Memorandum

To: *Elissa Ostergaard, Miller-Walker Basin Steward, King County*

From: *Eric Ferguson, Daniel Smith, David Funke and Dean Wilson, Water Quality Planners, King County*

Date: *April 9, 2014*

Subject: *Miller/Walker Creek Monitoring Activities for 2013*

This document describes the Miller/Walker Creek Water Quality Monitoring for 2013. The program is designed to monitor and assess water quality in Miller and Walker Creeks.

Data Collection and Evaluation

The monitoring completed in 2013 within the Miller and Walker Creek Basin included stream flow, stream water quality and stream biological assessments (Figure 1). This section summarizes the activities. Figures and Tables are presented at the end.

Individual probes for dissolved oxygen (DO), pH and turbidity were deployed at sites in both Miller and Walker Creeks during the winter of 2012-13. These probes collect a continuous data series and can be compared to water quality standards and thresholds so that ecological and human health risks can be identified.

Use designations from the Washington State Water Quality Standards (WAC 173-201A) indicate that Miller and Walker Creeks are considered core salmon summer habitat. Juvenile coho salmon and cutthroat trout are observed in the stream year round. The State Water Quality Standards for temperature, dissolved oxygen (DO), turbidity and pH are listed in Table 1.

Key Findings

•Water quality in 2013 in Miller and Walker Creeks often did not meet state water quality standards for temperature, dissolved oxygen and pH. However, results are similar to other streams in urban areas.

•Monitoring indicated that flows in Miller Creek below Ambaum Pond peak with enough erosive force to damage instream habitat. Much of this stormwater flow originates from the downtown Burien area. Flows in Walker Creek were flashy but were lower in magnitude than Miller Creek.

Rainfall

King County operates a recording rain gage (42U) in the Miller Creek basin. The Miller Creek hydrologic monitoring took place mainly in water year 2013 (October 2012 – September 2013). The total rainfall for water year 2013 was 47.14 inches, which about the same as the total from National Weather Service Sea-Tac station (47.4 inches). Average annual rainfall based on the last 60 years of data from the Sea-Tac station is 38. 4 inches. The 23 year record (1991 – 2013) for King County gage 42U is 41.2 inches. Rainfall for the monitoring period was above average for the fall months October – December 2012, then below average during the winter months January – March 2013. A very wet April made the spring total above average. July was nearly dry, August normal, and September set a record for rain at over 6.7 inches. Monitoring continued into water year 2014. Both October and November 2013 were below average for rainfall.

The largest hourly accumulations occurred during summer storms in June, August and September. The largest 24 hour accumulation was 2.35 inches November 19, 2012. This represents about a two year recurrence interval storm. The largest seven day total was 4.73 inches the week ending November 23, 2013. This was about the median of the 23 annual maximum seven day totals for rain gage 42U.

Water Quality

In 2013, several different water quality monitoring activities occurred as outlined in the Miller/Walker Creek Basin Monitoring Sampling and Analysis Plan, including continuous measurements of temperature, dissolved oxygen, pH, and turbidity (King County, 2011).

Stream water quality data from the sensors within Miller and Walker Creeks are available via King County hydrologic web page:
http://green.kingcounty.gov/WLR/Waterres/hydrology/Default.aspx

Temperature

Temperature was measured at stream gauge sites along with flow. Measurements were taken continually and averaged for reporting every 15 minutes; temperature gauges are located along the stream bottom. The temperature standard (7 day average of the daily maximum: 7-DADM) for Miller and Walker Creeks is 16 degrees Celsius for core salmon summer habitat (Table 1) (King County, 2011). Both Miller and Walker creeks exceeded the temperature standard during the summer (Figure 2). These results in Miller and Walker Creeks are similar to other urbanized streams that exceed temperature standards during the summer. Miller Creek, Site 42A at the mouth, was above the standard for 89 days almost continuously from June 24 to September 21, 2013. Walker Creek, site 42E, was the coolest site monitored with a total of 11 days above the standard in July, August and September (Figure 2 and Table 2). In general, stream temperatures become higher when there is inadequate riparian vegetation to shade the streams, and when rainfall runs off of impervious surfaces, such as roofs and parking lots, directly into storm drains. Streams fed by groundwater and with wider floodplains are generally cooler.

Dissolved Oxygen

The dissolved oxygen (DO) water quality standard for the Miller/Walker basin is a daily minima value greater than 9.5 mg/L (Table 1). Miller and Walker creeks frequently did not meet this standard in 2013 (Figure 3 and Table 2). At Miller Creek, site 42A near the mouth, data showed that 139 days did not meet the standard out of 323 days monitored. Daily minimum values were below 9.5 mg/L almost continuously from May until mid-September (Figure 3). The Walker Creek site 42E, near the mouth, also did not meet standards, but for fewer days with 115. Additionally, this site showed numerous days from May through September that daily minimum value did not meet the standard (Table 2).

Dissolved oxygen is linked to stream temperature as higher water temperatures have lower oxygen solubility. Data from both Miller and Walker Creeks highlights this relationship by showing lower daily minima values of DO during periods of high temperatures (Figure 2 and Figure 3). Temperature is not the only controlling factor in DO values. Other factors that affect DO in stream are:

Altitude – higher elevations have less oxygen in the atmosphere; stream at higher elevations typically have lower DO levels;

Salinity – as the salt content in water increases, the amount of dissolved oxygen in the water decreases;

Flow – increased turbulence increases the amount of oxygen dissolved in the water such as shallow riffles;

Aquatic life – animals in the water use DO including bacteria that decompose organic material;

Vegetation – riparian vegetation release oxygen into the stream during photosynthesis.

pH

The pH water quality standard for both Miller and Walker Creeks is a daily mean value between 6.5 and 8.5 (Table 1). The data collected in 2013 for both creeks are within this range (Figure 4). The pH values decreased during periods of increased flow, see Figure 5 for an example at Miller Creek site 42A (near the mouth). An instrument drift is the likely cause of lower daily values at Site 42E in late October 2013. Additional work is ongoing to at this site including re-calibration.

Influencing factors on water quality include flow. Flow affects water quality parameters such as pH and turbidity as seen in Figure 5 and Figure 6, respectively. Increased flow, especially stormwater, lowers the stream pH as noted in the example in Figure 5. This lowering of pH is due to precipitation which typically has lower pH values (<6.0) than the stream.

Turbidity

The turbidity water quality standard for Miller-Walker Creek is 5 NTU over background if less than 50 NTU. This standard is intended to regulate activities and point discharges into receiving waters such as Miller Creek. The standard is not applied to turbidity that is the result of nonpoint sources or increase in streamflow. Miller and Walker Creeks do not have background turbidity ranges established. The data collected in 2013 show that turbidity values go up rapidly with increased flows. Both Miller Creek and Walker Creek exhibited very high maximum turbidity values (883 NTU Miller) (736 NTU Walker) (Table 2). This is consistent with results that King County has found in other small streams draining the west facing hills in the area (King County, 2012). These turbidity readings are associated with the higher flow velocities in the lower basins during stormflow. These spikes of stream turbidity are an effect of large quantities of stormwater entering the creek rapidly. See Figure 6 and Figure 7 for example of flow and turbidity at each site. No exceedances of turbidity standards have been reported due to the lack of background values in the basin. However, if the background were equal to the annual mean value of 7.3 NTU for Miller Creek and 6.9 NTU for Walker Creek, both sites would have exceeded the standard 80 or more days.

Specifically, Miller Creek had 80 days out of 430 days monitored (10/18/12 - 01/01/14) where the daily mean turbidity values were greater than the annual mean value. Walker Creek had 84 days of 321 days with the daily mean turbidity values greater than the annual mean value during a shorter monitoring period (01/17/13 - 12/03/13).

Flow

Flows in Miller and Walker Creeks have been measured at numerous locations since the early 1990s (Figure 1). Flow monitoring sites include 42A, at the mouth of Miller Creek, 42M – Miller Creek below Ambaum, 42L – Lake Burien tributary, 42N – Miller Tributary near Hwy 509, and 42E in Walker Creek, as noted in the sampling and analysis plan (King County, 2011).

The four flow-monitoring stations in Miller Creek, noted above, provide the data plotted in Figure 8. This plot uses a September 6, 2013 rain event (total 1.41 inches) as an example. The timing and magnitude of the flow peaks at sites 42M (which includes input from downtown Burien) and 42N (which drains a portion of Hwy 509) show that they contribute to the peak at 42A (the mouth of Miller creek). A discontinued monitoring site on the Lake Burien tributary (42L) showed that it also has flows that contribute < 10 % of such storm peaks at the mouth of Miller Creek.

Hydrologic indicators can be used to assess flow conditions within stream basins and link this hydrologic alteration to biological impairment (DeGasperi et al., 2009). Flow sites within the Miller/Walker basin were evaluated for selected hydrologic indicators – High Pulse Count, High Pulse Range and Low Flow – 7 day for the past two water years (Table 3). See Table 3 for definition of each hydrologic indicator and results. All sites had more High Pulse Counts and longer periods of High Pulse Range in 2013 when compared to 2012. This increase is in part due to Water Year (WY) 2013 being wetter (~10 inches) compared to WY2012 (Table 3). Water year 2012 data is presented to highlight that with average rainfall, the hydrologic indicators for sites in this basin still show high (>10) high pulse counts and high pulse ranges greater than 120 days. DeGasperi et al (2009) report in their Table 7 hydrologic indicator values for full forested and current (1995) conditions for the Miller Creek basin. The fully forested conditions were reported with a high pulse count of 7 and high pulse range of 99 days while 1995 conditions were 25 and 317 days, respectively (DeGasperi et al.,2009). The 2013 high pulse count decreased (17 to 12) at each successive site upstream from the mouth on Miller creek while the High Pulse Range stayed nearly the same at 334 to 336 days.

These peak stormwater flows in Miller Creek have adversely increased the erosive power in the creek, increased the pollutant load, and degraded the instream habitat

(Executive Committee, 2006). These damaging flows (defined as 95 cfs or higher for a 1-year return period) can be attributed to past practices of urban development, which efficiently routed storm flows into the creek (Executive Committee – Appendix D, 2006).

The Executive Committee – Appendix E section (2006) presents the following about analysis of erosive work:

> Work is calculated as the total amount of time or duration of time exceeding a particular flow threshold. For erosive work that threshold is one-half the 2-yearpeak flow for forested conditions. Because field investigations revealed that Miller Creek has experienced severe erosion in many areas, a measure of erosive work was developed. First, the erosive work on the stream was calculated for the range of flows expected under various scenarios. Erosive work is expressed as a ratio relative to an undeveloped or forested condition as follows:
> (Erosive Work for Scenario X) / (Erosive Work for Forested Scenario)
>
> In Exhibit E-4 Scenario X was one of the following scenarios: current, goal, forest, or no mitigation. With forested condition being the basis for comparison, the other scenarios are shown as ratios. Under current (1995-7) conditions, erosive work is over 400 percent greater than it would be for a forested condition at the mouth of Miller Creek.

The areas which contribute most to the damaging flows to Miller Creek are not uniformly distributed throughout the basin, however. The majority of the basin, from east of Hwy 509 including SeaTac Airport, SeaTac, north Burien, and unincorporated King County, produces peak flows which are lower in magnitude and occur later than peak flow that originate from the area that encompasses Hwy 509 and the densely developed area of Burien. This is shown in Figure 8 by the timing of the peak at 42J (located above Highway 509), which occurs after the peak at the mouth (42A), therefore it cannot contribute to the peak at the mouth. Also the shape of the curve for flow above Highway 509 (42J) is much broader than the peak flows recorded at the mouth. The hydrograph from the upstream areas shows that flows rise more slowly and peak with lower velocities. These data confirm that the most effective stormwater controls would be ones that can be located in the downtown Burien area.

The magnitude and timing of the peak flow in Walker Creek are less than Miller Creek, yet are still flashy in response to precipitation events (Figure 9). These higher velocities represent a much higher erosional force in the lower portions of the creek during storm events (Executive Committee – Appendix E, 2006).

Stream flow data for Miller and Walker Creeks is available via King County hydrologic web page: http://green.kingcounty.gov/WLR/Waterres/hydrology/Default.aspx

Stream Life/Ecosystem Health

In addition to water quality, stream health can also be assessed by using benthic macroinvertebrate and salmon monitoring studies.

Benthic Invertebrate Monitoring

Benthic macroinvertebrate sampling was done in the basin at 3 sites in 2013. Two sites were sampled in Miller Creek and one site within Walker Creek. The analysis is not complete yet and will not be available until early 2014. The 2012 benthic invertebrate data from the Miller Creeks sites averaged to a score of 7.4 out of 100 and ranked Very Poor. The Walker Creek site had a score of 31.3 out of 100 and ranked Poor. Previous work completed on Miller and Walker Creeks have been entered in the Puget Sound Stream Benthos database. This work was done from 2003 to 2012 at seven sites around the basin. The average BIBI (Benthic Index of Biotic Integrity) score for each creek was 11.8 out of 100 for Miller Creek and 27.7 out of 100 for Walker Creek. Both creeks ranked in the Poor to Very Poor range. Data from Miller\Walker Creek basin is similar to other urbanized creeks with associated rankings of poor to very poor.

Stream benthos data is available via Puget Sound stream benthos online database web pages: http://www.pugetsoundstreambenthos.org/

Community Salmon Investigation Monitoring

Prespawn mortality of coho salmon has been linked to stormwater runoff from urbanized landscapes. Salmon monitoring assessments have been done in Miller and Walker Creeks since 2010. Surveys began in October and continued daily through December. The results of this work are presented to the community.

The primary purpose of the Community Salmon Investigations for Highline (CSI: Highline) work is to document the rate of coho pre-spawn mortality (PSM) in Miller and Walker Creeks, in order to understand the magnitude of the problem, and document improvements as mitigation projects are installed. Too few coho returned in 2010 to document an accurate PSM rate. In 2011 and 2012, coho PSM was much higher in both Miller and Walker creeks than in an average pristine creek, which is about one percent. In fall 2011, coho PSM was 39%, and in fall 2012, coho PSM was 88% in both creeks combined.

Additional information about this work can be found in the Miller-Walker Creek Salmon Monitoring Program web page:

http://www.kingcounty.gov/environment/watersheds/central-puget-sound/miller-walker-creeks/salmon-monitoring.aspx

This work was made possible by a Cooperative Watershed Management grant from the King Flood Control District, and additional participation from the Miller-Walker basin steward program partners: City of Burien, City of SeaTac, City of Normandy Park, King County, and Port of Seattle.

References

DeGasperi, Curtis L., Hans B. Berge, Kelly R. Whiting, Jeff J. Burkey, Jan L. Cassin, and Robert R. Fuerstenberg, 2009. Linking Hydrologic Alteration to Biological Impairment in Urbanizing Streams of the Puget Lowland, Washington, USA. Journal of the American Water Resources Association (JAWRA) 45(2):512-533.

Executive Committee. 2006. Miller and Walker Creek Basin Plan - Executive Proposed. February 2006. Prepared by The Resource Group Consultants, Inc. King County Department of Natural Resources and Parks, Seattle, WA. http://www.kingcounty.gov/environment/watersheds/central-puget-sound/miller-walker-creeks/basin-plan.aspx

King County, 2011, Miller-Walker Creek Basin Monitoring Sampling and Analysis Plan, King County Water and Land Resources Division. April, 2011. Seattle, Washington. http://www.kingcounty.gov/environment/watersheds/central-puget-sound/miller-walker-creeks/monitoring.aspx#MSAP

King County, 2012, Data Report for Field Data Collection for the Development of a Stormwater Retrofit Plan for Water Resources Inventory Area (WRIA 9, King County Water and Land Resources Division. April, 2011. Seattle, Washington. http://your.kingcounty.gov/dnrp/library/water-and-land/watersheds/green-duwamish/stormwater-retrofit-project/data-report-for-field-data-collection.pdf

Figures

Tables

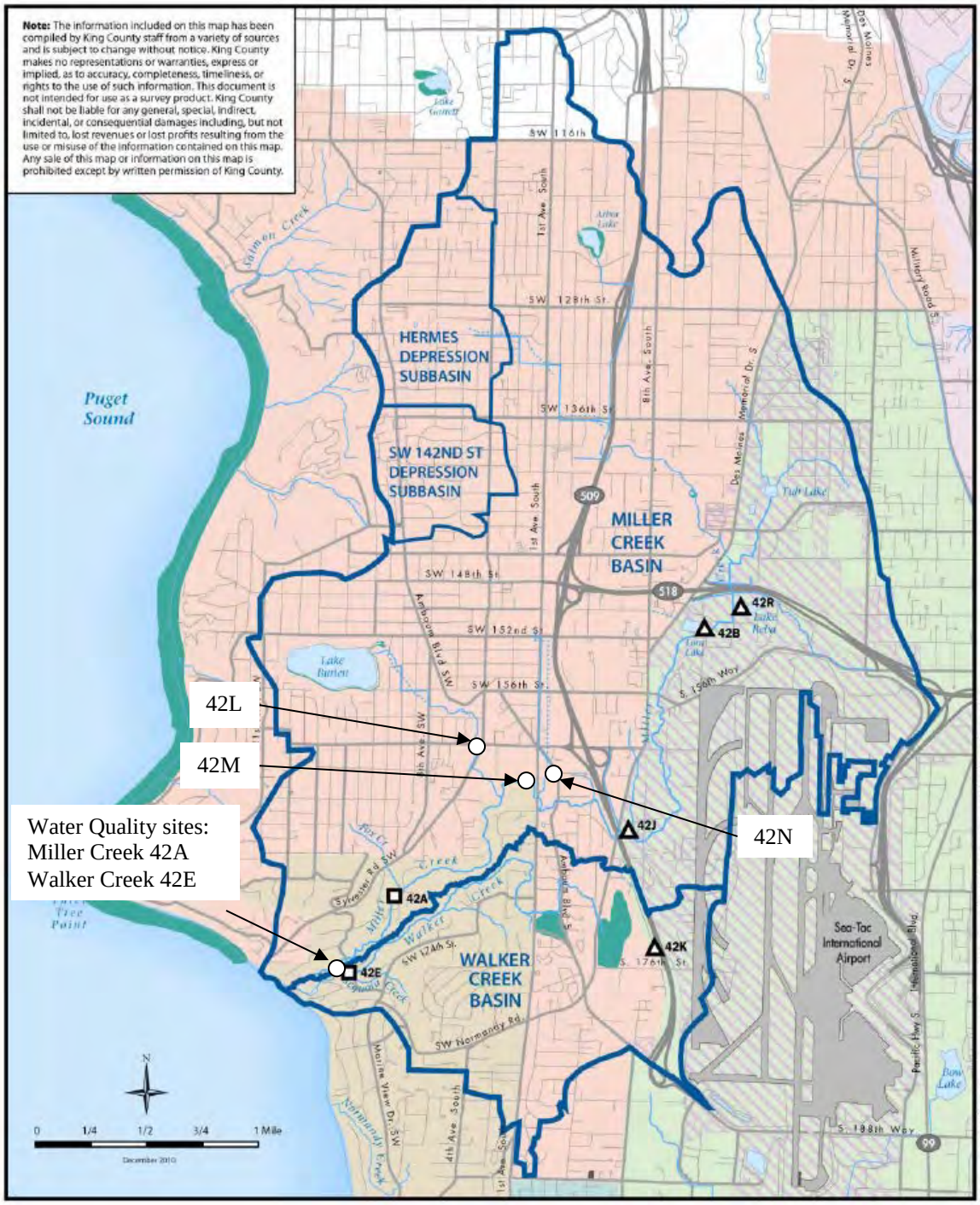

Figure 1. Monitoring sites within the Miller/Walker Basin. Water quality (sonde) sites were started in fall 2012 at 42A, Miller Creek – near mouth, and 42E, Walker Creek - near the mouth. Two new hydrologic monitoring sites began in water year 2013: site 42L, Lake

Burien tributary; site 42M, Miller Creek below Aubaum Pond;, and site 42N – tributary near HWY 509. Figure adapted from King County, 2011.

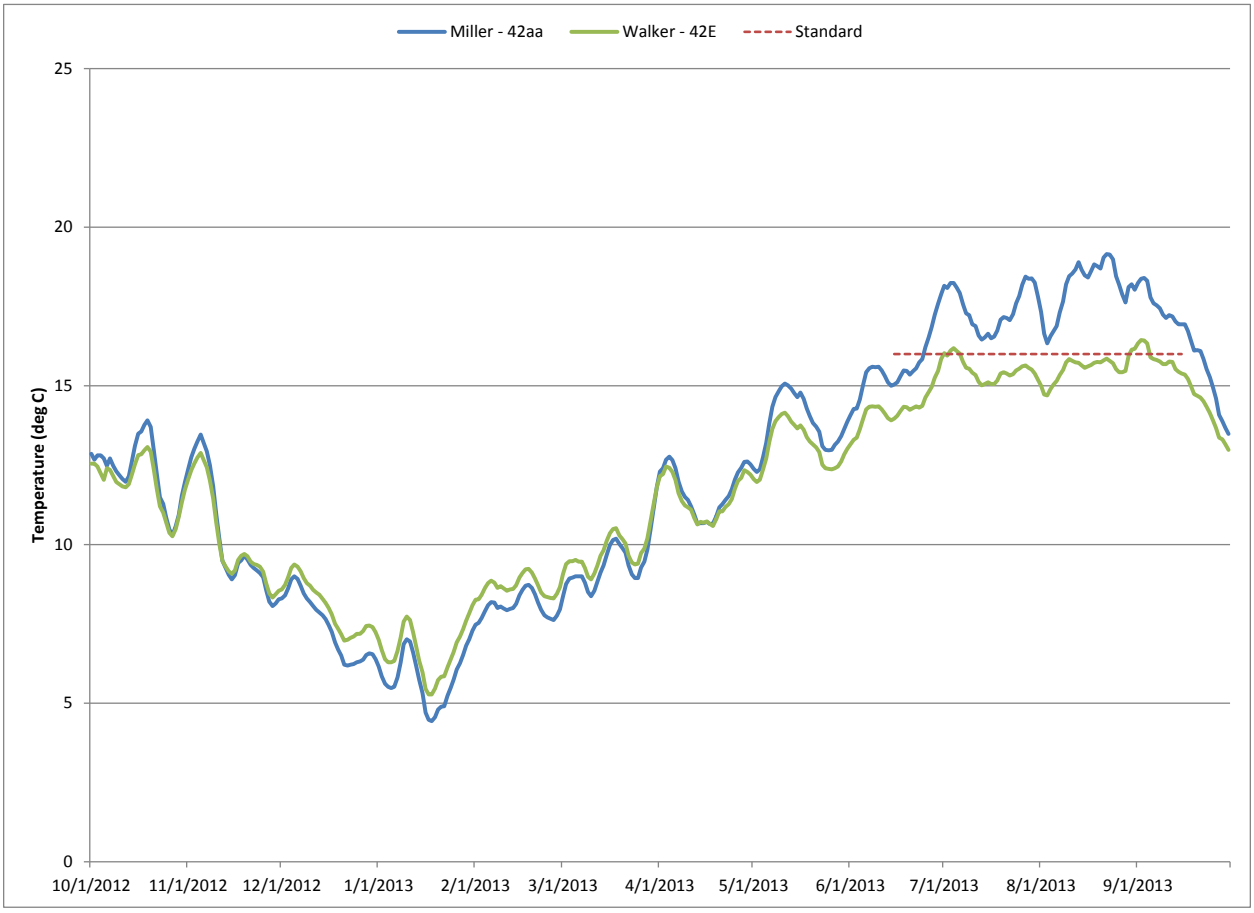

Figure 2. Stream Water Quality: Temperature – 2 sites within the Miller/Walker Basin. Temperature reported as 7-day average of the daily maximum values. Standard is 16 degrees from June 15th to September 15th . All sites had days above the standard. Miller Creek near the mouth (site 42A) had the most days over with 83. Walker Creek was the coolest of the sites monitored with only 11 days above the standard, Table 1.

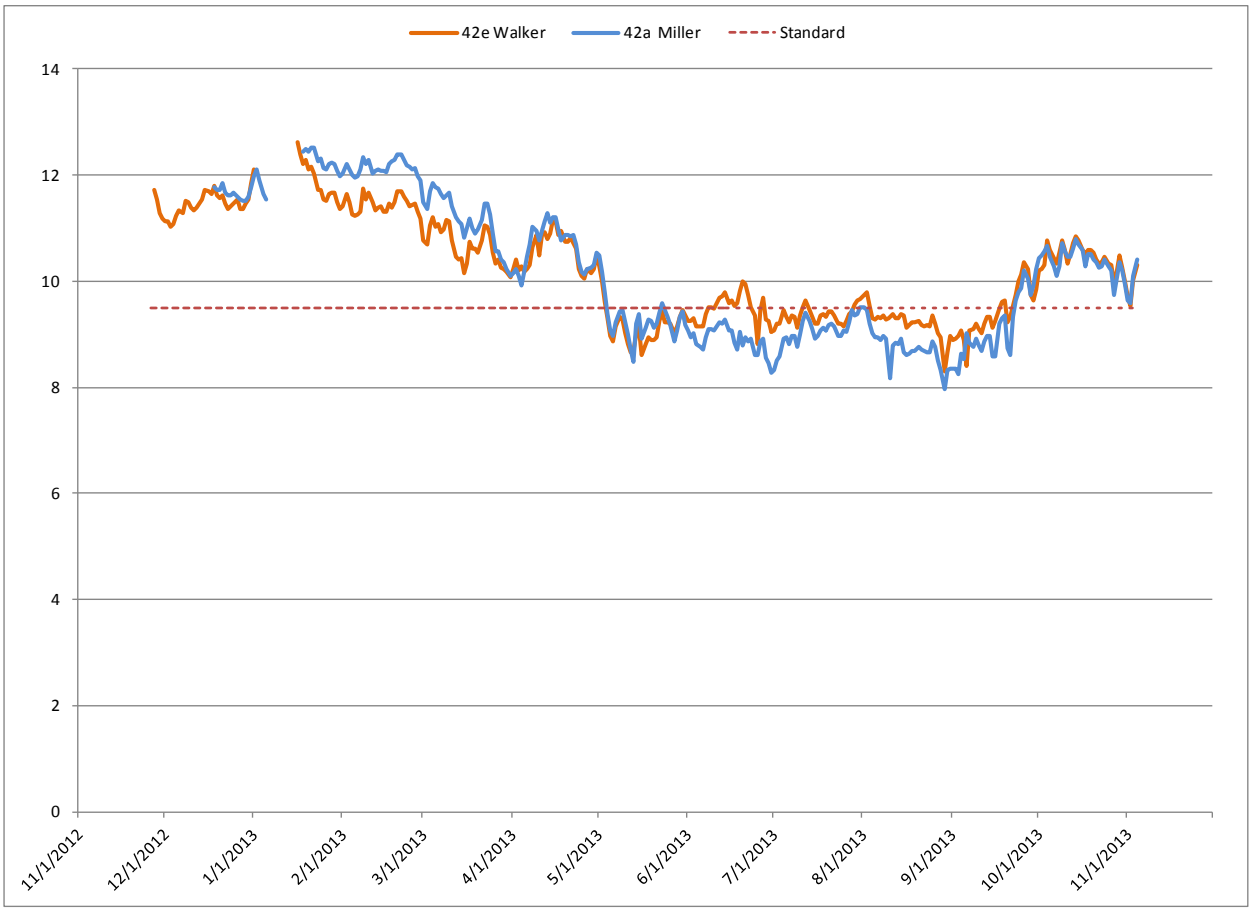

Figure 3. Stream Water Quality – Dissolved oxygen data from Miller (42A) and Walker (42E) creeks. The data presented are the daily minimum values and the water quality standard is a minima of 9.5 mg/L. Site 42A (Miller Creek) had more days below the standard (low DO) than Walker Creek, 42E, see Table 2. Units are mg/L.

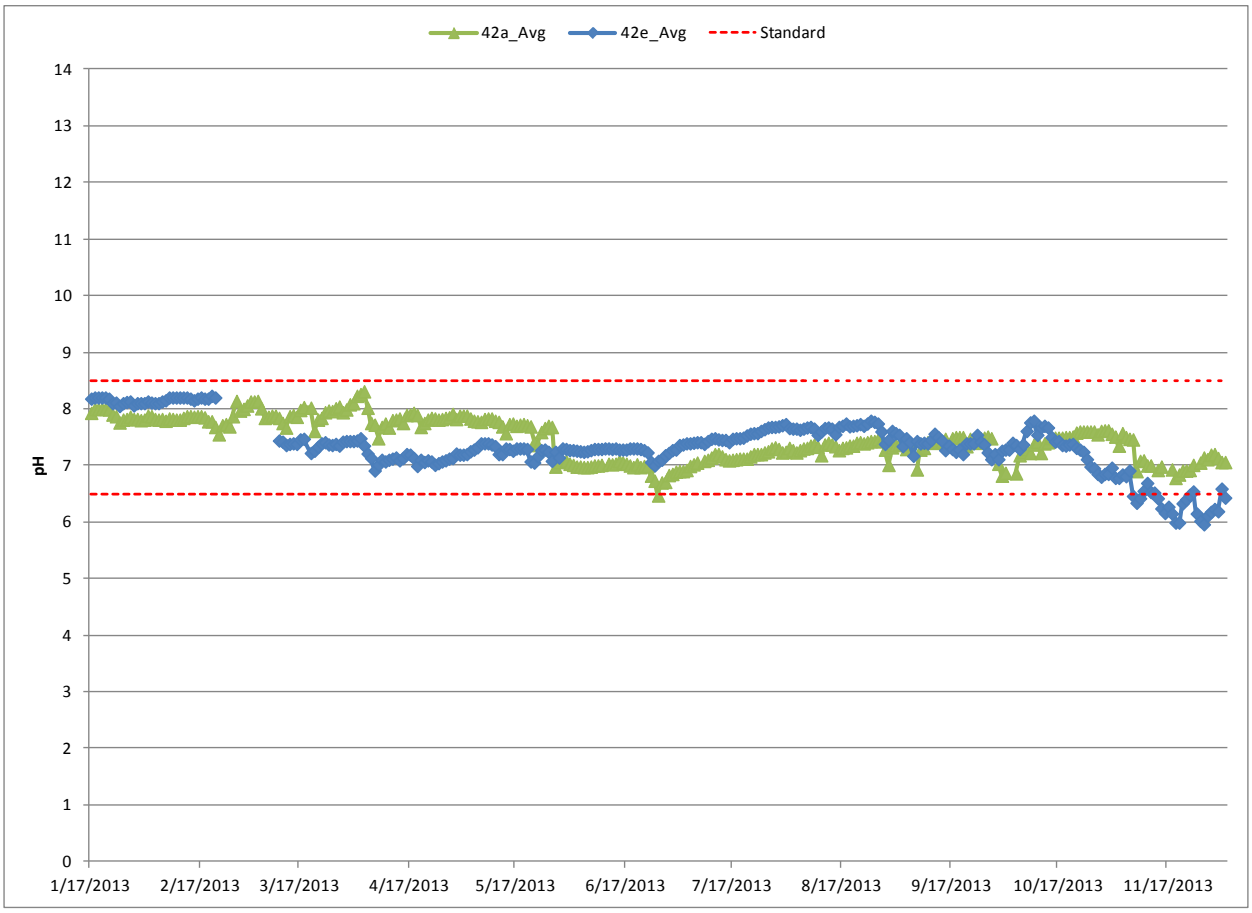

Figure 4. Stream Water Quality - pH values for continually monitored sites, 42A - Miller and 42E – Walker Creek. Values reported as daily averages. Standard for pH is below 6.5 or above 8.5, see Table 2.

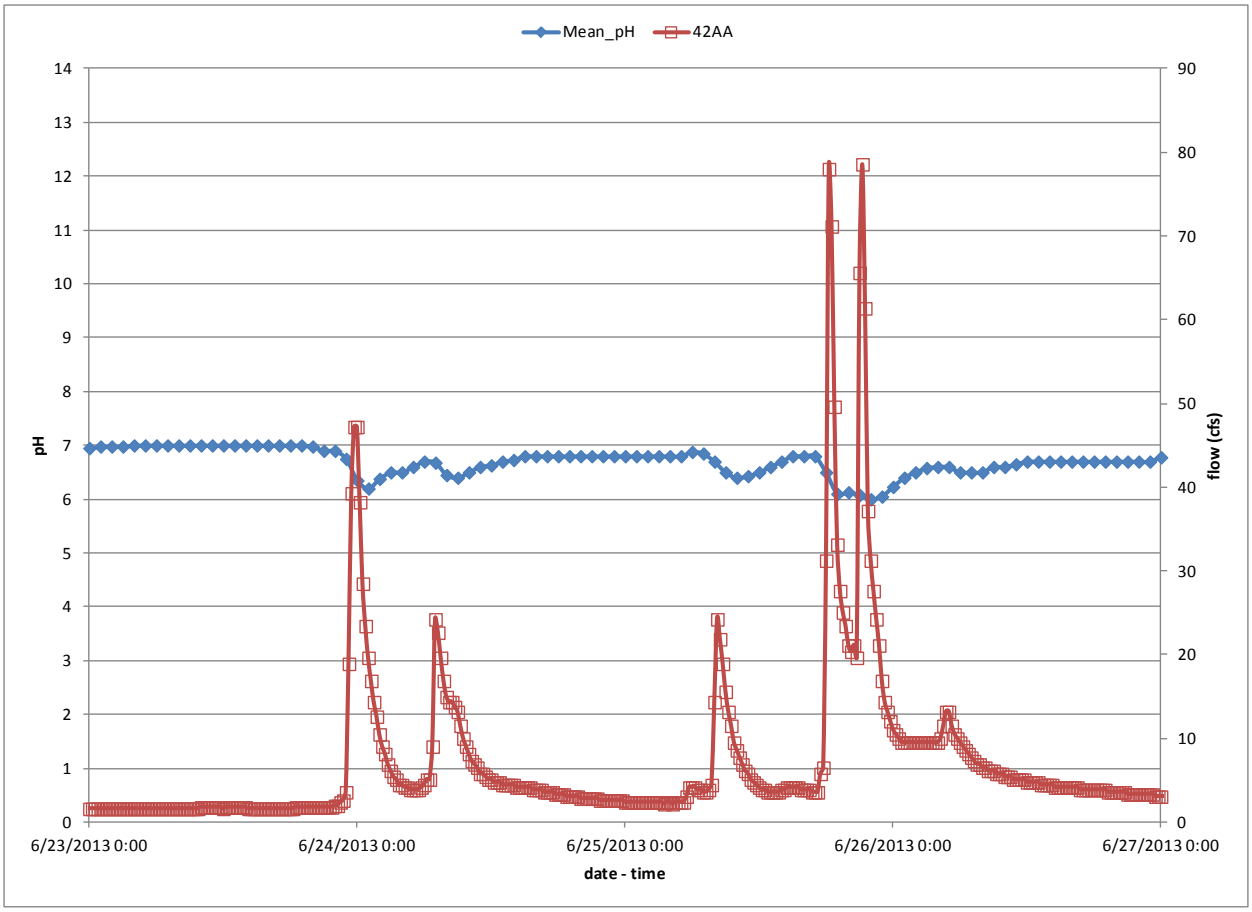

Figure 5. Stream Water Quality – pH and flow – Miller Creek site – at the mouth. The data presented show lower pH values during periods of increased flow. Units are pH units and cubic feet per second (cfs) for flow.

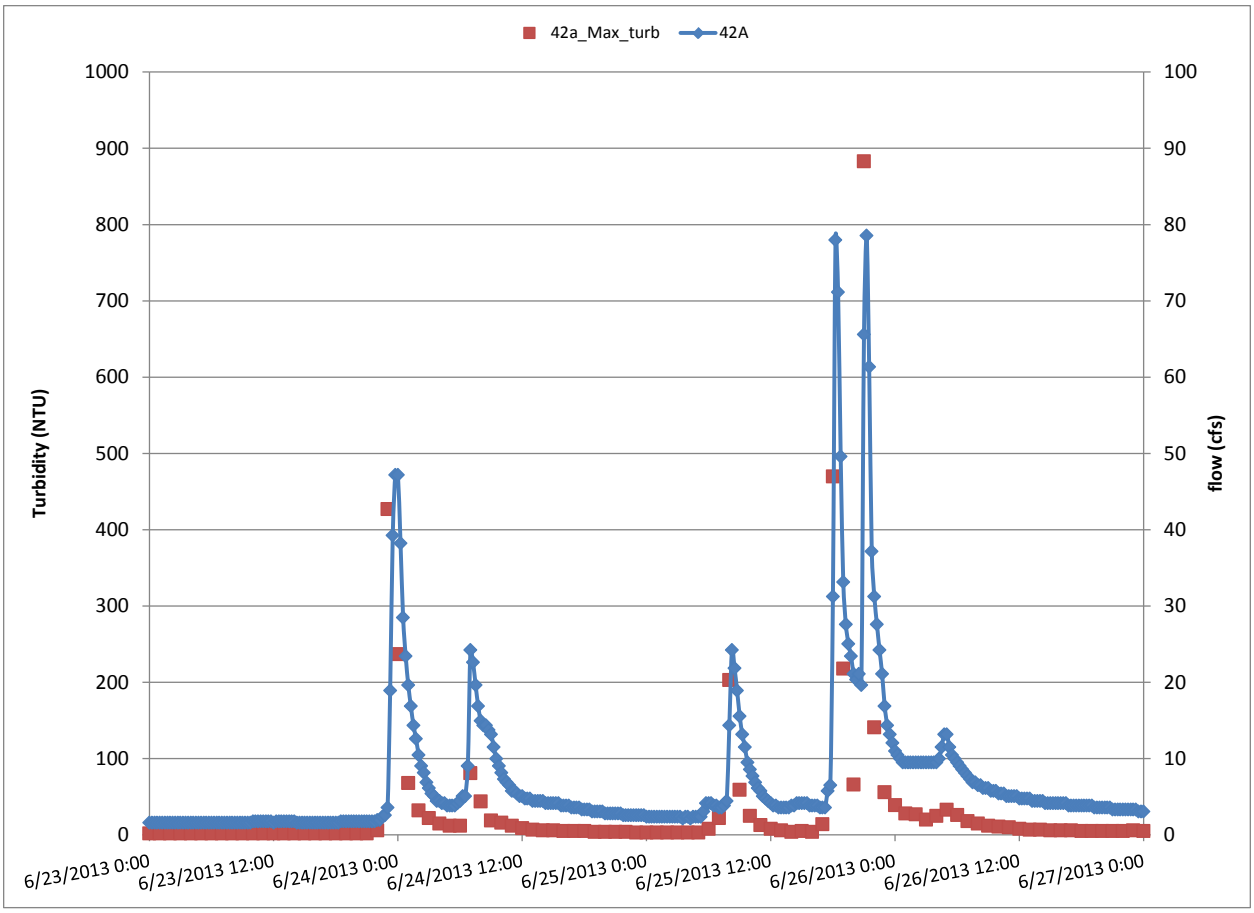

Figure 6. Stream Water Quality –Turbidity and flow – Miller Creek, site 42A. Data shows increased turbidity due to increased flow. Rapid rise in flow is causing increased turbidity in the creeks from re-suspension of sediment and/or erosion of stream channel.

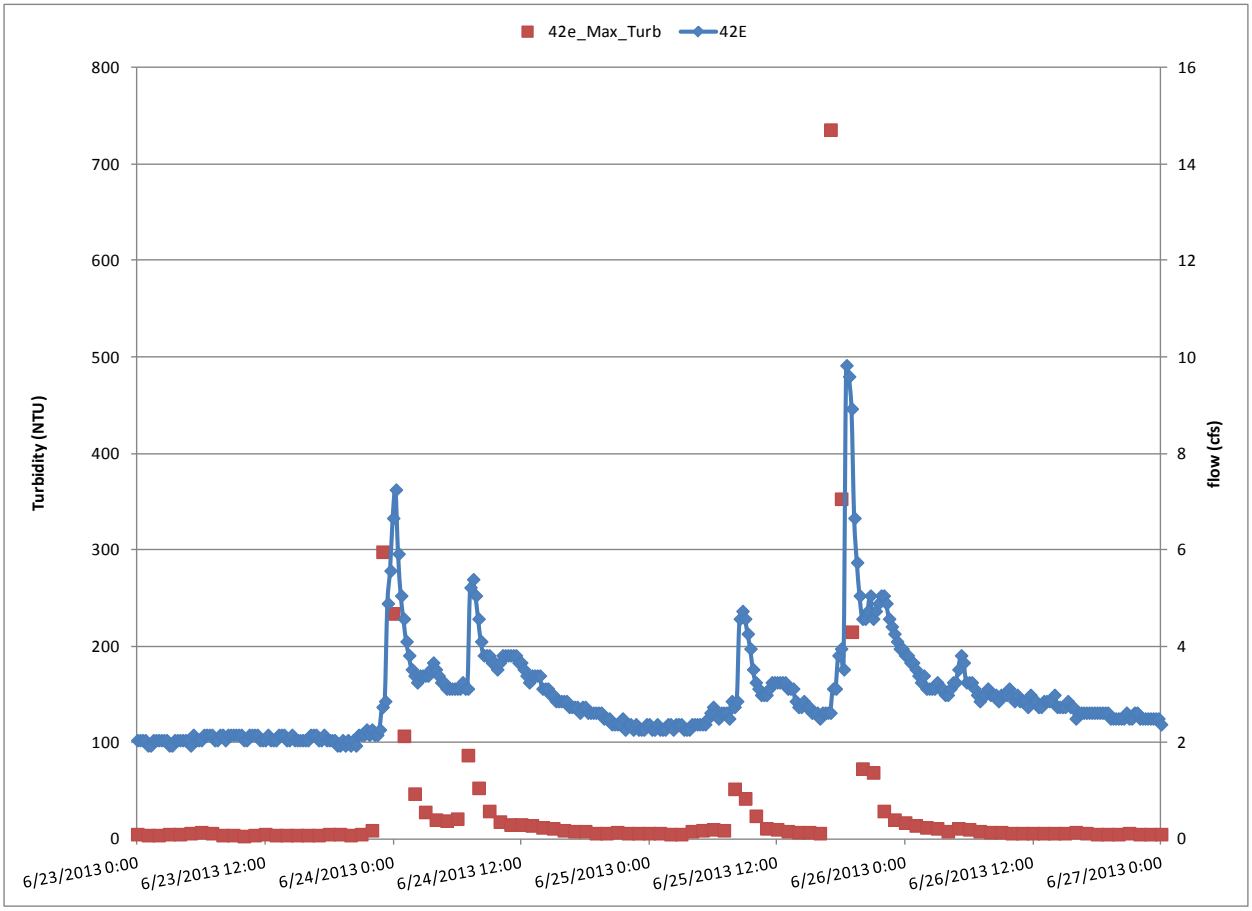

Figure 7. Stream Water Quality –Turbidity and flow – Walker Creek, site 42E. Data shows increased turbidity due to increased flow. Rapid rise in flow causing increased turbidity in the creeks from re-suspension of sediment and/or erosion of stream channel.

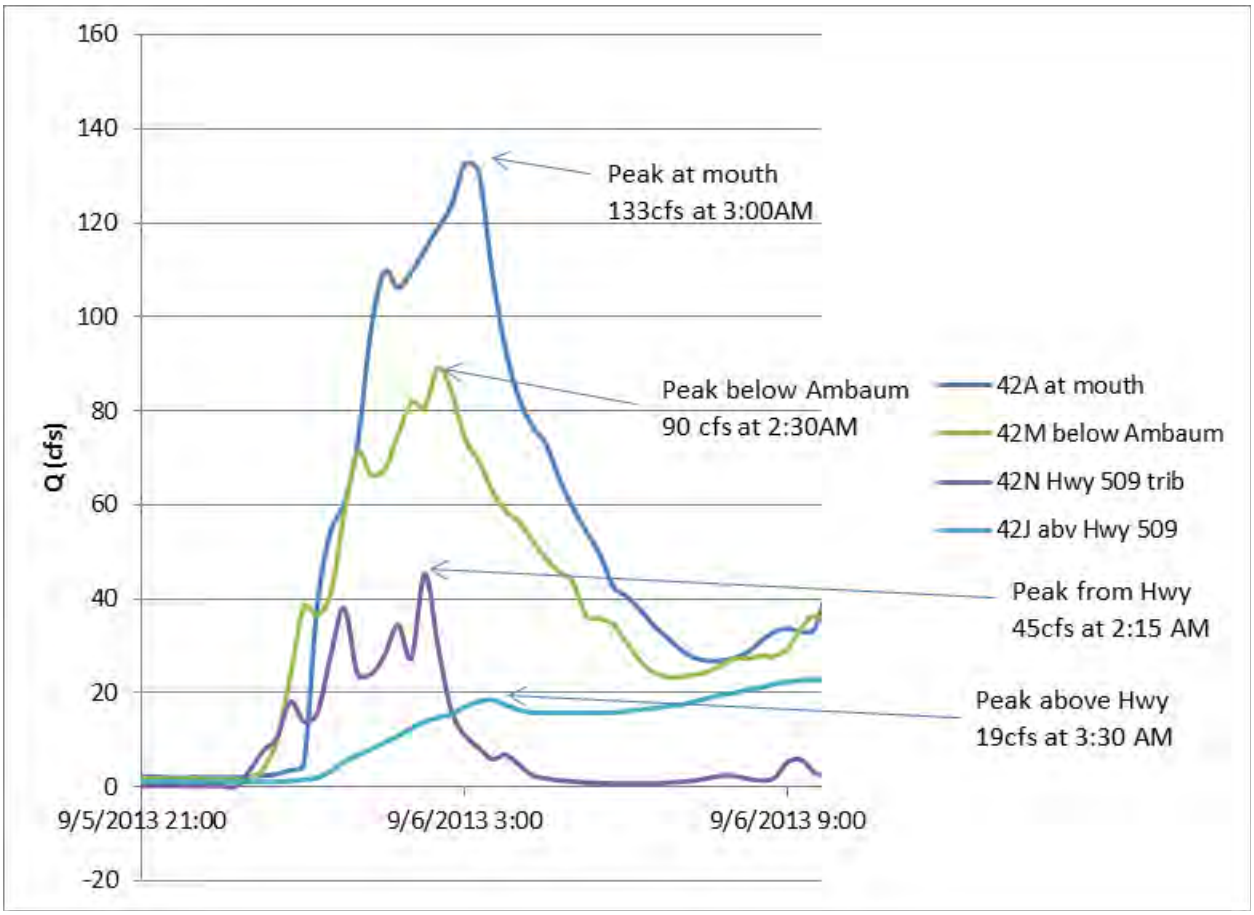

Figure 8. Stream Flow – Miller Sites 42A, 42M, 42N, 42J [mouth –> upstream] (Higher flow response for bigger rainfall storm total 1.41in). Timing and magnitude of peak flows are shown are monitoring sites: 42A Miller Creek at mouth; 42M Miller creek below Ambaum/1st Ave S.; 42N Miller tributary (near hwy 509); 42J Miller Creek above Hwy 509. Q refers of stream flow with unit of CFS (cubic feet per second).

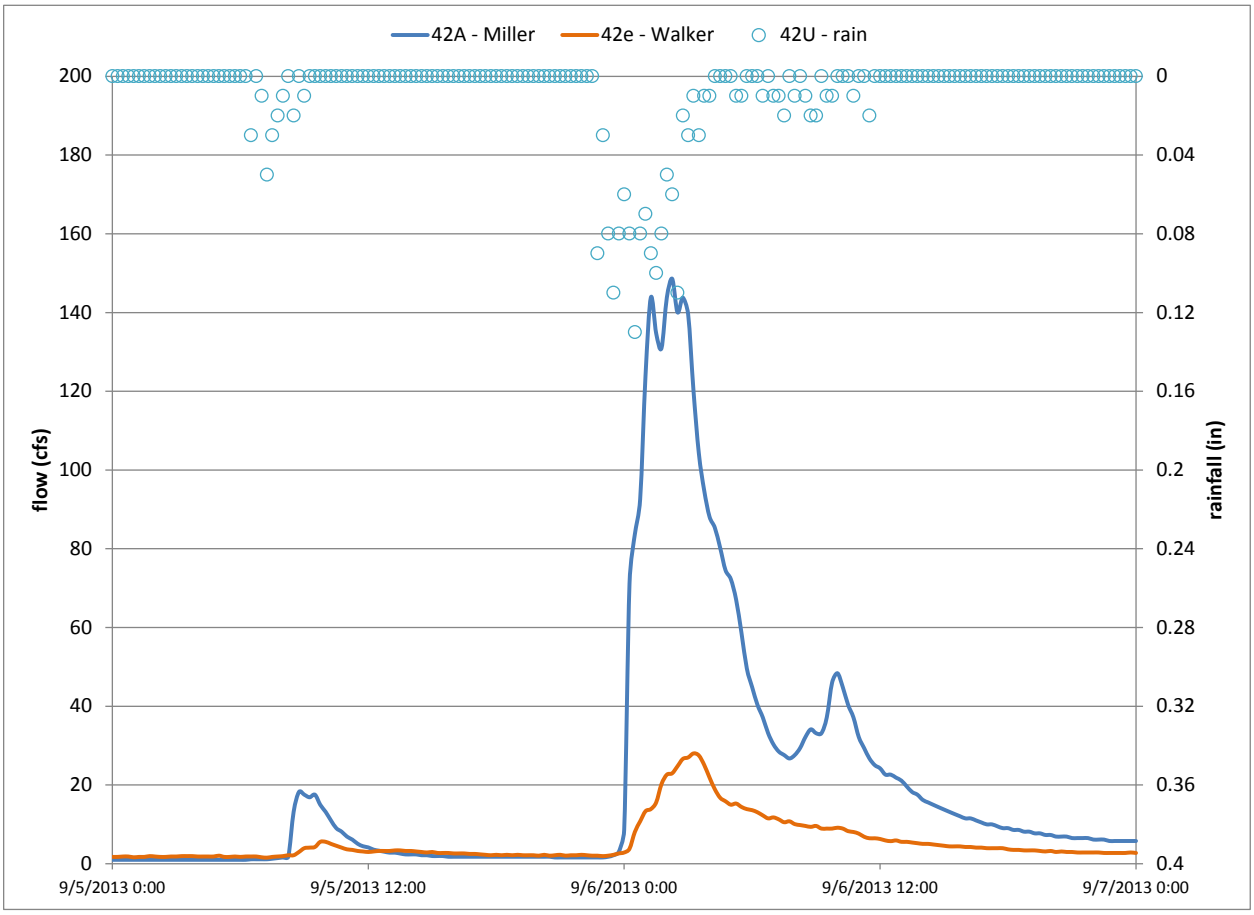

Figure 9. Stream Flow - Miller verse Walker Creek – Flow responses at the mouth to same rain fall events. The flow in Walker Creek has less (about 1/5) magnitude than Miller Creek for the same precipitation event. The timing of the peak flow is typically later in Walker Creek when compared to Miller. Two axes, left - stream flow (cfs) and right - rainfall amount (inch), showing the rapid response of each creek to the same precipitation events.

Table 1. State Water Quality Standards for Temperature, DO, Turbidity and pH in Miller/Walker Creeks. Adapted from WAC 173-210A-200 Fresh water designated uses and criteria (Source: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-200)

Parameter	State Water Quality Standards
Temperature	16°C*
Dissolved Oxygen	9.5 mg/L
Turbidity	5 NTU over background if 50 NTUs or less, or 10% over background if background is greater than 50 NTUs
pH	6.5 to 8.5

* temperature standard is based on the 7-day average of the daily maximum values (7-DADM)

Table 2. Miller and Walker Creek water quality data of temperature, dissolved oxygen, pH and turbidity collected in 2013 at 2 sites. Data presented are average, maximum and minimum of parameters collected continuously. Units vary by parameter and are as follows: temperature — degree Celsius; dissolved oxygen — milligrams per liter ; pH – pH units and turbidity — NTU.

	42A - Miller Creek				42Ewq - Walker Creek			
Parameter	Mean	Max	Min	Days exceed standard#	Mean	Max	Min	Days exceed standard#
Temperature^	11.8	21.1	2.8	89	10.9	18.8	3.4	11
Dissolved Oxygen	10.4	12.8	**8.0**	139	10.5	12.9	**8.3**	115
pH	7.5	**9.0**	**6.0**	7	7.3	8.3	**5.6**	28*
turbidity	7.3	883	< 1	NA	6.9	736	<1	NA

: each parameter has a different water quality standard, see table 1 for details;
^ : temperature standard is based on the 7-day average of the daily maximum values (7-DADM); days exceed standard are based on the 7-DADM, other table values are based on the daily data;
* : pH values beyond the standard range are likely a result of instrument drift;
NA : Not applicable due to the lack of established background values.

Table 3. Hydrologic Indicators for Miller and Walker Creek. Data from water year 2012 and 2013 shown for comparison.

GAUGE_ID	High Pulse Count	High Pulse Range (days)	Low flow - 7-day (cfs)

Miller Creek	WY12	WY13	WY12	WY13	WY12	WY13
42a - Mouth	15	17	239	336	1.48	1.03
42m - below Ambaum	NA*	15	NA*	336	NA*	0.85
42j - above Hwy 509	12	13	128	334	0.3	0.32
42b - Detention Facility	9	12	128	336	0.19	0.17
Walker Creek	**WY12**	**WY13**	**WY12**	**WY13**	**WY12**	**WY13**
42e - mouth	12	14	170	336	1.7	1.63

Total Rainfall (in)	WY12	WY13
42u - Lake Reba	37.7	47.6

NA* : Incomplete water year data due to when data monitoring started.
WY = Water year is a 12 month period from October 1 to September 30 of the following year.
CFS = cubic feet per second
IN – inch

Indicators definitions from DeGasperi et al., 2009:
High Flow Pulse: Occurrence of a period of daily average flows that are equal to or greater than a threshold of twice the long-term daily average flow rate.
High Pulse Count: Number of discrete high flow pulses that occur in a water year. .
High Pulse Range: Range in days between the start of the first high flow pulse and the end of the last high flow pulse during a water year.
Low Flow – 7-day: Centered seven-day moving average annual (calendar year) minimum flow.