Corvallis Watershed Stream Temperature Monitoring

Summer 2014

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Executive Summary

The intensive stream temperature monitoring in the Corvallis Watershed that was begun in 2010 was continued in 2014. In addition to air and water temperatures, stream flow data was collected for a second summer to better analyze the heat input into Rock Creek from the reservoir spillway.

Precipitation, air temperatures, and stream flow for the last five years were compared to show the variability in some of the factors that influence stream temperature. Cumulative precipitation amounts were lower in 2014 compared to the previous 4 years. In addition, 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. In 2013, air temperatures were above 80 F for fifteen days, in 2014 it was thirty days. The combination of lower flows and sustained warm days resulted in more days that were above the state standard of 64F for the 7-day average of daily maximum temperatures in 2014. In addition, the bottom of the reservoir was 2 to 5 degrees (F) warmer in 2013 than in 2012, and and 2 degrees (F) warmer in 2014 than in 2013. For the first time in three years of monitoring data, the bottom of the reservoir was slightly warmer (64.52 F) than the state standard of 64 F in early September of 2014.

Stream temperatures in most of the tributaries continue to meet state standards for summer water temperatures. The exception was Stilson Creek, which had a 7-day average of the daily maximum temperature of 64.12 F. Stilson Creek flows on a south-facing slope, which may explain this tributary's slightly higher temperature. In 2014, the mainstem of Rock Creek was warmer than 2013 by a couple of degrees.

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 64F for the 7-day average of the daily maximum temperatures.

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 three 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. The ongoing objectives of the stream temperature monitoring are:

- To characterize and track trends in the stream temperatures throughout the watershed.

- To determine the effects of restoration efforts, such as plantation thinning, riparian planting, and wood placement.
- To determine if it is possible to detect effects of the reservoir on downstream temperatures.

This report documents the results of the 2014 monitoring, and compares the 2014 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 and 2014 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.

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 64F for the 7-day average maximum temperature in 2012 through 2014. For the most part, the maximum temperatures were similar, although for the sites that exceeded 64 degrees F, the number of warm days was more numerous in 2014. The increase in number of days over 64F may reflect the combination of lower stream flows and the greater number of days with warmer air temperatures in 2014.

Graphs of the daily minimum and maximum temperatures for the individual sites are included in Appendix A. Photos of some of the monitoring sites, including the spillway flow through the summer are in Appendix B. Photos of the spillway capture the change in flow through the summer, as included in Appendix C.

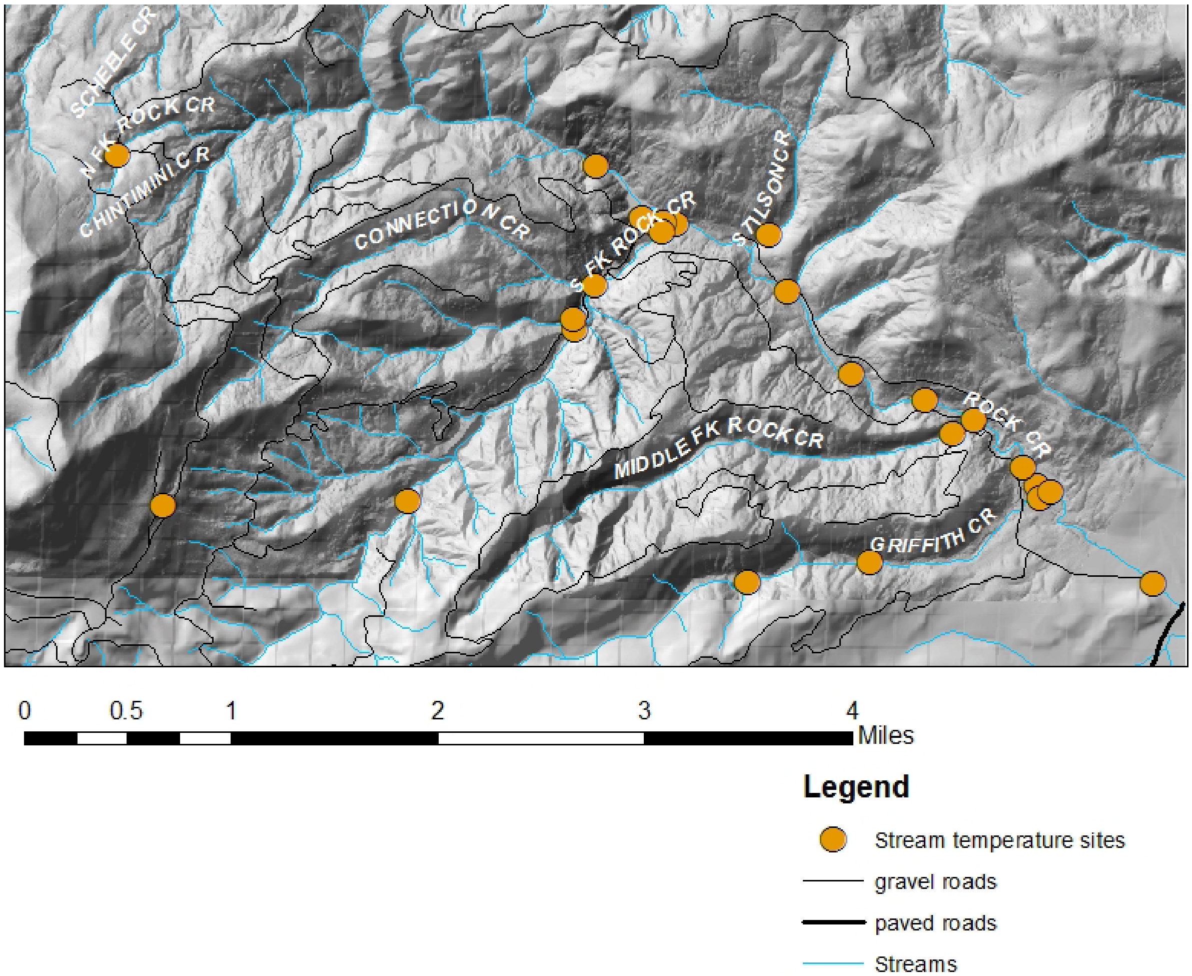

Figure 1. Overview map of stream temperature monitoring sites in the Corvallis (Rock Creek) Watershed.

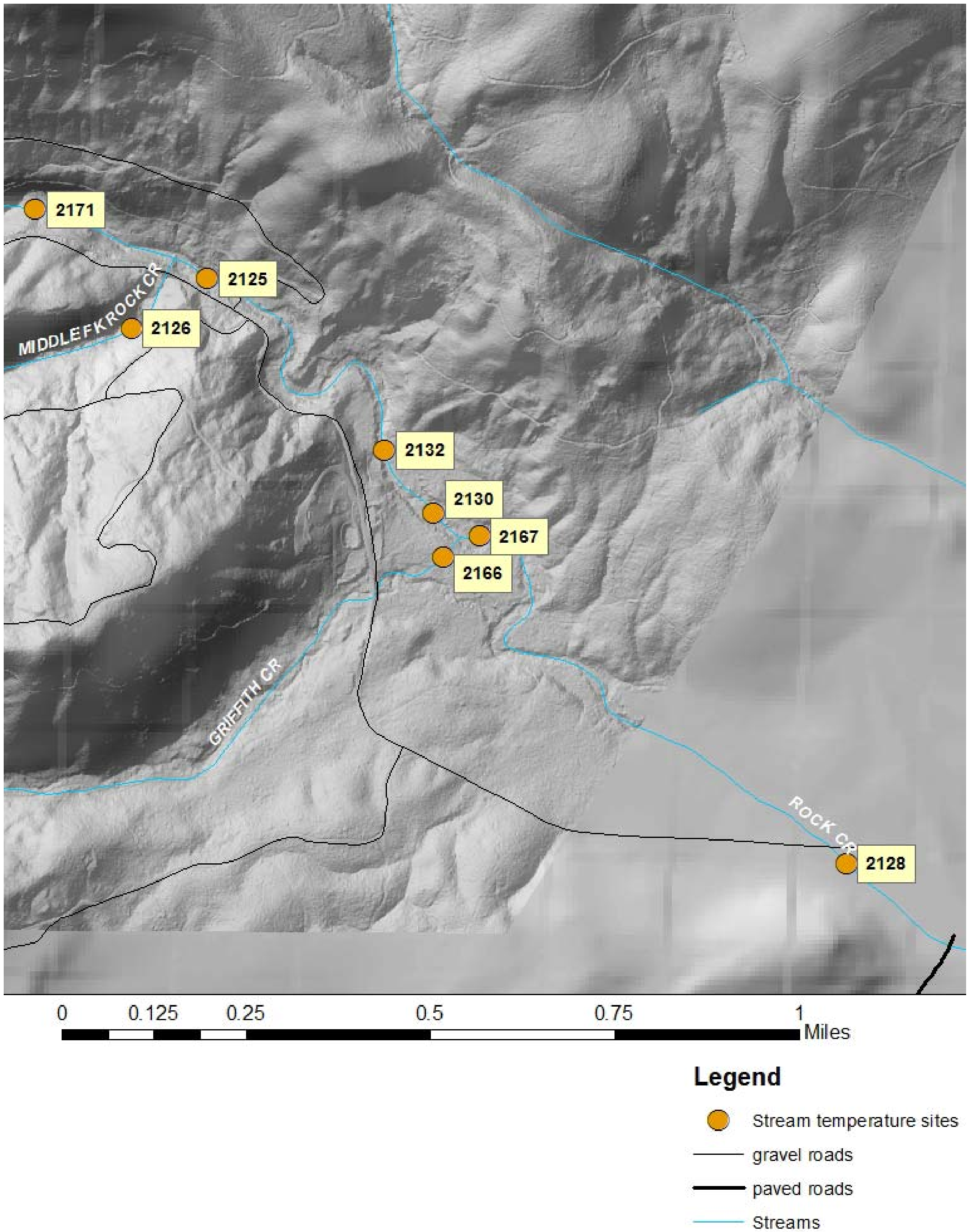

Figure 2. Stream temperature monitoring sites with site numbers , lower reaches of Rock Creek.

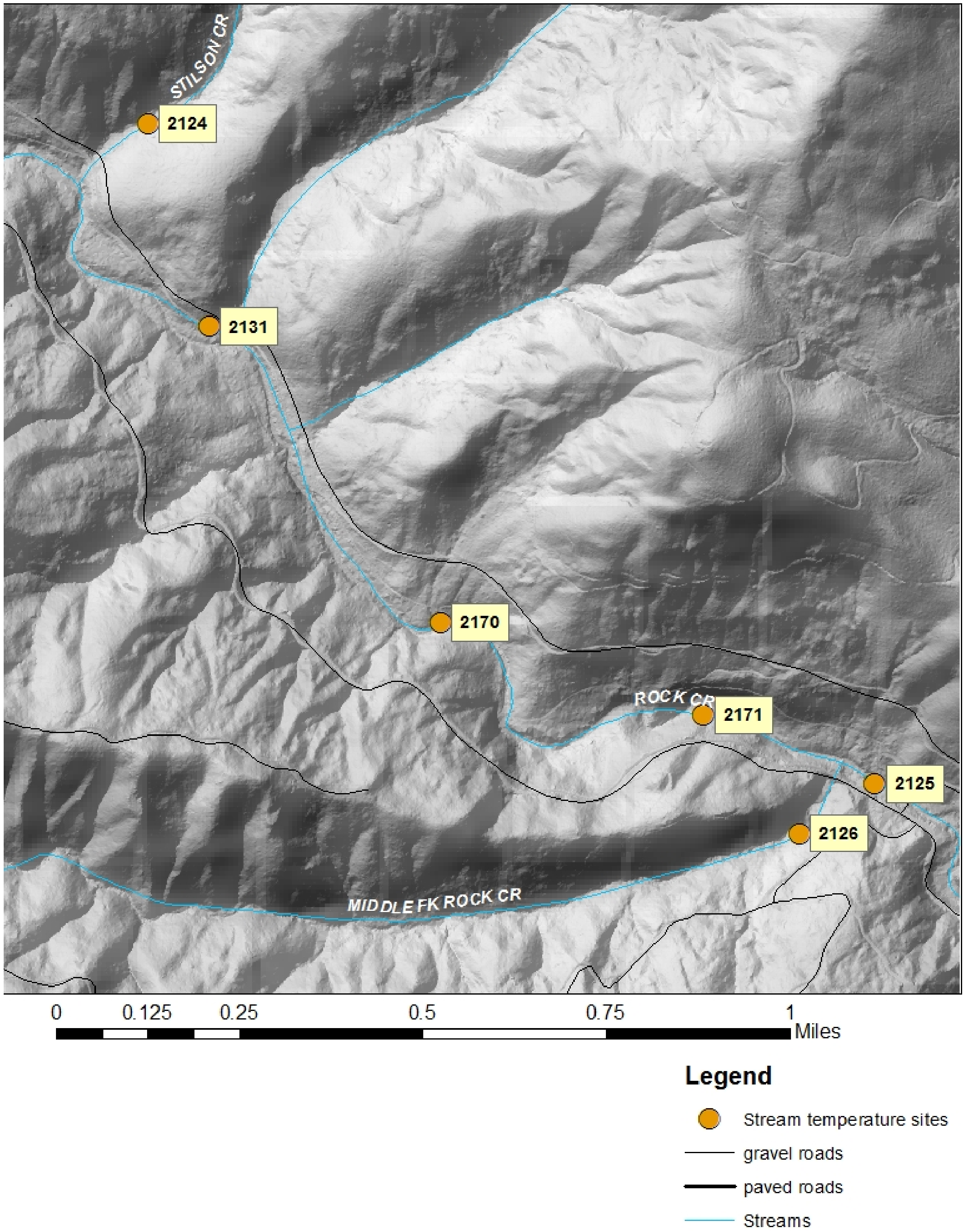

Figure 3. Stream temperature monitoring sites in Rock Creek between Middle Fork Rock Creek and Stilson Creek.

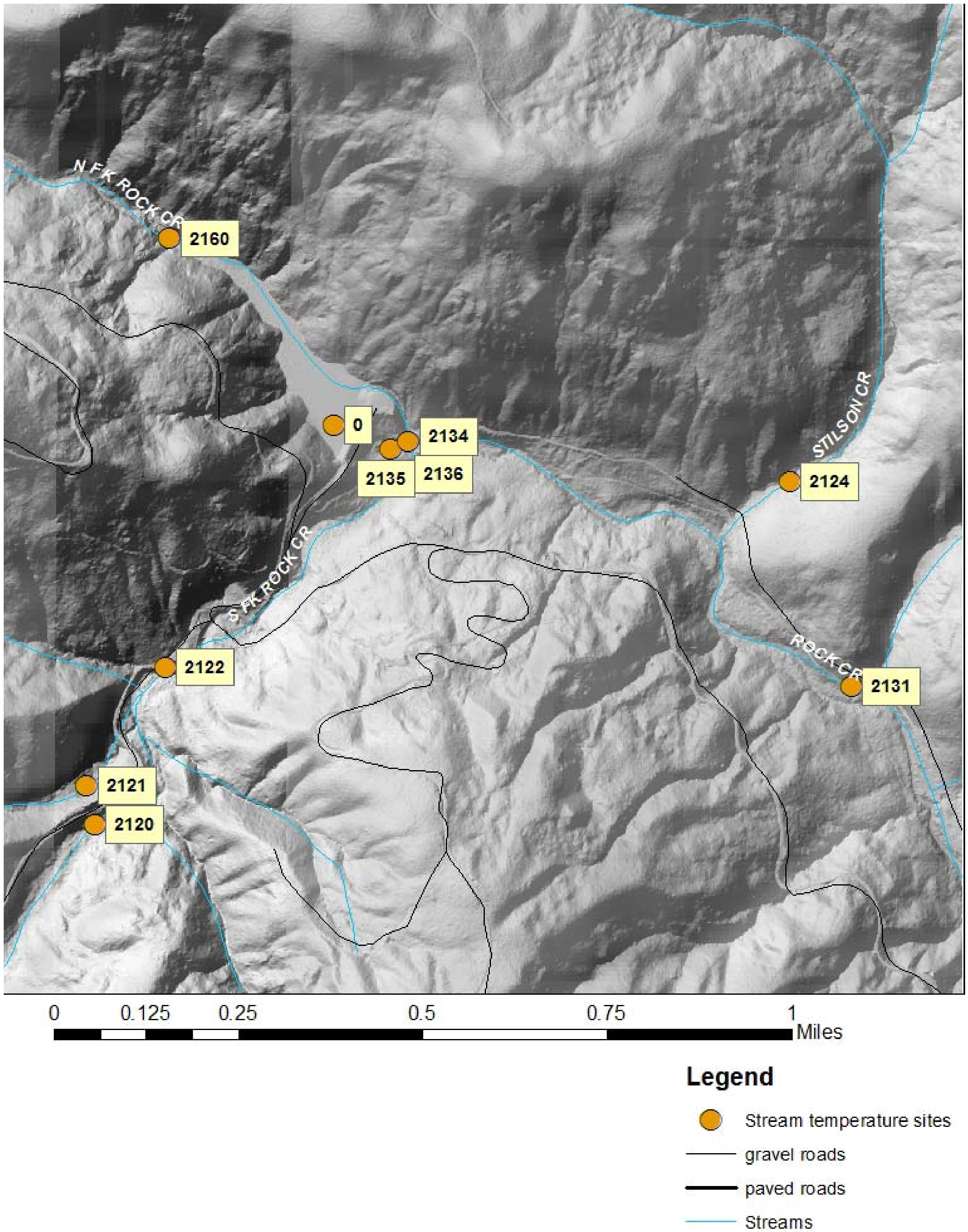

Figure 4. Stream temperature monitoring sites in lower reaches of South Fork Rock Creek and around reservoir.

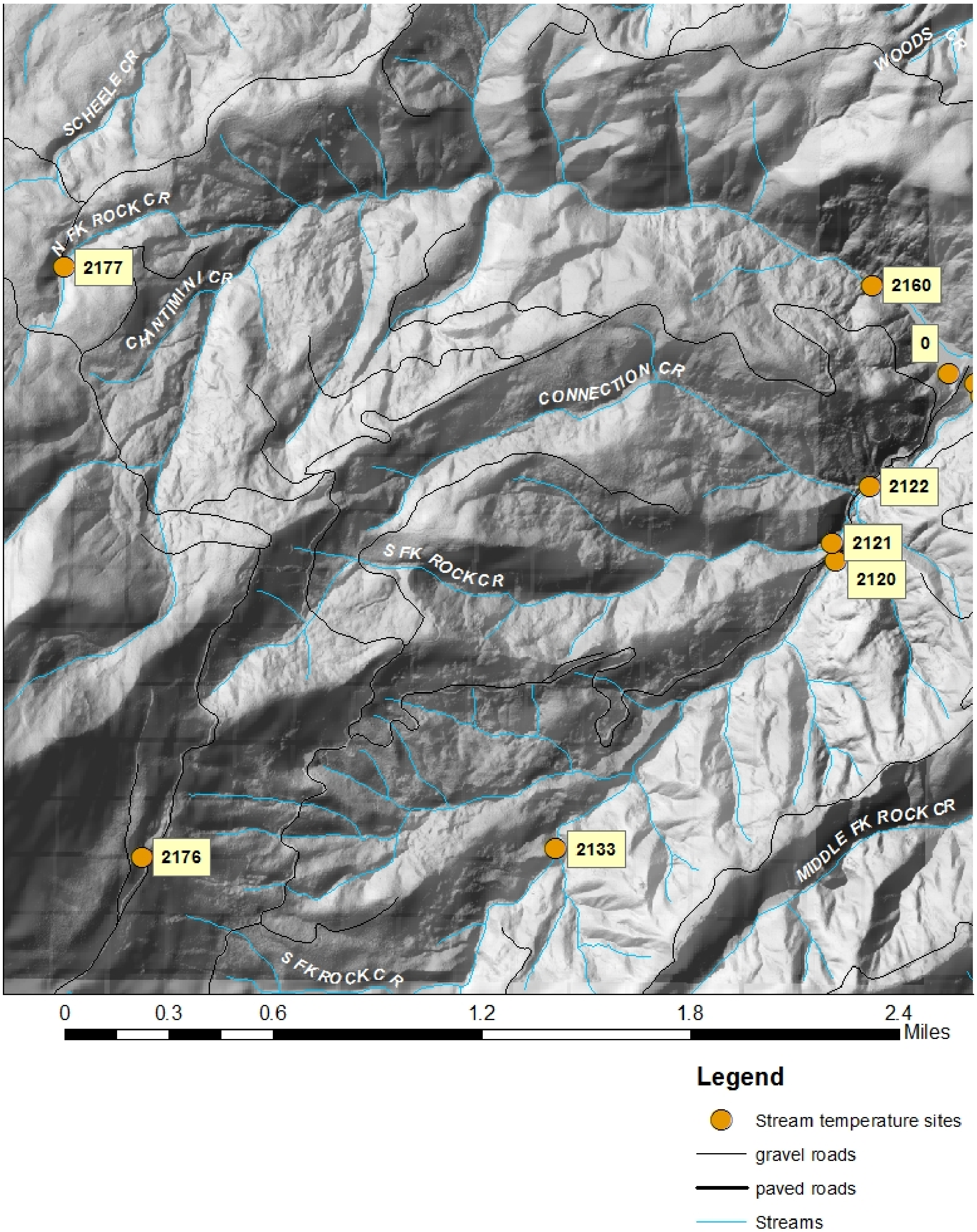

Figure 5. Stream temperature monitoring sites in the headwater springs of North Fork and South Fork Rock Creek. The sites around the reservoir are on the right side of map.

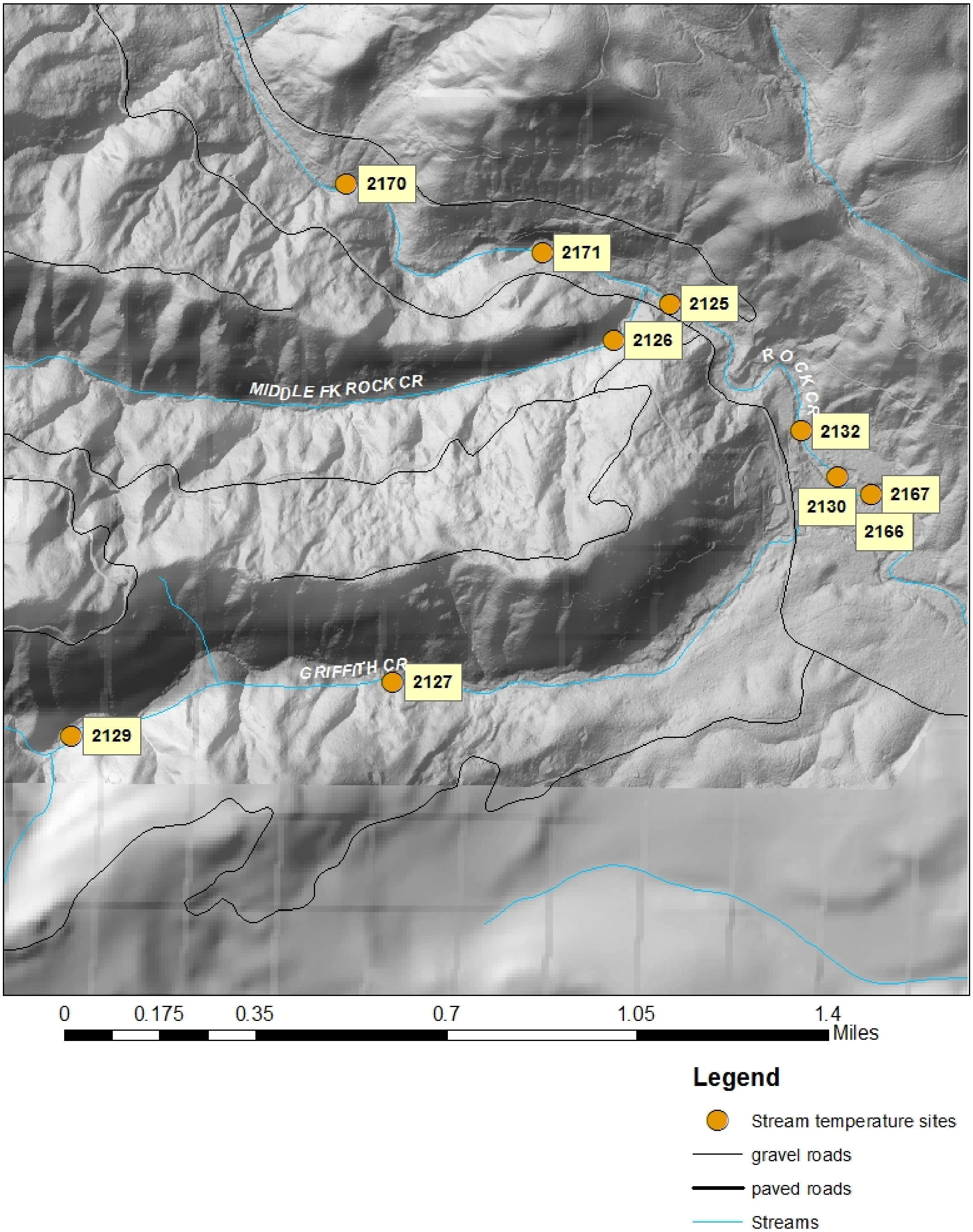

Figure 6. Stream temperature monitoring sites in Griffith Creek and lower Rock Creek.

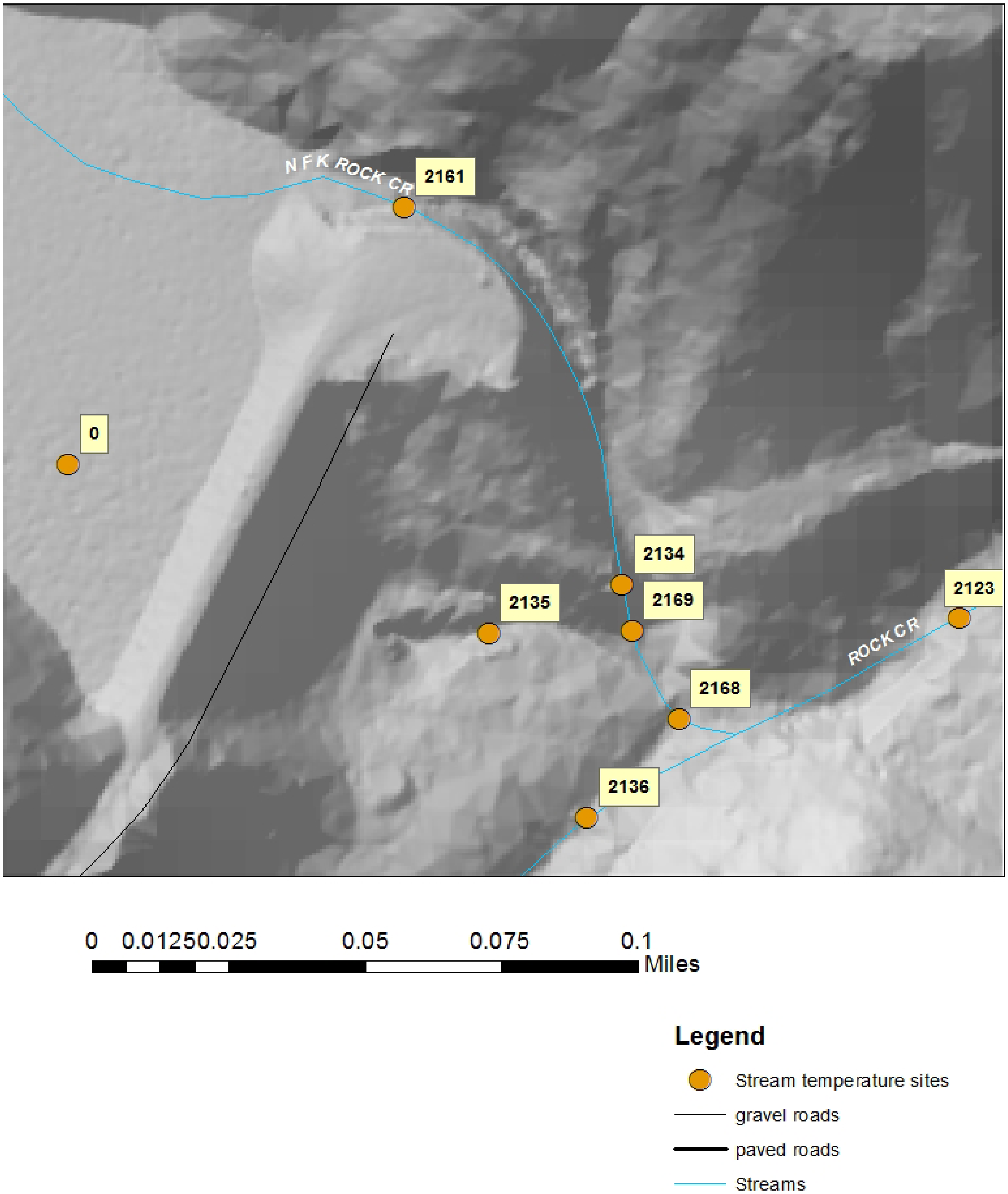

Figure 7. Stream temperature monitoring sites around the reservoir. The site marked with "0" is the valve tower in the reservoir. Six probes were suspended vertically on a rope in the reservoir.

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
S FK Rock Creek	upstream from Connection Creek	2120			60.8		59.2	60.12	61.74	no data	61.76
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	62.83
S FK Rock Creek	Above weir tied to trash rack	2122			60.9		58.8	60.14	61.51	60.99	63.22
S FK Rock Creek AIR TEMP		2122					79.06	79.11	83.22	82.52	81.12
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	65.02
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	64.12
Rock Creek mainstem	upstream from rd 111 bridge	2125			67.8		63.2	64.4	65.25	64.98	67.41
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	62.96
Griffith Creek	upstream from weir	2127			60.9		59.3	60.19	61.6	61.35	62.96

Rock Creek	below bridge near entrance gate	2128					64.2	65.66	66.33	65.76	68.57
Griffith Creek	below thinning unit approx 1 mi from intake	2129					61.5	60.27	61.57	61.25	63.26
Rock Cr mainstem	at waterline crossing upstream of Griffith Cr	2130					63.9	65.2	65.98	65.71	67.93
Rock Cr mainstem	0.08 miles upstream from Trib "b"	2131					61.9	63.13	LOST	64.29	66.34
Rock Cr mainstem	at City/pvt boundary above outflow in log complex	2132					63.3	64.49	65.84	65.37	67.46
S Fk Rock Creek	below thinning stand	2133	63.5	65.94			58.3	59.26	LOST	59.86	61.72
N Fk Rock Creek spillway below dam	pool below spillway	2134						77.04			74.90
Dam outlet small channel	Just below dam in small channel fed by valve leakage	2135							60.12	62.87	64.16
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
Top of Spillway at reservoir	Near metal ladder below sill	2161							78.91	79.57	
North Fork Rock Creek	Above reservoir where creek enters reservoir	2160							60.66	60.84	61.89
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,	2162							74.6	72.76	76.33

Reservoir, tied to tower rope	Installed June 5 2012 at 3.75 ft below water surface, 50' from bottom anchor	2163							70.87	69.65	
Reservoir, tied to tower rope	12 feet below water surface, 45.3 feet above bottom anchor	2173								67.26	70.1
Reservoir, tied to tower rope	22 feet below water surface	2180									66.82
Reservoir, tied to tower rope	17 feet below water surface, 40.3 feet above bottom anchor	2174								65.35	
Reservoir, tied to tower rope	37 feet below water surface	2181									65.46
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	2165							60.65	62.66	64.52
Griffith Creek	mouth of creek	2166							62.86	no data	64.89
Rock Creek	just downstream of Griffith Cr mouth	2167							65.81	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
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

Bottom of Spillway	In gravel channel just below spillway, moved from stagnant pool location used in 2011.	2169							76.99	78.46	78.87
Rock Creek mainstem	Approximately 2200 feet downstream from Trib "b"	2170								65.7	66.0
Rock Creek mainstem	Approximately 4500 feet downstream from Trib "b"	2171								66.77	67.5
Headwaters of South Fork	Bluff Springs above Road 2005	2176								45.65	45.94
Headwaters of North Fork	Just downstream of Road 2005	2177								50.11	51.46

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

Year	Site Number	Site Description	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	2123	Rock Creek mainstem, below confluence of North and South Fork Rock Creek	65.48	63.4	5	8/4/2012 to 8/13/2012
2013	2123	Rock Creek mainstem, below confluence of North and South Fork Rock Creek	65.92	64.34	4	6/30/2013 to 7/3/2013
2014	2123	Rock Creek mainstem, below confluence of North and South Fork Rock Creek	65.02	63.47	8	7/7/2014 to 8/27/2014
2012	2131	Mainstem Rock Creek 0.08 miles above Trib "B"		LOST IN 2012		

2013	2131	Mainstem Rock Creek 0.08 miles above Trib "B"	65.7	64.29	6	6/30/2013 to 7/26/2013 intermittently
2014	2131	Mainstem Rock Creek 0.08 miles above Trib "B"	66.34	64.59	21	7/7/2014 to 8/28/2014
2013	2170	Mainstem Rock Creek,Approximately 2200 feet downstream from Trib "B"	65.7	64.19	9	6/30/2013 to 8/6/2013 intermittently
2014	2170	Mainstem Rock Creek,Approximately 2200 feet downstream from Trib "B"	66.0	64.85	24	7/7/2014 to 8/27/2014
2013	2171	Mainstem Rock Creek,Approximately 4500 feet downstream from Trib "B"	66.77	65.17	17	6/28/2013 to 9/12/2013 intermittently
2014	2171	Mainstem Rock Creek,Approximately 4500 feet downstream from Trib "B"	67.5	65.93	32	7/7/2014 to 8/29/2014

2012	2125	Rock Creek mainstem, below Middle Fork and above the Road 111 bridge	66	65.25	9	8/4/2012 to 8/17/2012
2013	2125	Rock Creek mainstem, below Middle Fork and above the Road 111 bridge	66.56	64.98	15	6/25/2013 to 9/11/2013 intermittently
2014	2125	Rock Creek mainstem, below Middle Fork and above the Road 111 bridge	67.41	65.82	22	7/7/ to ? Probe was taken out of water on 8/13/2014
2012	2132	Rock Creek mainstem at City property boundary upstream from plant outflow in a log complex	67.01	65.84	9	8/3/2012 to 8/18/2012
2013	2132	Rock Creek mainstem at City property boundary upstream from plant outflow in a log complex	66.98	65.37	21	6/27/2013 to 9/10/2103 intermittently

2014	2132	Rock Creek mainstem at City property boundary upstream from plant outflow in a log complex	67.46	66.03	33	7/7/2014 to 8/29/2014
2012	2130	Rock Creek mainstem upstream from Griffith Creek	67.63	65.98	10	8/3/2012 to 8/18/2012
2013	2130	Rock Creek mainstem upstream from Griffith Creek	67.07	65.71	30	6/30/2013 to 9/13/2013 intermittently
2014	2130	Rock Creek mainstem upstream from Griffith Creek	67.93	66.83	43	7/6/2014 to 9/2/2014
2012	2128	Rock Creek below main bridge near mouth of creek, upstream from Greasy Creek confluence	67.28	66.33	14	8/2/2012 to 8/19/2012
2013	2128	Rock Creek below main bridge near mouth of creek, upstream from Greasy Creek confluence	67.41	65.76	32	6/27/2013 to 9/13/2013
2014	2128	Rock Creek below main bridge near mouth of creek, upstream from Greasy Creek confluence	68.57	67.27	43	7/6/2014 to 8/28/2014
2012	2122	AIR Temperature at South Fork Rock Creek	84.812	83.21	96	5/31/2012 to 10/2/2012
2013	2122	AIR Temperature at South Fork Rock Creek	85.85	82.52	106	5/18/2013 to 10/21/2013
2014	2122	AIR Temperature at South Fork Rock Creek	86.07	81.12	81	5/16/2014 to 10/9/2014

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, and precipitation data from the Wilkinson Ridge and Finley Wildlife Refuge (Finley) Remote Automated Weather Stations (RAWS), are compared for the previous 4 years to show the variability from year to year.

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. This variation is also reflected in the water temperatures, with the warmest water temperatures coinciding with the warmest air temperatures each year.

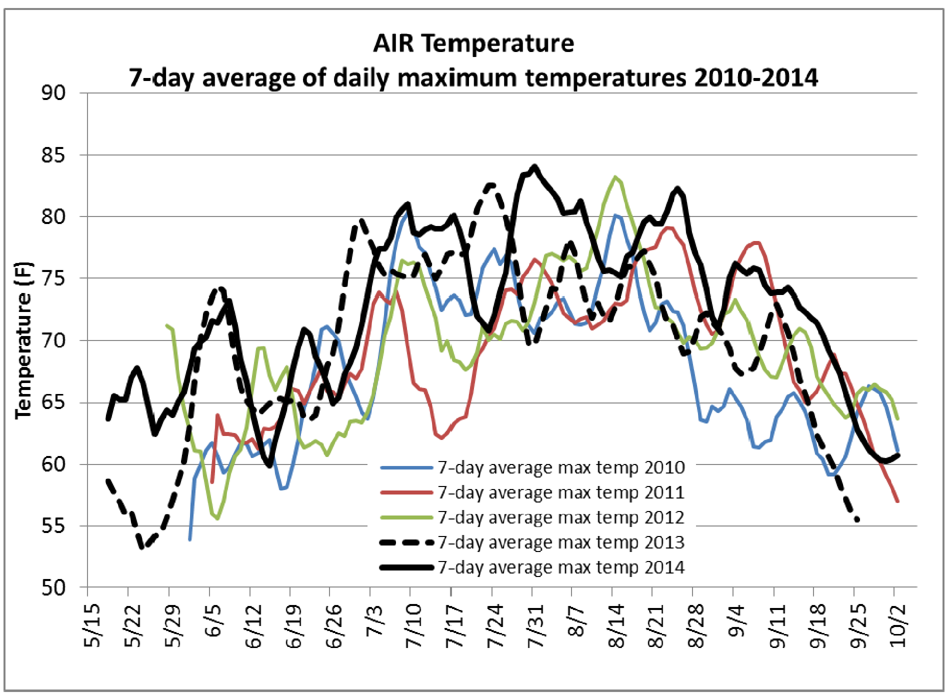

Figure 8. The 7-day running average of the daily maximum temperatures for the years 2010 through 2013.

The last two years' of air temperatures are compared in Figure 9. In 2014, air temperatures were warmer in August and September.

Separate graphs of each year's air temperatures from 2010 through 2014 are shown in Figure 10.

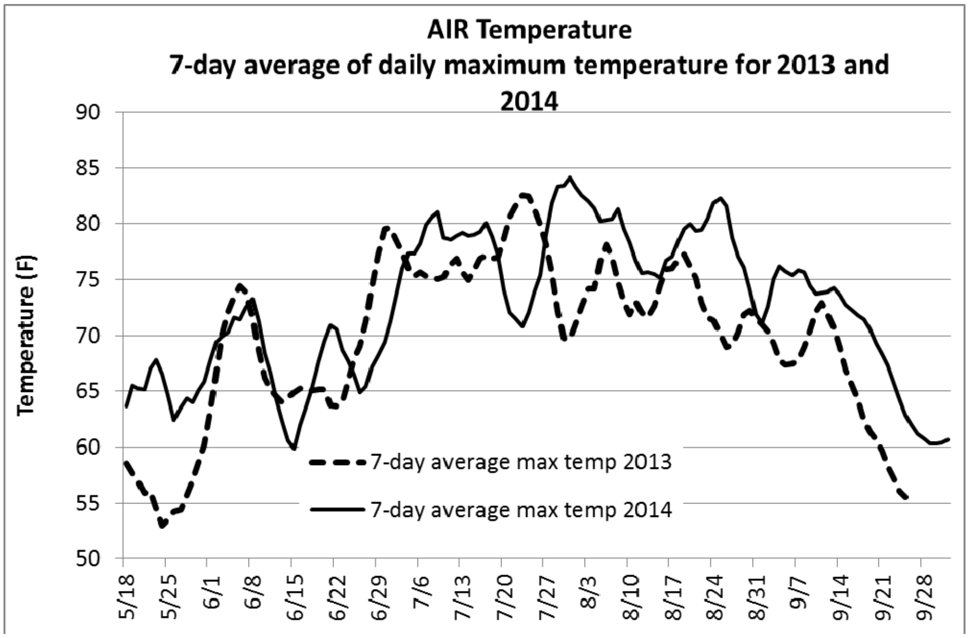

Figure 9. Comparison of the 7-day average of the daily maximum temperature for 2013 and 2014. Temperatures were similar in early summer until the first part of July. 2014 temperatures were warmer in the latter half of the summer, including through September.

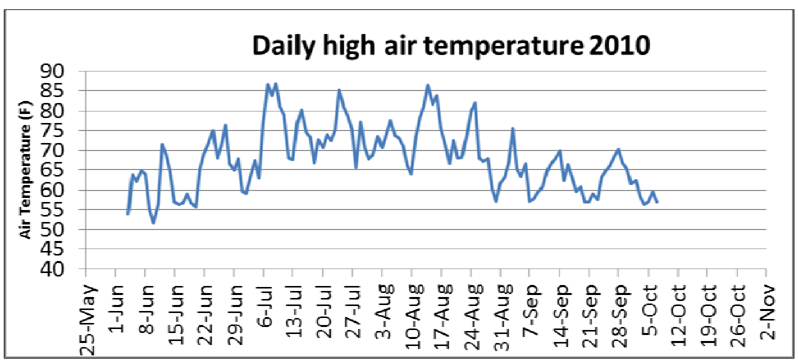

Figure 10a

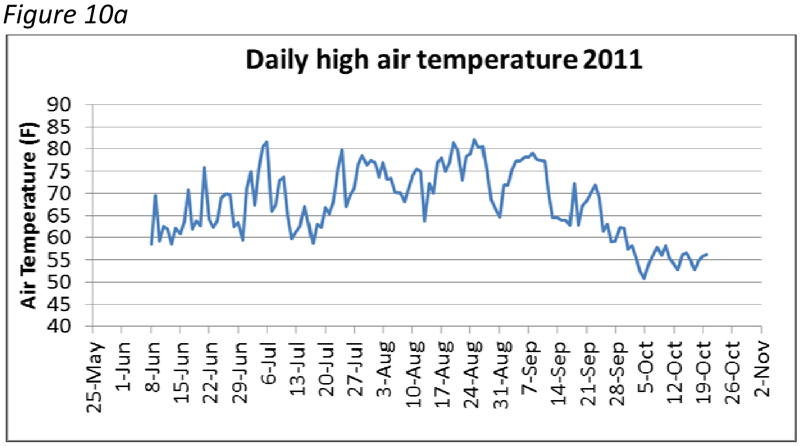

Figure 10b

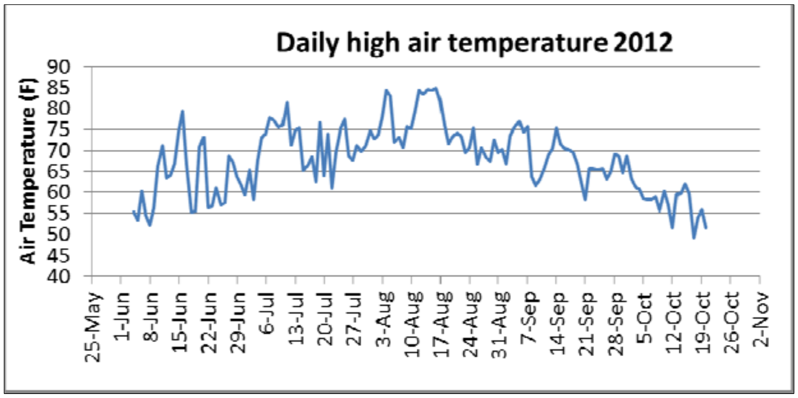

Figure 10c

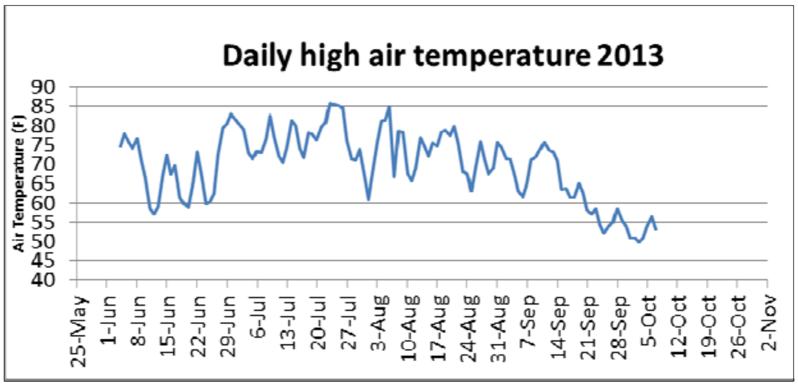

Figure 10d

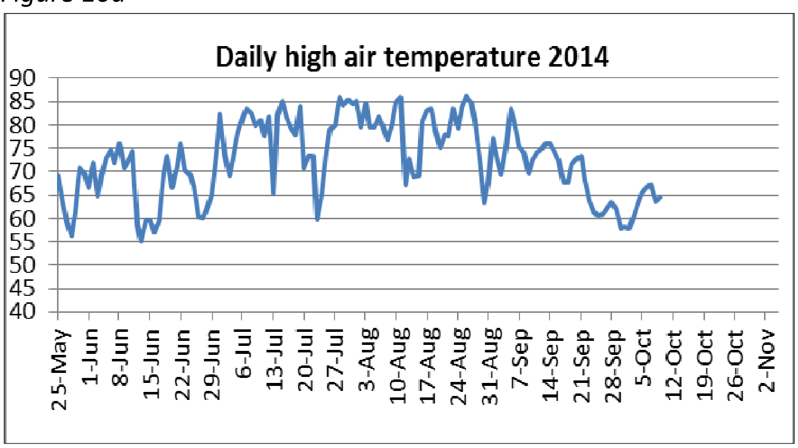

Figure 10e.

Figure 10. Comparison of daily maximum air temperatures for the last 5 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 and 2014. The data for 2011 was suspect, as the station did not record any precipitation for several months in the spring for that year. Data from the Finley RAWS site was also graphed to compare results to Wilkinson Ridge.

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. The higher spring precipitation amount is reflected in the flow data that was collected in May around the confluence of the North and South Forks of Rock Creek. Flow data is discussed in the next section. Figure 12 compares the last two years of data.

The cumulative precipitation amounts (Figure 13) show that 2014 had the lowest annual precipitation.

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.

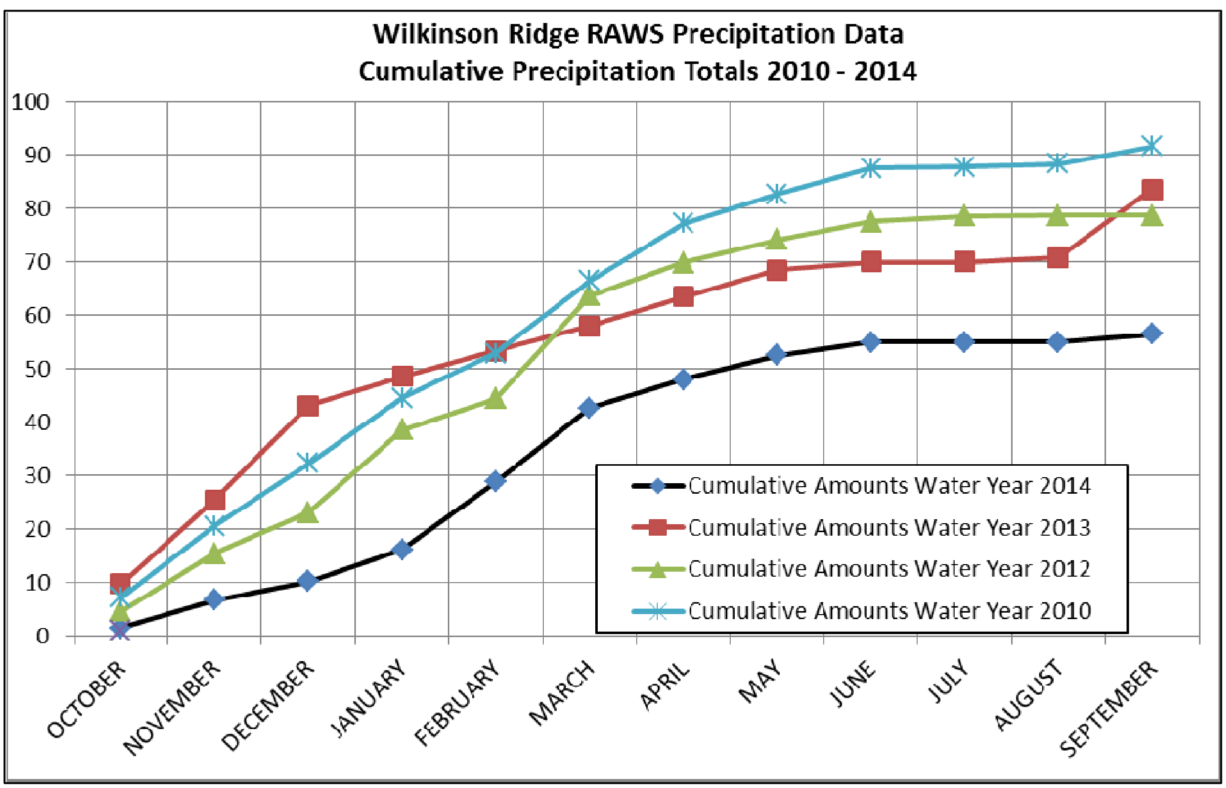

Figure 13. Annual cumulative amounts of precipitation for the Wilkinson RAWS station. The annual total amount in 2014 is significantly lower than previous years.

The weather station at Finley shows similar precipitation trends, although the amounts are less (Figures 14 and 15).

Figure 14. Monthly precipitation amounts for the Finley RAWS station for 2010-2014.

Figure 15. Annual cumulative amounts of precipitation for the Finley RAWS station. The annual total amount in 2014 is 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 16, which compares water temperature to the drainage area above that point. The lines representing different years' temperature data are all parallel, with a similar slope; however, they reflect the warmer vs. cooler years. For instance, 2012 had the highest peak air temperature, and the 7-day average of the maximum water temperature throughout the watershed reflects 2012's air temperatures.

In 2014, stream temperatures were the warmest since 2010. Figure 16 shows that the stream temperatures throughout the watershed have been generally on a warming trend during the 5 years of consecutive years of monitoring. In 2014, the higher 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. As a result, 2014 had the warmest stream temperatures since monitoring began in 2010.

Figure 16. Comparing 7-day average maximum stream temperatures to drainage area for 5 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 17 shows 4 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.

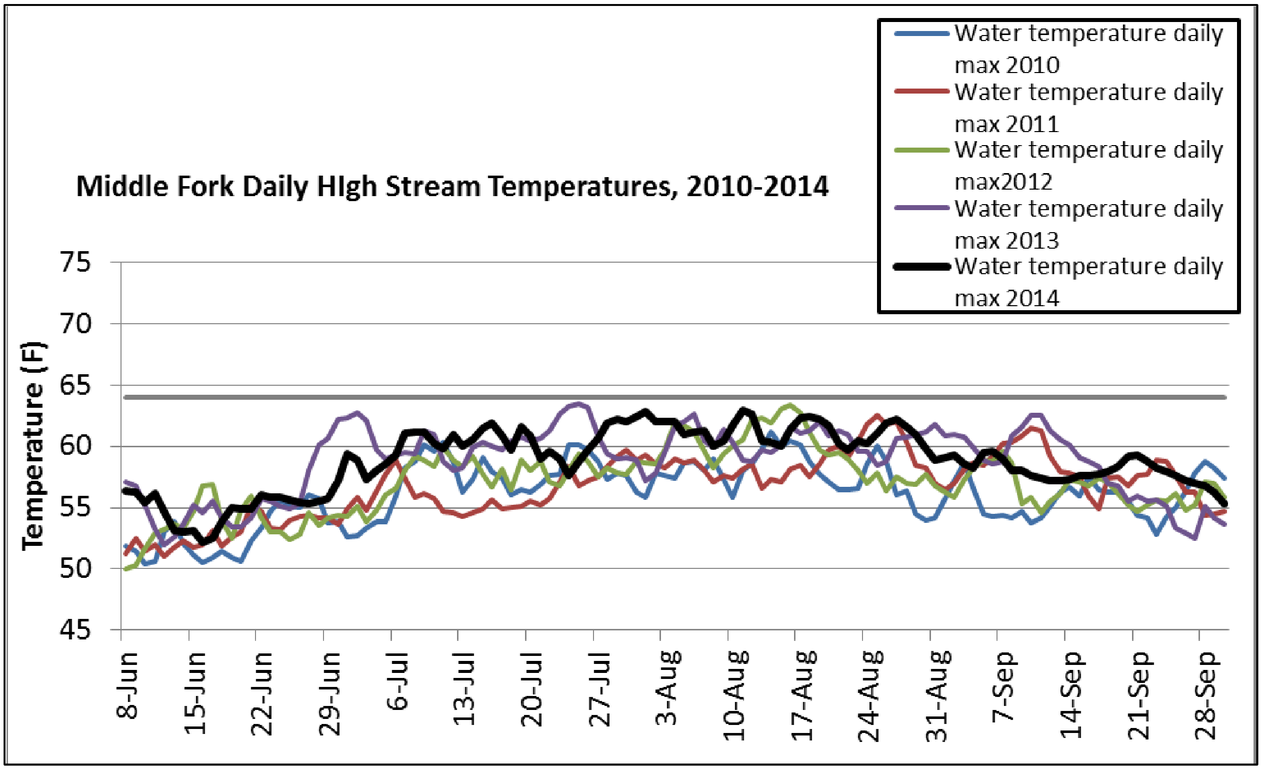

Figure 17. Daily maximum stream temperatures for the Middle Fork Rock Creek, 2010-2014.

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 and 2014. 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, there was more rain in the spring of 2014, which is reflected in the significantly higher flows in May (Figures 18 to 25). 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 (Figure 21). 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 (Tables 3 and 4)

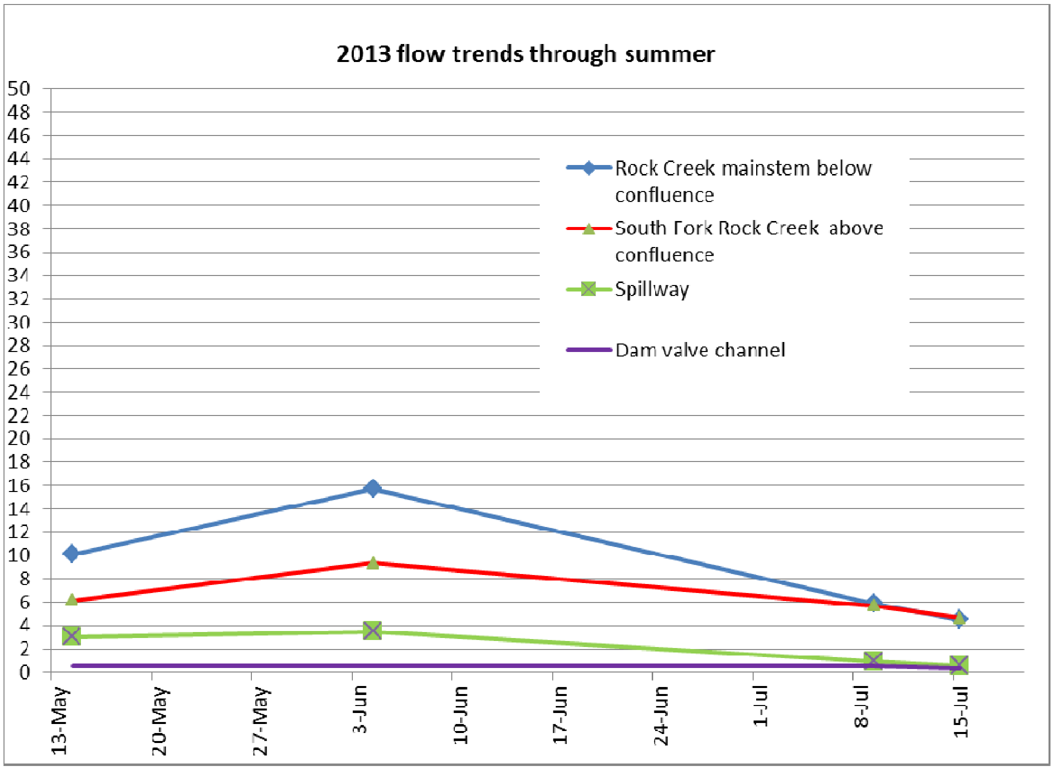

Figure 18: Line graph comparing flows measured around the confluence during the summer of 2013.

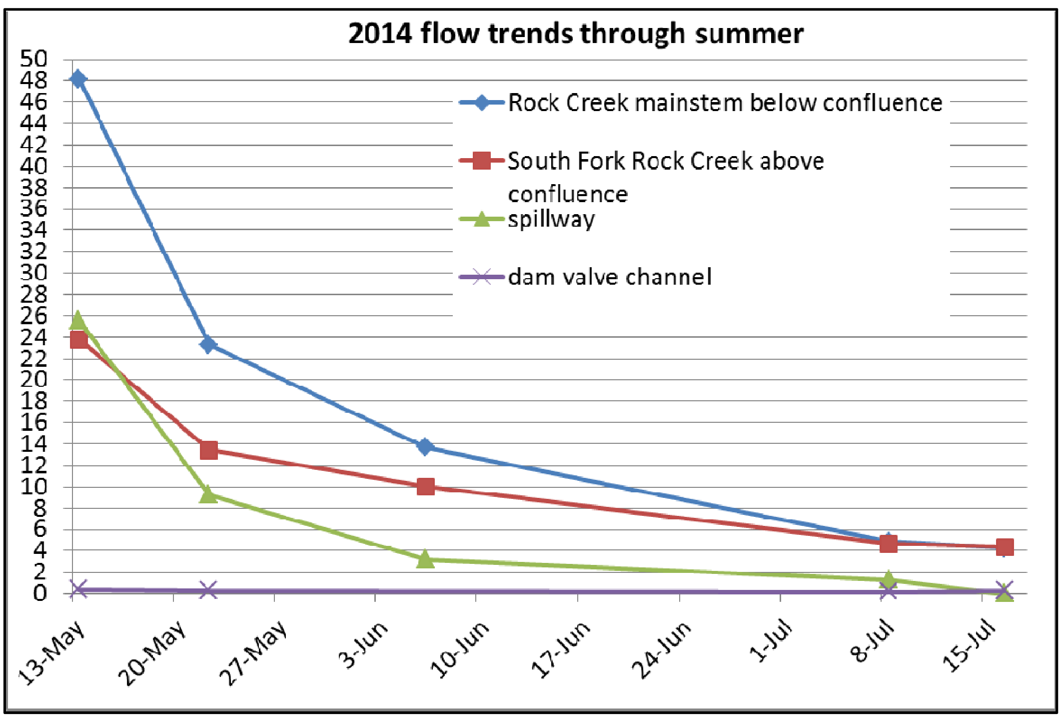

Figure 19: Line graph comparing flows measured around the confluence during the summer of 2014 until the spillway stops flowing on July 14.

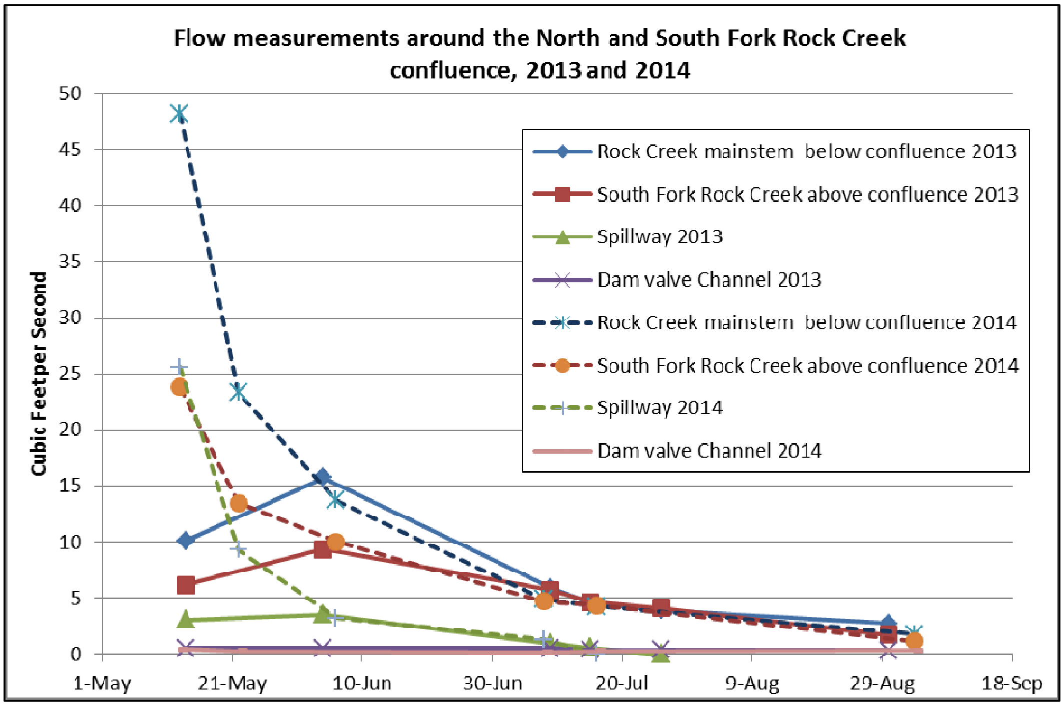

Figure 20: Comparing flow measurements from both 2013 and 2014.

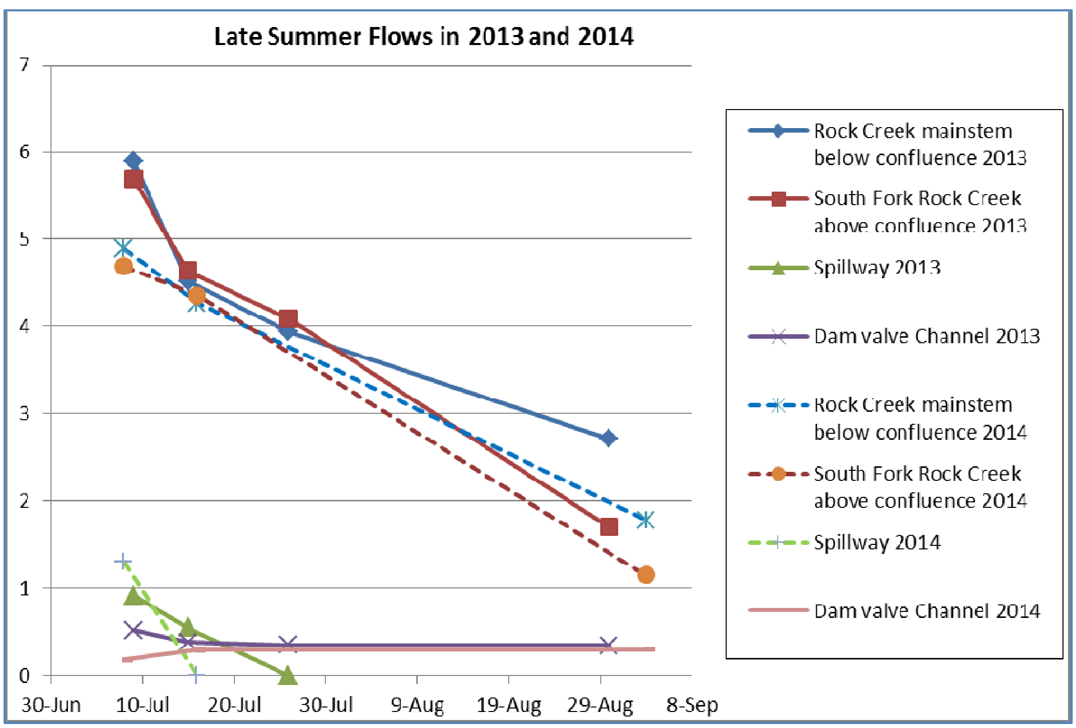

Figure 21: 2013 and 2014 late summer flows compared. Note that after approximately July 20, the flows are lower in 2014.

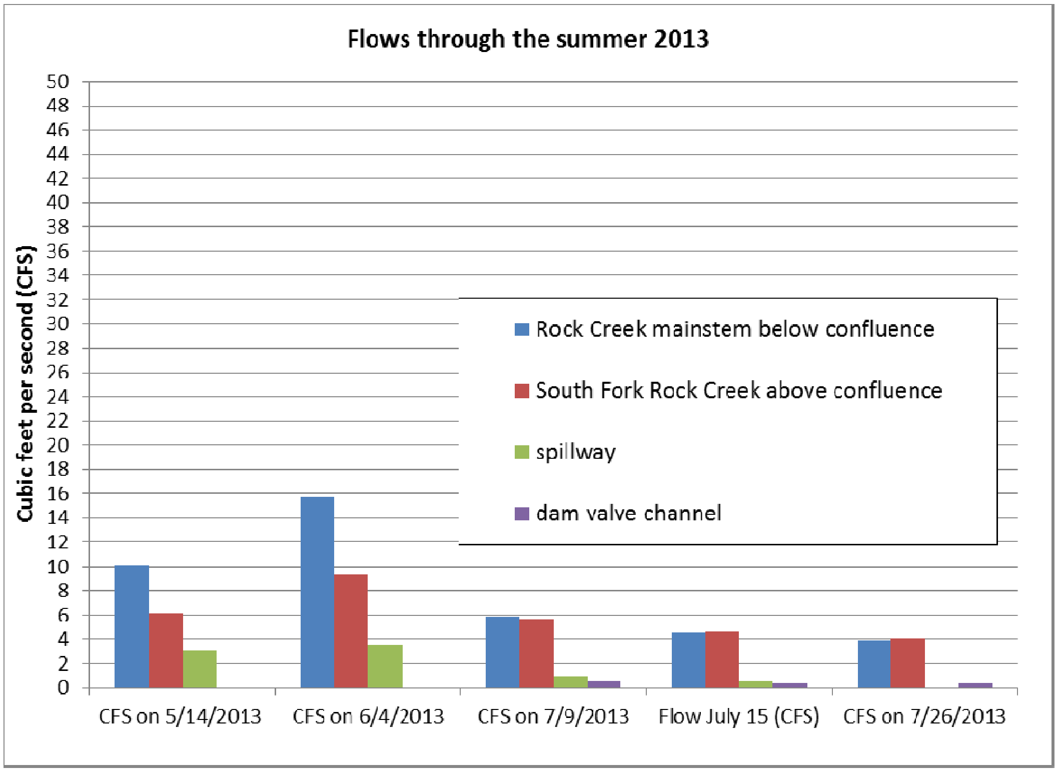

Figure 22: Comparison of flows above and below the North and South Fork Rock Creek confluence in 2013. The spillway stopped flowing on July 26. The dam valve channel has a relatively consistent flow through the summer.

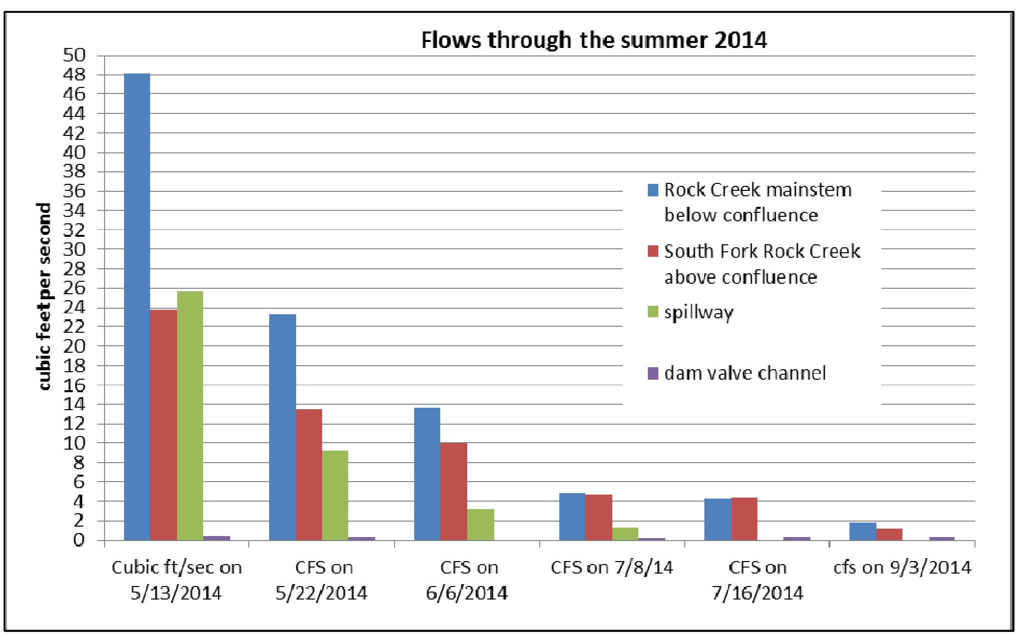

Figure 23. Comparison of flows above and below the North and South Fork Rock Creek confluence in 2014. The spillway stopped flowing on July 14.. The dam valve channel has a relatively consistent flow through the summer. The peak flow for the monitoring period was in May, and significantly higher than in 2013.

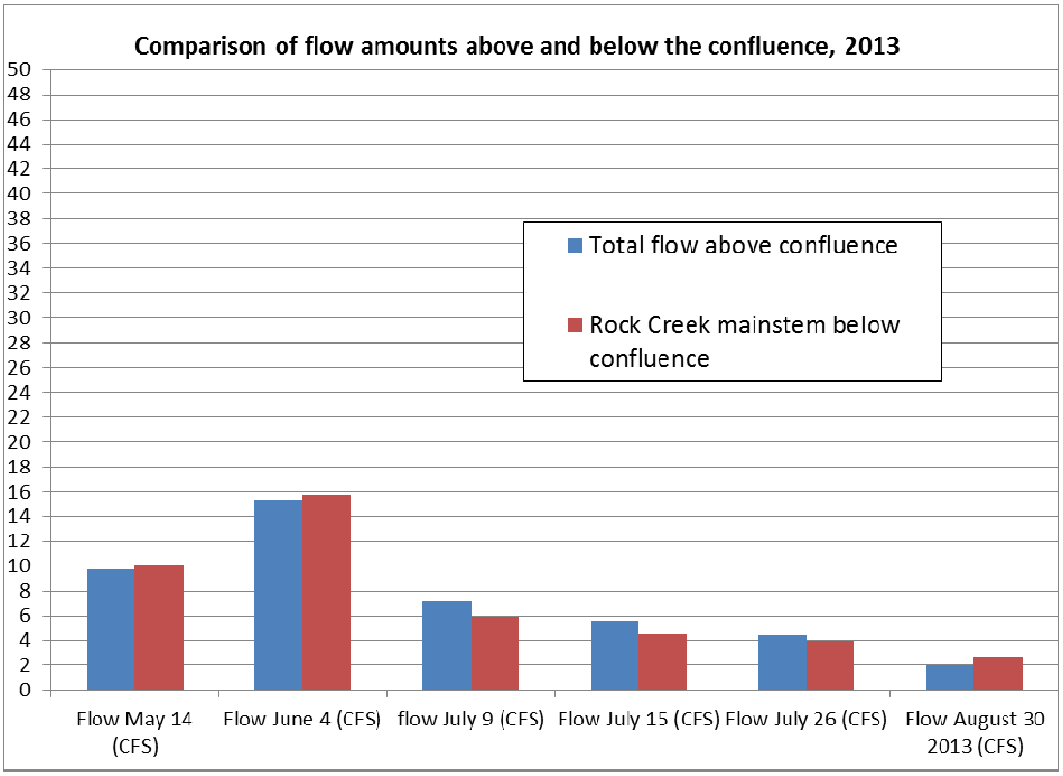

Figure 24. Bar graph comparing total amount of flow above the confluence with the Rock Creek mainstem below the confluence, 2013

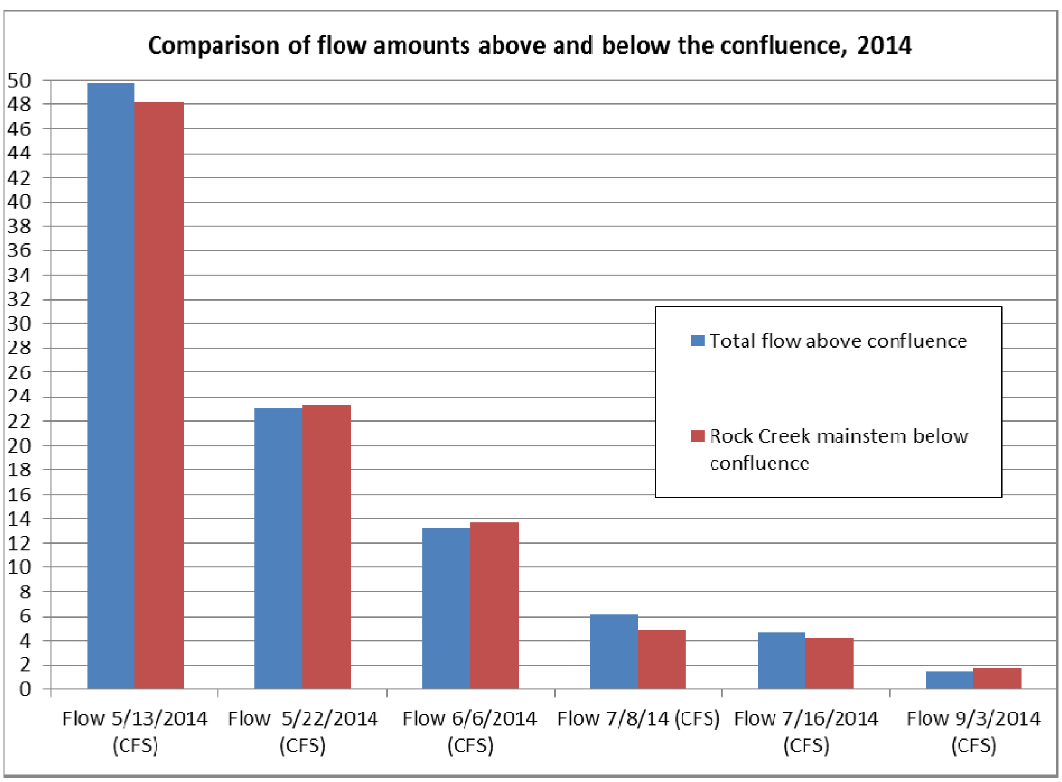

Figure 25. Bar graph comparing total amount of flow above the confluence with the Rock Creek mainstem below the confluence, 2014

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**

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 26).

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 27). 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.

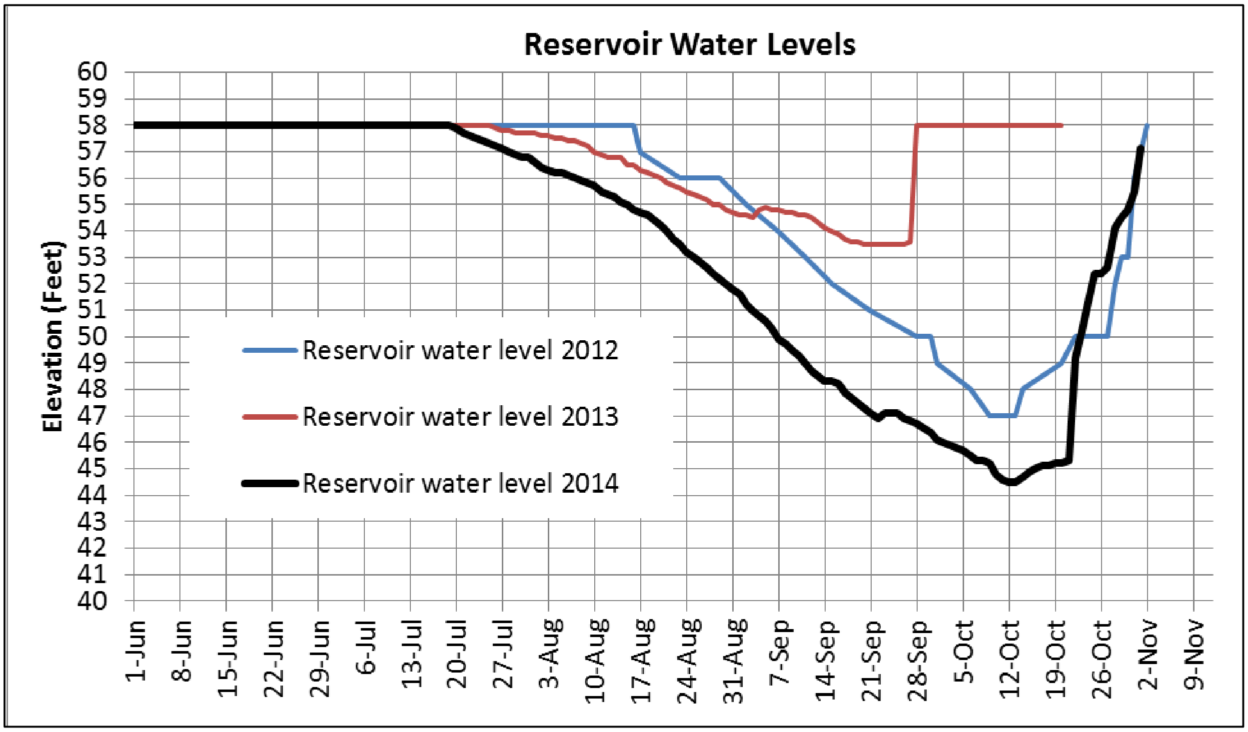

Figure 26. Comparison of summer reservoir levels in 2012, 2013 and 2014. The reservoir level began to drop on July 26, 2013; two weeks earlier than in 2012. The reservoir re-filled in one day, due to the significant rainstorm at the end of September, 2013. In 2012 and 2014, the reservoir continued to 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.

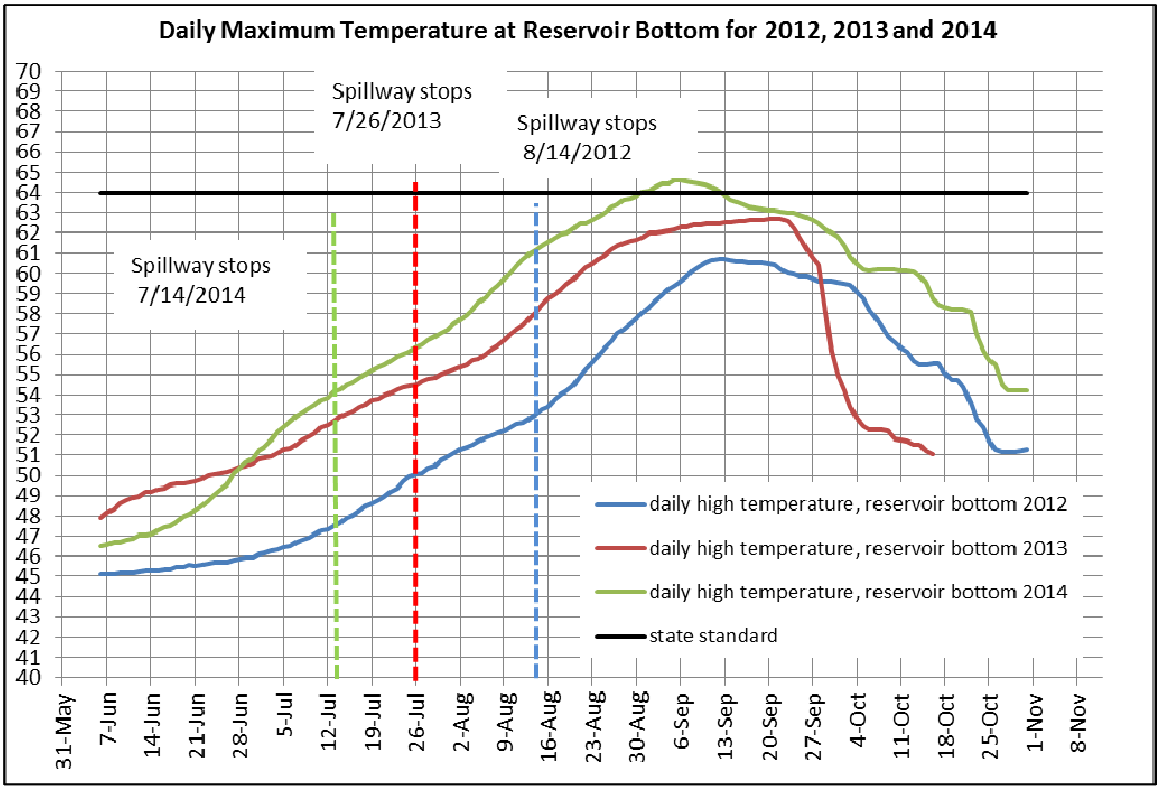

Figure 27. Comparison of the temperatures at the bottom of the reservoir in 2012, 2013 and 2014.

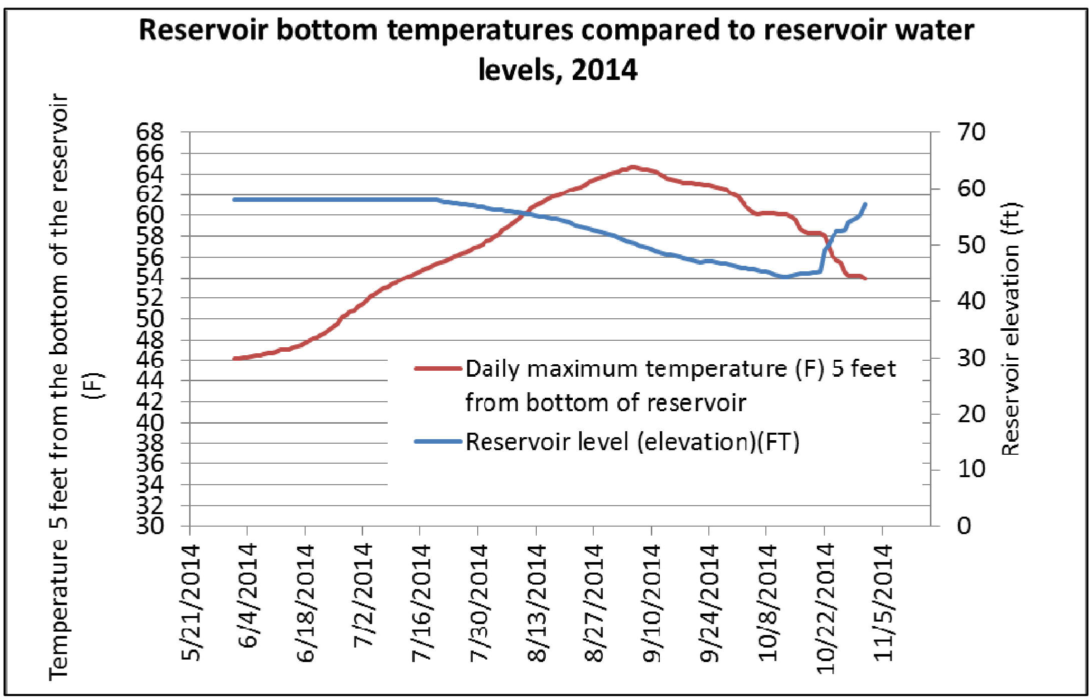

Figure 28. Temperature trends at the bottom of the reservoir are compared to the reservoir water levels through the summer of 2014. The bottom temperature gradually rises, even in the early summer when the reservoir is full and the water level isn't changing.

Figures 4 and 7 show the map view of the probes that bracketed the reservoir. 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. Figure 29 shows the depth of the probes and the level of the reservoir through the summer.

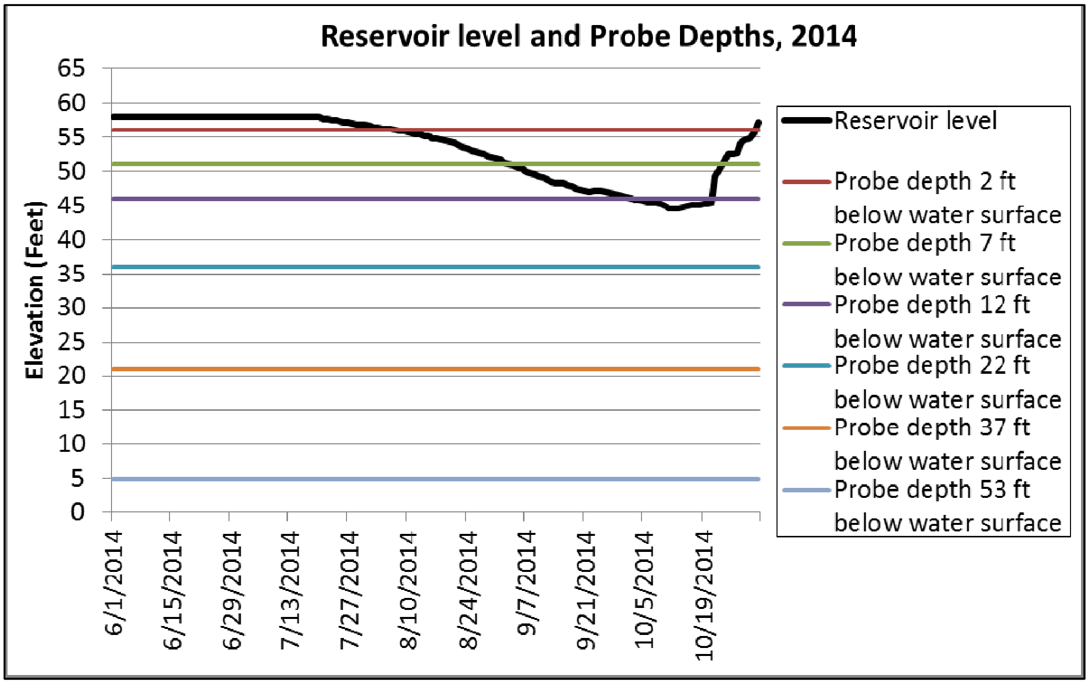

Figure 29. Depth of temperature probes on rope suspended from wooden tower in the reservoir.

Figures 30 shows the reservoir temperatures by depth in 2014.

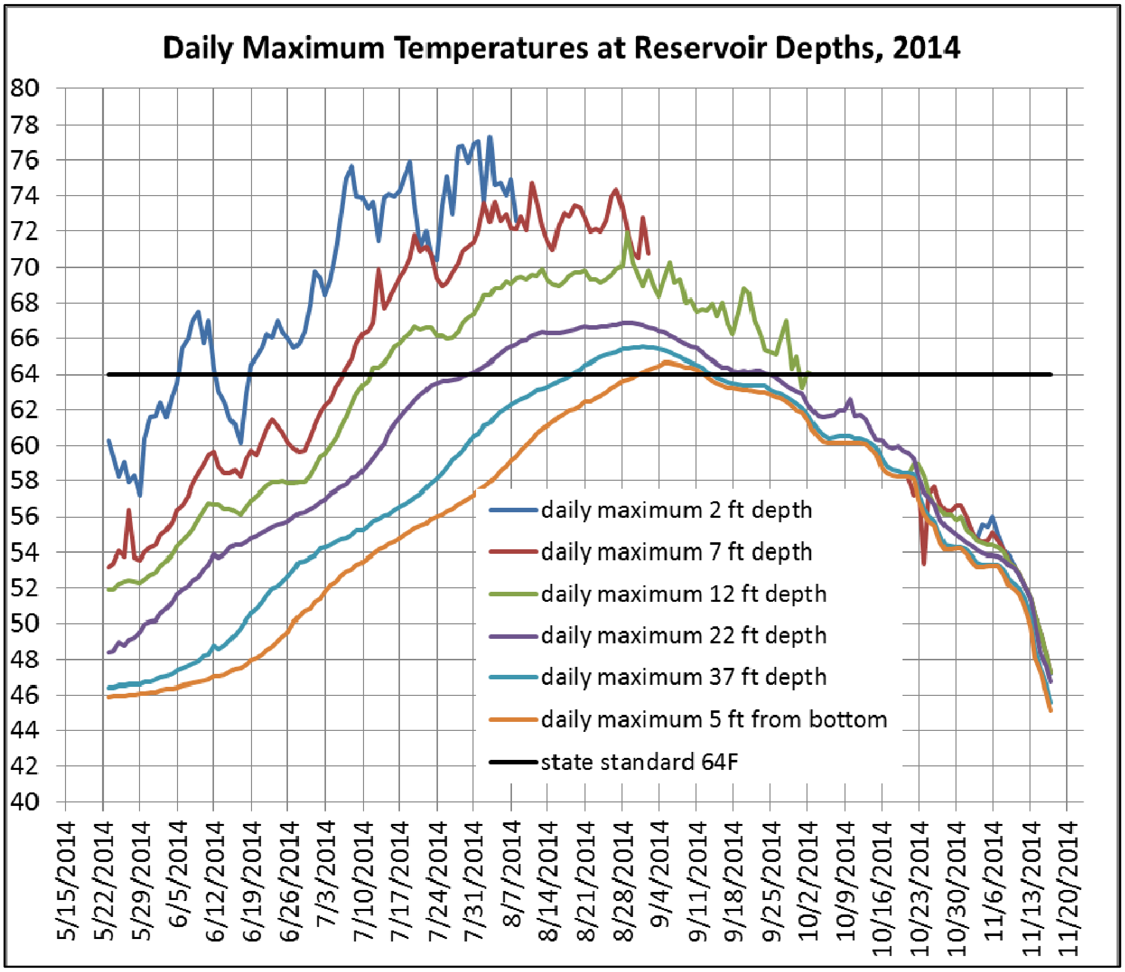

Figure 30. Comparison of temperatures in the reservoir at the monitored depths. The bottom of the reservoir was slightly above 64F in early September for the first time since the reservoir was monitored.

Figures 29 and 30 show the comparison of daily maximum water temperatures around the North and South Fork confluence below the dam for 2013 and 2014, respectively. 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 both years. At that point the temperatures just above the confluence are cooler than the spillway, reflecting the decreasing flows from the spillway. The spillway stopped flowing on July 26, 2013 and July 14, 2014.

In both 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.

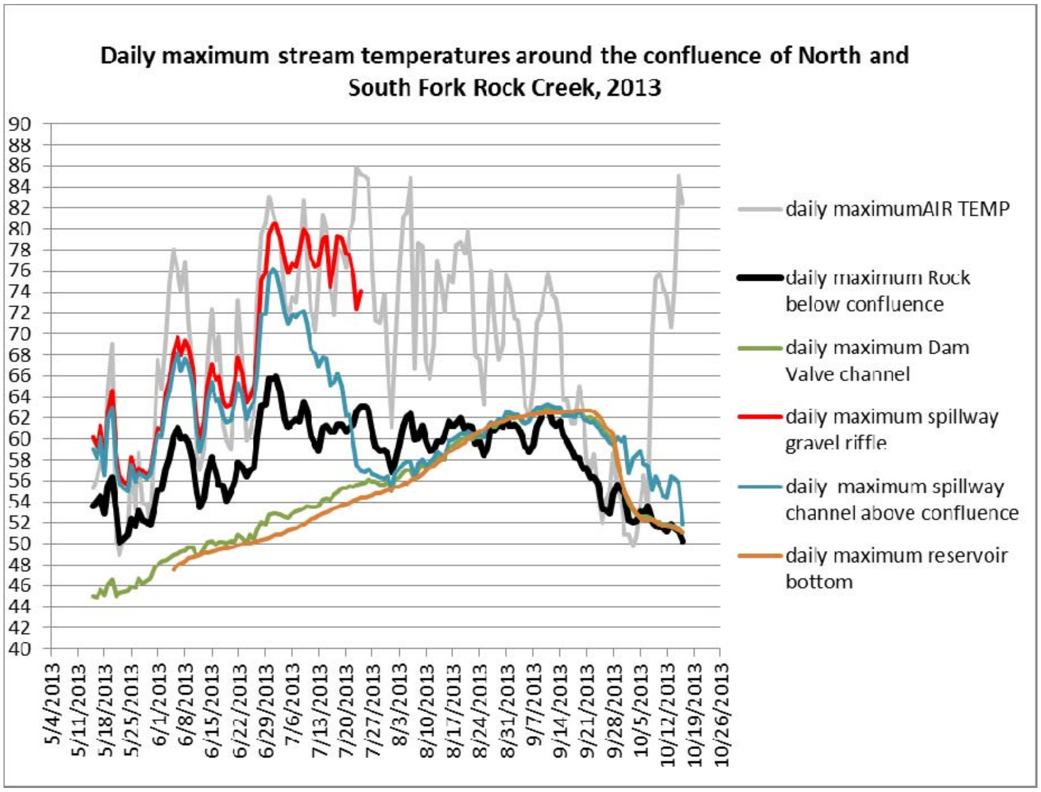

Figure 31. Comparison of daily maximum temperatures in the channels below the dam and around the confluence of the North and South Forks of Rock Creek, 2013.

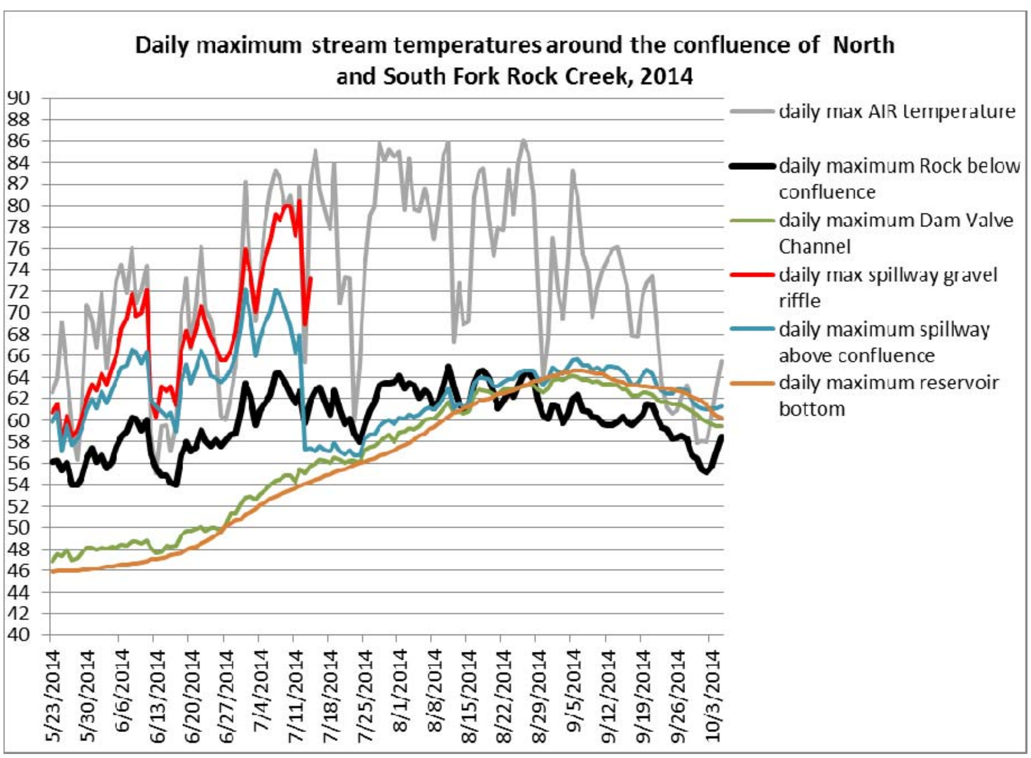

Figure 33. Comparison of daily maximum temperatures in the channels below the dam and around the confluence of the North and South Forks of Rock Creek 2014.

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. 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 Figures 34 and 35. The amounts above and below the confluence are reasonably close, and parallel the flow amount comparisons in figures 24 and 25.

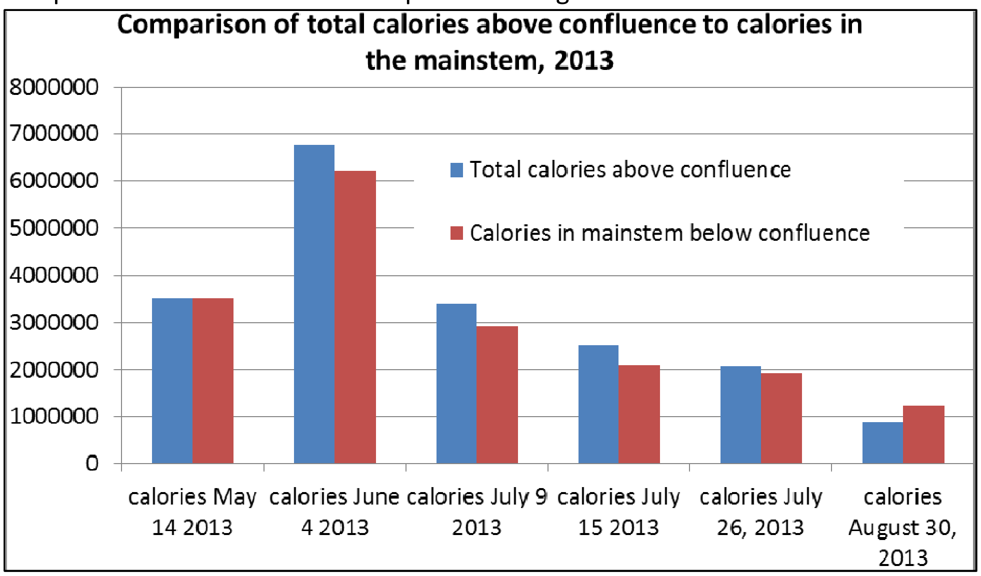

Figure 34: Graphs showing the comparison of caloric content in the sum of the channels above the confluence and the mainstem below the confluence in 2013.

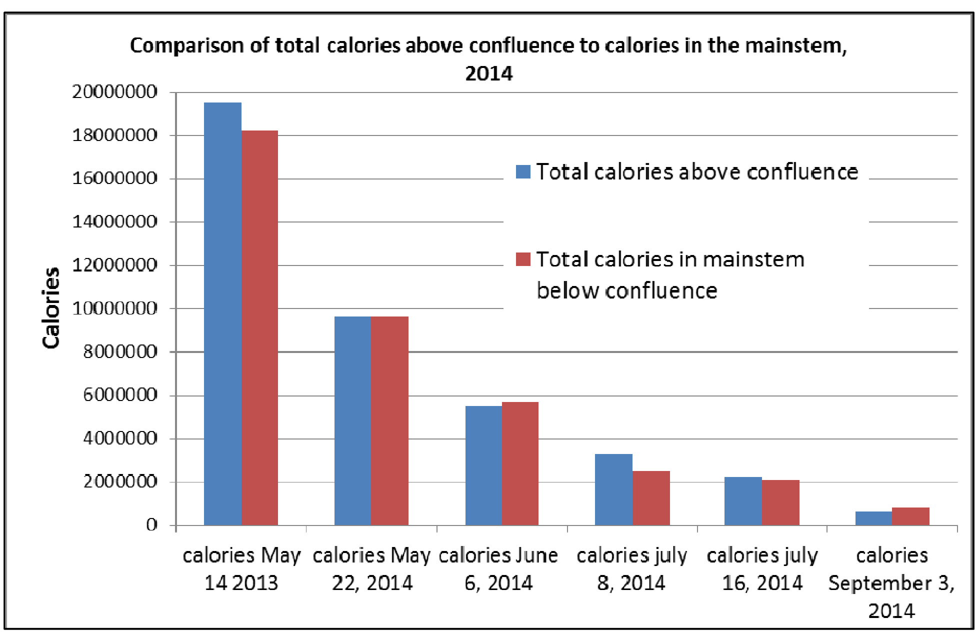

Figure 35. Graphs showing the comparison of caloric content in the sum of the channels above the confluence and the mainstem below the confluence in 2014.

Tables 5 through 8 show the actual measured data used for the 2013 calculations, and Tables 9 through 12 show the data used for 2014.

Tables 13 through 16 show the results of the calculations.

Data used in 2013 calculations

Table 5: Data for May 14, 2013

Site	CFS May 14, 2013	Temp C May 14, 2013	calories May 14 2013
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 6. Data for June 4, 2013

Site	CFS June 4 2013	Temp C June 4, 2013	calories June 4 2013
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 7. Data for July 9, 2013

Site	CFS July 9, 2013	Temp C July 9, 2013	calories July 9, 2013
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 8. Data for July 15, 2013

Site	CFS July 15, 2013	Temp C July 15, 2013	calories July 15, 2013
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

Table 9. Data for May 14, 2013

Site	cfs May 13, 2014	Temp C May 13, 2014	calories May 13, 2014
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 10. Data for May 22, 2014

Site	cfs May 22, 2014	Temp C May 22, 2014	calories May 22, 2014
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 11. Data for June 6, 2014

Site	cfs June 6, 2014	Temp C	calories June 6, 2014
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 12. Data for July 8, 2014

Site	CFS July 8, 2014	Temp C	calories July 8, 2014
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

Results for 2013

Table 13. 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 14. 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 36 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.

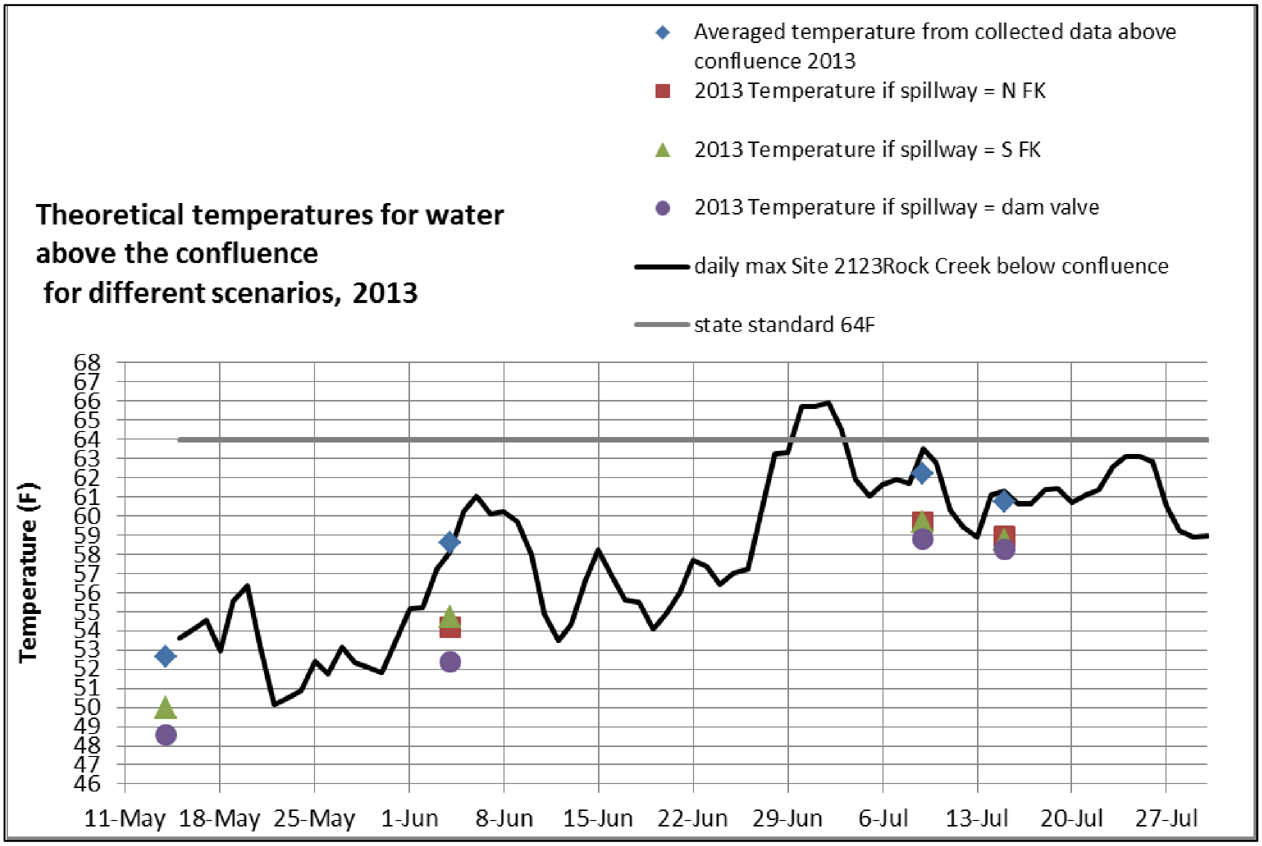

Figure 36. The theoretical difference in temperature between the averaged temperature above the confluence from measured data, and the calculated temperatures based on difference scenarios for 2013. The calculations, represented as points, are done for days when flow was measured. The solid black line 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.

Comparison of results for 2014

Table 15. 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 16. 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 37 shows the 2014 results in graphic form, and is the same data for a different year as figure 36.

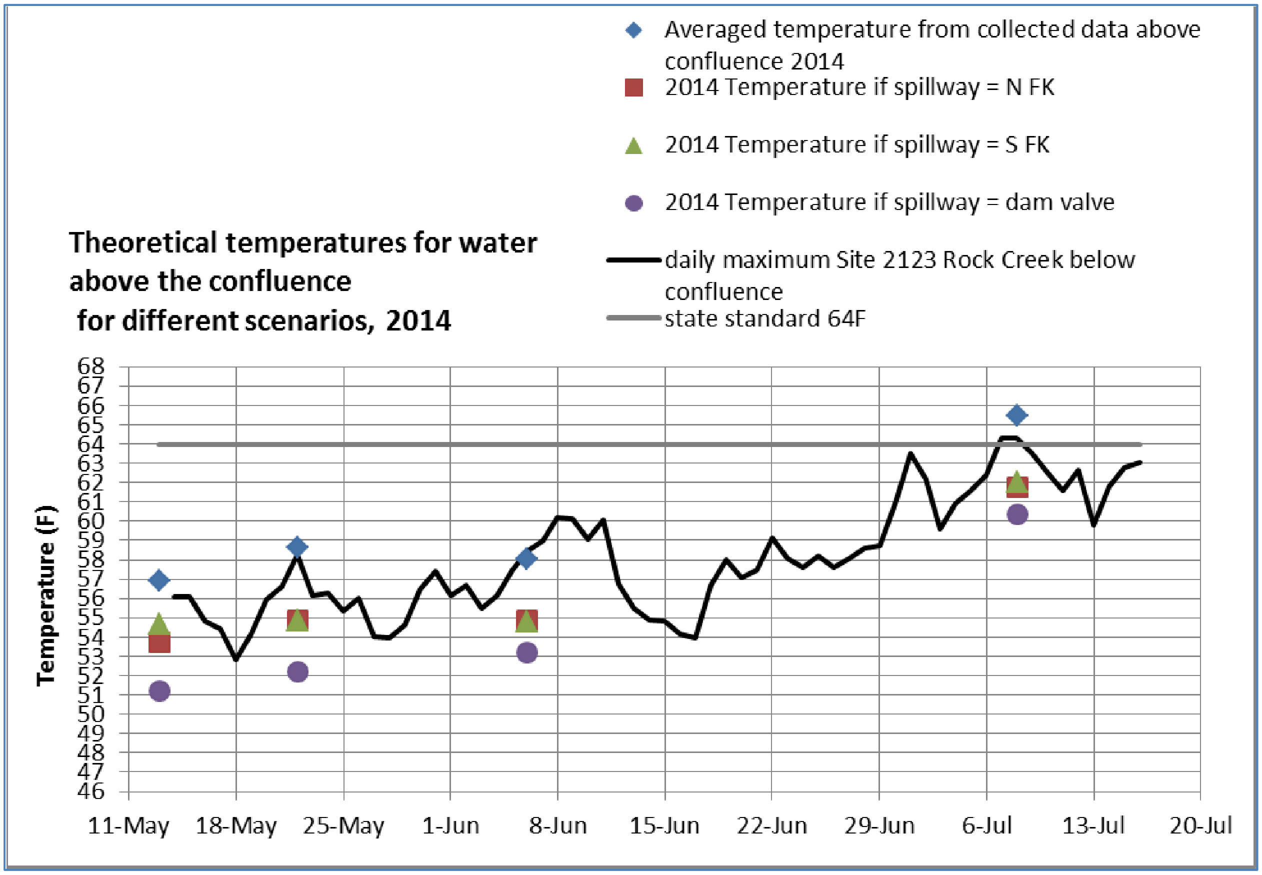

Figure 37.

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 Figures 38, 39 and 40, 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 both 2013 and 2014. The average difference in temperature is 1.7 F in 2013, and 1.4 F in 2014. 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 41).

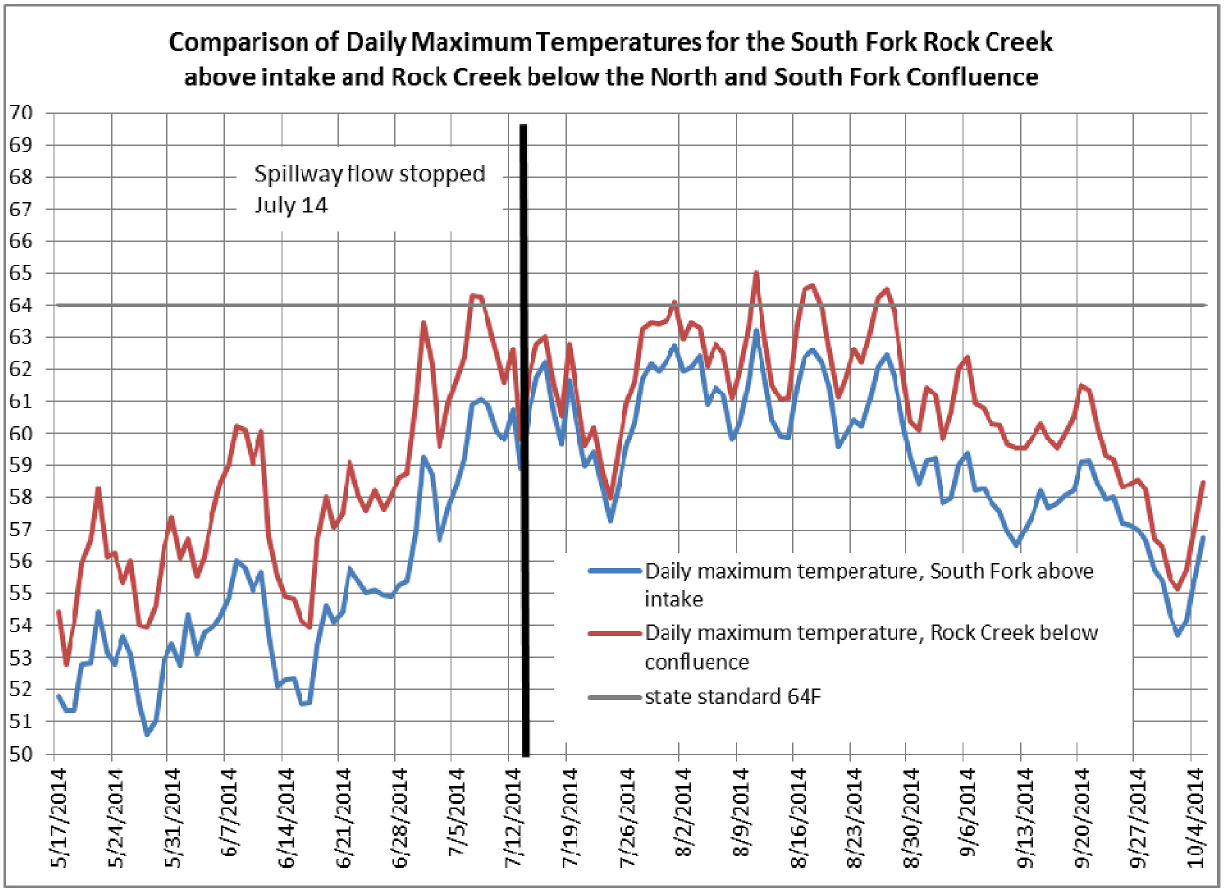

Figure 38: 2014 daily maximum temperatures above and below the influence of the dam and spillway. Note that after the spillway stops flowing on July 14, the difference is less.

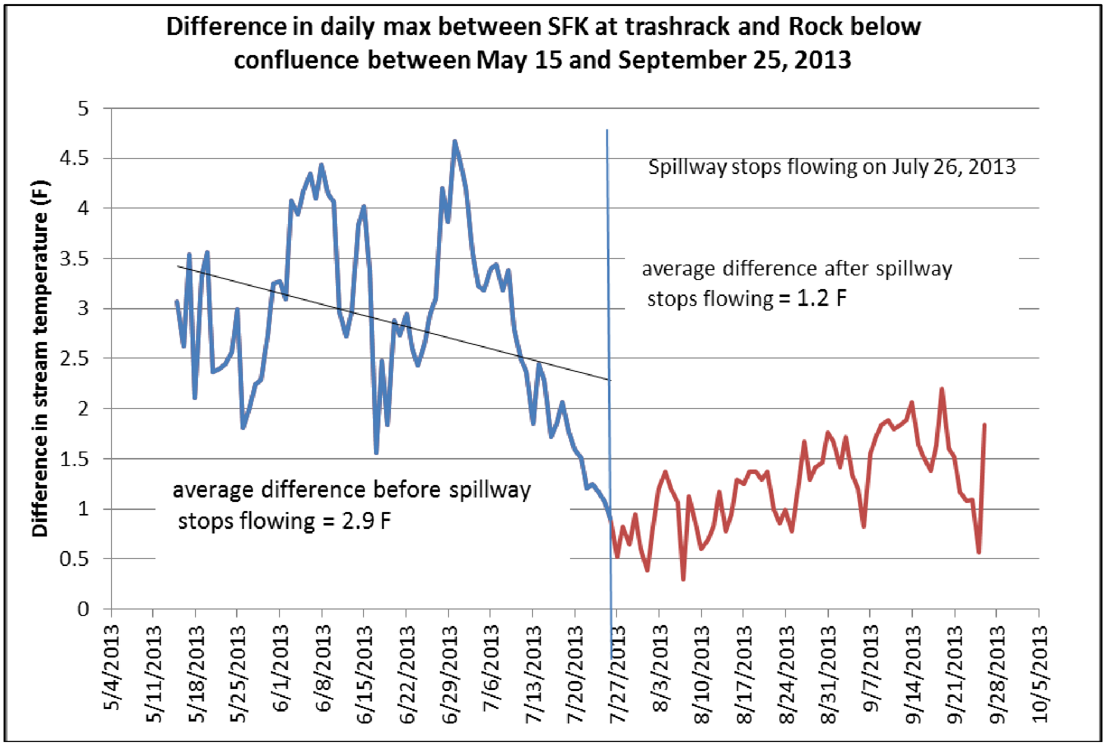

Figure 39. Difference in daily maximum temperatures between the South Fork Rock Creek and the mainstem Rock Creek below the confluence in 2013. The black line is the trend line.

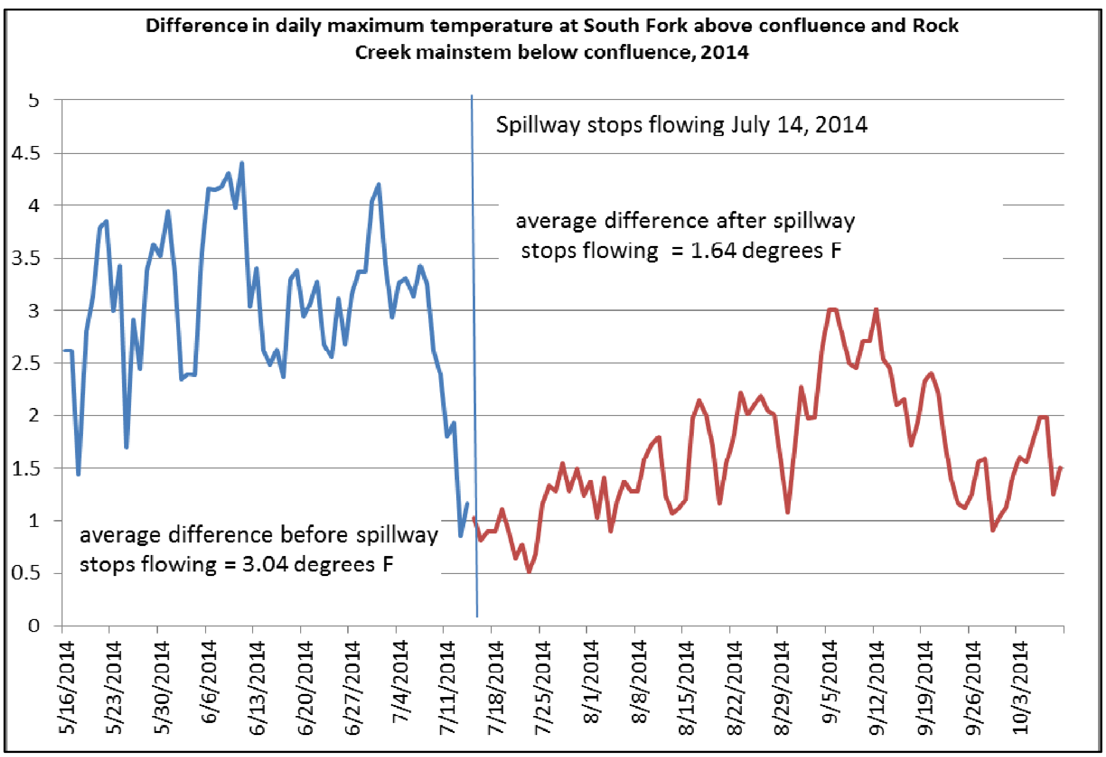

Figure 40. Difference in daily maximum temperatures between the South Fork Rock Creek and the mainstem Rock Creek below the confluence in 2014.

Figure 41: 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 below the confluence between end of June through July 14. 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 graph (Figure 41) 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 decrease in the temperature difference as the spillway flow diminishes. On May 13, the spillway contributed 40% of the mainstem's flow below the confluence

(Figure 42). It decreased to 24% on June 6; it was 26.5% of the mainstem's flow on July 8, and stopped flowing on July 14. 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 difference 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?

Figure 43 shows the air temperature trends for the same period of time as Figure 42. Note that there is no abrupt drop in air temperatures in mid-July.

The graphs in Figure 44 show the difference in daily maximum temperature between the Rock Creek mainstem sites and the South Fork above the intake from June 6 to July 14, the day the spillway stopped and would no longer have an influence on temperature. 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.

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

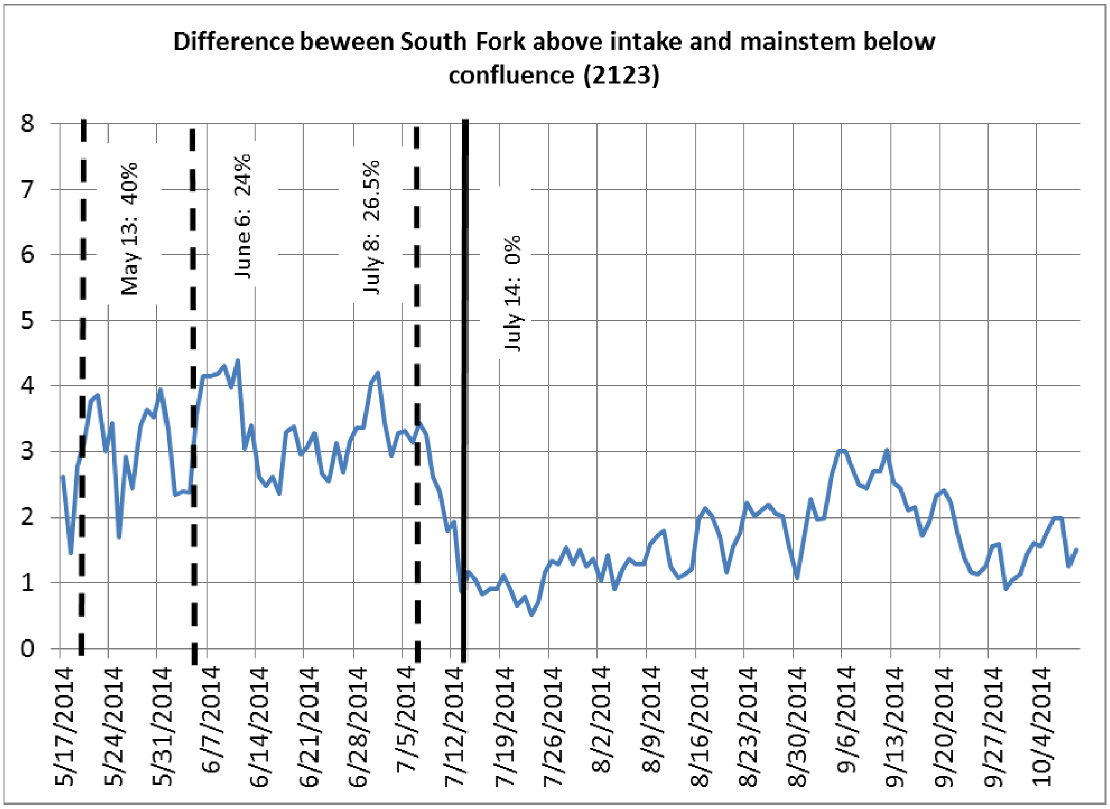

Figure 42. The difference in temperature (F) is calculated by subtracting the daily maximum stream temperature at the South Fork Rock Creek site above the intake from the Rock Creek mainstem site 120 feet below the confluence of the North and South Forks of Rock Creek. As the spillway flow contribution decreases, the difference in temperature decreases.

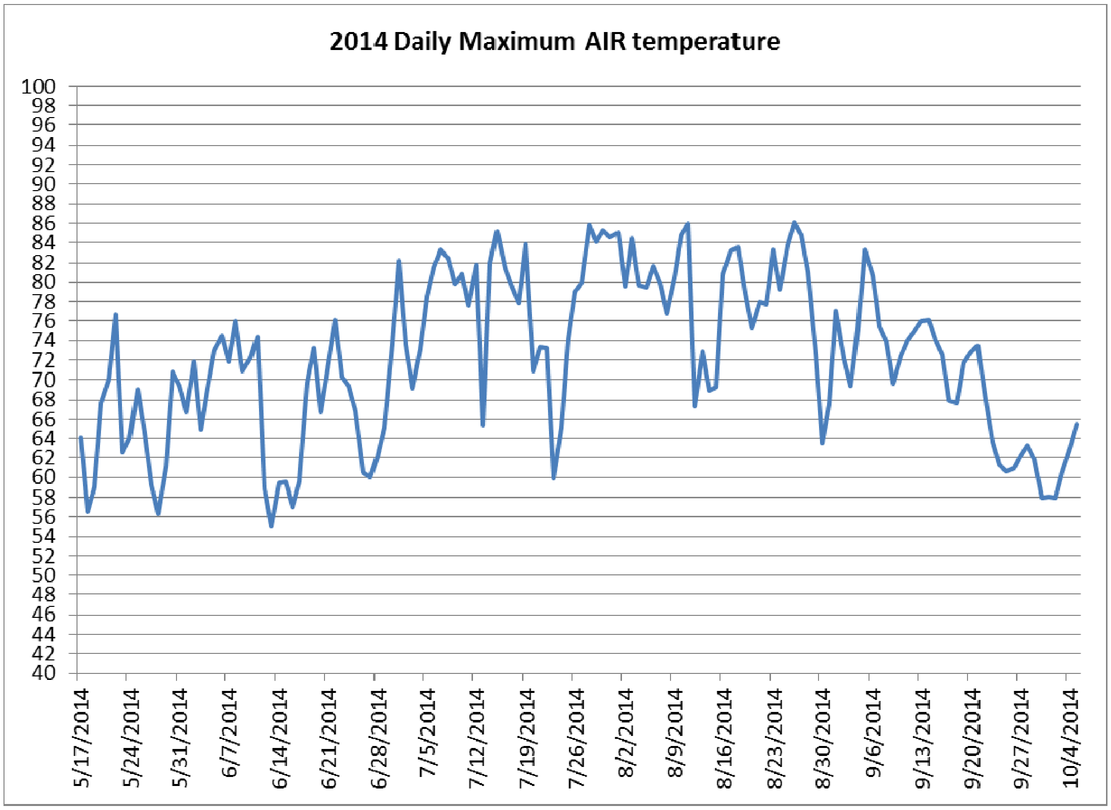

Figure 43. Daily maximum air temperature measured in the riparian zone at the South Fork site above the intake.

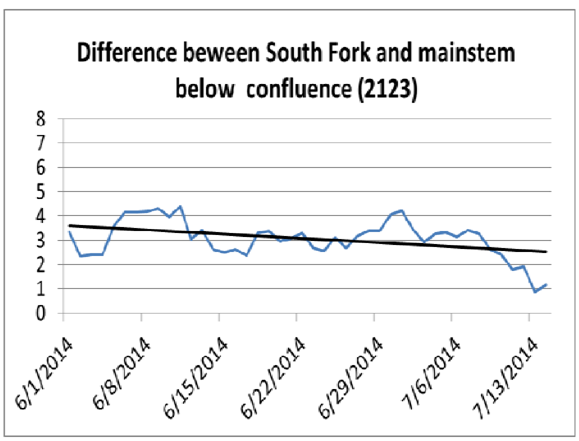

Figure 44a. Site 2123 is .02 miles downstream from the dam. Drainage area to site 2123 is 8.53 square miles.

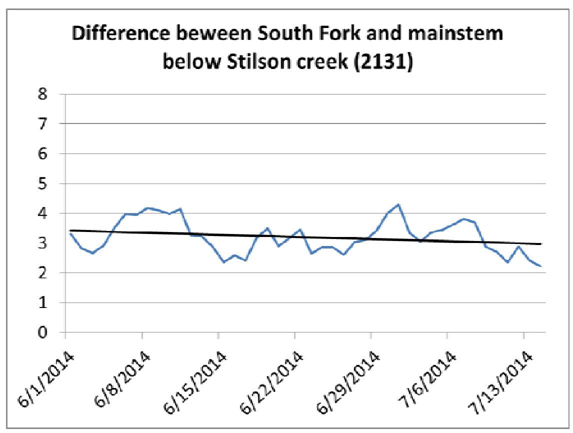

Figure 44b. Site 2131 is 0.77 miles downstream from the dam. Drainage area to site 2131 is 9.65 square miles.

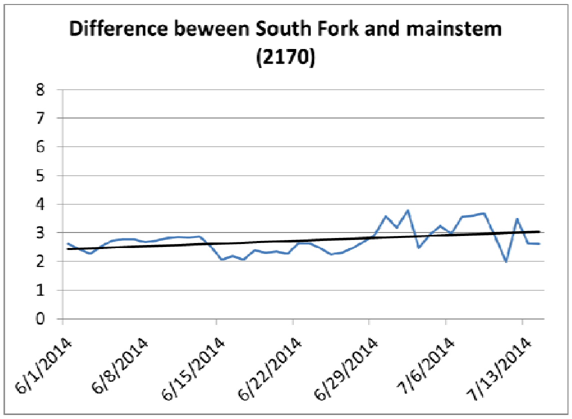

Figure 44.: Site 2170 is 1.35 miles downstream from the dam. Drainage area to site 2170 is 10.6 square miles.

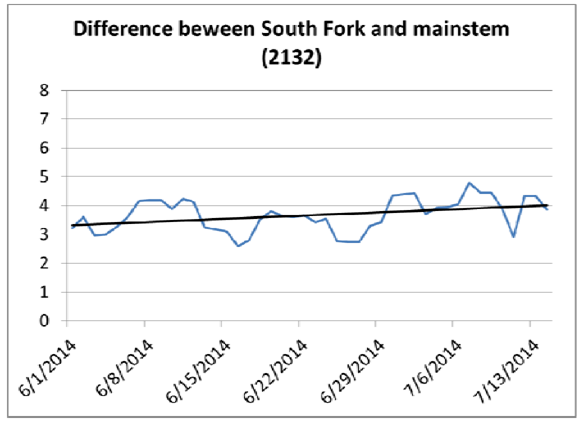

Figure 44f. Site 2132 is 2.67 miles downstream from the dam. Drainage area to site 2132 is 12.3 square miles.

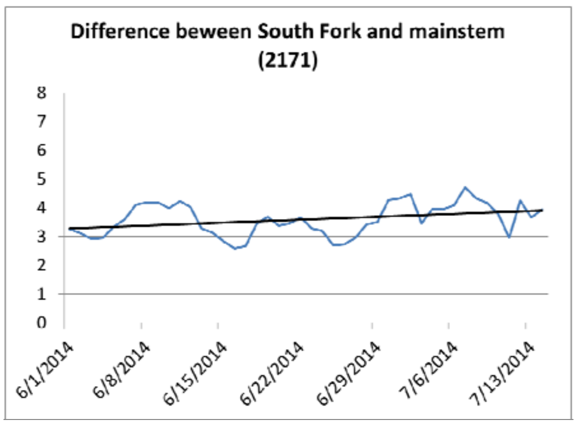

Figure 44d. Site 2171 is 1.9 miles downstream from the dam. Drainage area to site 2171 is 10.8 square miles.

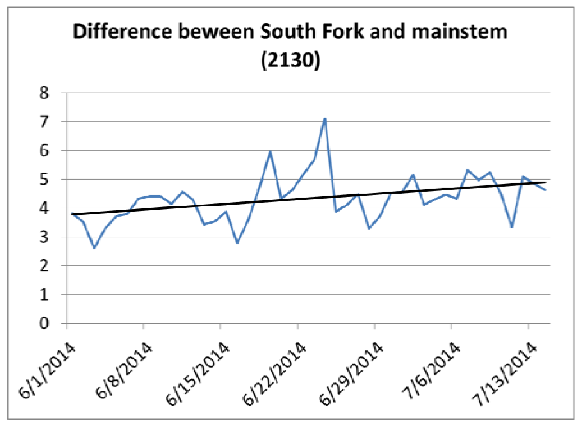

Figure 44g. Site 2130 is 2.79 miles downstream from the dam. Drainage area to site 2130 is 12.4 square miles

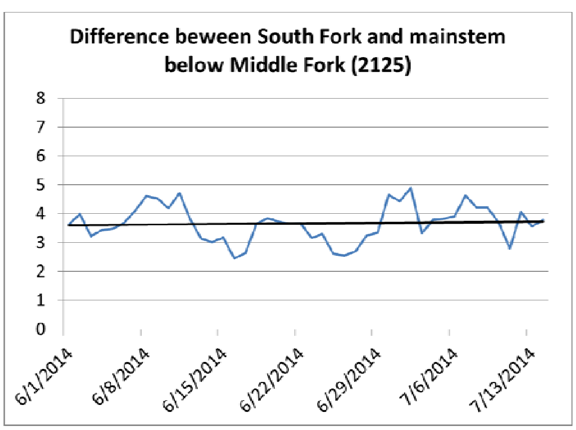

Figure 44e. Site 2125 is 2.17 miles downstream from the dam. Drainage area to site 2125 is 12.2 square miles.

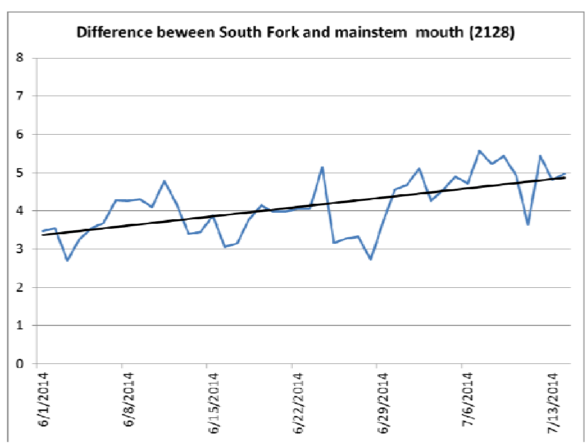

Figure 44h. Site 2128 is 3.72 miles downstream from the dam. Drainage area to site 2128 is 14.8 square miles.

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.

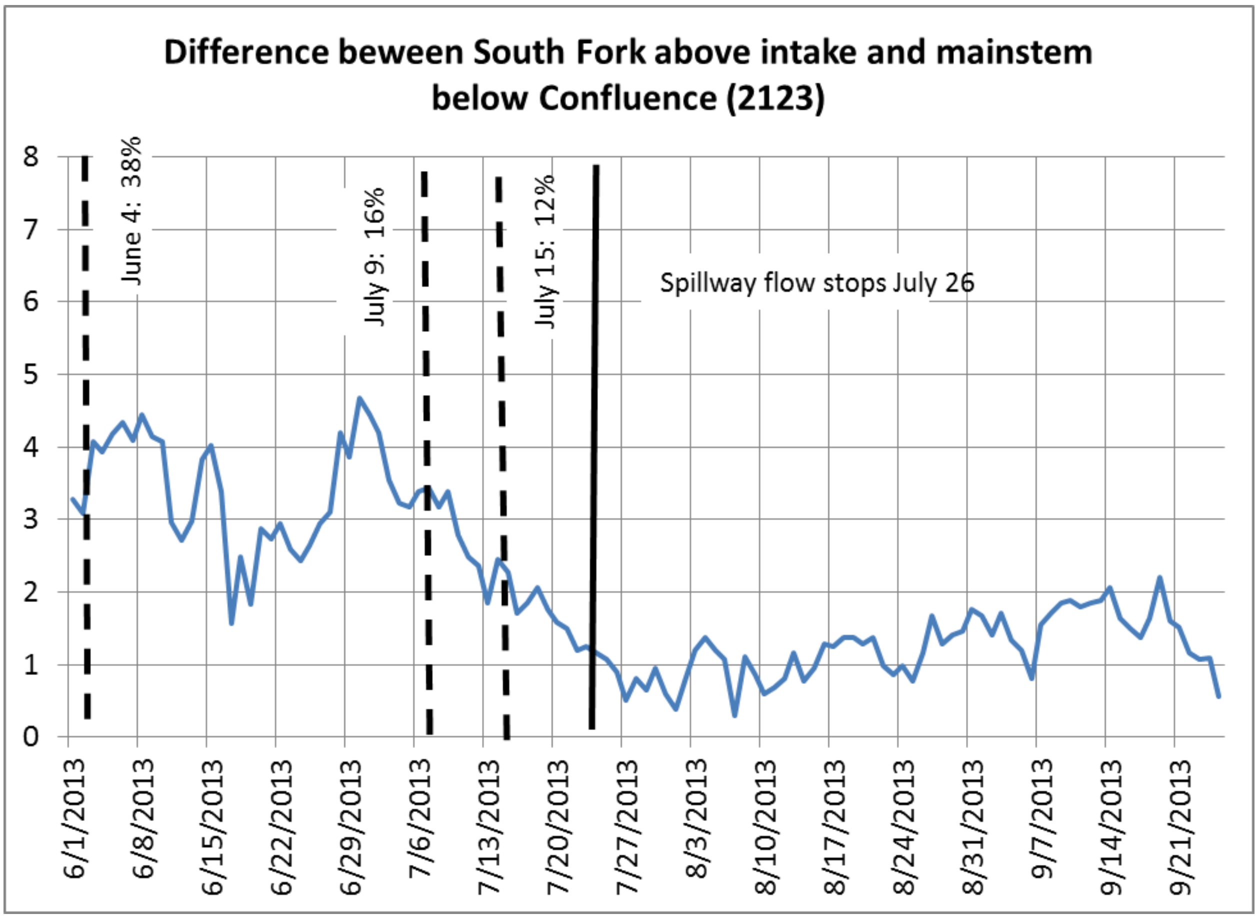

Figure 45. 2013 comparison of the daily maximum stream temperatures at the South Fork above the intake and the mainstem below the confluence. The % of the mainstem flow that is contributed by the spillway is shown next to the vertical lines.

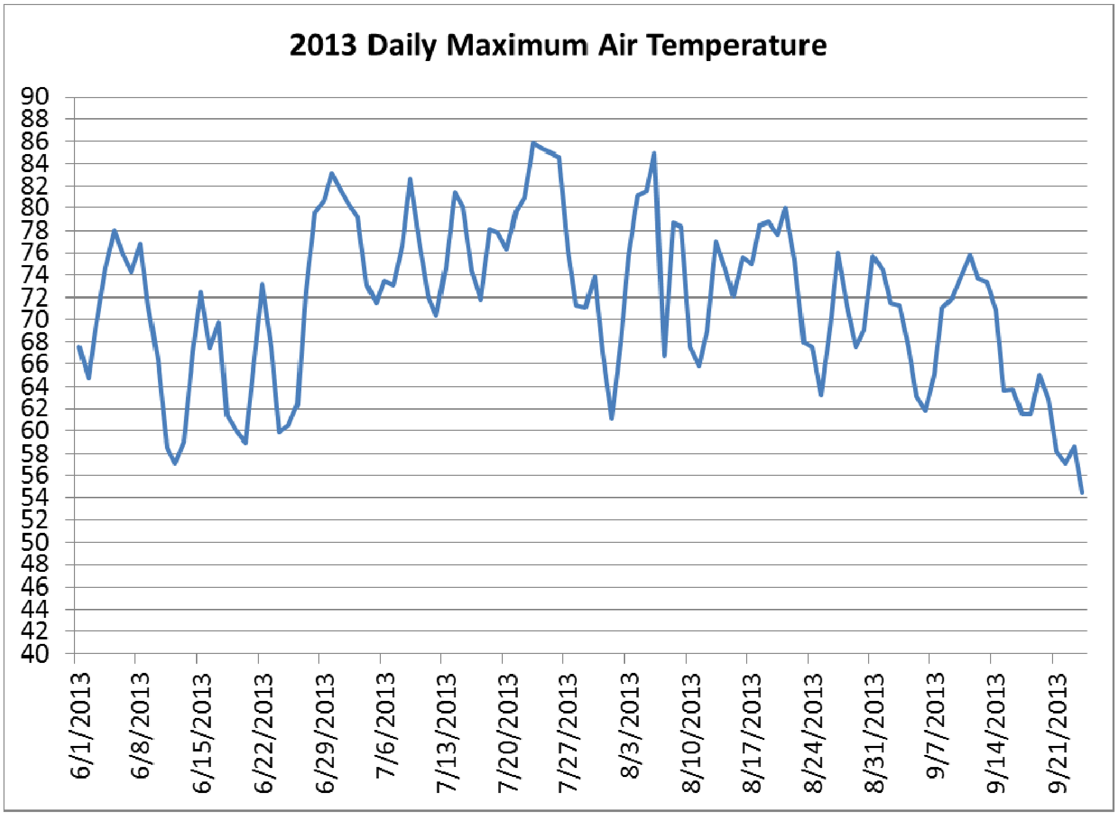

Figure 46. Air temperatures for 2013.

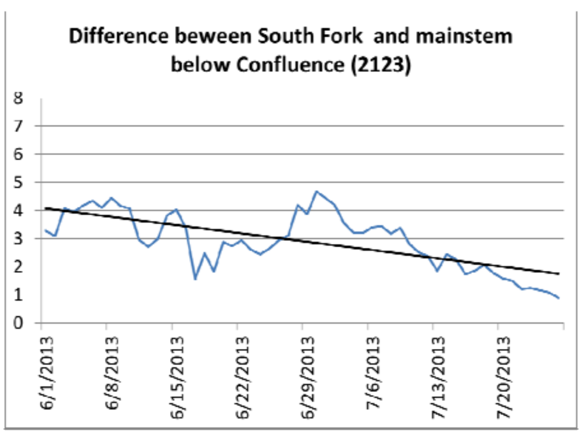

Figure 47a. Site 2123 is .02 miles downstream from the dam.

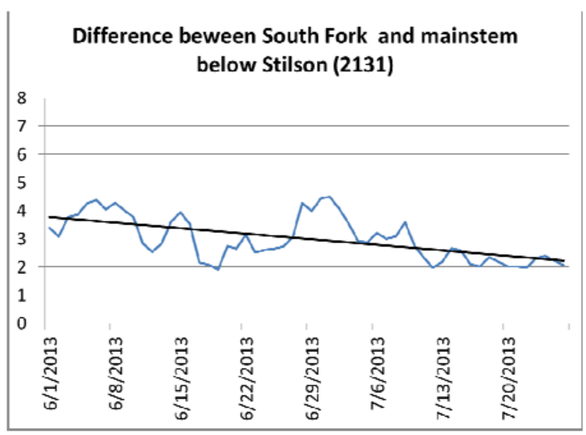

Figure 47b. Site 2131 is 0.77 miles downstream from the dam.

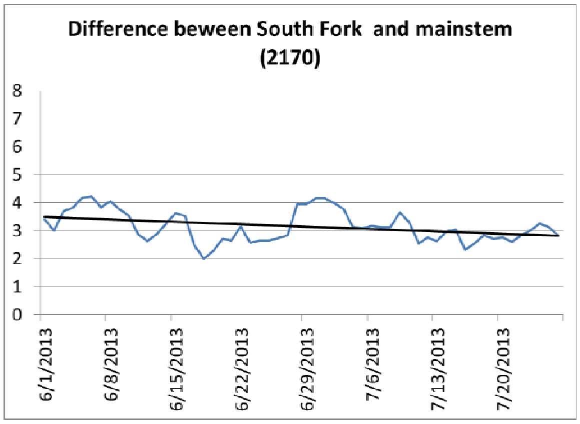

Figure 47c. Site 2170 is 1.35 miles downstream from the dam.

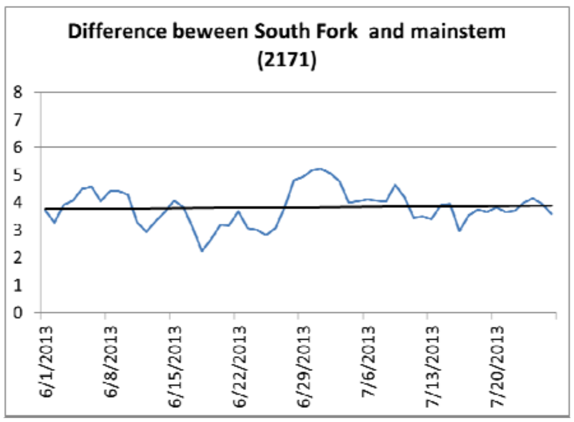

Figure 47d. Site 2171 is 1.9 miles downstream from the dam.

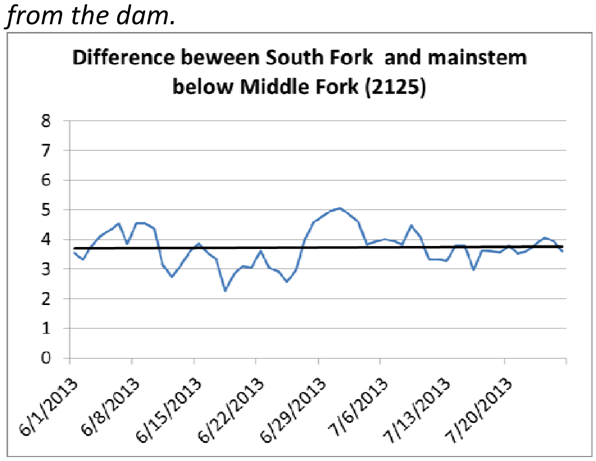

Figure 47e. Site 2125 is 2.17 miles downstream from the dam.

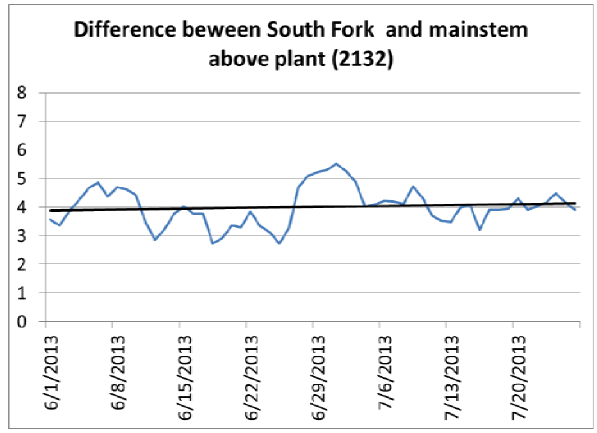

Figure 47f. Site 2132 is 2.67 miles downstream from the dam.

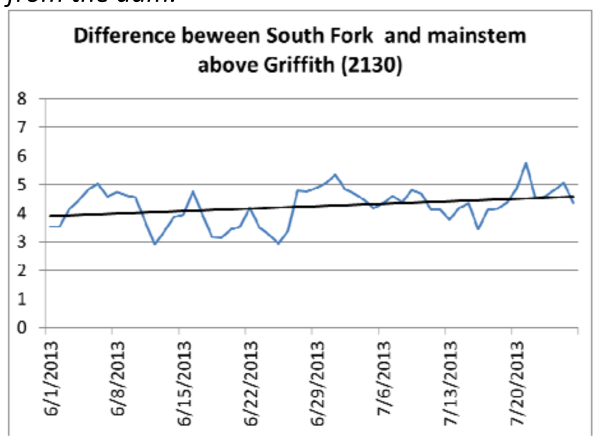

Figure 47g. Site 2130 is 2.79 miles downstream from the dam.

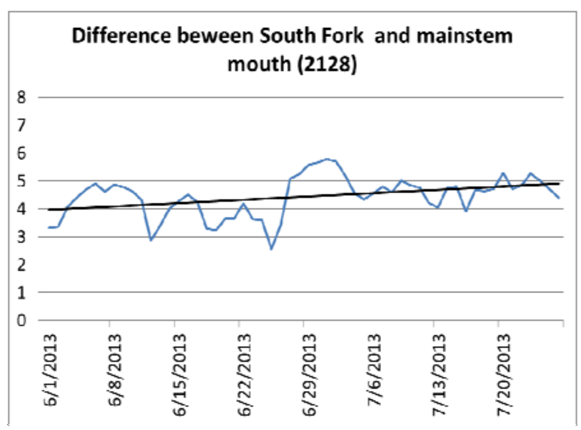

Figure 47h. Site 2128 is 3.72 miles downstream from the dam.

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.

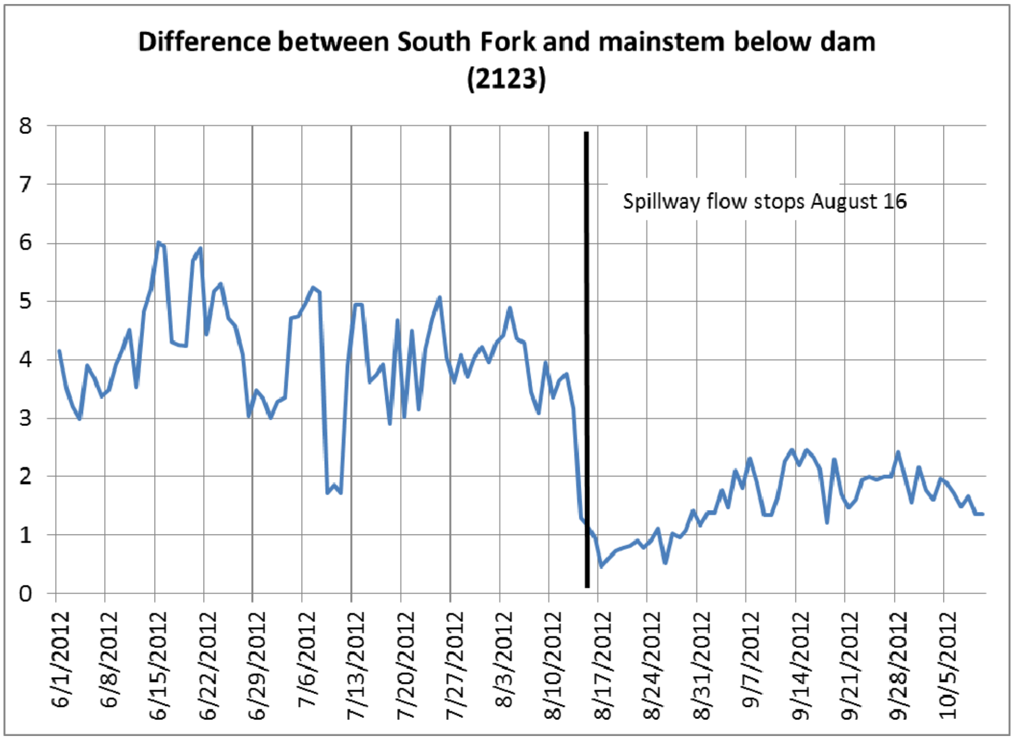

Figure 48. Difference beween the South Fork Rock Creek above the confluence and Rock Creek below the confluence for 2012.

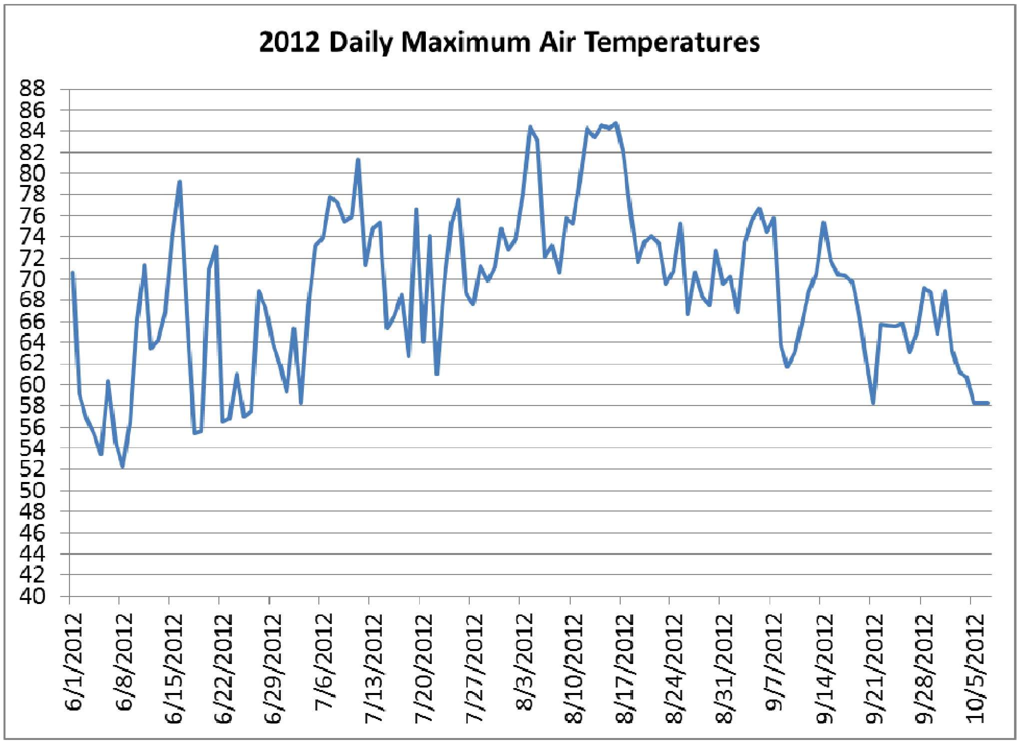

Figure 49. Maximum daily air temperatures for 2012.

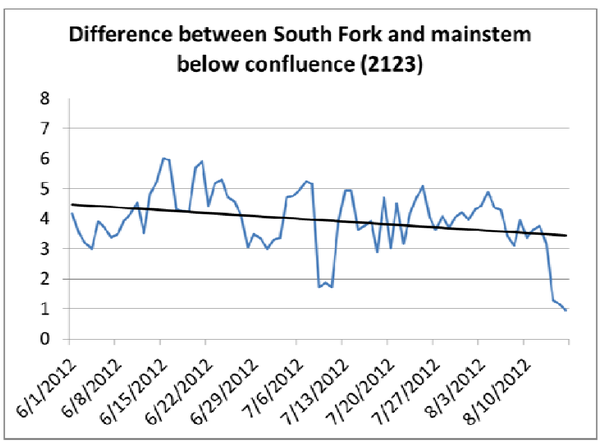

Figure 50a. Site 2123 is .02 miles downstream from dam.

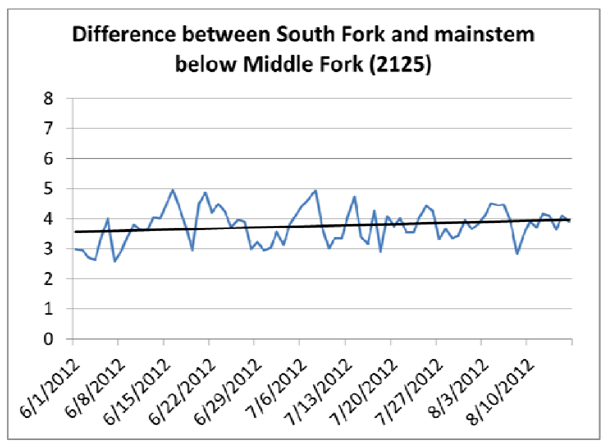

Figure 50b. Site 2125 is 2.17 miles downstream from the dam.

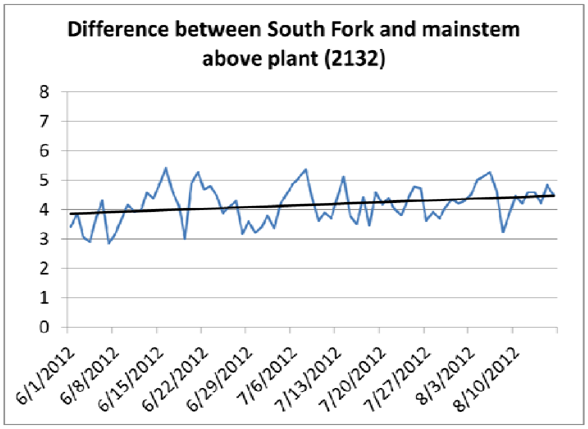

Figure 50c. Site 2132 is 2.67 miles downstream from the dam.

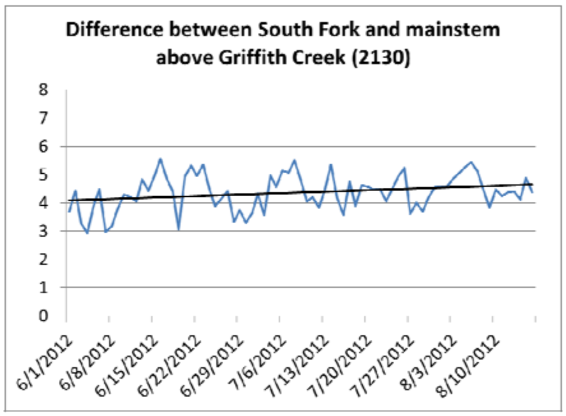

Figure 50d. Site 2130 is 2.79 miles downstream from the dam.

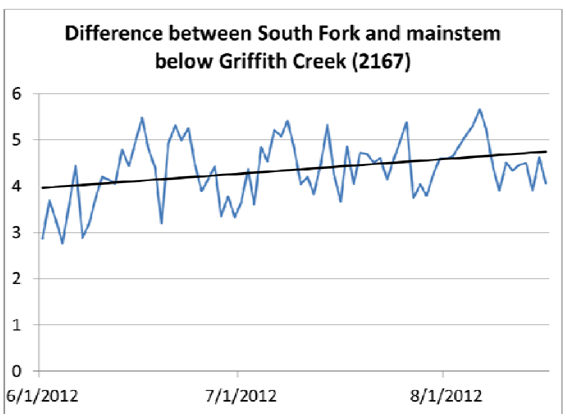

Figure 50e. Site 2167 is 2.89 miles downstream from the dam.

Three years of data suggest that the effects of the spillway are become increasing difficult to detect between one and two miles downstream of the dam. Two of the larger tributaries, Middle Fork Rock Creek and Griffith Creek increase the stream flow and dilute the effects of the spillway flow. It is unlikely that the heat contribution from the spillway is reaching as far as the confluence of Rock Creek with Greasy Creek.

Summary and Conclusions

The summer of 2014 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. 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 began to drop and the spillway stopped flowing on July 14, 2014, which is two weeks earlier than in 2013. At its lowest point on October 12, 2014, it was over 2 feet lower than in 2013. Starting in late June, 2014, the bottom of the reservoir was one to two degrees warmer than in 2013. The bottom of the reservoir was warmer in 2013 by 2 to 5 degrees F, compared to 2012. By mid-August in the last two years, the bottom of the reservoir was the same temperature or slightly warmer than the mainstem of Rock Creek below the confluence.

With the exception of Stilson Creek, where the 7-day average maximum temperature reached 64.12 F, the tributaries all met the state water quality standards.

As in 2013, flow data was collected during the summer in 2014, 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 both years. The May 14 and June 4, 2013 results were corrected for in this year's report due to an initial error in 2013 while calculating flows.

While the spillway was flowing in 2013, an increase of approximately 2 to 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 both years, stream temperatures in the late spring to mid-summer were relatively cool when the spillway flow was higher. During the periods of high spillway flow, the mainstem was below the state water quality standard of 64 F for the 7-day average of the daily maximum temperature.

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. Therefore, it is unlikely that the spillway temperatures are having an effect at the mouth of Rock Creek.