Corvallis Watershed Stream Temperature Monitoring
Summer 2015
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Report submitted January 2016

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Executive Summary

The intensive stream temperature monitoring in the Corvallis Watershed that was begun in 2010 was continued in 2015 to test the consistency of trends and results found in previous years' data. In addition to air and water temperatures, stream flow data was collected to better analyze the heat input into Rock Creek from the reservoir spillway.

The stream temperatures recorded in the Corvallis (Rock Creek) Watershed reflected regional climate records. In 2015, Oregon and Washington each had their warmest summer on record. Oregon's summer temperature was 4.6°F above average, besting the previous record set in 2003 by 0.6°F. Washington's summer temperature was 5.3°F above average, beating the previous record set in 1958 by 1.1°F. Several cities, including Portland, Oregon and Seattle, Washington also had their warmest summer on record. August marked the fourth consecutive month of widespread above normal temperatures in the Pacific Northwest. Portland, Oregon recorded its 3rd warmest August with an average of 72.4 F (22.4 C) and its warmest summer (June-July-August) on record at 72.2 F (22.3 C). *(NOAA National Centers for Environmental Information, State of the Climate: National Overview for August 2015, published online September 2015, retrieved on January 6, 2016 from http://www.ncdc.noaa.gov/sotc/national/201508).*

Precipitation, air temperatures, and stream flow for the last six years were compared to show the variability in some of the factors that influence stream temperature. Although the maximum air temperatures were similar in 2013 and 2014, the number of days that air temperatures were above 80°F doubled in 2014 compared to 2013. In 2013, air temperatures were above 80°F for fifteen days, in 2014 it was thirty days. In 2015, air temperatures were above 80°F for 35 days. The combination of lower flows and sustained warm days resulted in more days that were above the state standard of 64°F for the 7-day average of daily maximum temperatures in 2014, and the trend of increasing days above 64F for stream temperatures continued in 2015. In addition, the bottom of the reservoir was 2 to 5 degrees (F) warmer in 2013 than in 2012, 2 degrees (F) warmer in 2014 than in 2013. Bottom temperatures in 2015 were 0.2 degrees cooler than in 2014; however, they were warmer than previous years in June. In both 2014 and 2015, the bottom of the reservoir had peak temperatures slightly warmer than the state standard of 64°F.

In 2015, for the first time, stream temperatures at the mouths of the three major tributaries to the mainstem of Rock Creek (Stilson Creek, Middle Fork, and Griffith Creek) had a 7-day average of the daily maximum temperature slightly above 64°F.

Flow data was collected during the summer, and combined with stream temperatures to calculate the effect of the reservoir on stream temperatures immediately downstream in the mainstem of Rock Creek. While the spillway was flowing, an increase in stream temperatures could be attributed to the spillway. The effect is more noticeable in the spring and early summer when the spillway has more flow. The effect is reduced as the spillway flow is reduced. When the spillway has the most flow, and therefore the most effect on temperatures, water temperatures are below the state standard of 64°F for the 7-day average of the daily maximum temperatures. In 2015, the spillway stopped flowing on June 16, a month earlier than in 2014, which greatly reduced the time that the spillway could have any effect.

The effects of the spillway contributions to the downstream water temperatures could not be detected in the mainstem downstream of the Middle Fork of Rock Creek in four years of data. Two major tributaries to Rock Creek contribute flow between the dam and the confluence of Rock and Greasy Creeks. It is unlikely that the effects of the spillway are having an impact on temperatures at the mouth of Rock Creek.

Introduction

The City of Corvallis and the Siuslaw National Forest have cooperatively monitored stream temperatures in the Rock Creek Watershed during the summers of 2005, 2006, and 2010 through 2014. Monitoring efforts continued in 2015 on a volunteer basis. The ongoing objectives of the stream temperature monitoring are:

1. To characterize and track trends in the stream temperatures throughout the watershed.
2. To determine the effects of restoration efforts, such as plantation thinning, riparian planting, and wood placement.
3. To determine if it is possible to detect effects of the reservoir on downstream temperatures.

Data collected over six years of monitoring have been useful in addressing the first and third objective. Determining the effects of restoration projects on stream temperature has been unanswered, due to the difficulty of separating the effects of variable climate and streamflow from the effects of restoration.

This report documents the results of the 2015 monitoring, and compares the 2015 data to previous years' monitoring data. To address the question of the reservoir's effects in more detail, streamflow data was gathered from channels around the base of the dam in 2013, 2014 and 2015 at the location of stream temperature monitoring sites.

In addition to the stream temperatures, air temperature was monitored at the same site as previous years to compare air and water temperatures and to see what the air temperature trend is between years. The air temperature station is in the riparian zone near the South Fork Rock Creek intake weir.

Figures 1 through 7 show the location of the stream temperature monitoring sites.

Results of the stream temperature monitoring efforts are summarized in Table 1, which shows the 7-day average maximum temperatures for the monitoring sites.

Table 2 shows more detailed data summaries for the sites that exceeded the state standard of 64°F for the 7-day average maximum temperature in 2012 through 2015. In 2015, the 7-day average maximum temperatures in the Rock Creek mainstem were one to two degrees warmer than in 2014, and the number of days that stream temperatures were above 64°F increased. The effects were more noticeable in the sites farthest downstream from the North and South Fork Rock Creek confluence.

The increase in number of days over 64°F may reflect the combination of lower stream flows and the greater number of days with warmer air temperatures in 2015, similar to 2014.

Graphs of the daily minimum and maximum temperatures for the individual sites are included in Appendix A. Photos of the Rock Creek mainstem below the confluence of the North and South Forks of Rock Creek are in Appendix B. These photos capture the change in flow through the summer.

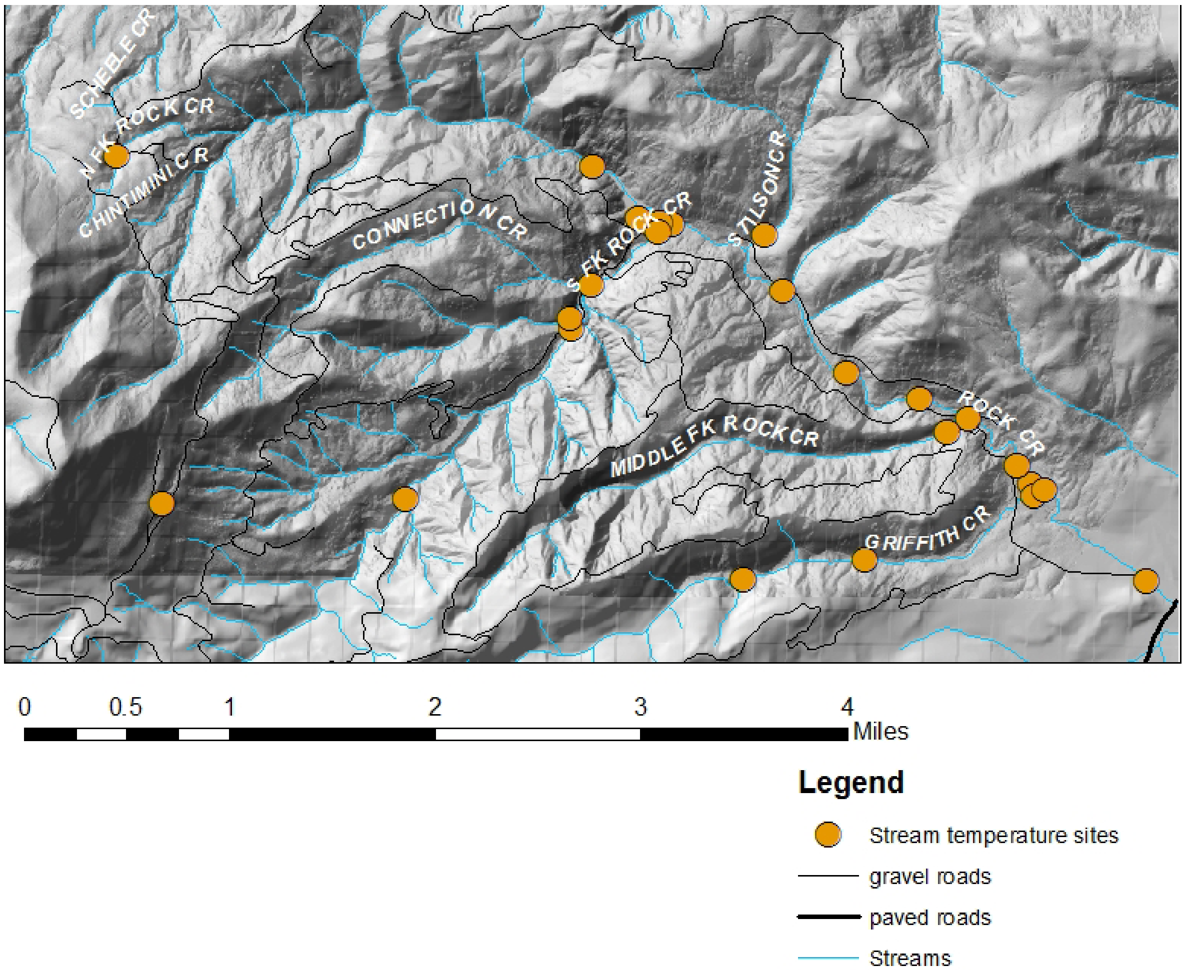


Figure 1. Overview map of stream temperature monitoring sites in the Corvallis (Rock Creek) Watershed.

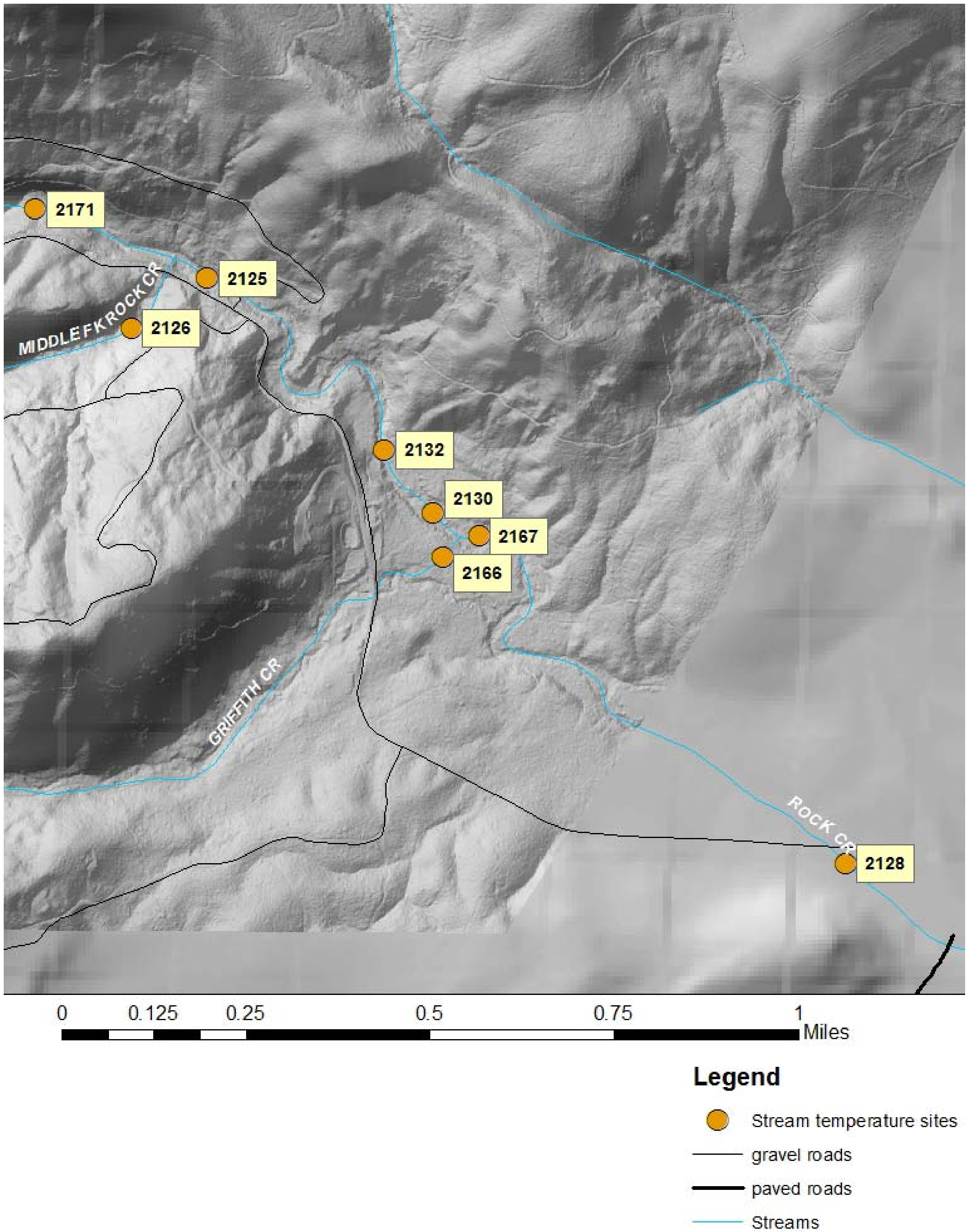


Figure 2. Stream temperature monitoring sites with site numbers , lower reaches of Rock Creek.

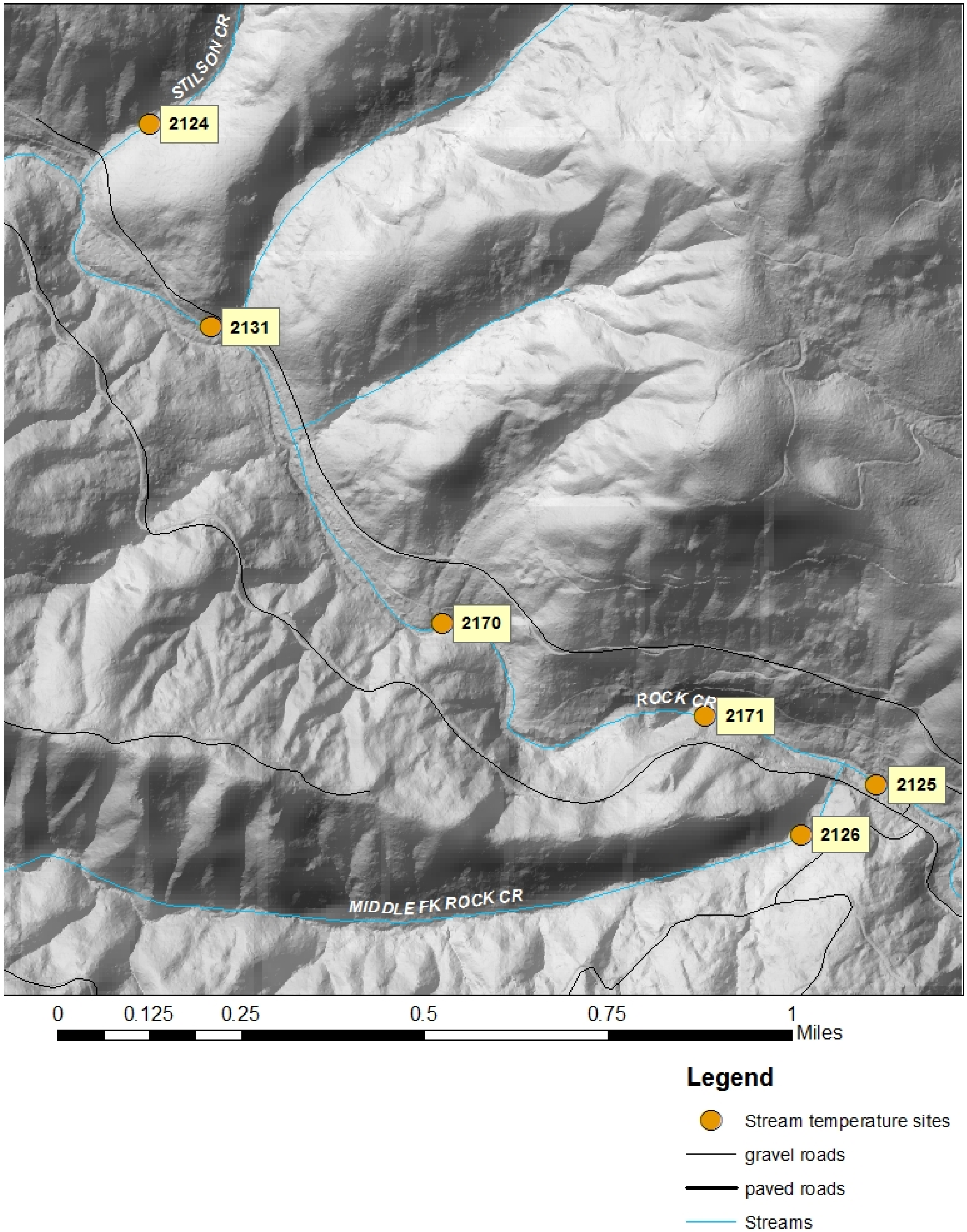


Figure 3. Stream temperature monitoring sites in Rock Creek between Middle Fork Rock Creek and Stilson Creek.

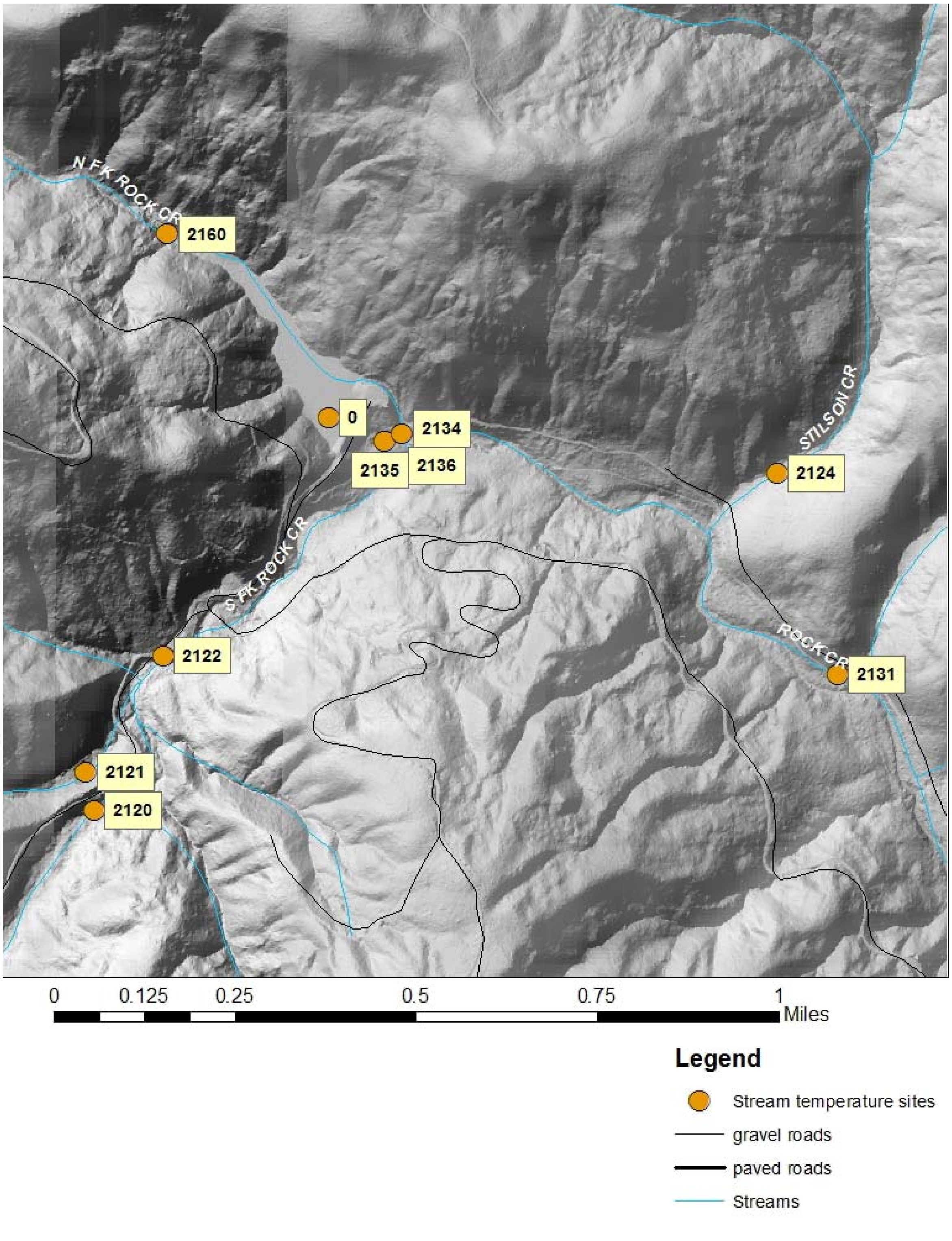


Figure 4. Stream temperature monitoring sites in lower reaches of South Fork Rock Creek and around reservoir. The site labelled "0" is the location of the probes at different depths in the reservoir.

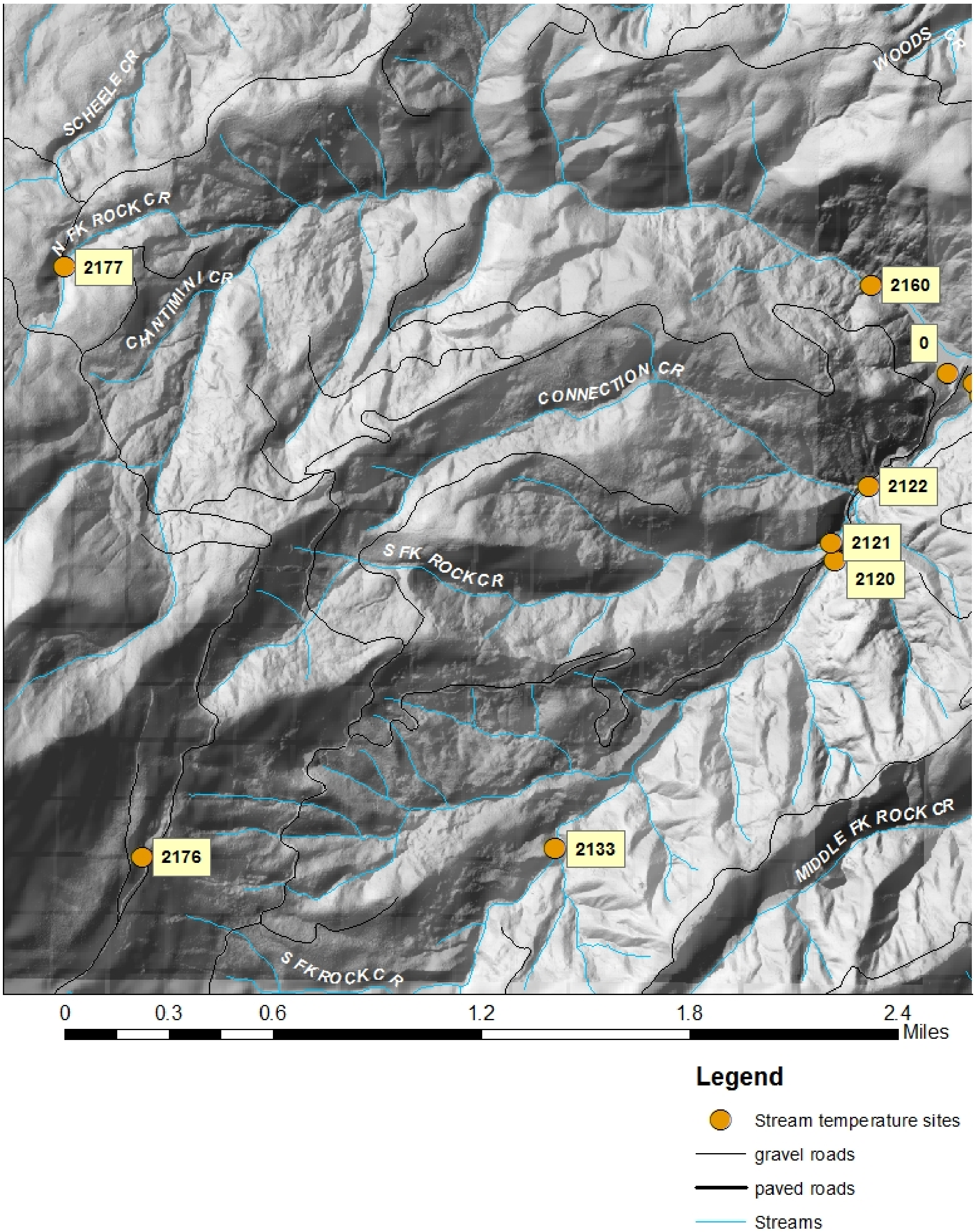


Figure 5. Stream temperature monitoring sites in the headwater springs of North Fork and South Fork Rock Creek. The sites around the reservoir are on the right side of map.

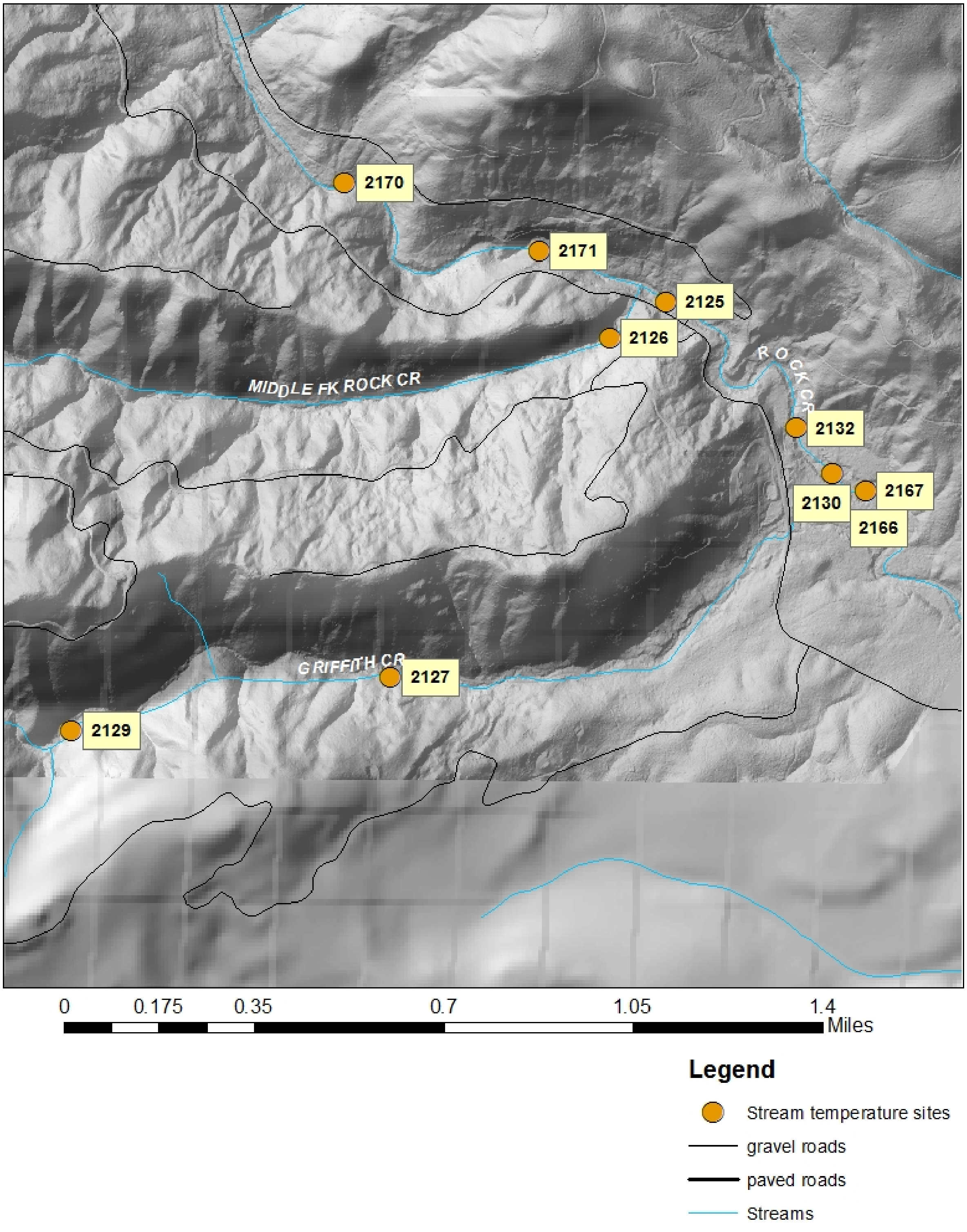


Figure 6. Stream temperature monitoring sites in Griffith Creek and lower Rock Creek.

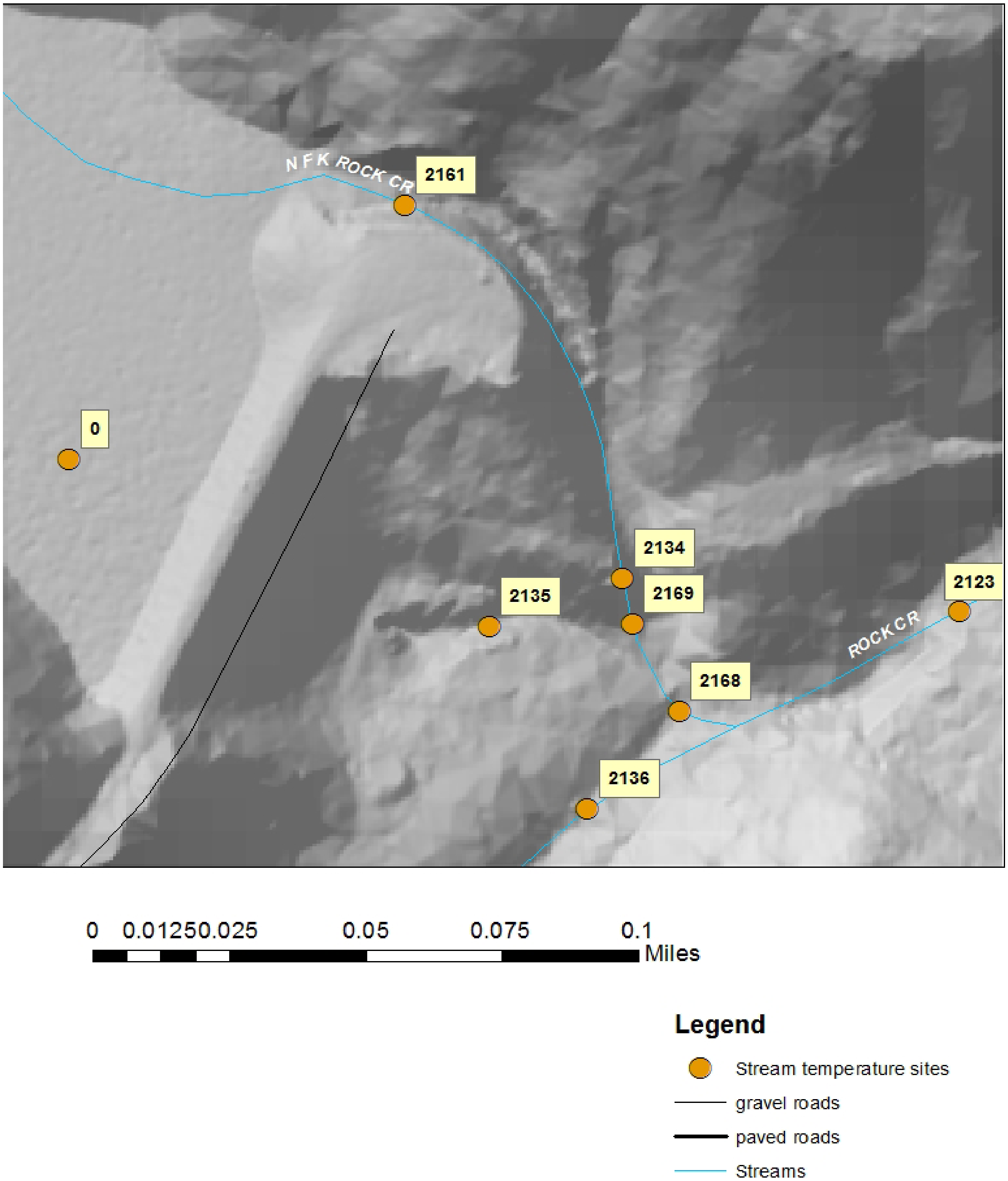


Figure 7. Stream temperature monitoring sites around the reservoir. The site marked with "0" is the valve tower in the reservoir. Six probes were suspended vertically on a rope in the reservoir.

Table 1: Data from multiple years for 7-day average maximum of daily high temperatures, Corvallis Watershed. Sites in the reservoir are shaded.

STREAM	LOCATION	STATION number	1978 7-day ave max	1980 7-day ave max	2005 7-day ave max	2006 7-day ave max	2010 7-day ave max	2011 7-day ave max	2012 7-day ave max	2013 7-day ave max	2014 7-day ave max	2015 7-day ave max
S FK Rock Creek	upstream from Connection Creek	2120			60.8		59.2	60.12	61.74	no data	61.08	63.52
Tributary to S FK Connection Creek	Tributary is upstream from and next to Connection Creek	2121			61.2		58.8	59.61	60.76	no data	62.59	62.97
S FK Rock Creek	Above weir tied to trash rack	2122			60.9		58.8	60.14	61.51	60.99	62.22	63.51
S FK Rock Creek AIR TEMP		2122					79.06	79.11	83.22	82.52	81.12	86.25
Rock Cr mainstem Water Temp	downstream from confluence of N Fk and S FK Rock Creek	2123			66.4	67.5	61.9	61.04	63.4	64.34	63.47	64.31
Rock Cr mainstem AIR TEMP	downstream from confluence of N Fk and S FK Rock Creek	2123			81	92						
Stilson Creek	upstream from rd 111	2124			62.5		60.2	61.39	62.12	61.86	62.96	64.07
Rock Creek mainstem	upstream from rd 111 bridge	2125			67.8		63.2	64.4	65.25	64.98	65.82	67.06
Rock Creek mainstem AIR TEMP	upstream from rd 111 bridge	2125					81.3					
Middle Fork Rock Creek	upstream from rd 3405	2126			62.3		59.6	61.44	62.35	62.16	62.20	64.31
Griffith Creek	upstream from weir	2127			60.9		59.3	60.19	61.6	61.35	62.14	63.49

Rock Creek	below bridge near entrance gate	2128					64.2	65.66	66.33	65.76	67.27	68.83
Griffith Creek	below thinning unit approx 1 mi from intake	2129					61.5	60.27	61.57	61.25	62.48	63.8
Rock Cr mainstem	at waterline crossing upstream of Griffith Cr	2130					63.9	65.2	65.98	65.71	66.83	68.3
Rock Cr mainstem	0.08 miles upstream from Trib "b"	2131					61.9	63.13	LOST	64.29	64.59	65.31
Rock Cr mainstem	at City/pvt boundary above outflow in log complex	2132					63.3	64.49	65.84	65.37	66.03	68.05
S Fk Rock Creek	below thinning stand	2133	63.5	65.94			58.3	59.26	LOST	59.86	61.25	62.89
N Fk Rock Creek spillway below dam	pool below spillway	2134						77.04				
Dam outlet small channel	Just below dam in small channel fed by valve leakage	2135							60.12	62.87	63.92	64.14
S Fk Rock Creek	above thinning stand (HCC in 1979?)		60.54	58.13								
S Fork Rock Creek	above dam outlet and confluence with N Fork Rock Cr	2136						62.12	62.99	no data	63.5	65.37
Top of Spillway at reservoir	Near metal ladder below sill	2161							78.91	79.57	Not used	Not used
North Fork Rock Creek	Above reservoir where creek enters reservoir	2160							60.66	60.84	61.89	61.56

Reservoir, tied to tower rope, top probe initially	Installed June 5 2012 at 1.1 ft below water surface, 55' above bottom. Moved on 8/29/2012 to 105" below water surface. In 2014 and 2015, probe deployed 2 feet below water surface at 56 feet above bottom.	2162							74.6	72.76	76.33	73.86
Reservoir, tied to tower rope	Installed June 5 2012 at 3.75 ft below water surface, 50' from bottom anchor. In 2014 and 2015, probe was 5 feet below water surface.	2163							70.87	69.65		64.31
Reservoir, tied to tower rope	12 feet below water surface, 45.3 feet above bottom anchor	2173								67.26	70.1	69.65
Reservoir, tied to tower rope	22 feet below water surface	2180									66.82	66.74
Reservoir, tied to tower rope	17 feet below water surface, 40.3 feet above bottom anchor	2174								65.35		Not used
Reservoir, tied to tower rope	37 feet below water surface	2181									65.46	65.32
Reservoir, tied to tower rope	Installed on June 5 2012 25.5 below water surface, 28.3 ft from bottom anchor	2164							62.61	64.63		
Reservoir, tied to tower rope, near bottom	Installed 3.7' from bottom anchor in 2012, at 5 feet from bottom in 2014 and 2015.	2165							60.65	62.66	64.52	64.31

Griffith Creek	mouth of creek	2166							62.86	no data	63.65	64.93
Rock Creek	just downstream of Griffith Cr mouth	2167							65.81	no data	No data	No data
Spillway/dam outlet channel, 7-day ave. max when spillway is flowing	Just below spillway and dam outlet channel convergence, and upstream of South Fork Rock Creek confluence.	2168							71.4	73.96	72.22	71.29
Spillway/dam outlet channel, temperature after spillway stops flowing	Just below spillway and dam outlet channel c, and upstream of South Fork-Rock Creek confluence.	2168							61.1	63.08	69.95	64.10
Bottom of Spillway	In gravel channel just below spillway, moved from stagnant pool location used in 2011.	2169							76.99	78.46	78.87	76.03
Rock Creek mainstem	Approximately 2200 feet downstream from Trib "b"	2170								65.7	64.85	66.61
Rock Creek mainstem	Approximately 4500 feet downstream from Trib "b"	2171								66.77	65.93	66.98
Headwaters of South Fork	Bluff Springs above Road 2005	2176								45.65	45.66	46.16
Headwaters of North Fork	Just downstream of Road 2005	2177								50.11	50.26	51.19

Table 2: Comparison of sites that were above 64°F in 2012, 2013, 2014 and 2015

Site 2123: Rock Creek mainstem, below confluence of North and South Fork Rock Creek

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	65.48	63.4	5	8/4/2012 to 8/13/2012
2013	65.92	64.34	4	6/30/2013 to 7/3/2013
2014	65.02	63.47	8	7/7/2014 to 8/27/2014
2015	66.73	64.31	14	6/7/2015 to 8/21/2015

Site 2131: Mainstem Rock Creek 0.08 miles above Trib "B"

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012		LOST IN 2012		
2013	65.7	64.29	6	6/30/2013 to 7/26/2013 intermittently
2014	66.34	64.59	21	7/7/2014 to 8/28/2014
2015	66.9	66.32	22	6/7/2015 to 8/20/2015

Site 2170: Mainstem Rock Creek,Approximately 2200 feet downstream from Trib "B"

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2013	65.7	64.19	9	6/30/2013 to 8/6/2013 intermittently
2014	66.0	64.85	24	7/7/2014 to 8/27/2014
2015	68.23	66.61	24	6/7/2015 to 8/21/2015

Site 2171: Mainstem Rock Creek,Approximately 4500 feet downstream from Trib "B"

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2013	66.77	65.17	17	6/28/2013 to 9/12/2013 intermittently
2014	67.5	65.93	32	7/7/2014 to 8/29/2014
2015	68.53	66.98	35	6/7/2015 to 8/21/2015

Site 2125: Rock Creek mainstem, below Middle Fork and above the Road 111 bridge

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	66	65.25	9	8/4/2012 to 8/17/2012
2013	66.56	64.98	15	6/25/2013 to 9/11/2013 intermittently
2014	67.41	65.82	22	7/7/ to ? Probe was taken out of water on 8/13/2014
2015	68.66	67.06	36	6/7/2015 to 8/21/2015

Site 2132: Rock Creek mainstem at City property boundary upstream from plant outflow in a log complex.

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	67.01	65.84	9	8/3/2012 to 8/18/2012
2013	66.98	65.37	21	6/27/2013 to 9/10/2103 intermittently
2014	67.46	66.03	33	7/7/2014 to 8/29/2014
2015	69.47	68.05	44	6/7/2015 to 8/21/2015

Site 2130: Rock Creek mainstem upstream from Griffith Creek

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	67.63	65.98	10	8/3/2012 to 8/18/2012
2013	67.07	65.71	30	6/30/2013 to 9/13/2013 intermittently
2014	67.93	66.83	43	7/6/2014 to 9/2/2014
2015	69.73	68.30	60	6/7/2015 to 9/13/2015

Site 2128: Rock Creek below main bridge near mouth of creek, upstream from Greasy Creek confluence

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	67.28	66.33	14	8/2/2012 to 8/19/2012
2013	67.41	65.76	32	6/27/2013 to 9/13/2013
2014	68.57	67.27	43	7/6/2014 to 8/28/2014
2015	70.16	68.83	59	6/6/2015 to 8/28/2015

Site 2122: **AIR** Temperature at South Fork Rock Creek

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	84.812	83.21	96	5/31/2012 to 10/2/2012
2013	85.85	82.52	106	5/18/2013 to 10/21/2013
2014	86.07	81.12	81	5/16/2014 to 10/9/2014
2015	94.8	86.35	118	5/7/2015 to 9/24/2015

Variability in Air Temperatures, Precipitation and Stream Flows from Year to Year

Stream temperatures are influenced by a number of factors, including yearly variations in weather conditions. Air temperatures collected in the Corvallis Watershed in the riparian zone at the South Fork Rock Creek intake, and precipitation data from the Wilkinson Ridge Remote Automated Weather Stations (RAWS), are compared for the previous 5 years to show the variability from year to year. Data for several days were missing during the 2015 spring months at the Finley RAWS. Because of the missing data, Finley data was not included in the 2015 report.

Air Temperature Variability

Air temperature is shown as the 7-day average of the daily maximum temperature. Maximum temperatures were warmer in 2012 through 2014 than in 2010 and 2011, as shown in Figure 8. Timing of the highest temperatures during the summer also varies from year to year. In 2014, warm temperatures persisted later into September than in other years. In 2013, in contrast, the warmest temperatures were in July. In 2015, temperatures in June were warmer than previous years, and the peak air temperature was on July 2. This variation is also reflected in the water temperatures, with the warmest water temperatures coinciding with the warmest air temperatures each year. Figure 9 shows air temperatures from 2013 to 2015 to simplify the comparison of the last three years. Figure 10 shows graphs of air temperatures from individual years.

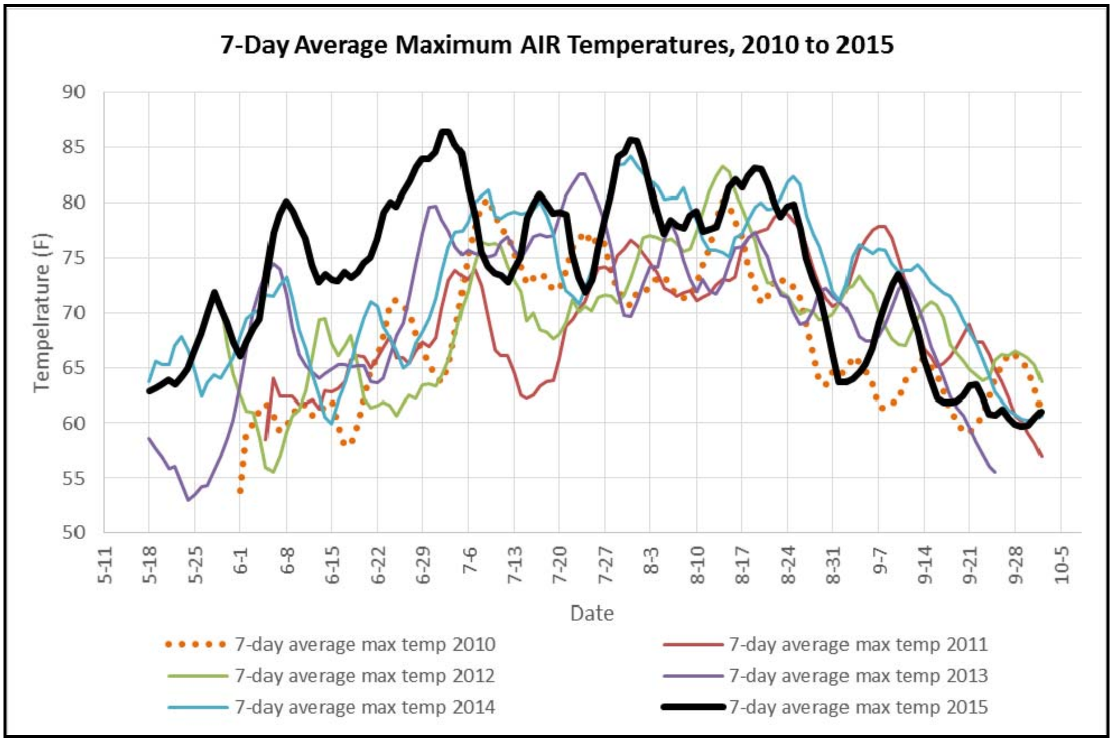


Figure 8. The 7-day running average of the daily maximum temperatures for the years 2010 through 2015. Air temperatures at the end of June, 2015 were the warmest air temperatures in the last 6 years. The last three years' of air temperatures are compared in Figure 9. Separate graphs of each year's air temperatures from 2010 through 2015 are shown in Figure 10.

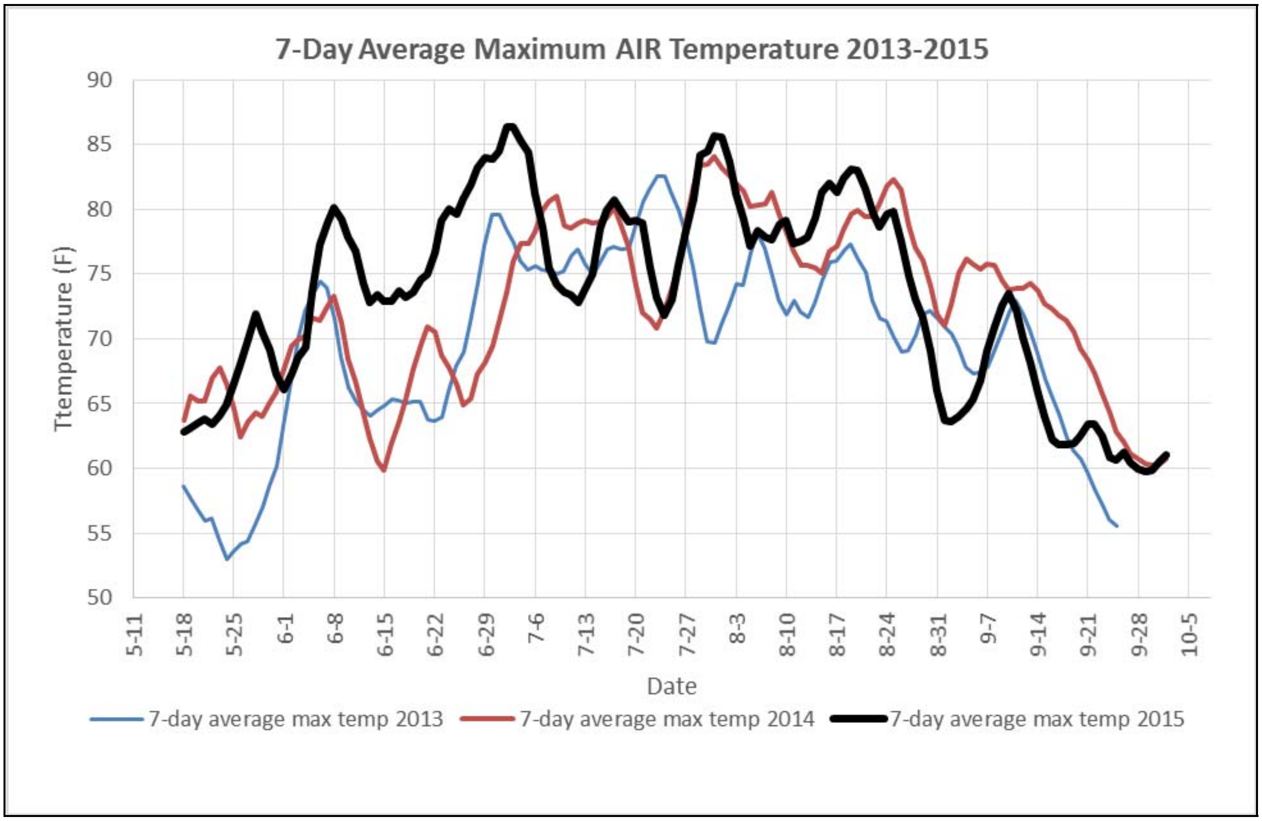


Figure 9. Comparison of the 7-day average of the daily maximum temperature for 2013, 2014 and 2015.

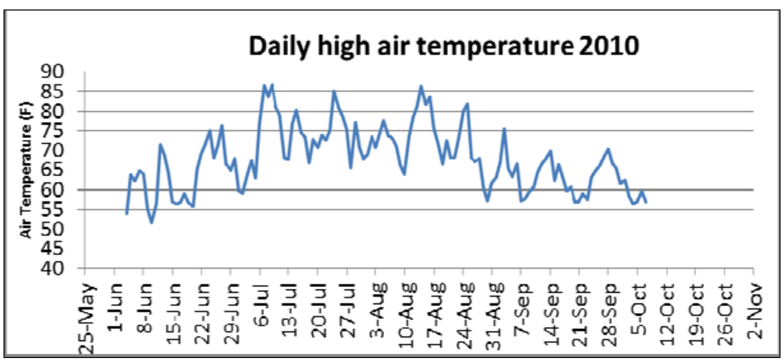


Figure 10a

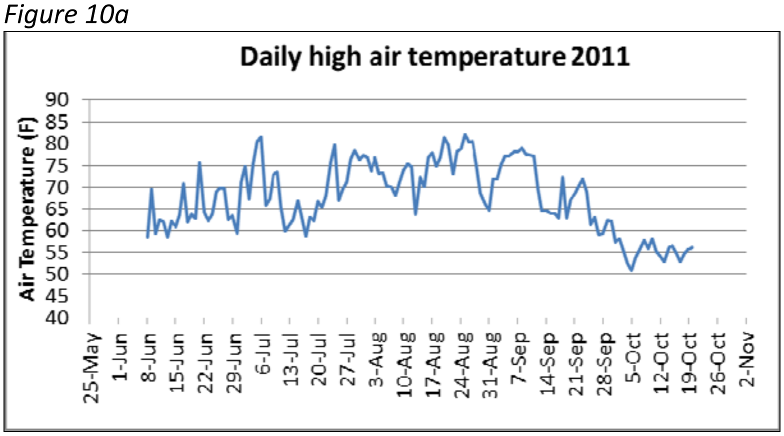


Figure 10b

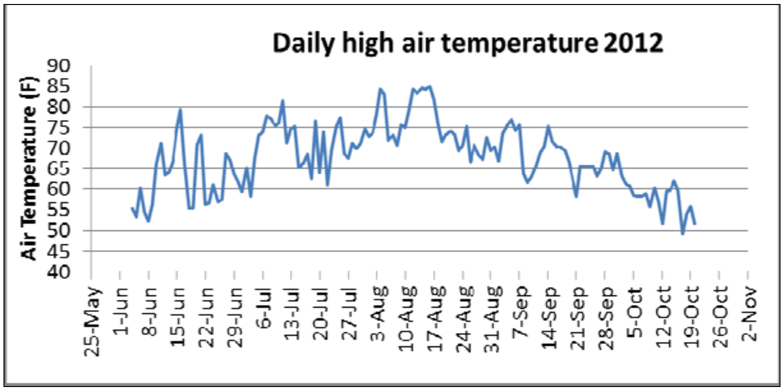


Figure 10c

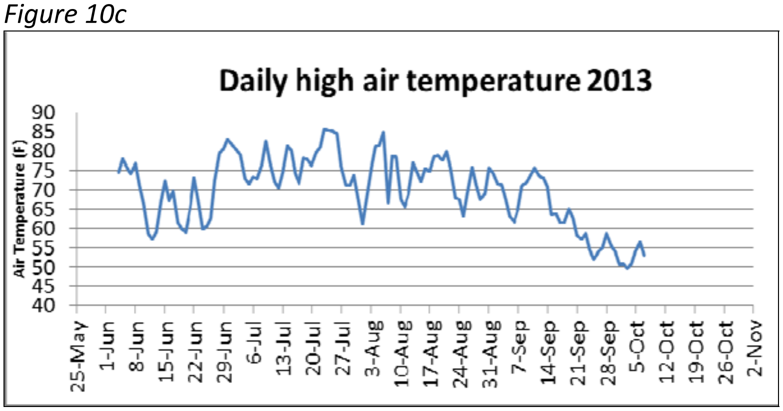


Figure 10d

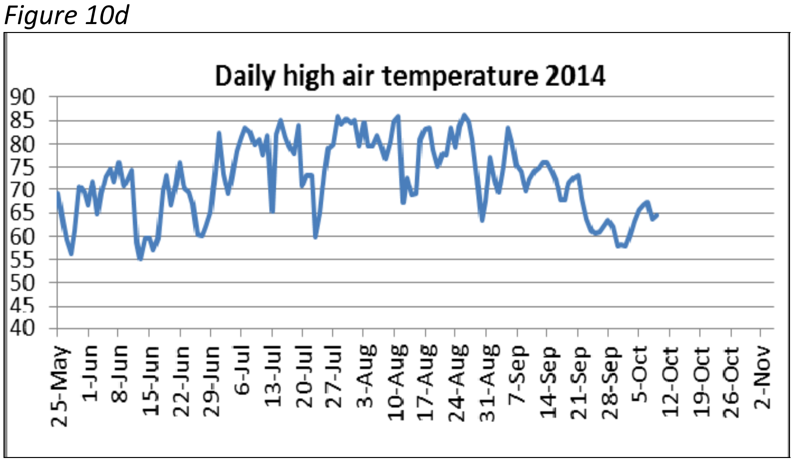


Figure 10e.

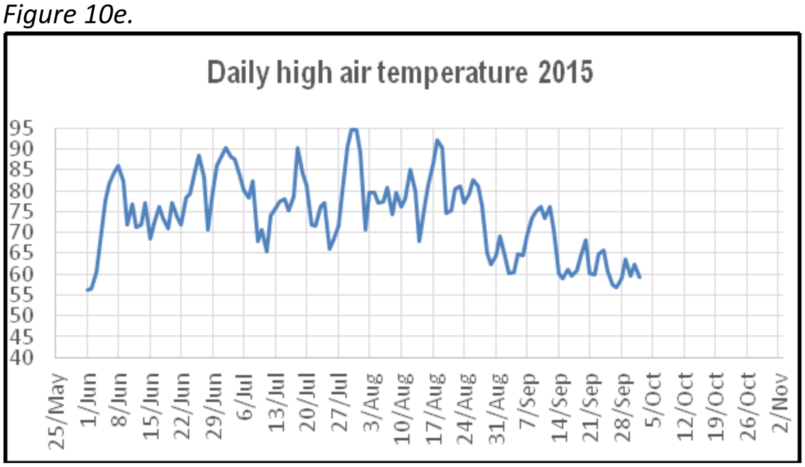


Figure 10f.

Figure 10. Comparison of daily maximum air temperatures for the last 6 years.

Variability in Annual Precipitation

Precipitation data for monthly total precipitation from the Wilkinson Ridge RAWS site was used to compare the years 2010, 2012, 2013, 2014 and 2015. The data for 2011 was suspect, as the station did not record any precipitation for several months in the spring for that year.

In 2013, higher amounts of precipitation fell during the first three months of the water year, which is defined as October through December (Figure 11). After that, however, the late winter and spring months were relatively dry. The big increase in September came at the end of the month, when 7.52 inches of rain were recorded between September 27 and September 30. As a result of the large rainstorm at the end of September 2013, the reservoir levels rose abruptly and re-filled the reservoir in one day.

In 2014, the winter months were relatively dry, but precipitation amounts were greater in the spring.

In 2015, precipitation in October through December was similar to 2010-2013, but by May it was the driest water year in the last 6 years. Figure 12 compares the last three years of precipitation data.The cumulative precipitation amounts (Figure 13) show that 2014 had the lowest annual precipitation, with 2015 a close second.

Flow data is discussed in the next section.

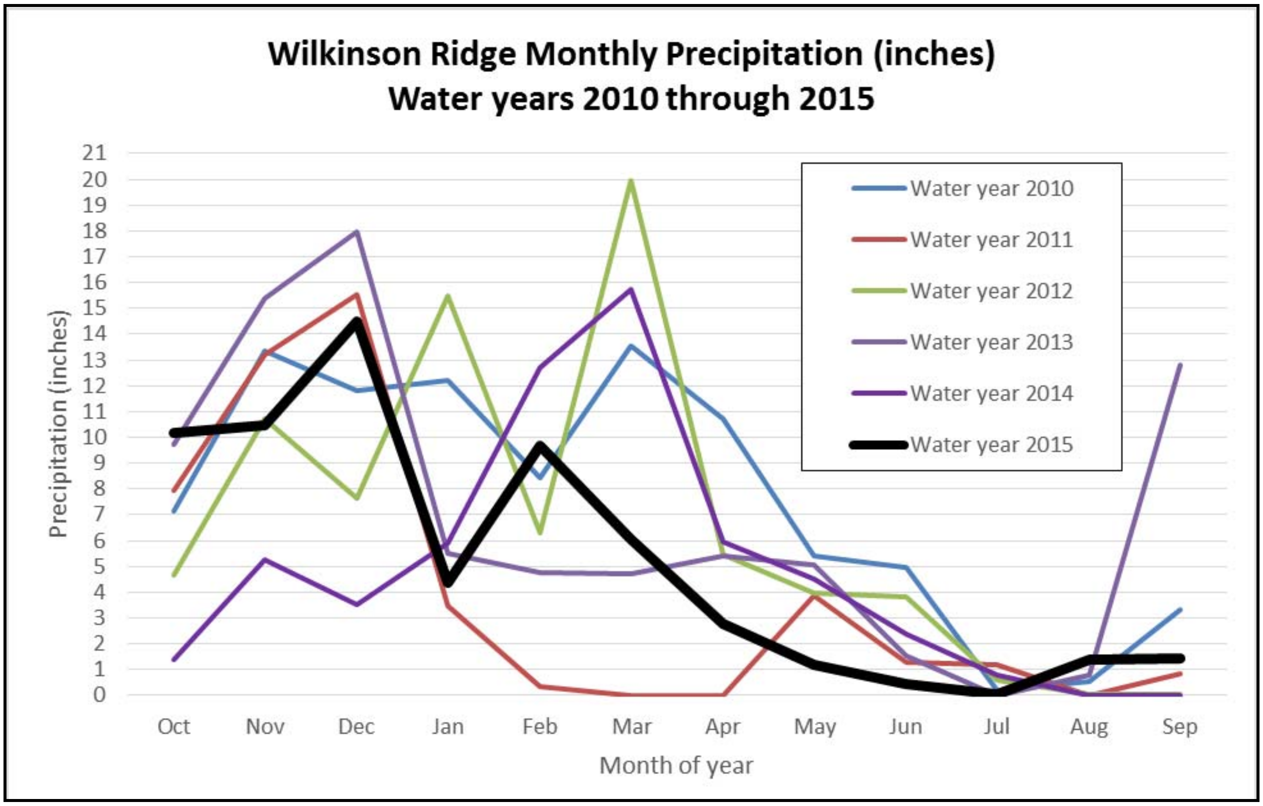


Figure 11. Monthly cumulative precipitation amounts for the Wilkinson Ridge Remote Automated Weather Station for the years 2010 through 2014. The data from 2011 (red line) was suspect, as several months recorded no precipitation.

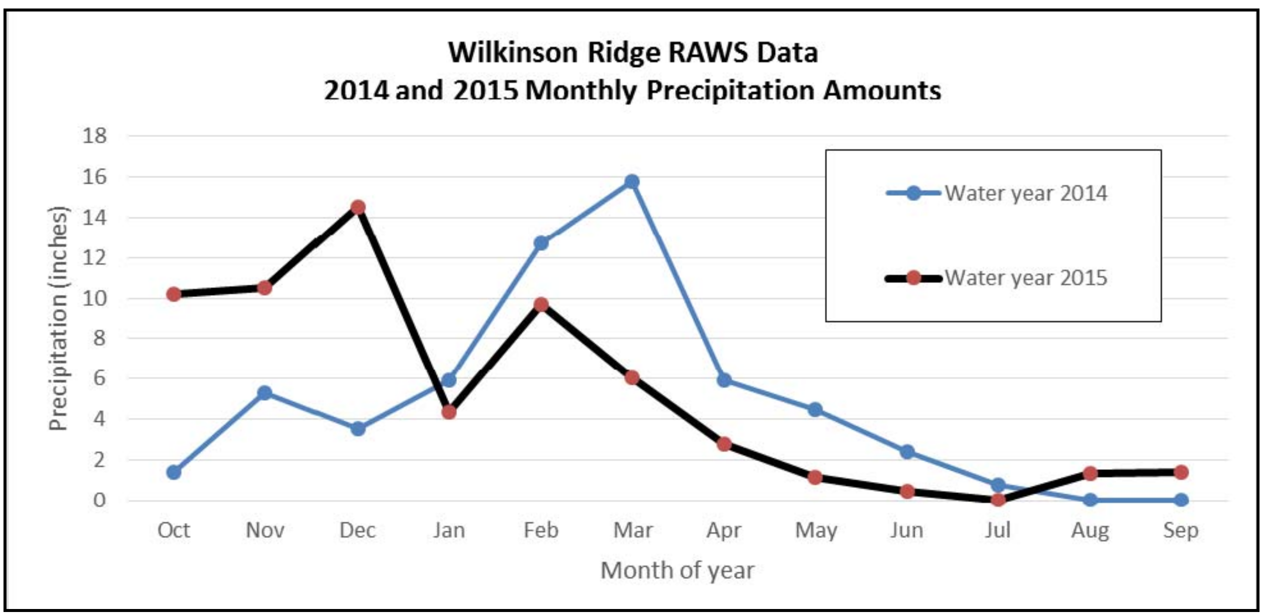


Figure 12. Comparison of month-to-month precipitation amounts at Wilkinson Ridge in 2013 and 2014. The winter was wetter in 2013; the spring was wetter in 2014.

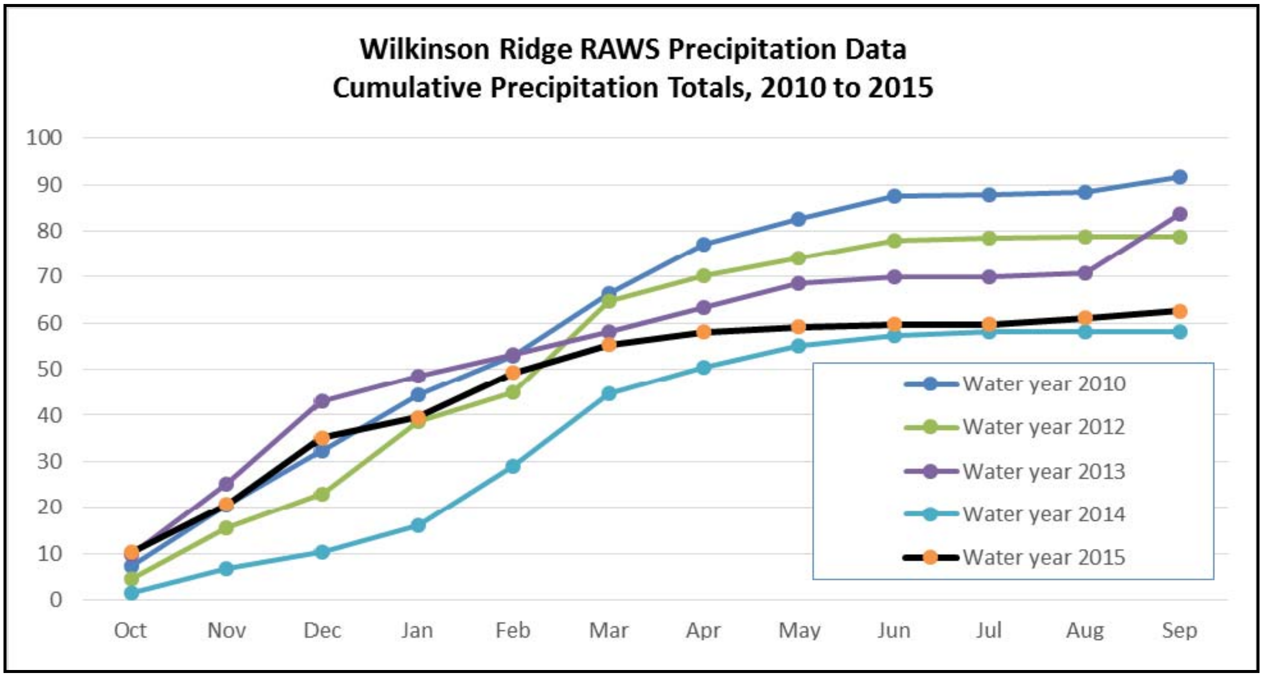


Figure 13. Annual cumulative amounts of precipitation for the Wilkinson RAWS station. The annual total amount in 2014 is significantly lower than previous years.

Effects of Yearly Weather Variability on Stream Temperatures

One effect of the yearly weather variability on stream temperatures can be seen in Figure 14, which compares water temperature to the drainage area above that monitoring site. The lines representing different years' temperature data are all parallel, with a similar slope; however, they reflect the warmer vs. cooler years. For instance, 2015 had the highest peak air temperature, and the 7-day average of the maximum water temperature throughout the watershed reflects 2015's air temperatures.

In 2015, stream temperatures were the warmest since 2010. Figure 14 shows that the stream temperatures throughout the watershed have been generally on a warming trend during the 6 years of consecutive years of monitoring. In 2014 and 2015, the higher stream temperatures reflect the combination of low precipitation which resulted in low streamflow, and the longer extended period of warmer days. In 2013, air temperatures were above 80°F for 15 days between May and October; in 2014 there were 30 days above 80°F. In 2015, 35 days were above 80°F. As a result, 2015 had the warmest stream temperatures since monitoring began in 2010.

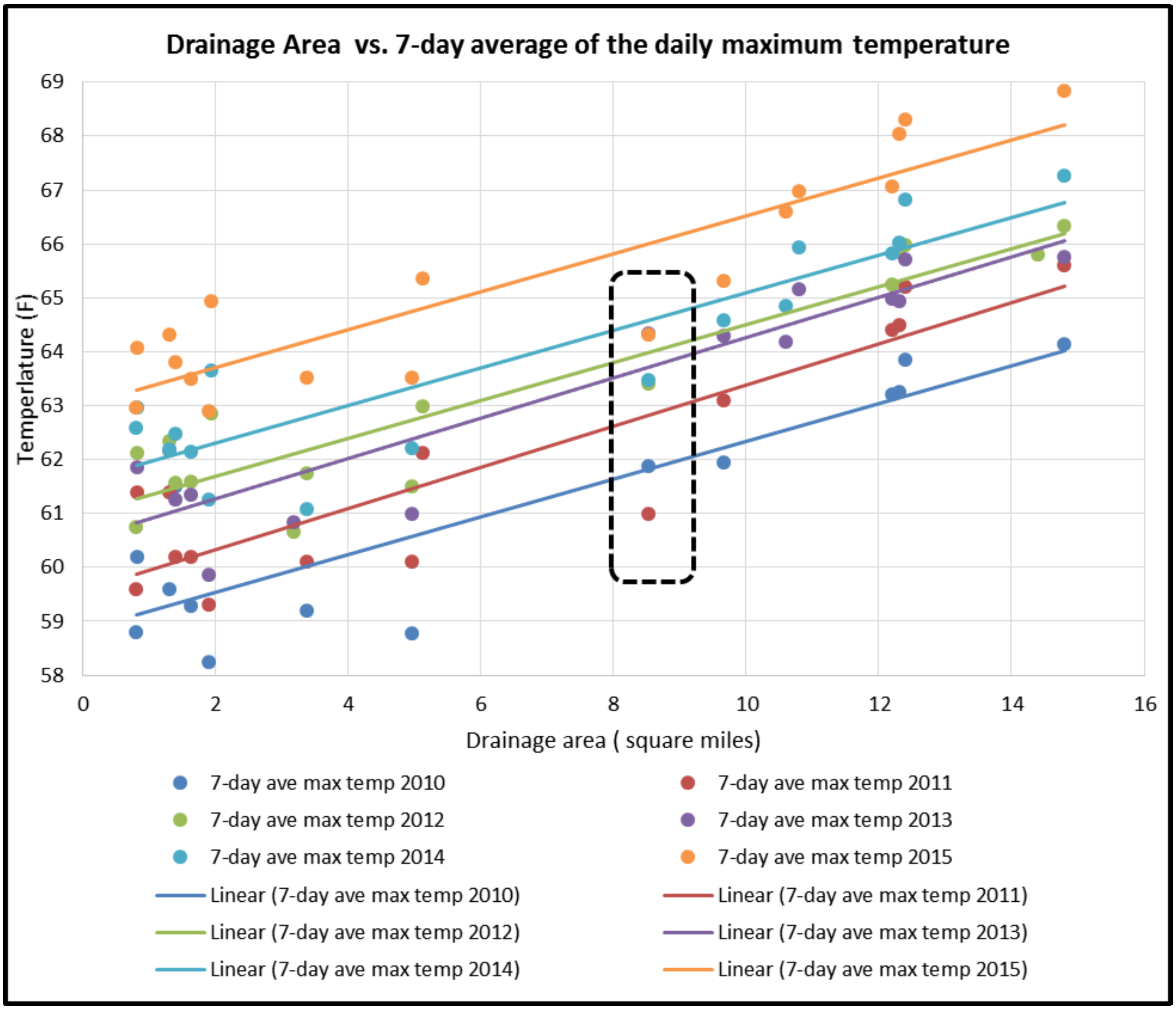


Figure 14. Comparing 7-day average maximum stream temperatures to drainage area for 6 years. The blue dotted box contains the data points for the Rock Creek mainstem site below the North and South Fork Rock Creek confluence.

As an example of the variability in stream temperatures and the timing of peak temperatures between years, Figure 15 shows 5 years of daily maximum stream temperatures for the Middle Fork Rock Creek. This site is on a tributary and is not downstream of the dam and reservoir. Figure 16 shows 2015 data for the Middle Fork Rock Creek compared to 2014. The 2015 reflects the warm June air temperatures, with the peak stream temperature coinciding with the peak in air temperatures.

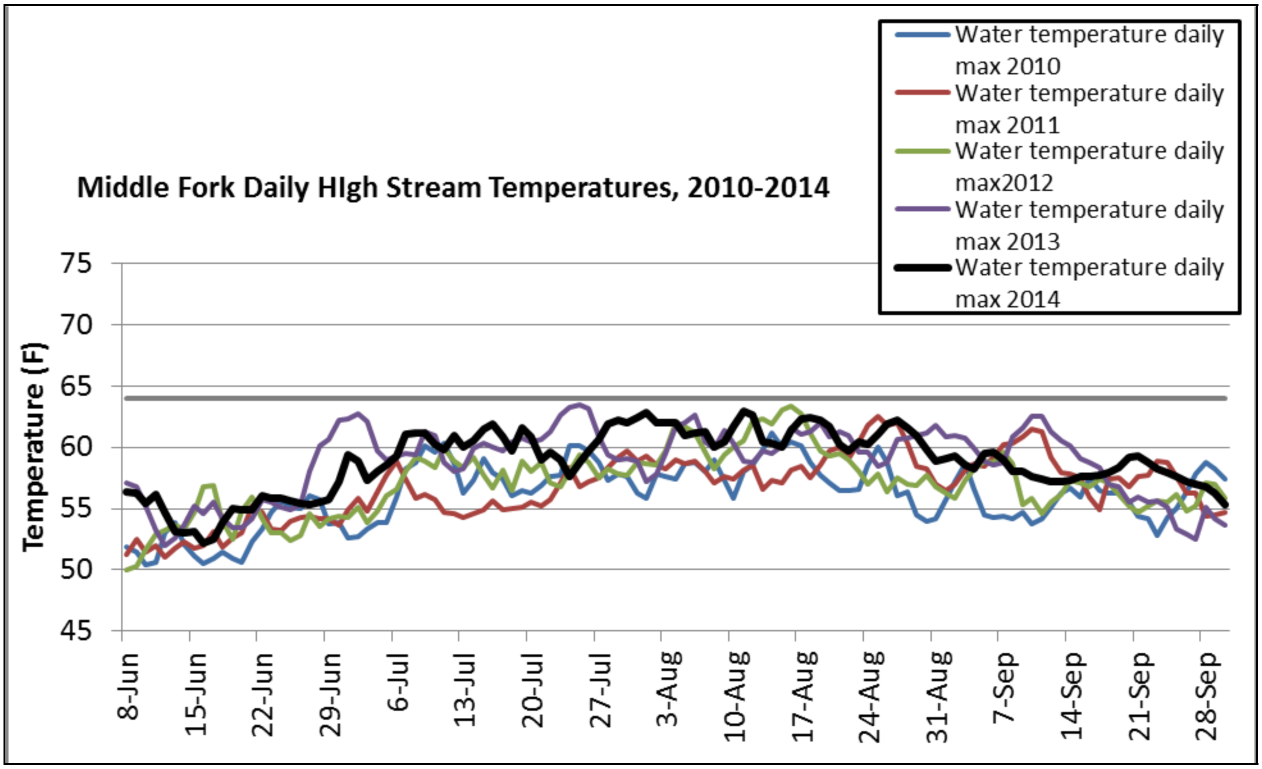


Figure 15. Daily maximum stream temperatures for the Middle Fork Rock Creek, 2010-2014.

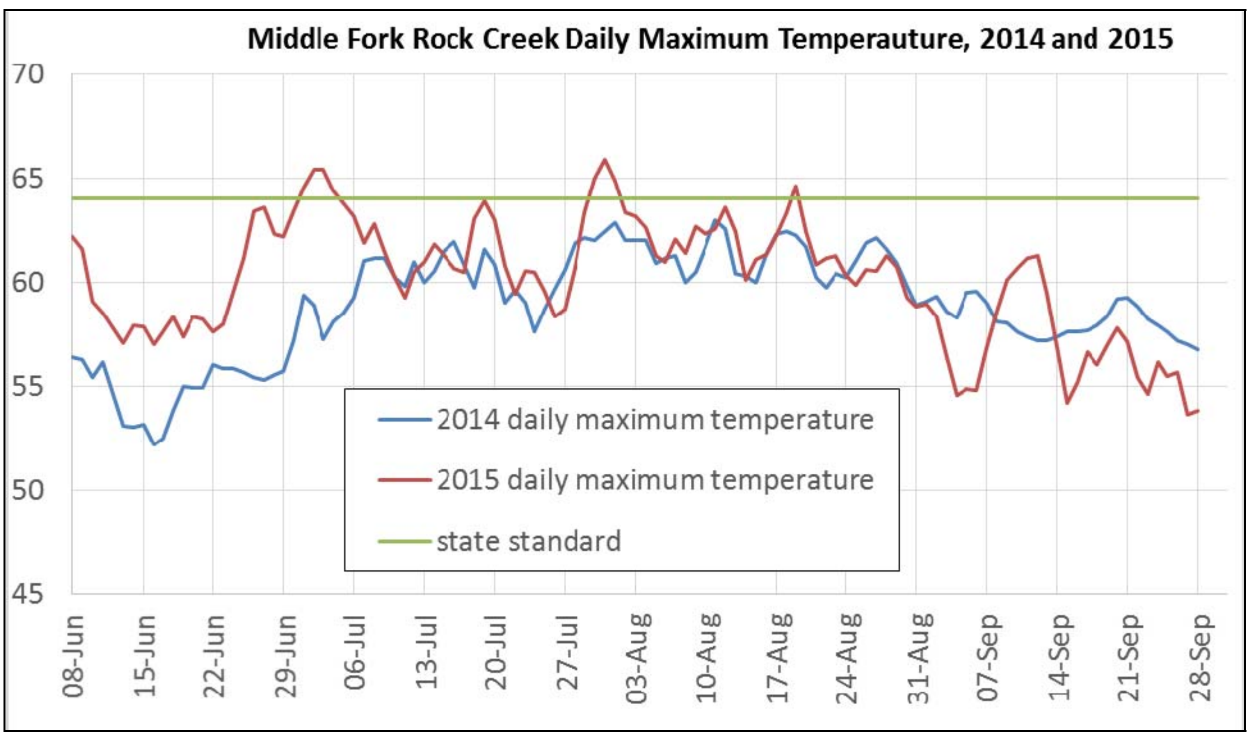


Figure 16. Daily maximum stream temperatures for the Middle Fork Rock Creek, 2014 and 2015.

Flow data

In addition to the closely bracketed temperature data around the dam and confluence of the North and South Forks of Rock Creek, stream flow data was collected in the three channels above the confluence and just downstream of the confluence in the mainstem of Rock Creek in 2013, 2014 and 2015. The locations of the flow measurements were at the temperature site 2169 in the lower spillway, temperature site 2135 in the dam valve channel just downstream of the dam, the South Fork Rock Creek temperature site 2136 above the confluence, and the Rock Creek mainstem site 2123 below the confluence.

Stream flows were measured along the same cross-sections several times during the summer using a Marsh-McBirney flowmeter.

Compared to 2013 and 2015, there was more rain in the spring of 2014, which is reflected in the significantly higher flows in May 2014 (Figure 17 and 18). However, by the end of the summer and after the spillway stopped flowing on July 14, the 2014 flows were lower than the previous summer, and 2015 late summer flows were lower than 2014 (Figure 19). Figure 20 compares the amount of flow from the four flow monitoring locations. Figure 21 compares the total flow above the confluence to the flow in the mainstem below the confluence. In years with lower flows, such as 2013 and 2015, there is slightly more flow in the mainstem below the confluence than the total flow above the confluence in the spring and early summer. This data suggests that another source, such as groundwater, or subsurface flow from the surrounding hillsides might be making up the difference.

Prior to July 14, 2014, the percent of flow contributed from the spillway to the Rock Creek mainstem below the confluence was higher in the spring through mid-July than in 2013 and 2015 (Tables 3 to 5)

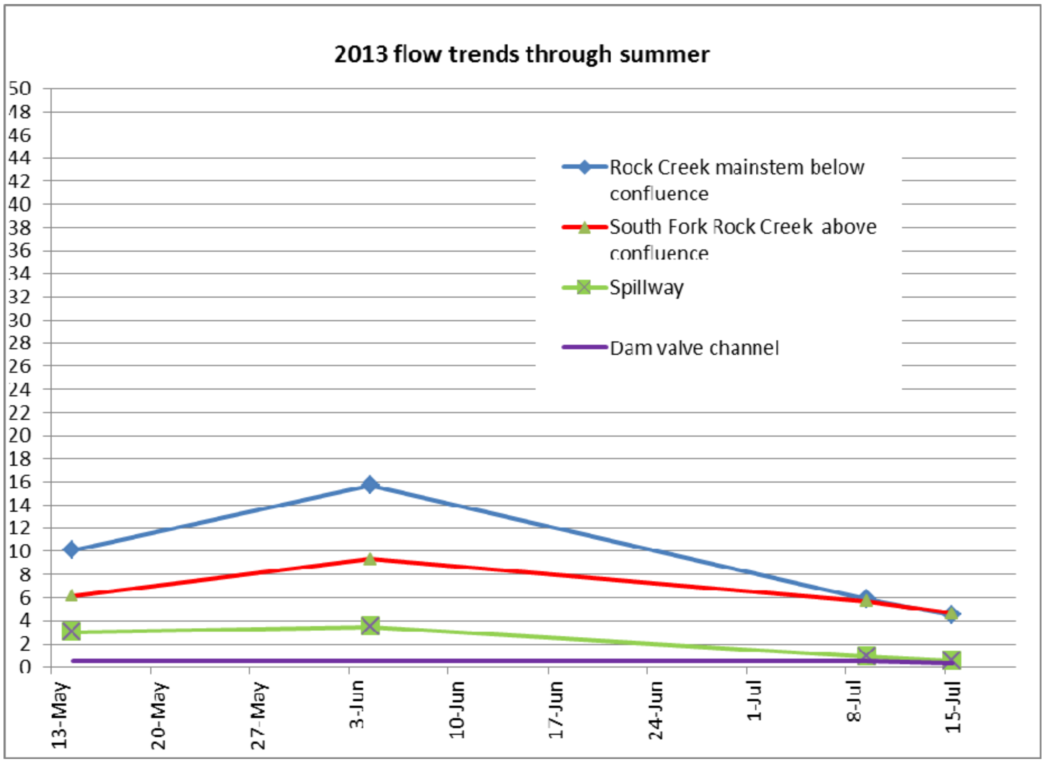


Figure 17a: Line graph comparing flows measured around the confluence during the summer of 2013.

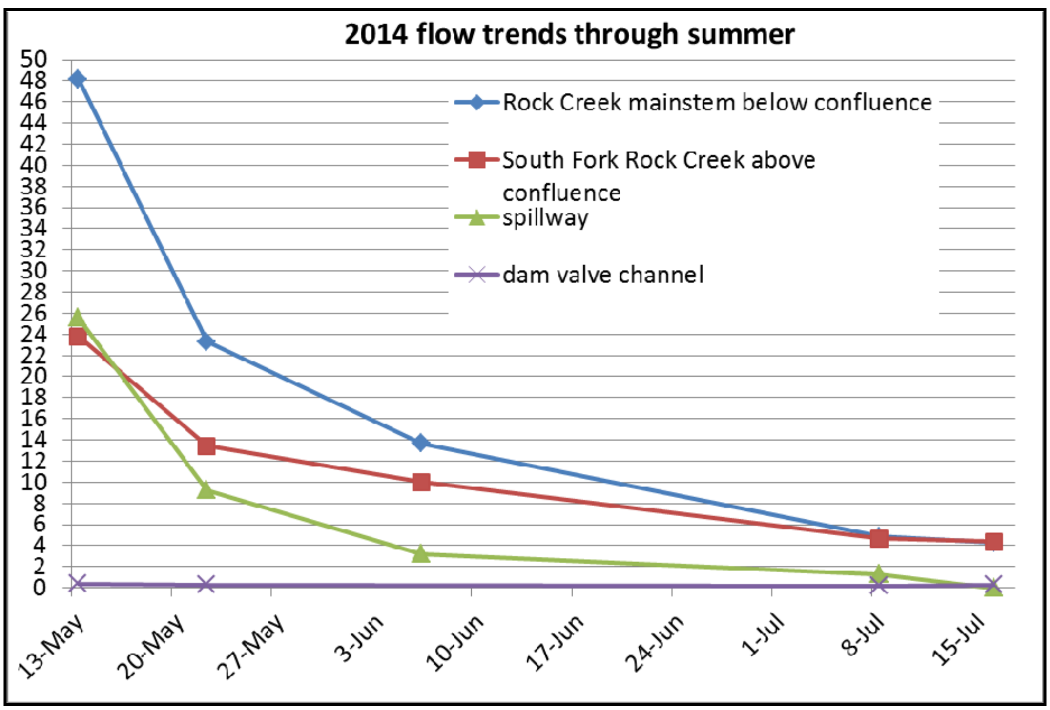


Figure 17b: Line graph comparing flows measured around the confluence during the summer of 2014 until the spillway stops flowing on July 14.

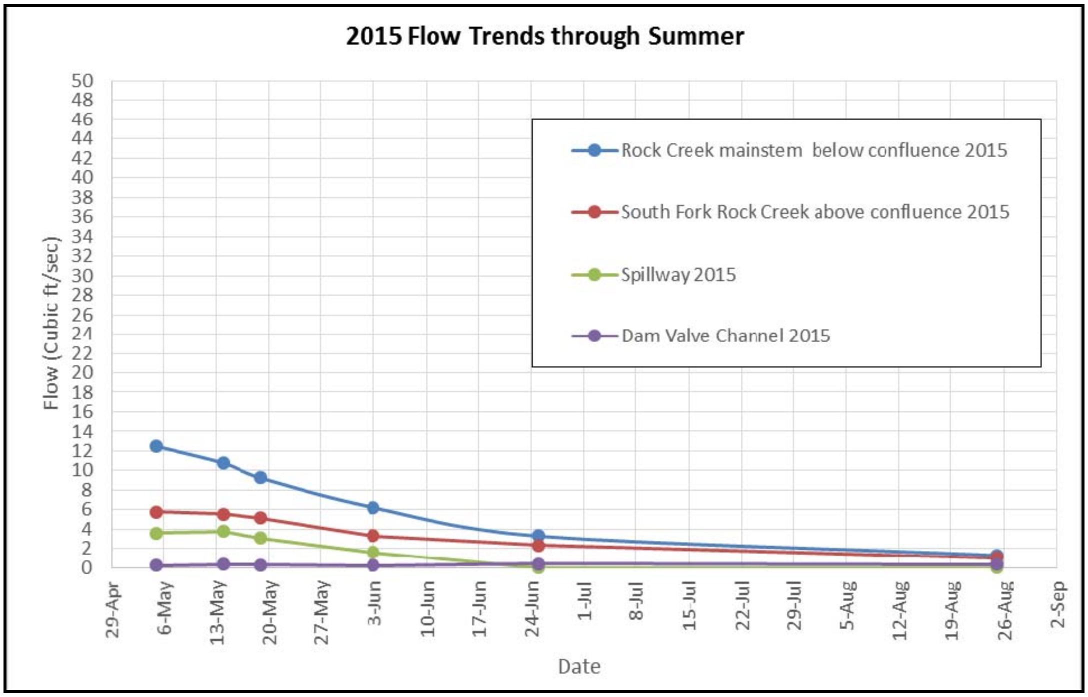


Figure 17c: Line graph comparing flows measured around the confluence during the summer of 2015. The spillway stopped flowing on June 16, 2015.

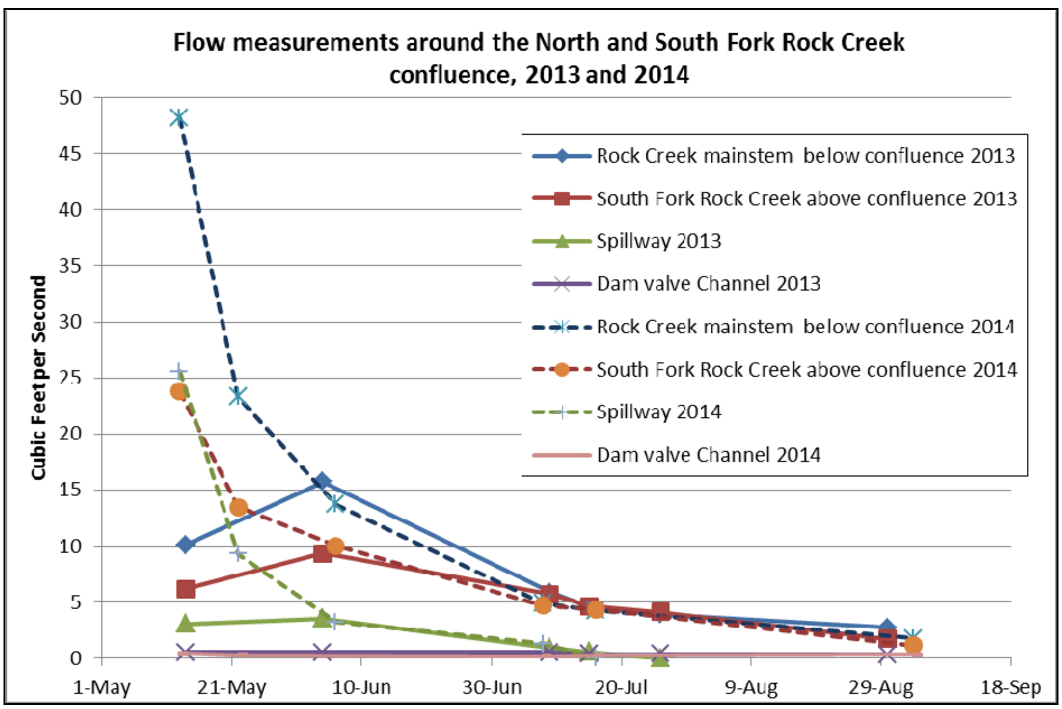


Figure 18a: Comparing flow measurements from both 2013 and 2014.

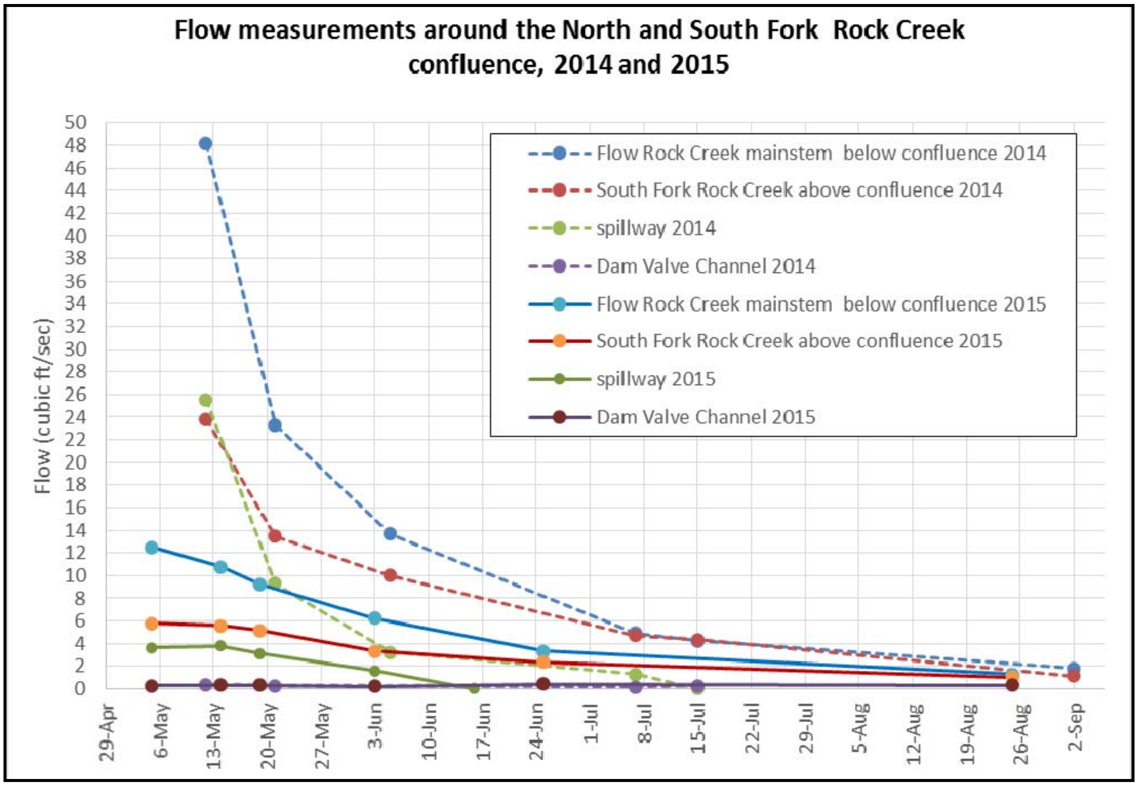


Figure 18b. Comparing flow measurements from 2014 and 2015.

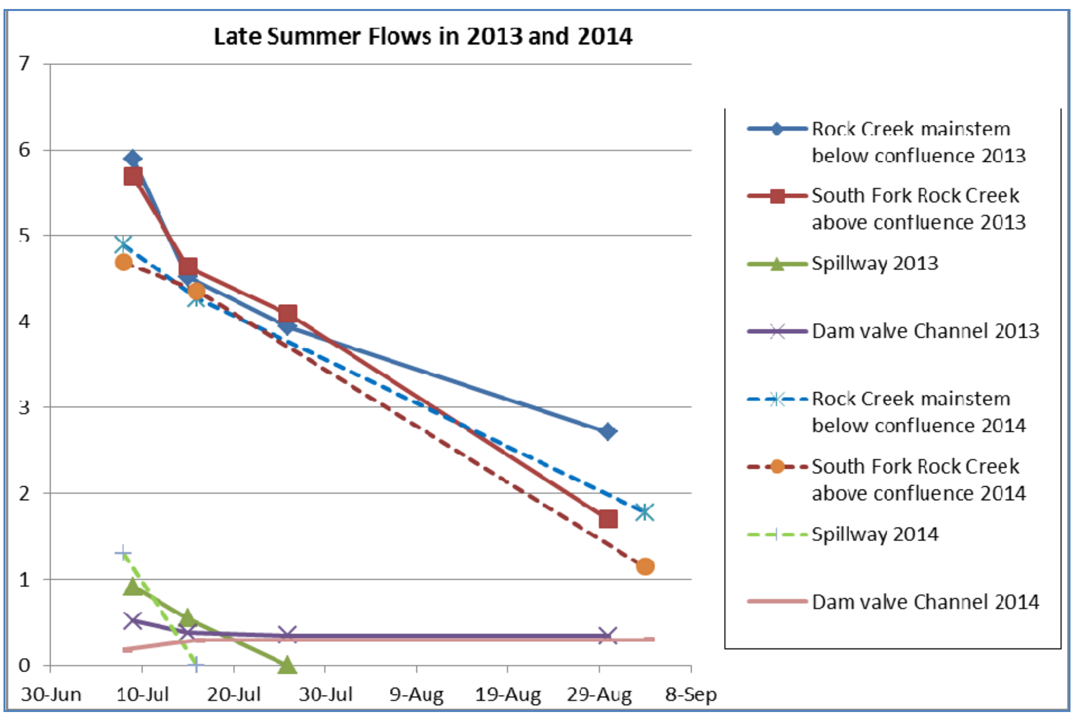


Figure 19a: 2013 and 2014 late summer flows compared. Note that after approximately July 20, the flows are lower in 2014.

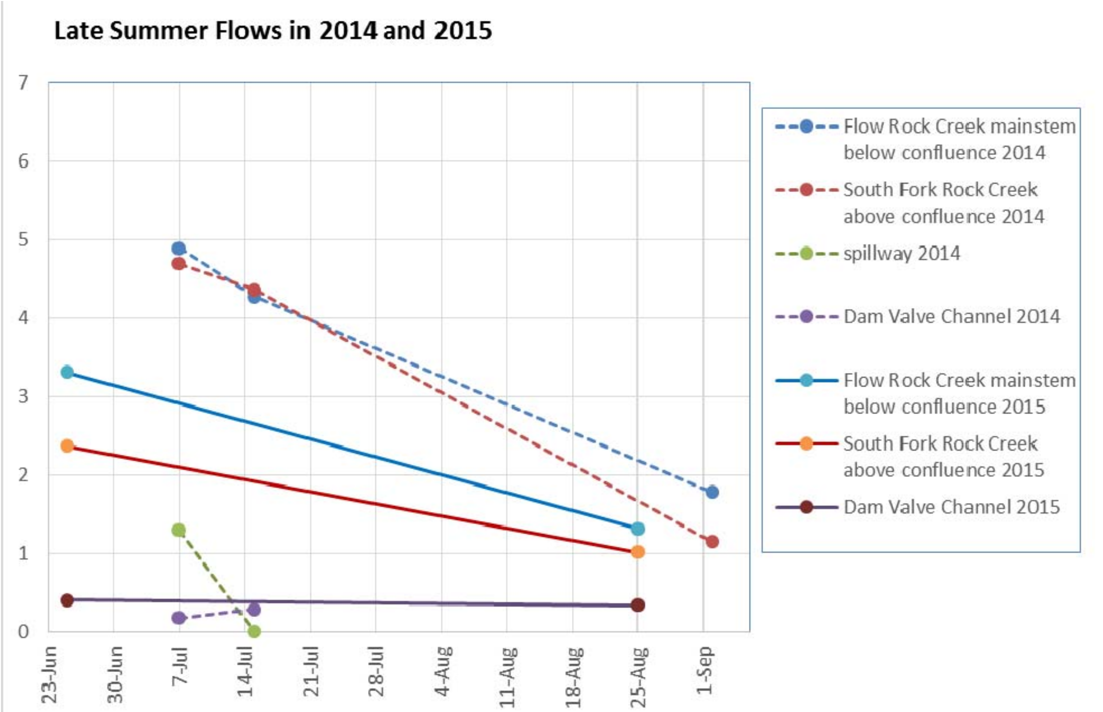


Figure 19b: 2014 and 2015 late summer flows compared.

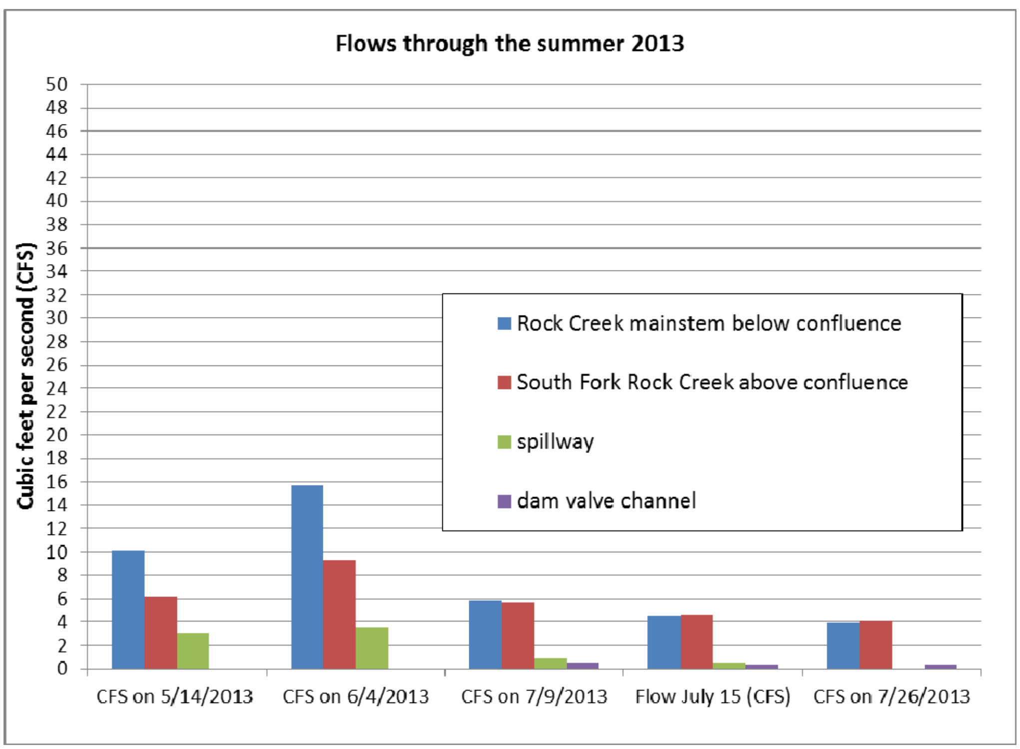


Figure 20a: Comparison of flows above and below the North and South Fork Rock Creek confluence in 2013. The spillway stopped flowing on July 26. The dam valve channel has a relatively consistent flow through the summer.

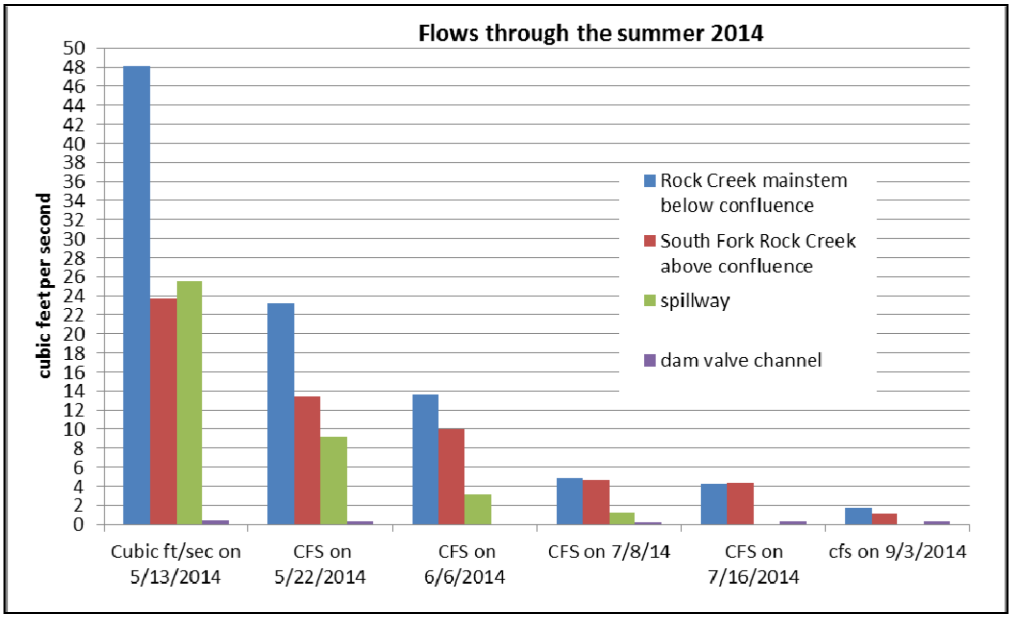


Figure 20b. Comparison of flows above and below the North and South Fork Rock Creek confluence in 2014. The spillway stopped flowing on July 14. The dam valve channel has a relatively consistent flow through the summer. The peak flow for the monitoring period was in May, and significantly higher than in 2013.

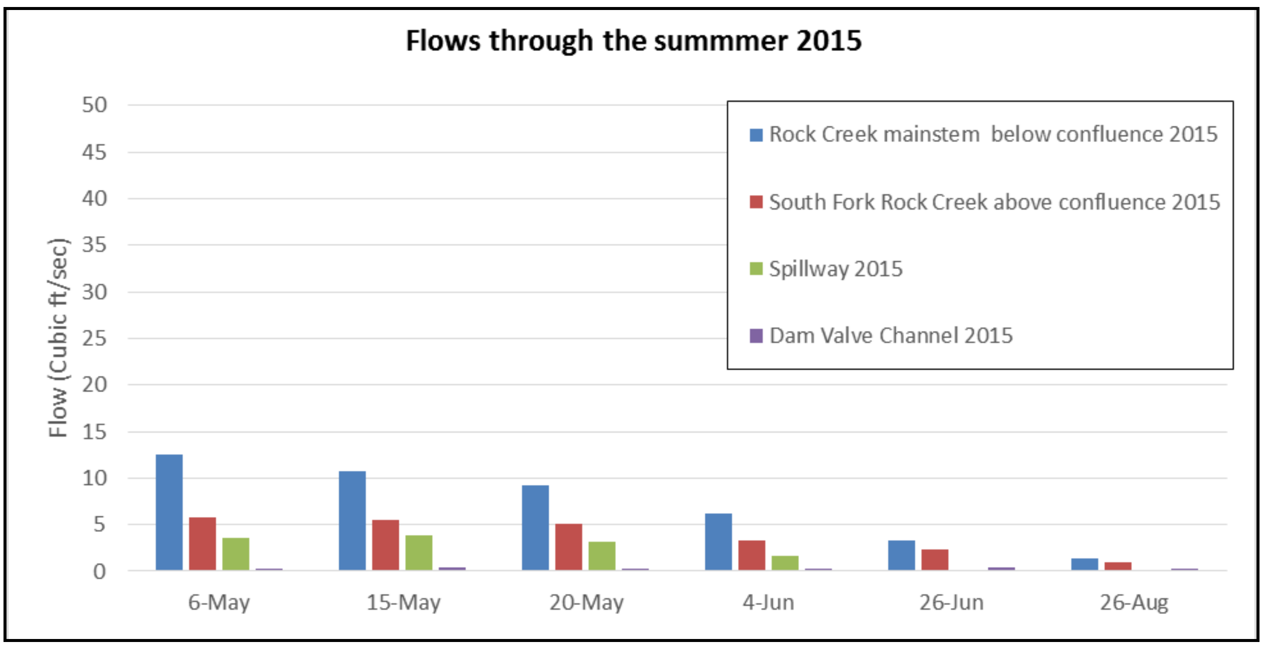


Figure 20c: Comparison of flows aabove and below the North and South Fork Rock Creek confluence in 2015. The spillway stopped flowing on June 16, 2015. Flows were lower than the previous two years.

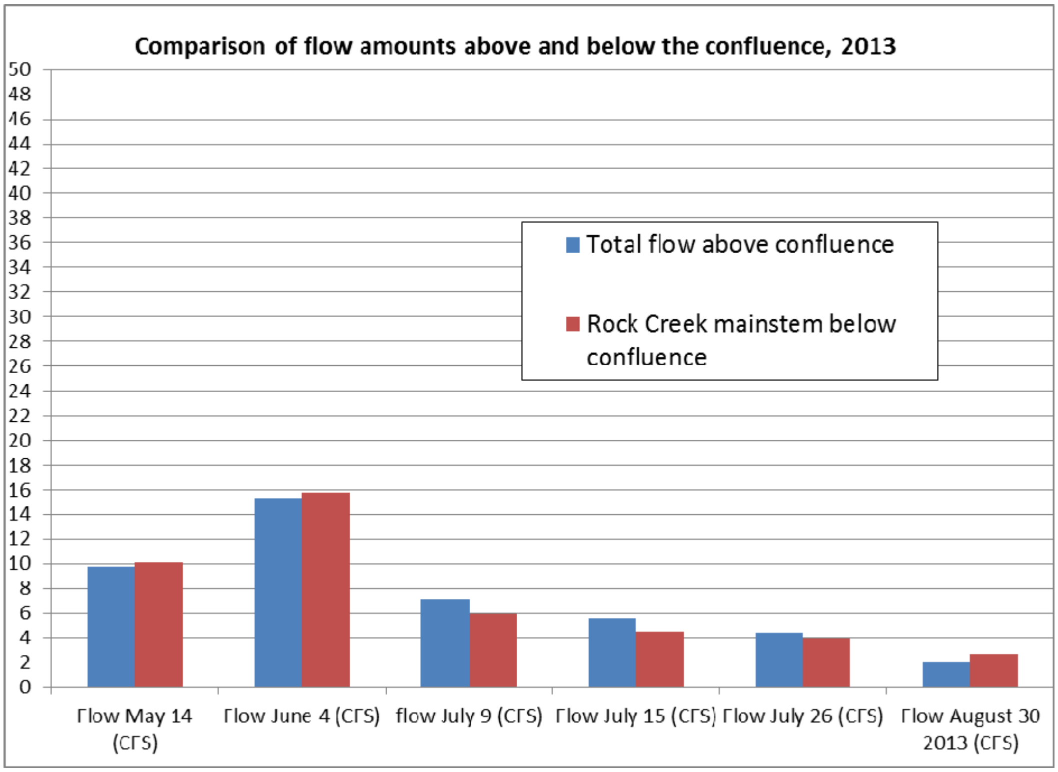


Figure 21a. Bar graph comparing total amount of flow above the confluence with the Rock Creek mainstem below the confluence, 2013

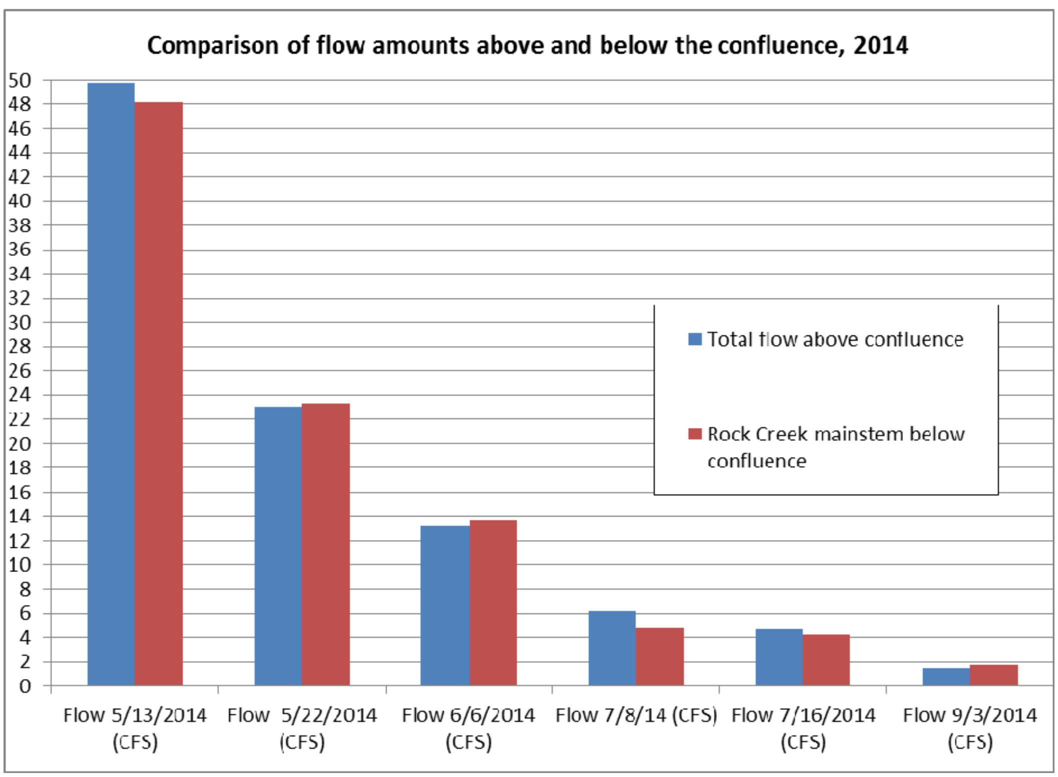


Figure 21b. Bar graph comparing total amount of flow above the confluence with the Rock Creek mainstem below the confluence, 2014

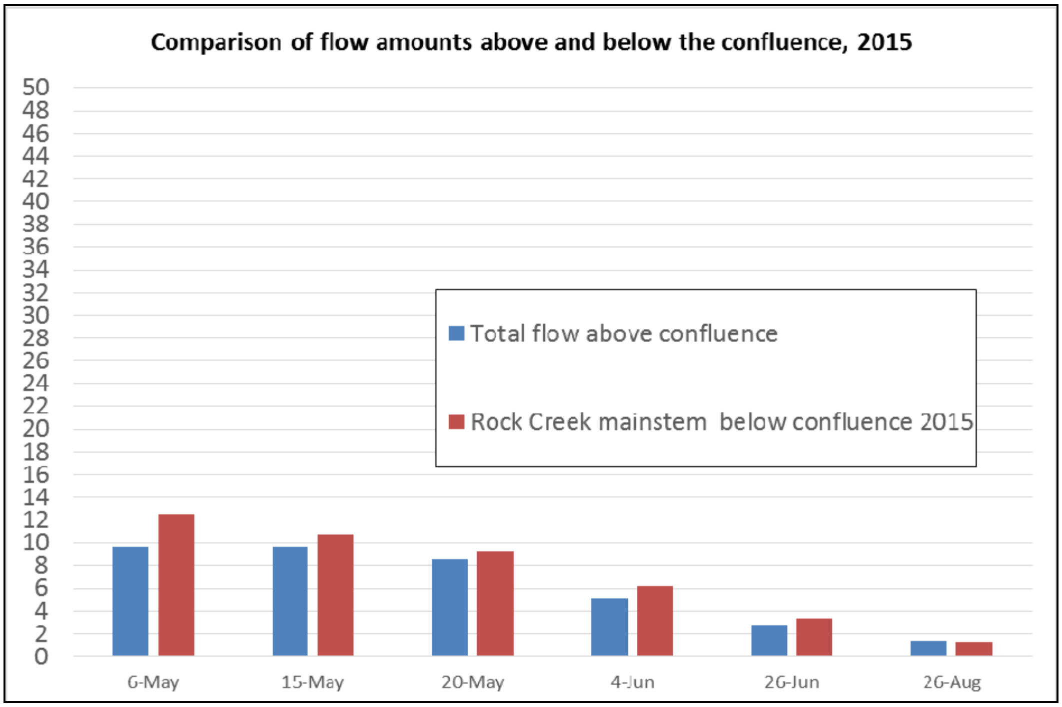


Figure 21c. Bar graph comparing total amount of flow above the confluence with the Rock Creek mainstem below the confluence, 2015

Table 3: Stream flows measured through the summer in cubic feet per second (CFS) 2013. *(Numbers in red were corrected after the 2013 report was written).*

Site	Flow May 14 (CFS)	Flow June 4 (CFS)	flow July 9 (CFS)	Flow July 15 (CFS)	Flow July 26 (CFS)
Rock Creek mainstem below confluence	10.12	15.15	5.9	4.52	3.94
South Fork Rock Creek above confluence	7.39	9.71	5.7	4.64	4.09
Lower Spillway cross-section	2.9	5.94	0.92	0.55	0
Dam valve channel			0.52	0.38	0.35
Ratio of lower spillway to mainstem flow	***0.30***	***0.22***	***0.16***	***0.12***	***0.00***

Table 4: Stream flows measured through the summer in cubic feet per second (CFS) 2014.

Site	Cubic ft/sec on 5/13/2014	CFS on 5/22/2014	CFS on 6/6/2014	CFS on 7/8/14	CFS on 7/16/2014
Rock Creek mainstem below confluence	48.16	23.3	13.69	4.89	4.27
South Fork Rock Creek above confluence	23.8	13.45	9.99	4.69	4.36
Lower Spillway cross-section	25.55	9.27	3.22	1.3	0
Dam valve channel	0.39	0.29	not measured	0.18	0.29
Ratio of lower spillway to mainstem flow	**0.53**	**0.40**	**0.24**	**0.26**	**0**

Table 5: Stream flows measured through the summer in cubic feet per second (CFS) 2015.

Site	Cubic ft/sec on 5/6/2015	Cubic ft/sec on 5/15/2015	Cubic ft/sec on 5/20/2015	Cubic ft/sec 6/4/2015	Cubic Ft/sec on 6/26/2015	Cubic ft/sec on 8/26/2015
Rock Creek mainstem below confluence	12.5	10.77	9.25	6.235	3.31	1.32
South Fork Rock Creek above confluence	5.8	5.55	5.156	3.328	2.37	1.02
Lower Spillway	3.62	3.8	3.12	1.612	0	0
Dam valve channel	0.25	0.34	0.317	0.233	0.41	0.34
Ratio of lower spillway to mainstem flow	**.29**	**.35**	**.34**	**.26**	**0**	**0**

Temperature Monitoring Results from the Reservoir

Reservoir temperatures are influenced by both stream flow and air temperatures.

Water levels in the reservoir reflect the differences between yearly stream flows. Stream flow was lower in the spring and early summer of 2013 as compared to 2012, and the cumulative precipitation amounts were even lower in 2014. As a result, the reservoir stopped spilling 2 weeks earlier in 2013 than 2012, and even earlier in 2014 (Figure 22). This trend continued in 2015, when the spillway stopped flowing on June 16, 2015, and month earlier than the previous year.

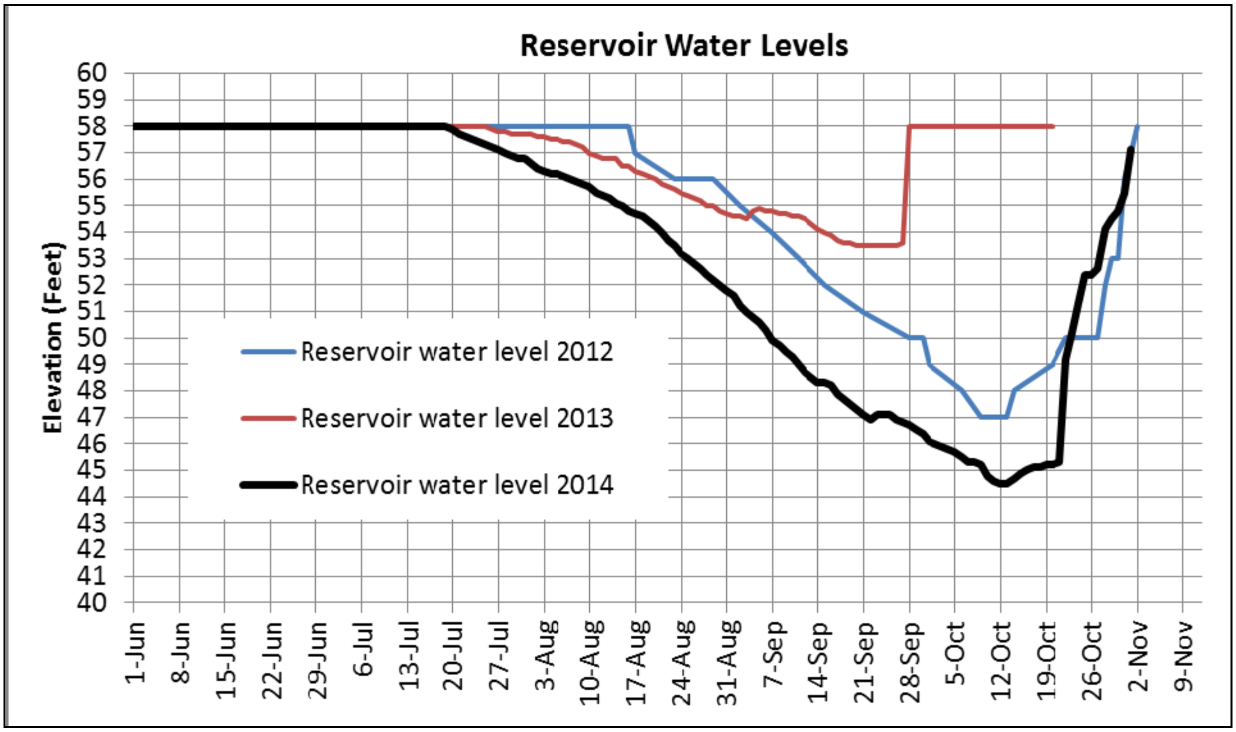


Figure 22a. Comparison of summer reservoir levels in 2012, 2013 and 2014. The reservoir level began to drop on July 26, 2013; two weeks earlier than in 2012. The reservoir re-filled in one day, due to the significant rainstorm at the end of September, 2013. In 2012 and 2014, the reservoir continued to drop until mid-October, and gradually re-filled after that. In 2014, the reservoir began dropping on July 14, 2014, and was lower throughout the latter part of the summer than the previous two years.

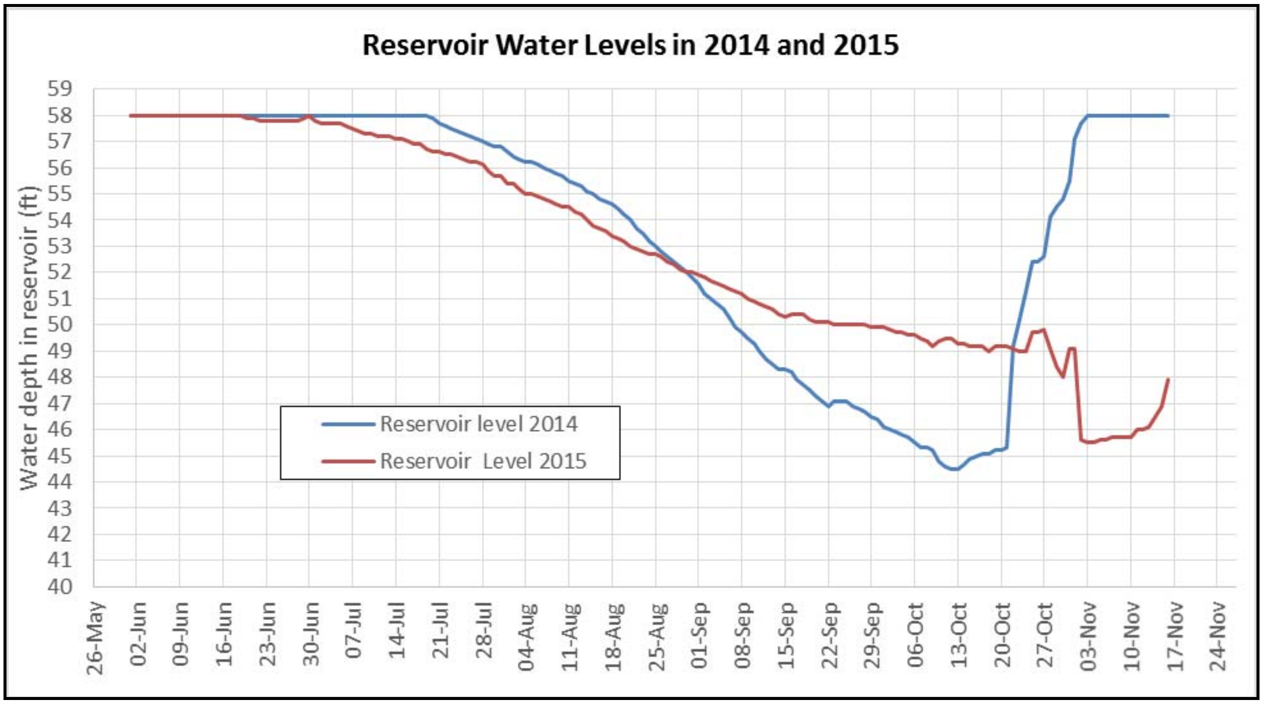


Figure 22b. Comparison of the temperatures at the bottom of the reservoir 2014 and 2015.

In addition to the probes that were placed in the North Fork Rock Creek above the reservoir, and the probes placed in channel locations downstream of the reservoir, six probes were suspended on a rope from the tower in the deepest part of the reservoir. Figures 4 and 7 show the map view of the probes that bracketed the reservoir Figure 23 shows the depth of the probes and the level of the reservoir through the summers in 2014 and 2015.

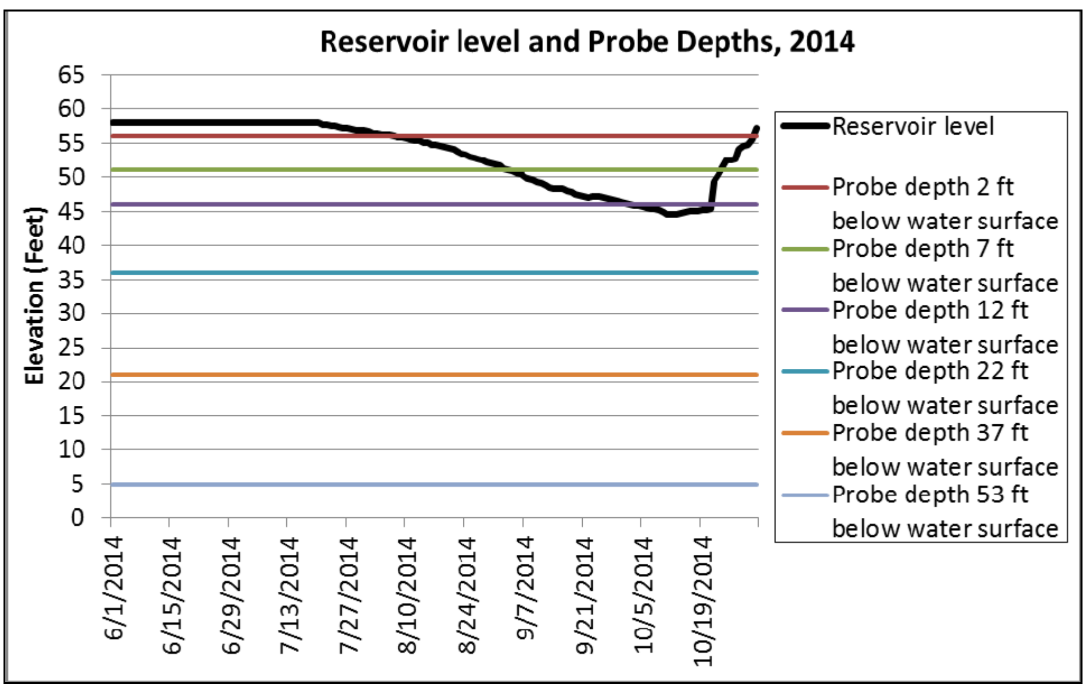


Figure 23a. Depth of temperature probes on rope suspended from wooden tower in the reservoir.

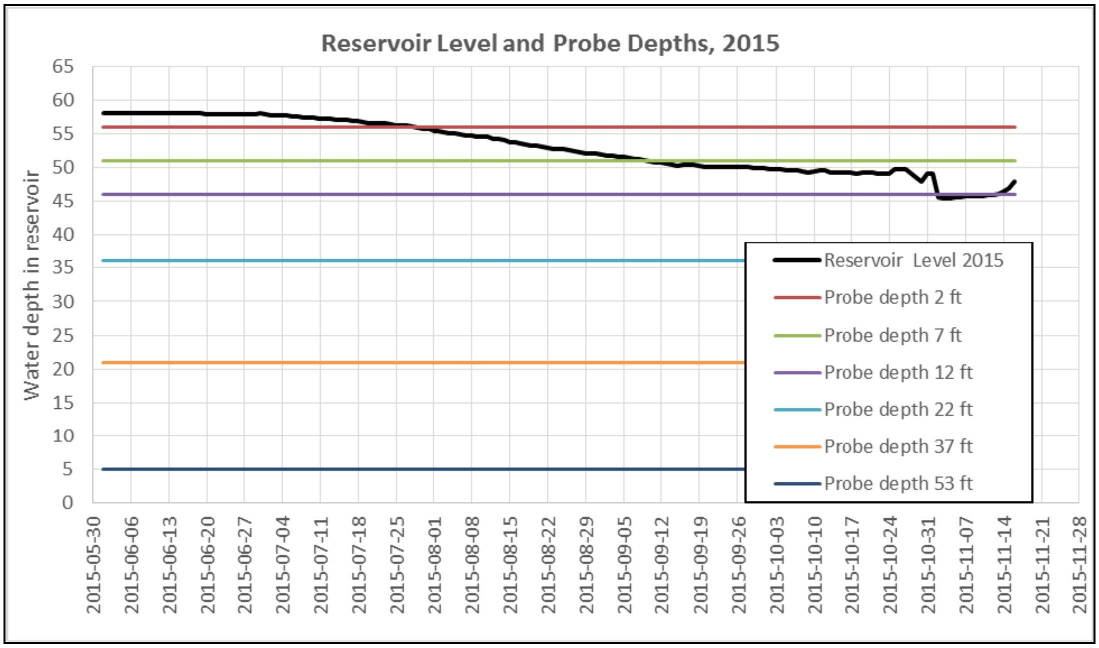


Figure 23b: *Depth of temperature probes on rope suspended from wooden tower in the reservoir.*

Reservoir temperatures at the bottom also reflect the climatic variables. Air temperatures are similar in 2012 and 2013; the difference in the 7-day average of the daily maximum temperature is only 0.7° (F) degrees between the two years. However, the air temperatures were warmer early in the season in 2013. As a result of the lower stream flows and the earlier warm temperatures, as compared to 2012, water temperatures at the bottom of the reservoir were around 4° (F) degrees warmer in 2013 in May and June, and 5.3 degrees warmer in 2013 on August 19. Reservoir bottom temperatures reached a daily high of 62.7 in late September 2013 (Figure 24). In 2014, reservoir bottom temperatures were consistently a couple of degrees warmer than 2013 from early July through the first of November, even though the 7-day average of the maximum daily air temperature was slightly cooler. In 2015, in keeping with an unusually warm June, the reservoir bottom temperatures were the warmest recorded in June in six years of data collection (Figure 24).

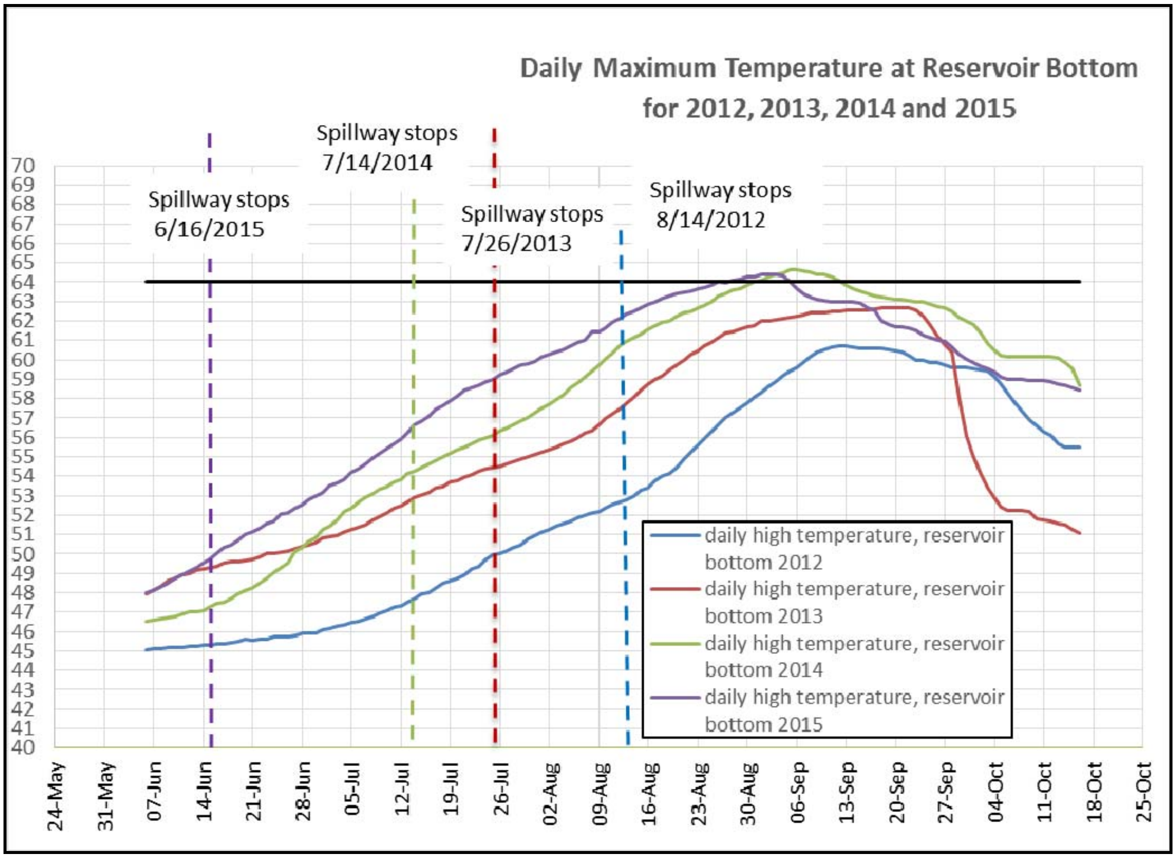


Figure 24: Temperature trends at the bottom of the reservoir are compared to the reservoir water levels through the summer of 2015. The bottom temperature gradually rises, even in the early summer when the reservoir is full and the water level isn't changing.

The bottom of the reservoir begins to warm up before the spillway stops flowing, and reservoir levels begin to drop (Figure 25). Therefore, depth of the water column above the bottom of the reservoir is not a driving factor in the warming of the reservoir bottom.

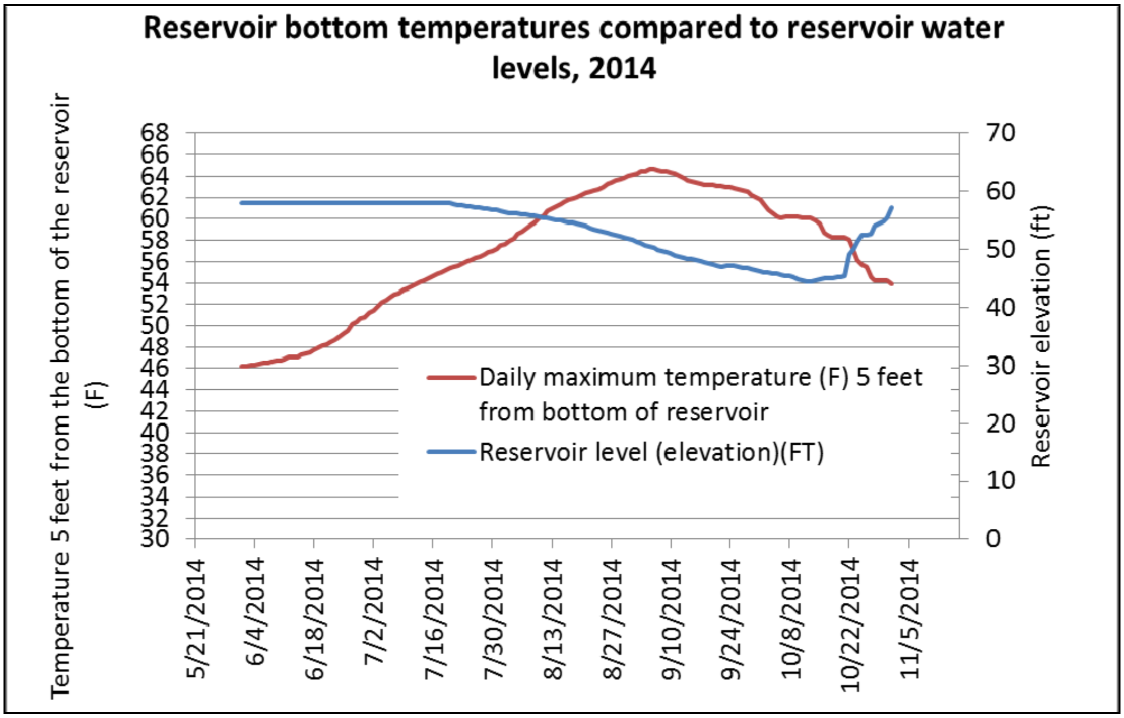


Figure 25a

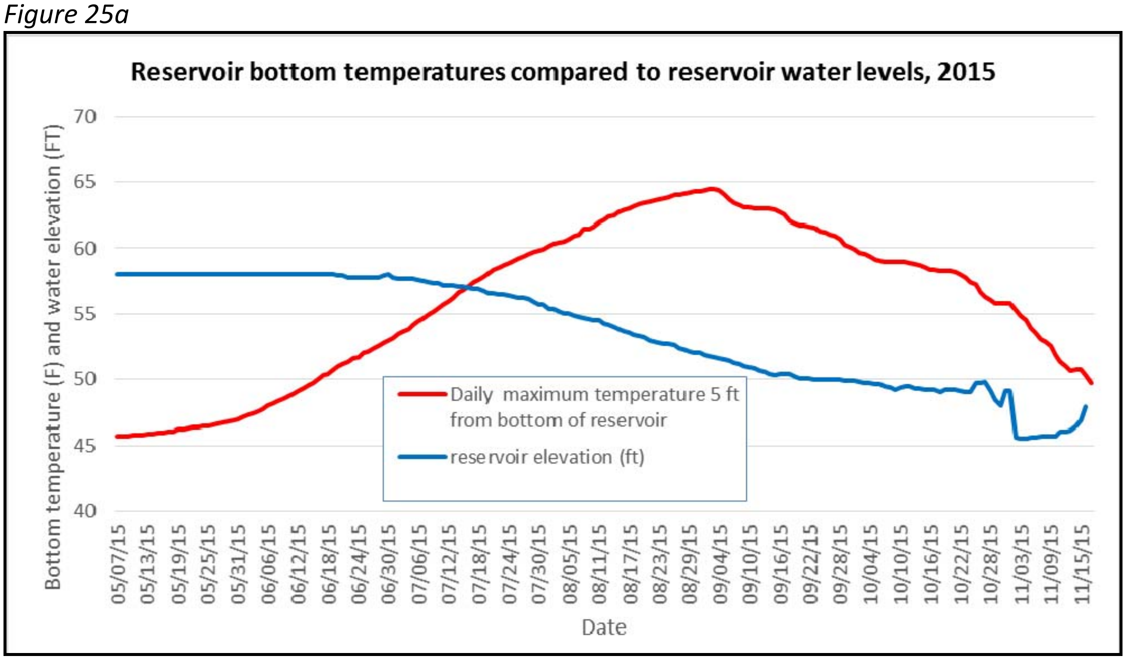


Figure 25b.

Figure 25: Temperature trends at the bottom of the reservoir are compared to the reservoir water levels through the summer of 2014 and 2015. The bottom temperature gradually rises, even in the early summer when the reservoir is full and the water level isn't changing.

The largest variability between the top and the bottom of the reservoir occurs in the early summer (Figure 26). By September, the difference in temperature between the surface of the water and the bottom of the reservoir is greatly reduced.

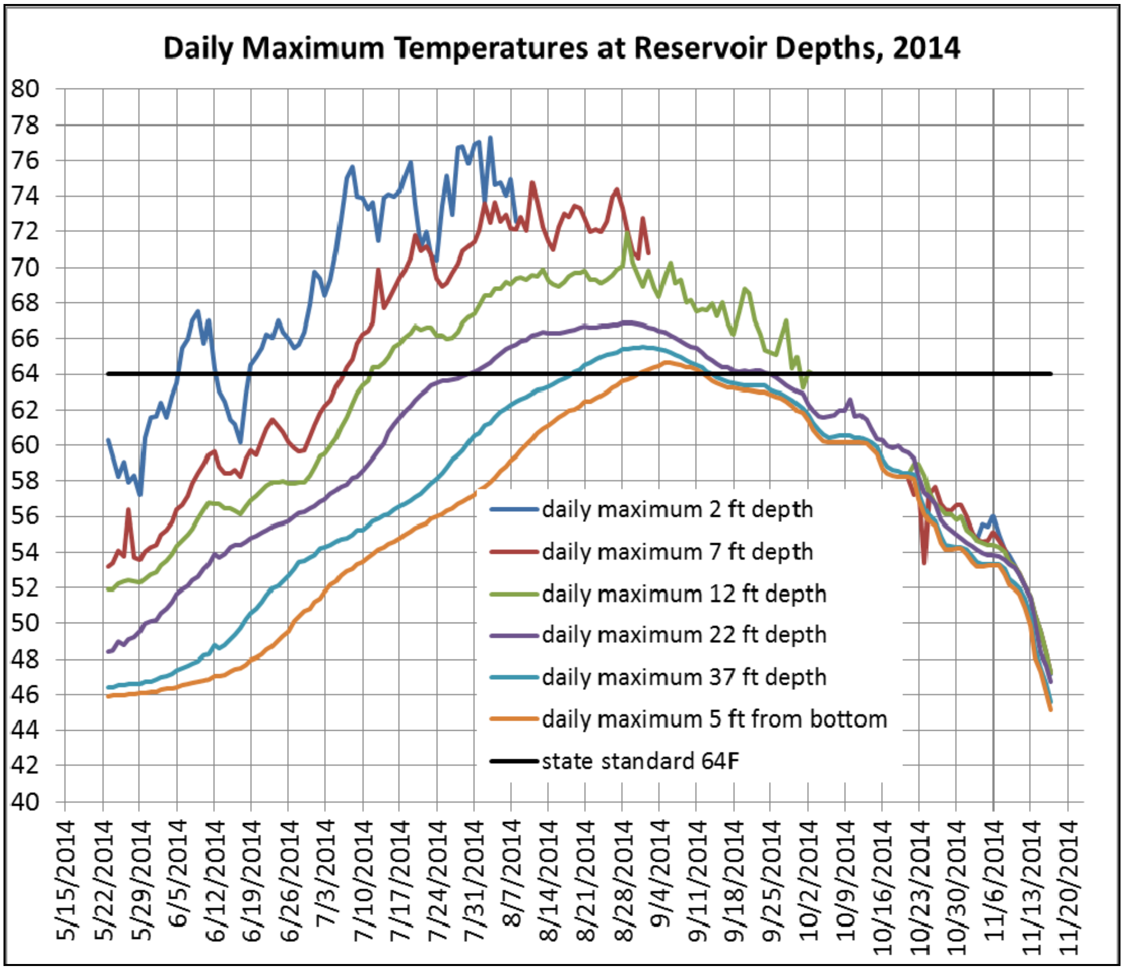


Figure 26a. Comparison of temperatures in the reservoir at the monitored depths. The bottom of the reservoir was slightly above 64F in early September, 2014 for the first time since the reservoir was monitored. By early September, the bottom of the reservoir is only a couple of degrees cooler than the surface waters. The probe that was installed at 12 feet depth in May is near the surface of the water in September.

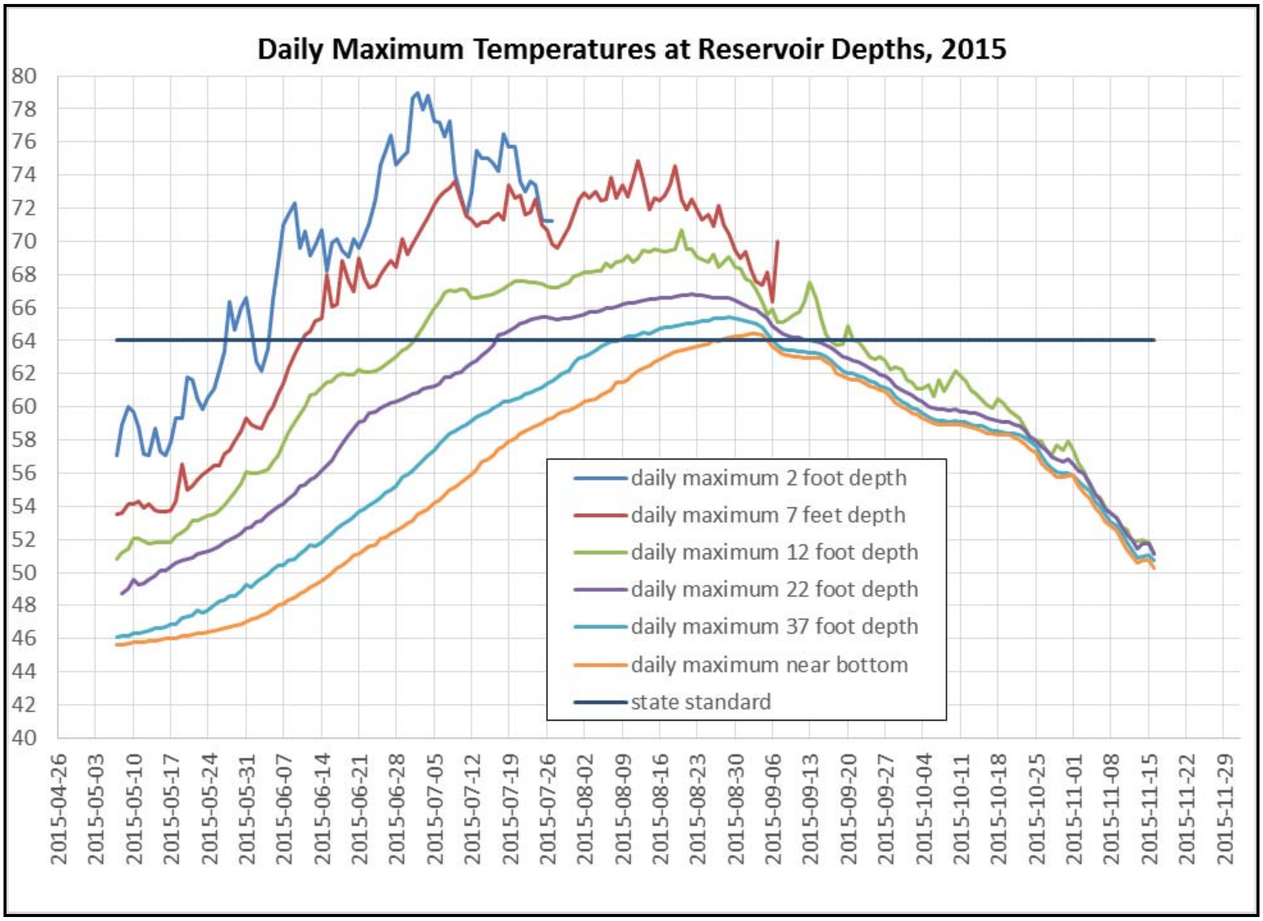


Figure 26b: Comparison of temperatures in the reservoir at the monitored depths. The bottom of the reservoir was slightly above 64F in early September,

Figure 27 shows the comparison of daily maximum water temperatures around the North and South Fork confluence below the dam for 2013, 2014, and 2015. The probe that was in place just above the confluence of the South Fork and the mainstem, and below both the spillway and the dam valve channel (light blue line) is very close in temperature to the spillway until early July for 2013 and 2014. The spillway stopped flowing on July 26, 2013 and July 14, 2014, and June 16, 2015.

In all three years, beginning in early August, the temperatures of the dam valve channel, the bottom of the reservoir, and the mainstem of Rock Creek below the confluence begin to converge, and there isn't much difference between the bottom of the reservoir and the Rock Creek mainstem. After early September, the bottom of the reservoir is actually warmer than the mainstem of Rock Creek.

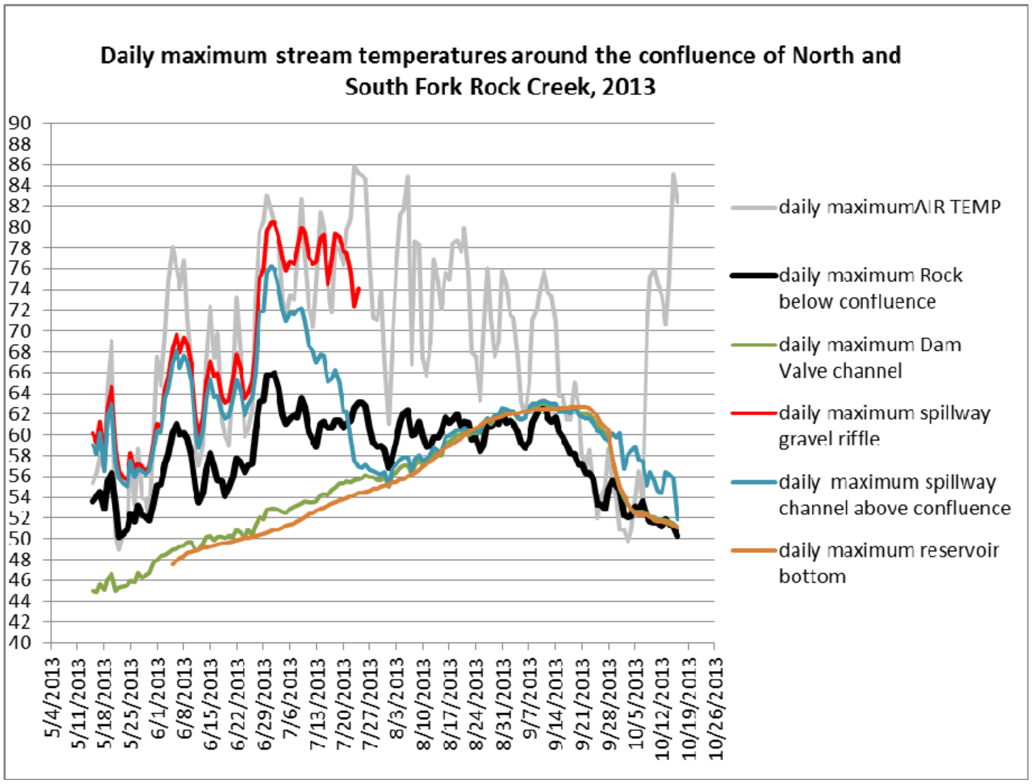


Figure 27a. Comparison of daily maximum temperatures in the channels below the dam and around the confluence of the North and South Forks of Rock Creek, 2013.

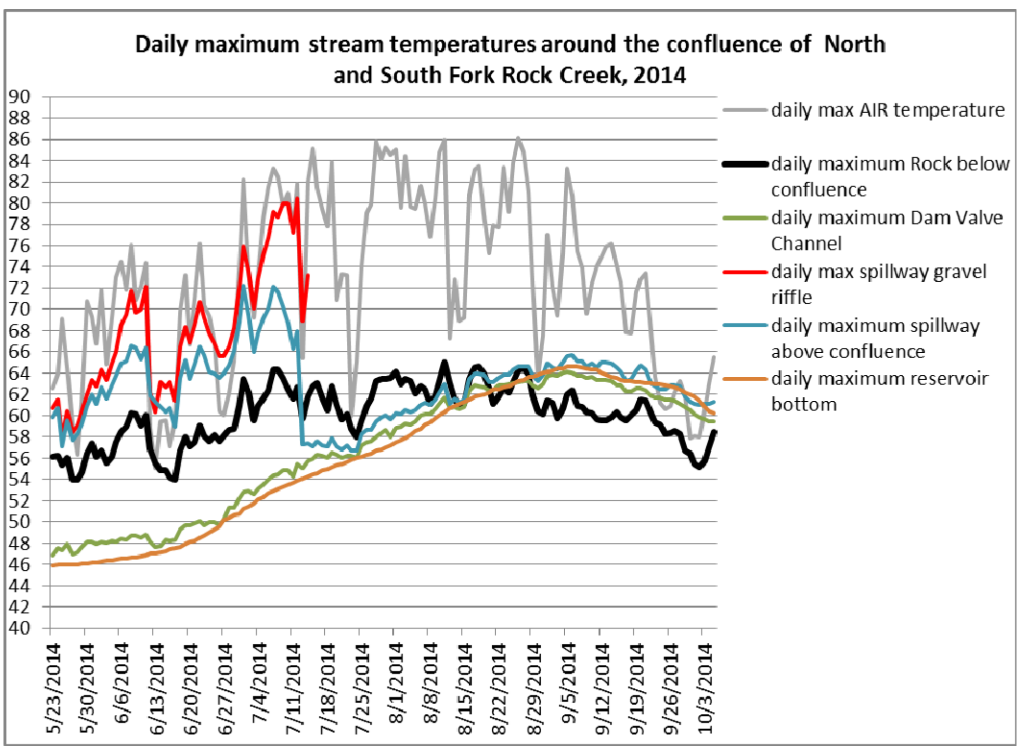


Figure 27b. Comparison of daily maximum temperatures in the channels below the dam and around the confluence of the North and South Forks of Rock Creek 2014.

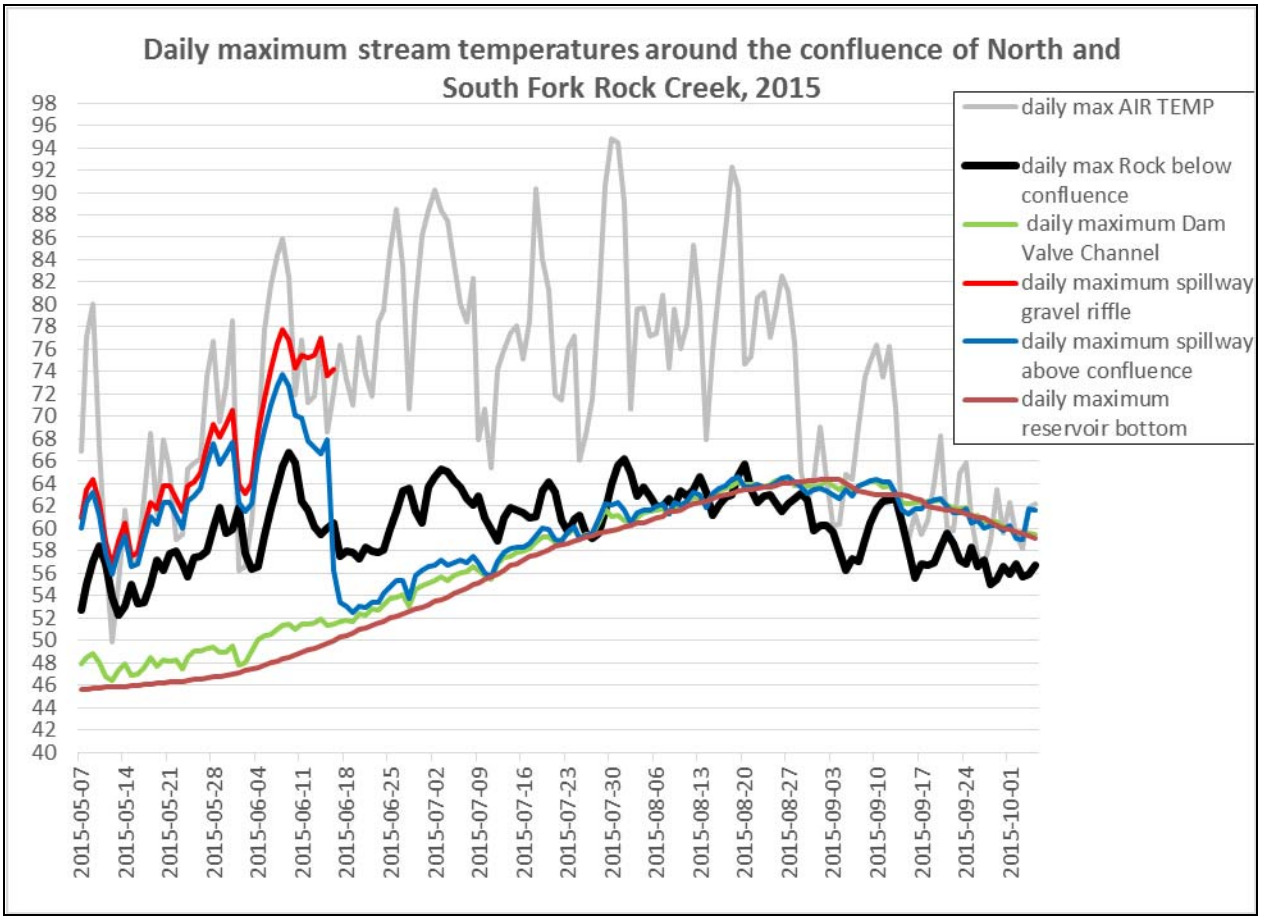


Figure 27c: Comparison of daily maximum temperatures in the channels below the dam and around the confluence of the North and South Forks of Rock Creek 2015.

How much heat does the spillway contribute?

Background

The methodology used in 2013 to calculate the heat contribution from the spillway was repeated in 2014 and 2015. To review, temperature is a measurement independent of the quantity of water. Enthalpy is the amount of heat (calories) in a body of water and depends on the quantity of water and the temperature together. For water, the amount of calories contained in a gram of water is a number very close to the temperature in centigrade.

The amount of heat can be calculated by multiplying the water quantity by the calories per gram for a specific temperature, or:

Heat (calories) = mass (grams) X calories per gram at a specific temperature.

The heat contribution of the spillway was determined using the following method. The temperature data used was the maximum daily temperature when the flow was measured. The number of calories above the confluence was calculated by adding together the calories contributed by the spillway, the dam valve channel and the South Fork Rock Creek as measured at the site above the confluence of the North and South Forks. In other words:

> Total calories in the water above the confluence = (Calories contributed by the spillway) + (Calories contributed by the South Fork above the confluence) + (Calories contributed by the dam valve channel)

To calculate how much of the temperature above the confluence can be attributed to the spillway, "what if" calculations can be made to theoretically eliminate the effects of the spillway. Total calories above the confluence can be calculated for various scenarios that assume the spillway temperatures are the same as a nearby source that isn't influenced by reservoir surface temperatures. The calculations are made by adding up the calories and the flow for a given scenario, then dividing total calories by total flow to get the averaged temperature for the water above the confluence. This result is then subtracted from the averaged temperature of the actual data to see what difference the scenario would make in temperature.

These scenarios are as follows:

1. What if the spillway water temperature was the same as the North Fork Rock Creek above the reservoir? This scenario approximates the absence of the reservoir; however, the cold water from the dam valve channel is still in the equation.

2. What if the spillway water temperature was the same as the South Fork Rock Creek above the confluence? This scenario assumes no spillage from the dam.

3. What if the spillway water temperature was the same as the dam valve channel (water coming from the bottom of the reservoir? This scenario assumes that all contributions from the reservoir come from the bottom of the reservoir.

The first two scenarios simulate the absence of the dam and reservoir; the third scenario was developed to see what effect substituting water from the bottom of the reservoir for the spillway flow would have. With the third scenario, the benefit would probably be reduced more than the calculations suggest as the summer progresses because water from higher in the reservoir would be flowing out of the bottom of the reservoir as the reservoir level was lowered.

As a consistency check, the total calories above the confluence are compared to the calories below the confluence in Figure 28. The amounts above and below the confluence are reasonably close, and parallel the flow amount comparisons in Figure 21.

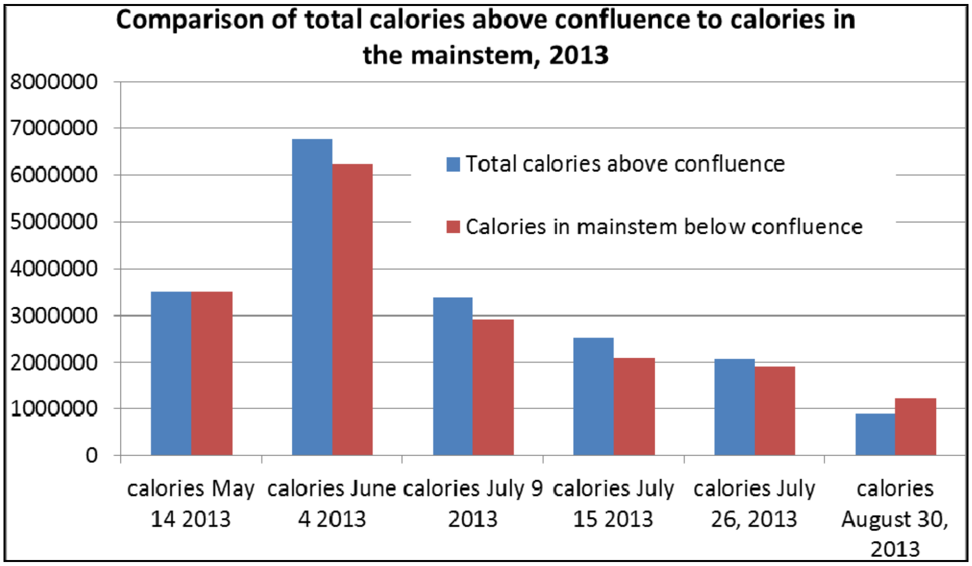


Figure 28a: Graphs showing the comparison of caloric content in the sum of the channels above the confluence and the mainstem below the confluence in 2013.

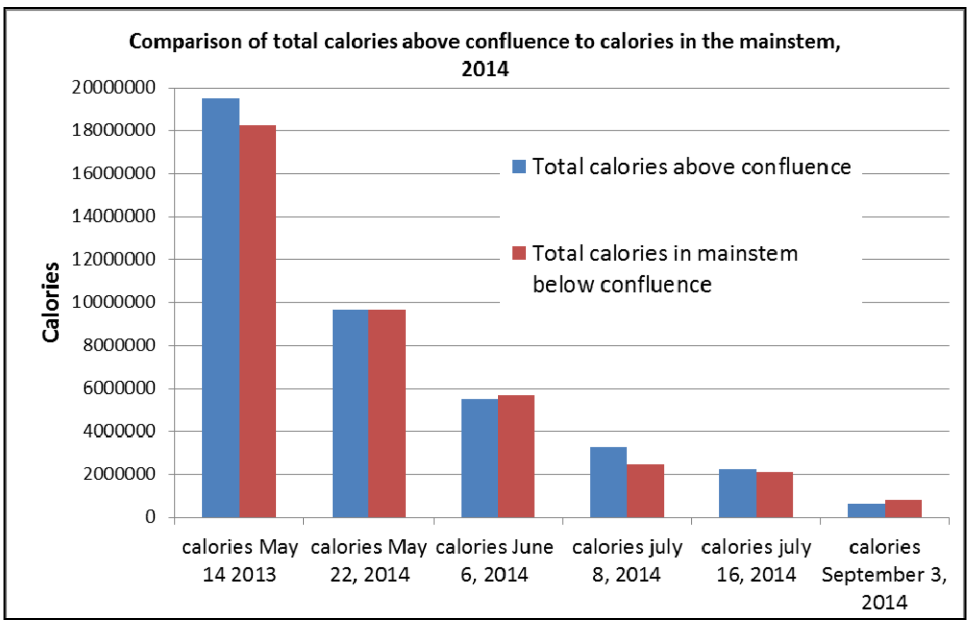


Figure 28b. Graphs showing the comparison of caloric content in the sum of the channels above the confluence and the mainstem below the confluence in 2014.

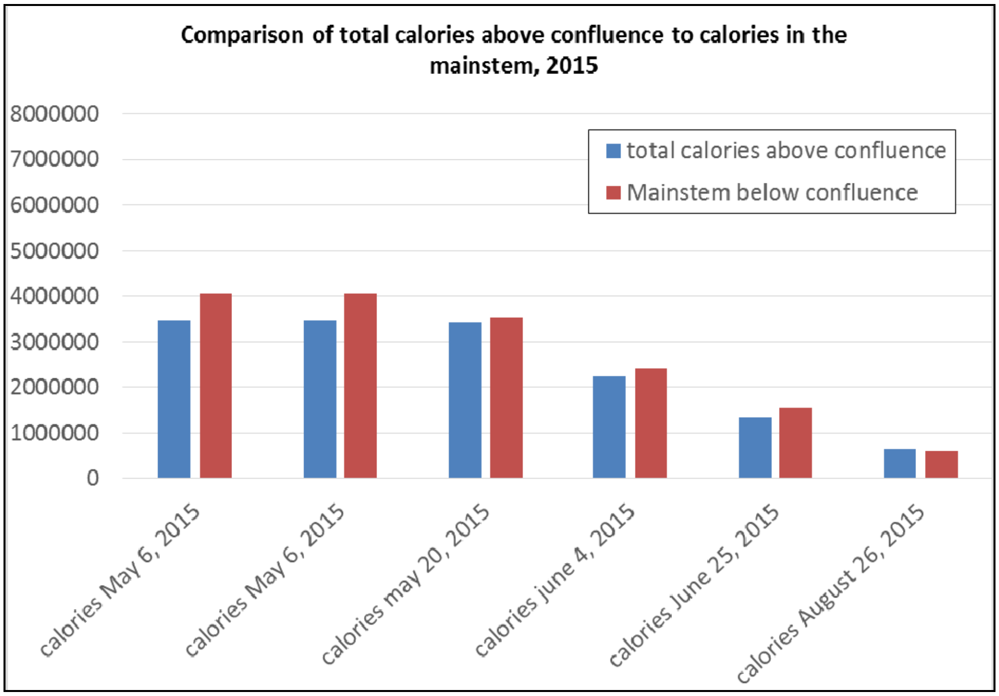


Figure 28c: *Graphs showing the comparison of caloric content in the sum of the channels above the confluence and the mainstem below the confluence in 2015.*

The following section shows the data used for the calculations, as well as the results.

Data used in 2013 calculations

Table 6a: Data for May 14, 2013

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	2.90	15.63	1283171.17
Dam Valve channel	0.52	7.22	106284.07
South Fork above confluence	7.39	10.14	2121338.69
Totals above confluence	10.81		3510793.93
Mainstem below confluence	10.31	12.03	3511170.44
North Fork			
Spillway flow as % of total flow above confluence	39%		
Average temp above confluence (total calories above confluence divided by total flow above confluence)		11.47	

Table 6b. Data for June 4, 2013

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	5.94	18.65	3136121.65
Dam Valve channel	0.52	9.24	136020.05
South Fork above confluence	9.71	12.72	3496503.44
Totals above confluence	16.17		6768645.14
Mainstem below confluence	15.15	14.51	6223112.67
North Fork		12.00	
Spillway flow as % of total flow above confluence	61%		
Average temp above confluence (total calories above confluence divided by total flow above confluence)		14.79	

Table 6c. Data for July 9, 2013

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	0.92	26.67	694605.89
Dam Valve channel	0.52	11.91	175324.55
South Fork above confluence	5.70	15.63	2522095.07
Totals above confluence	7.14		3392025.50
Mainstem below confluence	5.90	17.51	2924595.29
North Fork		15.79	
Spillway flow as % of total flow above confluence	16%		
Average temp above confluence (total calories above confluence divided by total flow above confluence)		16.78	

Table 6d. Data for July 15, 2013

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	0.55	26.28	409181.20
Dam Valve channel	0.38	12.41	133500.53
South Fork above confluence	4.64	15.03	1974261.06
Totals above confluence	5.57		2516942.79
Mainstem below confluence	4.52	16.29	2084429.15
North Fork		15.20	
Spillway flow as % of total flow above confluence	12%		
Average temp above confluence (total calories above confluence divided by total flow above confluence)		15.96	

Note: Spillway stopped flowing July 26, 2013

Data used in 2014 calculations

Table7a. Data for May 14, 2013

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	25.55	15.03	10871200.46
Dam Valve channel	0.39	8.87	97930.02058
South Fork above confluence	23.8	12.63	8509576.101
Totals above confluence	49.74		19478706.58
Mainstem below confluence	48.16	13.38	18241905.88
spillway flow as % of total above confluence	51%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		13.83	

Table 7b. Data for May 22, 2014

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	9.27	17.94	4707927.776
Dam Valve channel	0.29	9.09	74625.88595
South Fork above confluence	13.45	12.73	4847059.009
Totals above confluence	23.01		9629612.671
Mainstem below confluence	23.3	14.6	9630224.15
spillway flow as % of total above confluence	40%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		14.78	

Table 7c. Data for June 6, 2014

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	3.22	20.32	1852282.375
Dam Valve channel	0.2	9.12	51635.98345
South Fork above confluence	9.99	12.71	3594501.405
Totals above confluence	13.41		5498419.763
Mainstem below confluence	13.69	14.7	5697028.628
spillway flow as % of total above confluence	24%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		14.48	

Table 7d. Data for July 8, 2014

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	1.3	25.92	953906.8521
Dam Valve channel	0.18	12.51	63746.65983
South Fork above confluence	4.69	16.79	2229210.899
Totals above confluence	6.17		3246864.411
Mainstem below confluence	4.89	17.94	2483469.992
spillway flow as % of total above confluence	21%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		18.58	

Note: Spillway stopped flowing July 14, 2014

Data used in 2015 calculations

Table 8a. Data for May 6, 2015

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	3.62	16.08	1648209.07
Dam Valve Channel	0.25	8.82	62398.20
South fork above confluence	5.8	10.71	1758693.60
Mainstem below confluence	12.5	11.49	4067482.22
totals above confluence	**9.67**		3469300.87
spillway flow as % of total above confluence	37.4%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		12.67	

Table 8b. Data for May 15, 2015

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	3.8	14.17	1524576.48
Dam Valve Channel	0.34	8.24	79353.85
South fork above confluence	5.55	10.39	1633134.41
Mainstem below confluence	10.77	12.78	3895818.35
totals above confluence	**9.69**		3237064.74
spillway flow as % of total above confluence	35.28%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		11.08	

Table 8c. Data for May 20 2015

Site	Flow (cfs) on	Temperature (Centigrade)	calories
Spillway bottom	3.12	17.68	1561384.74
Dam Valve Channel	0.317	9.04	81115.15
South fork above confluence	5.156	12.32	1797768.48
Mainstem below confluence	9.25	13.47	3527838.01
totals above confluence	**8.593**		3440268.36
spillway flow as % of total above confluence	33.73%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		14.14	

Table 8d. Data for June 4, 2015

Site	Flow (cfs)	Temperature (Centigrade)	calories
Spillway bottom	1.612	20.32	927139.66
Dam Valve Channel	0.233	10.05	66290.25
South fork above confluence	3.328	13.26	1248846.09
Mainstem below confluence	6.235	13.69	2416196.89
totals above confluence	**5.173**		2242275.99
spillway flow as % of total above confluence	25.85%		
Averaged temp above confluence (total calories above confluence divided by total flow above confluence)		17.16	

Results for 2013

Table 9a. Scenario comparison in Centigrade, 2013

	Temp C May 14, 2013	Temp C June 4, 2013	Temp C July 9, 2013	Temp C July 15, 2013
Averaged temperature above confluence	***11.47***	***14.79***	***16.78***	***15.96***
Averaged temp above confluence (total calories above confluence/total flow) (IF SPILLWAY = NORTHFORK)	no data	12.34	15.38	14.87
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = NORTHFORK)		2.44	1.40	1.09
Average Temp above confluence (IF SPILLWAY = SOUTH FORK)	10.00	12.61	15.36	14.85
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = SOUTH FORK)	1.47	2.18	1.42	1.11
Average temp above confluence (IF SPILLWAY = DAM VALVE CHANNEL)	9.22	11.33	14.88	14.59
Difference between actual averaged temperature above confluence and theoretical (IF SPILLWAY = DAM VALVE CHANNEL)	2.26	3.46	1.90	1.37
Temperature in Rock Creek mainstem below confluence	***12.03***	***14.51***	***17.51***	***16.29***

Table 9b. Scenario comparison in Fahrenheit, 2013

	Temp F May 14, 2013	Temp F June 4, 2013	Temp F July 9, 2013	Temp F July 15, 2013
Averaged temperature above confluence	***52.65***	***58.62***	***62.21***	***60.73***
Averaged temp above confluence (total calories above confluence/total flow) (IF SPILLWAY = NORTHFORK)	no data	54.22	59.68	58.76
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = NORTHFORK)		4.40	2.52	1.97
Average Temp above confluence (IF SPILLWAY = SOUTH FORK)	50.00	54.69	59.65	58.73
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = SOUTH FORK)	2.65	3.92	2.56	2.00
Average temp above confluence (IF SPILLWAY = DAM VALVE CHANNEL)	48.59	52.39	58.78	58.27
Difference between actual averaged temperature above confluence and theoretical (IF SPILLWAY = DAM VALVE CHANNEL)	4.06	6.22	3.42	2.47
Temperature in Rock Creek mainstem below confluence	***53.65***	***58.12***	***63.52***	***61.32***

Figure 29 shows the 2013 results in graphic form. The solid black line is the daily maximum temperatures from Rock Creek below the confluence (Site 2123). The theoretical difference in temperature above the confluence for all scenarios decreases as the summer progresses.

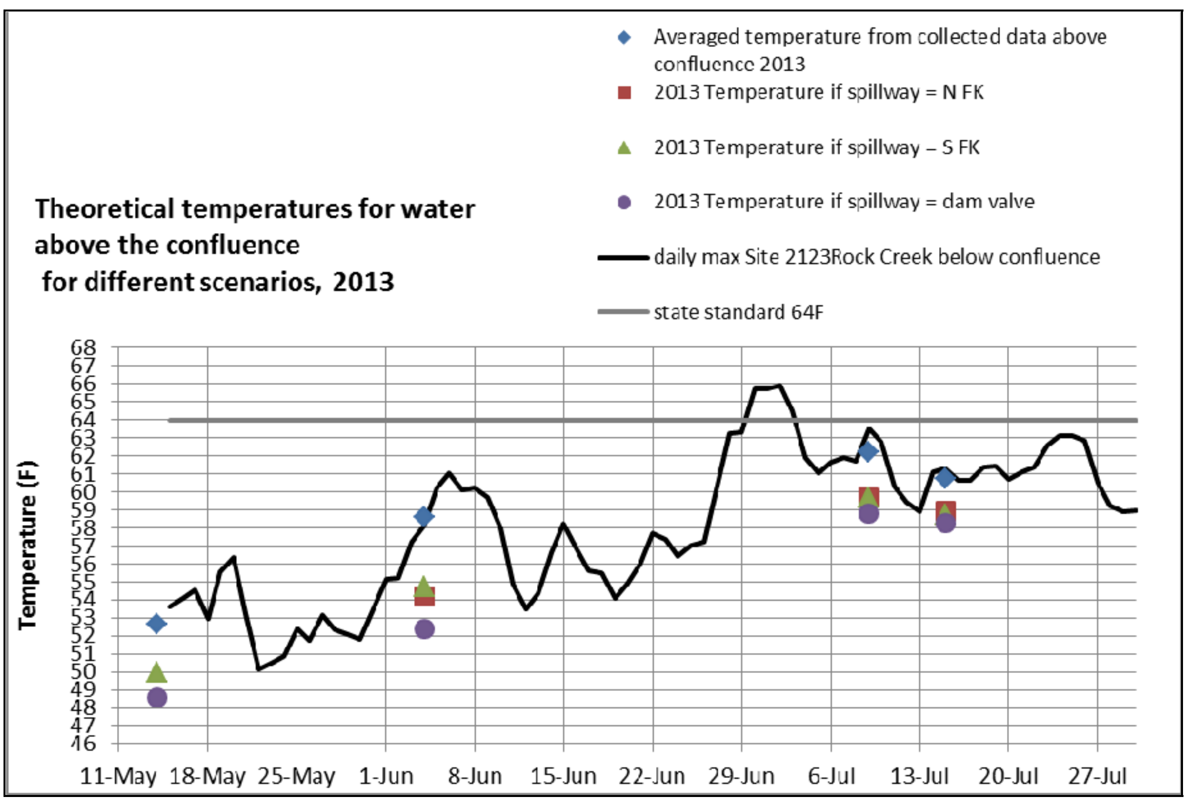


Figure 29. The theoretical difference in temperature between the averaged temperature above the confluence from measured data, and the calculated temperatures based on difference scenarios for 2013. The calculations, represented as points, are done for days when flow was measured. The solid black line is the actual daily maximum temperatures measured at Site 2123, Rock Creek below the confluence. Note that the calculated averaged temperature, which combines the data from all stream sources above the confluence, is the same as the actual measured temperature below the confluence.

Results for 2014

Table 10a. Scenario comparison in Centigrade, 2014

	Temp C May 13 2014	Temp C May 22, 2014	Temp C June 6, 2014	Temp C July 8, 2014
Averaged temperature above confluence	***13.83***	***14.78***	***14.48***	***18.59***
Averaged temp above confluence (total calories above confluence/total flow) (IF SPILLWAY = NORTHFORK)	12.09	12.69	12.69	16.53
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = NORTHFORK)	1.75	2.09	1.79	2.06
Average Temp above confluence (IF SPILLWAY = SOUTH FORK)	12.60	12.68	12.66	16.67
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = SOUTH FORK)	1.23	2.10	1.83	1.92
Average temp above confluence (IF SPILLWAY = DAM VALVE CHANNEL)	10.67	11.22	11.79	15.76
Difference between actual averaged temperature above confluence and theoretical (IF SPILLWAY = DAM VALVE CHANNEL)	3.16	3.57	2.69	2.83
Temperature in Rock Creek mainstem below confluence	***13.38***	***14.60***	***14.70***	***17.94***

Table 10b. Scenario comparison in Fahrenheit, 2014

Site	Temp F May 13 2014	Temp C=F May 22, 2014	Temp F June 6, 2014	Temp F July 8, 2014
Averaged temperature above confluence	*56.90*	*58.61*	*58.07*	*65.46*
Averaged temp above confluence (total calories above confluence/total flow) (IF SPILLWAY = NORTHFORK)	53.76	54.84	54.84	61.75
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = NORTHFORK)	3.14	3.77	3.23	3.71
Average Temp above confluence (IF SPILLWAY = SOUTH FORK)	54.68	54.83	54.78	62.00
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = SOUTH FORK)	2.22	3.78	3.29	3.46
Average temp above confluence (IF SPILLWAY = DAM VALVE CHANNEL)	51.20	52.19	53.23	60.37
Difference between actual averaged temperature above confluence and theoretical (IF SPILLWAY = DAM VALVE CHANNEL)	5.70	6.42	4.84	5.09
Temperature in Rock Creek mainstem below confluence	**56.08**	**58.28**	**58.46**	**64.29**

Figure 30 shows the 2014 results in graphic form, and is the same data for a different year as figure 29.

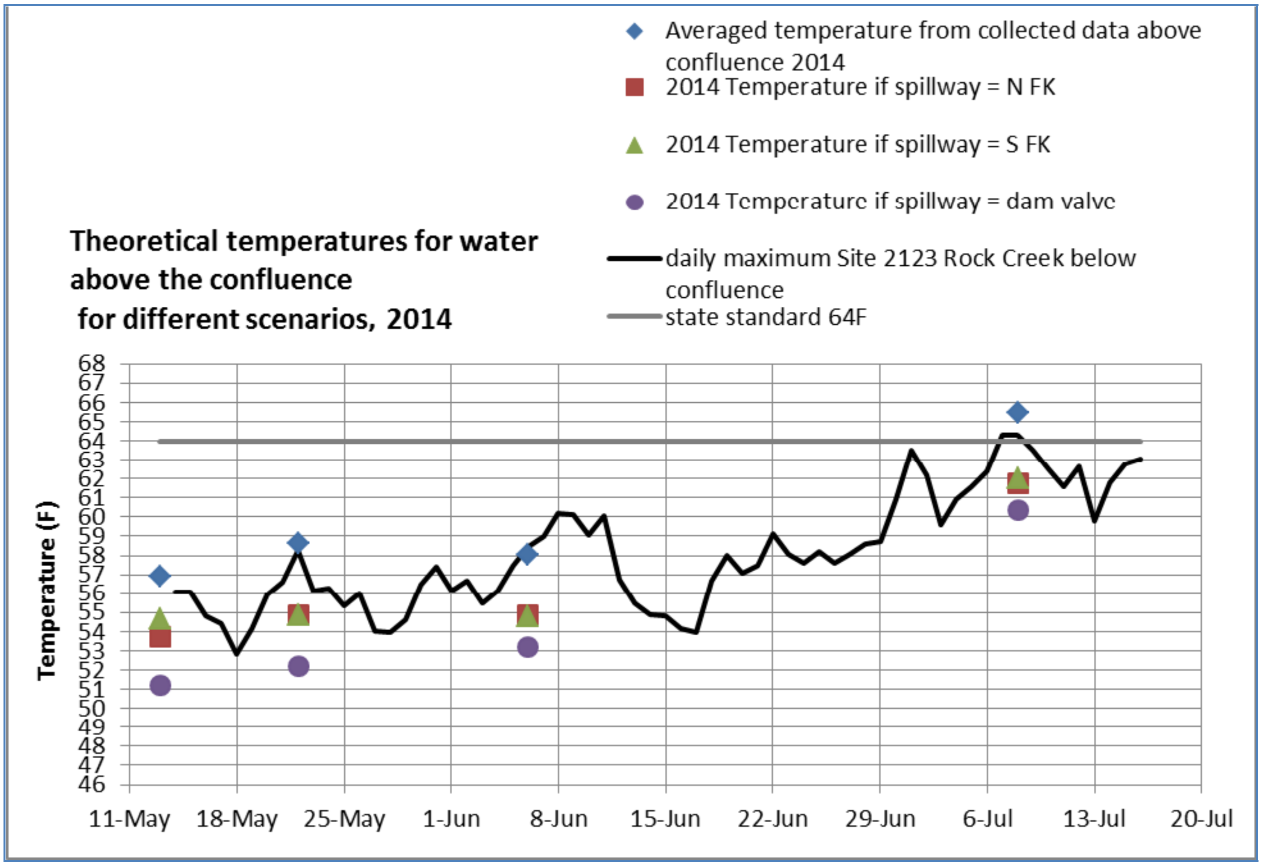


Figure 30. The theoretical difference in temperature between the averaged temperature above the confluence from measured data, and the calculated temperatures based on difference scenarios for 2014. The calculations, represented as points, are done for days when flow was measured. The solid black line is the actual daily maximum temperatures measured at Site 2123, Rock Creek below the confluence. Note that the calculated averaged temperature, which combines the data from all stream sources above the confluence, is the same as the actual measured temperature below the confluence.

Results for 2015

Table 11a. Scenario comparison in Centigrade, 2015

	Temp C May 6, 2015	Temp C May 15, 2015	Temp C May 20, 2015	Temp C June 4, 2015
Averaged temperature above confluence	***12.67***	***11.8***	***14.14***	***15.31***
Averaged temp above confluence (total calories above confluence/total flow) (IF SPILLWAY = NORTHFORK)	10.67	10.16	12.35	13.25
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = NORTHFORK)	2.00	1.64	2.17	2.54
Average Temp above confluence (IF SPILLWAY = SOUTH FORK)	10.66	10.32	12.19	13.11
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = SOUTH FORK)	2.01	1.48	1.95	2.2
Average temp above confluence (IF SPILLWAY = DAM VALVE CHANNEL)	9.95	9.48	11.01	12.12
Difference between actual averaged temperature above confluence and theoretical (IF SPILLWAY = DAM VALVE CHANNEL)	2.72	2.32	3.13	3.19
Temperature in Rock Creek mainstem below confluence	***11.49***	***12.77***	***13.47***	***13.68***

Table 11b. Scenario comparison in Fahrenheit, 2015

Site	Temp F May 6, 2015	Temp F May 15, 2015	Temp F May 20, 2015	Temp F June 4, 2015
Averaged temperature above confluence	***54.81***	***53.24***	***57.45***	***59.56***
Averaged temp above confluence (total calories above confluence/total flow) (IF SPILLWAY = NORTHFORK)	51.21	50.29	54.23	55.85
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = NORTHFORK)	3.6	2.95	3.22	3.71
Average Temp above confluence (IF SPILLWAY = SOUTH FORK)	51.19	50.58	53.94	55.60
Difference between actual averaged temperature above confluence and theoretical temperature (IF SPILLWAY = SOUTH FORK)	3.62	2.66	3.51	3.96
Average temp above confluence (IF SPILLWAY = DAM VALVE CHANNEL)	49.91	49.06	51.82	53.82
Difference between actual averaged temperature above confluence and theoretical (IF SPILLWAY = DAM VALVE CHANNEL)	4.9	4.18	5.63	5.74
Temperature in Rock Creek mainstem below confluence	**53.91**	**55.00**	**56.25**	**56.64**

Figure 31 shows the 2014 results in graphic form.

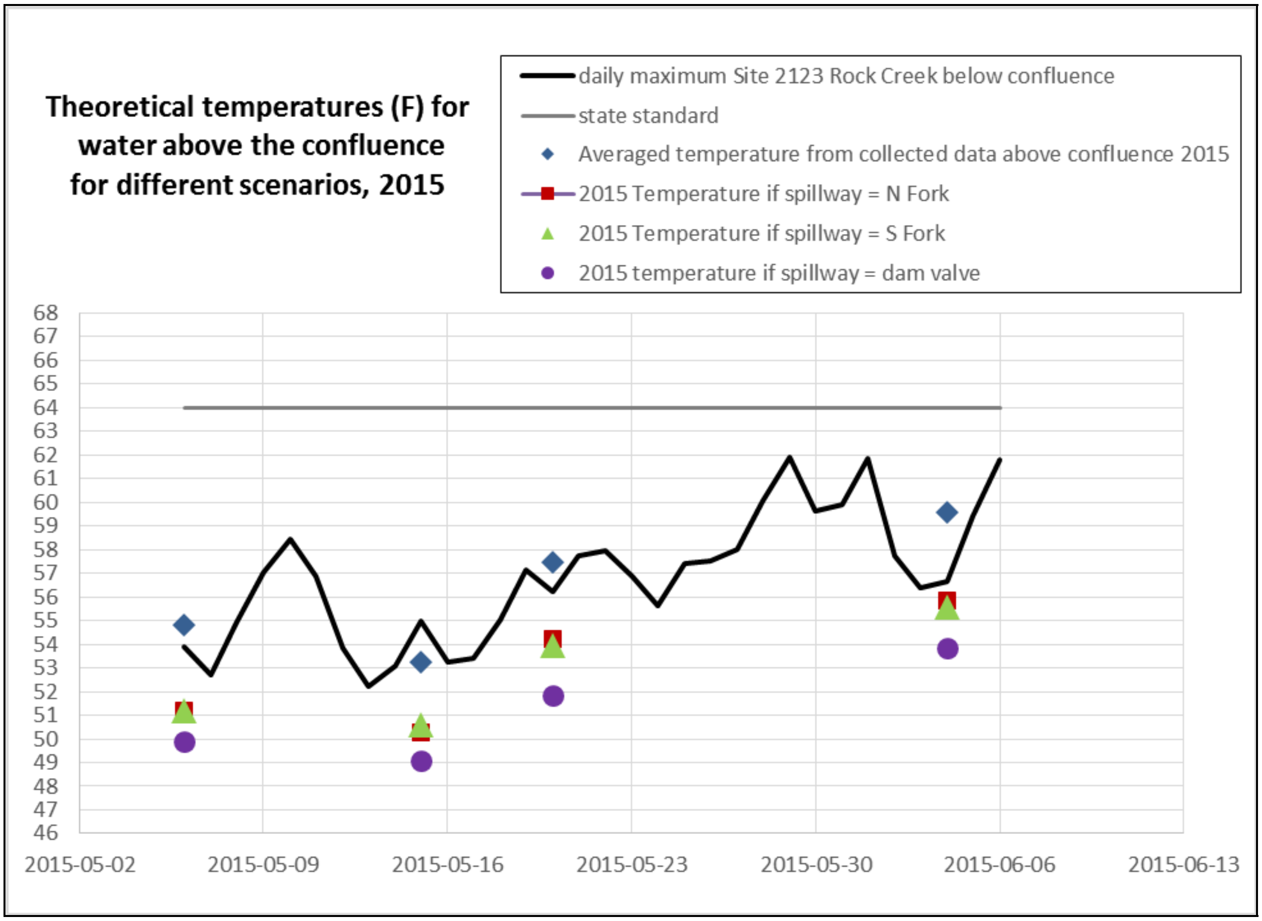


Figure 31. The theoretical difference in temperature between the averaged temperature above the confluence from measured data, and the calculated temperatures based on difference scenarios for 2015. The calculations, represented as points, are done for days when flow was measured. The solid black line is the actual daily maximum temperatures measured at Site 2123, Rock Creek below the confluence. Note that the calculated averaged temperature, which combines the data from all stream sources above the confluence, is the close to the actual measured temperature below the confluence, but in 2015 the averaged temperature above the confluence is actually slightly warmer than the actual temperatures below the confluence..

How far downstream does the spillway temperature effects extend?

A signature of the spillway effects on downstream temperatures can be seen by subtracting the daily maximum temperature at a site downstream of the spillway from a site unaffected by the dam to find the difference in temperature between the two sites. In this case, the South Fork Rock Creek temperature monitoring site above the intake was chosen as the "control". In Figure 32 and 33, the <u>difference</u> in temperature between the South Fork and the mainstem downstream of the dam shows a definite decrease in value shortly before the spillway stops flowing completely for all three years. The average difference in temperature is 1.7°F in 2013, and 1.4°F in 2014 and 2.7°F in 2015. This result is derived by subtracting the average difference after the spillway stops flowing from the average difference during spillway flow in figure 33. This signature drop is not seen in the difference between the South Fork and tributaries unaffected by the spillway, such as Middle Fork and Stilson Creek (Figure 34).

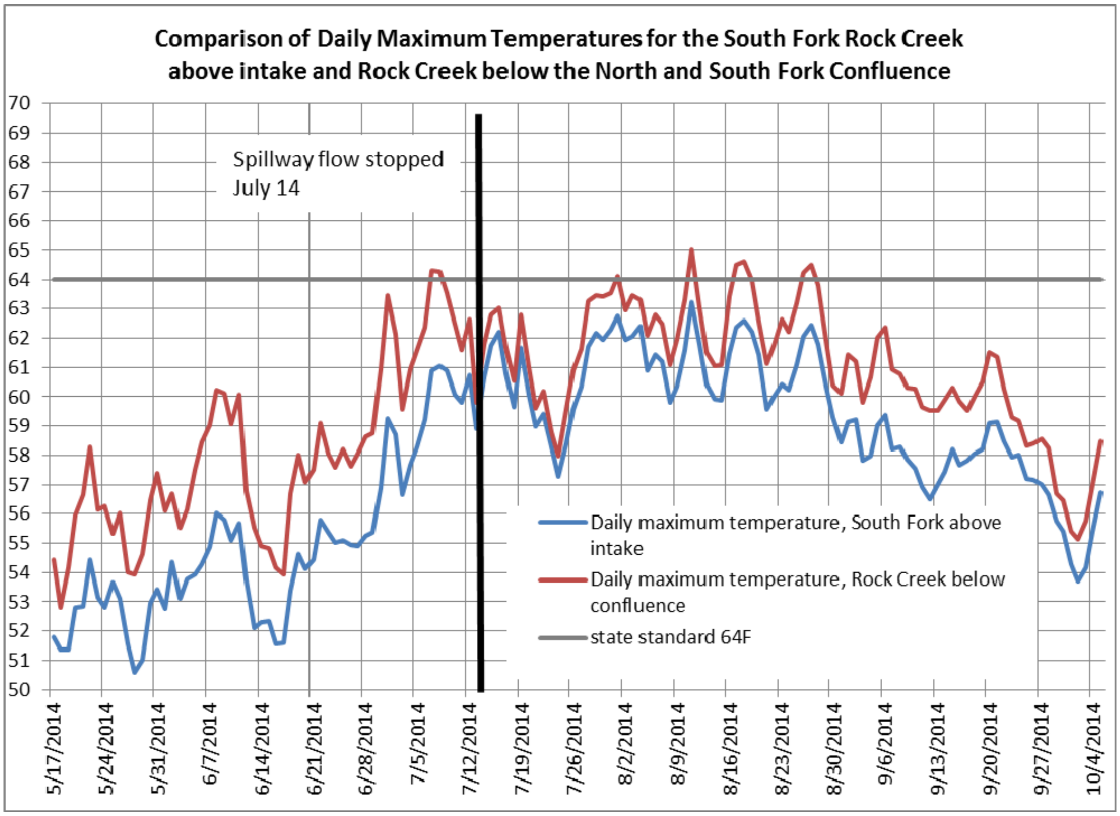


Figure 32a: 2014 daily maximum temperatures above and below the influence of the dam and spillway. Note that after the spillway stops flowing on July 14, the difference is less.

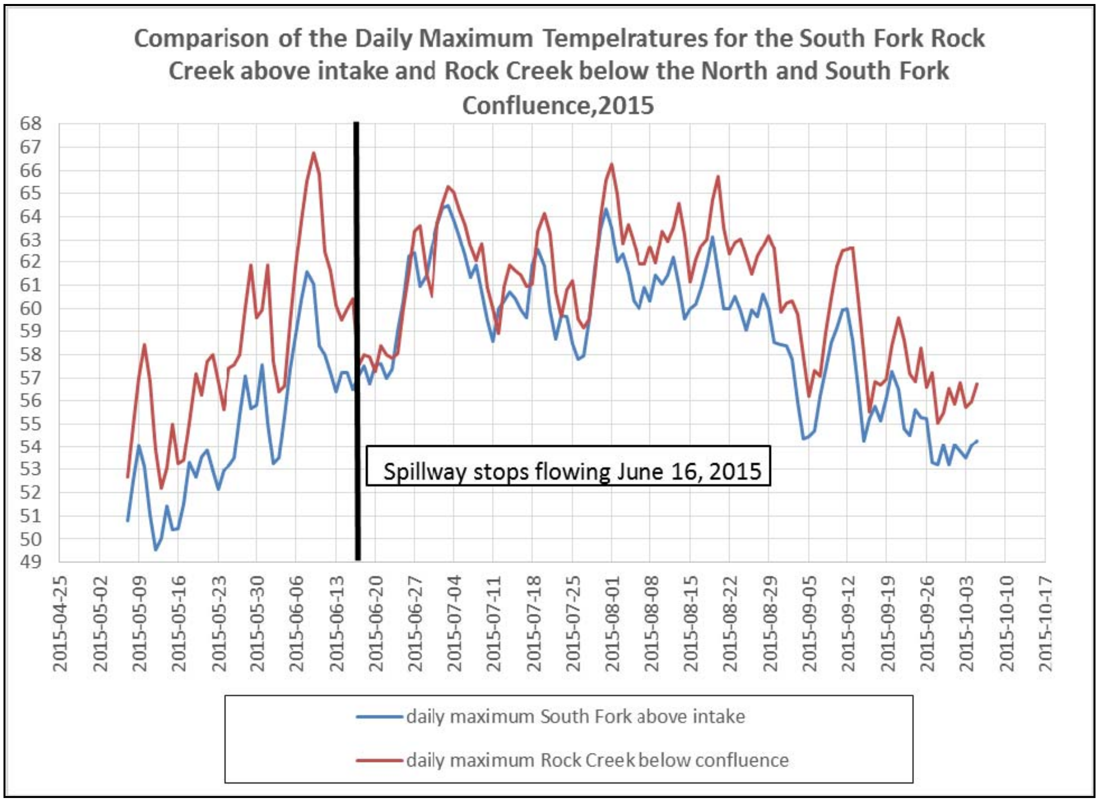


Figure 32b. 2015 daily maximum temperatures above and below the influence of the dam and spillway. Note that after the spillway stops flowing on June 16, the difference is less

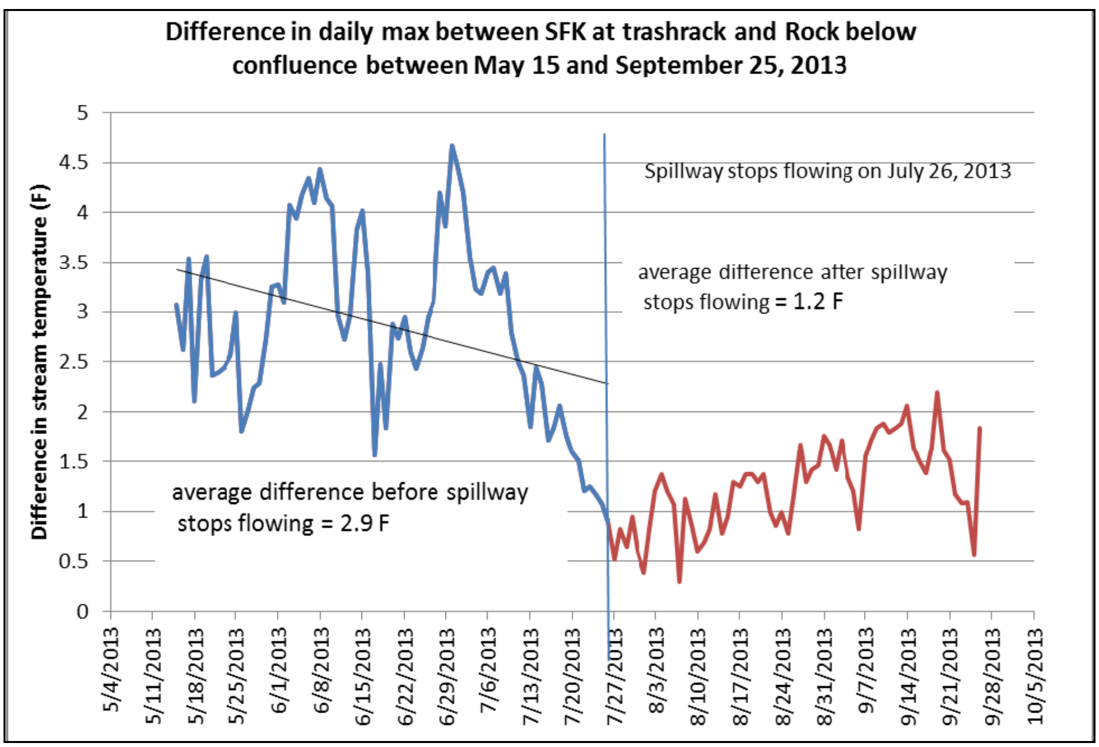


Figure 33a. Difference in daily maximum temperatures between the South Fork Rock Creek and the mainstem Rock Creek below the confluence in 2013. The black line is the trend line.

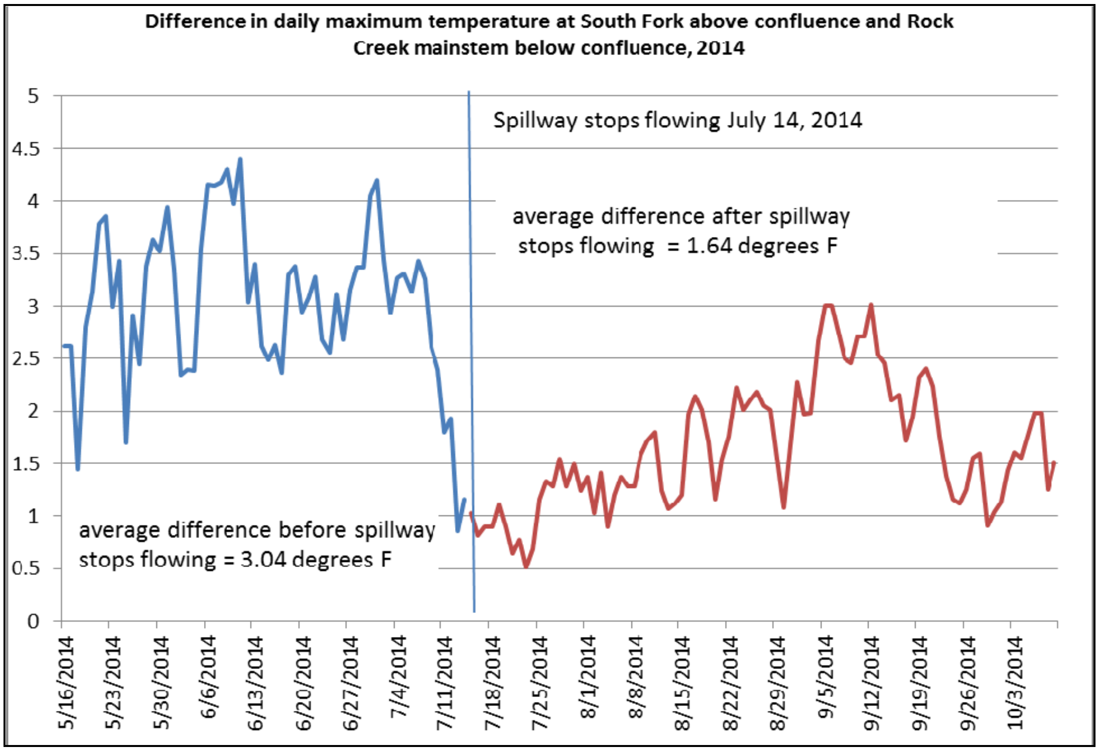


Figure 33b:. Difference in daily maximum temperatures between the South Fork Rock Creek and the mainstem Rock Creek below the confluence in 2014.

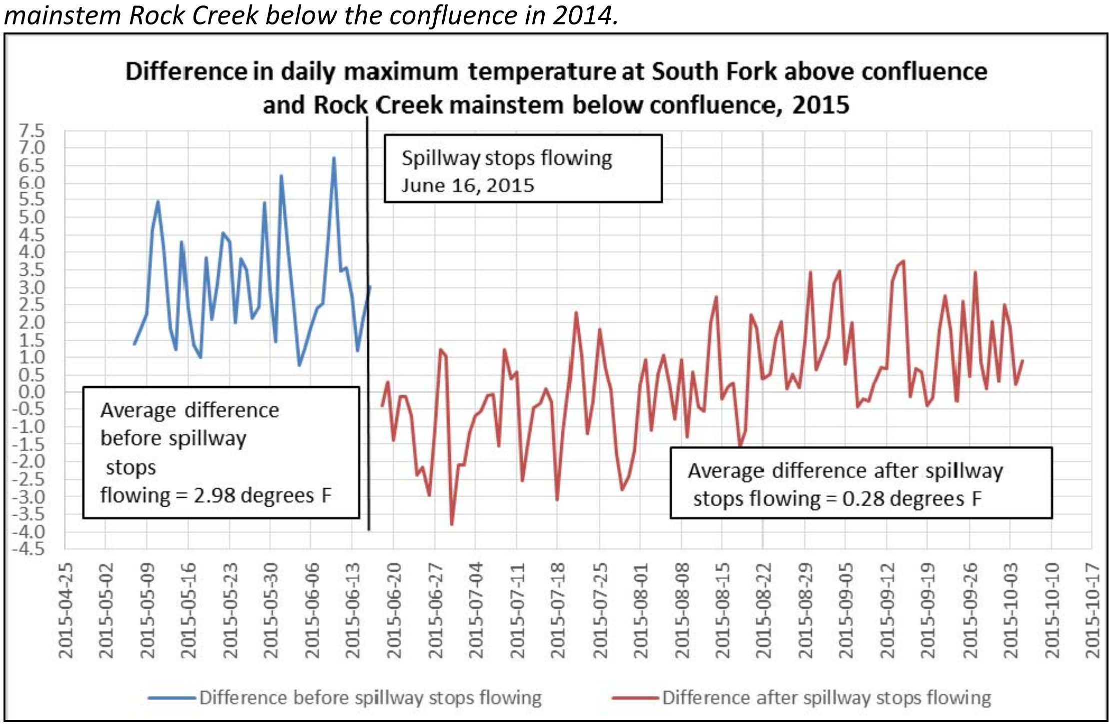


Figure 33c. Difference in daily maximum temperatures between the South Fork Rock Creek and the mainstem Rock Creek below the confluence in 2015.

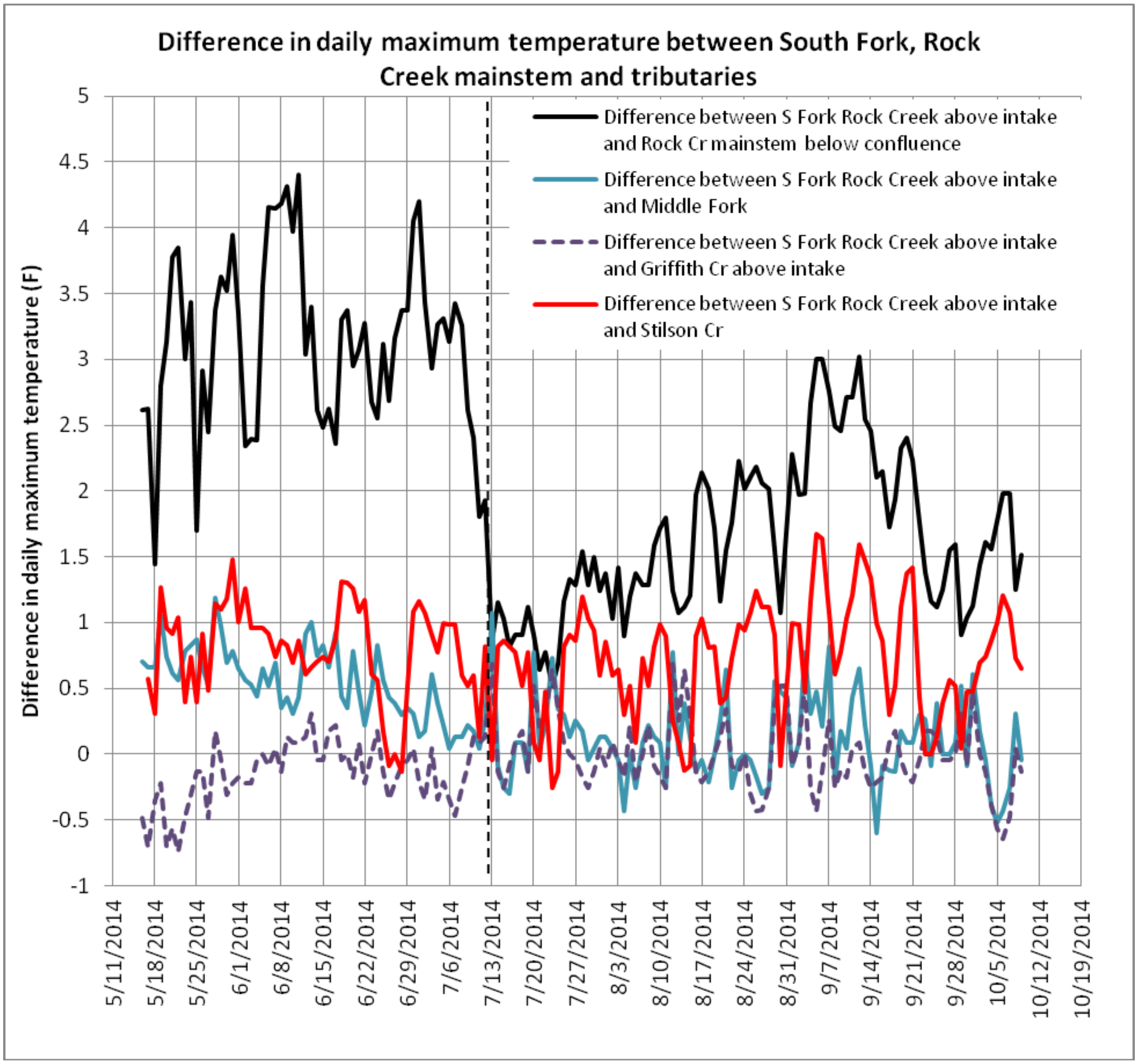


Figure 34a: Comparison of temperature differences between the South Fork and the Rock Creek mainstem below the confluence, and the South Fork and tributaries, which are not influenced by the spillway. Note that the sudden change in the temperature difference between the South Fork and the mainstem is not replicated in the tributaries.

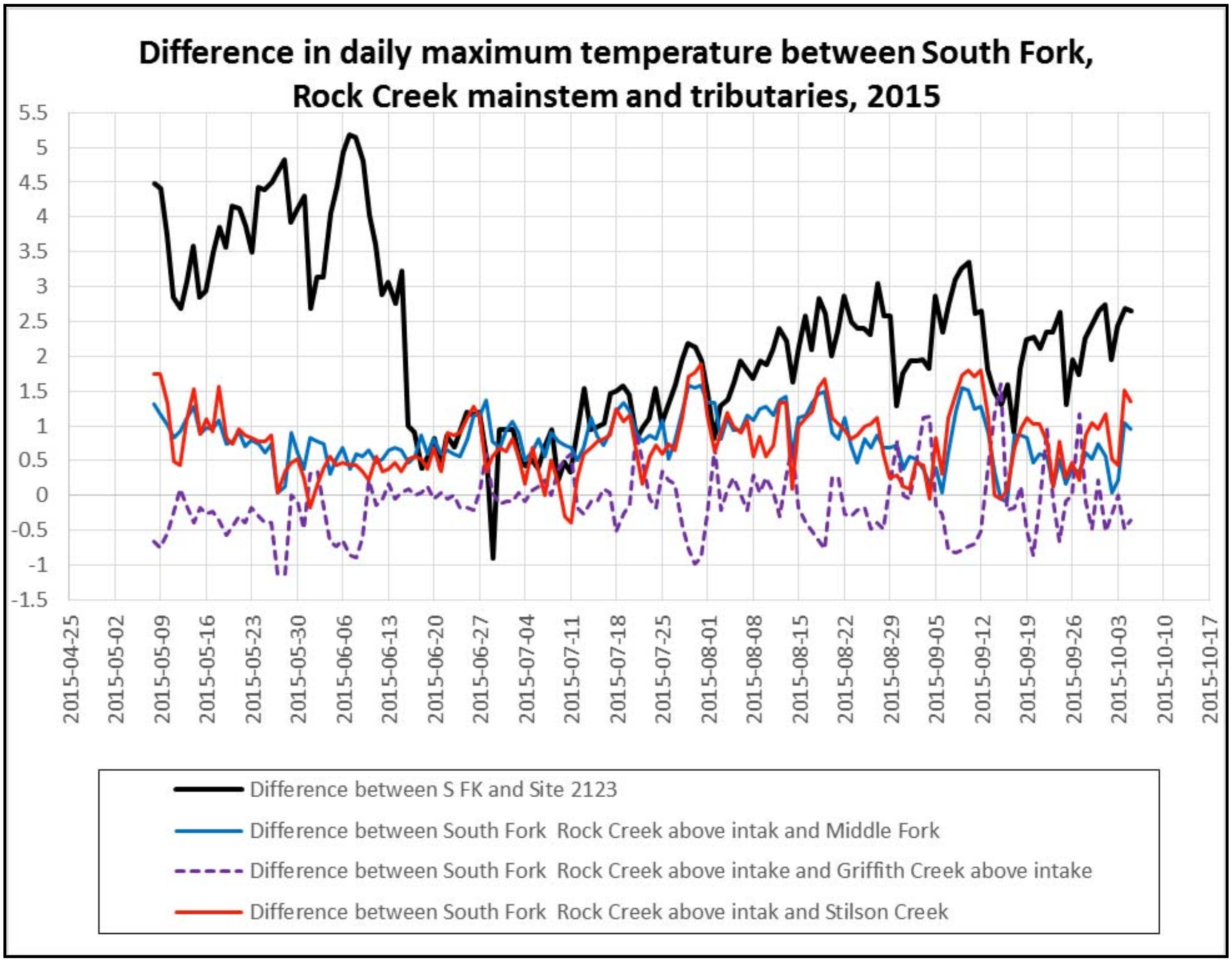


Figure 34b

Figure 34: The vertical black dashed line marks the date spillway flow stops. Note the abrupt drop in the difference in temperature between the South Fork Rock Creek and the mainstem after the spillway stops flowing. This decrease in the temperature difference is due to the decrease in the spillway flow contribution downstream. It can be seen as an indicator of the effect of the spillway downstream.

How far downstream can the effect of the spillway be detected in the mainstem stream temperatures below the dam? To analyze this question, the temperature between the South Fork Rock Creek site above the intake was compared to the temperature of sites in the downstream Rock Creek mainstem. In other words, the South Fork Rock Creek temperature (daily maximum temperature) above the intake was subtracted from the temperature at the mainstem sites. The graphs (Figure 34) of the difference in temperature (F) between the site below the confluence of the North and South Forks, and the South Fork above the intake shows that there is a <u>decrease</u> in the temperature difference as the spillway flow diminishes. After the spillway flow stopped, daily maximum temperatures below the confluence were closer to the temperatures of the South Fork. There is a distinctive "signature" to the graph. Can this abrupt decrease in the <u>difference</u> in temperature between sites be seen farther downstream? At what point does the difference in a site's temperature compared to the South Fork before and after the spillway flow stops become similar?

The graphs in the following section analyzing the differences in temperature for 2012, 2013, 2014 and 2015 show the difference in daily maximum temperature between the Rock Creek mainstem sites and the South Fork above the intake until the spillway stops flowing., A linear trend line was added to the graphs to clarify the trend in the temperature differences. In 2014, the trend lines for Sites 2123 (Rock Creek mainstem below the confluence) and Site 2131 (Rock Creek below Stilson Creek) have a negative slope, showing that as the spillway flow decreased the temperature difference between these two sites and the South Fork also decreases as the spillway flow diminishes. However, at site 2170, which is 1.35 miles downstream from the dam, the trend line has a positive slope, suggesting that the decrease in spillway flow has little effect, and the site is responding to air temperatures more than the spillway flow. The sites downstream also have a positive trend.

Similar results can be seen for the years 2012 and 2013 and 2015.

2012 difference between South Fork site above the intake and Rock Creek mainstem sites below the dam

In 2012, flows were not measured, and the Sites 2170 and 2171 were not monitored until 2013. However, the positive slope to the trendline at Site 2125 (Figure 50b), just downstream of Middle Fork, suggests that the effects of the spillway are not detectable 2.17 miles downstream. The data from 2012 are consistent with data from the years 2013 and 2014.

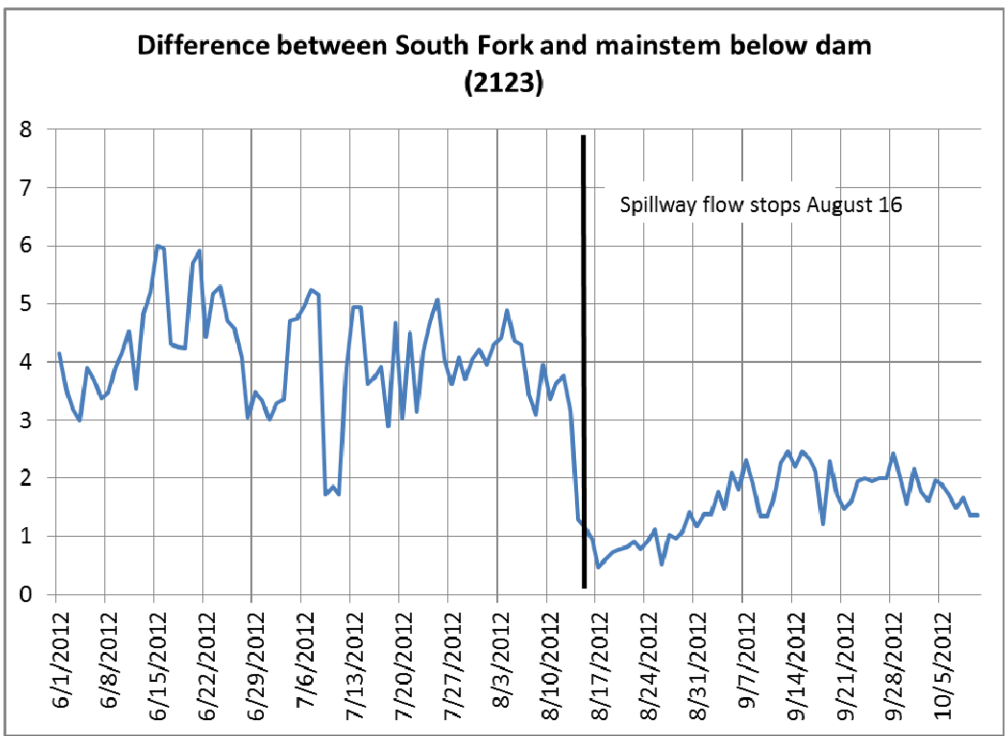


Figure 35. Difference between the South Fork Rock Creek above the confluence and Rock Creek below the confluence for 2012.

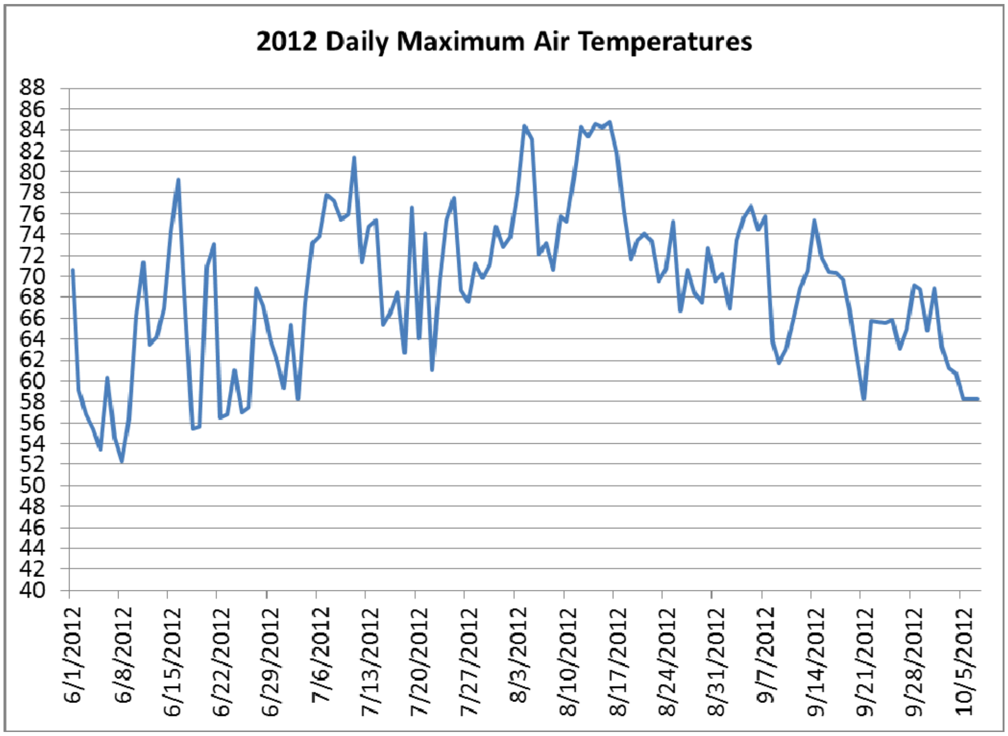


Figure 36. Maximum daily air temperatures for 2012.

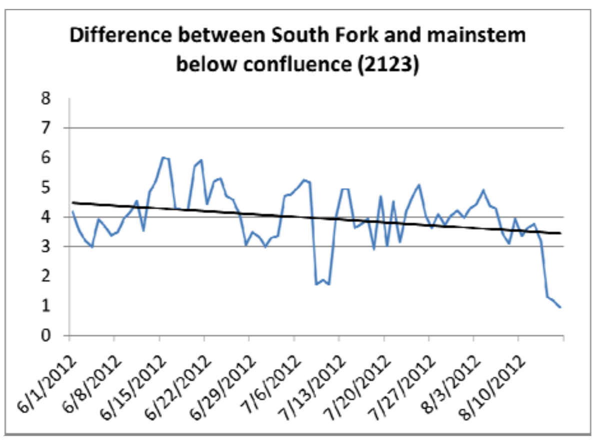


Figure 37a. Site 2123 is .02 miles downstream from dam.

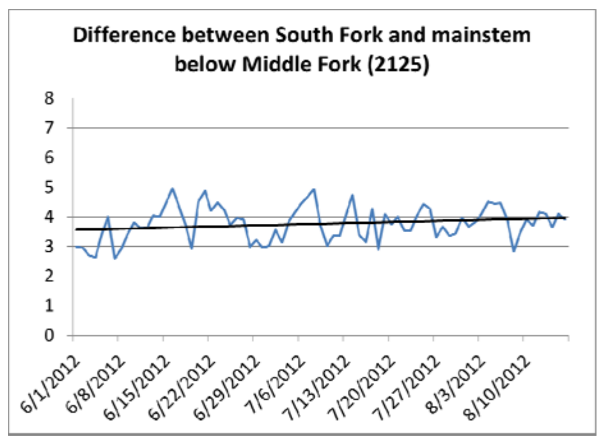


Figure 37b. Site 2125 is 2.17 miles downstream from the dam.

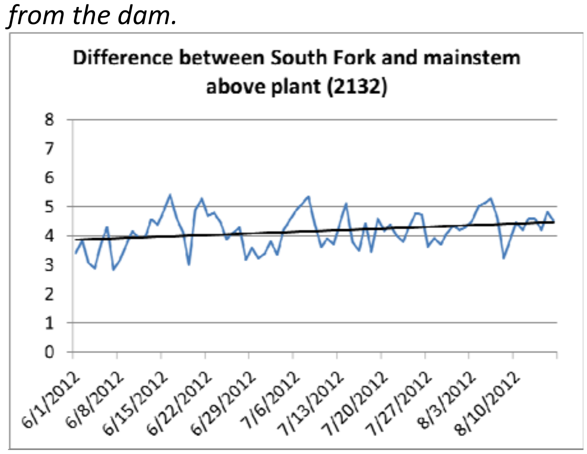


Figure 37c. Site 2132 is 2.67 miles downstream from the dam.

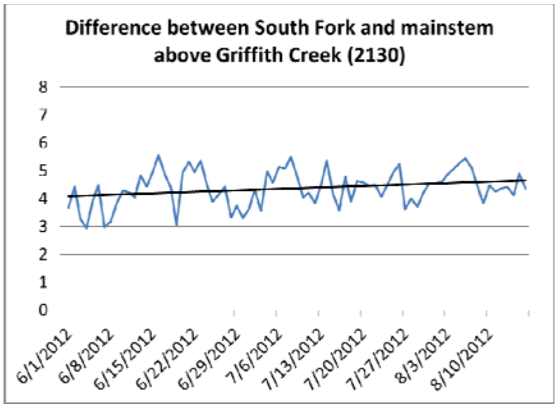


Figure 37d. Site 2130 is 2.79 miles downstream from the dam.

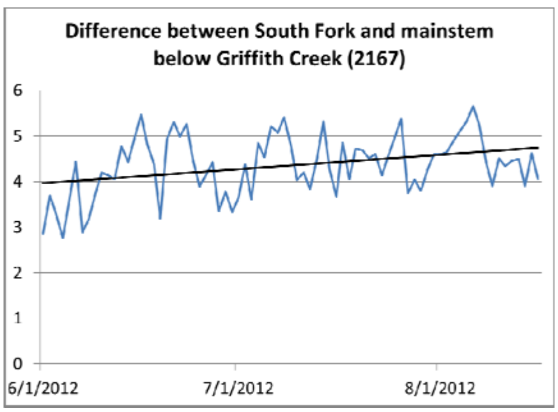


Figure 37e. Site 2167 is 2.89 miles downstream from the dam.

2013 Comparison of the South Fork Rock Creek site above the intake with mainstem sites below the dam

In 2013, the decrease in the temperature difference between the South Fork above the intake and the mainstem below the confluence is more gradual from the first of July until the spillway stops flowing on July 26. However, the difference in temperature is less after the flow stops (Figure 45). Air temperatures during July did not decrease (Figure 46).

In 2013, the negative linear trend line for the difference in temperatures between the South Fork and the mainstem sites is present to site 2170, 1.35 miles downstream (Figure 47c). At Site 2171, 1.9 miles downstream (Figure 47d), the linear trend is positive, suggesting that the spillway flow effect diminishes somewhere between 1.35 and 1.9 miles downstream from the dam.

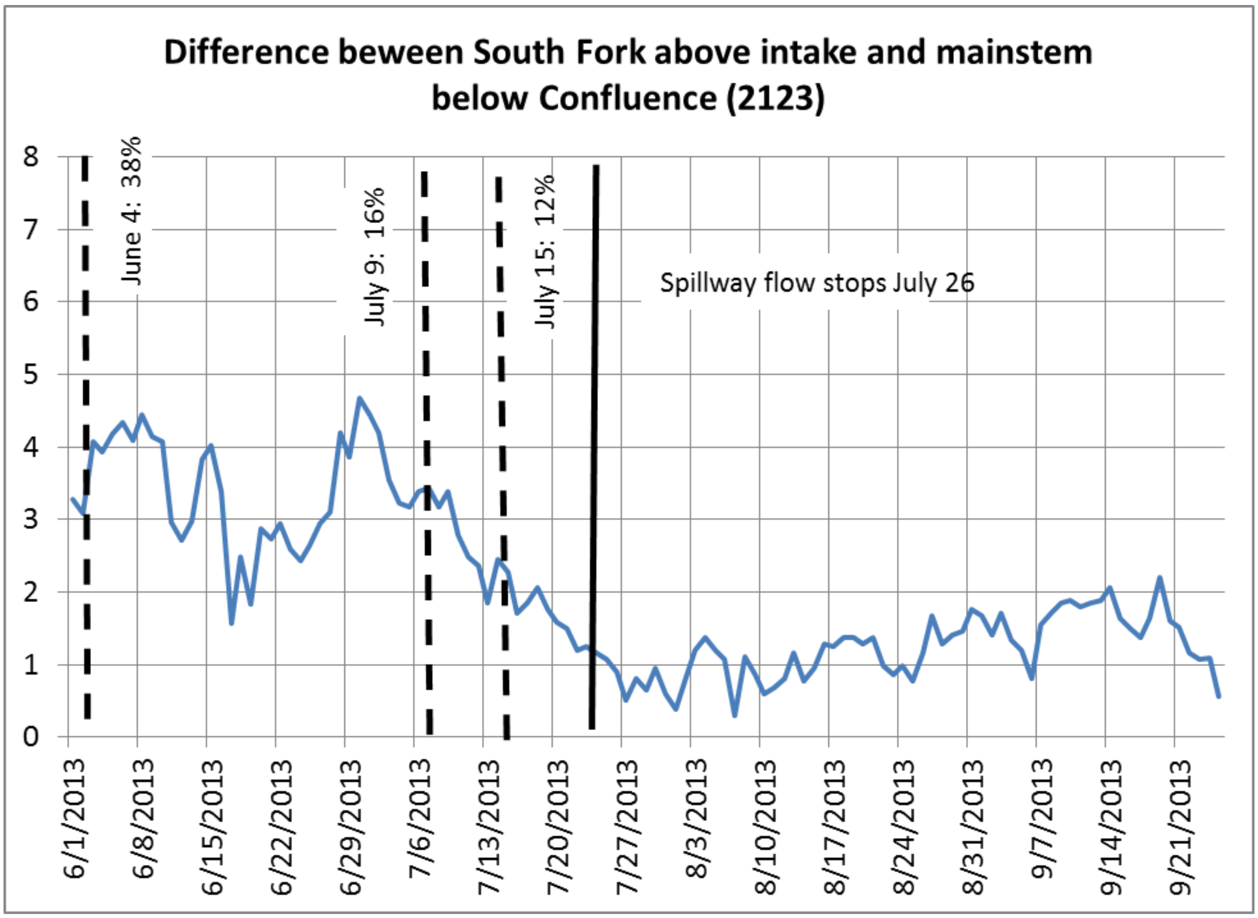


Figure 38. 2013 comparison of the daily maximum stream temperatures at the South Fork above the intake and the mainstem below the confluence. The % of the mainstem flow that is contributed by the spillway is shown next to the vertical lines.

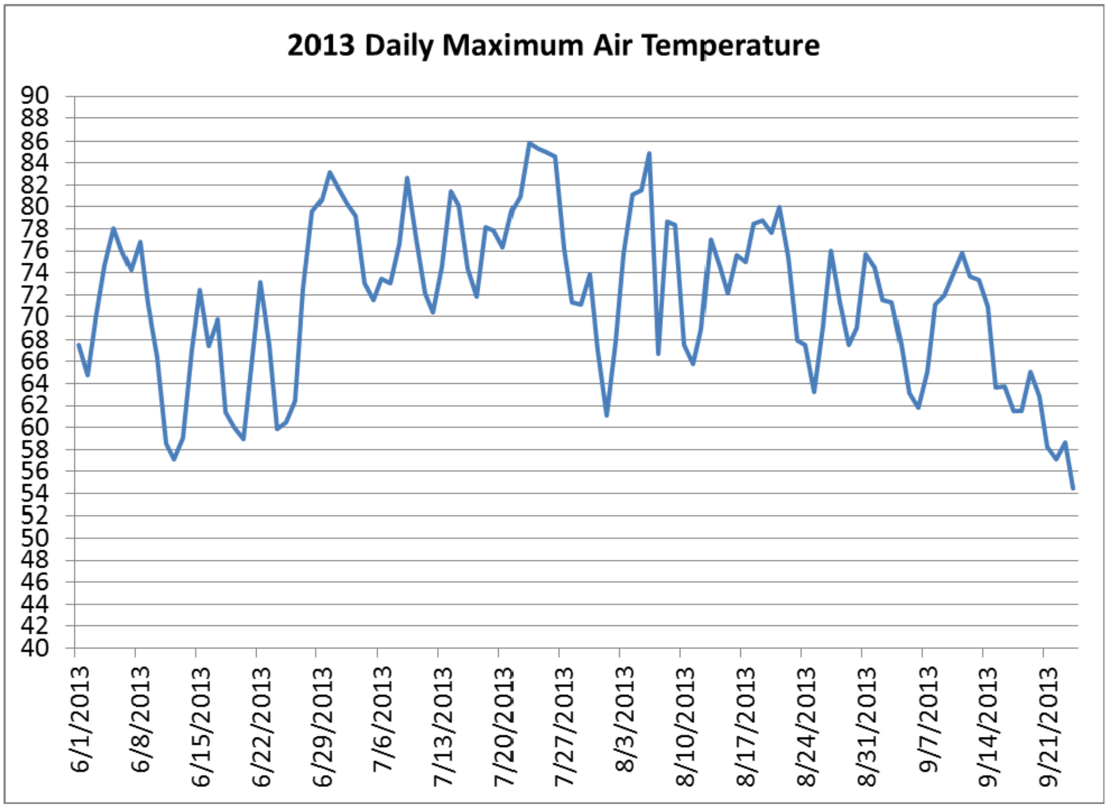


Figure 39. Air temperatures for 2013.

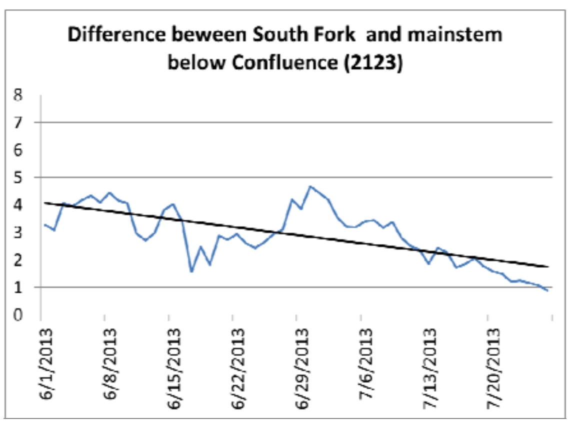


Figure 40a. Site 2123 is .02 miles downstream from the dam.

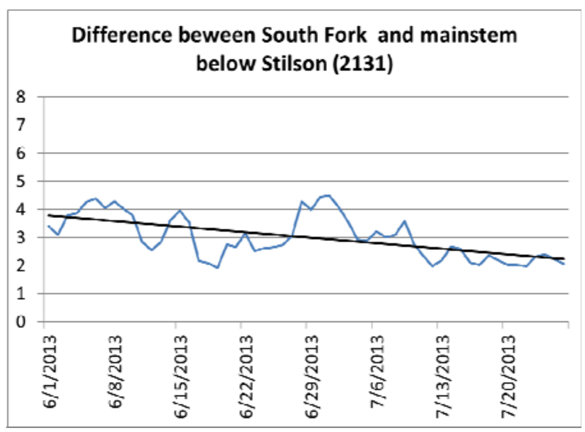


Figure 40b. Site 2131 is 0.77 miles downstream from the dam.

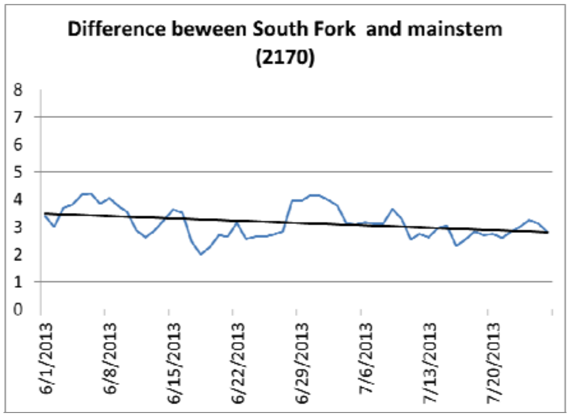


Figure 40c. Site 2170 is 1.35 miles downstream from the dam.

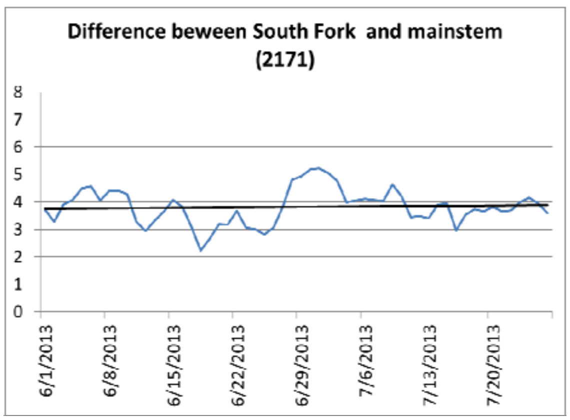


Figure 40d. Site 2171 is 1.9 miles downstream from the dam.

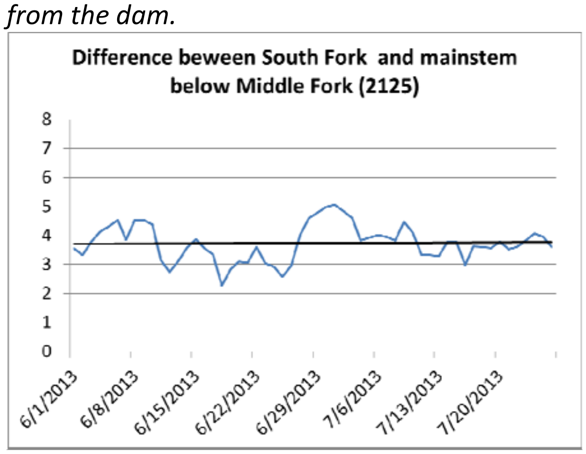


Figure 40e. Site 2125 is 2.17 miles downstream from the dam.

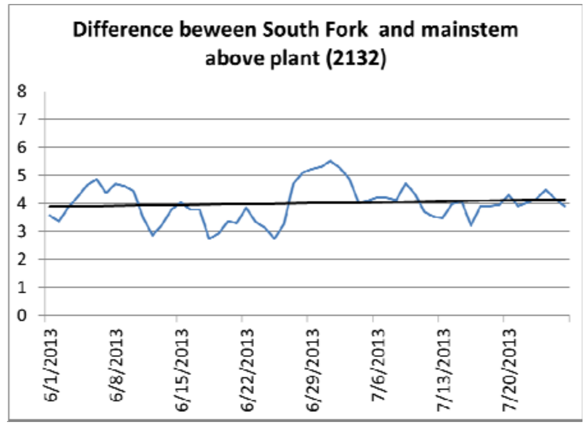


Figure 40f. Site 2132 is 2.67 miles downstream from the dam.

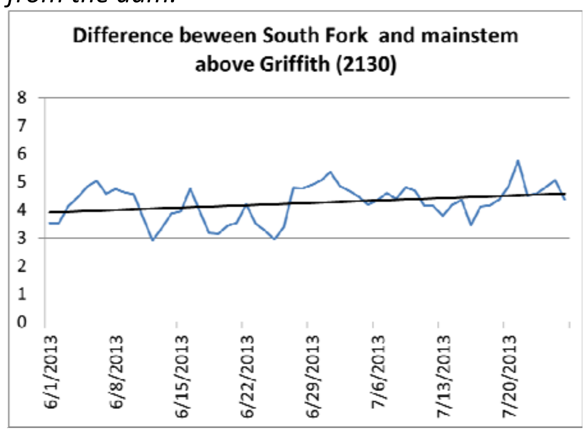


Figure 40g. Site 2130 is 2.79 miles downstream from the dam.

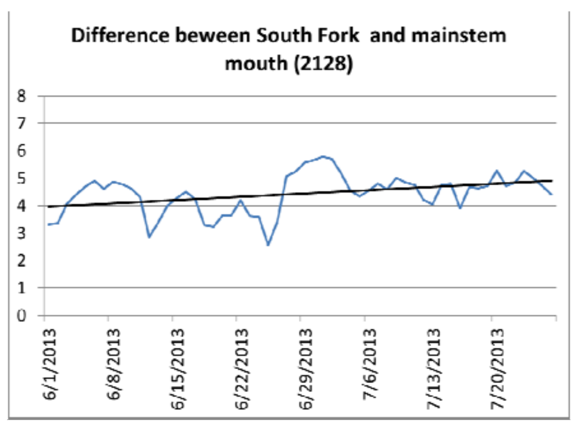


Figure 40h. Site 2128 is 3.72 miles downstream from the dam.

2014 Comparison of the South Fork Rock Creek site above the intake with mainstem sites below the dam

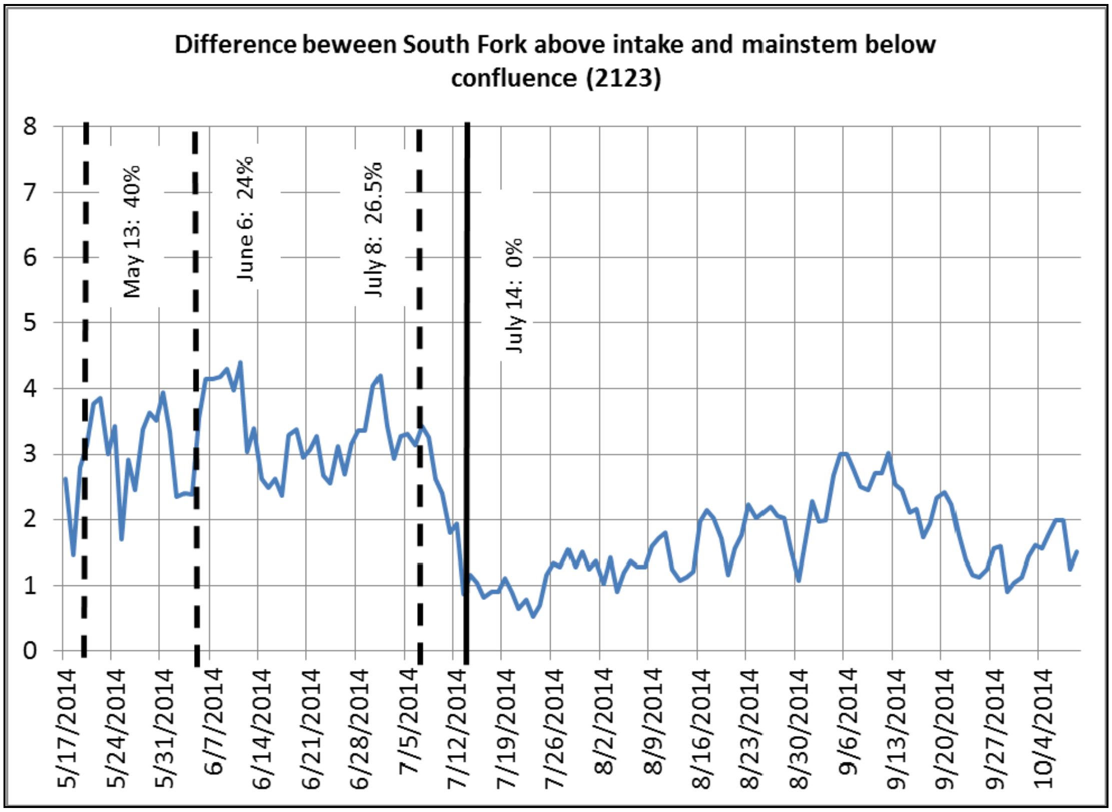


Figure 41. The difference in temperature (F) is calculated by subtracting the daily maximum stream temperature at the South Fork Rock Creek site above the intake from the Rock Creek mainstem site 120 feet below the confluence of the North and South Forks of Rock Creek.

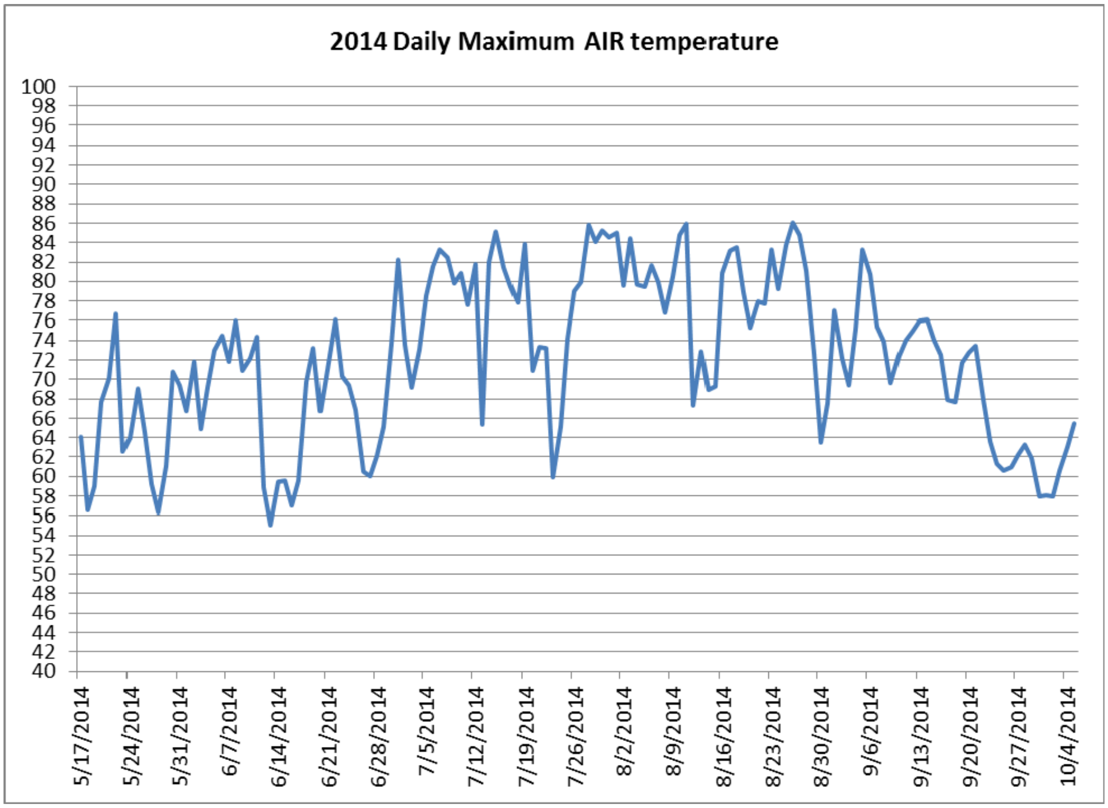


Figure 42. Daily maximum air temperature measured in the riparian zone at the South Fork site above the intake.

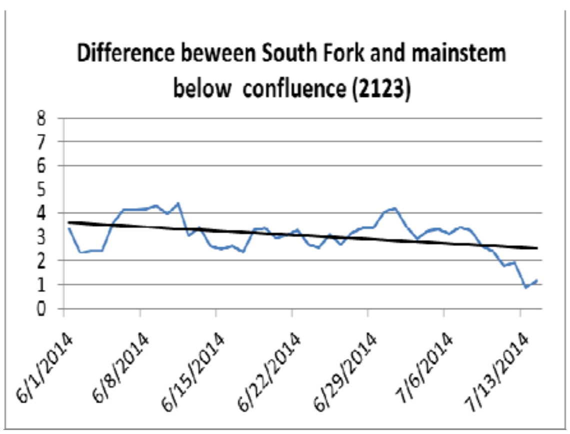


Figure 42a. Site 2123 is .02 miles downstream from the dam. Drainage area to site 2123 is 8.53 square miles.

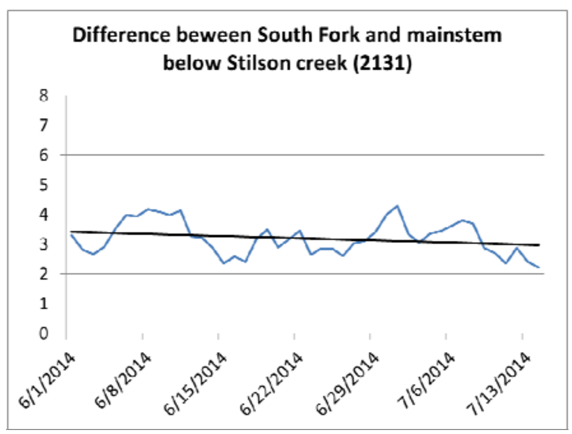


Figure 42b. Site 2131 is 0.77 miles downstream from the dam. Drainage area to site 2131 is 9.65 square miles.

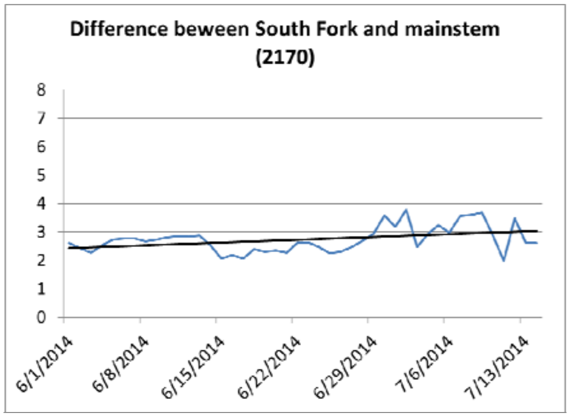


Figure 42c.: Site 2170 is 1.35 miles downstream from the dam. Drainage area to site 2170 is 10.6 square miles.

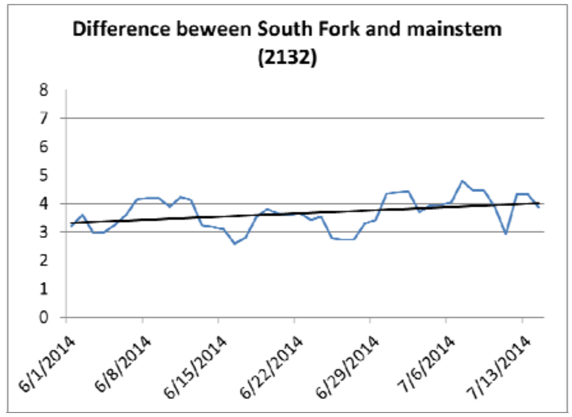


Figure 42f. Site 2132 is 2.67 miles downstream from the dam. Drainage area to site 2132 is 12.3 square miles.

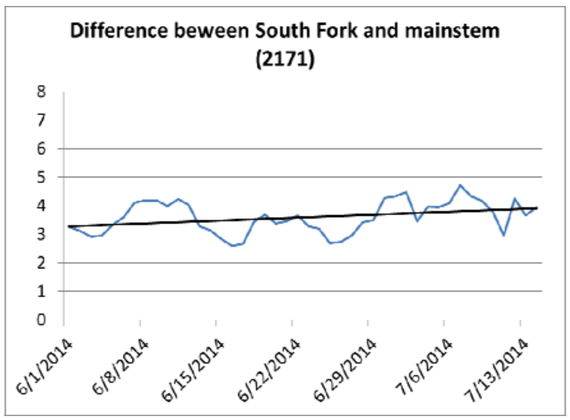


Figure 42d. Site 2171 is 1.9 miles downstream from the dam. Drainage area to site 2171 is 10.8 square miles.

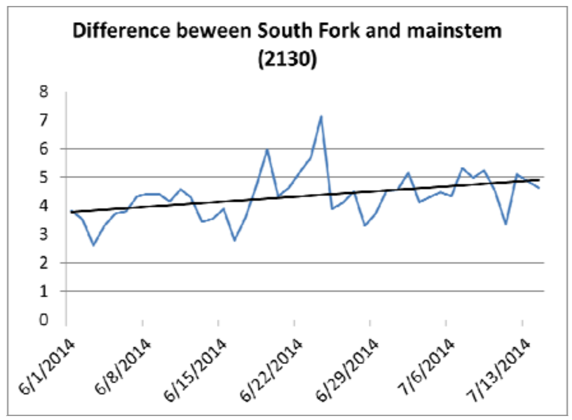


Figure 43g. Site 2130 is 2.79 miles downstream from the dam. Drainage area to site 2130 is 12.4 square miles

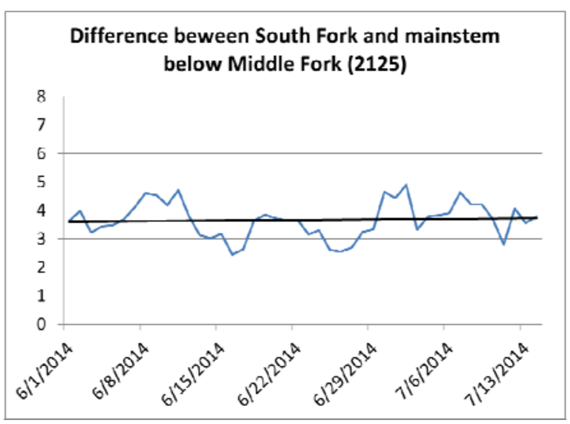


Figure 43e. Site 2125 is 2.17 miles downstream from the dam. Drainage area to site 2125 is 12.2 square miles.

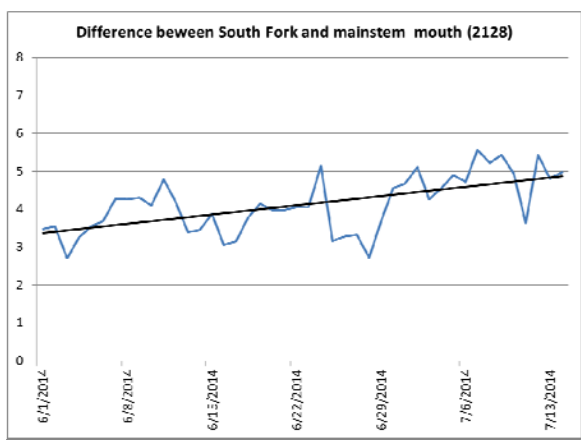


Figure 43h. Site 2128 is 3.72 miles downstream from the dam. Drainage area to site 2128 is 14.8 square miles.

2015 Difference between South Fork site above the intake and Rock Creek mainstem sites below the dam

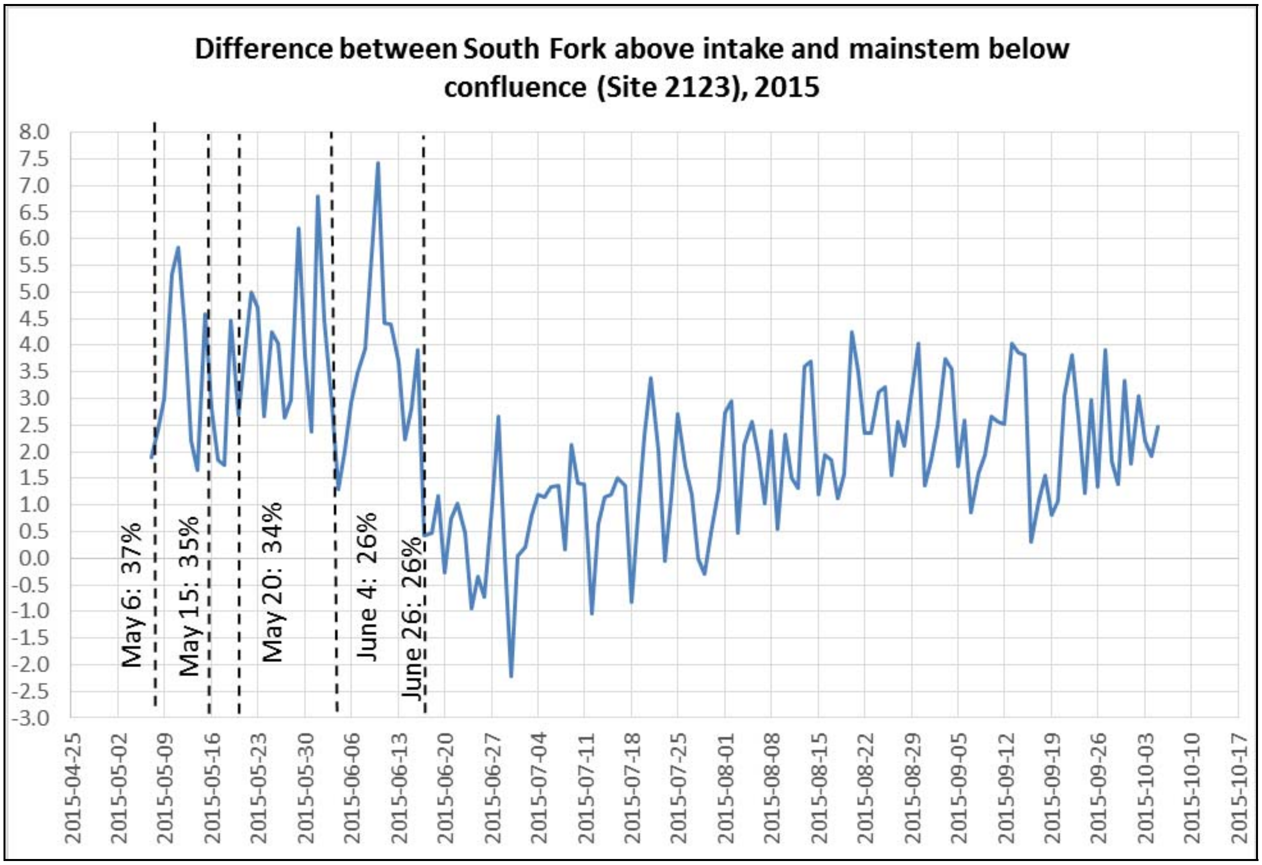


Figure 44: *The difference in temperature (F) is calculated by subtracting the daily maximum stream temperature at the South Fork Rock Creek site above the intake from the Rock Creek mainstem site 120 feet below the confluence of the North and South Forks of Rock Creek.*

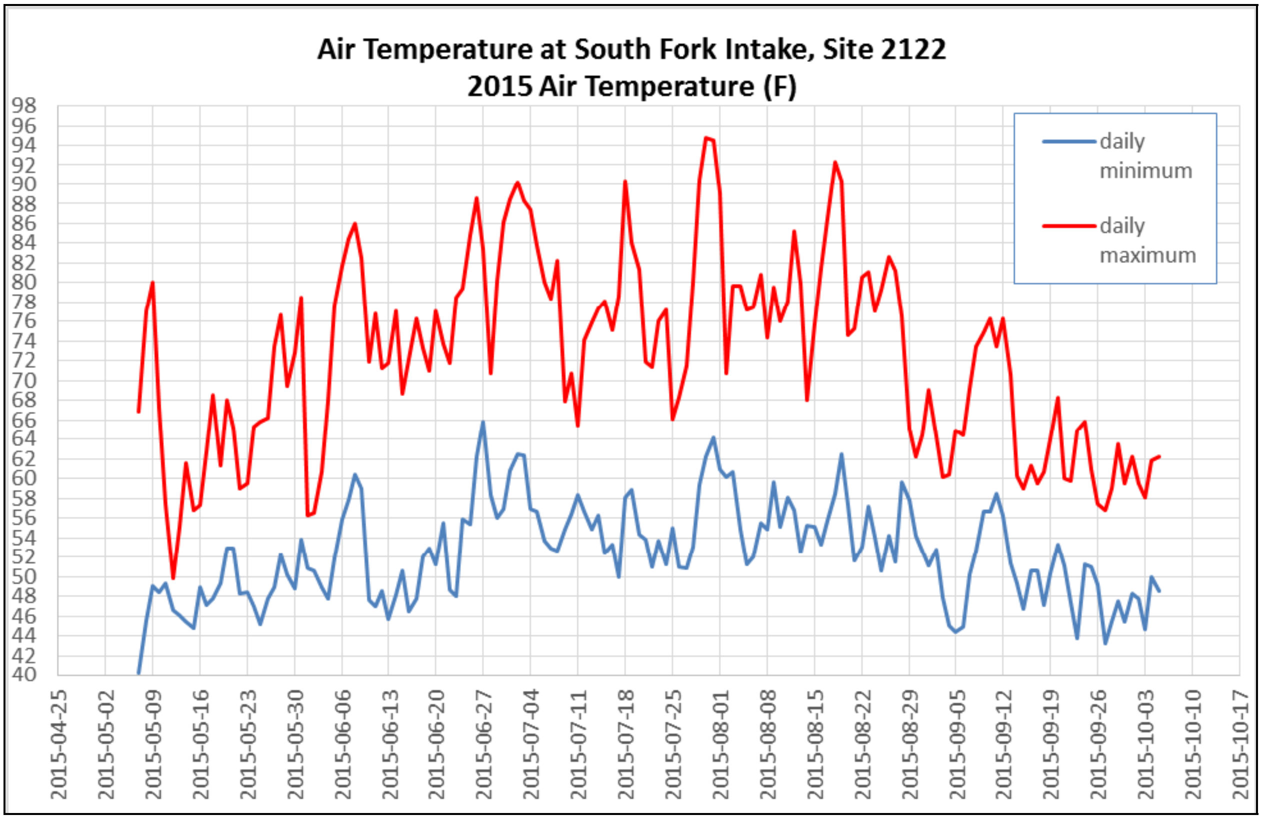


Figure 45. Daily maximum air temperature measured in the riparian zone at the South Fork site above the intake.

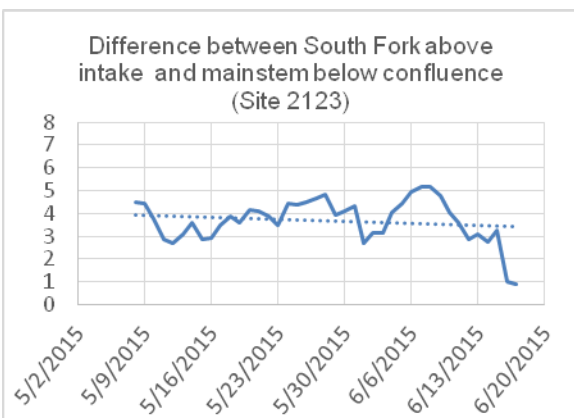


Figure 46a. Site 2123 is .02 miles downstream from the dam. Drainage area to site 2123 is 8.53 square miles.

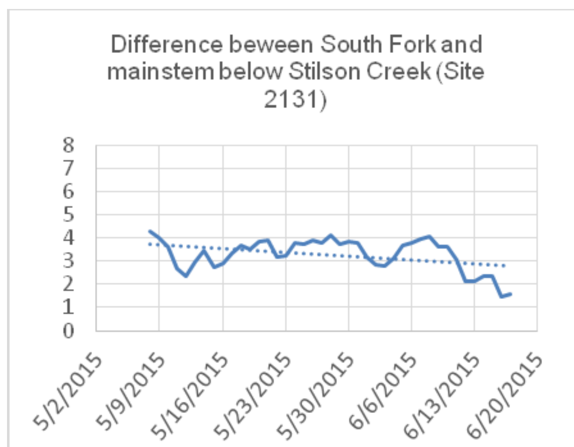


Figure 46b. Site 2131 is 0.77 miles downstream from the dam. Drainage area to site 2131 is 9.65 square miles.

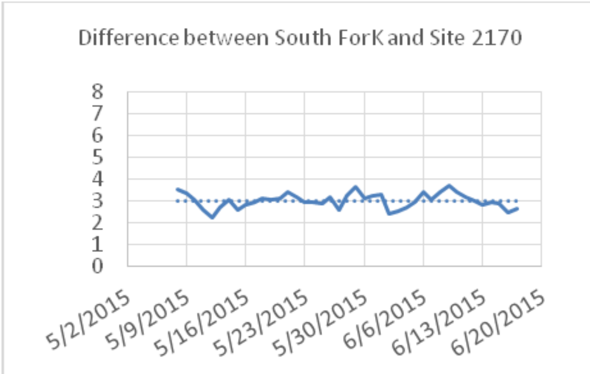


Figure 46c.: Site 2170 is 1.35 miles downstream from the dam. Drainage area to site 2170 is 10.6 square miles.

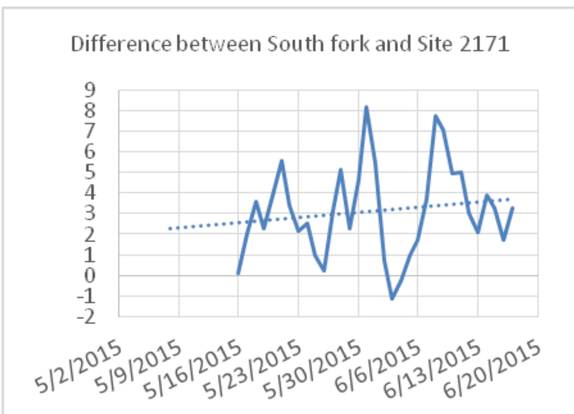


Figure 46d. Site 2171 is 1.9 miles downstream from the dam. Drainage area to site 2171 is 10.8 square miles.

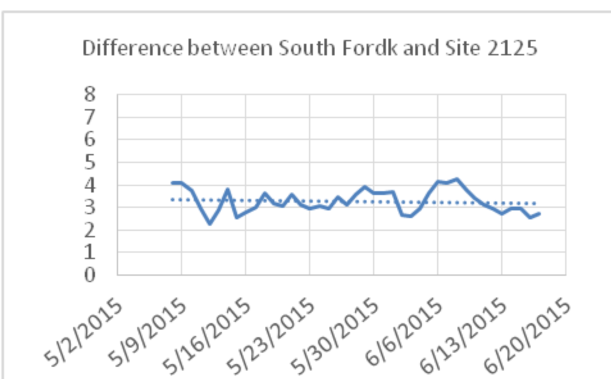


Figure 46e. Site 2125 is 2.17 miles downstream from the dam. Drainage area to site 2125 is 12.2 square miles.

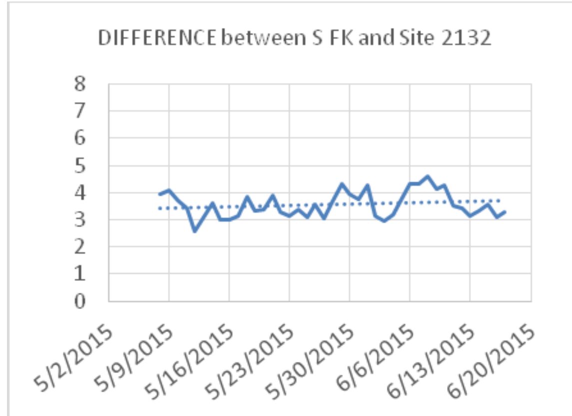


Figure 46f. Site 2132 is 2.67 miles downstream from the dam. Drainage area to site 2132 is 12.3 square miles.

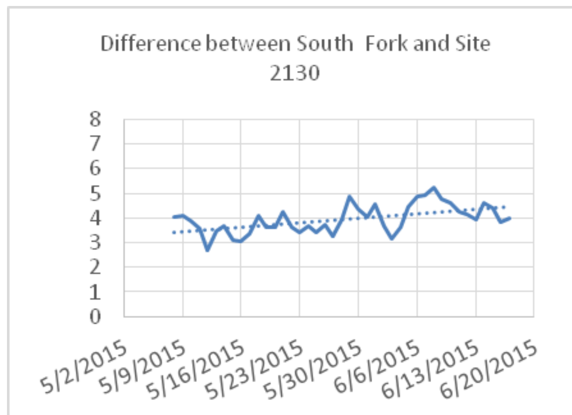


Figure 46g. Site 2130 is 2.79 miles downstream from the dam. Drainage area to site 2130 is 12.4 square miles

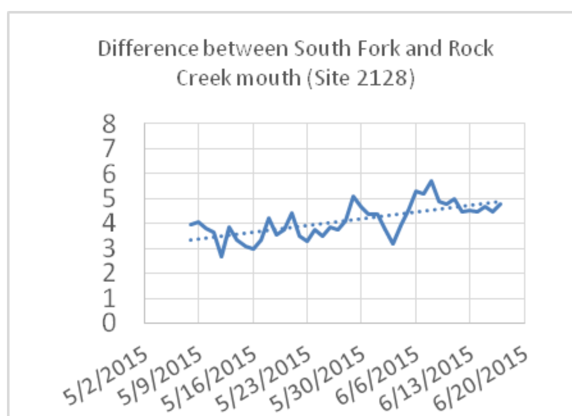


Figure 46h. Site 2128 is 3.72 miles downstream from the dam. Drainage area to site 2128 is 14.8 square miles.

For the past 4 years of data, the effects of the spillway on stream temperature in the mainstem of Rock Creek cannot be detected farther than just past Site 2125, just downstream from the Middle Fork Rock Creek (2.17 miles from the dam). The length of the mainstem where the temperature difference signature can be detected varies by year. For instance, in 2014, which had higher springtime flows, the effects of the spillway were lost between 0.77 and 1.35 miles downstream; in 2015, which had low flows in the spring, the effects of the spillway were detected to approximately 2.17 miles from the dam. None of the years of data showed an effect of the spillway persisting to the mouth of Rock Creek. Therefore, alterations to flow management at the dam would not have an effect on the contribution of temperature regulation by Rock Creek on Greasy Creek.

Table 12: Summary of the trends in temperature differences between the South Fork Rock Creek above the intake and sites in the Rock Creek mainstem. A downward trend suggests the spillway flow is having an influence, an upward trend suggests that the spillway is not a factor in stream temperatures at that site.

	distance downstream from dam (miles)	**Summer 2012**	**Summer 2013**	**Summer 2014**	**Summer 2015**
2123	0.02	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference
2131	0.77	no data	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference
2170	1.35	no data	downward trend in temperature difference	upward trend in temperature difference	neutral
2171	1.9	no data	upward trend in temperature difference	upward trend in temperature difference	downward trend in temperature difference
2125	2.17	upward trend in temperature difference	neutral	neutral	slightly downward trend in temperature difference
2132	2.67	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference
2130	2.79	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference
2128	3.72	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference

Summary and Conclusions

Regional climatic trends are reflected in the stream temperatures and flow amounts recorded in the Corvallis Watershed. According the National Oceanic and Atmospheric Administration (NOAA), 2015 was the warmest summer on record for Oregon, and was 4.6°F above normal. In the Corvallis Watershed, the summer of 2015 had the warmest stream temperatures since monitoring began in 2010. Temperatures were higher throughout the watershed, regardless of whether or not they were downstream of the dam. For the first time since 2010, the 7-day average of the maximum daily temperature the mouths of the three main tributaries, Stilson Creek, Middle Fork, and Griffith, were slightly warmer than 64F. The warmer water temperatures were likely due to more prolonged periods of warm air temperatures, and lower amounts of precipitation and stream flow.

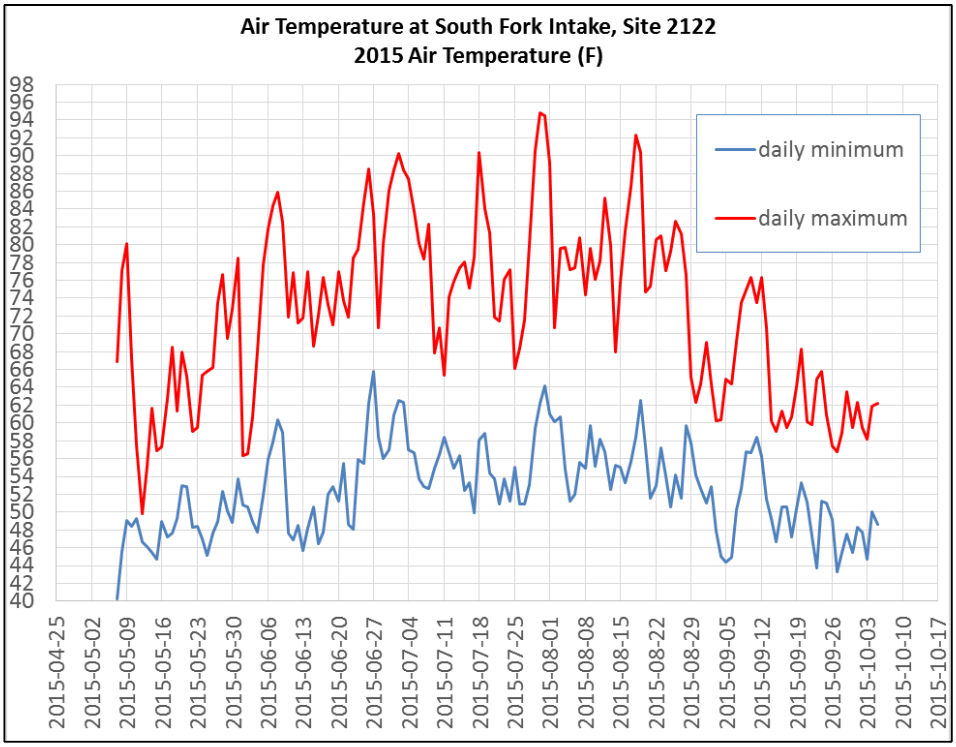
The reservoir spillway stopped flowing on June 16, 2015, which is a month earlier than in 2014. In 2015, the bottom of the reservoir was slightly warmer than in 2014, and June in the reservoir was the warmest in the six years of monitoring, reflecting the warmest June air temperatures recorded since 2010 in the Corvallis Watershed.

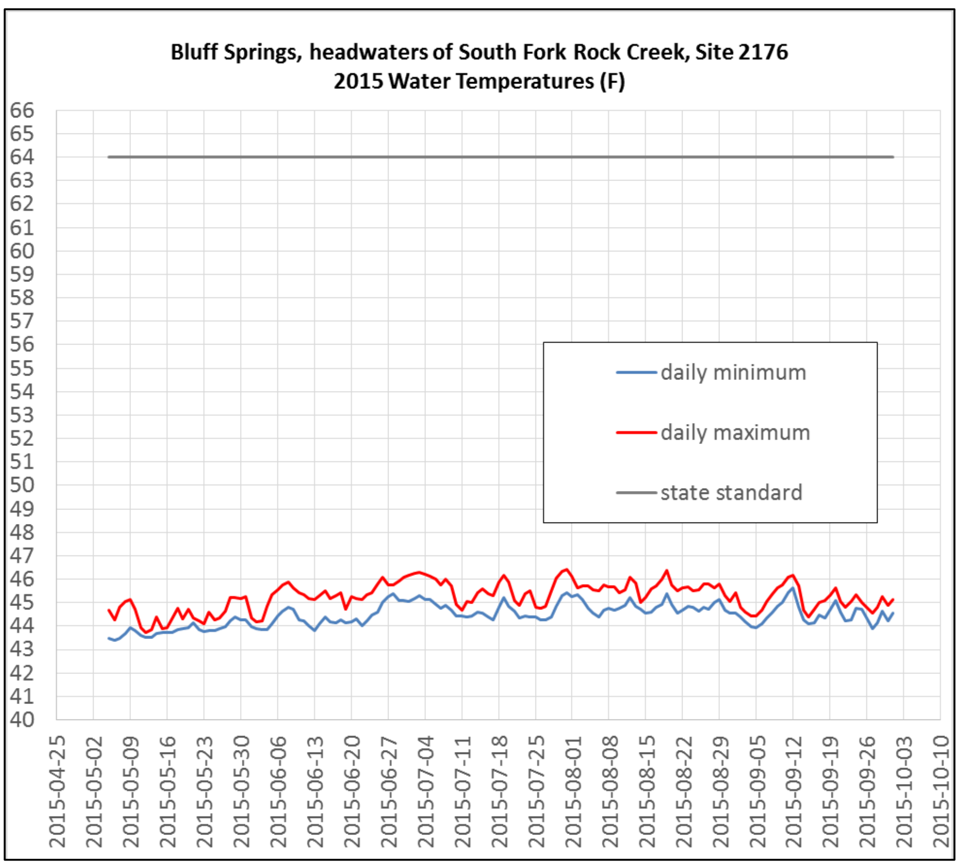
As in 2013 and 2014, flow data was collected during the summer in 2015, and combined with stream temperatures to calculate the effect of the reservoir on stream temperatures immediately downstream in the mainstem of Rock Creek. The same methodology and equations were used in all years.

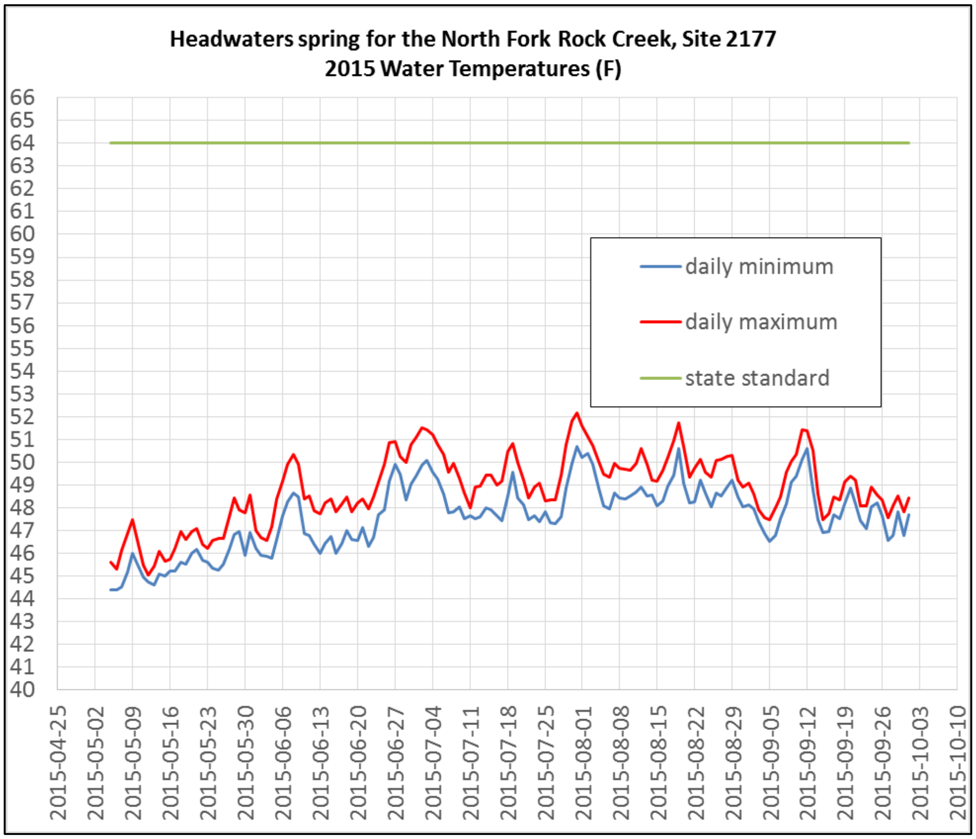
While the spillway was flowing in 2013, an increase of 2 to 4.4 degrees F could be attributed to the spillway, if either the North Fork or South Fork water temperatures were substituted for the spillway temperatures. These two scenarios are the most realistic in showing what heat the dam and spillway contribute downstream, since they mimic the absence of the reservoir. The heat input was reduced as the spillway flow diminished. In 2014, an increase of 2.2 to 3.8 degrees F could be attributed to the spillway, again assuming that the North or South Fork temperatures were substituted for the spillway. In 2015 an increase of 2.7 to 4.0 degrees F could be attributed to the spillway, reflecting the fact that the period of time the spillway was flowing was a month shorter than the previous year. However, even with the heat contribution of the spillway, it is important to note that most of the time that the spillway was flowing, stream temperatures downstream were below 64 °F.

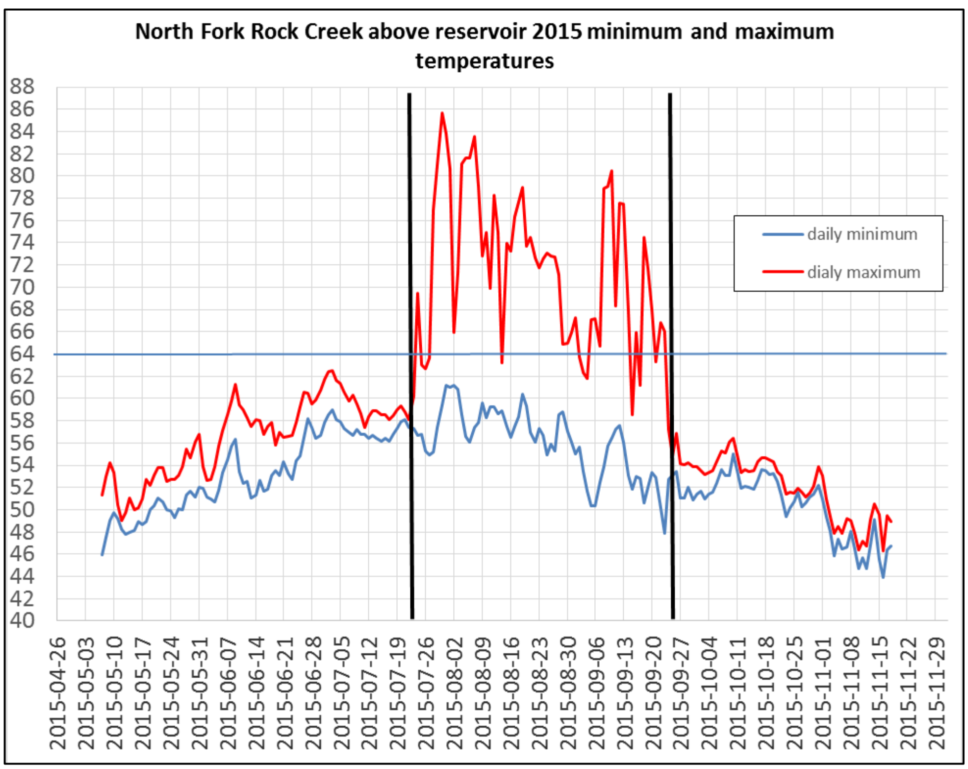
In 2015, data confirmed previous years' findings that the effects of the spillway are diluted progressing downstream. The signature of a noticeable difference between maximum daily temperatures above the dam and spillway in the South Fork and mainstem sites below the dam diminishes in a downstream direction, and cannot be detected in the mainstem of Rock Creek below the Middle Fork Rock Creek in data collected since 2012. Therefore, it is unlikely that the spillway temperatures are having an effect on stream temperatures at the mouth of Rock Creek.

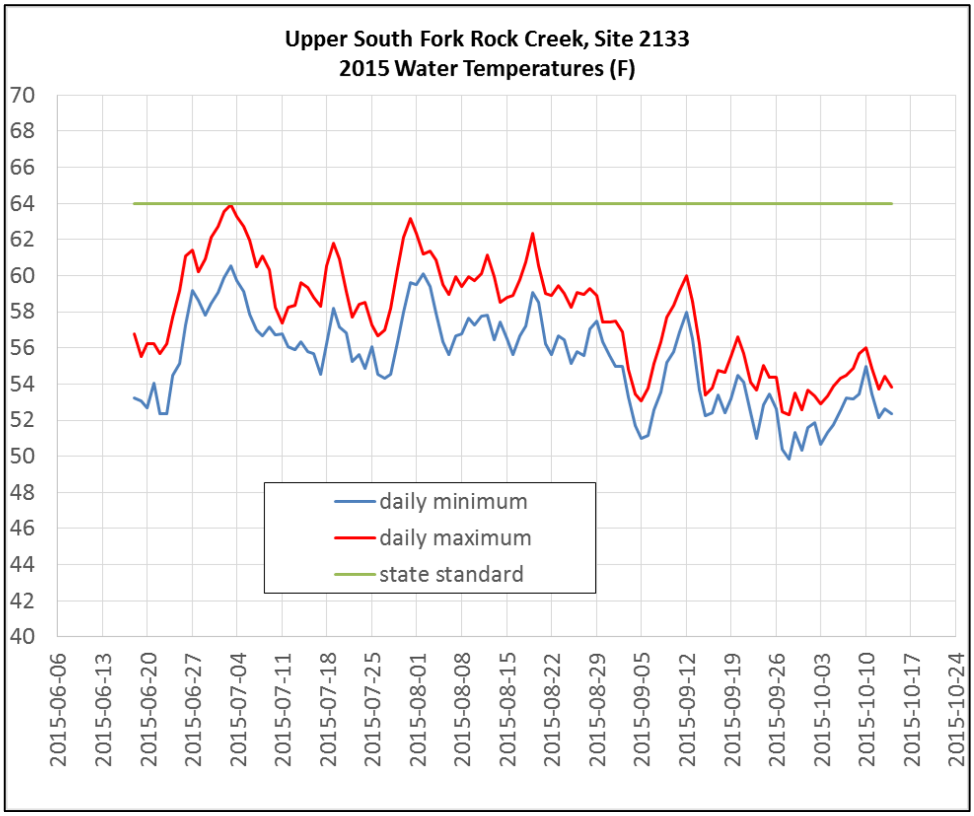
Appendix A: Stream Temperature Graphs of Individual Sites, 2014

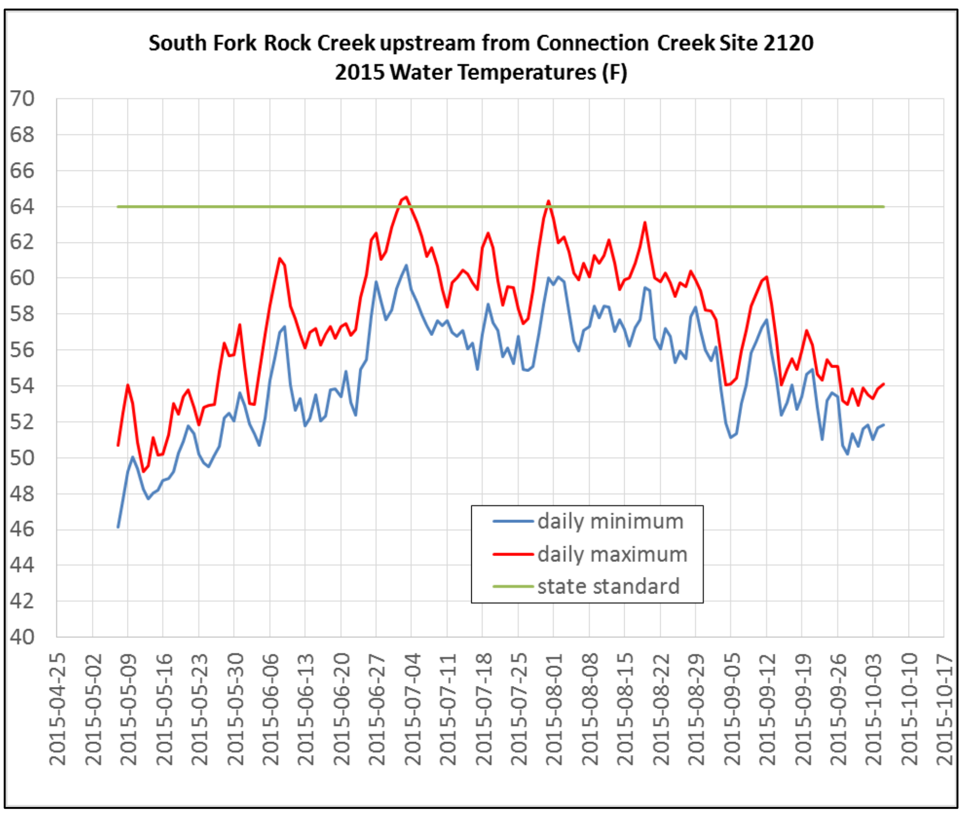


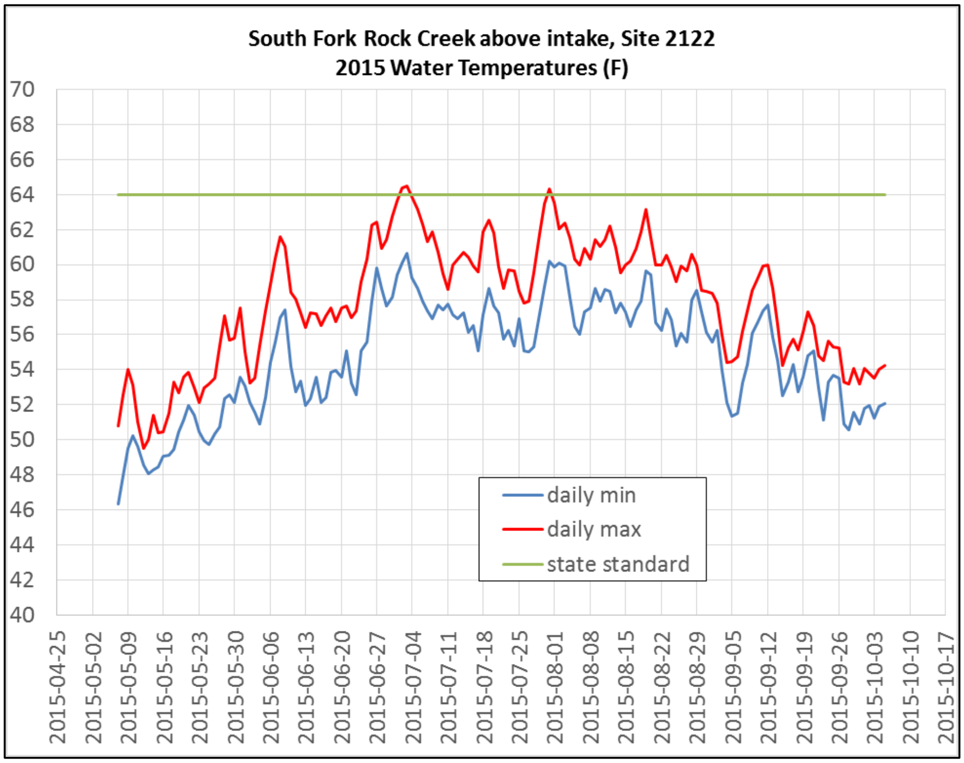


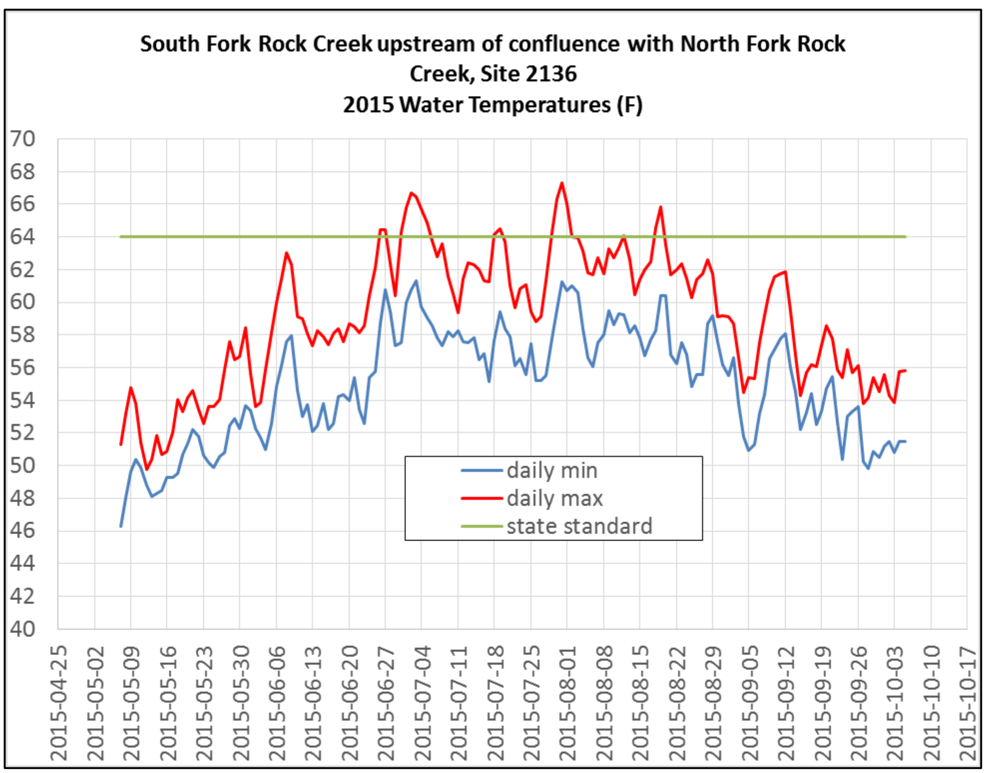

Headwaters spring for the North Fork Rock Creek, Site 2177
2015 Water Temperatures (F)
daily minimum
daily maximum
state standard

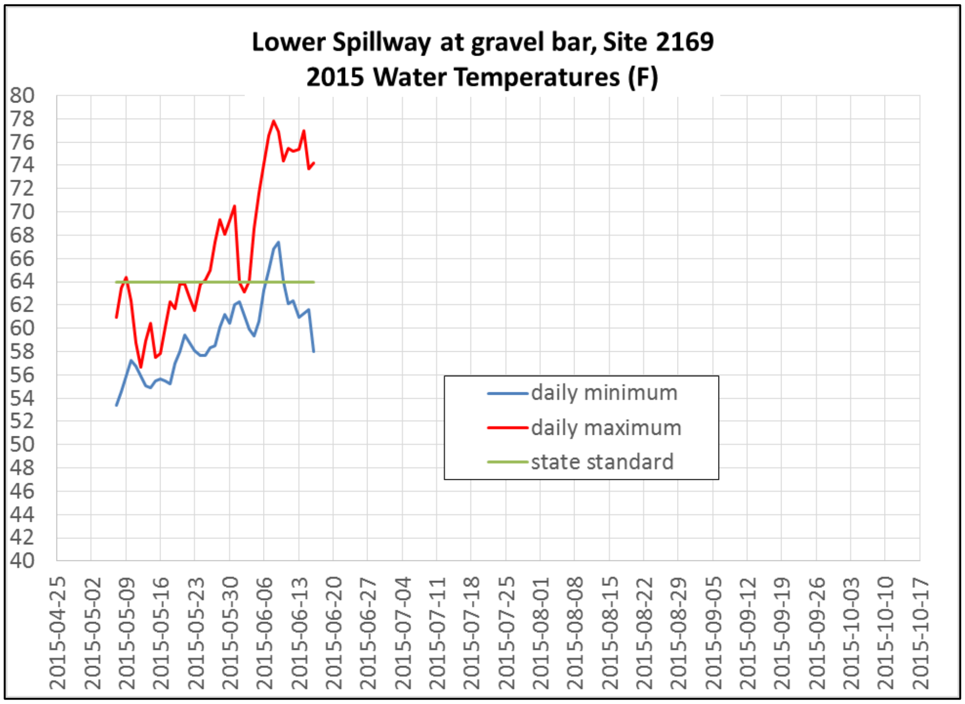

North Fork Rock Creek above reservoir 2015 minimum and maximum temperatures
daily minimum
dialy maximum

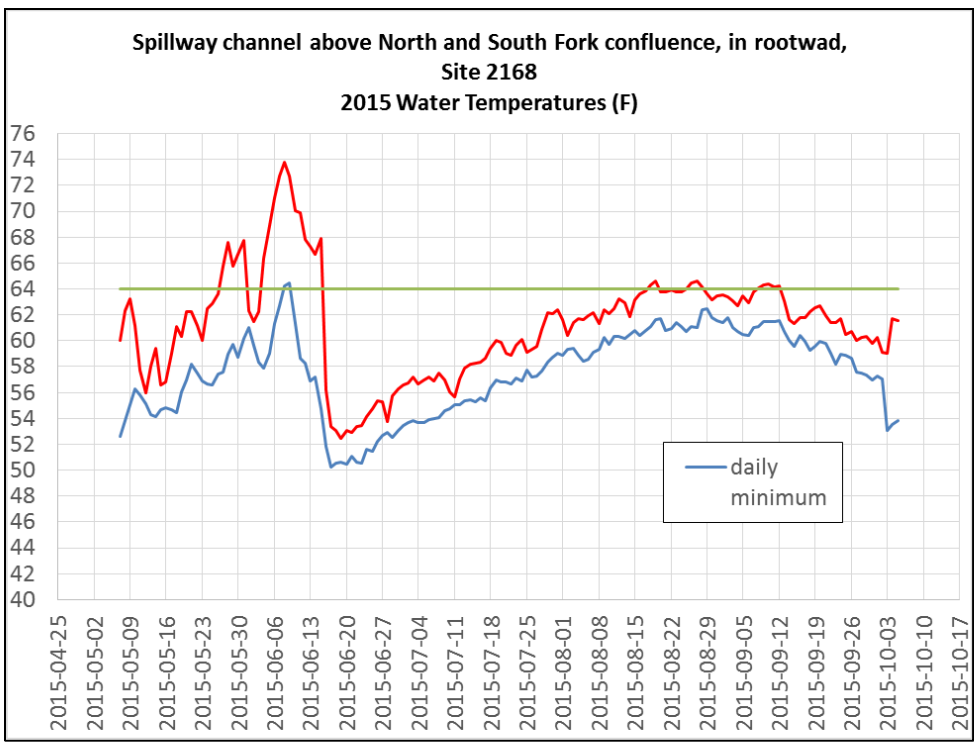

Upper South Fork Rock Creek, Site 2133
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily minimum
daily maximum
state standard
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
2015-10-24

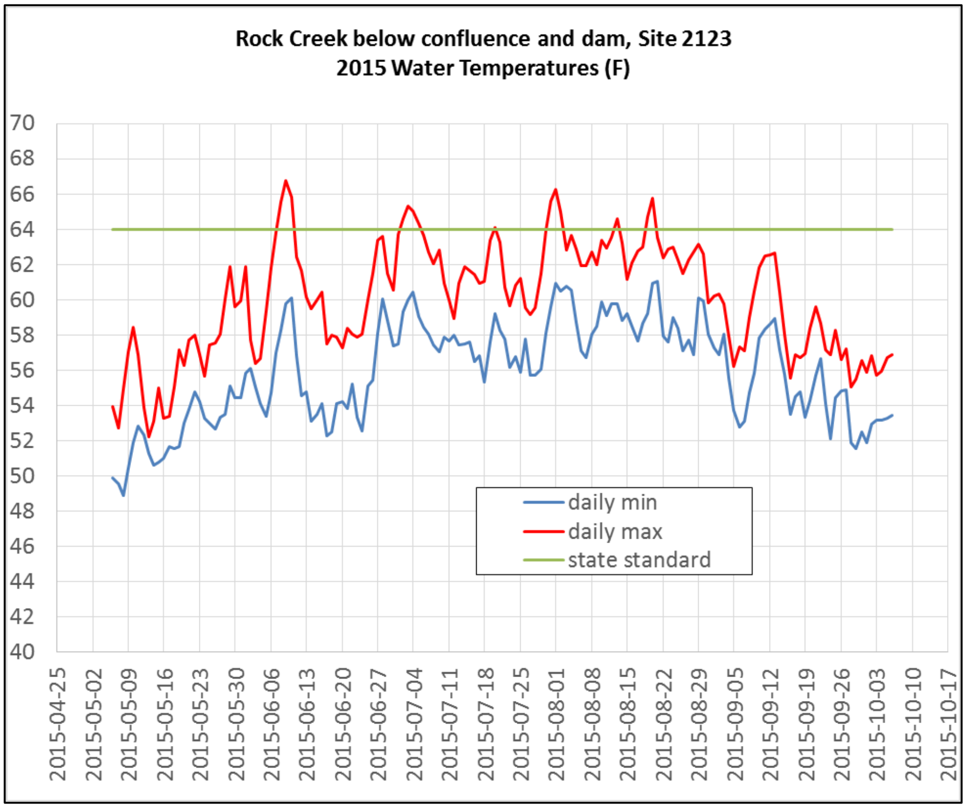

South Fork Rock Creek upstream from Connection Creek Site 2120
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily minimum
daily maximum
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17

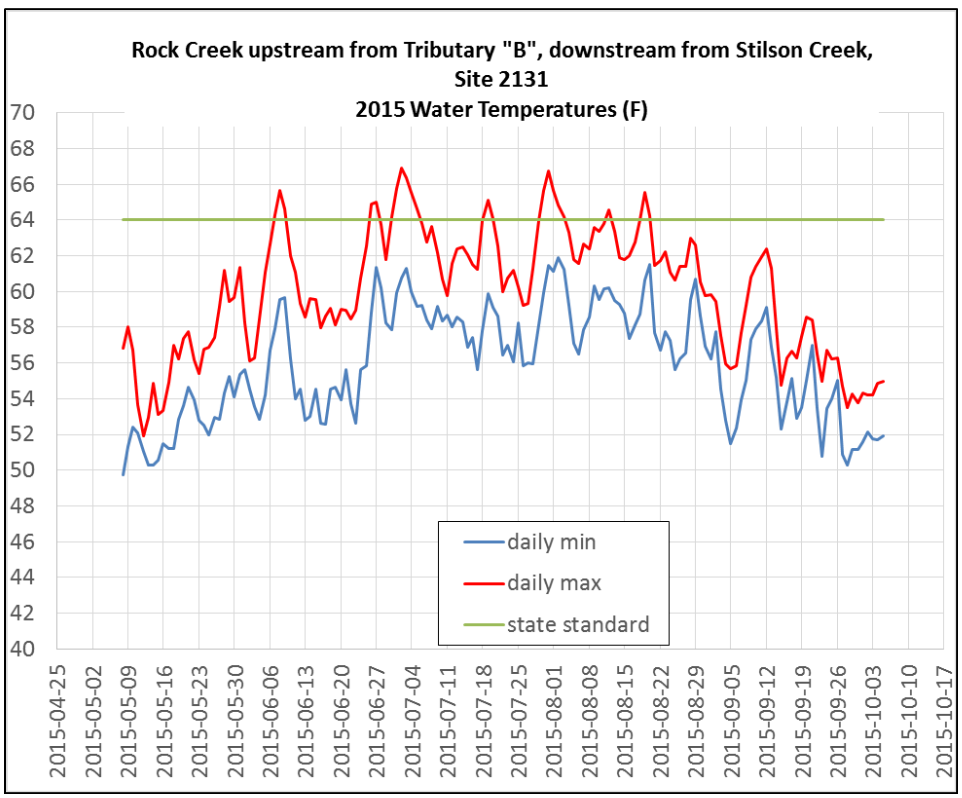

South Fork Rock Creek above intake, Site 2122
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
daily min
daily max
state standard

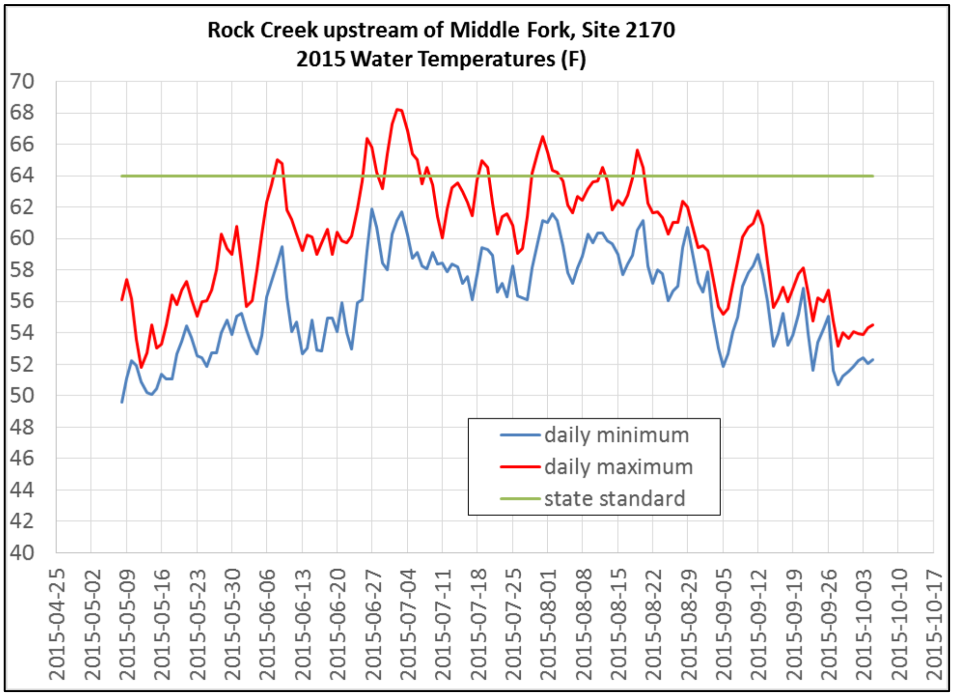

South Fork Rock Creek upstream of confluence with North Fork Rock Creek, Site 2136
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
daily min
daily max
state standard

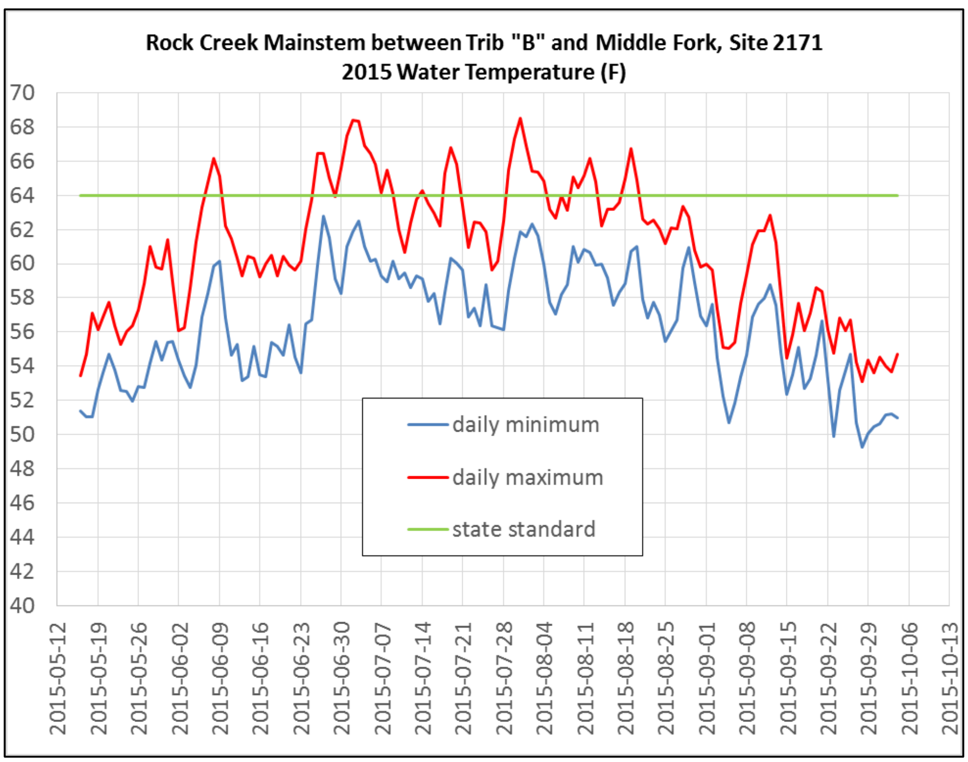

Lower Spillway at gravel bar, Site 2169
2015 Water Temperatures (F)
daily minimum
daily maximum
state standard

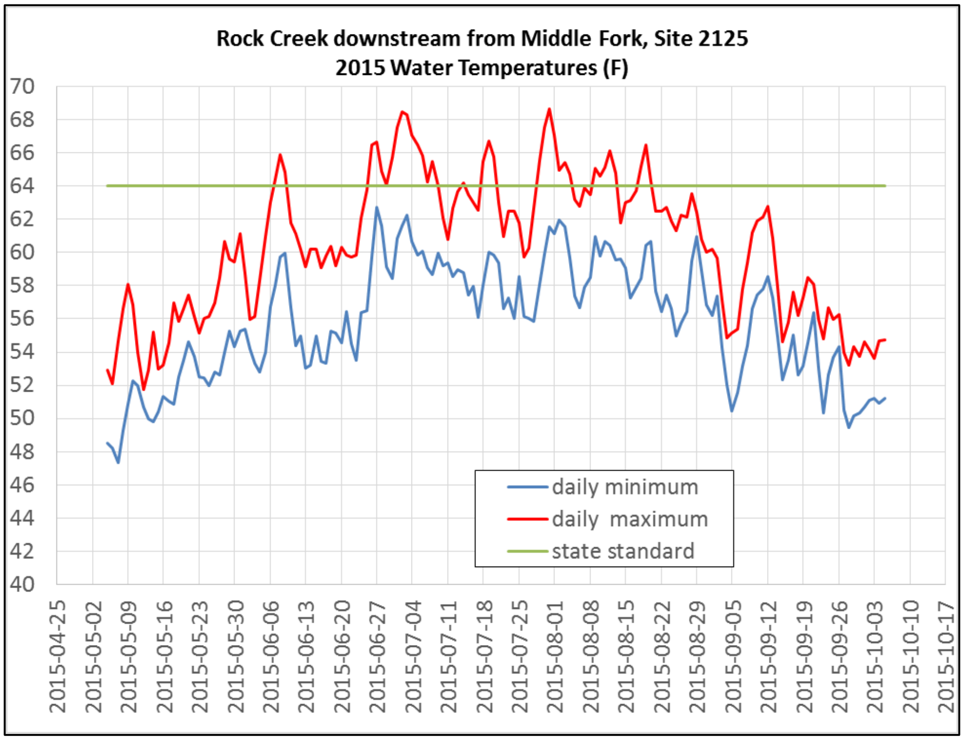

Spillway channel above North and South Fork confluence, in rootwad, Site 2168
2015 Water Temperatures (F)
daily minimum

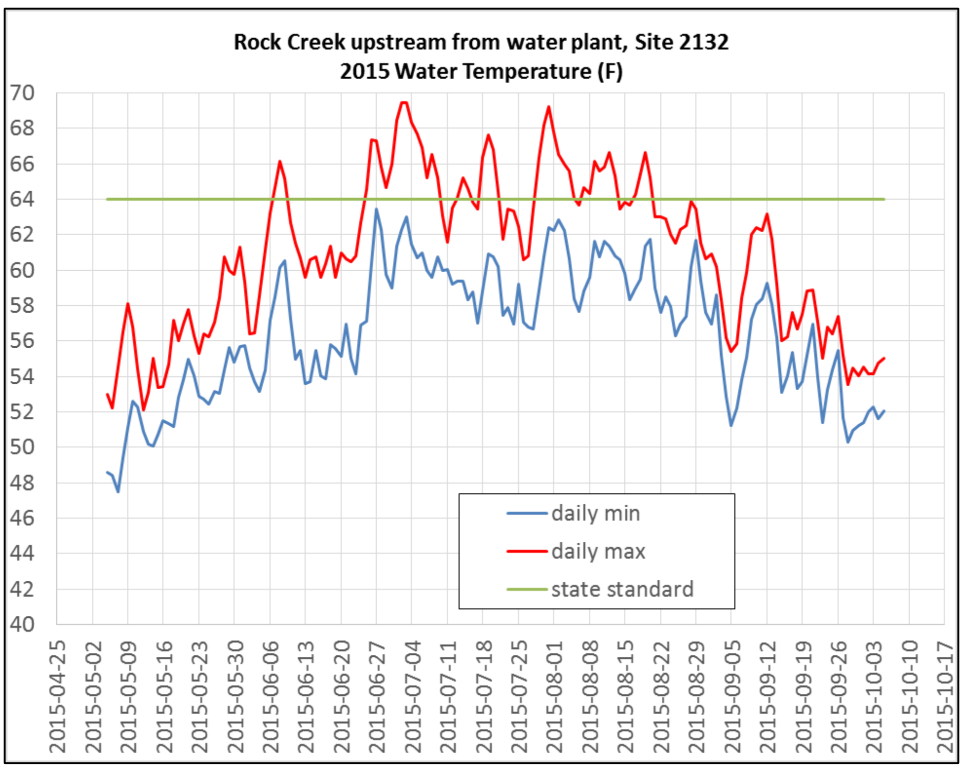

Rock Creek below confluence and dam, Site 2123
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily min
daily max
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17

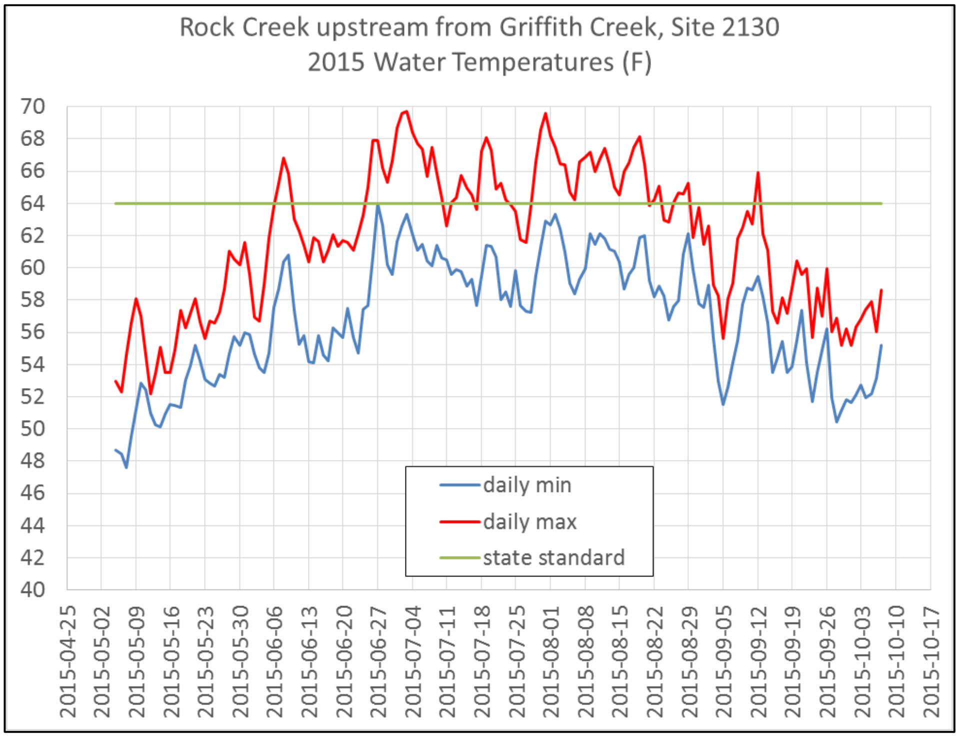

Rock Creek upstream from Tributary "B", downstream from Stilson Creek,
Site 2131
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily min
daily max
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17


Rock Creek upstream of Middle Fork, Site 2170
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily minimum
daily maximum
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17


Rock Creek Mainstem between Trib "B" and Middle Fork, Site 2171
2015 Water Temperature (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily minimum
daily maximum
state standard
2015-05-12
2015-05-19
2015-05-26
2015-06-02
2015-06-09
2015-06-16
2015-06-23
2015-06-30
2015-07-07
2015-07-14
2015-07-21
2015-07-28
2015-08-04
2015-08-11
2015-08-18
2015-08-25
2015-09-01
2015-09-08
2015-09-15
2015-09-22
2015-09-29
2015-10-06
2015-10-13


Rock Creek downstream from Middle Fork, Site 2125
2015 Water Temperatures (F)
daily minimum
daily maximum
state standard


Rock Creek upstream from water plant, Site 2132
2015 Water Temperature (F)
daily min
daily max
state standard


Rock Creek upstream from Griffith Creek, Site 2130
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily min
daily max
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
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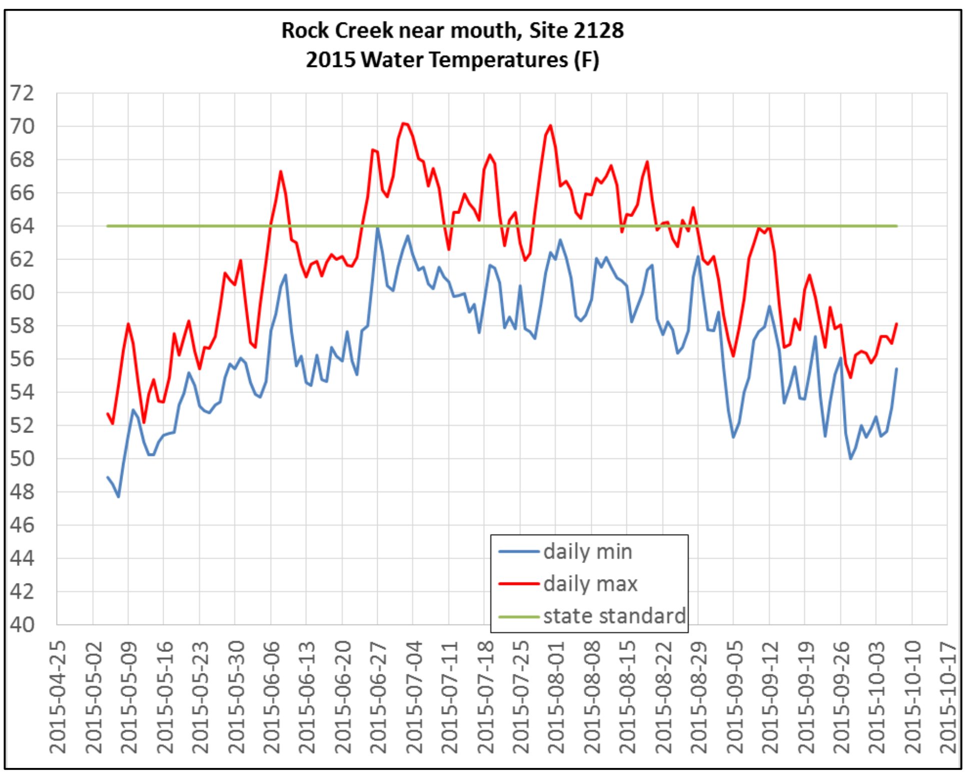
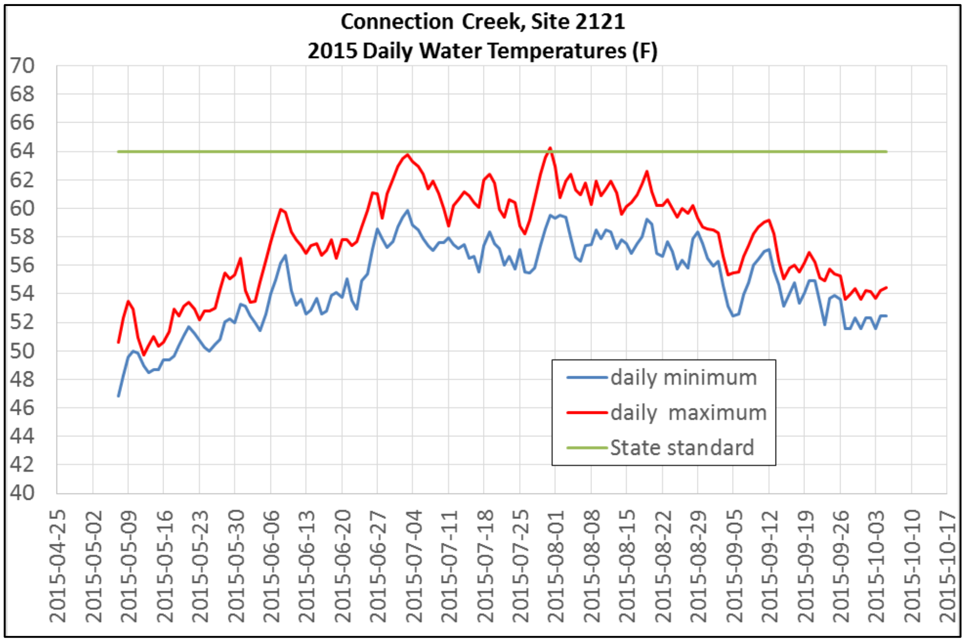
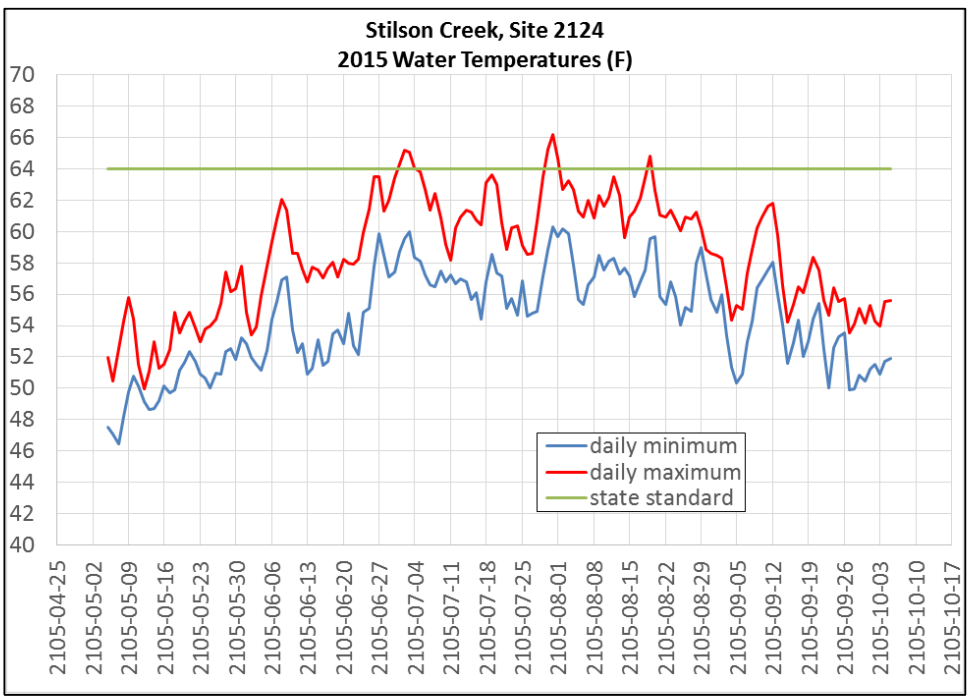
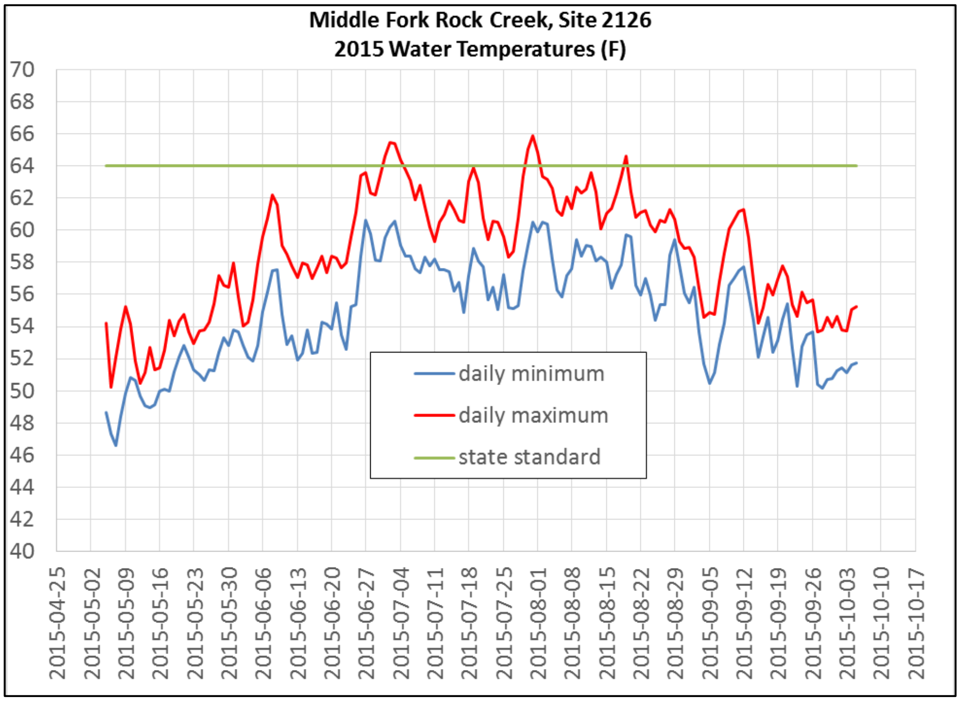
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17

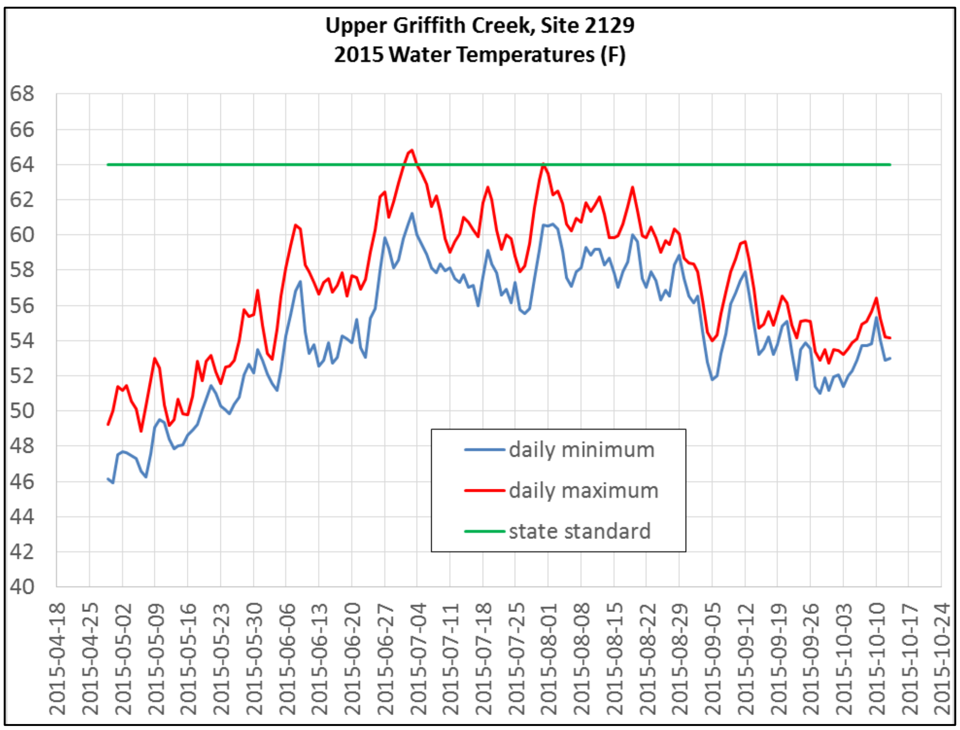

Rock Creek near mouth, Site 2128
2015 Water Temperatures (F)
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily min
daily max
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17

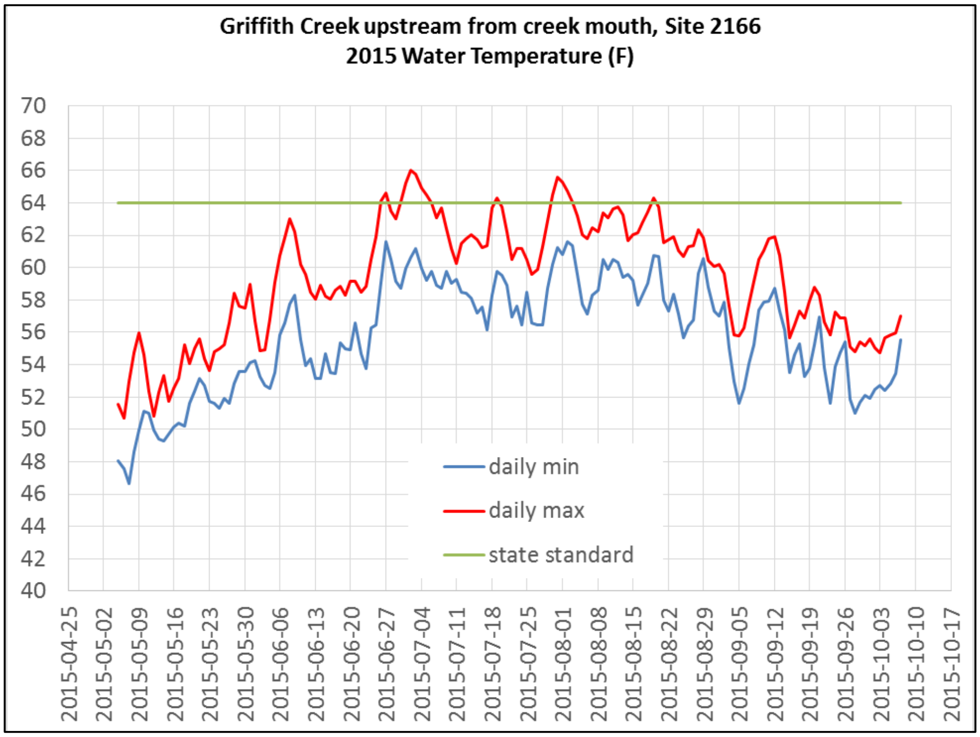
Tributaries to Rock Creek



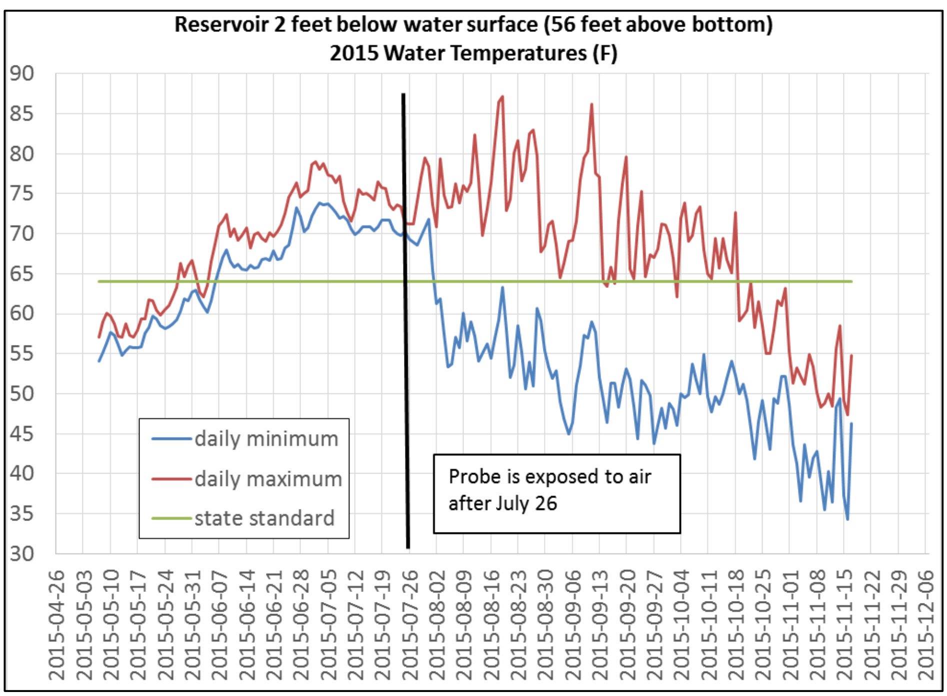


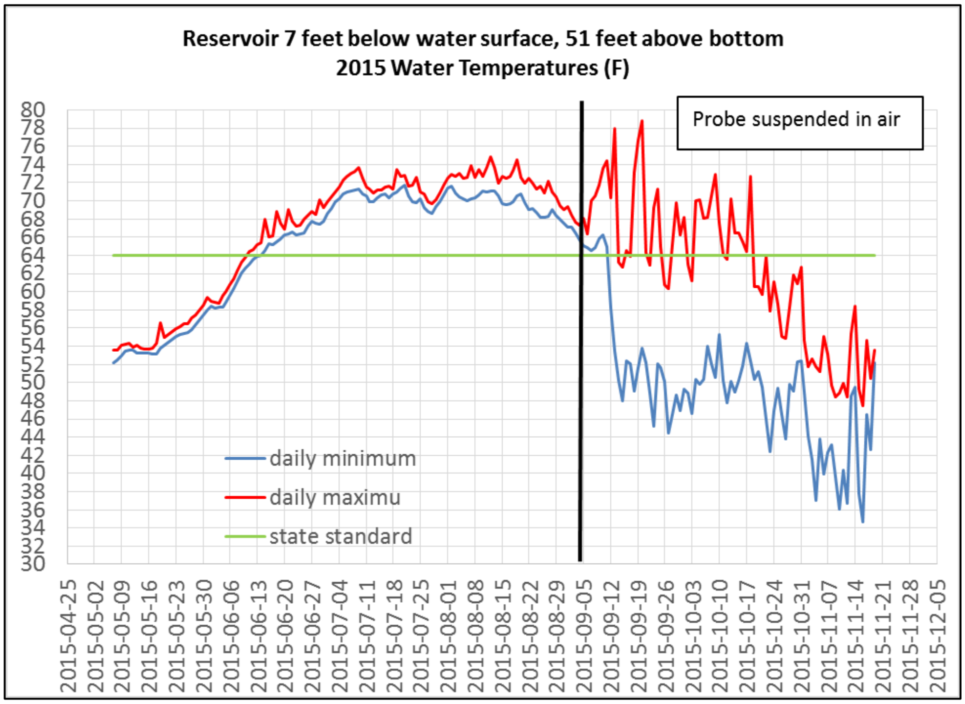

Middle Fork Rock Creek, Site 2126
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
daily minimum
daily maximum
state standard

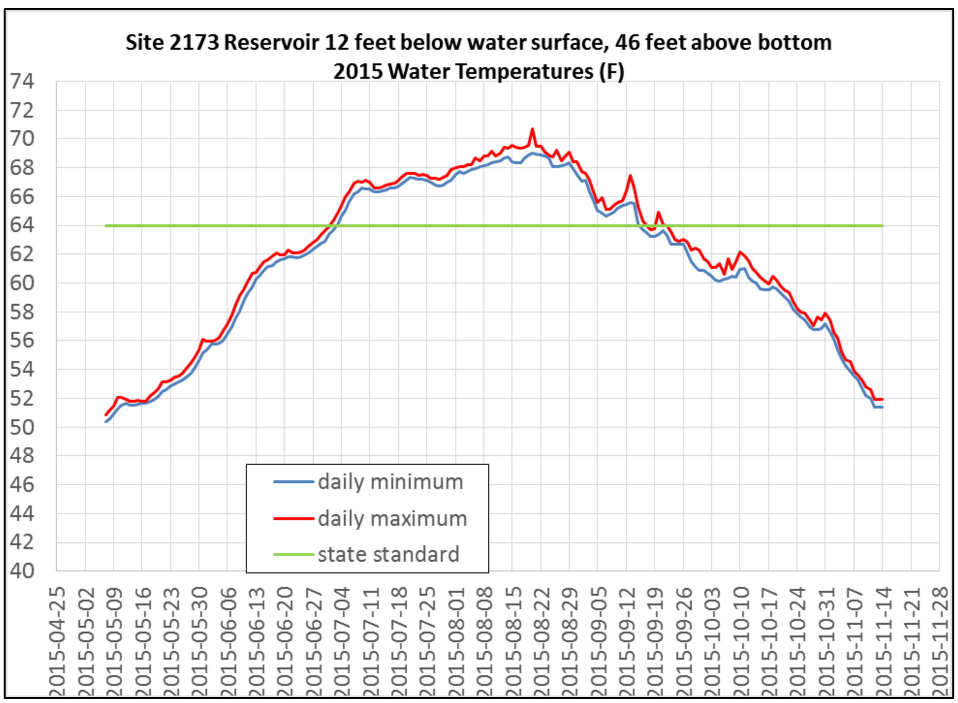

Upper Griffith Creek, Site 2129
2015 Water Temperatures (F)
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
2015-04-18
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
2015-10-24
daily minimum
daily maximum
state standard

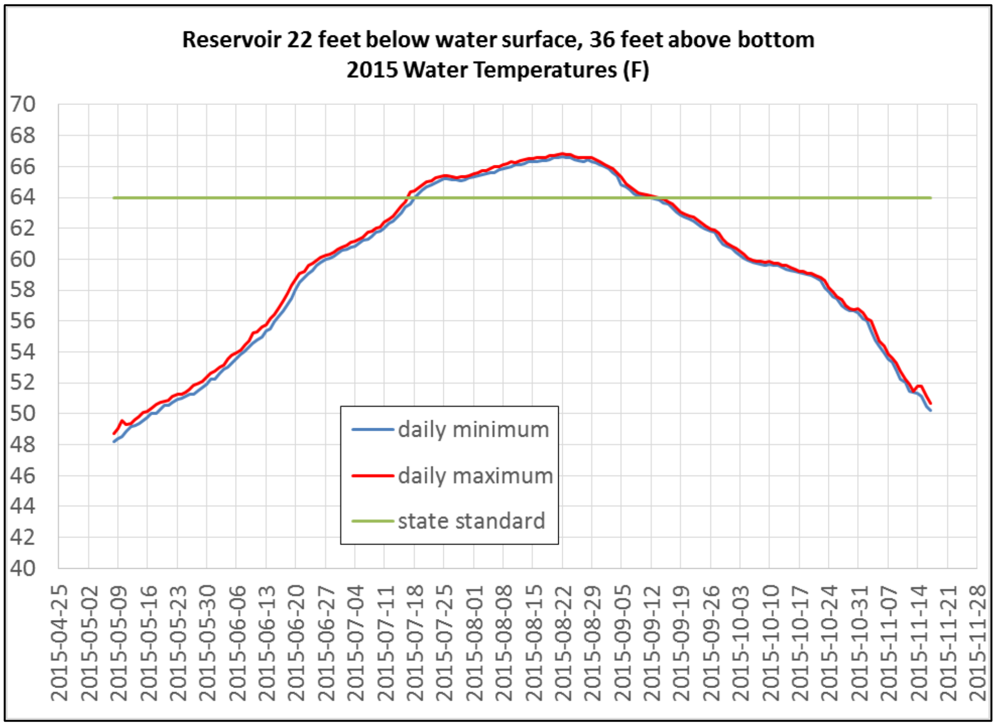


IN RESERVOIR

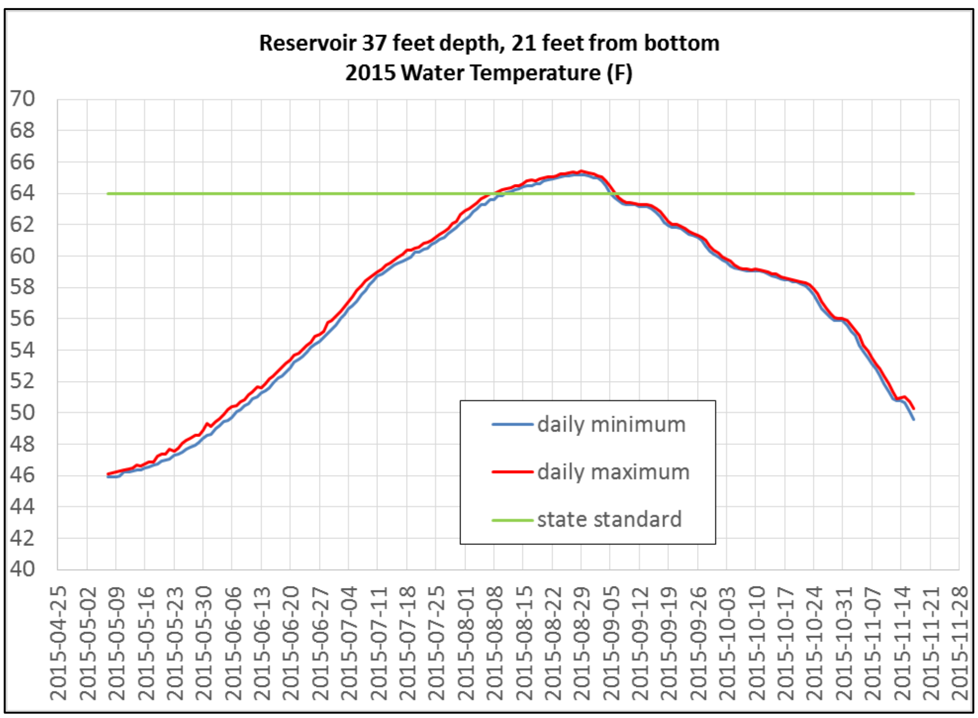



Reservoir 7 feet below water surface, 51 feet above bottom
2015 Water Temperatures (F)
Probe suspended in air
daily minimum
daily maximu
state standard

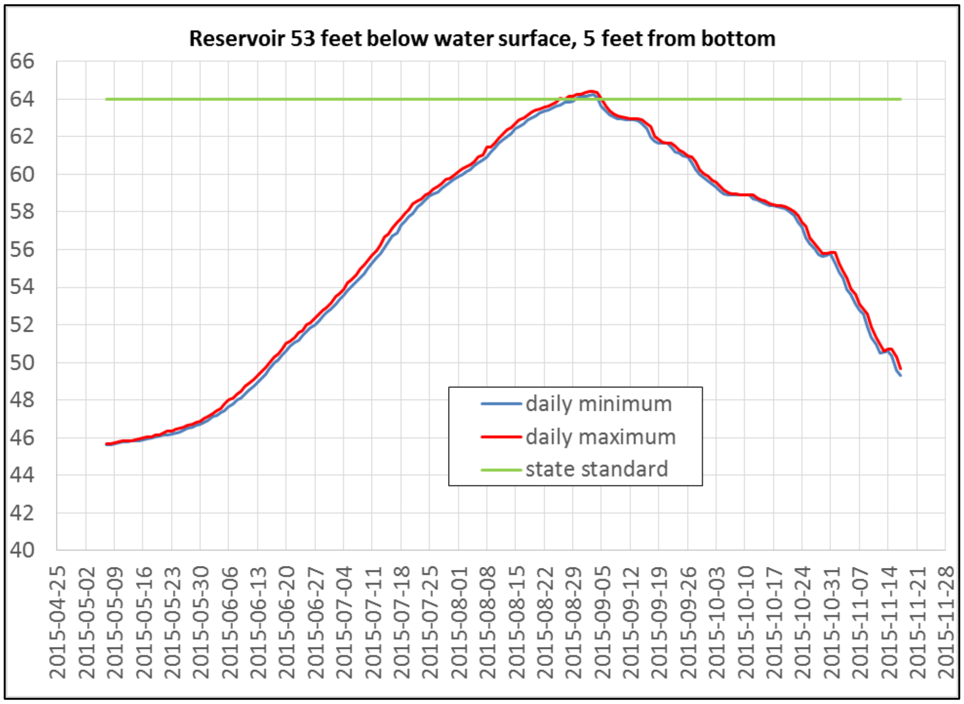

Site 2173 Reservoir 12 feet below water surface, 46 feet above bottom
2015 Water Temperatures (F)
daily minimum
daily maximum
state standard



Reservoir 22 feet below water surface, 36 feet above bottom
2015 Water Temperatures (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily minimum
daily maximum
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
2015-10-24
2015-10-31
2015-11-07
2015-11-14
2015-11-21
2015-11-28



Reservoir 37 feet depth, 21 feet from bottom
2015 Water Temperature (F)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
daily minimum
daily maximum
state standard
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
2015-10-24
2015-10-31
2015-11-07
2015-11-14
2015-11-21
2015-11-28



Reservoir 53 feet below water surface, 5 feet from bottom
66
64
62
60
58
56
54
52
50
48
46
44
42
40
2015-04-25
2015-05-02
2015-05-09
2015-05-16
2015-05-23
2015-05-30
2015-06-06
2015-06-13
2015-06-20
2015-06-27
2015-07-04
2015-07-11
2015-07-18
2015-07-25
2015-08-01
2015-08-08
2015-08-15
2015-08-22
2015-08-29
2015-09-05
2015-09-12
2015-09-19
2015-09-26
2015-10-03
2015-10-10
2015-10-17
2015-10-24
2015-10-31
2015-11-07
2015-11-14
2015-11-21
2015-11-28
daily minimum
daily maximum
state standard

Appendix B: Photos of the Rock Creek mainstem downstream from the North Fork and South Fork Rock Creek Confluence

Photos show different flow levels through the spring and summer.

Photo Location 1

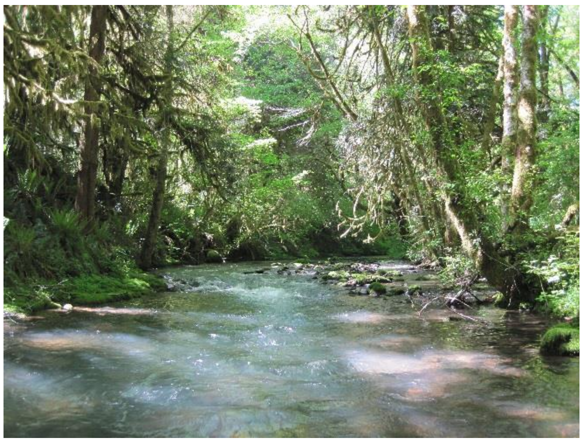


Photo 1: May 12, 2014 Flow is48.16 cfs


Photo 1: May 4, 2015 Flow is 12.5 cfs


Photo 1: May 20, 2015 Flow is 9.25 cfs


Photo 1: June 4, 2015 Flow is 6.24 cfs


Photo 1: August 26, 2015 Flow is 1.32 cfs.

Photo location 2

Photo 2a: May 12, 2014 Flow is48.16 cfs

Photo 2b: May 4, 2015 Flow is 12.5 cfs

Photo 2b: May 20, 2015 Flow is 9.25 cfs

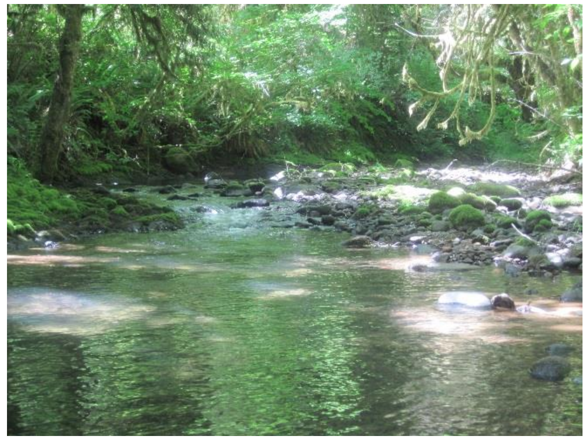


Photo 2: June 4, 2015 Flow is 6.24 cfs

Photo 2: August 26, 2015 2015 Flow is 1.32 cfs

Photo location 3


Photo 3: May 4, 2015 Flow is 12.5 cfs


Photo 3: May 20, 2015 Flow is 9.25 cfs


Photo 3: June 4, 2015 Flow is 6.24 cfs


Photo 3: August 26, 2015 2015 Flow is 1.32 cfs

Photo location 4


Photo 4: August 26, 2015 2015 Flow is 1.32 cfs
The horizontal yellow tape is the location of the cross-section used to measure flows.