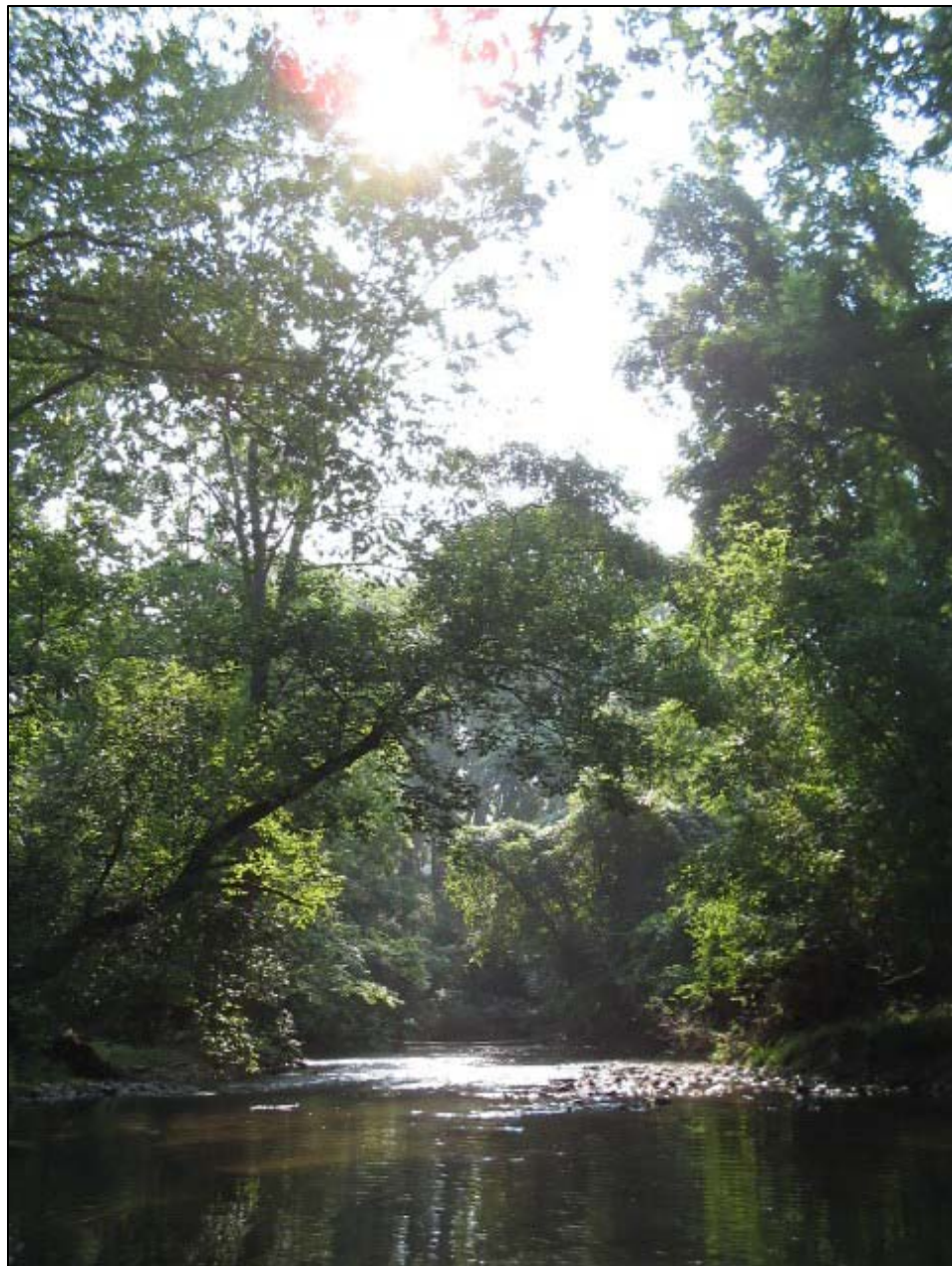




Valley Creek Discharge and Turbidity Data Report for Water Year 2010

Natural Resource Data Series NPS/MIDN/NRDS—2011/211



ON THE COVER

Valley Creek at Valley Forge National Historical Park

Photograph courtesy of: Valley Forge National Historical Park

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Natural Resource Data Series NPS/MIDN/NRDS—2011/211

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December 2011

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Please cite this publication as:

Dammeyer, N. 2011. Valley Creek discharge and turbidity data report for water year 2010. Natural Resource Data Series NPS/MIDN/NRDS—2011/211. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	iv
Tables.....	iv
Introduction.....	1
Methods.....	2
Results and Discussion	3
Discharge	3
Suspended Sediment.....	4
Water Quality and Biological Indices.....	4
Conclusion and Discussion	5
Literature Cited	11
Appendix A: Discharge WY 1983 – 2010.....	12

Figures

	Page
Figure 1. Deviation, by water year, from annual mean daily discharge (WY 1983 – 2010: 33.8 cfs).	6
Figure 2. Deviation from monthly mean daily discharge (WY 1983 – 2010) by month for WY 2010 (Oct. 2009 – Sept. 2010).....	7
Figure 3. Valley Creek hydrograph for WY 2010 (Oct. 2009 – Sept. 2010) with daily precipitation.	8
Figure 4. Cumulative suspended sediment load for WY 2010 (Oct. 2009 – Sept. 2010).	9

Tables

	Page
Table 1. Peak discharge (cfs), estimated suspended sediment load (Metric tons), and percent of WY 2010 annual sediment load for the three largest storm events of WY 2010 (Oct. 2009 – Sept. 2010).	10
Table 2. Deviation from annual mean daily discharge (WY 1983 – 2010: 33.8 cfs) and sediment load for WY 2006, 2009, and 2010.	10
Table 3. Mean (SD) water quality values (WY 1999 – 2009) and WY 2010 (Oct. 2009 – Sept. 2010) measurements.	10
Table 4. Mean (SD) values for the three biological indices based on macroinvertebrate data for the period of record and values for WY 2010 (Oct. 2009 – Sept. 2010).	10

Introduction

Prior to its confluence with the Schuylkill River northwest of Philadelphia, PA, the final 2.3 miles (3.7 km) of Valley Creek lies within Valley Forge National Historical Park (VAFO). This area represents an important resource to the National Park Service (NPS) both for its cultural significance, as the site of the 1777-78 winter encampment of the Continental Army under General George Washington, and its natural resource value. The value of the natural resources surrounding Valley Creek is exemplified by the number of watershed residents, anglers, and community groups that are involved with the protection and restoration of the stream. The Valley Creek Partnership is dedicated to the protection and restoration of the Valley Creek Watershed and is composed of representatives of local, state, and federal government agencies and non-profit environmental organizations. Visitors actively participate in the conservation of Valley Creek through organizations such as Trout Unlimited and through NPS volunteer events. These events include the Crayfish Corps which works to reduce pressure on native crayfish species by removing the non-native, invasive rusty crayfish (*Orconectes rusticus*). Recently, an un-described native species of crayfish, a member of the *Cambarus acuminatus* complex, was discovered in Valley Creek (Lieb et al. 2008). This discovery is important because it represents a range extension for the complex and the species might be an endemic that is narrowly distributed to Valley Creek and possibly a small number of adjacent streams.

As one of the two Class A wild trout streams in southeastern Pennsylvania, Valley Creek demonstrates great ecological significance and has been designated a stream of Exceptional Value by the Pennsylvania Department of Environmental Protection (PADEP). Despite this designation, multiple segments of Valley Creek and its tributaries have been included in the PADEP 303(d) list of impaired waters and a fish consumption advisory has been issued based on elevated accumulation of polychlorinated biphenyls (PCBs; PADEP 2010). The PCB contamination has been attributed primarily to one point source, the Paoli Rail Yard, which is on the US Environmental Protection Agency's (EPA) National Priority List (i.e. superfund sites). A Total Maximum Daily Load (TMDL) for PCBs in Valley Creek and a restoration plan for the Paoli Rail Yard have been implemented in an effort to remediate this source of contamination. In addition to the PCB contamination, a TMDL is required by 2015 to address siltation, turbidity, and bank modification within multiple segments of Valley Creek as a result of not attaining designated use criteria. Despite the well-established value of this stream, there are numerous threats and challenges facing Valley Creek and its contributing watershed.

The Valley Creek watershed is principally found (> 90%) in Chester County, which lies within the piedmont region of Pennsylvania and is chiefly underlain by karst geology. The total catchment of Valley Creek is 23.3-square miles (60.3 km²) with 20.8-square miles (53.9 km²) found upstream of a US Geological Survey (USGS) gaging station near the boundary of VAFO. The watershed has undergone numerous and varied development pressures since European settlement when the region was predominantly forested. Aerial photos from 1937 indicate that approximately 50% of the watershed had been converted for use as agricultural land, 24% was forested, and only 4% of the lands were considered developed (urban/suburban/commercial; CCWRA 2010). However, by 1997, land use shifted away from agriculture (7%) towards development (48%) and forested land cover (32%; Rief 2004). The trend of increasing development is expected to continue into the future, as demonstrated by 2005 land cover where agricultural land had decreased to 3.7%, forested cover was reduced to 28.4%, and developed

land cover had increased to 54.8% (CCWRA 2010). Urban development has lead to numerous challenges in terms of the health and ecosystem function of Valley Creek and has been identified as a source of impairment. These impacts are generally related to stormwater runoff from the contributing watershed where contaminants (e.g. PCBs and soils) are carried into the stream and the characteristics of the runoff regime are altered. By increasing the amount of impervious cover in the watershed, both the discharge rate (cfs) and total volume of water that directly enters the stream through overland pathways increase. The combination of increased discharge and water volume results in a larger input of energy to the stream channel in any given storm event, which in turn leads to larger amounts of contaminants released from the watershed as well as a greater capacity to erode stream banks and alter stream morphology.

Numerous organizations, such as federal, state, and local governments, universities, and community organizations have contributed to a broad body of knowledge concerning Valley Creek and adjacent streams. Chester County, through the Chester County Water Resources Authority (CCRWA), and the USGS have partnered to investigate water quality and stream health conditions throughout the county for over four decades. The NPS, through VAFO and the Mid-Atlantic Inventory and Monitoring Network (MIDN), has joined this effort by supporting monitoring of Valley Creek. The body of knowledge available indicates that contaminant loading from the watershed as well as alteration to runoff characteristics related to storm events are the primary factors affecting the degradation of water quality and stream morphology in Valley Creek (CCWRA 2004, Rief 2004, Fraley et al. 2007, CCWRA 2010). NPS has provided funding to support the acquisition of data concerning turbidity near the upstream boundary of VAFO in Valley Creek at the USGS gage. This report will therefore focus on discharge and turbidity characteristics of Valley Creek as a method to address the concerns of VAFO management. Additionally, data concerning other water quality and biological indices collected and processed by the USGS will be briefly discussed.

Methods

All discharge and turbidity data discussed in this report were collected at USGS gage 01473169 located 0.9 miles (1.4 km) downstream from the confluence of Little Valley Creek, near the Pennsylvania turnpike bridge and upstream from VAFO (< 0.1 km). Data acquired for this report were generated from USGS data portals (i.e. NWIS, IDA) or directly from USGS staff. In addition, biological and stream chemistry data were accessed from the USGS (<http://pa.water.usgs.gov/projects/assessments/chesco>). This report focuses on water year 2010 (WY 2010: Oct. 2009 - Sept. 2010) and references prior water years for context. Data from WY 2010 is listed as provisional by USGS staff and subject to revision. Available parameters at this site include gage height (WY 1983-present), discharge (WY 1983-present), turbidity (WY 2007-present), and precipitation (WY 2006-present) recorded at 15 minute intervals. Gage height was determined using a water-stage recorder (Datum 108.62 ft above MSL; 33.11 m above MSL) which was converted to discharge using a USGS developed rating curve. Records equal to or less than 400 cubic feet per second (cfs) were rated as good, while those exceeding 400 cfs were rated as fair by USGS staff using quality assurance criteria. All mean discharge values discussed, unless otherwise noted, refer to mean daily values for the indicated time period. Turbidity was monitored with a single parameter optical sonde (YSI; Yellow Springs, Ohio). Sediment loading was determined by two separate, but not independent, methods developed from samples taken at the USGS gage in Valley Creek (Fraley et al. 2007). Suspended sediment

loading was estimated using a power law relationship between turbidity and suspended sediment concentration which was then combined with the discharge record to create a time series of suspended sediment discharge values. This record was then numerically integrated over time, using the trapezoidal method, to estimate the sediment load for WY 2010 passing by the USGS gage (Fraley et al. 2007). Sediment loading was also estimated using a peak discharge method that defined a relationship between peak discharge of major storm events (peak flows greater than 70 cfs) and suspended sediment load based on the turbidity-suspended sediment relationship (Fraley et al. 2007). This relationship was developed using 36 major storm events and accounted for 95.3 per cent of the sediment load estimated by the sediment discharge integration method for these storm events. Fraley et al. (2007) found that the peak discharge method accounted for 87.7 percent of the sediment load between July 25, 2005 and September 30, 2006 as compared to the sediment discharge integration method.

Results and Discussion

Discharge

Annual mean daily discharge (43.3 cfs) for water year 2010 (WY 2010) was the sixth highest on record, 9.5 cfs above the long term mean (1983-2010: 33.8 cfs; Figure 1). Mean monthly values reveal that discharge generated during WY 2010 was not evenly distributed throughout the year with respect to historical patterns (Figure 2). Fall and winter months had especially high flows while the summer months dipped below their long-term mean. There were 68 days in WY 2010 that met or exceeded the 90th percentile for mean daily discharge over the period of record (54 cfs), and there were 39 individual storm events where peak discharge exceeded 70 cfs. There were 36 days less than or equal to the 10th percentile over the period of record (15 cfs) and the minimum discharge was 11 cfs on September 10, 2010.

Groundwater inputs and discrete storm events combine to support flows in Valley Creek. Groundwater enters the stream through natural seeps and springs as well as through groundwater pumping. Approximately 4 Mgal/day (6.2 cfs) is discharged to Cedar Hollow Run (tributary of Valley Creek) from a siphon operated at the Atwater Quarry (C. Marshall, Valley Creek Trustee Council, pers. comm.). As with all karst systems, the interaction between surface waters and the underlying aquifer is complex and problematic to characterize. However, some basic inferences can be drawn from a visual inspection of the Valley Creek hydrograph for WY 2010 (Figure 3). Baseflow conditions are supported by groundwater inputs to Valley Creek and are represented in the hydrograph by baseflow recession (slope of the hydrograph between precipitation-driven peak events). Generally, when substantial recharge to groundwater occurs, discharge to stream flow from groundwater increases which results in a vertical or horizontal shift in the baseflow recession of the hydrograph. The slope of the baseflow recession should remain consistent among baseflow periods unless substantial alteration to the contributing watershed or aquifer occurs. Following larger precipitation events during the fall and winter of WY 2010 there is an apparent shift in the hydrograph, likely representing a larger contribution of streamflow from the groundwater, or baseflow, component. This can be contrasted with the summer period where several smaller storms created peak storm flow events but there was little response in the groundwater component (Figure 3). The general trend of declining baseflows over the summer

leading to annual minimum flows during the fall or early winter is typical for high flow years and less apparent in low flow years (Appendix A).

Suspended Sediment

Suspended sediments are related to many of the impairments associated with Valley Creek. These impairments range from PCB-contaminated soils carried into the stream during storm events to bank erosion and siltation within the channel. For WY 2010, estimated annual sediment load at the USGS gage was 1,544 metric tons as estimated by the sediment discharge integration method (Figure 4). There were approximately 15 days during WY 2010 when the turbidity sonde was inoperable, missing three major storm events (>70 cfs). In WY 2010, the estimated sediment load using the peak discharge method was 1,536 metric tons. This value is close (>99% of total) to the estimate generated by turbidity record. One reason this should be expected is that the original peak discharge estimate (Fraley et al. 2007) was biased low (87.7% of total) and in WY 2010 the period of missing turbidity data biased the discharge-integrated turbidity record estimate low. It is important to note that these two methods of estimating sediment load do not represent independent confirmation of the sediment load as they are generated from the same data set. However, this does lend strong support that a vast majority of the sediment delivered to VAFO through Valley Creek is derived from major storm events (>70 cfs) and substantially less is contributed during smaller events and at baseflows. A relatively small number of storm events are responsible for a vast majority of the suspended sediment load. There were three individual storm events in WY 2010 that accounted for 45.0% of the annual sediment load as calculated by the peak discharge method (Table 1). Consistent with this, Fraley et al. (2007) found that three events accounted for 40.2% of the sediment load in Valley Creek between July 25, 2005 and September 30, 2006.

It should be noted that the correlation between peak discharge and suspended sediment should not be extended more broadly to other metrics such as mean annual or monthly discharge. The driving force behind the suspended sediment patterns, derived by either method, is the frequency and intensity of major storm events (i.e. >70 cfs) and not the total yield of water or baseline flow regime in any given year. This is evident by comparing mean annual discharge and sediment load from WY 2006, 2009, and 2010 (Table 2). Although WY 2009 was below average in terms of annual mean daily discharge it was within 6 % the annual sediment load for WY 2010, which was the sixth highest on record in terms of annual mean daily discharge. The estimated sediment load in WY 2006 was 45% above the WY 2010 estimate despite the annual mean daily discharge for WY 2010 far exceeding WY 2006. An examination of hydrographs for these years may help elucidate this relationship (Figure 3; Appendix A).

Water Quality and Biological Indices

Biotic and abiotic samples are collected annually by USGS staff at the gage site. In-situ parameters (dissolved oxygen, pH, specific conductance, temperature) are measured and water chemistry and biological (aquatic macroinvertebrate) samples are collected during fall or early winter. For WY 2010, water chemistry and biological samples were taken on October 6, 2009. All values for in-situ parameters fell within acceptable PADEP water quality standards and were near the long-term mean (1999-2009, Table 3). Three macroinvertebrate indices are calculated for Valley Creek by USGS staff including taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness, and Hilsenhoff's Biotic Index (HBI). Each index ranks the samples into

one of four categories; non-, slightly, moderately, or severely impacted. In WY 2010, each index ranked the site as slightly impacted. This ranking is consistent with what has been observed at this site historically (WY 2004-WY 2009), with the mean value for each index ranking the site in the slightly impacted category (Table 4). In WY 2011, five additional sites in the Valley Creek watershed (four upstream of the gage site) were sampled for aquatic macroinvertebrates by the USGS. Each of these sites fell within the slightly impacted category for each index.

Conclusion and Discussion

Despite its PADEP-designated Exceptional Value status, Valley Creek faces numerous challenges with respect to ecological and recreational function. These challenges are related to the development pressures present in the contributing watershed as well as legacy issues (i.e. PCBs and mill dams). As impervious cover increases in the watershed, discharge rate and total volume discharged both increase. Fraley et al. (2007) suggest that a large percentage of the sediment load at the USGS stream gage, measured as turbidity, is derived from stream bank erosion in the upstream reaches of the watershed. CCWRA (2004) found that thirty percent of the stream channels sampled within the Valley Creek watershed were severely eroded and noted that a consistent decline in bank stability has been observed through numerous surveys in Valley Creek. Bank erosion is more extreme in the lower reaches of Valley Creek and is a major concern within VAFO.

The severity of bank erosion within VAFO is likely the result of several contributing factors. Historic land use included instream structures (e.g. mill dams) for water use in this region which led to the development of a deep sediment layer upstream of impoundments. This sedimentation provides an easily erodible layer along the banks and stream bed of Valley Creek within VAFO. Over time, the erosion of this layer has resulted in the incising of the stream channel. With greater incision, the streamflow is further isolated from its natural floodplain. In-turn, this leads to increased erosion as energy stored in the storm pulse is not dispersed over the floodplain but instead used to erode the channel and stream banks. In effect, this functions as a feedback loop, where increased isolation from the floodplain leads to more bank erosion which results in increased isolation from the floodplain. This suggests that even as erosion controls are put in place throughout the watershed to protect Valley Creek from degradations originating across the watershed, the sediment load generated at the stream banks will continue affecting the physical and ecological integrity of Valley Creek. Discharge rates associated with storm events must be ameliorated if bank erosion at VAFO is to be controlled (Emerson et al. 2003). The deleterious effect of urbanization on Valley Creek and stream ecosystems in general has been well documented (Kemp & Spotila 1997; Lieb 2008). Although much of the urban development had taken place by the time the continuous discharge record was established in Valley Creek (1982), future data reports will look more deeply into trends in discharge over the period-of-record.

Additional areas of interest would be to repeat stream morphology surveys in VAFO and include stream temperature data, especially during low flow periods. Repeating stream morphology surveys would provide for an accurate record of bank erosion and stability over time. This can also help to assess the status of actions taken by Chester County and their partners to implement the Valley Creek Stormwater Management Plan (CCWRA 2010). Temperature data analyses may help reveal stressors on aquatic life, such as wild trout, as a result of the alteration of the hydrologic regime. These alterations are both direct (groundwater pumping and discharge) and

indirect (alteration to aquifer recharge) and can have positive or negative impacts on water quality. Additionally, inclusion of a metric which evaluates minimum instream flow (Q₇₋₁₀, Tennant, Instream Flow Incremental Methodology) should be considered for long term planning, such as in a Resource Stewardship Strategy document. Data concerning water quality, such as temperature and dissolved oxygen content, are currently collected at regular but infrequent intervals (annually). Consideration should be given to increasing the frequency at which these data are captured so that a more accurate accounting of water quality conditions can be acquired.

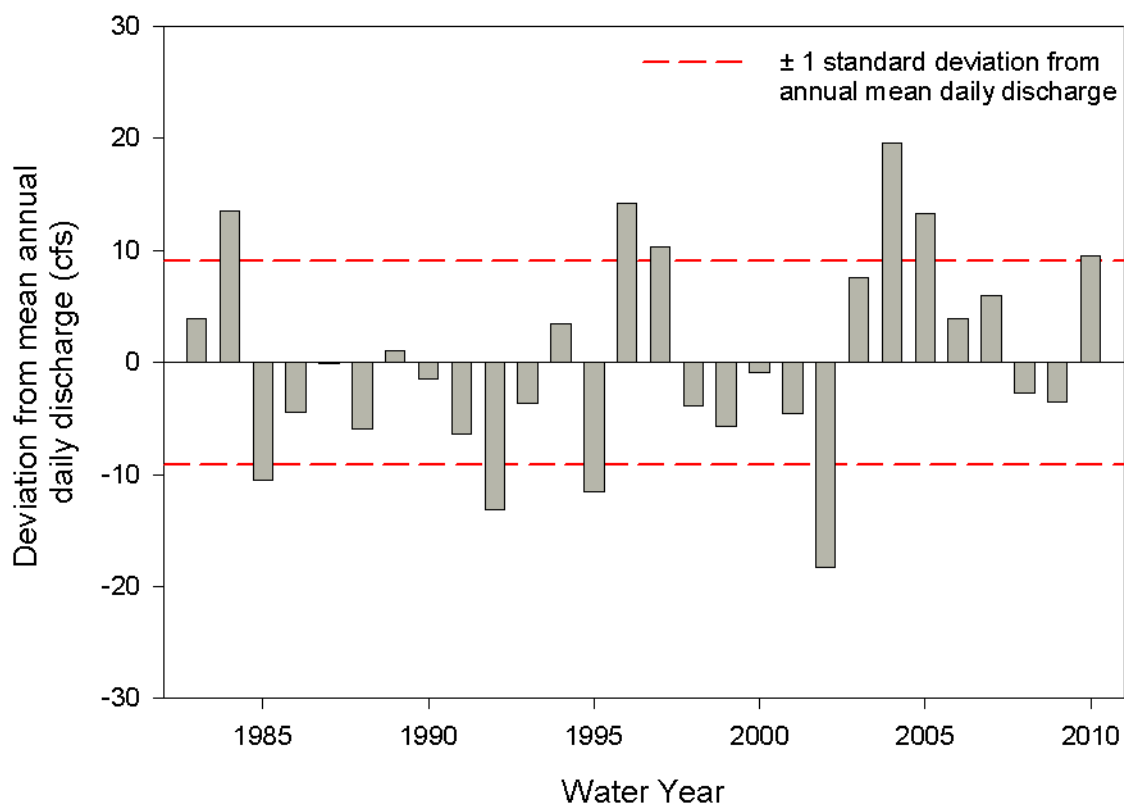


Figure 1. Deviation, by water year, from annual mean daily discharge (WY 1983 – 2010: 33.8 cfs).

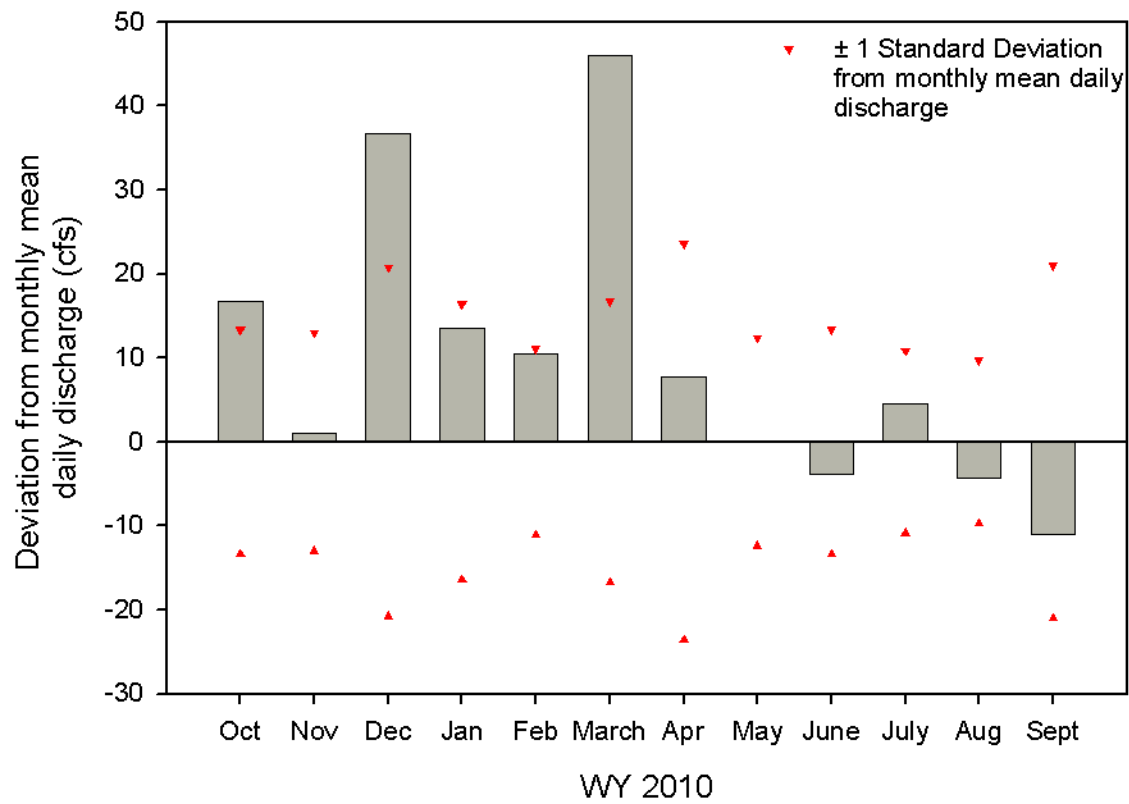


Figure 2. Deviation from monthly mean daily discharge (WY 1983 – 2010) by month for WY 2010 (Oct. 2009 – Sept. 2010).

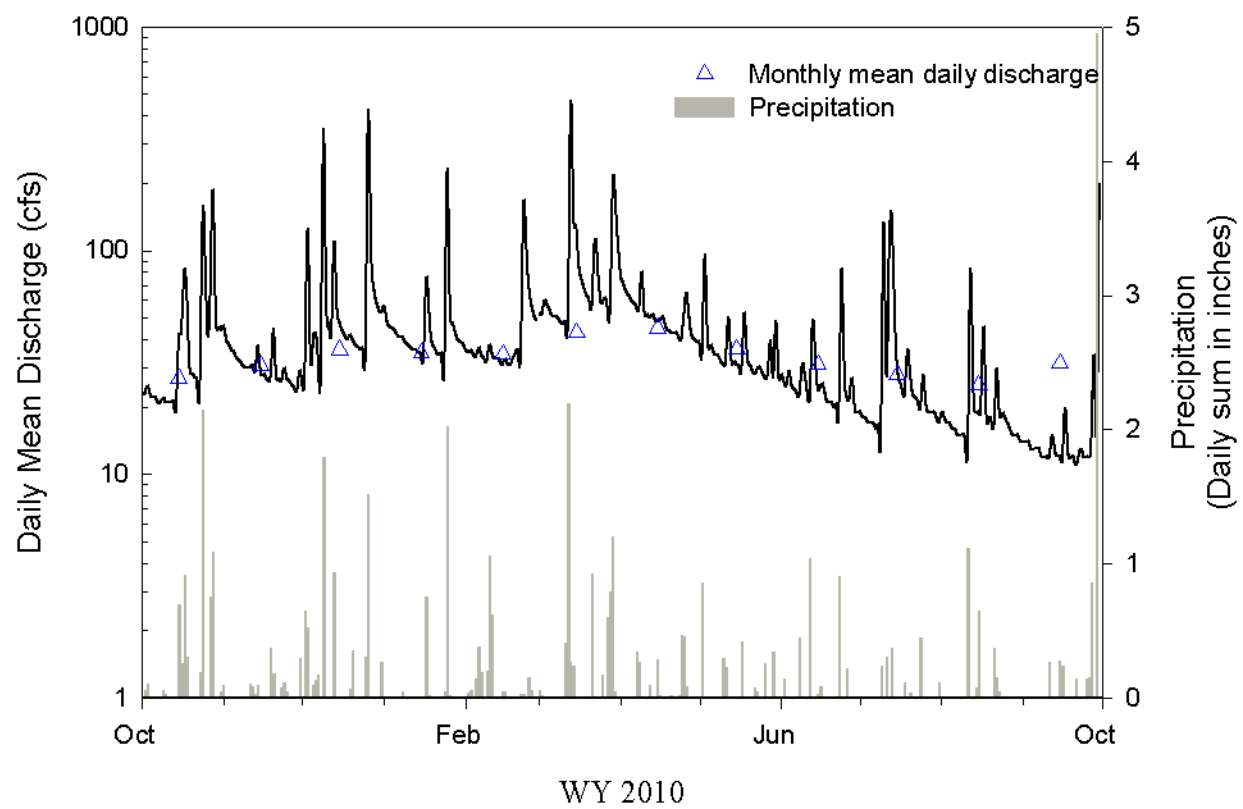


Figure 3. Valley Creek hydrograph for WY 2010 (Oct. 2009 – Sept. 2010) with daily precipitation.

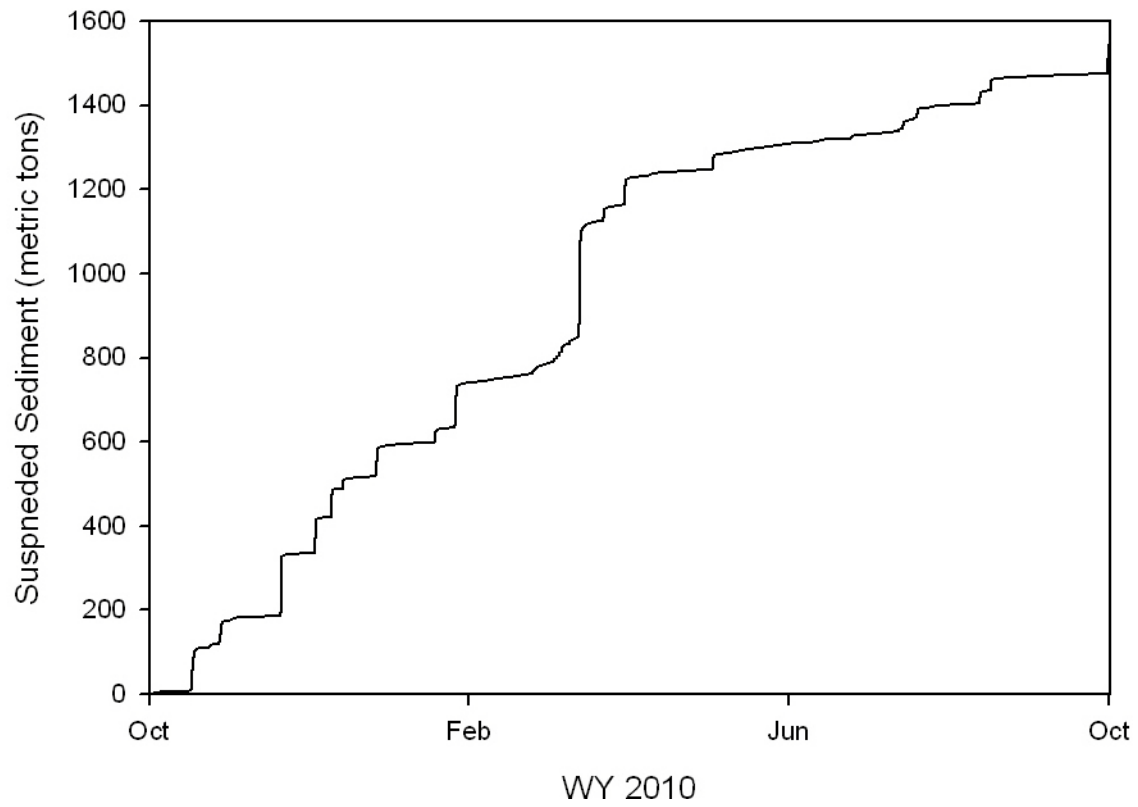


Figure 4. Cumulative suspended sediment load for WY 2010 (Oct. 2009 – Sept. 2010).

Table 1. Peak discharge (cfs), estimated suspended sediment load (Metric tons), and percent of WY 2010 annual sediment load for the three largest storm events of WY 2010 (Oct. 2009 – Sept. 2010).

Storm Event	Peak Discharge (cfs)	Suspended Sediment Load (tons)	% of Annual Load
3/13/2010	1304	255	17
11/20/2009	1203	225	15
12/9/2009	1107	198	13

Table 2. Deviation from annual mean daily discharge (WY 1983 – 2010: 33.8 cfs) and sediment load for WY 2006, 2009, and 2010.

Water Year	Annual Mean Daily Discharge (cfs)	Sediment Load (metric tons)
2006	+ 3.5	2230
2009	- 3.6	1450
2010	+ 9.5	1544

Table 3. Mean (SD) water quality values (WY 1999 – 2009) and WY 2010 (Oct. 2009 – Sept. 2010) measurements.

	Discharge (cfs)	Dissolved Oxygen (mg/l)	pH	Specific Conductance (µS/cm)	Temperature (°C)	ANC (mg/l)
WY 1999-2010	19.4 (7.9)	11.9 (1.2)	8.2 (0.2)	658.7 (41.2)	11.1 (1.6)	205.5 (17.0)
WY 2010	22	10.9	7.8	767	11.6	207

Table 4. Mean (SD) values for the three biological indices based on macroinvertebrate data for the period of record and values for WY 2010 (Oct. 2009 – Sept. 2010). All indices are classified into four impact classes (1) non-impacted (TR^a: 30-60; EPT TR^b: 10-30; HBI^c: 0-4), slightly impacted (TR: 20-30; EPT TR: 5-10; HBI: 4.51-6.50), moderately impacted (TR: 10-20; EPT TR: 1-5; HBI: 6.51-8.50), and severely impacted (TR: 0-10; EPT TR: 0-1; HBI: 8.51-10).

	Taxa Richness	EPT Taxa Richness	HBI
2004 - 2009	24 (3)	7 (2)	4.73 (0.23)
2010	23	9	4.91

^aTR = taxa richness

^bEPT TR = Ephemeroptera, Plecoptera, Trichoptera taxa richness

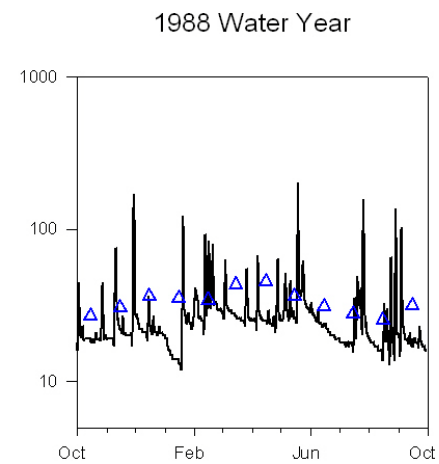
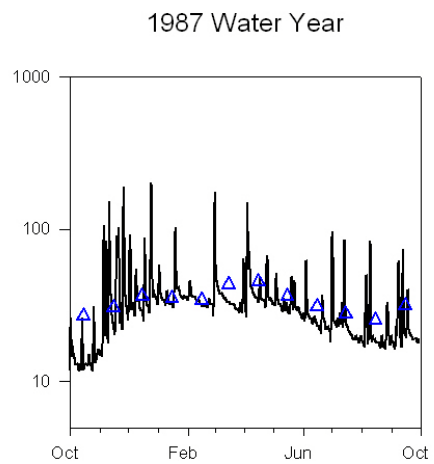
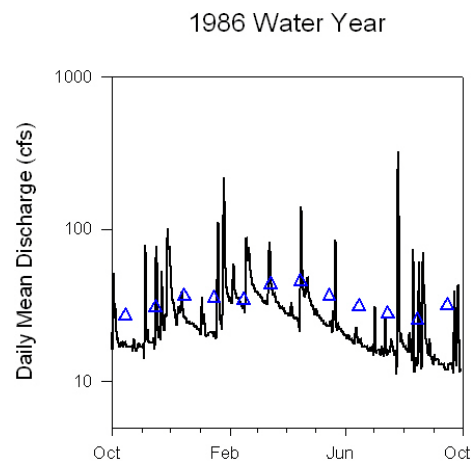
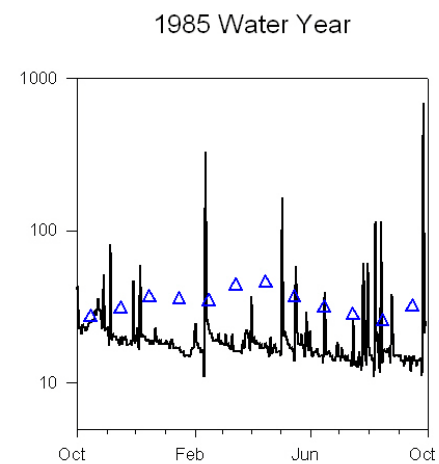
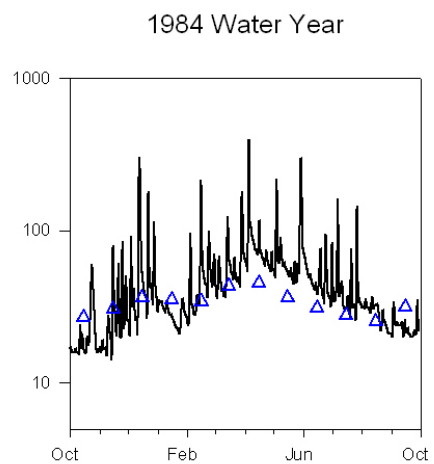
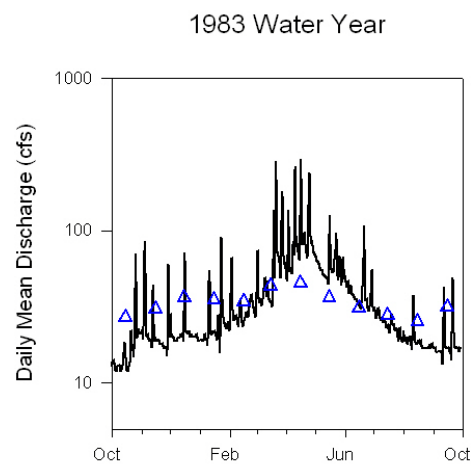
^cHBI = Hilsenhoff's Biotic Index

Literature Cited

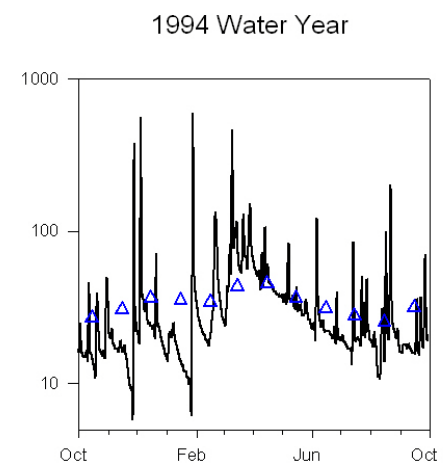
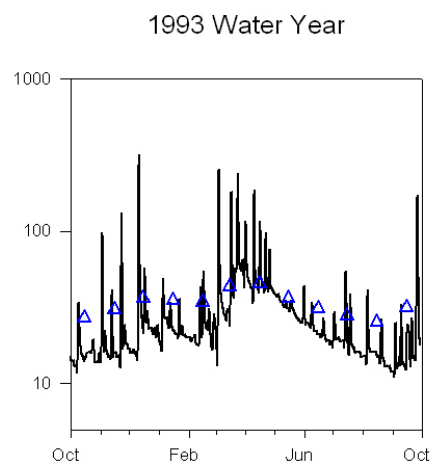
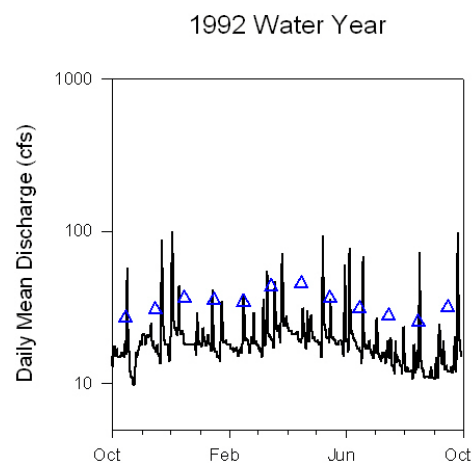
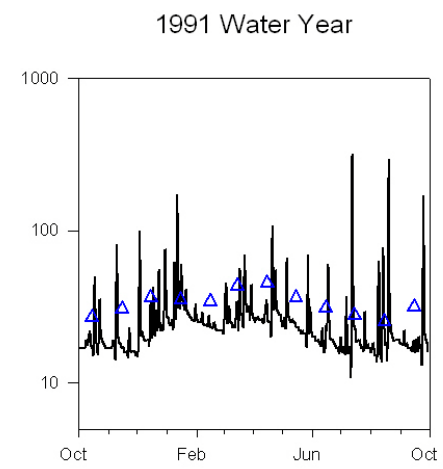
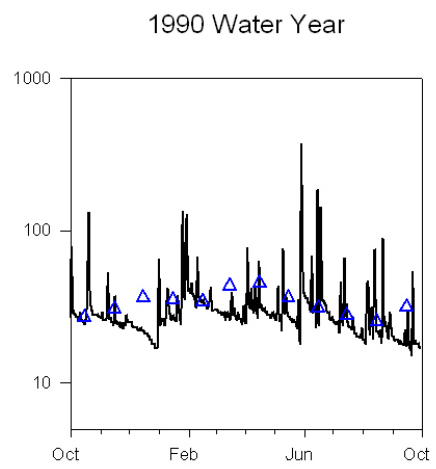
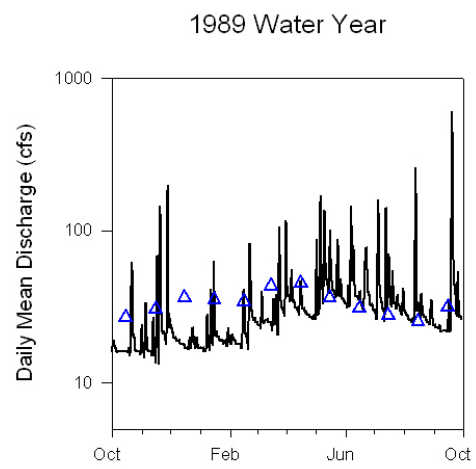
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Appendix A: Discharge WY 1983 – 2010

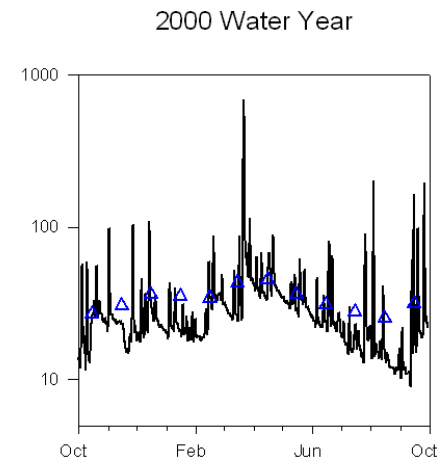
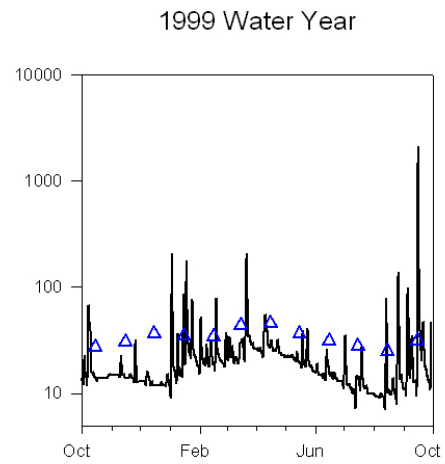
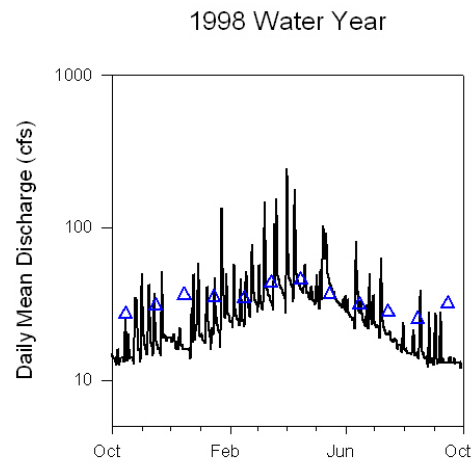
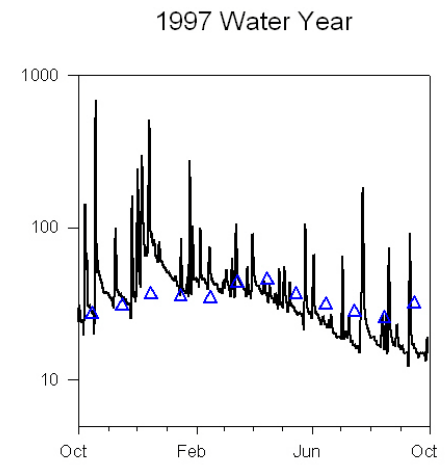
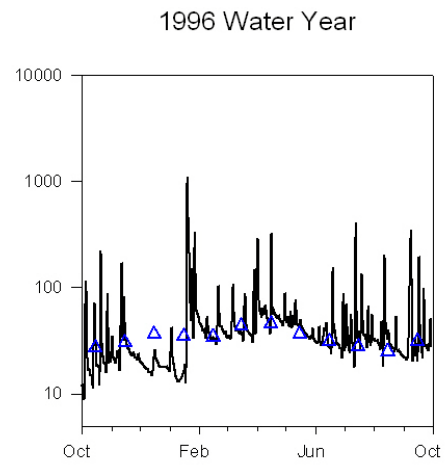
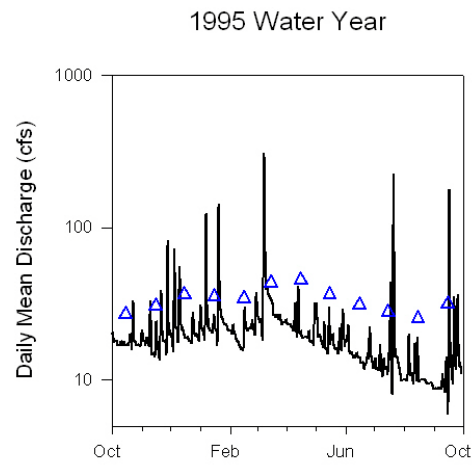
This section displays the hydrographs for WY 1983 – 2010 by water year. When available, precipitation data is presented along with instantaneous discharge.



△ Monthly mean daily discharge (1982-2009)

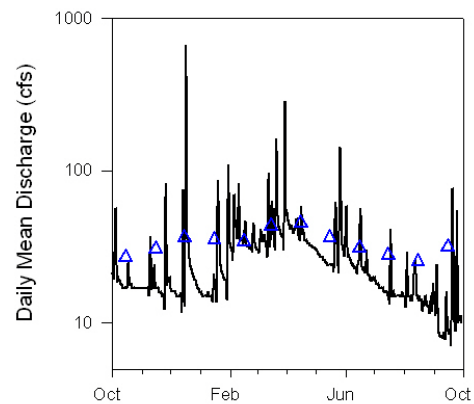


△ Monthly mean daily discharge (1982-2009)

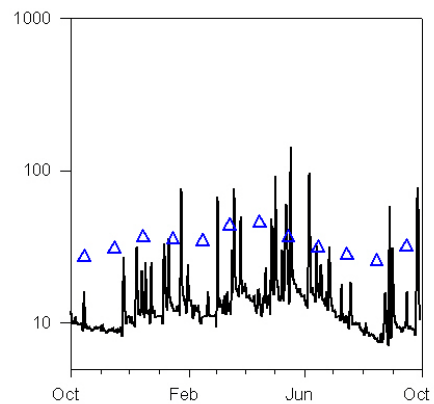


△ Monthly mean daily disharge (1982-2009)

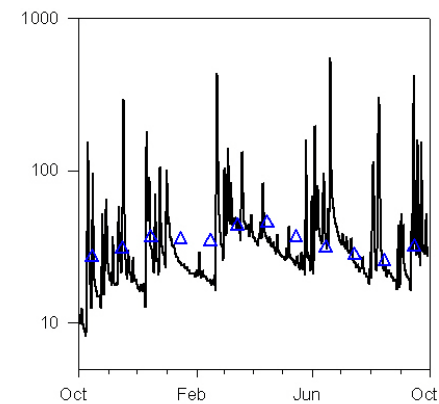
2001 Water Year



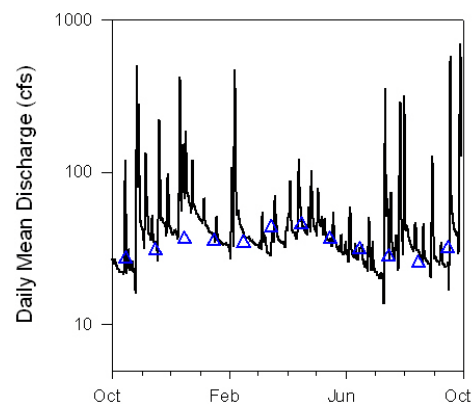
2002 Water Year



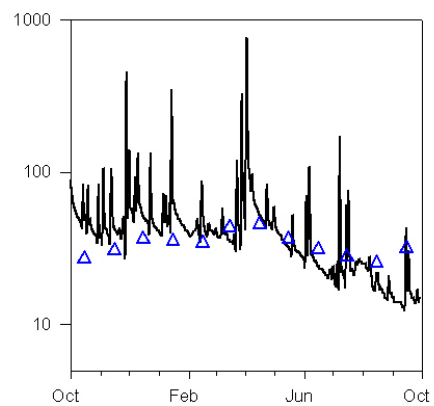
2003 Water Year



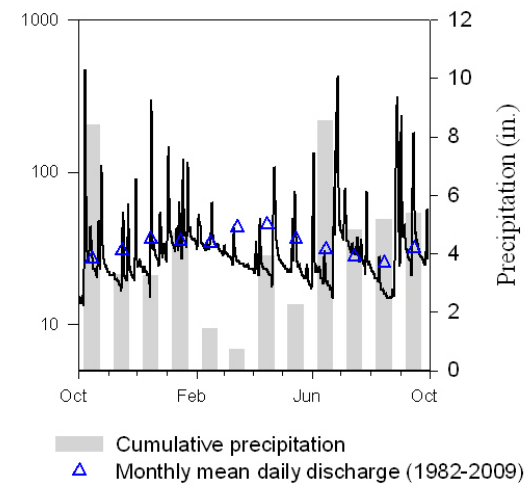
2004 Water Year

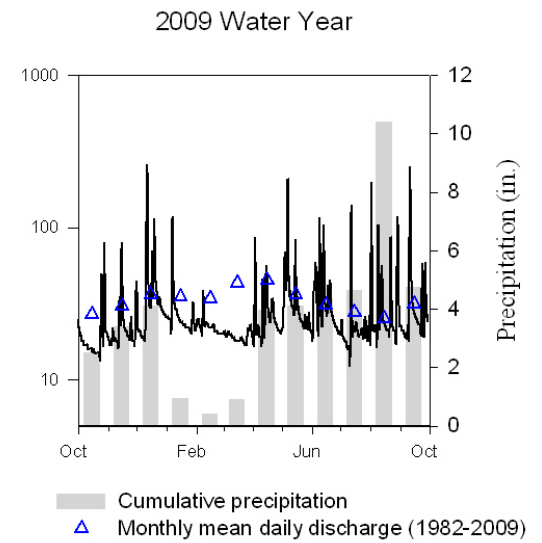
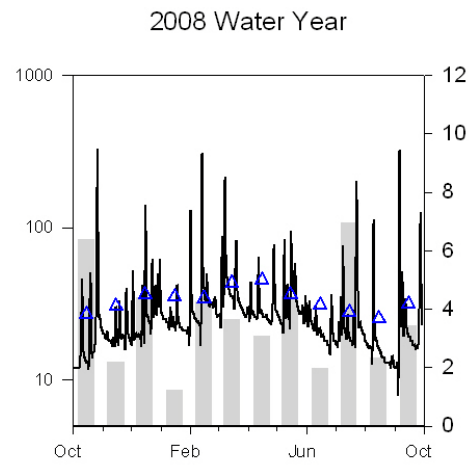
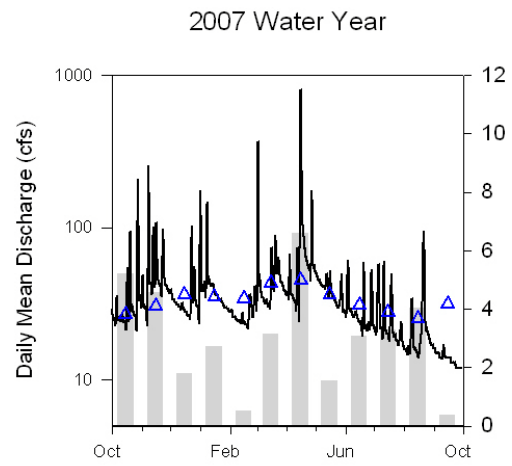


2005 Water Year



2006 Water Year





The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 464/111728, December 2011

National Park Service
U.S. Department of the Interior



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