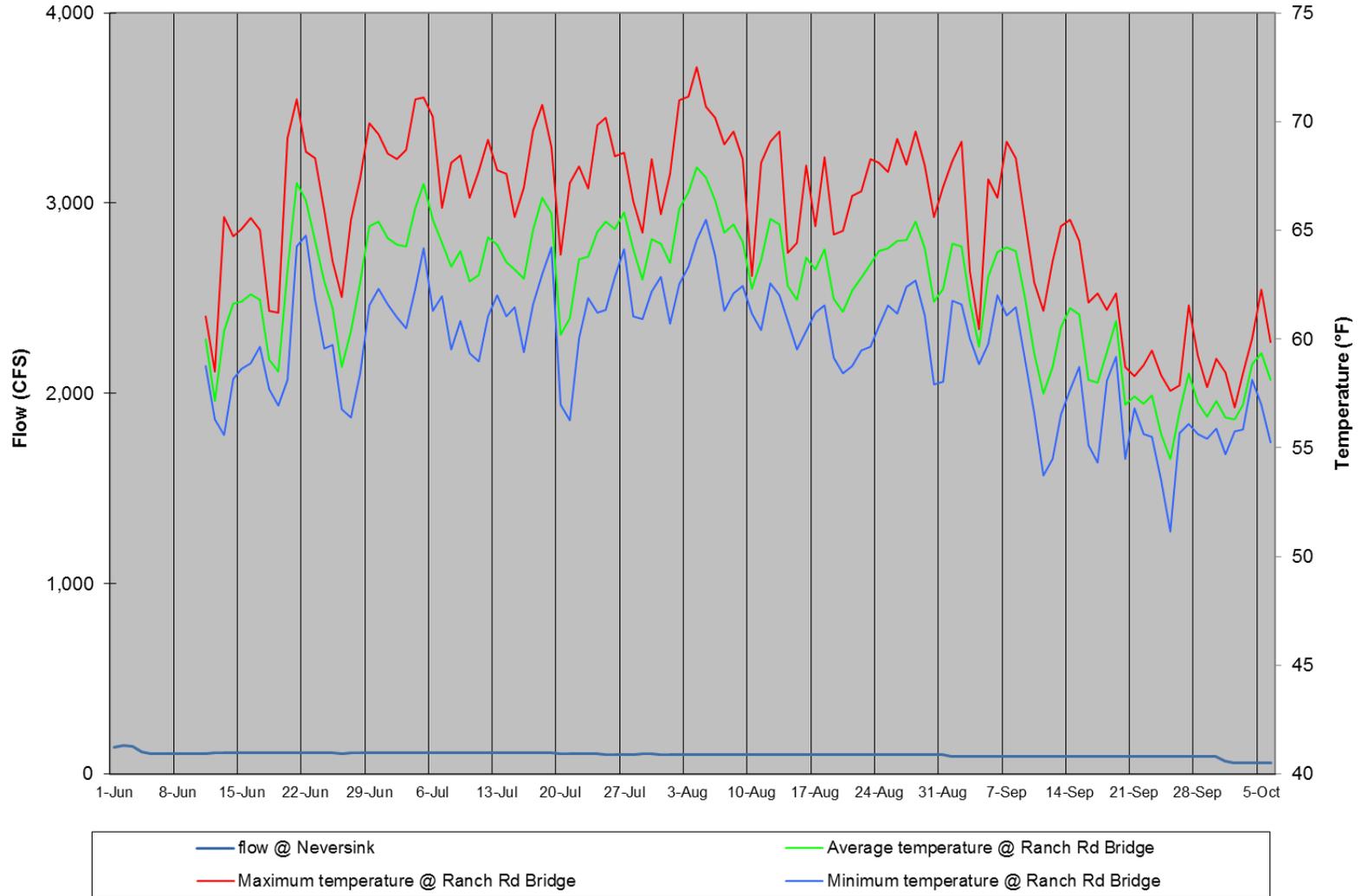
**Appendix 2U. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Woodbourne, along with daily average flows at Neversink, 2012.**



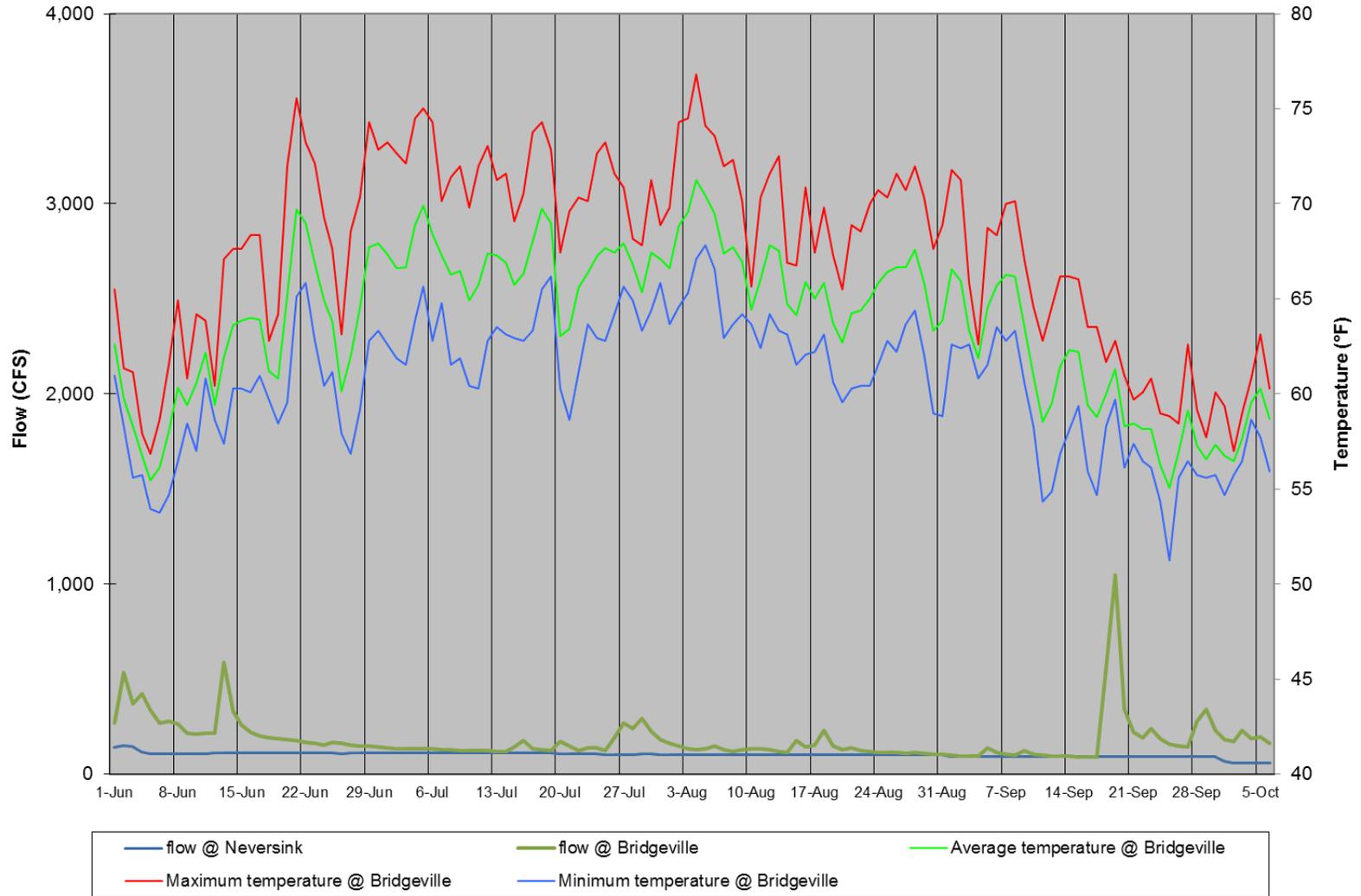
**Appendix 2V. Summer daily average, maximum, and minimum water temperature profiles on the Neversink just above Fallsburg, along with daily average flows at Neversink, 2012.**



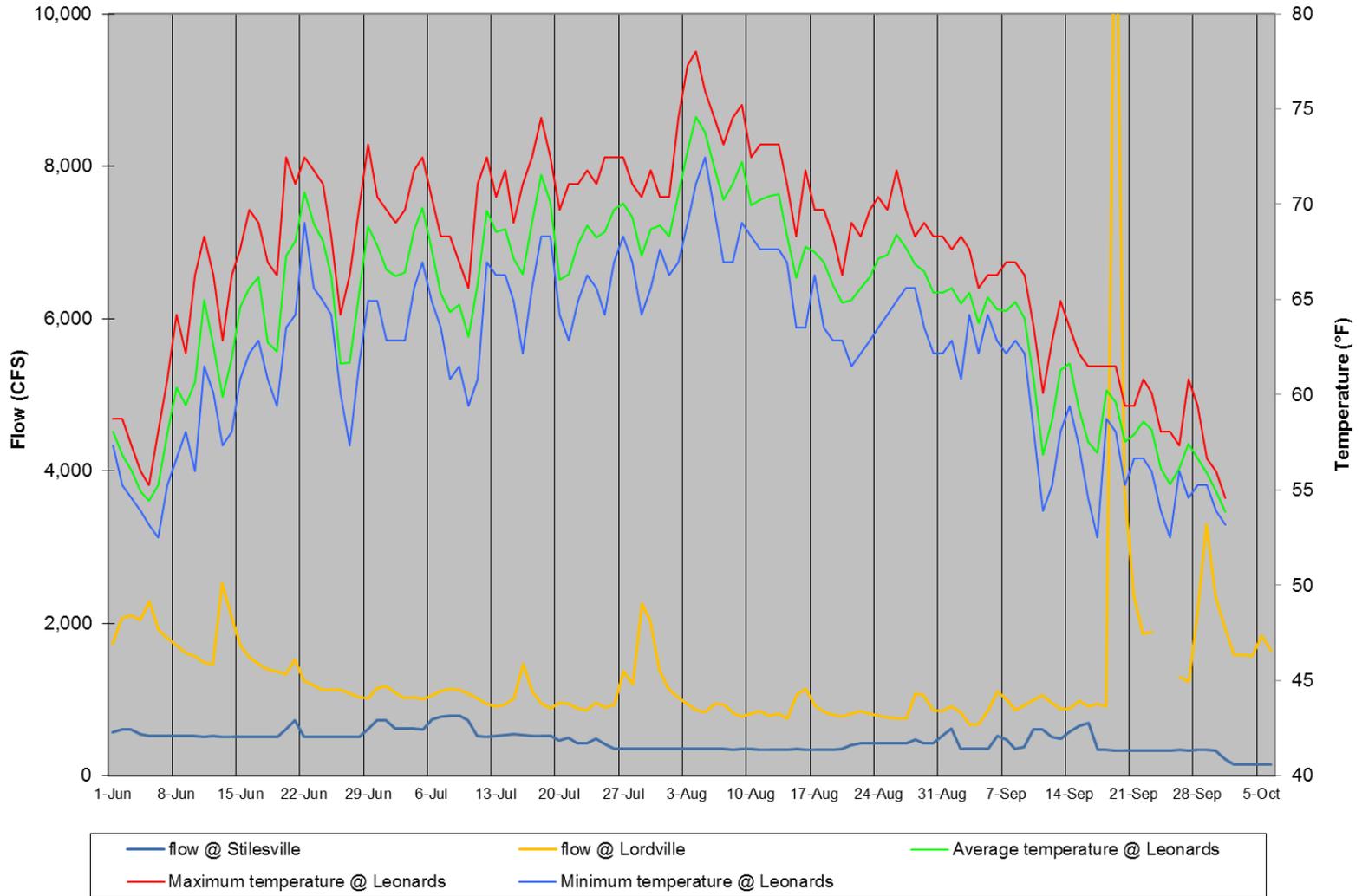
**Appendix 2W. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Ranch Rd bridge, along with daily average flows at Neversink, 2012.**



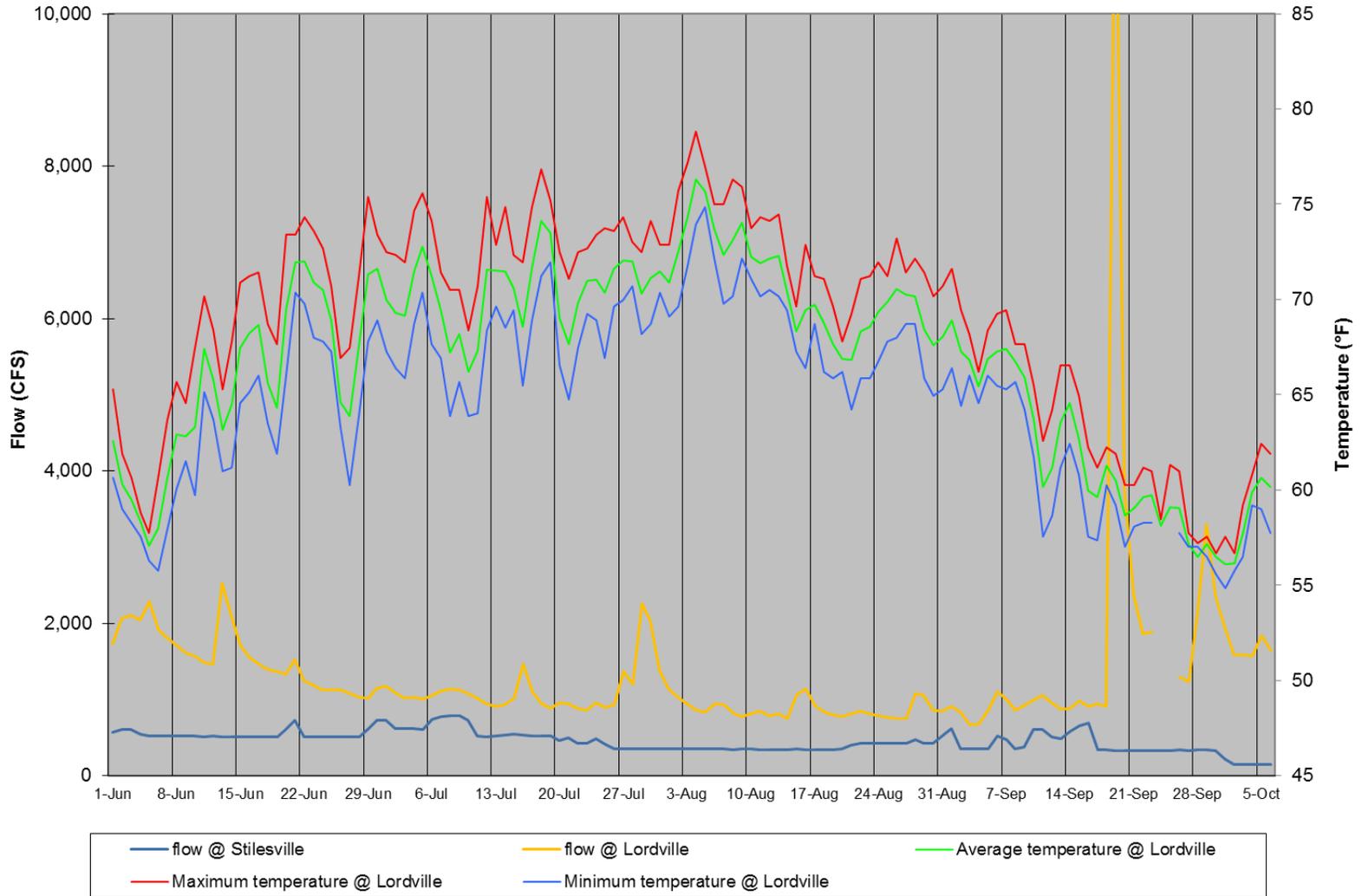
**Appendix 2X. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Bridgeville, along with daily average flows at Bridgeville & Neversink, 2012.**



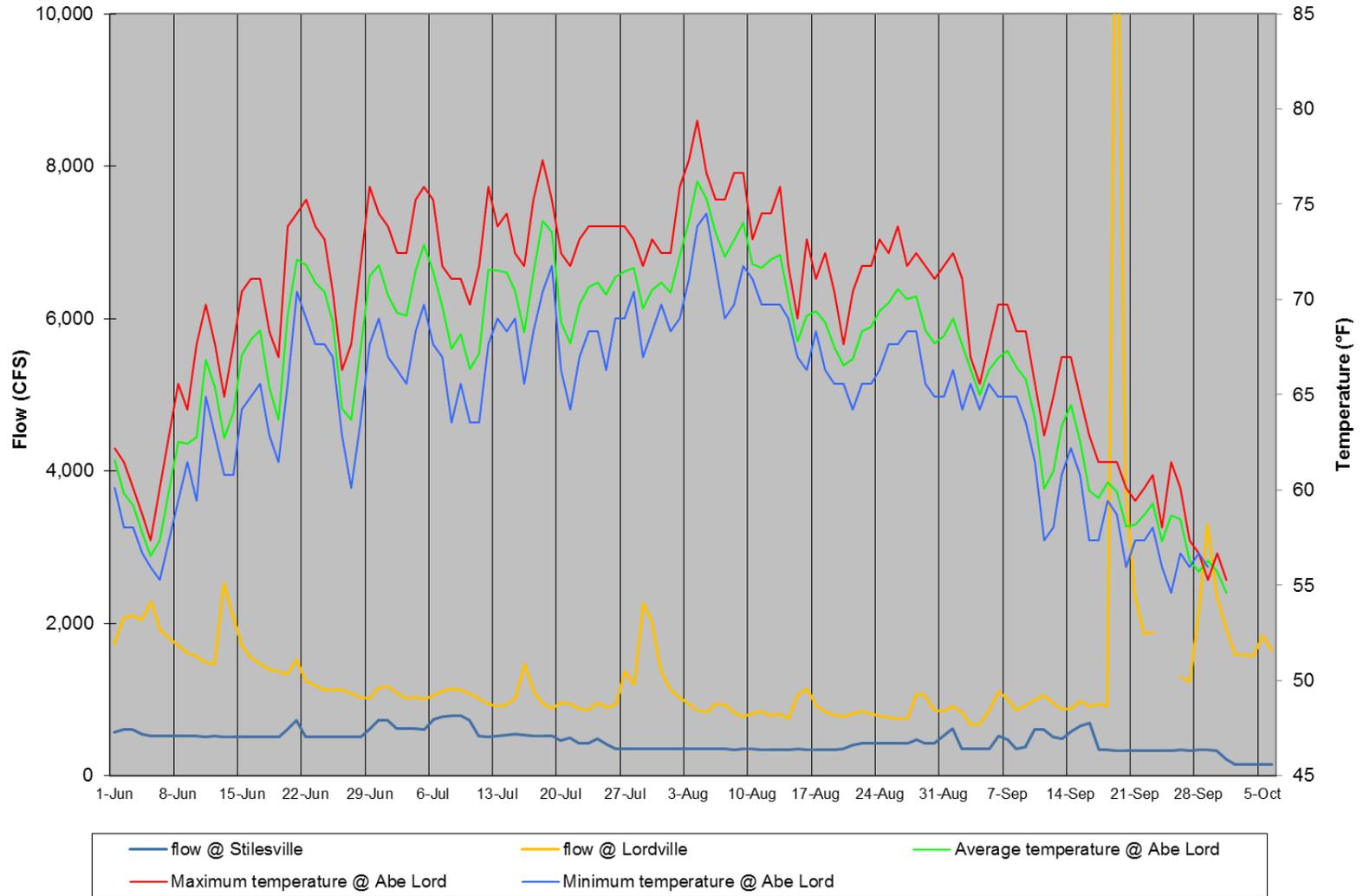
**Appendix 2Y. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Leonards, along with daily average flows at Stilesville on the West Branch and Lordville, 2012.**



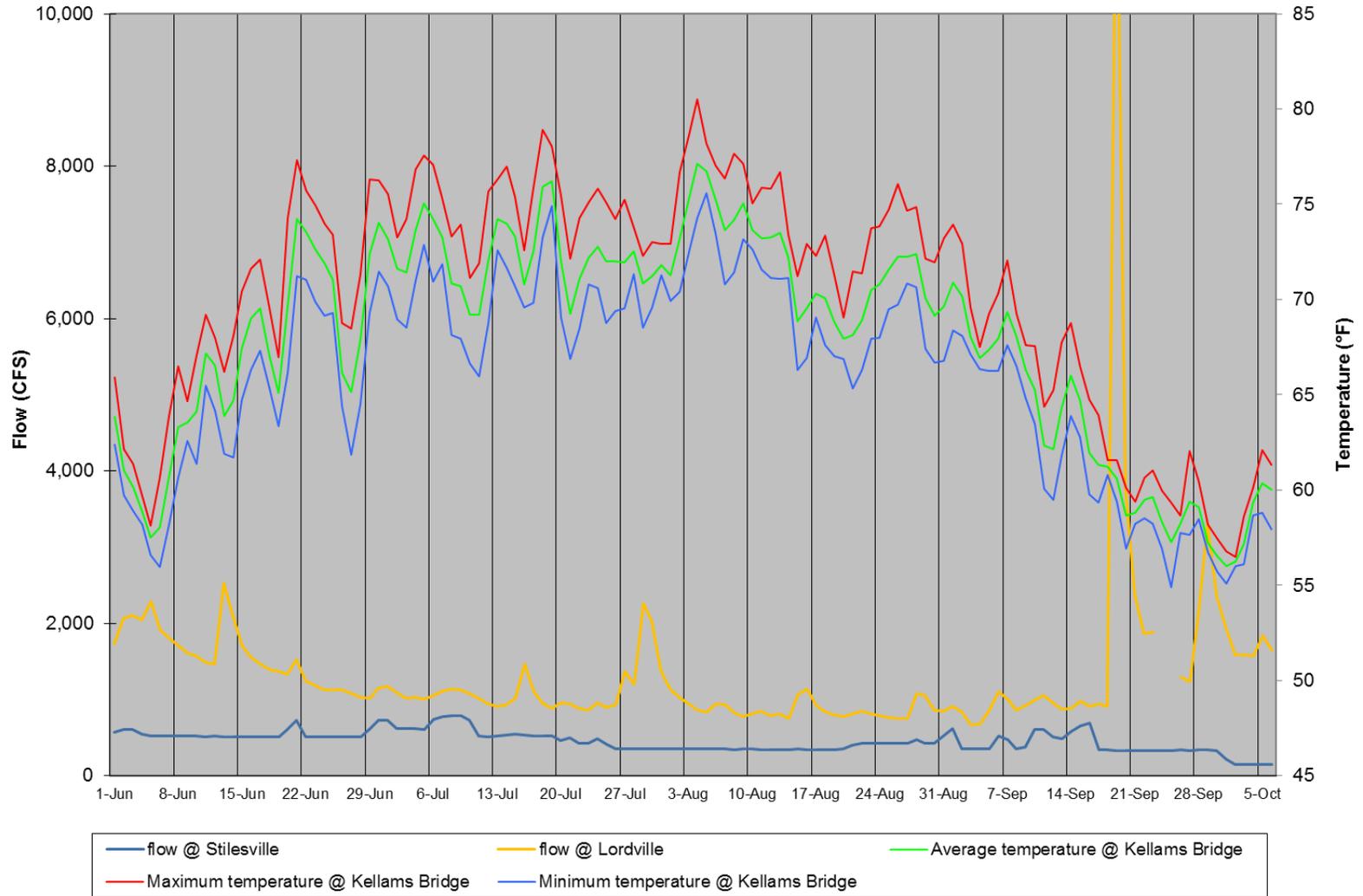
**Appendix 2Z. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Lordville, along with daily average flows at Stilesville on the West Branch and Lordville, 2012.**



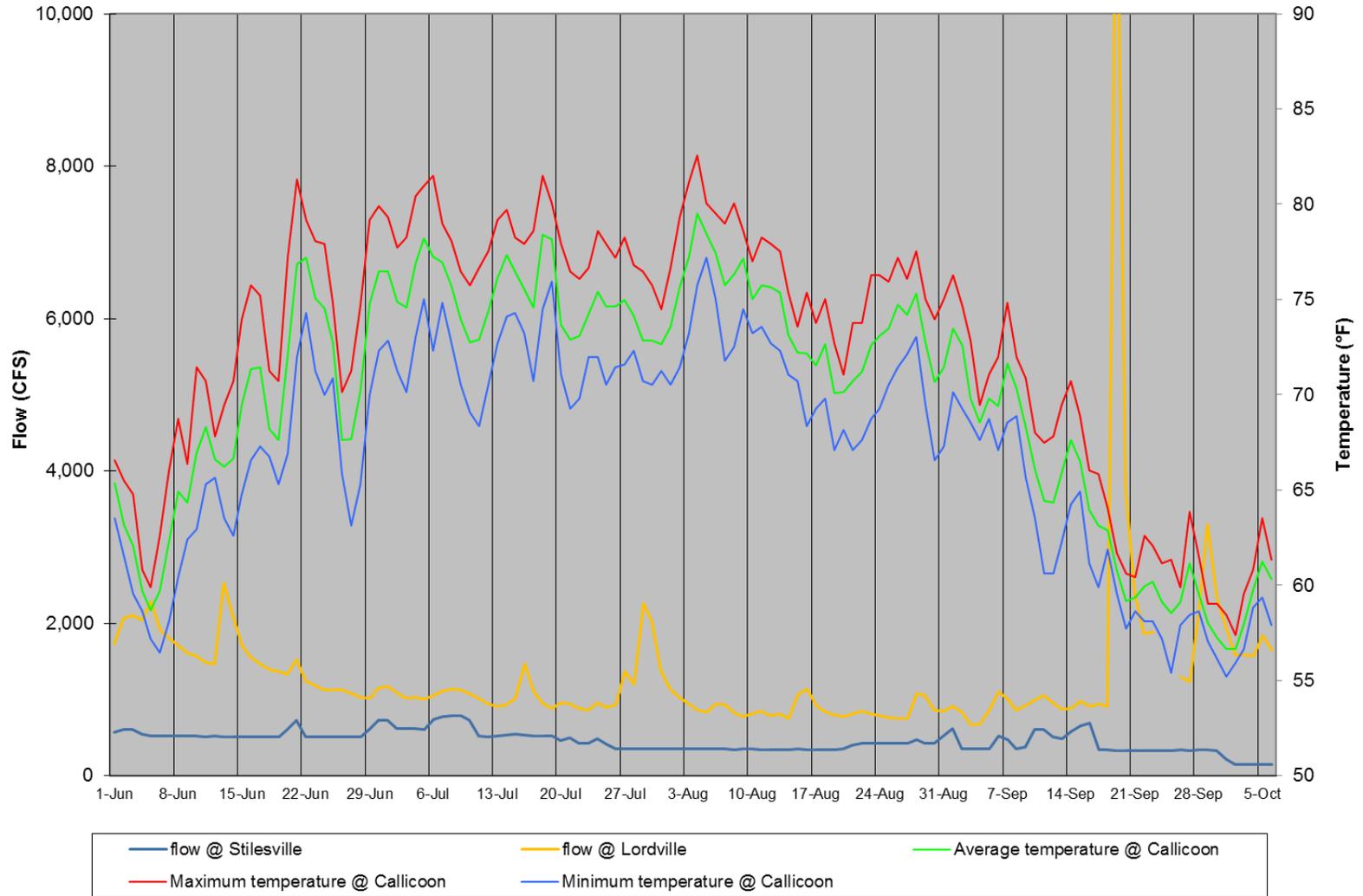
**Appendix 2AA. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Abe Lord, along with daily average flows at Stilesville on the West Branch and Lordville, 2012.**



**Appendix 2BB. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Kellams Bridge, along with daily average flows at Stilesville on the West Branch and Lordville, 2012.**



**Appendix 2CC. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Callicoon, along with daily average flows at Stilesville on the West Branch and Lordville, 2012.**



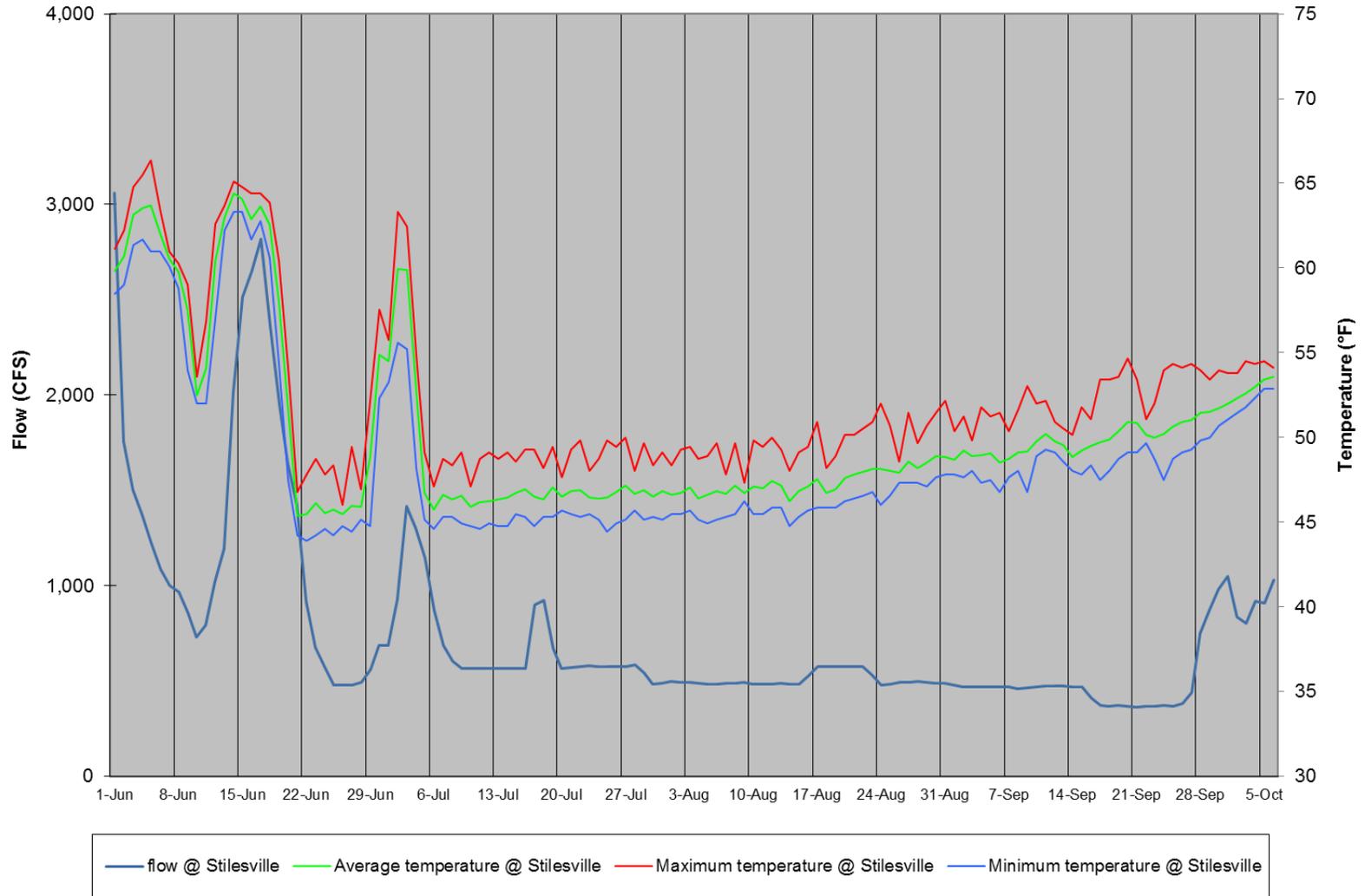
## Appendix 3:

### UPPER DELAWARE TAILWATERS

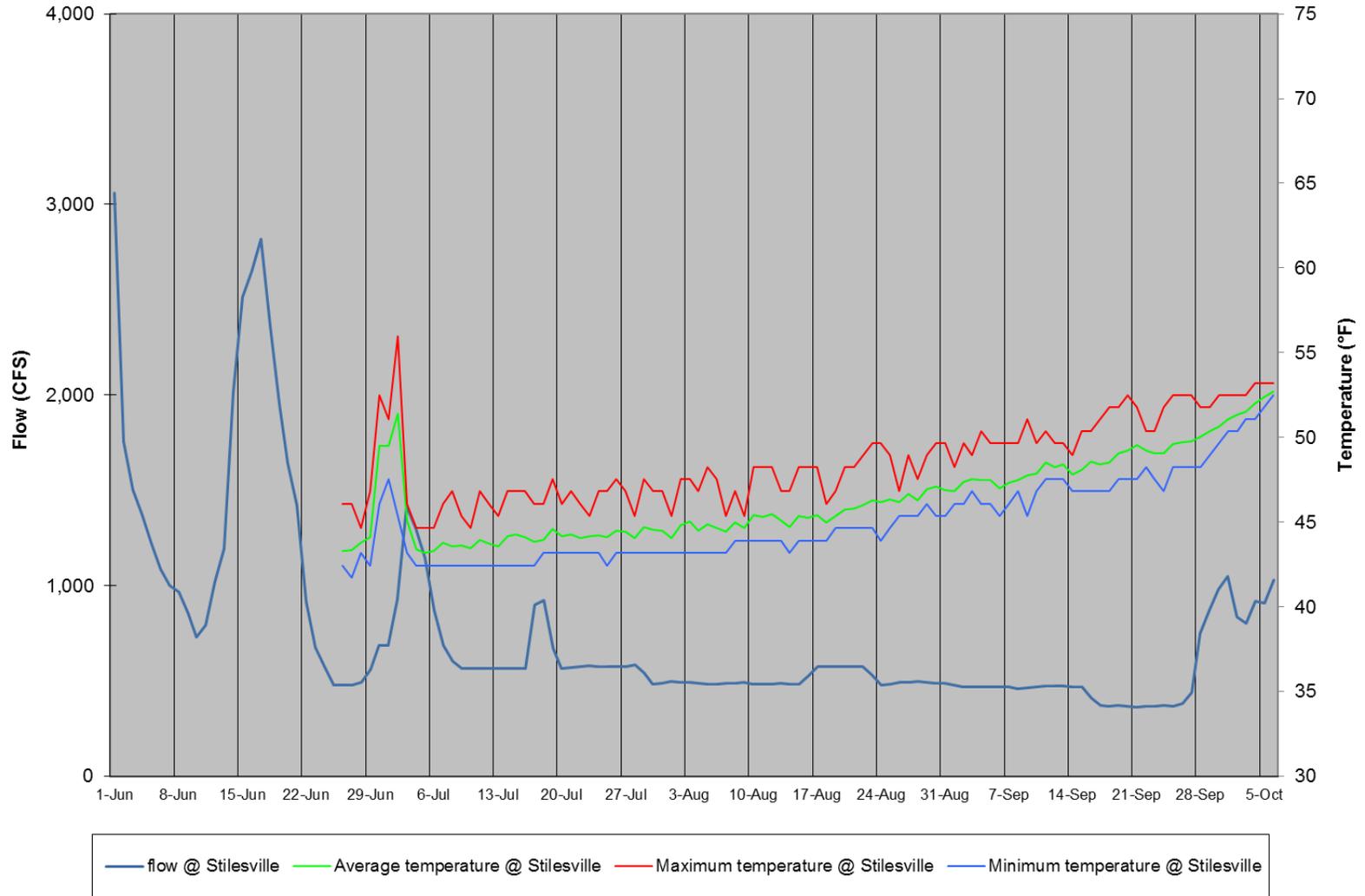
Maxima, minima, and average summer water temperature profile for each temperature monitoring site, 2013

West Branch: Appendices 3A to 3J East Branch: Appendices 3K to 3S Neversink River:  
Appendices 3T to 3X  
Delaware River: Appendices 3Y to 3CC

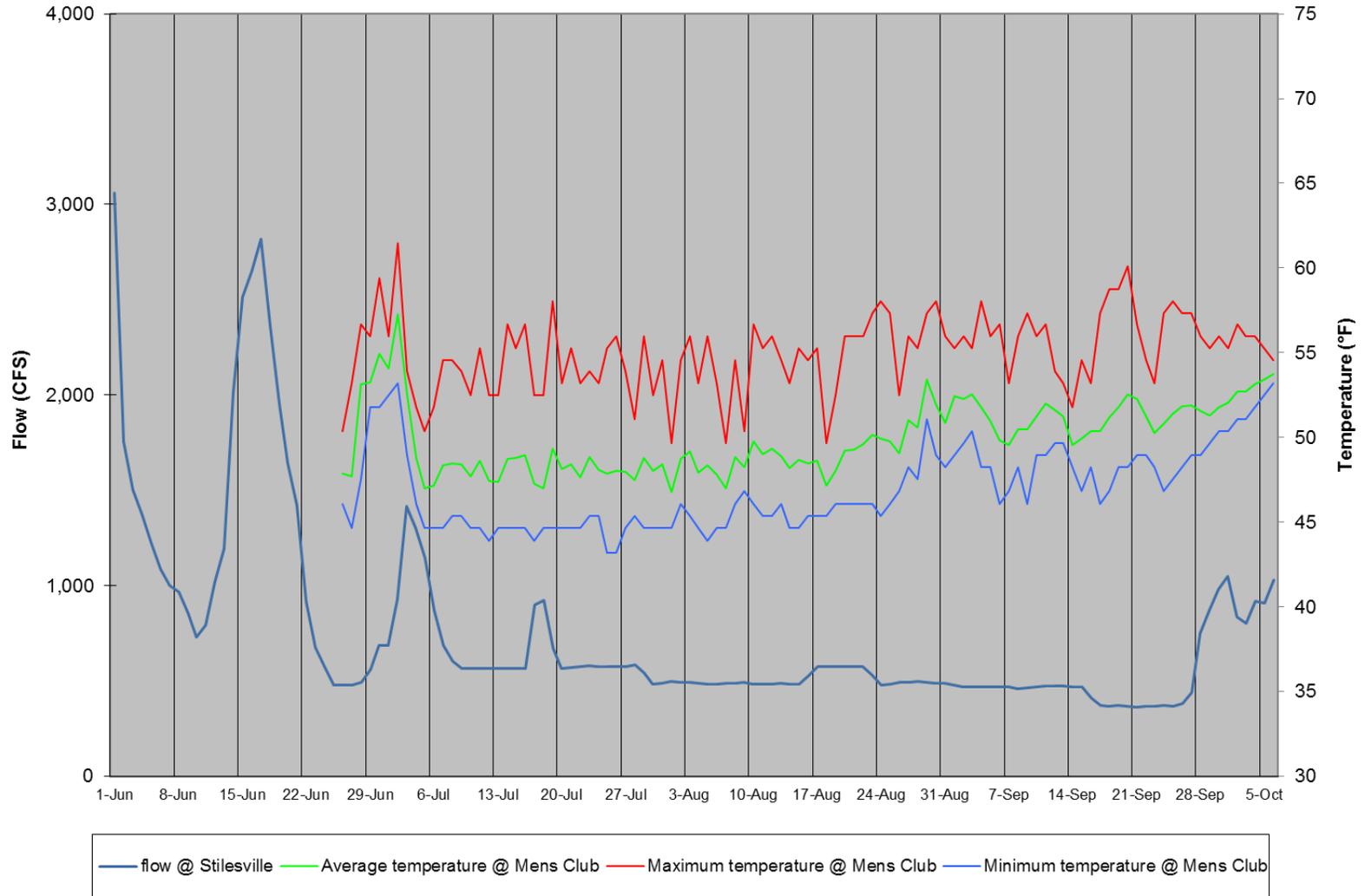
**Appendix 3A. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Stilesville, along with daily average flows at Stilesville, 2013.**



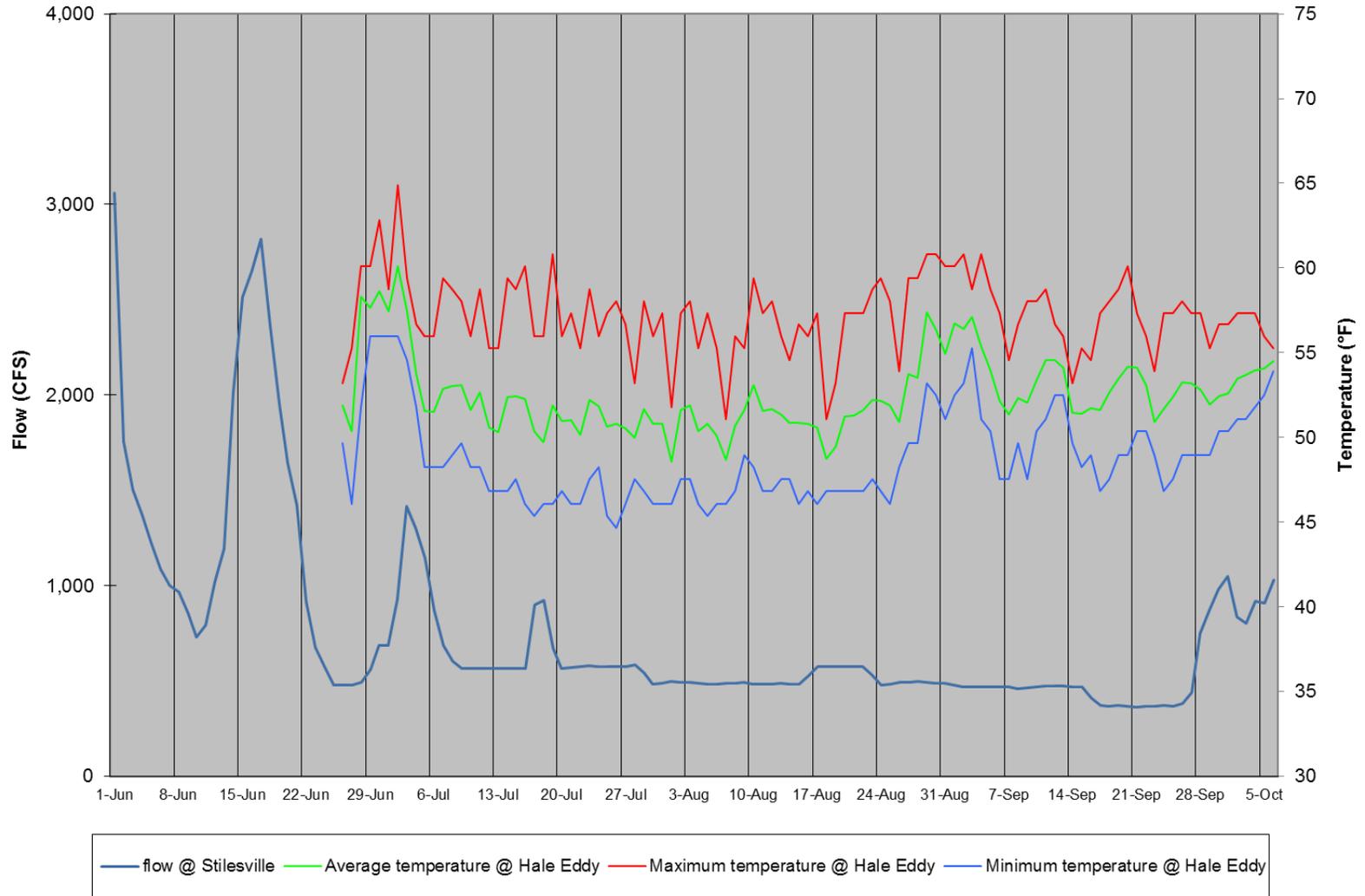
**Appendix 3B. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Stilesville, along with daily average flows at Stilesville, 2013.**



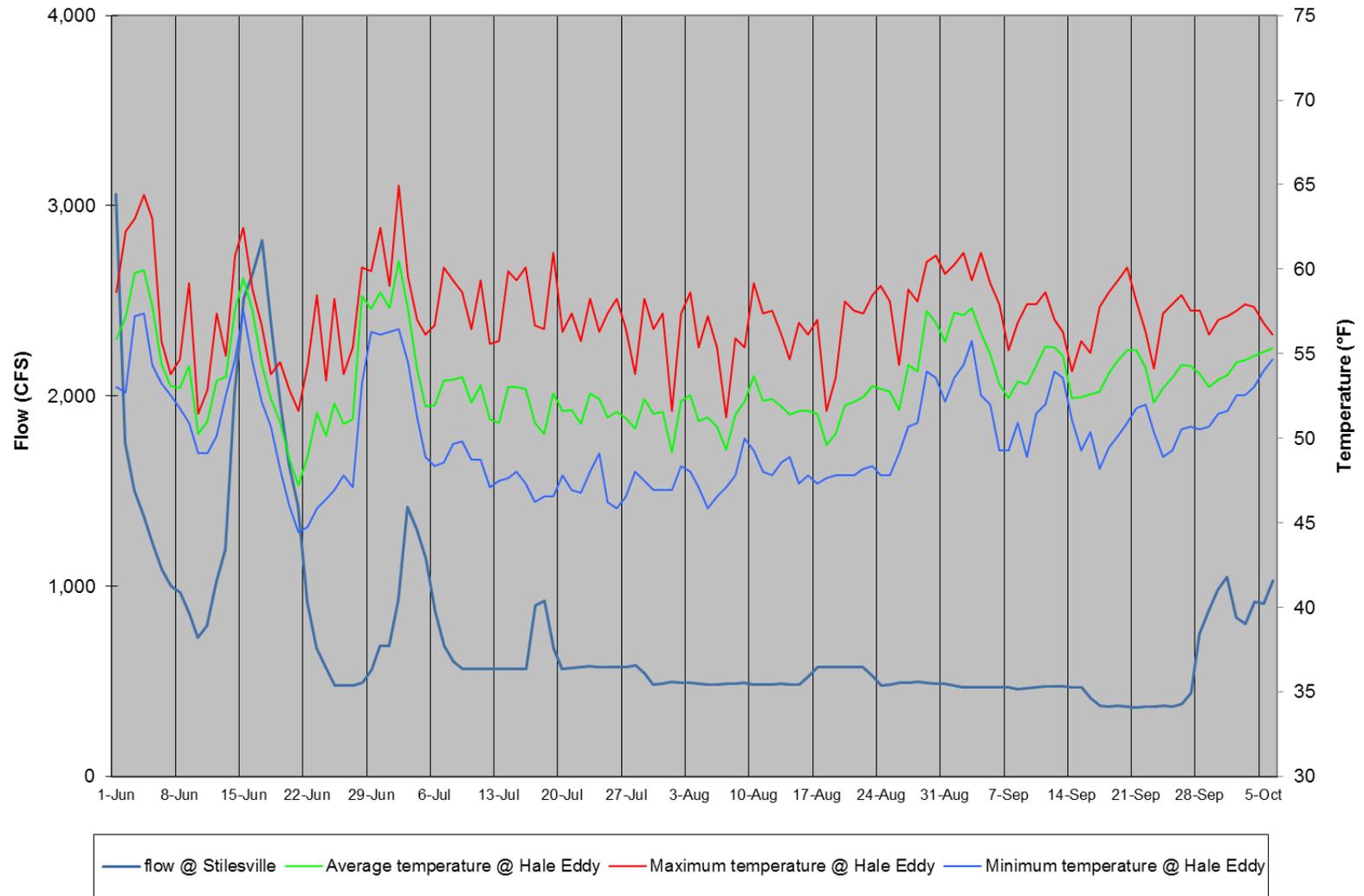
**Appendix 3C. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Men's Club, along with daily average flows at Stilesville, 2013.**



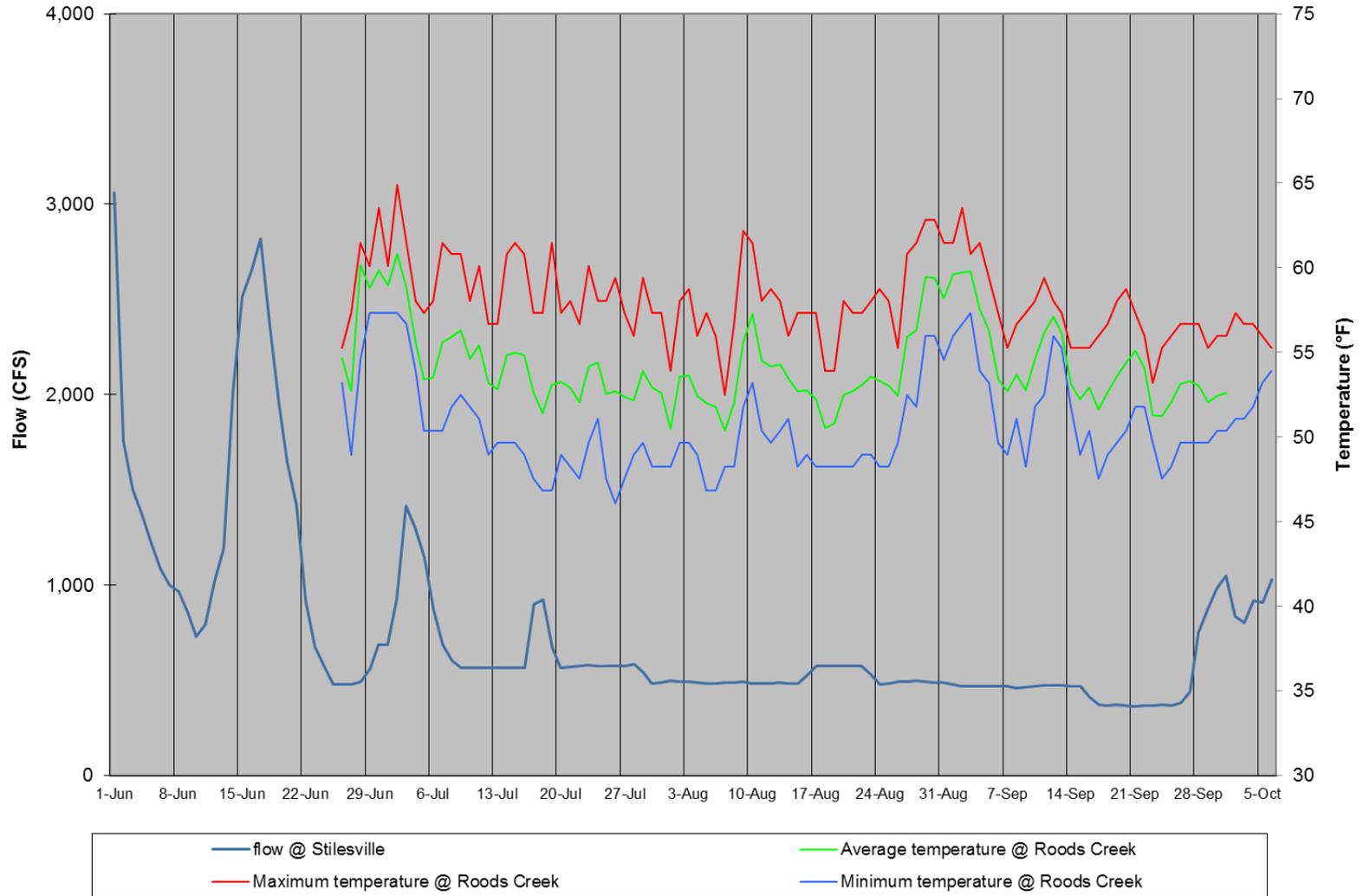
**Appendix 3D. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2013.**



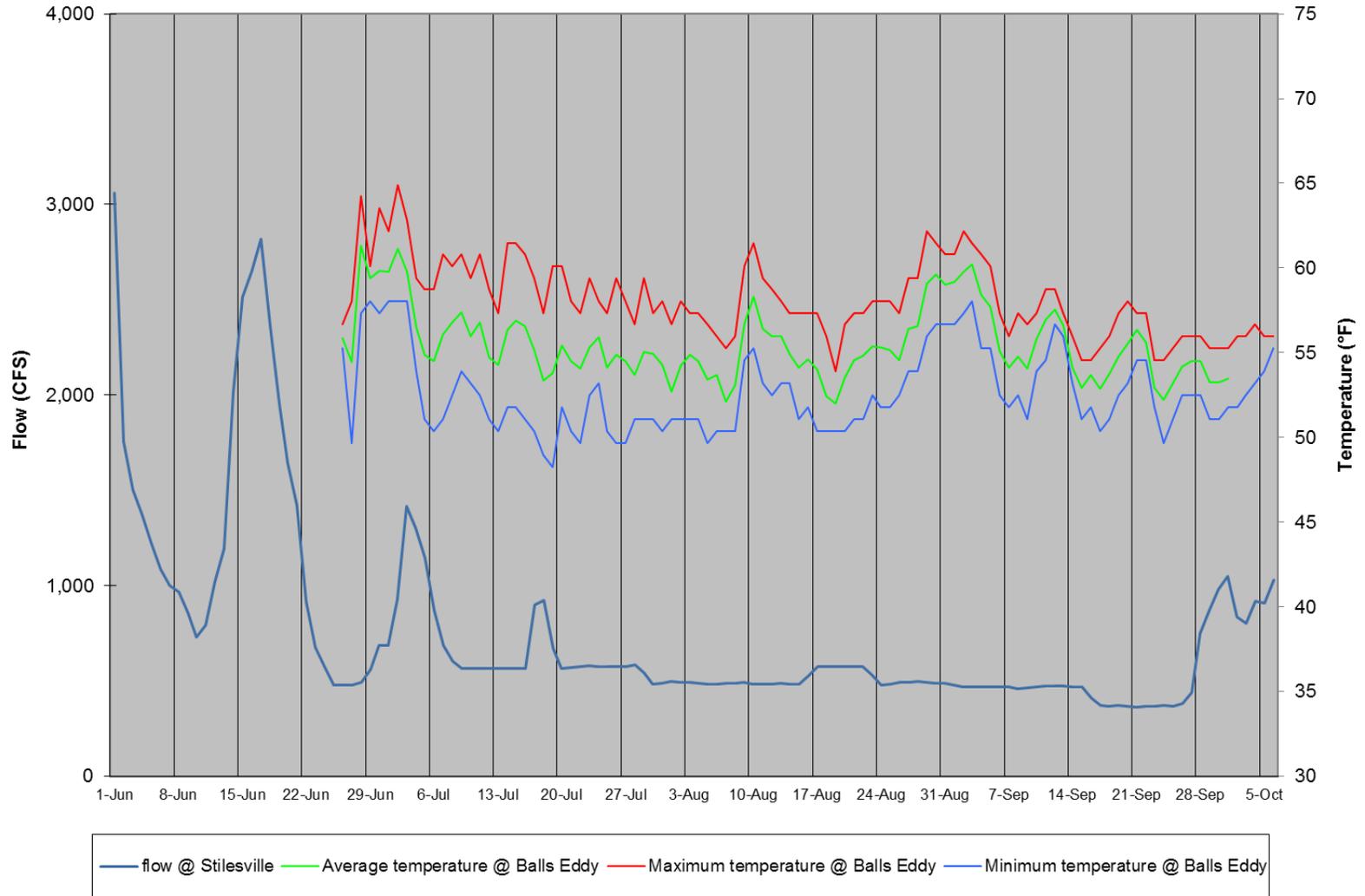
**Appendix 3E. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2013.**



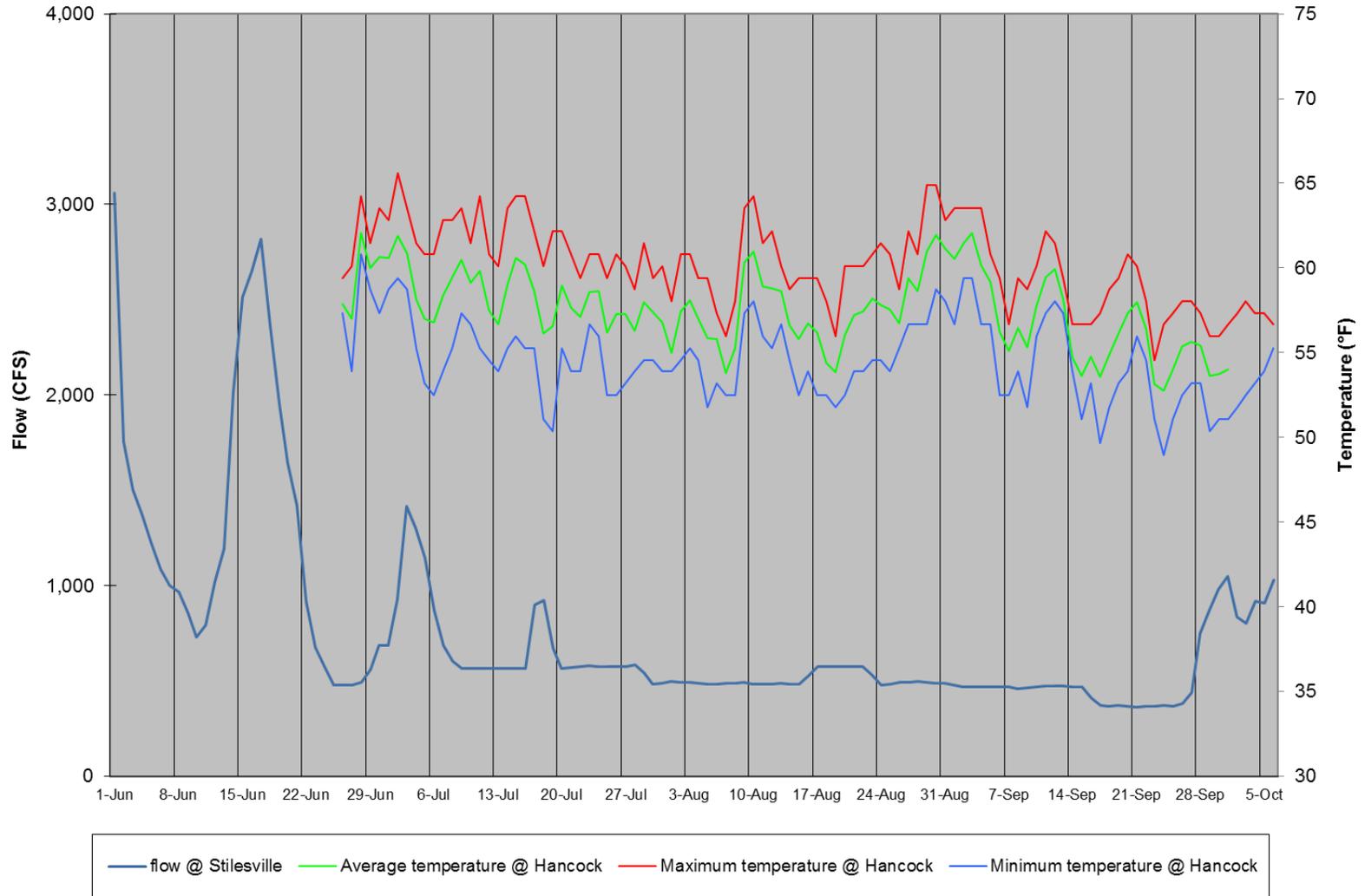
**Appendix 3F. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Roods Creek, along with daily average flows at Stilesville, 2013.**



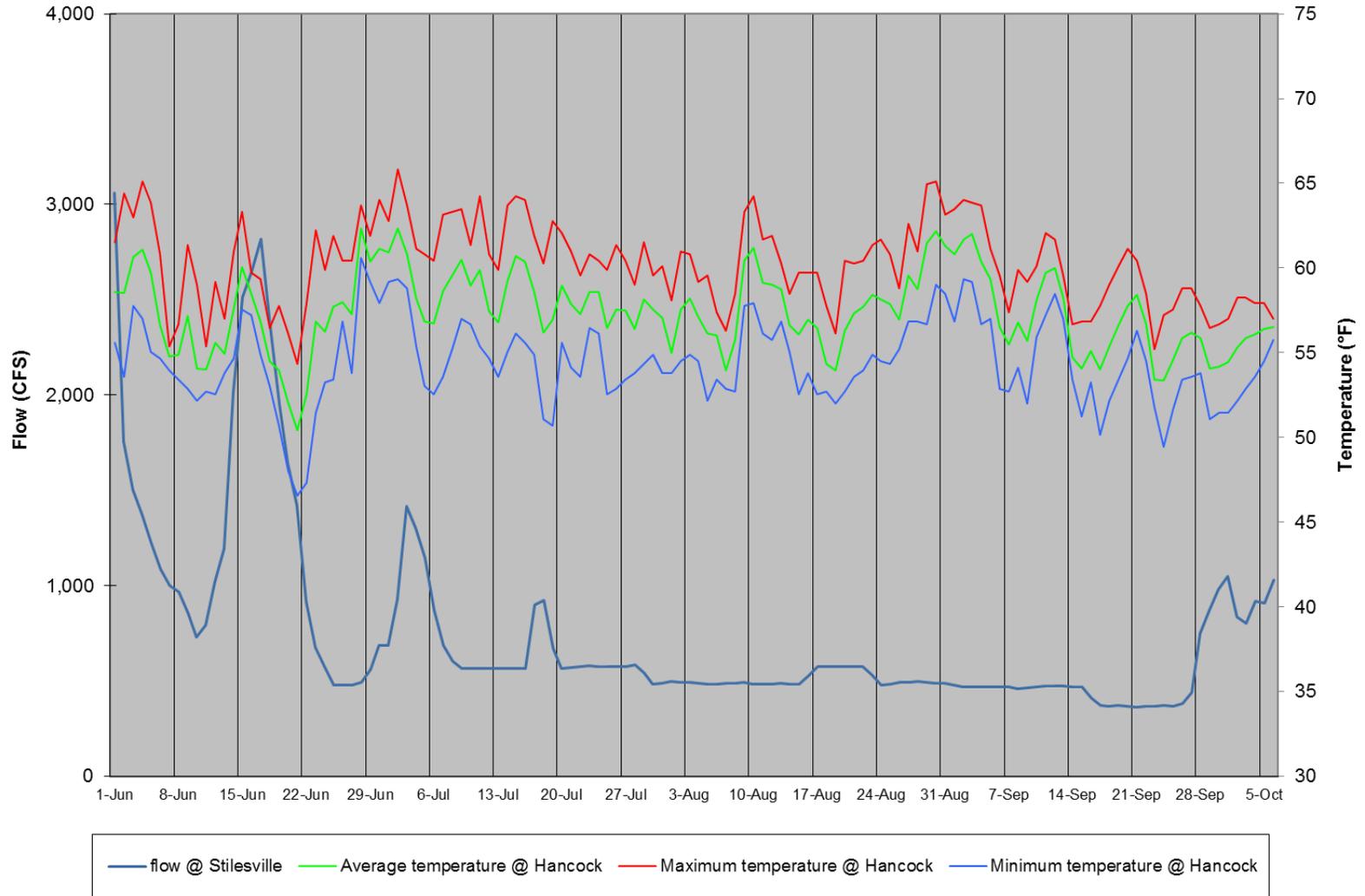
**Appendix 3G. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Balls Eddy, along with daily average flows at Stilesville, 2013.**



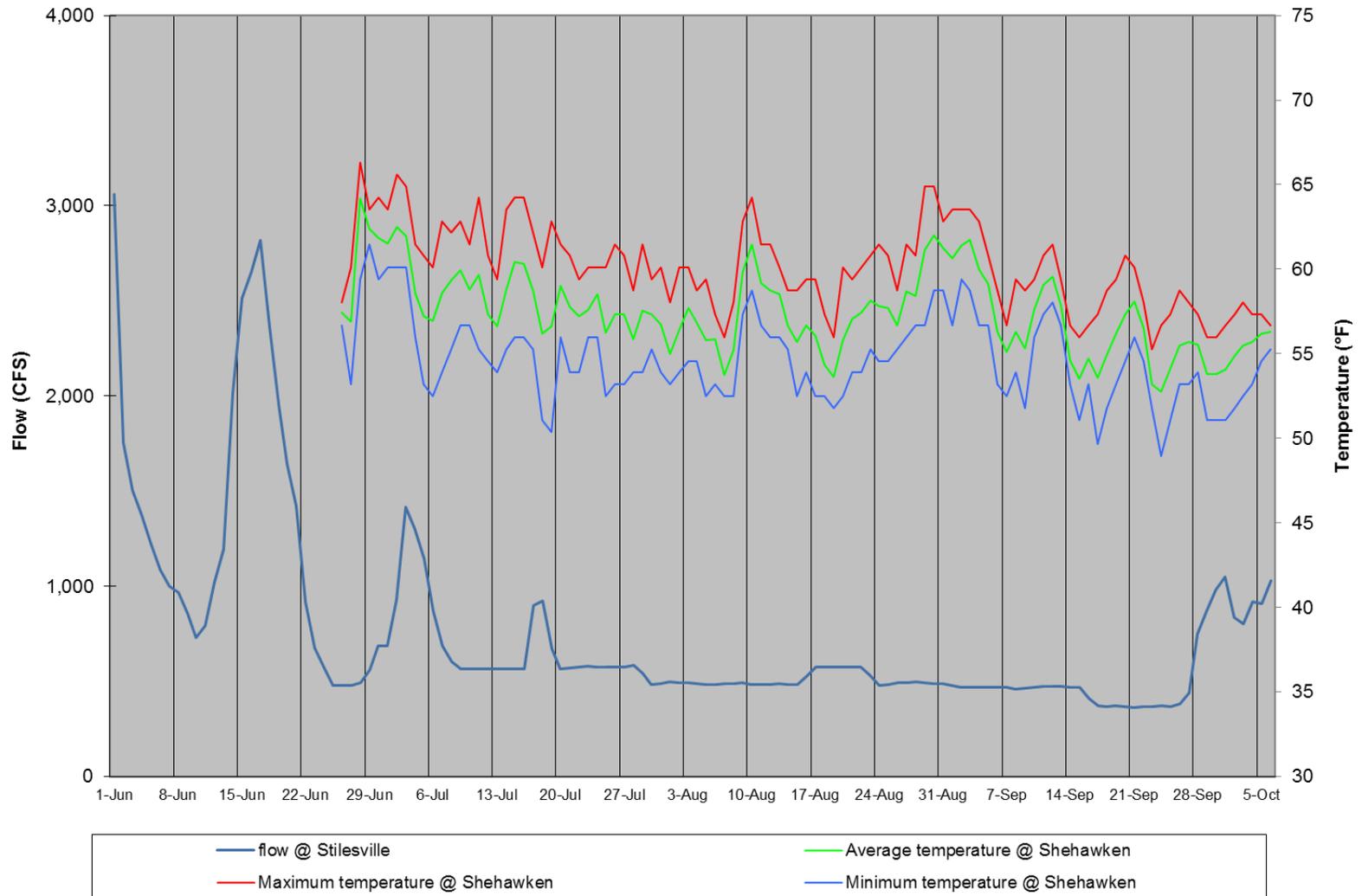
**Appendix 3H. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hancock, along with daily average flows at Stilesville, 2013.**



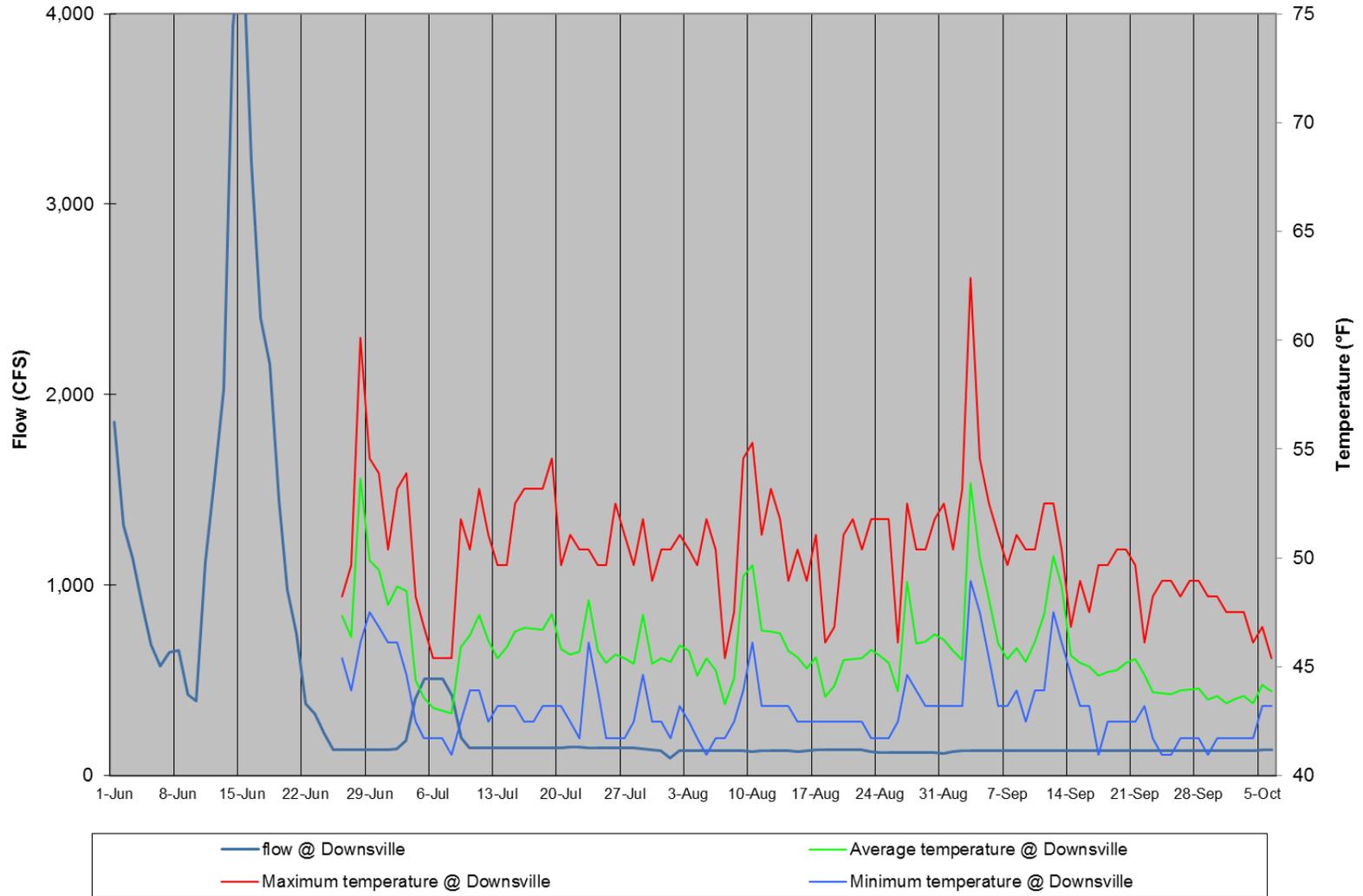
**Appendix 3I. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hancock, along with daily average flows at Stilesville, 2013.**



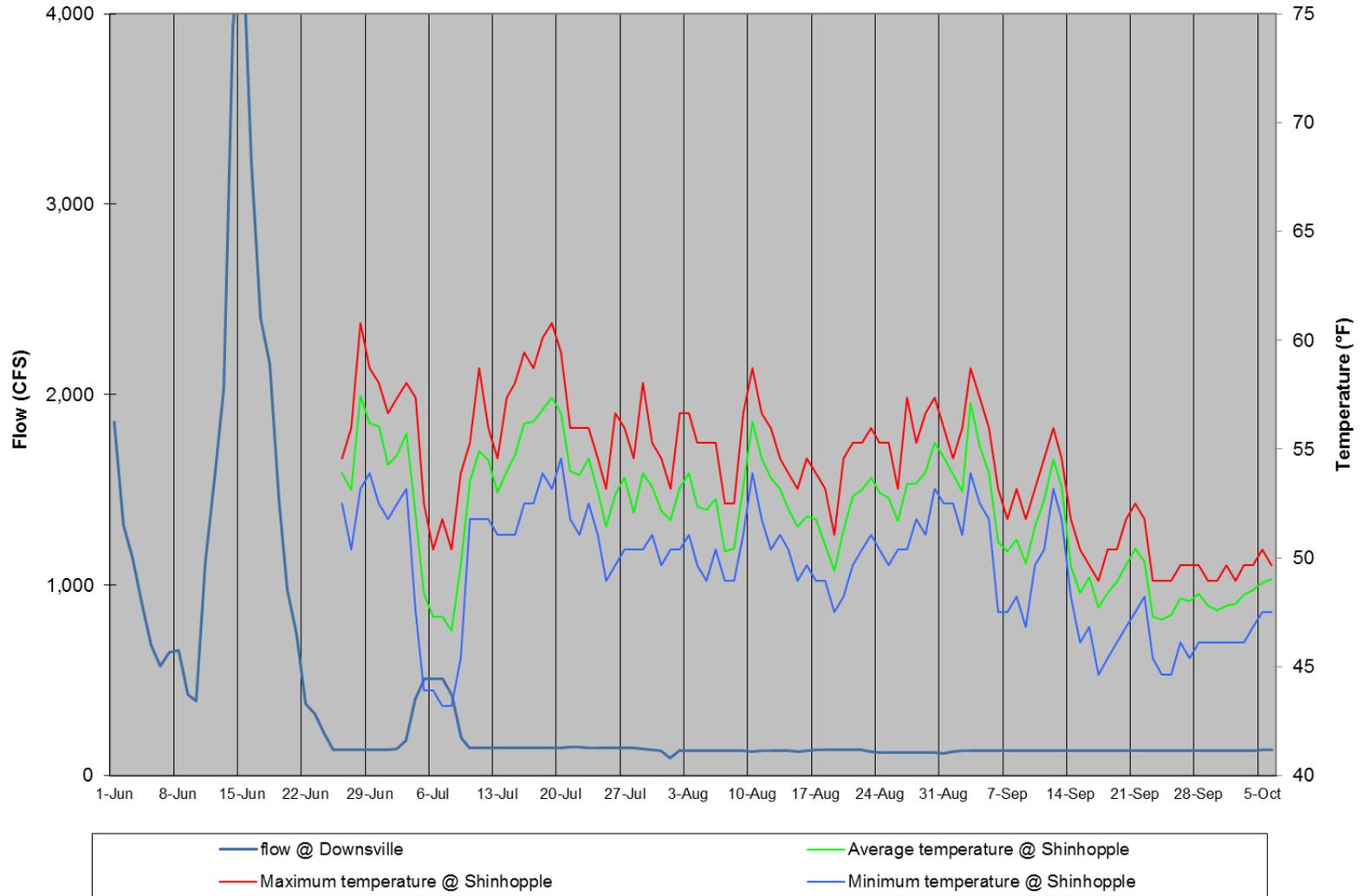
**Appendix 3J. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Shehawken, along with daily average flows at Stilesville, 2013.**



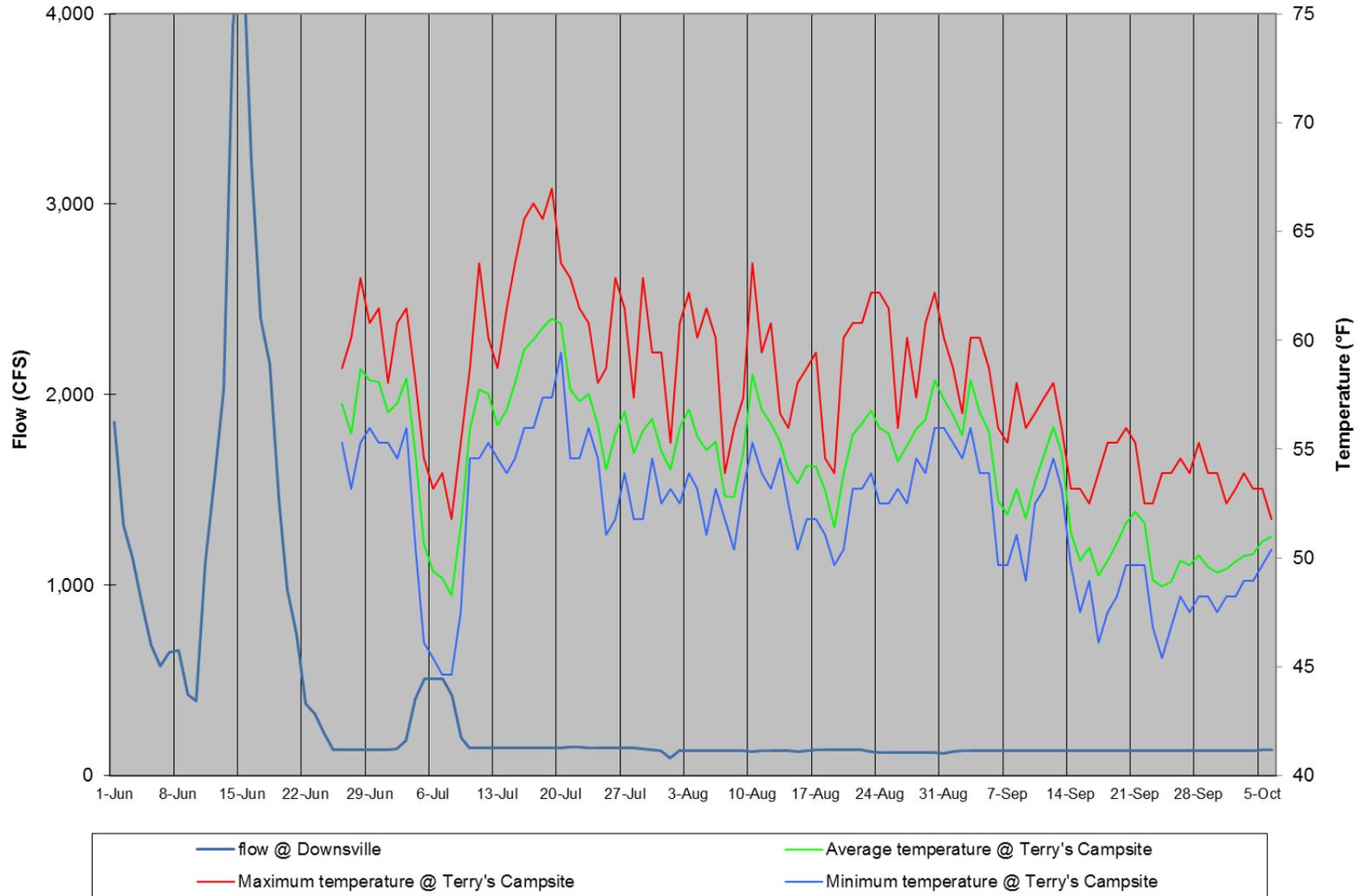
**Appendix 3K. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Downsville, along with daily average flows at Downsville, 2013.**



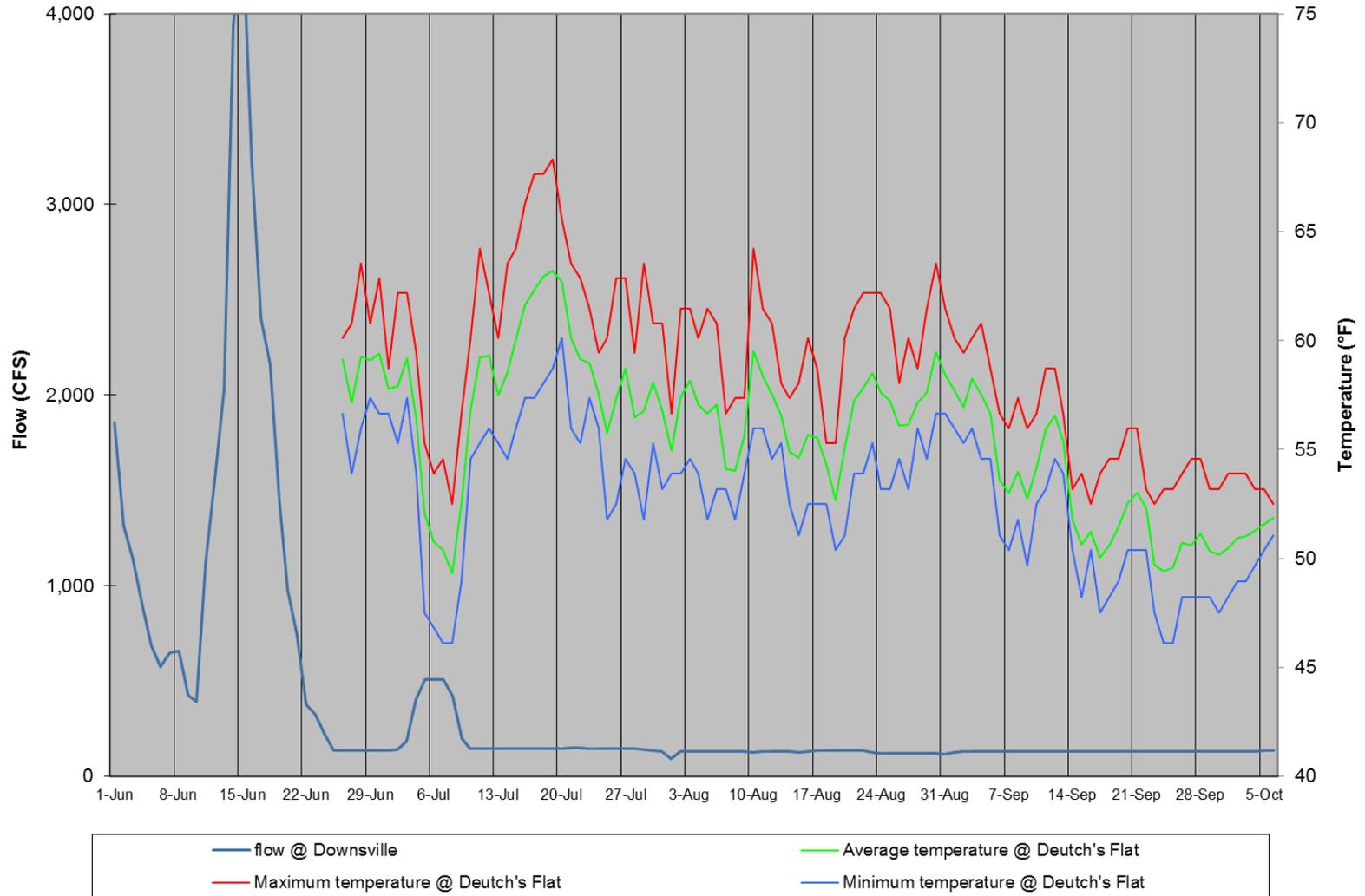
**Appendix 3L. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Shinhopple, along with daily average flows at Downsville, 2013.**



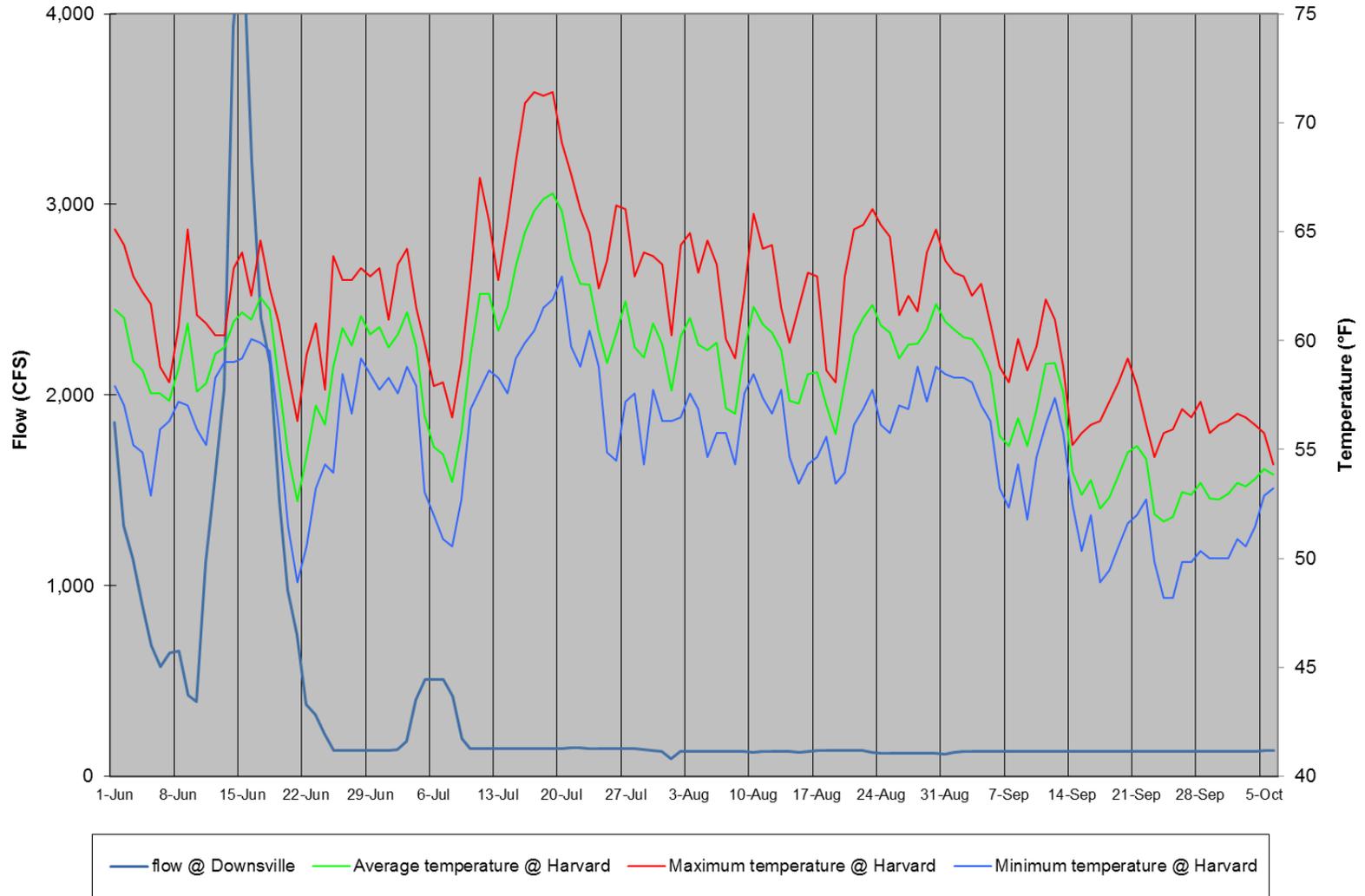
**Appendix 3M. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Terry's Campsite, along with daily average flows at Downsville, 2013.**



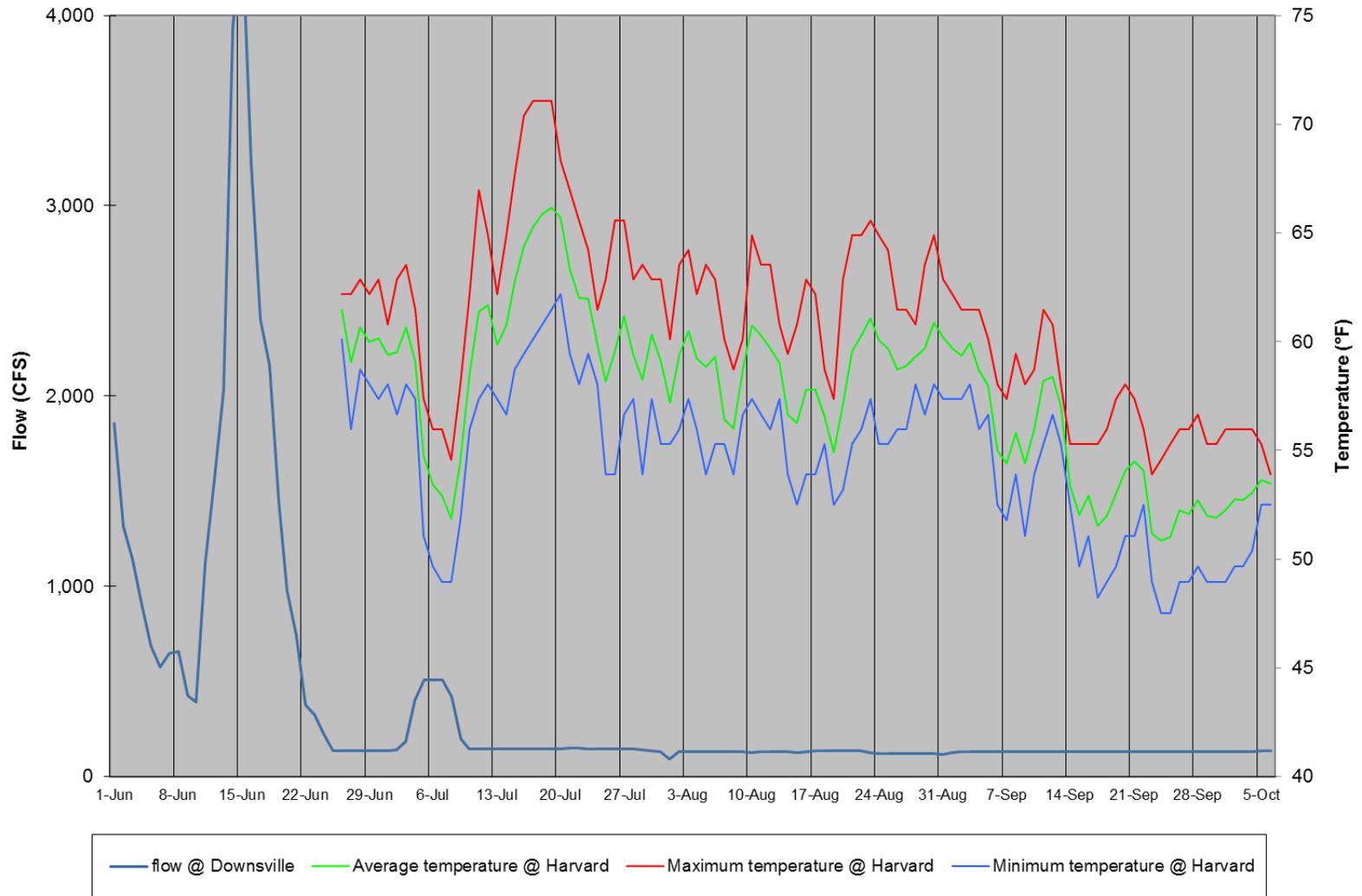
**Appendix 3N. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Deutch's Flat, along with daily average flows at Downsville, 2013.**



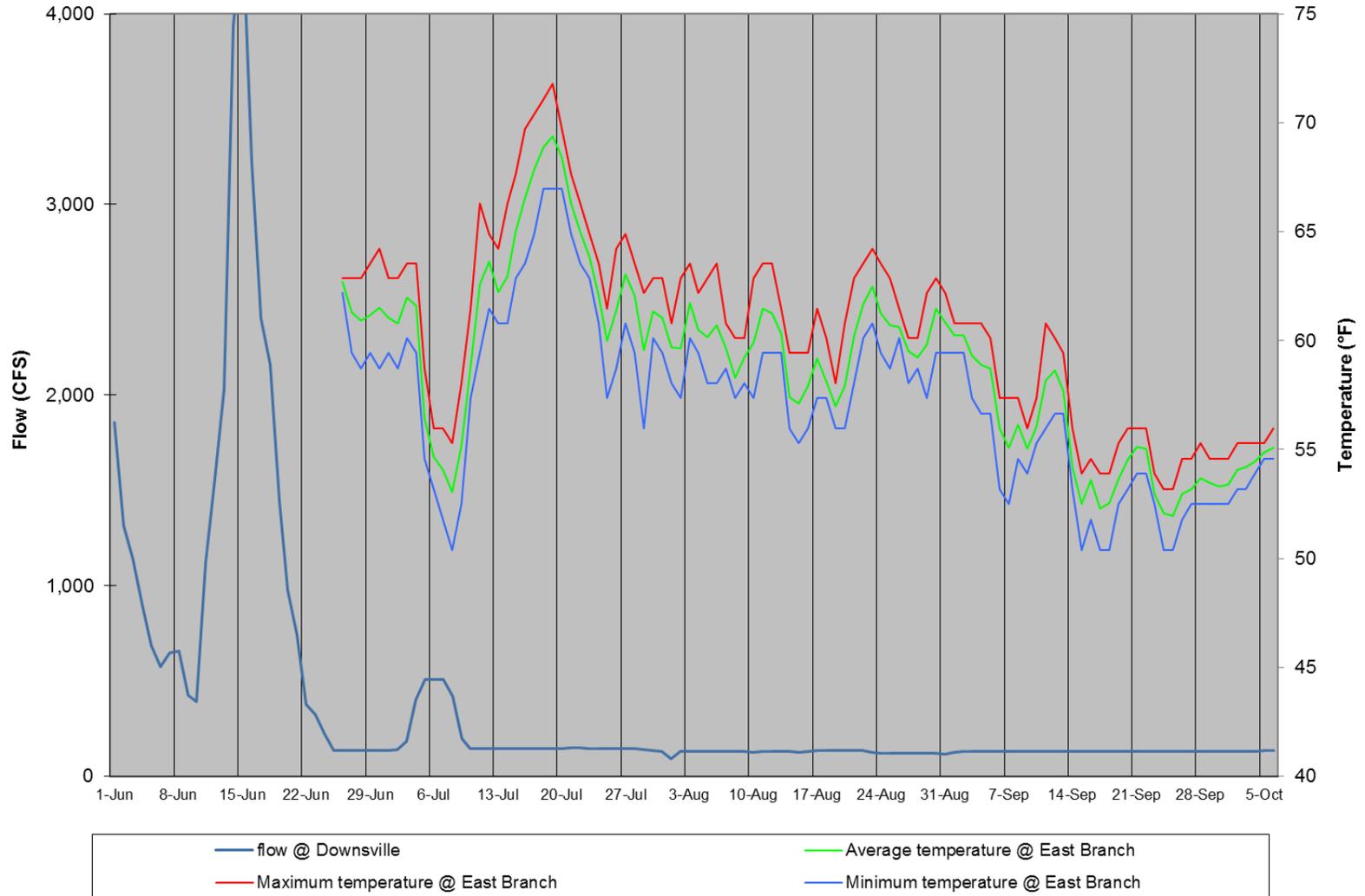
**Appendix 30. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Harvard, along with daily average flows at Downsville, 2013.**



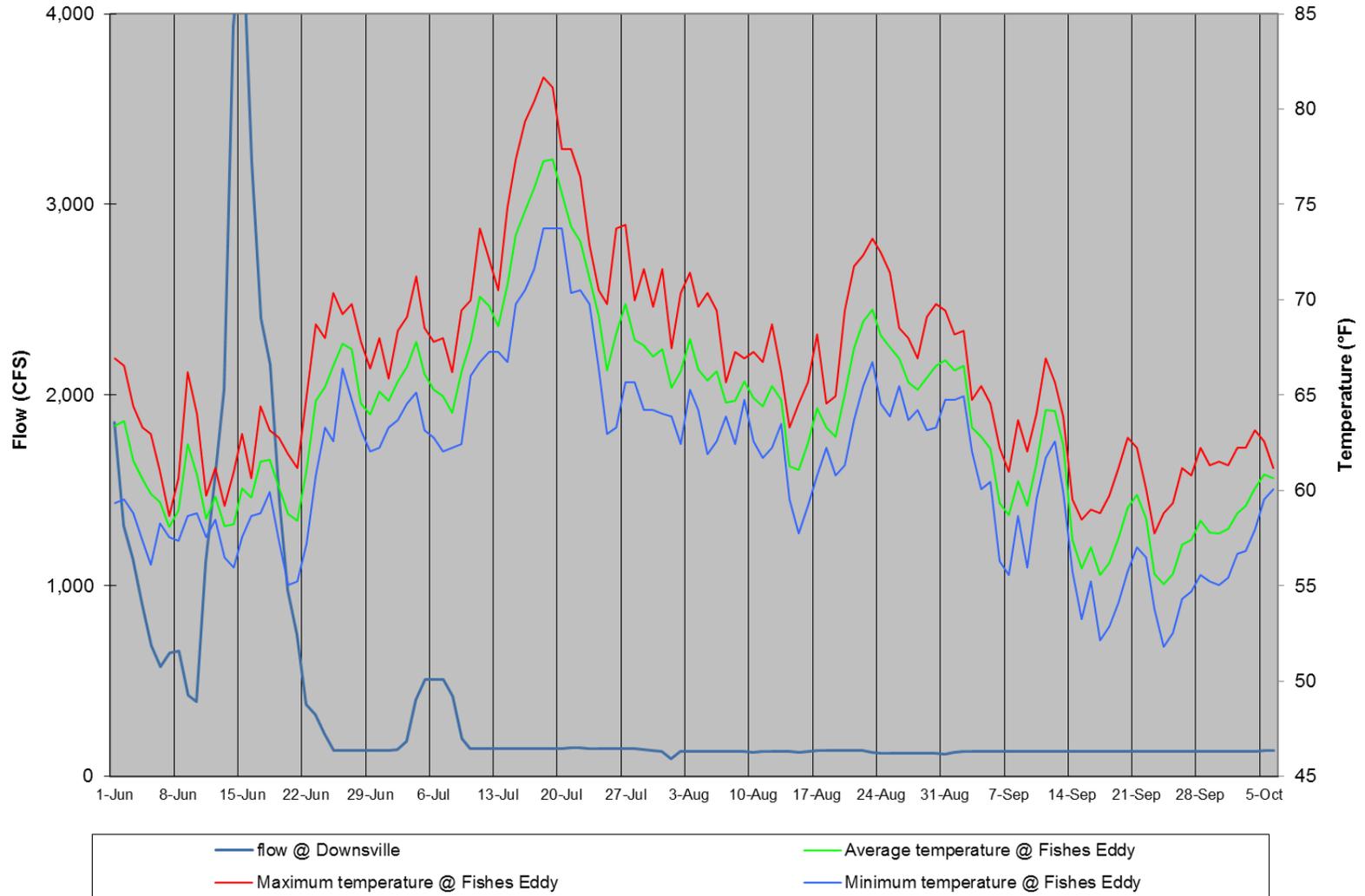
**Appendix 3P. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Harvard, along with daily average flows at Downsville, 2013.**



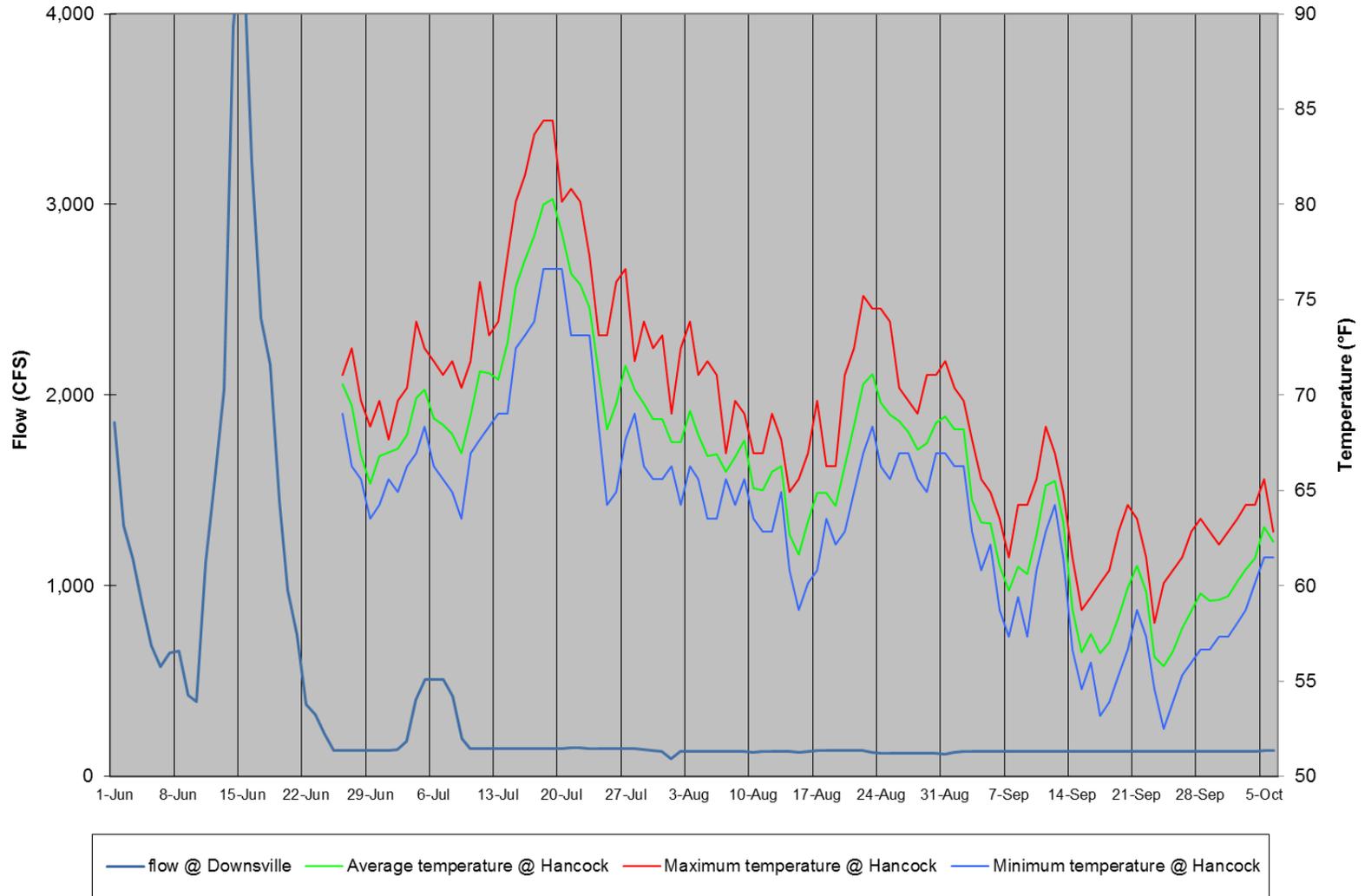
**Appendix 3Q. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at East Branch, along with daily average flows at Downsville, 2013.**



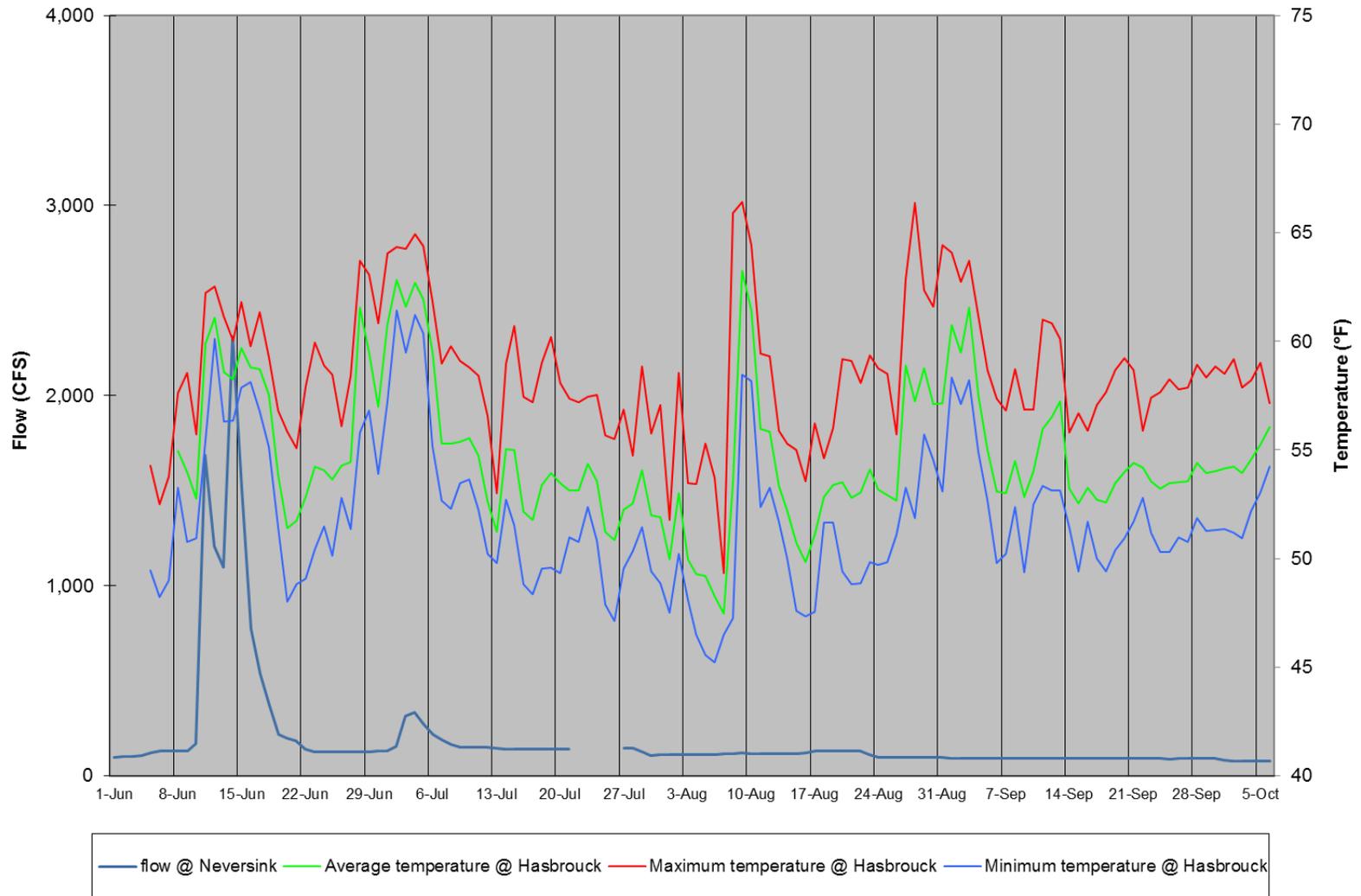
**Appendix 3R. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Fishes Eddy, along with daily average flows at Downsville, 2013.**



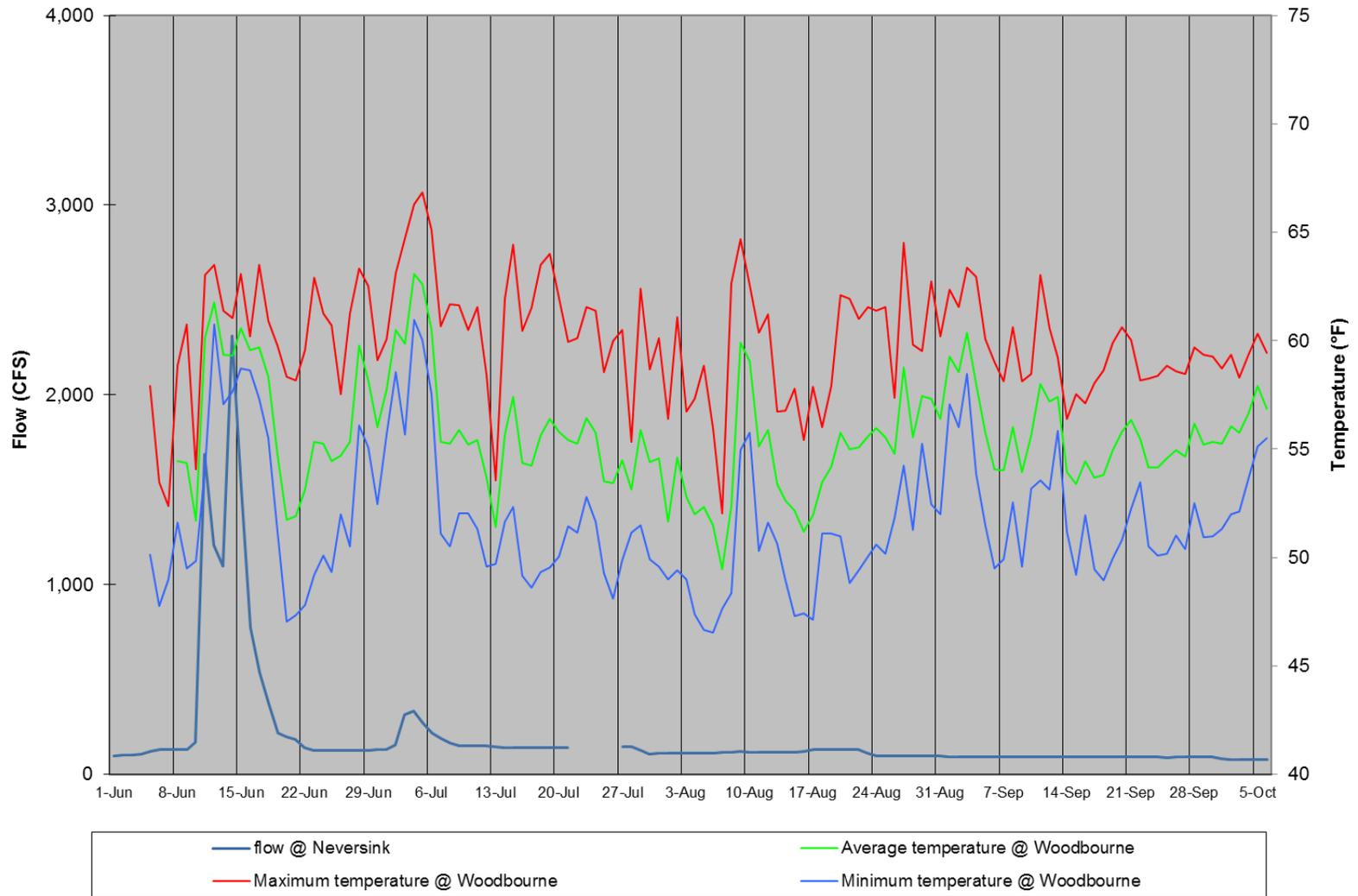
**Appendix 3S. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Hancock, along with daily average flows at Downsville, 2013.**



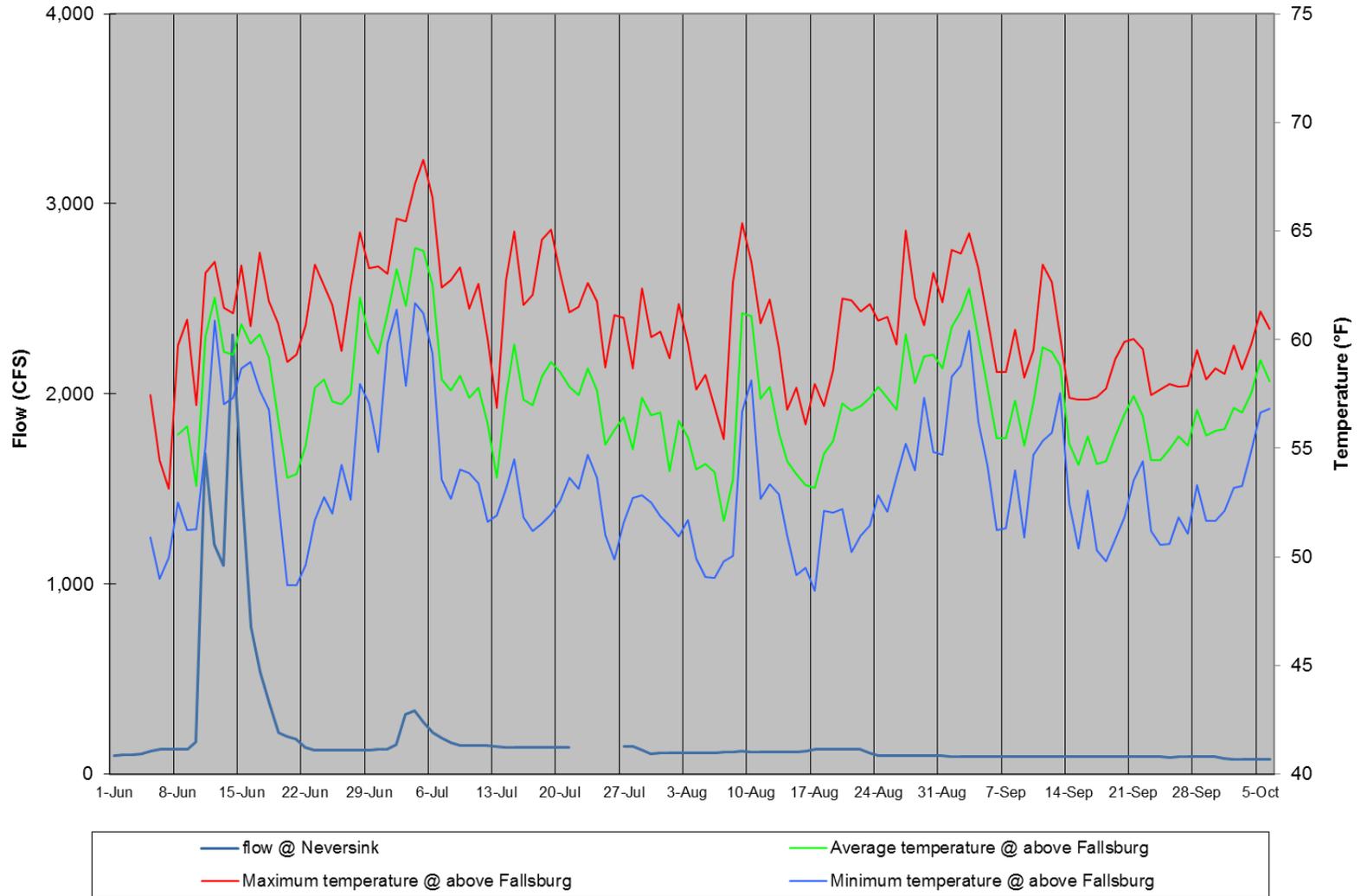
**Appendix 3T. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Hasbrouck, along with daily average flows at Neversink, 2013.**



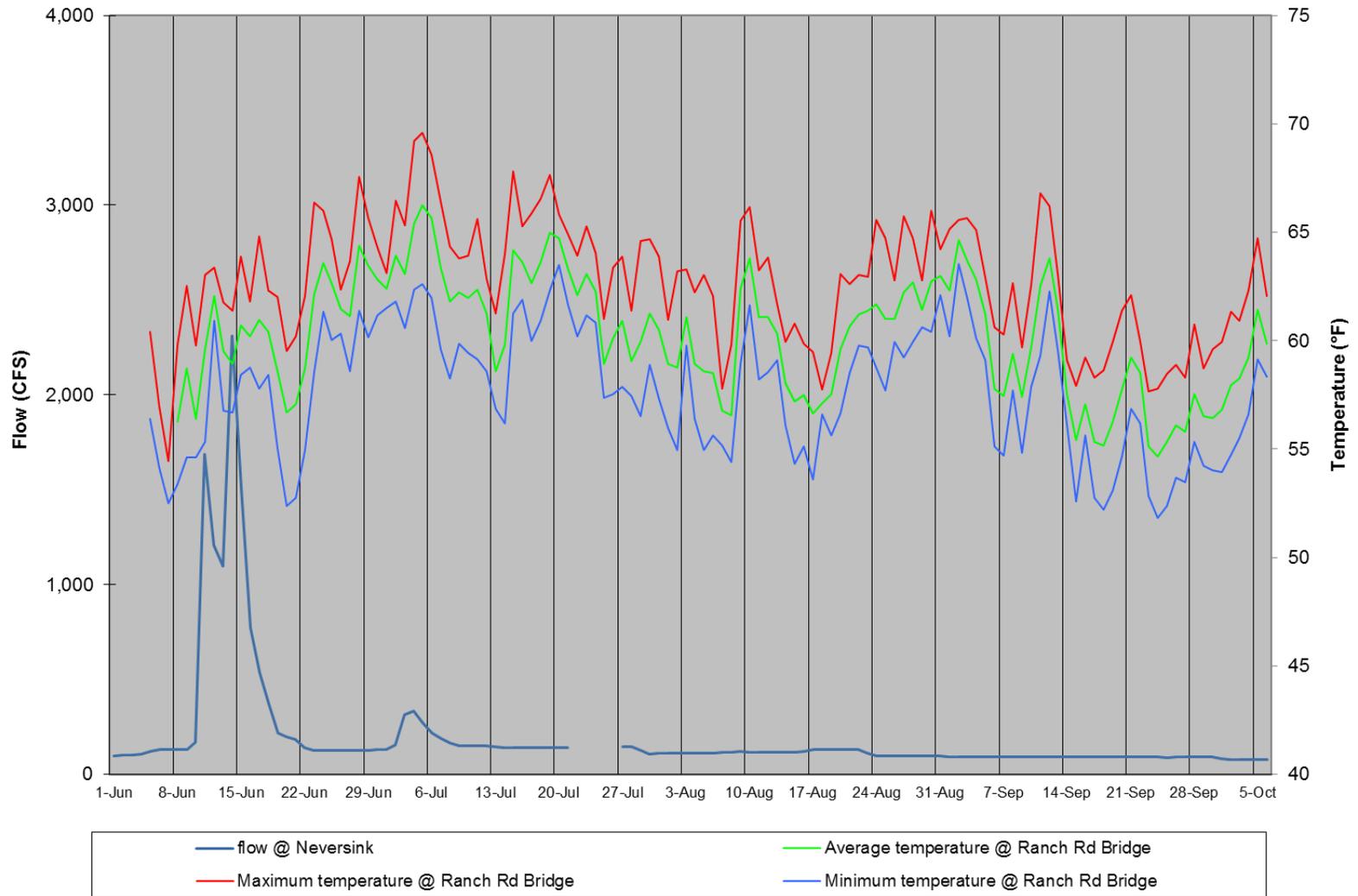
**Appendix 3U. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Woodbourne, along with daily average flows at Neversink, 2013.**



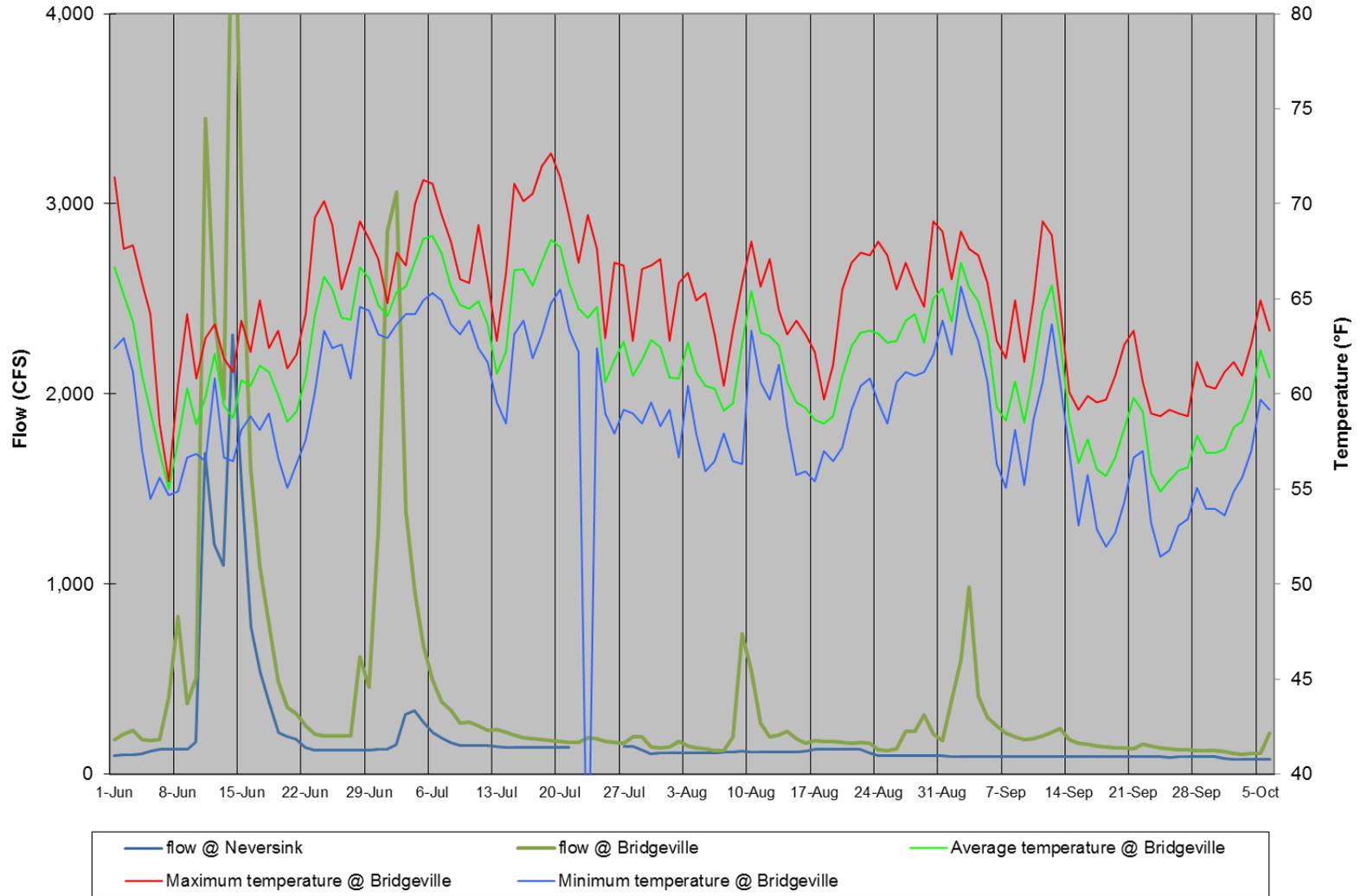
**Appendix 3V. Summer daily average, maximum, and minimum water temperature profiles on the Neversink just above Fallsburg, along with daily average flows at Neversink, 2013.**



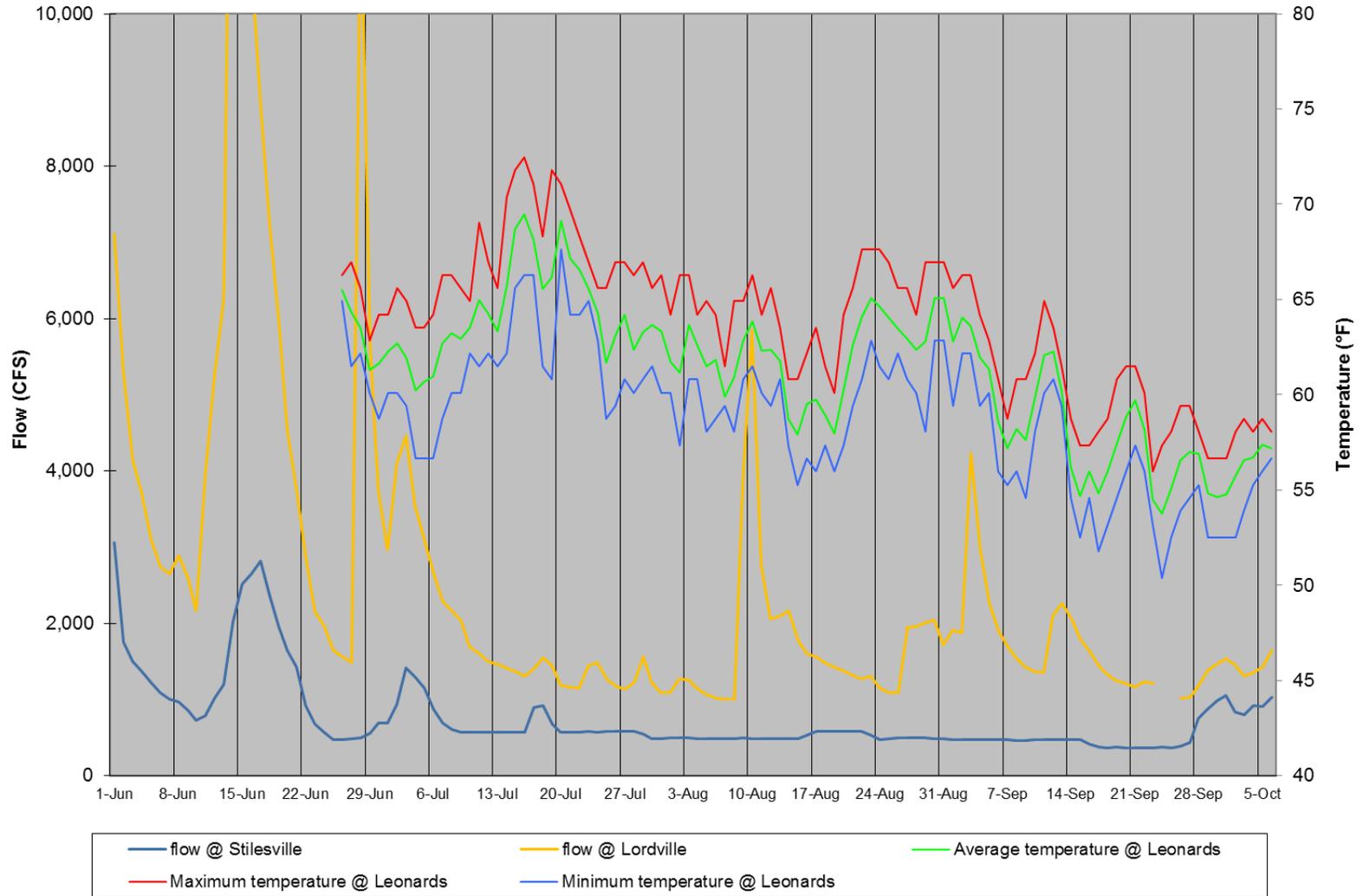
**Appendix 3W. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Ranch Rd bridge, along with daily average flows at Neversink, 2013.**



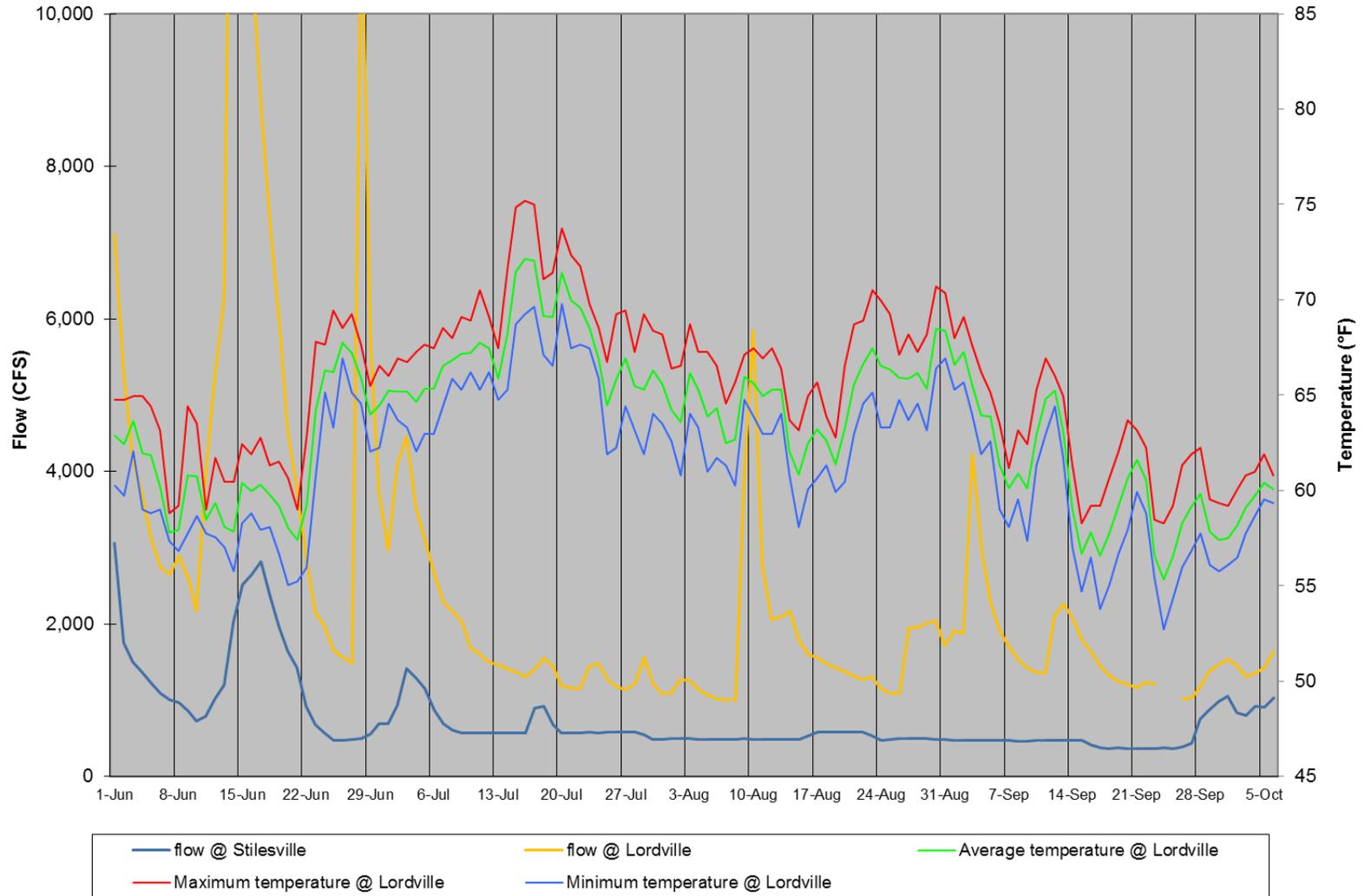
**Appendix 3X. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Bridgeville, along with daily average flows at Bridgeville & Neversink, 2013.**



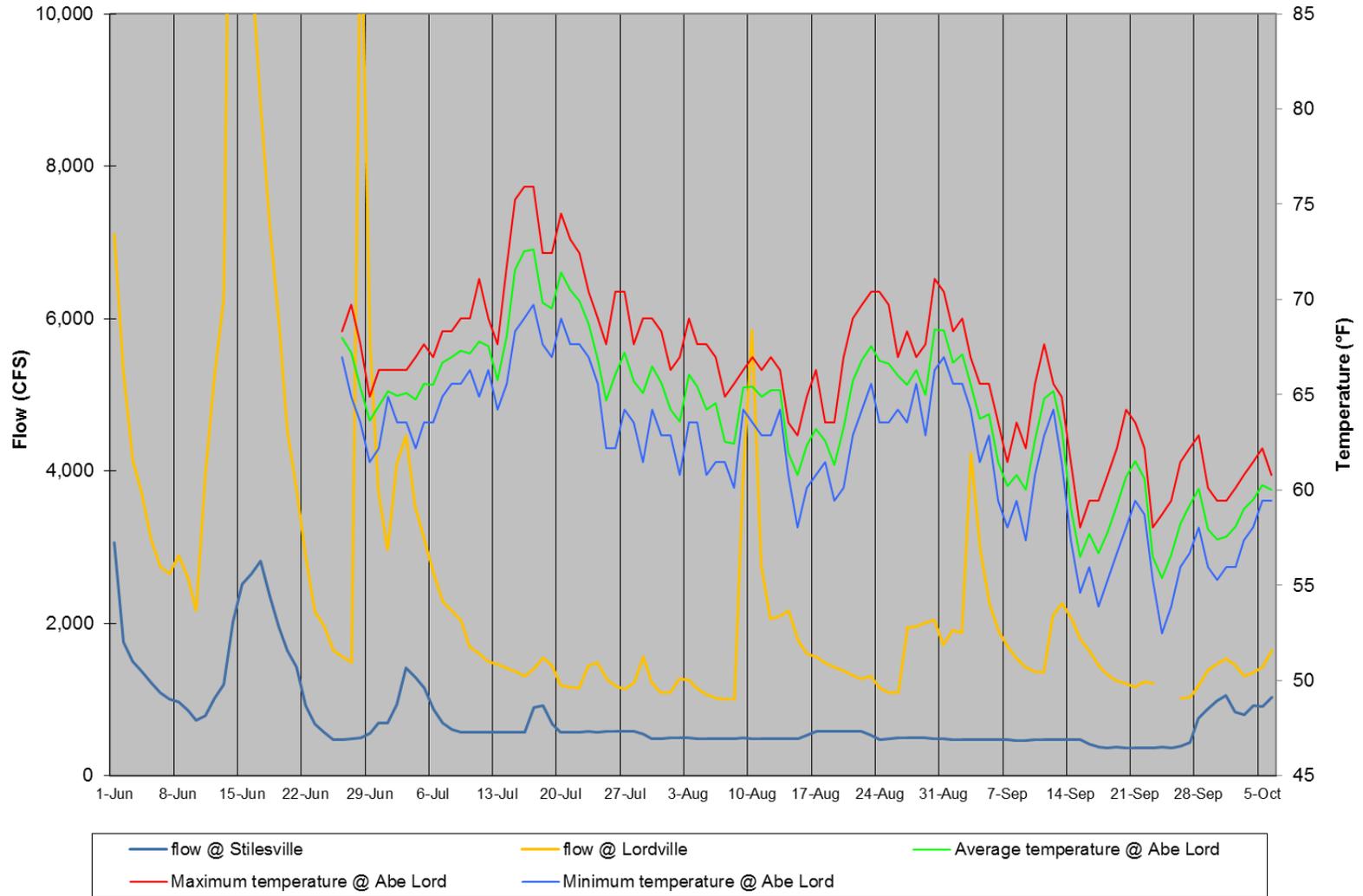
**Appendix 3Y. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Leonards, along with daily average flows at Stilesville on the West Branch and Lordville, 2013.**



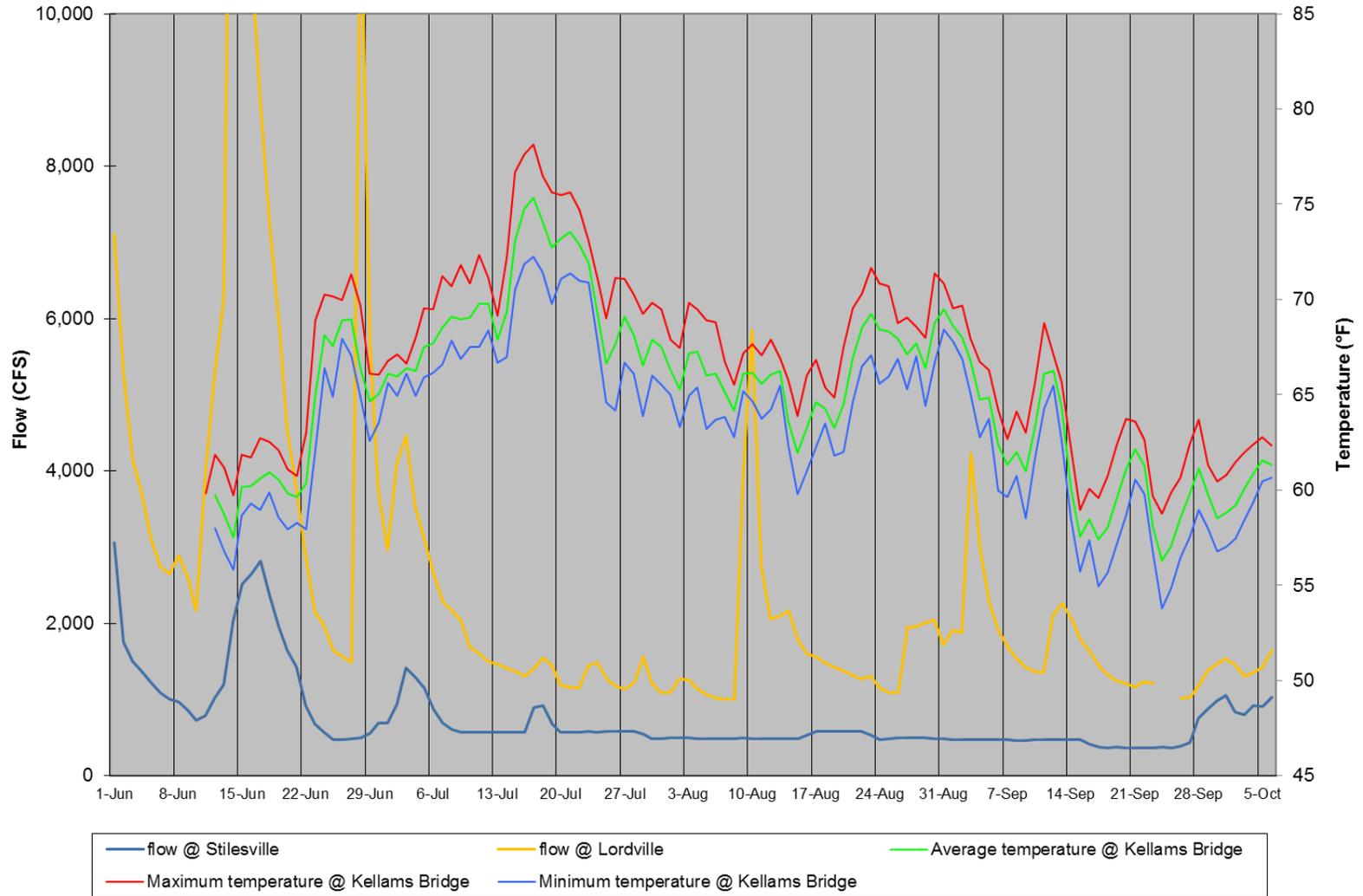
**Appendix 3Z. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Lordville, along with daily average flows at Stilesville on the West Branch and Lordville, 2013.**



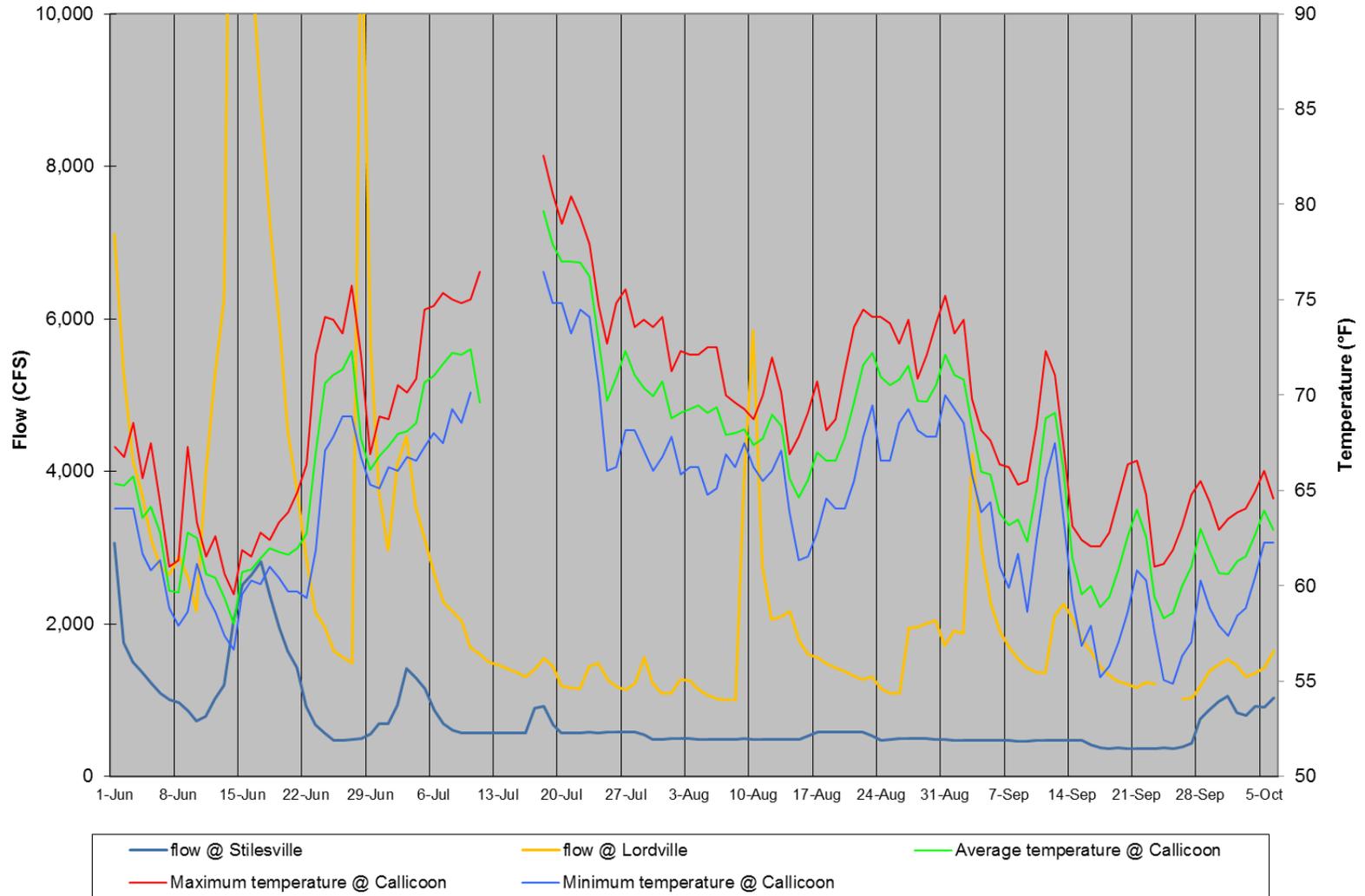
**Appendix 3AA. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Abe Lord, along with daily average flows at Stilesville on the West Branch and Lordville, 2013.**



**Appendix 3BB. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Kellams Bridge, along with daily average flows at Stilesville on the West Branch and Lordville, 2013.**



**Appendix 3CC. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Callicoon, along with daily average flows at Stilesville on the West Branch and Lordville, 2013.**



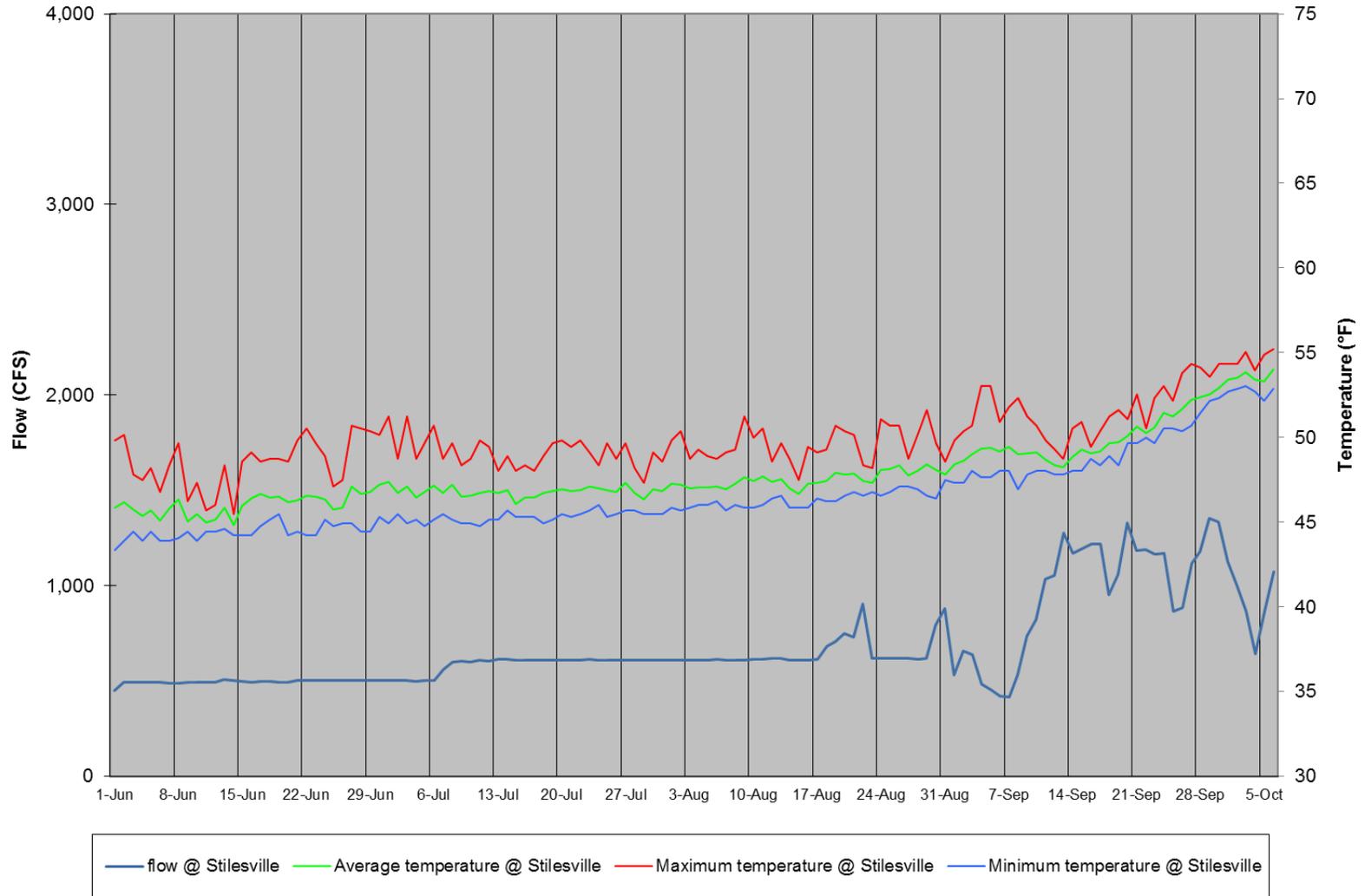
## Appendix 4:

### UPPER DELAWARE TAILWATERS

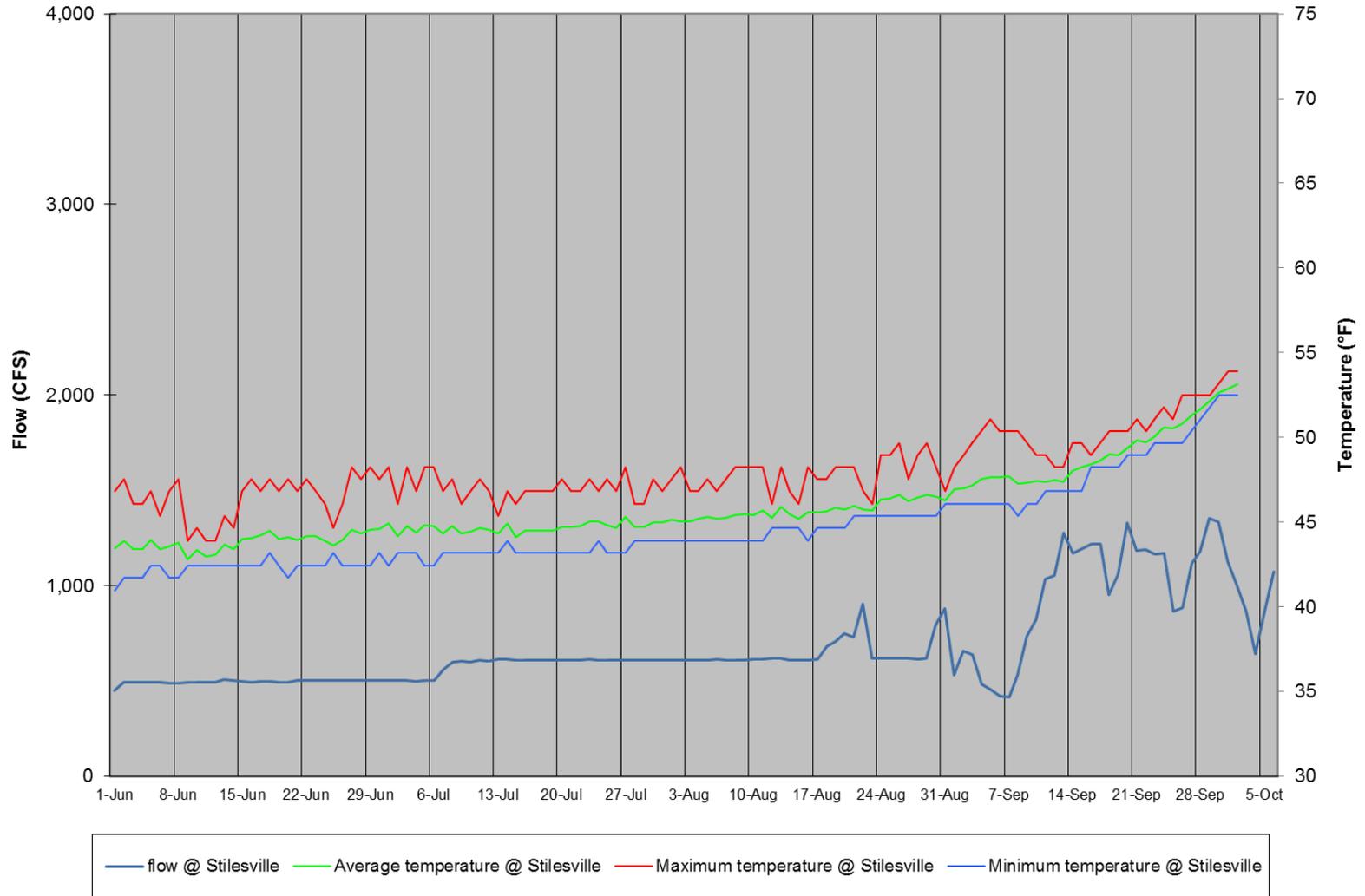
Maxima, minima, and average summer water temperature profile for each temperature monitoring site, 2014

West Branch: Appendices 4A to 4J East Branch: Appendices 4K to 4S Neversink River:  
Appendices 4T to 4X  
Delaware River: Appendices 4Y to 4CC

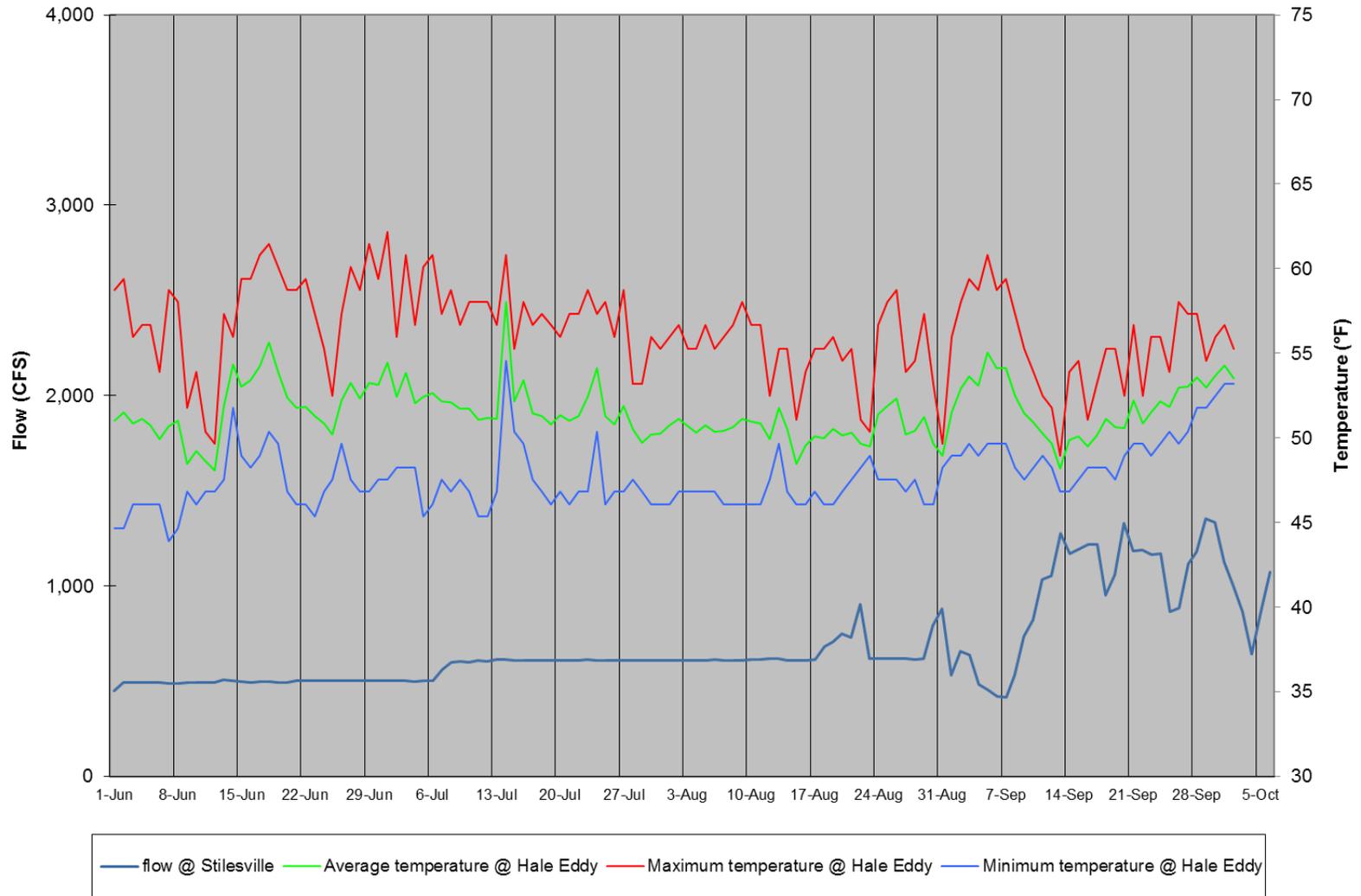
**Appendix 4A. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Stilesville, along with daily average flows at Stilesville, 2014.**



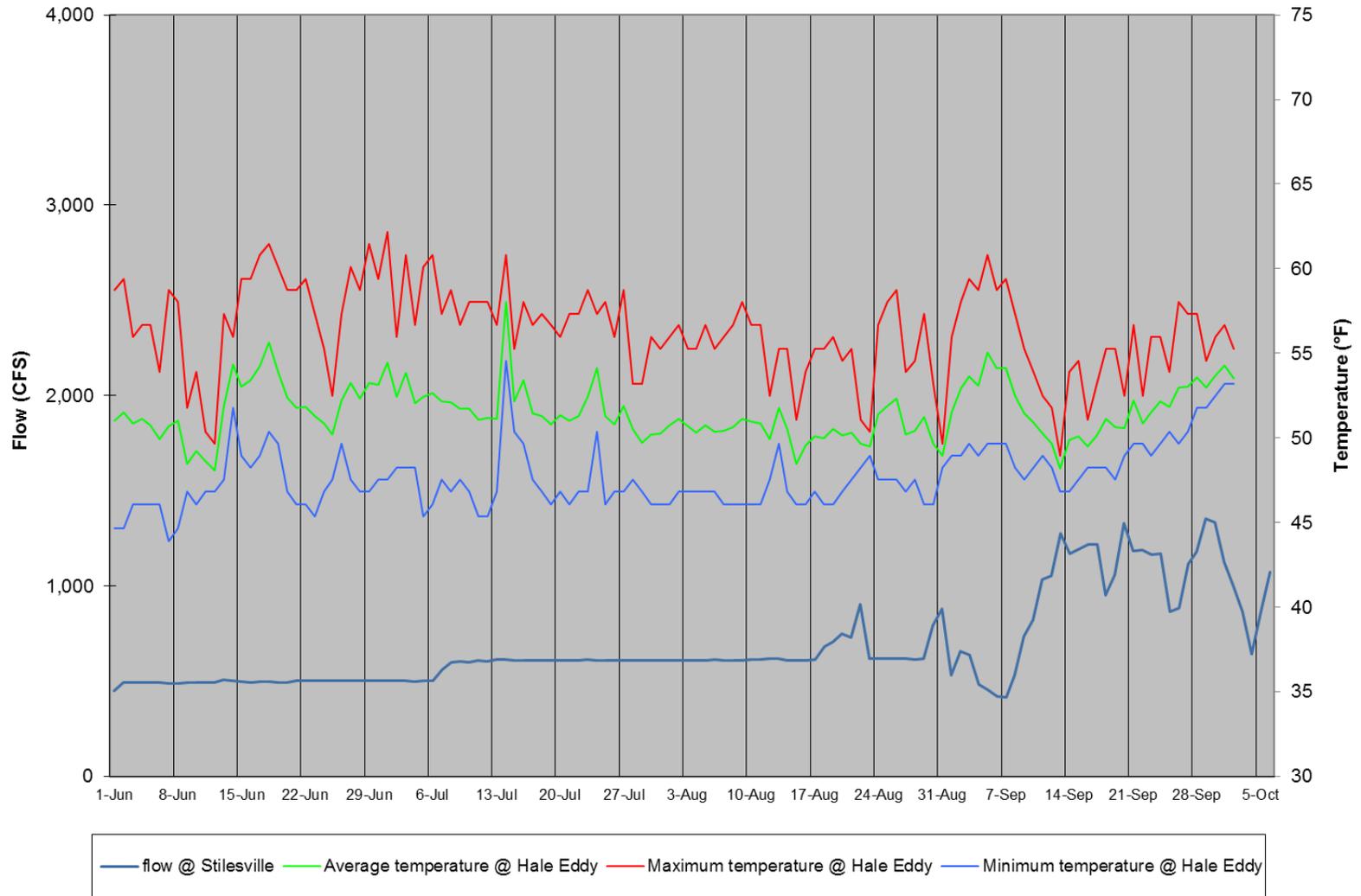
**Appendix 4B. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Stilesville, along with daily average flows at Stilesville, 2014.**



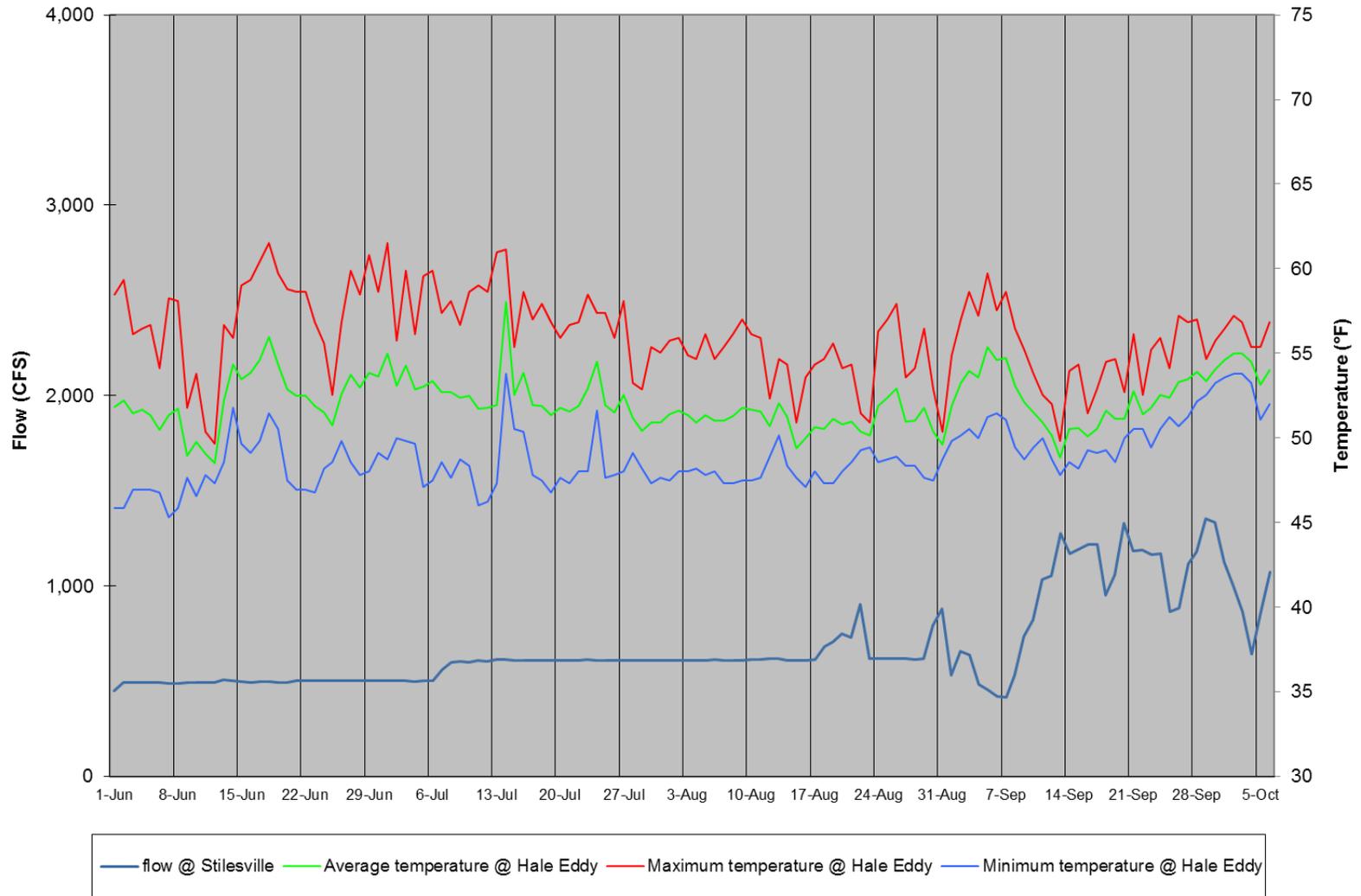
**Appendix 4C. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Mens Club, along with daily average flows at Stilesville, 2014.**



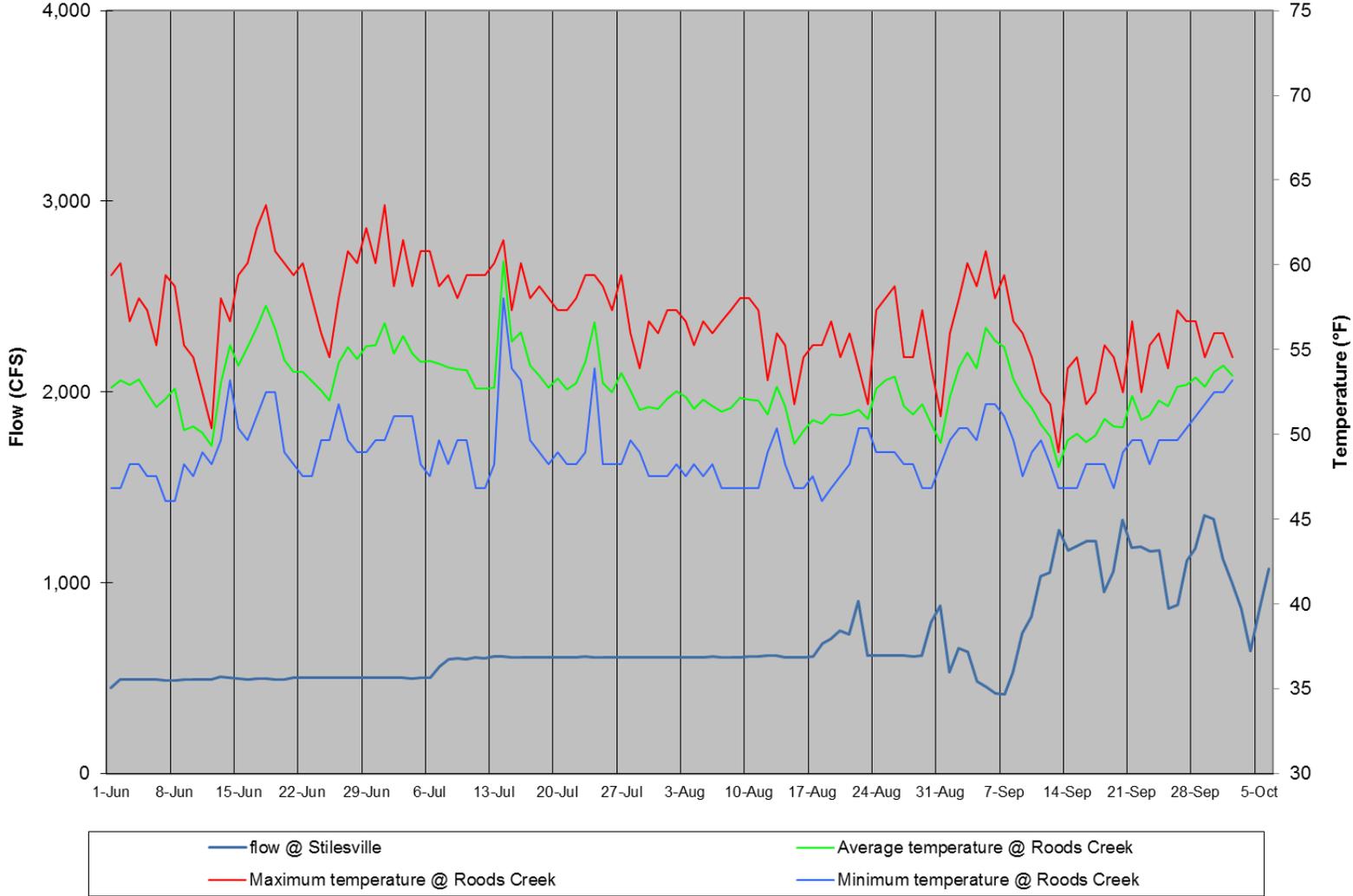
**Appendix 4D. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2014.**



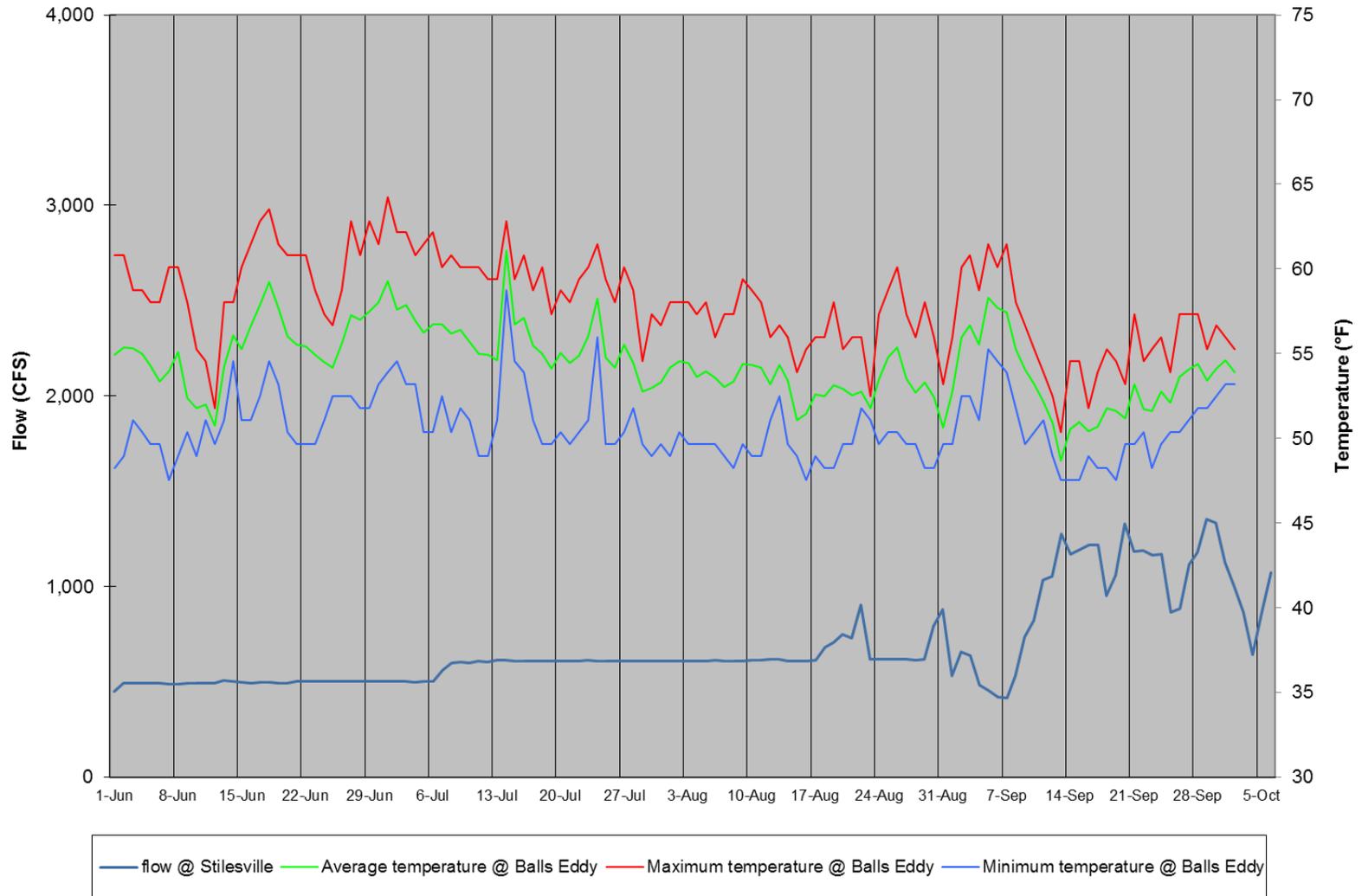
**Appendix 4E. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hale Eddy, along with daily average flows at Stilesville, 2014.**



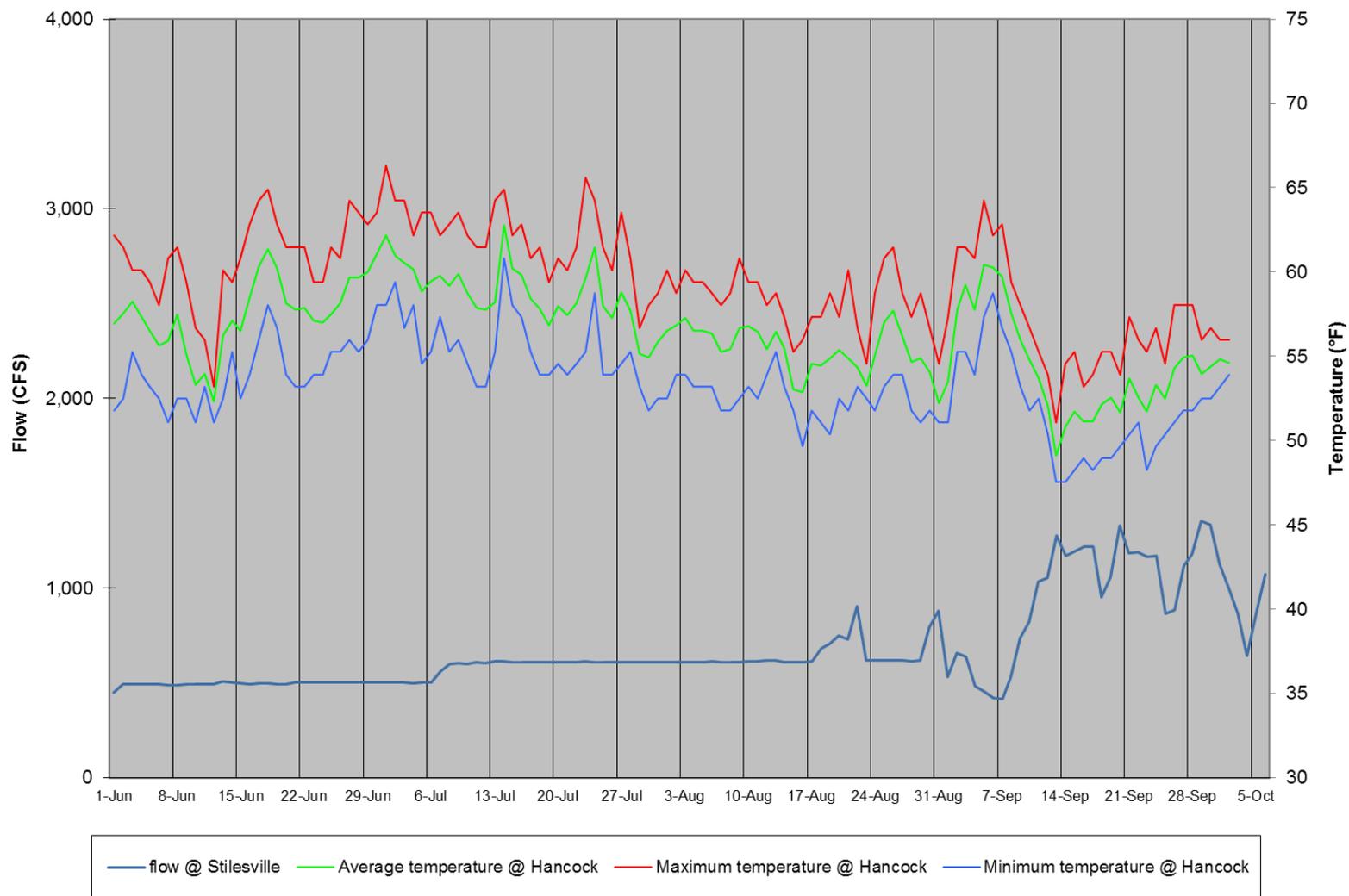
**Appendix 4F. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Roods Creek, along with daily average flows at Stilesville, 2014.**



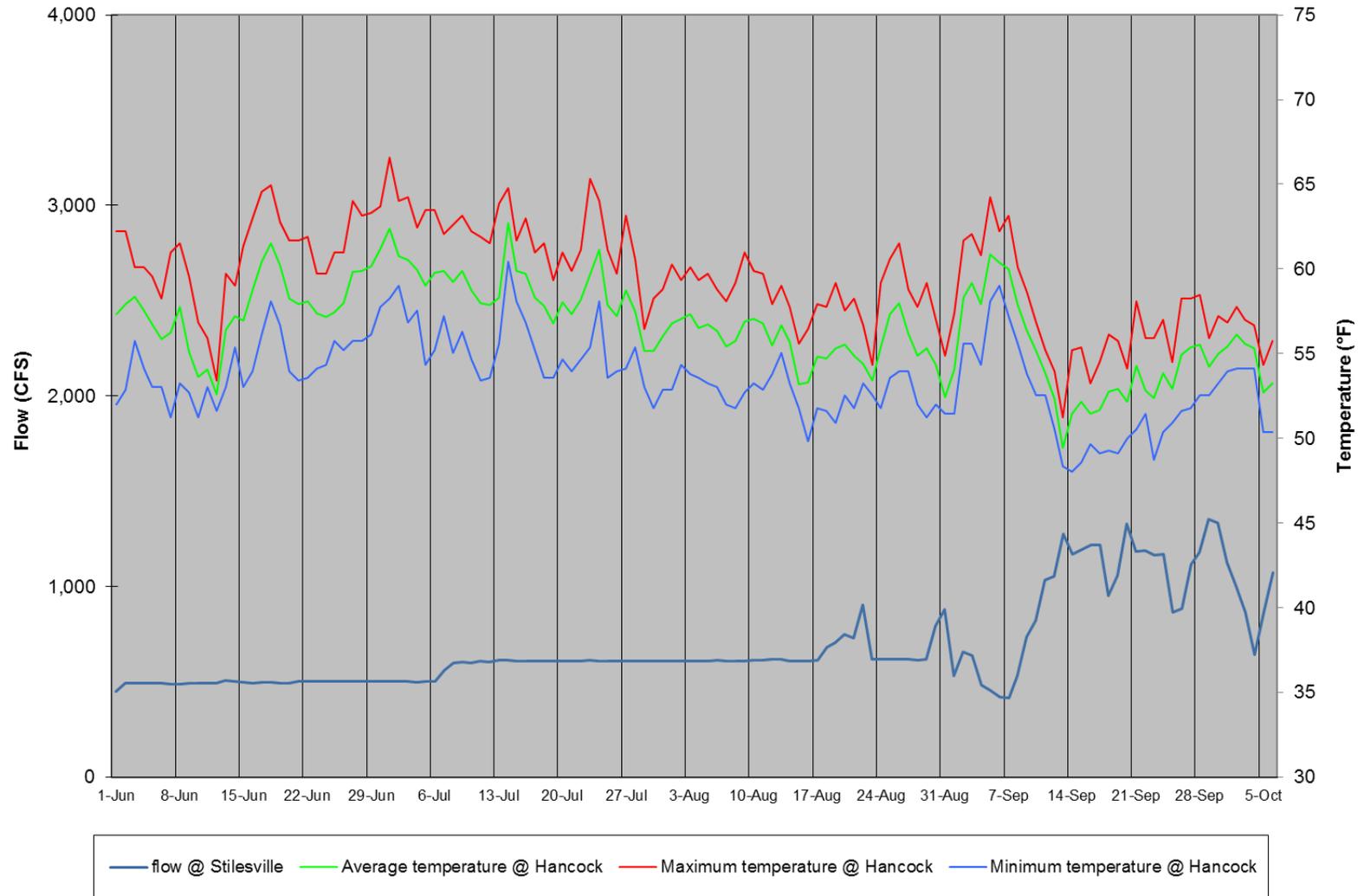
**Appendix 4G. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Balls Eddy, along with daily average flows at Stilesville, 2014.**



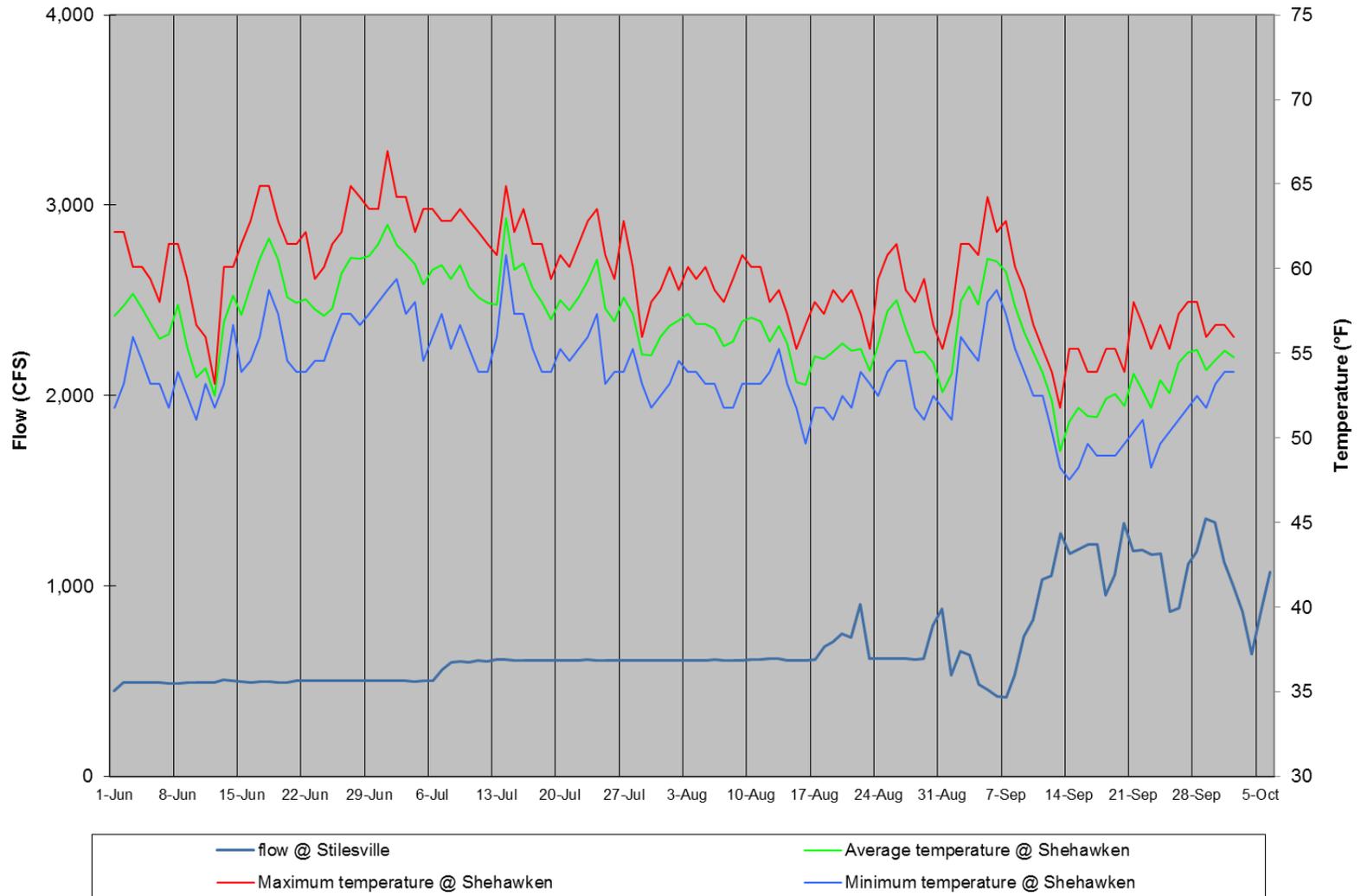
**Appendix 4H. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Hancock, along with daily average flows at Stilesville, 2014.**



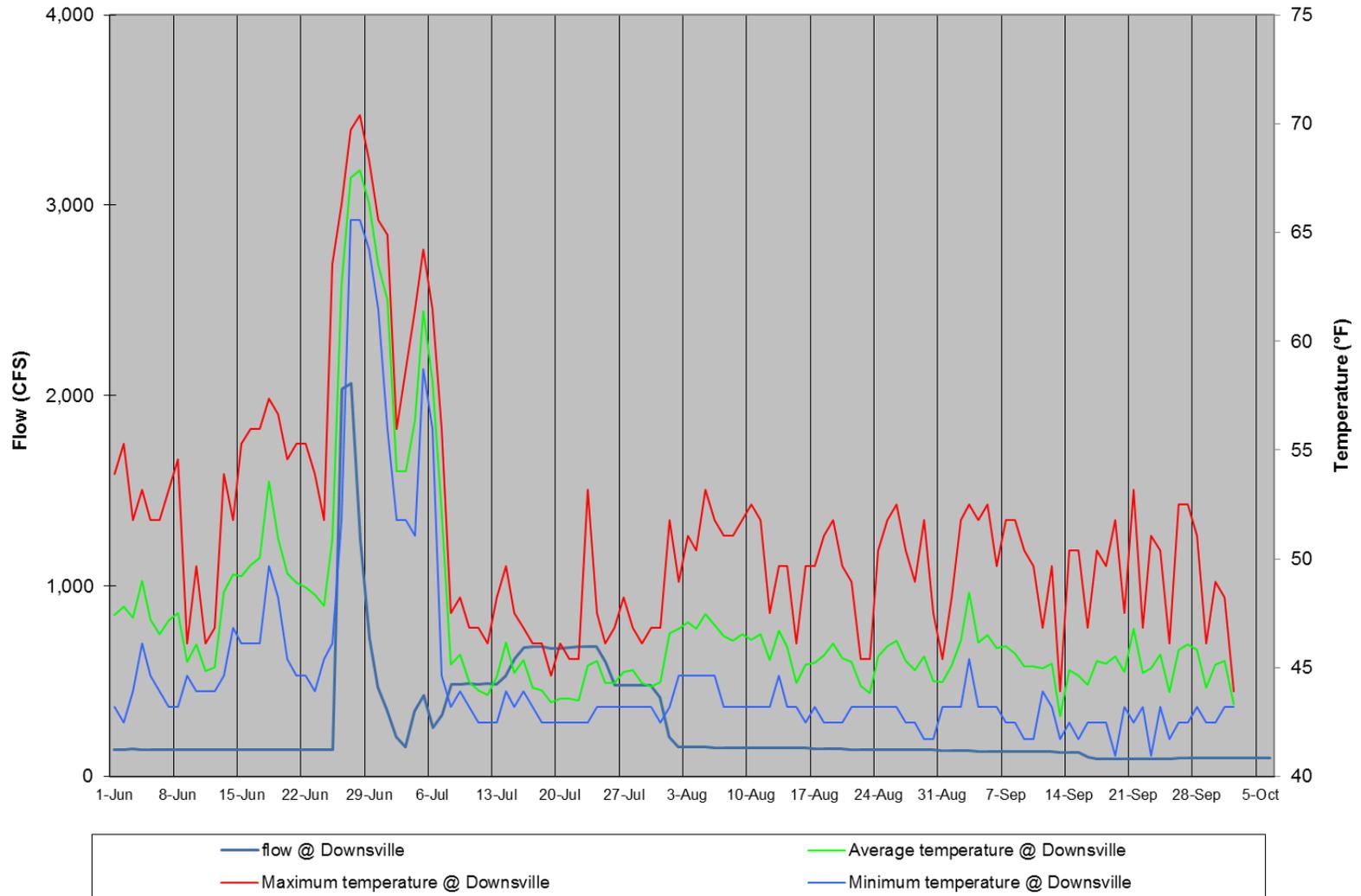
**Appendix 4I. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the West Branch at Hancock, along with daily average flows at Stilesville, 2014.**



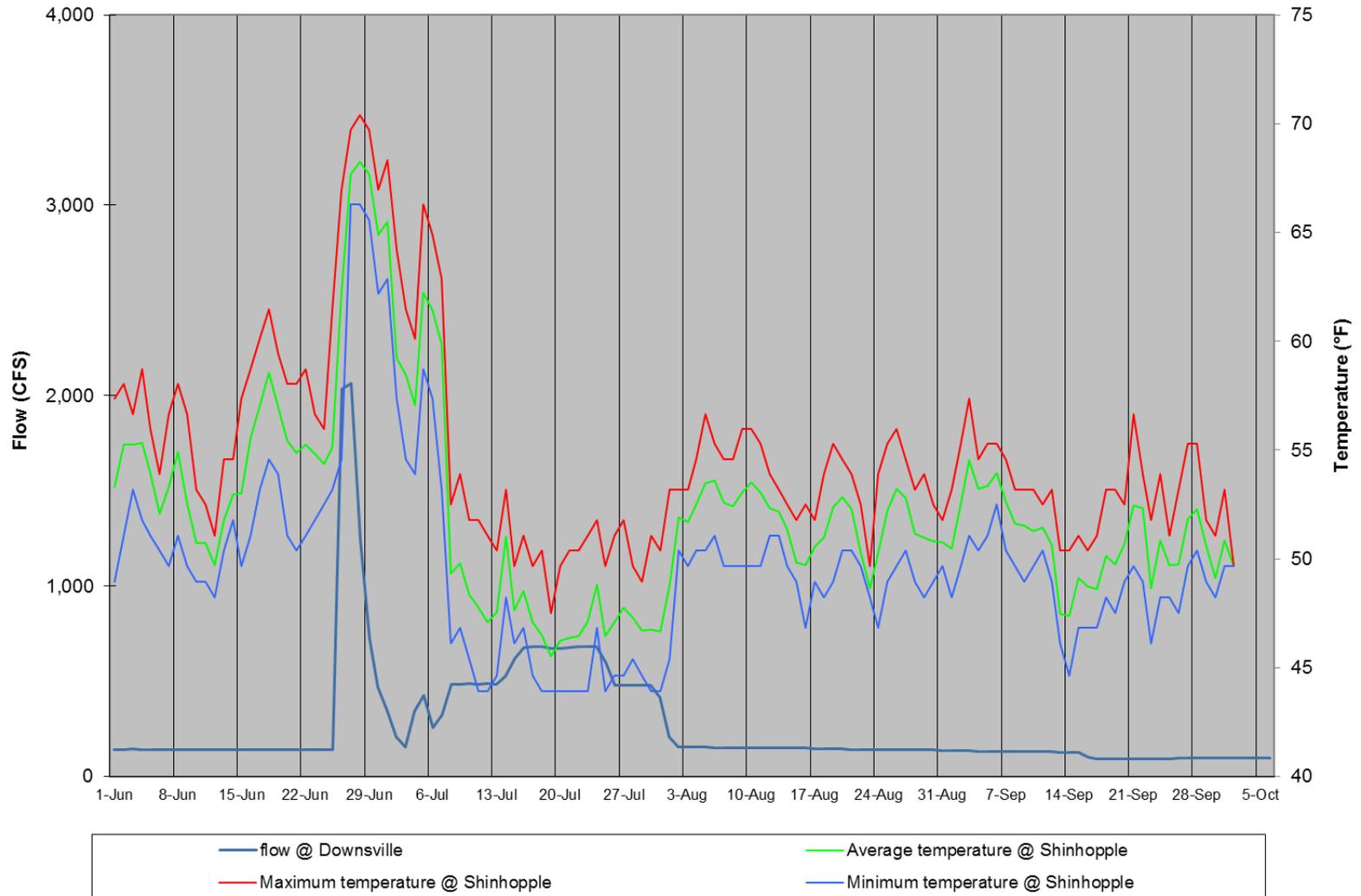
**Appendix 4J. Summer daily average, maximum, and minimum water temperature profiles on the West Branch at Shehawken, along with daily average flows at Stilesville, 2014.**



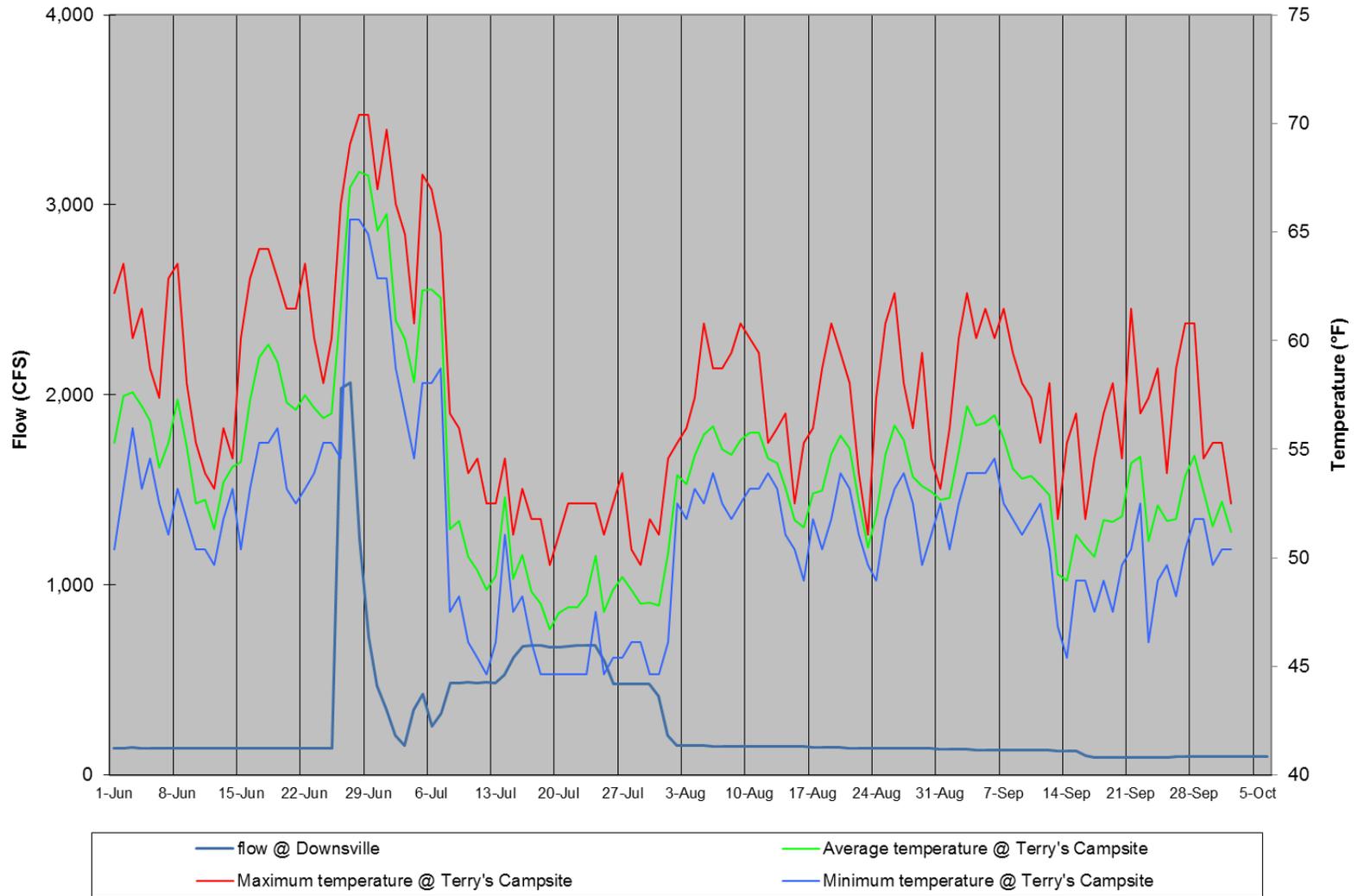
**Appendix 4K. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Downsville, along with daily average flows at Downsville, 2014.**



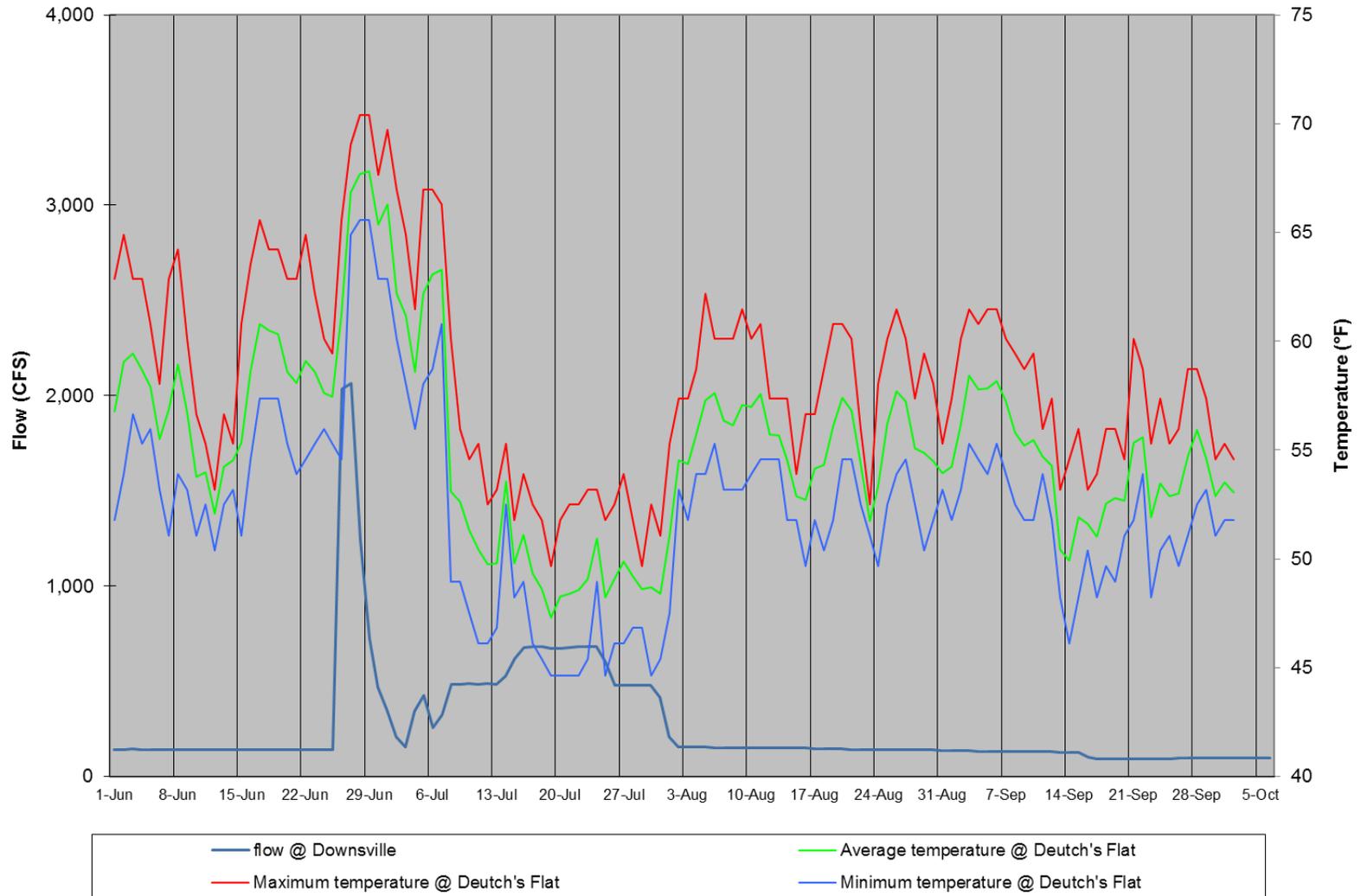
**Appendix 4L. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Shinhopple, along with daily average flows at Downsville, 2014.**



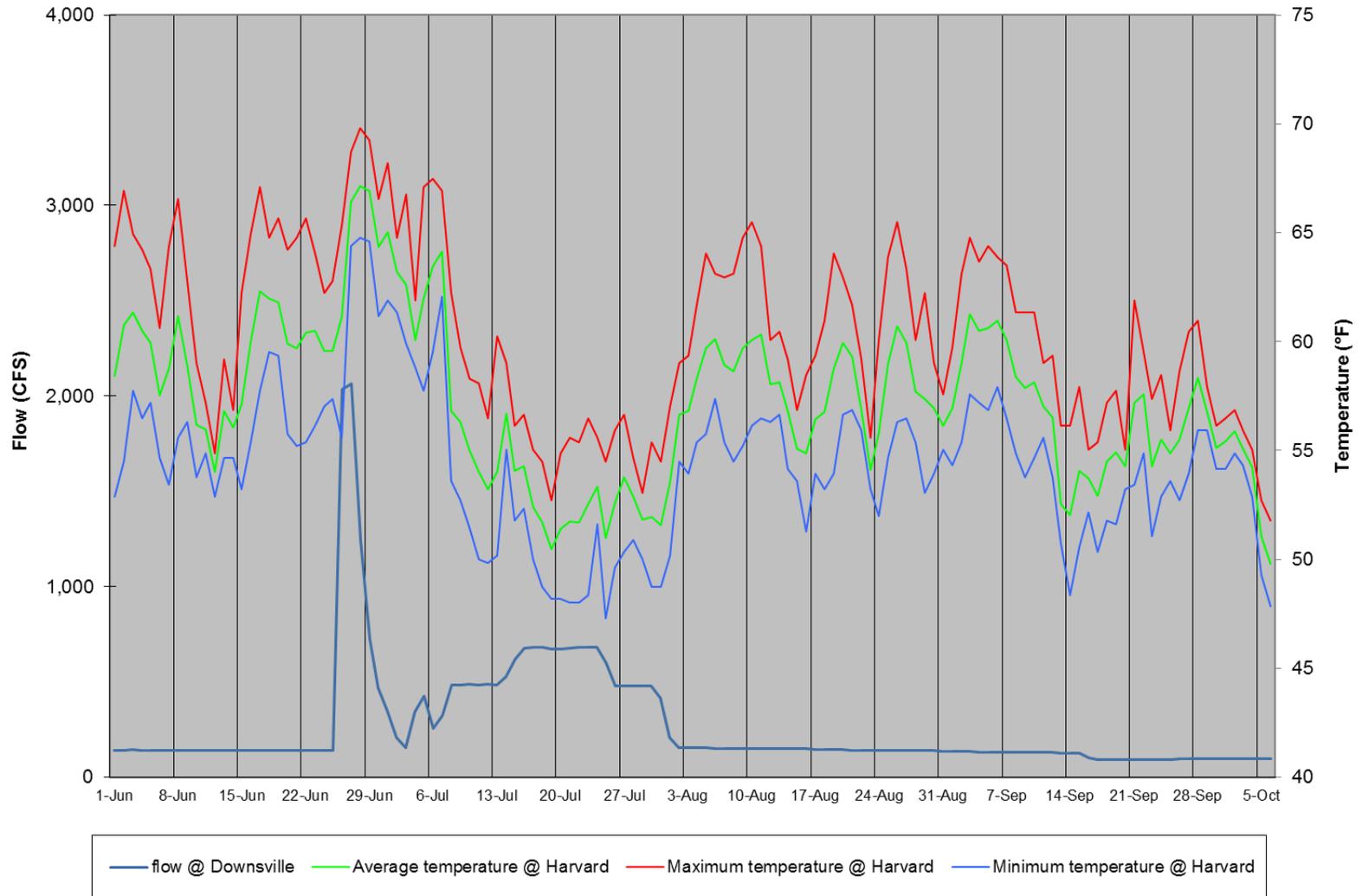
**Appendix 4M. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Terry's Campsite, along with daily average flows at Downsville, 2014.**



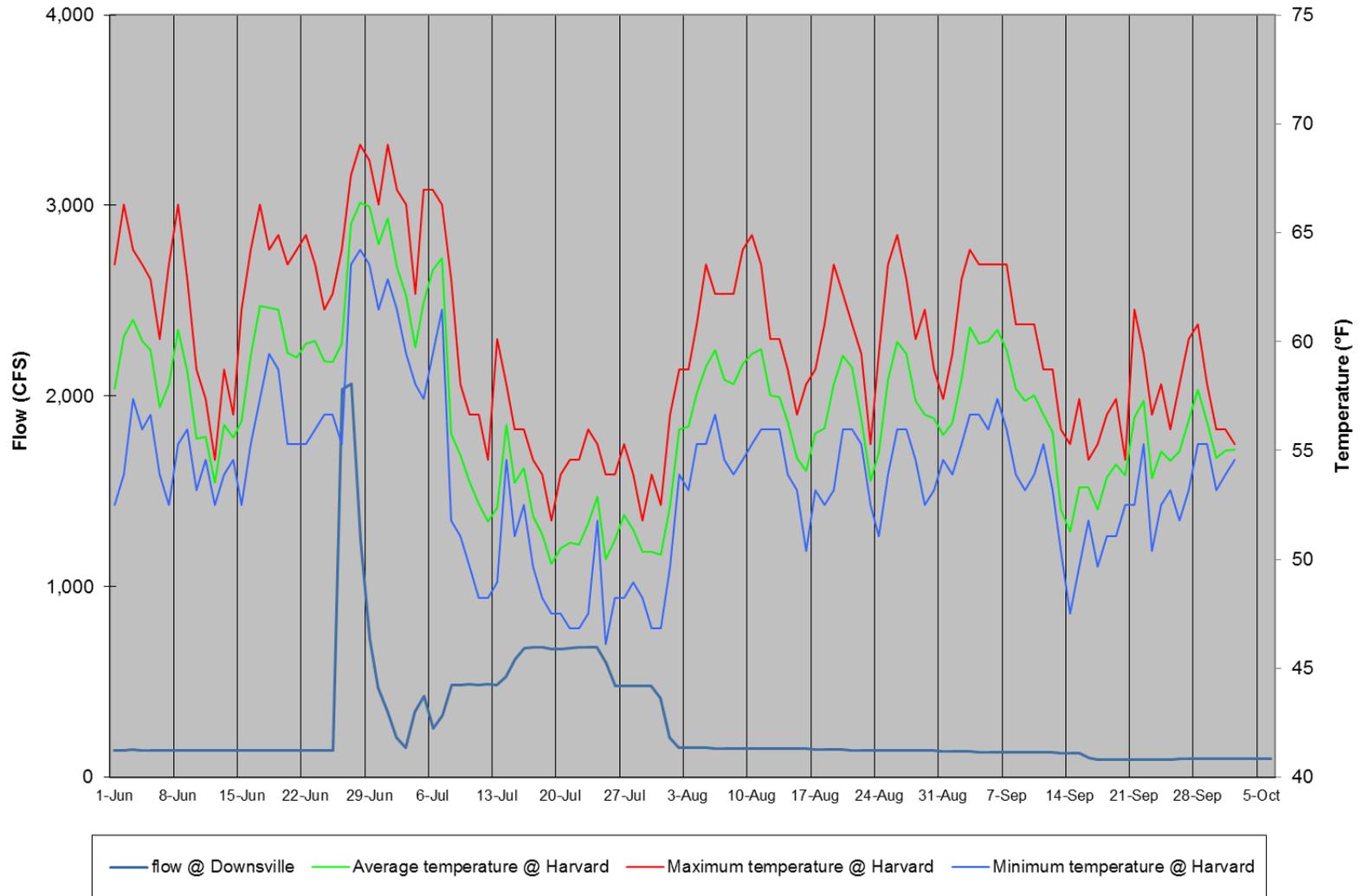
**Appendix 4N. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Deutch's Flat, along with daily average flows at Downsville, 2014.**



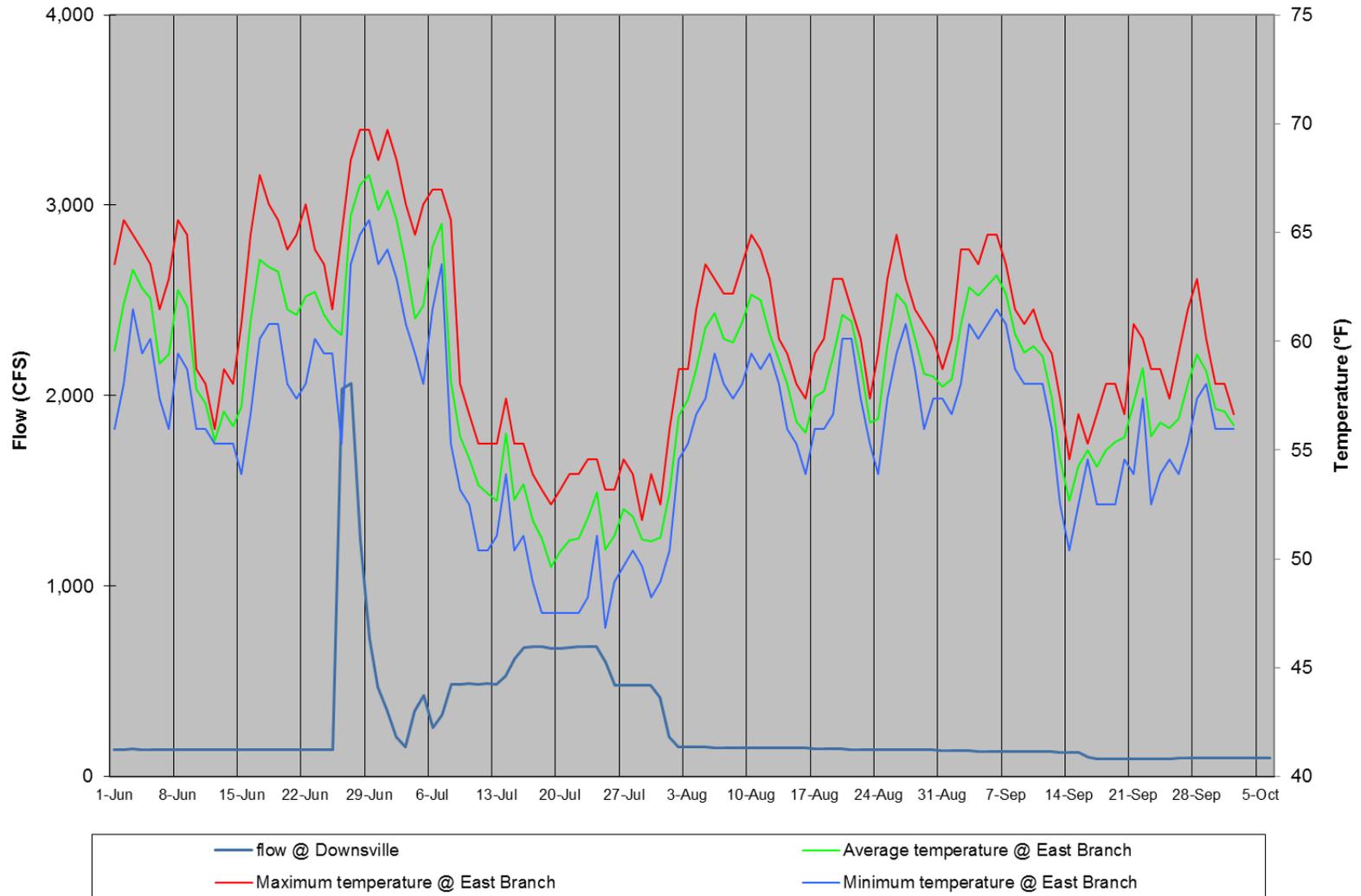
**Appendix 40. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Harvard, along with daily average flows at Downsville, 2014.**



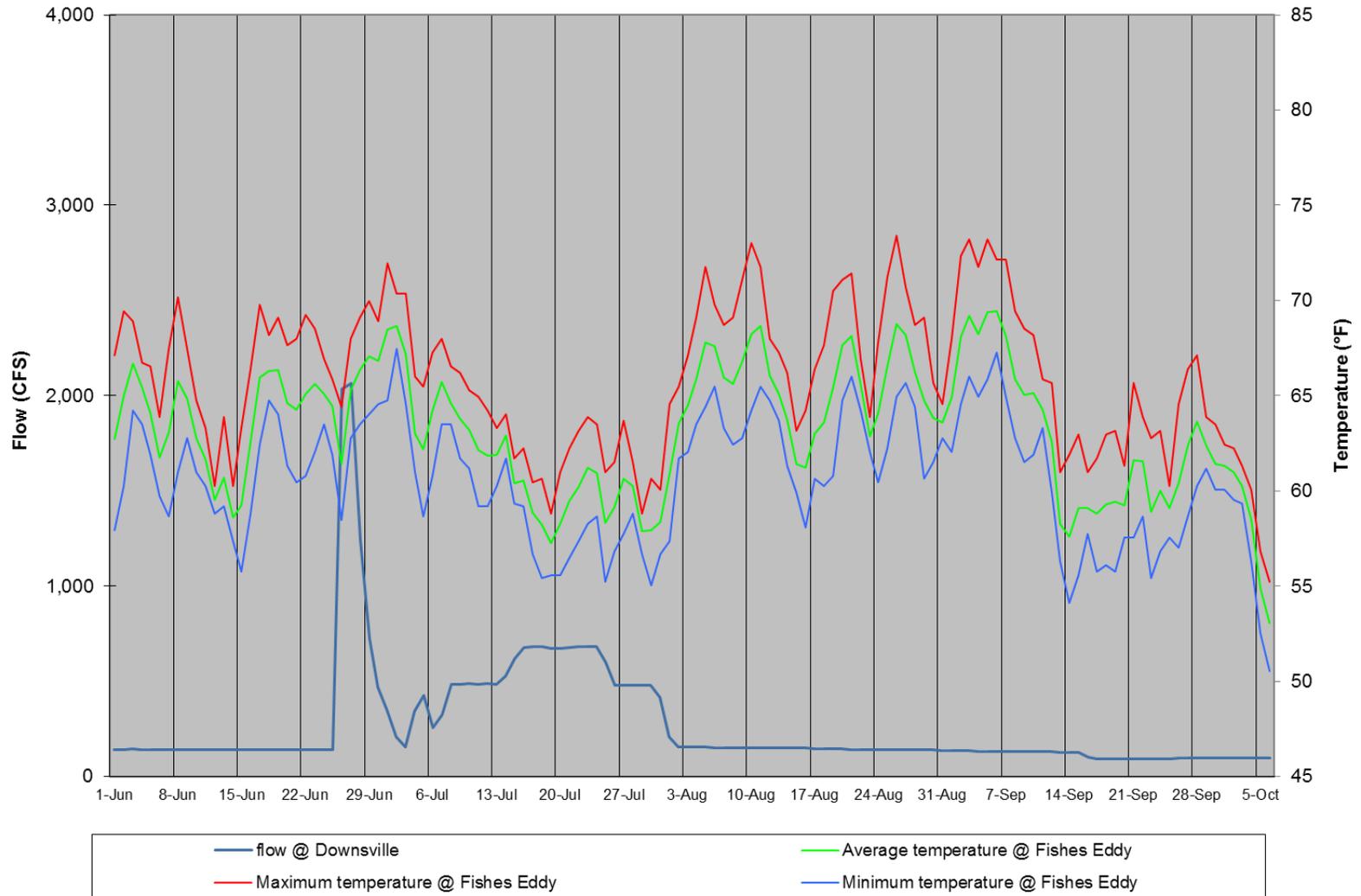
**Appendix 4P. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Harvard, along with daily average flows at Downsville, 2014.**



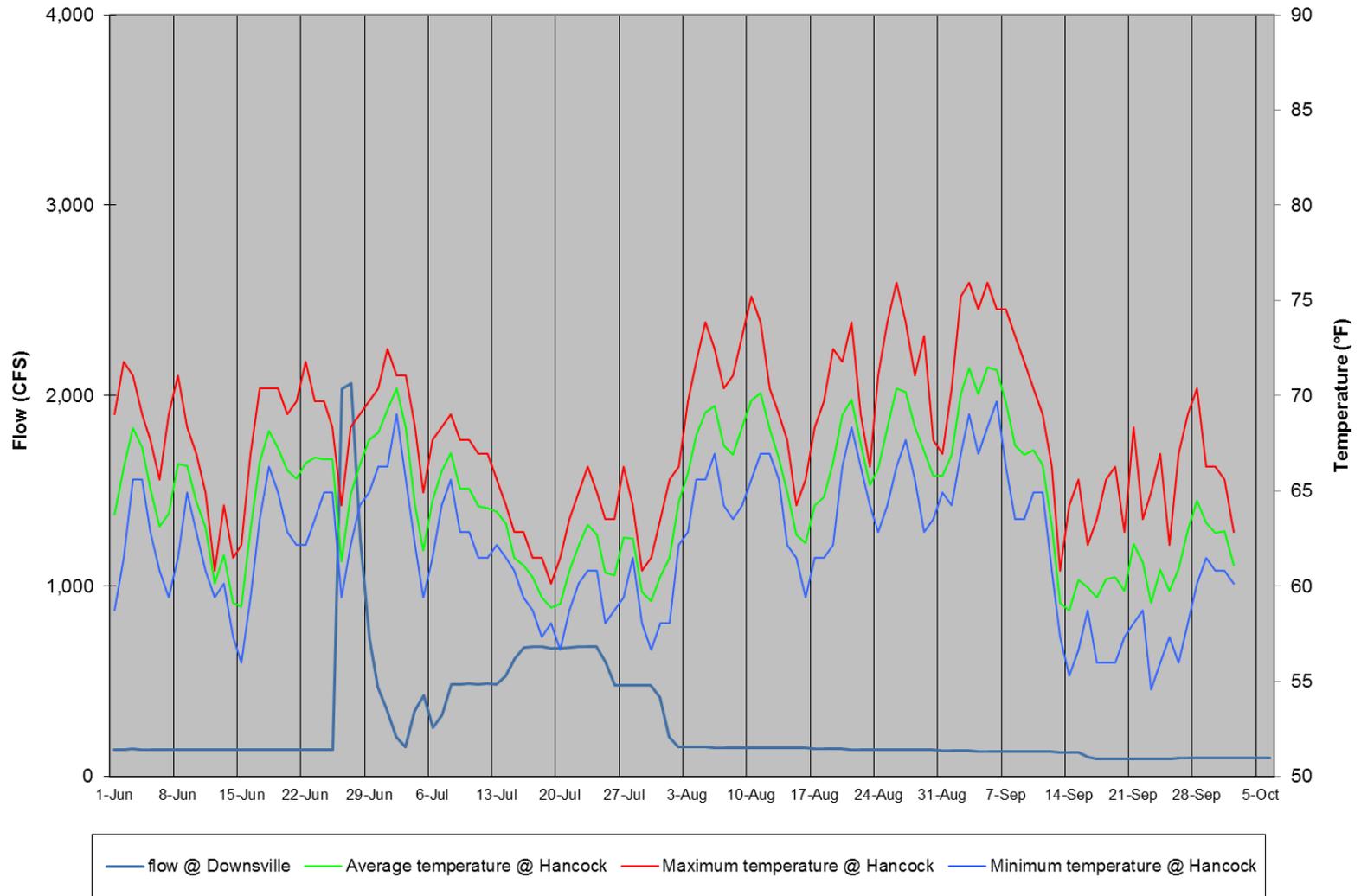
**Appendix 4Q. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at East Branch, along with daily average flows at Downsville, 2014.**



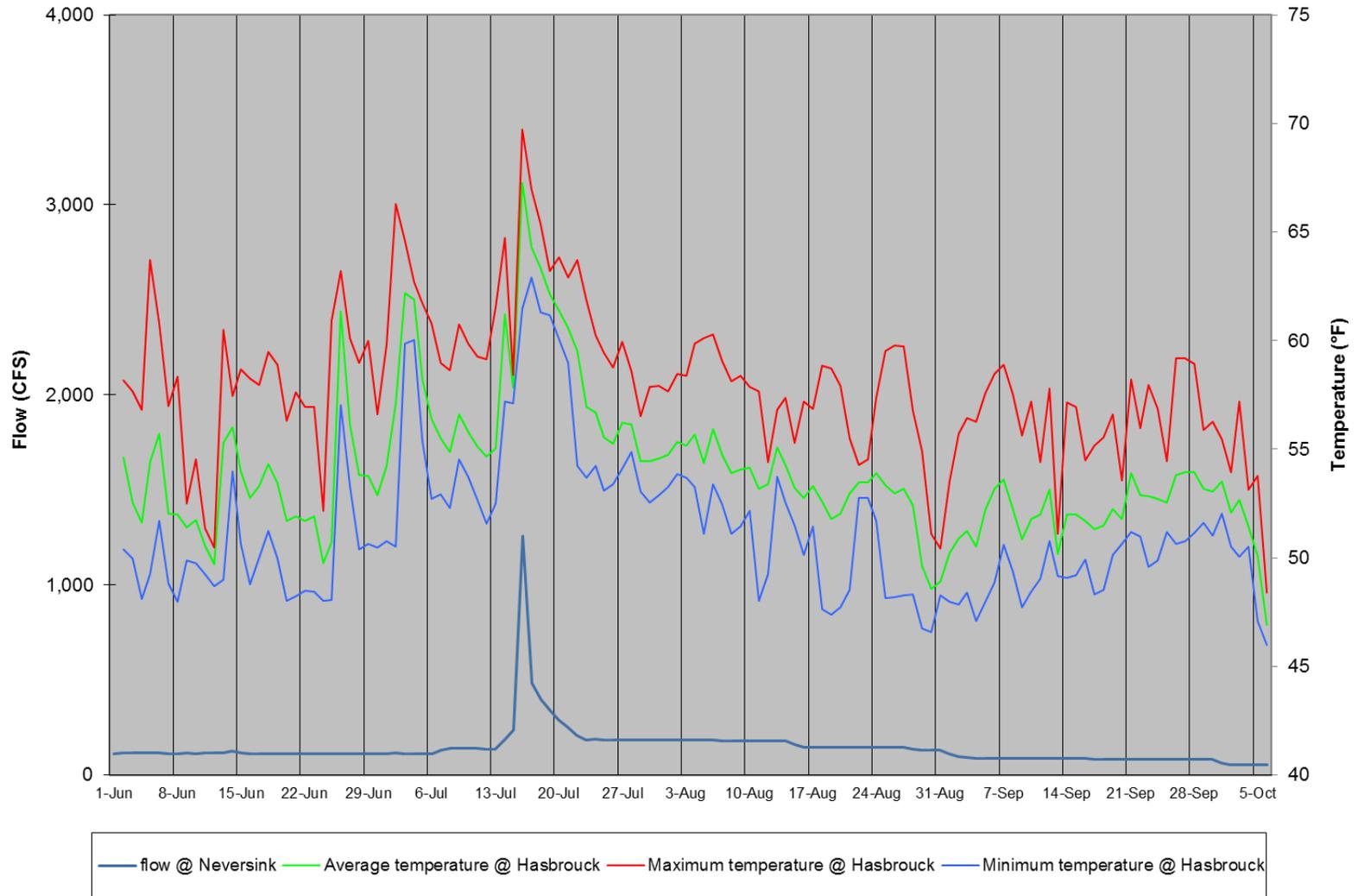
**Appendix 4R. Summer daily average, maximum, and minimum water temperature profiles from the USGS gage on the East Branch at Fishes Eddy, along with daily average flows at Downsville, 2014.**



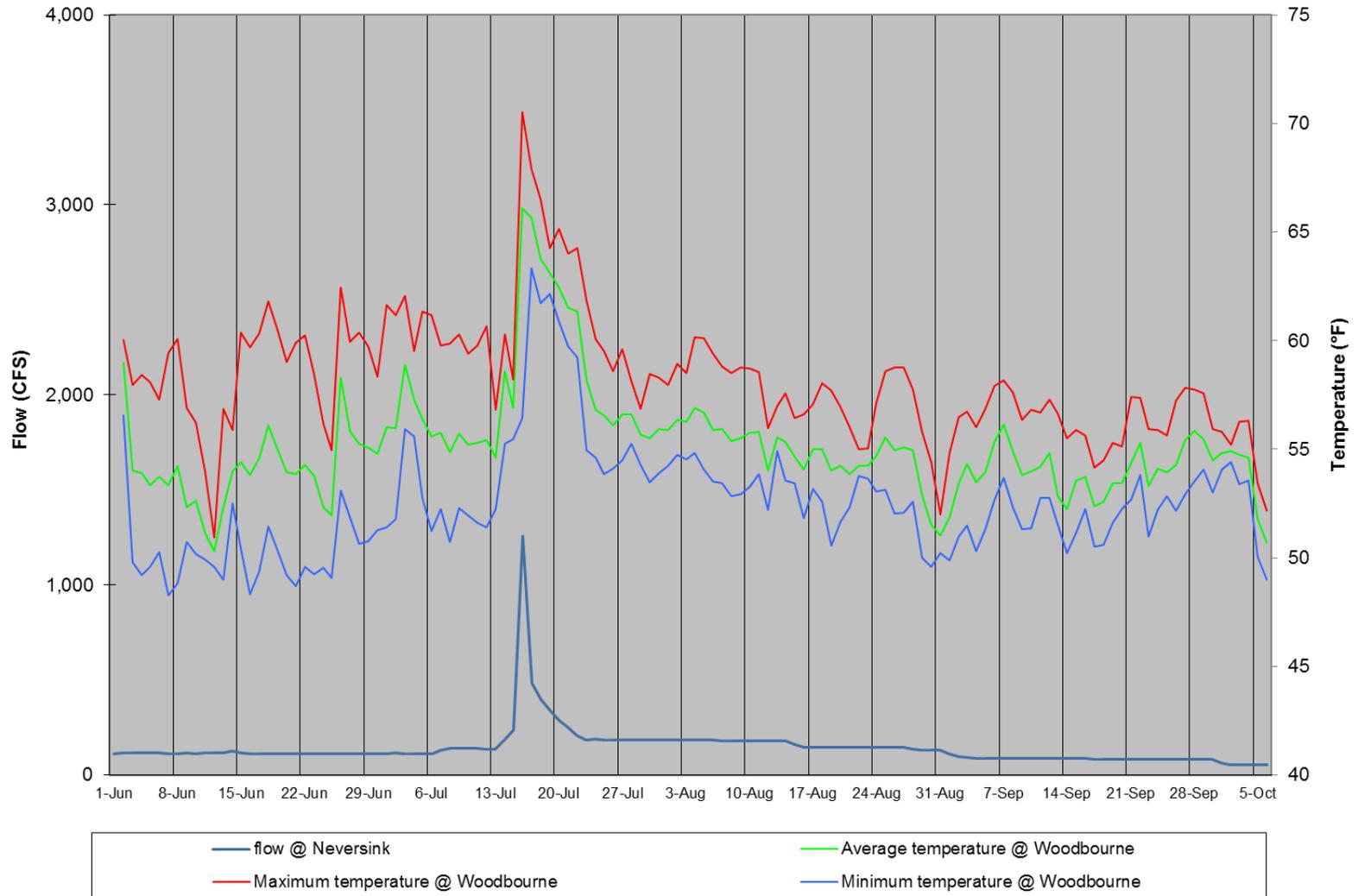
**Appendix 4S. Summer daily average, maximum, and minimum water temperature profiles on the East Branch at Hancock, along with daily average flows at Downsville, 2014.**



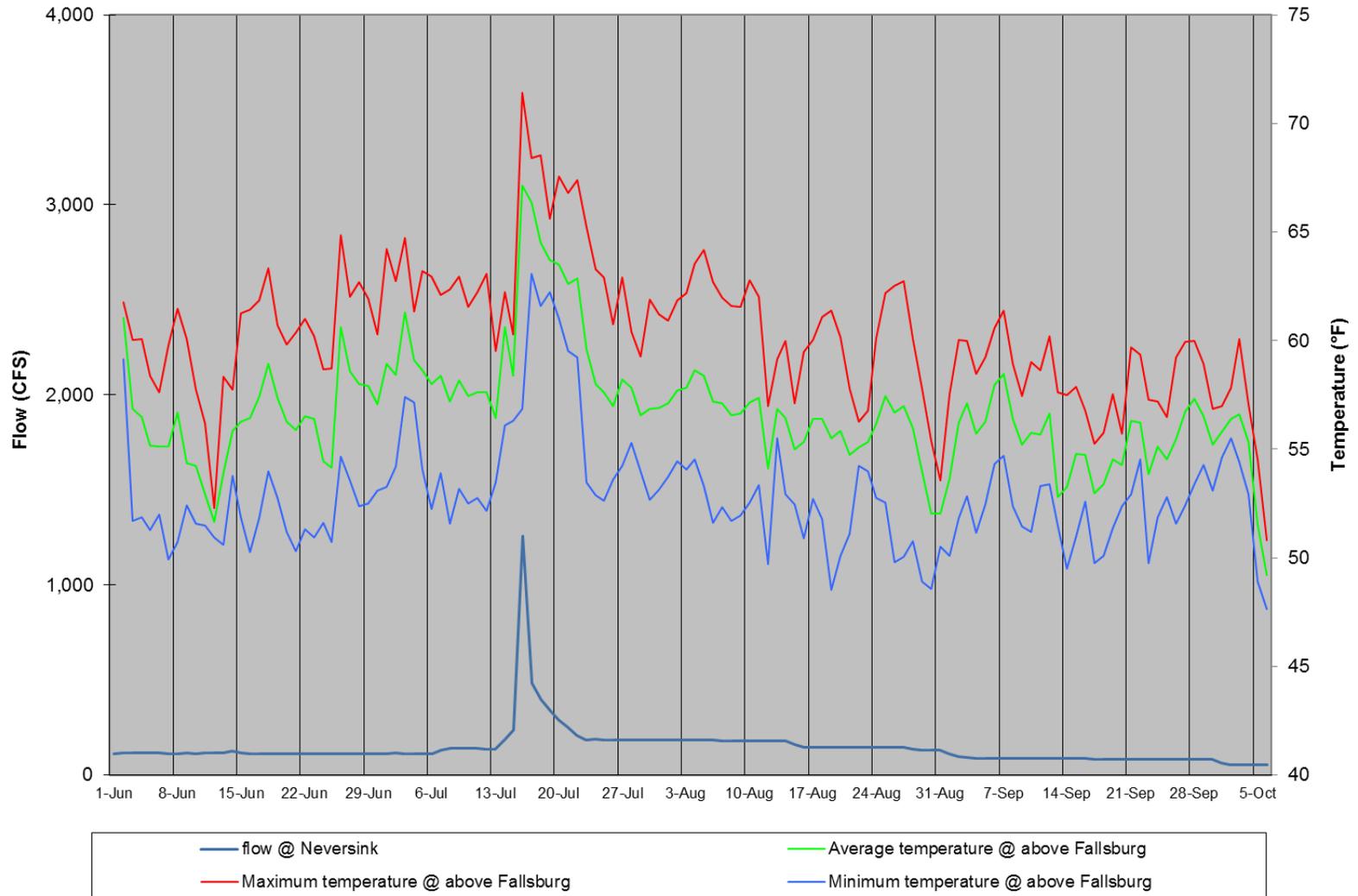
**Appendix 4T. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Hasbrouck, along with daily average flows at Neversink, 2014.**



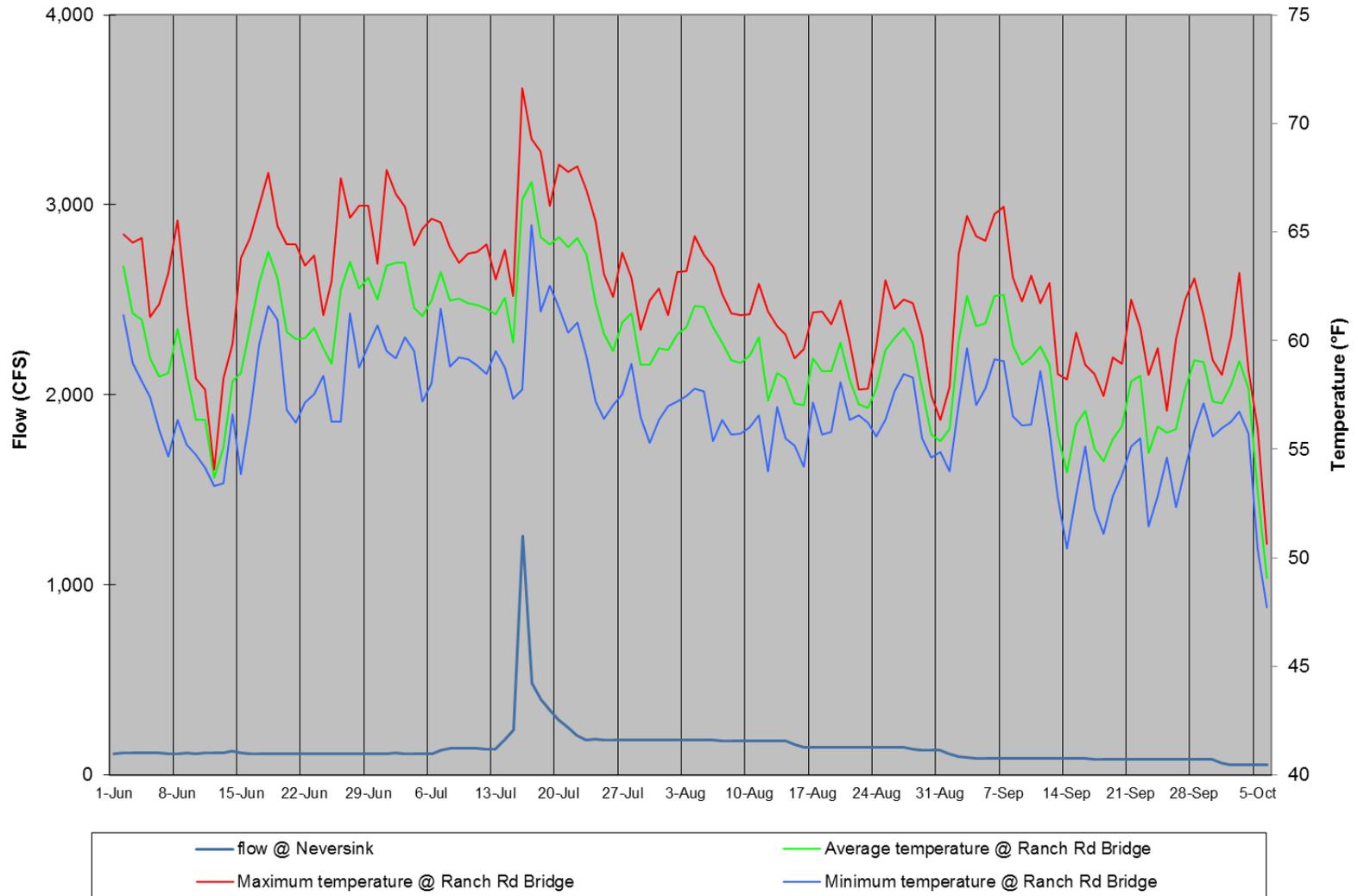
**Appendix 4U. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Woodbourne, along with daily average flows at Neversink, 2014.**



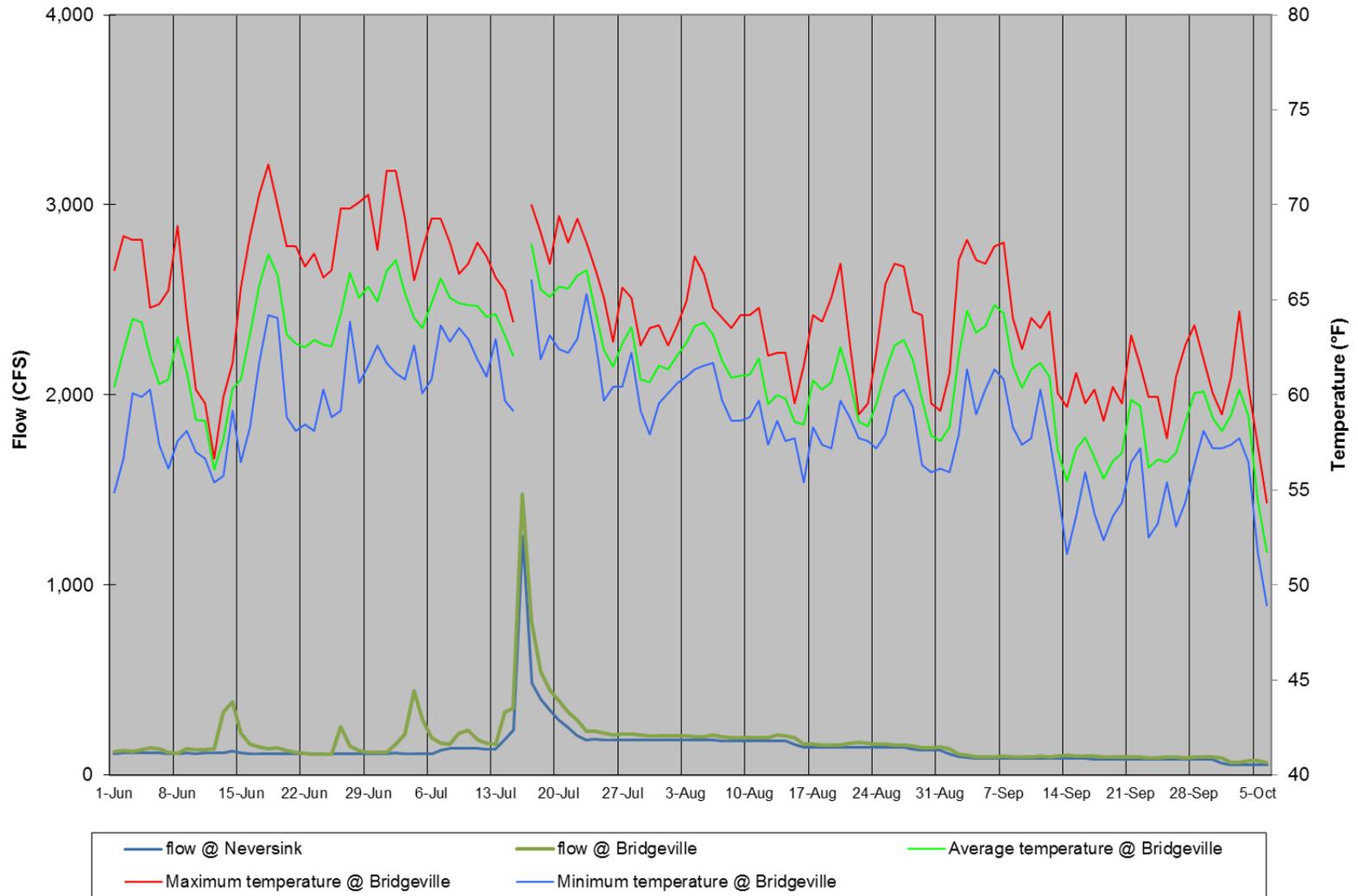
**Appendix 4V. Summer daily average, maximum, and minimum water temperature profiles on the Neversink just above Fallsburg, along with daily average flows at Neversink, 2014.**



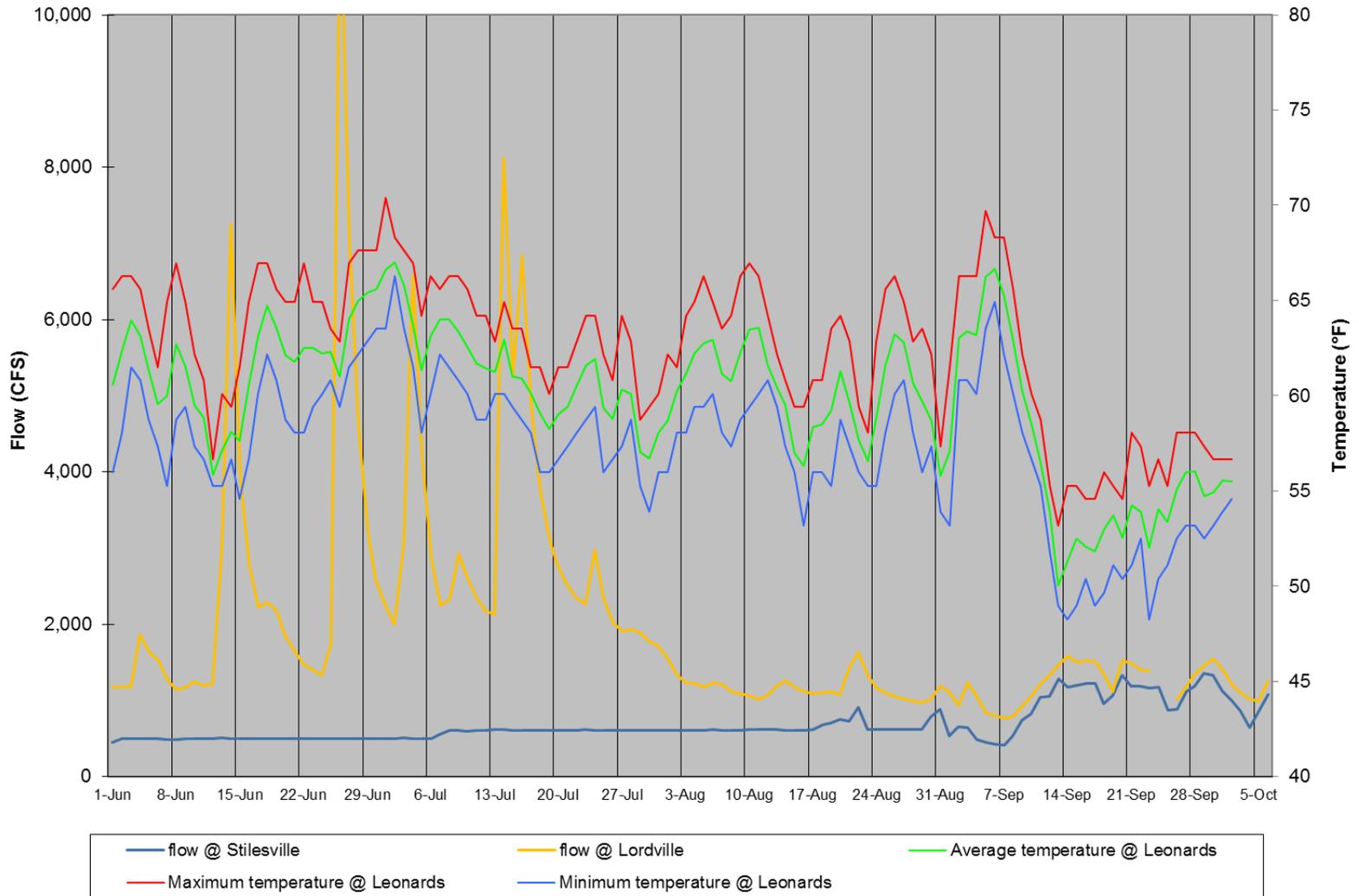
**Appendix 4W. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Ranch Rd bridge, along with daily average flows at Neversink, 2014.**



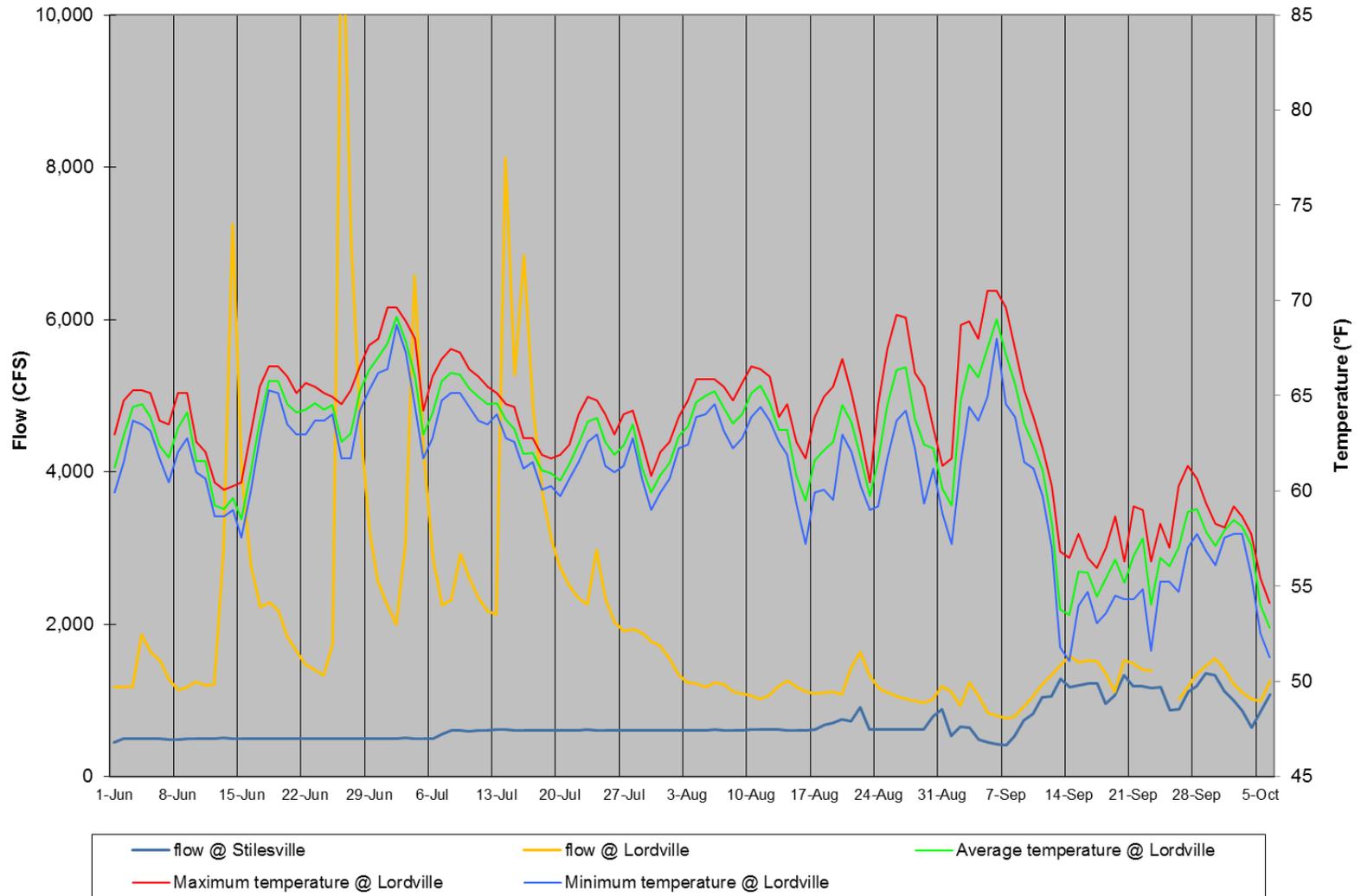
**Appendix 4X. Summer daily average, maximum, and minimum water temperature profiles on the Neversink at Bridgeville, along with daily average flows at Bridgeville & Neversink, 2014.**



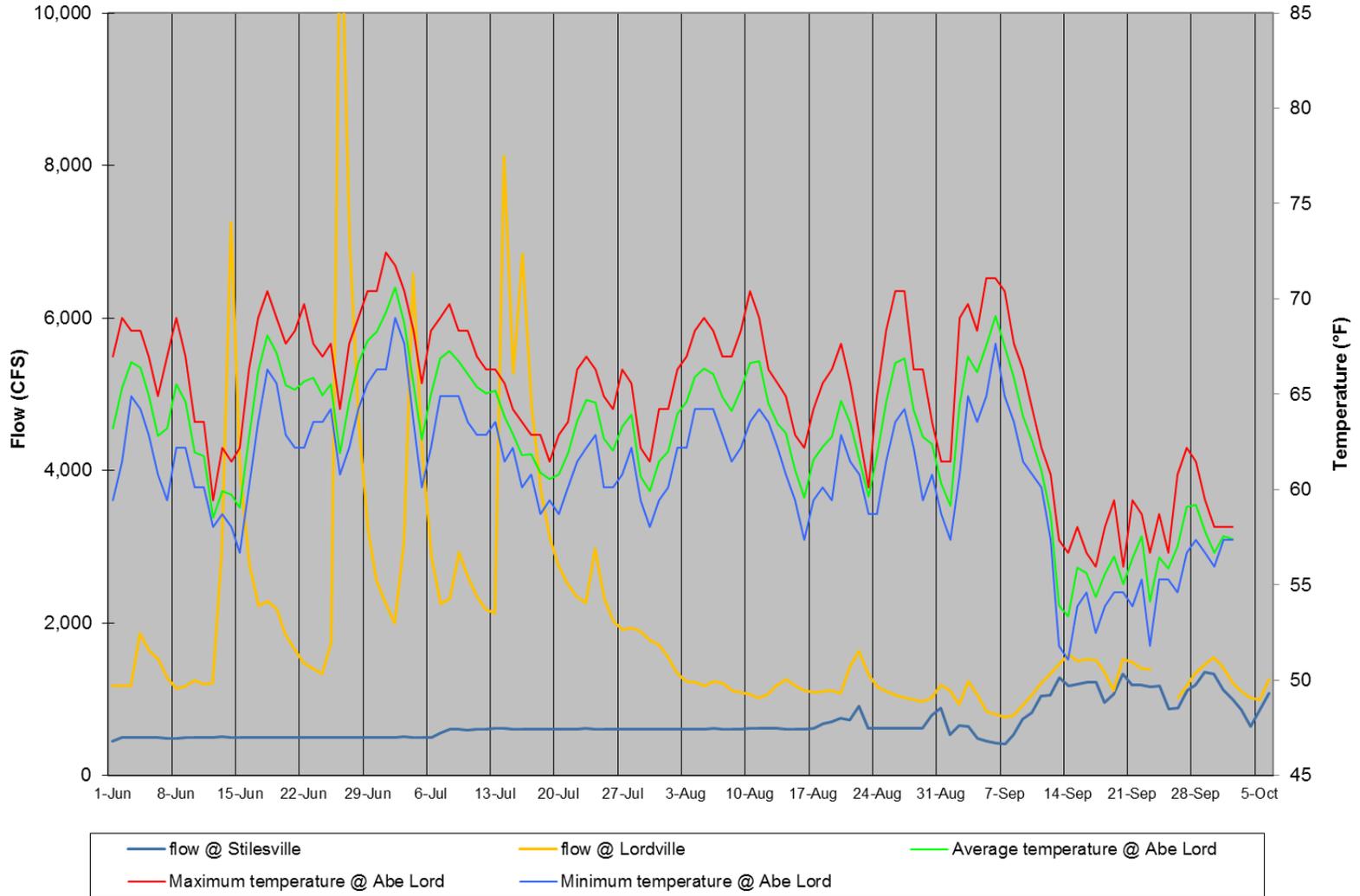
**Appendix 4Y. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Leonards, along with daily average flows at Stilesville on the West Branch and Lordville, 2014.**



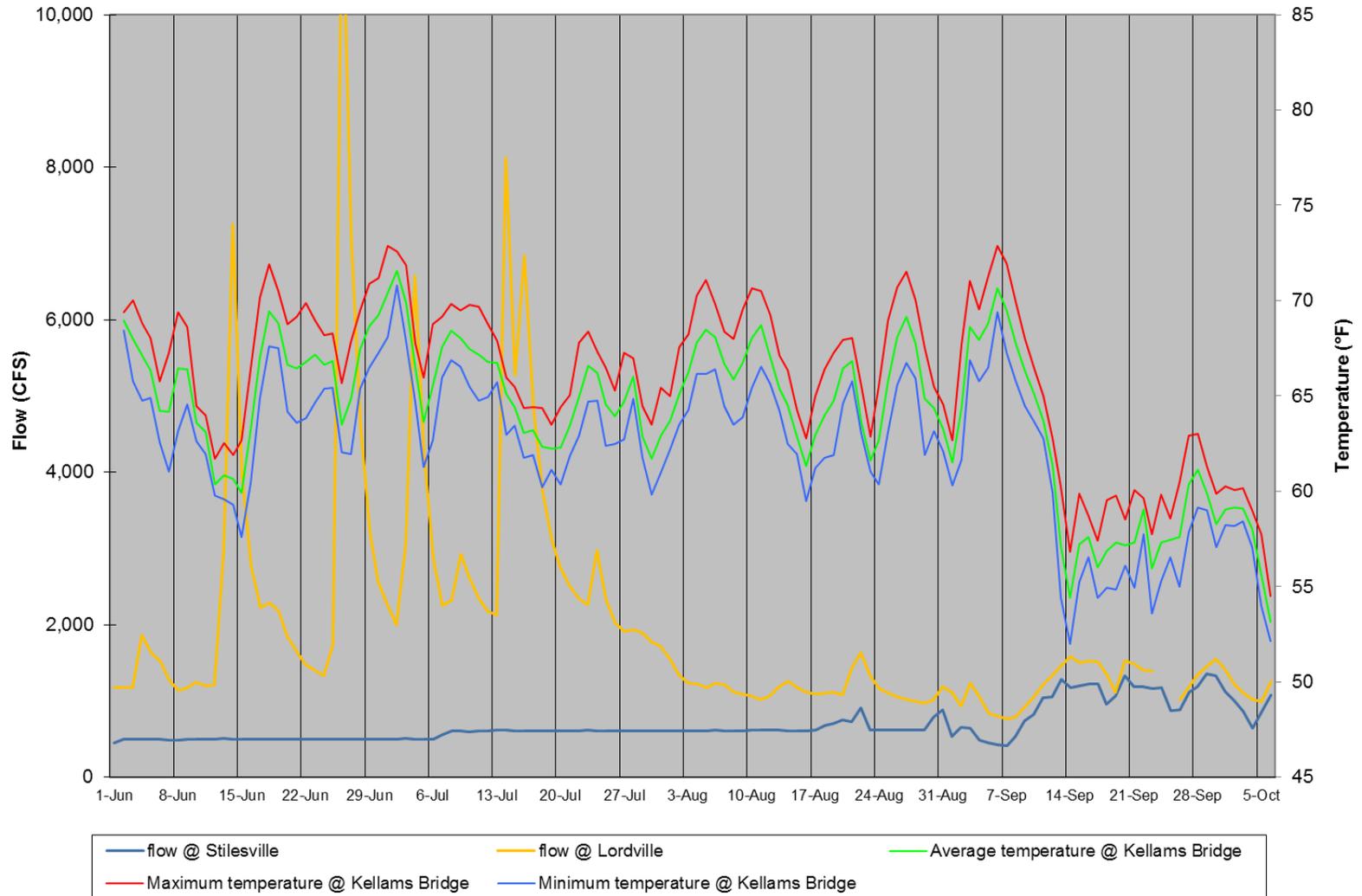
**Appendix 4Z. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Lordville, along with daily average flows at Stilesville on the West Branch and Lordville, 2014.**



**Appendix 4AA. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Abe Lord, along with daily average flows at Stilesville on the West Branch and Lordville, 2014.**



**Appendix 4BB. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Kellams Bridge, along with daily average flows at Stilesville on the West Branch and Lordville, 2014.**



**Appendix 4CC. Summer daily average, maximum, and minimum water temperature profiles on the Delaware River at Callicoon, along with daily average flows at Stilesville on the West Branch and Lordville, 2014.**

