From Drench to Dry:

Comparing 2011 and 2012

Spring Creek Watershed Association
Water Resources Monitoring Project

2011 State of the
Water Resources Report

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SPRING CREEK WATERSHED ASSOCIATION

A grassroots stakeholder initiative

From the Chair

In this issue of the State of the Water Resources we will examine the effects of widely varying amounts of recharge (precipitation) on the Spring Creek Watershed. The spring and fall of 2011 were very wet seasons during which we were experiencing extremely high amounts of precipitation when compared to long-term average precipitation for the area. (In fact, 2011 was the second wettest year on record.) In contrast, late-winter and spring of 2012 were very dry, when only 49% of the combined long-term average monthly precipitation for those months fell on our watershed.

Cycles of wet and dry have impacts on the quantity and quality of groundwater and surface water in the Spring Creek Watershed. The many springs that feed our streams can support a relatively healthy base flow during dry spells but when there is low precipitation for extended periods of time, groundwater levels can fall and stream flow can be diminished. Although a common perception was that stream levels in our watershed were abnormally low during the summer of 2012, stream flows were about average. This is testament to how very wet 2011 was and the robust groundwater support it provided for the dry spell in 2012.

In 2011 we introduced a new element to our watershed monitoring program, that of biological monitoring. Biological monitoring involves sampling and cataloging macroinvertebrates that live in the sediments at the bottom of our streams. Macroinvertebrates include insect larvae, crayfish, mussels, aquatics snails and worms. In a healthy stream, the benthic community will include a variety of pollution-sensitive macroinvertebrates. In-stream sampling for the first macroinvertebrate survey initiated by the WRMP was conducted in March of 2012 and sample analysis is currently ongoing. The results from this survey will be fully detailed in the 2012 State of the Water Resources Report.

We hope that you find this year's report on the State of the Water Resources both interesting and informative. Residents of the Spring Creek Watershed currently enjoy better water quality than the region has seen in nearly 100 years. The Water Resources Monitoring Project (WRMP), which has been in place for over 13 years, provides vital long-term data that can be used by local planning officials to make sound land use decisions. The advisory committee to the WRMP (or WRMC) is very appreciative of the donations the program receives on an annual basis from our sponsors. Your continued support will help maintain the program's ability to provide the data needed to monitor changes within the watershed as our community continues to grow.

Rick Vardrop

Rick Wardrop,

Chair

The Spring Creek Watershed Association (SCWA), a grassroots stakeholder group composed of concerned citizens and professionals, initiated the WRMP in 1997 as part of its strategic plan for the watershed. Their goal was to gather baseline information about the quantity and quality of the water resources in the Spring Creek Watershed that could be used for the long-term protection of these resources as demands on them increase over time. A group of local environmental professionals formed the Water Resources Monitoring Committee in 1998 to develop and oversee the WRMP (see the listing of the current committee on **Table 1**). The first surface water monitoring stations were established in late 1998/early 1999. Groundwater, surface water, stormwater and spring monitoring stations were added as the project gained momentum (see **Figure 1** for a timeline of events). Over the past thirteen years, the WRMP has strived to:

- Provide a description of the quantity and quality of the surface waters of Spring Creek and its tributaries, including springs;
- Provide a description of the quality of stormwater runoff throughout the watershed;
- Monitor groundwater levels in critical areas;
- Provide the means to detect changes in quantity and quality of surface waters under both baseflow and storm-water runoff conditions, as well as groundwater reserves;
- Provide sufficient measurement sensitivity through long-term monitoring to permit the assessment of the previously mentioned parameters.

The WRMP field stations and database are maintained primarily by the Water Resources Coordinator, a full-time staff position housed at ClearWater Conservancy, with the assistance of volunteers and ClearWater interns. A number of local partners continued to provide funding to carry out WRMP data collection activities to support this one-of-a-kind project in 2011. Donors in support of the 2011 effort included:

- Bellefonte Borough
- Benner Township
- College Township
- Ferguson Township
- Halfmoon Township
- Harris Township
- Patton Township
- Pennsylvania State University Office of Physical Plant
- Spring Township

WRMP Committee Member	Affiliation
Rick Wardrop, P.G. ***Committee Chair*** Hydrogeologist	Groundwater & Environmental Services, Inc.
Nick Schipanski Water Resources Coordinator	ClearWater Conservancy
Jason Brown Project Manager	University Area Joint Authority
Susan Buda Aquatic Ecologist	Citizen Volunteer
Robert Carline, Ph.D. Aquatic Ecologist	Pennsylvania Cooperative Fish and Wildlife Research Unit, USGS-retired
Ann Donovan Watershed Specialist	Centre County Conservation District
Larry Fennessey, Ph.D., P.E. Utility Systems Engineer - Stormwater	Office of Physical Plant, The Pennsylvania State University
Todd Giddings, Ph.D., P.G. Hydrogeologist	Todd Giddings and Associates, Inc.
James Hamlett, Ph.D. Associate Professor of Agricultural Engineering	Department of Agriculture and Biological Engineering, The Pennsylvania State University
Bert Lavan West Nile Virus Program Coordinator	Centre County Office of Planning and Community Development
Mark Ralston, P.G. Hydrogeologist	Converse Consultants
Kristen Saacke-Blunk Director	Agriculture and Environmental Policy Center, The Pennsylvania State University
Doug Weikel, P.E., C.S.I. Service Group Manager	Herbert, Rowland, and Grubic, Inc.
David Yoxtheimer, P.G. Extension Associate	Marcellus Center for Outreach and Research, The Pennsylvania State University

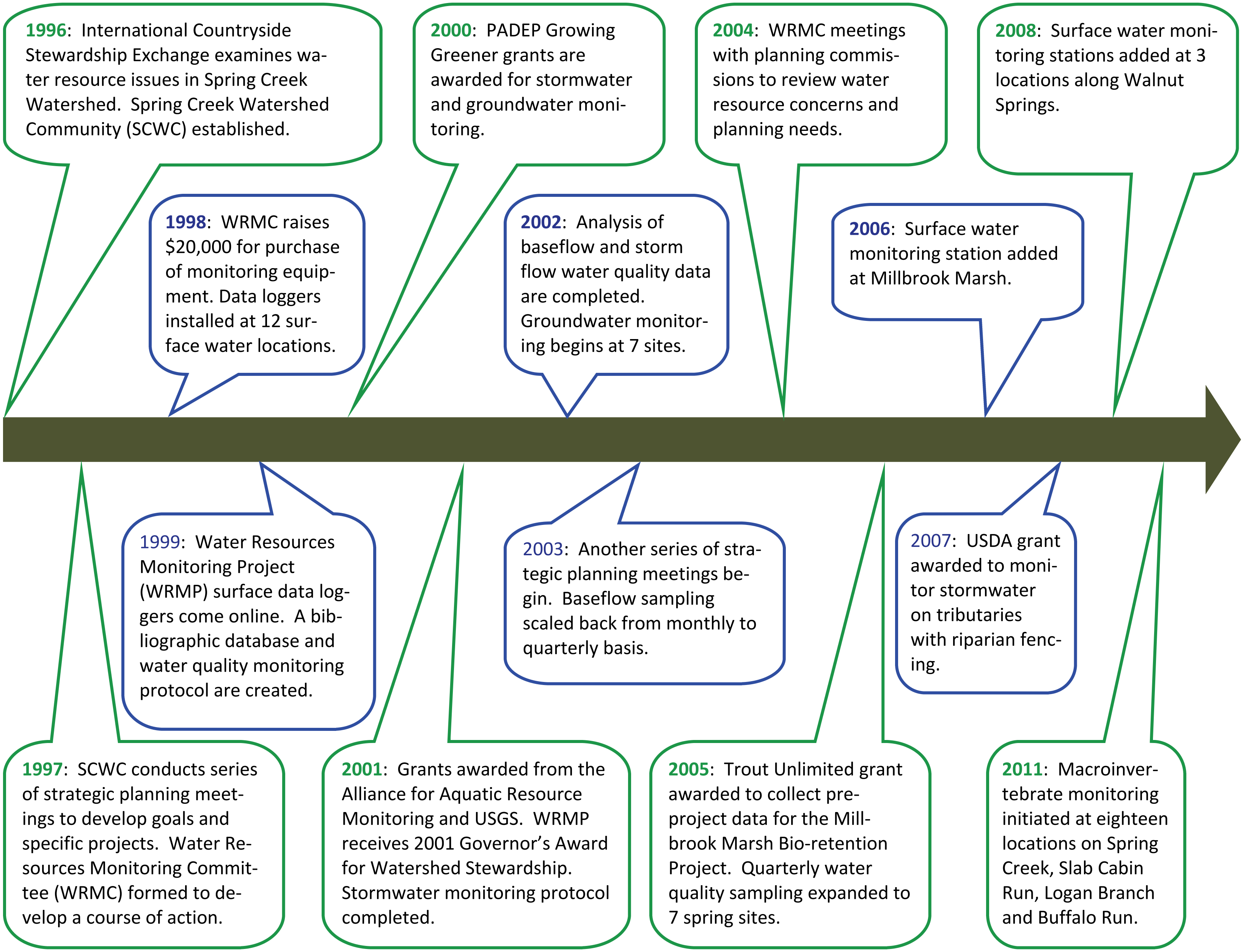
Table 1. Water Resources Monitoring Committee Members for 2011.

- Spring Township Water Authority
- State College Borough
- State College Borough Water Authority
- Spring Creek Chapter of Trout Unlimited
- University Area Joint Authority.

In addition to financial support, the WRMP received in-kind donations of professional services, water level and stream stage data, laboratory analyses and supplies, technical assistance, and transportation from the following in 2011:

- PA Department of Conservation of Natural Resources (PADCNR)
- Todd Giddings
- The Pennsylvania State University-Office of Physical Plant (PSU-OPP)
- United States Geological Survey (USGS)
- Pennsylvania Department of Environmental Protection (PADEP)
- Pennsylvania Cooperative Fish and Wildlife Research Unit
- University Area Joint Authority (UAJA)
- Volunteer field assistants
- Water Resources Monitoring Committee (WRMC) members.

WRMP Timeline



1996: International Countryside Stewardship Exchange examines water resource issues in Spring Creek Watershed. Spring Creek Watershed Community (SCWC) established.

1997: SCWC conducts series of strategic planning meetings to develop goals and specific projects. Water Resources Monitoring Committee (WRMC) formed to develop a course of action.

1998: WRMC raises $20,000 for purchase of monitoring equipment. Data loggers installed at 12 surface water locations.

1999: Water Resources Monitoring Project (WRMP) surface data loggers come online. A bibliographic database and water quality monitoring protocol are created.

2000: PADEP Growing Greener grants are awarded for stormwater and groundwater monitoring.

2001: Grants awarded from the Alliance for Aquatic Resource Monitoring and USGS. WRMP receives 2001 Governor's Award for Watershed Stewardship. Stormwater monitoring protocol completed.

2002: Analysis of baseflow and storm flow water quality data are completed. Groundwater monitoring begins at 7 sites.

2003: Another series of strategic planning meetings begin. Baseflow sampling scaled back from monthly to quarterly basis.

2004: WRMC meetings with planning commissions to review water resource concerns and planning needs.

2005: Trout Unlimited grant awarded to collect pre-project data for the Millbrook Marsh Bio-retention Project. Quarterly water quality sampling expanded to 7 spring sites.

2006: Surface water monitoring station added at Millbrook Marsh.

2007: USDA grant awarded to monitor stormwater on tributaries with riparian fencing.

2008: Surface water monitoring stations added at 3 locations along Walnut Springs.

2011: Macroinvertebrate monitoring initiated at eighteen locations on Spring Creek, Slab Cabin Run, Logan Branch Run and Buffalo Run.

Figure 1. Timeline of major events associated with the Water Resources Monitoring Project.

Stream Monitoring Stations

The WRMP measures conditions at four sites along the main stem of Spring Creek and fourteen tributary sites located throughout the stream's five major subbasins (**Figure 2**). Twelve of the eighteen sites currently included in the WRMP have been monitored since 1998. The WRMC chose the twelve original sites to be representative of land use practices across the watershed. Three of the original sites were chosen to coincide with existing USGS gaging stations. In 2004, the WRMP added two water quality monitoring sites on headwater tributaries to serve as baselines (Buffalo Run Valley View and Galbraith Gap Run). A fifteenth WRMP stream monitoring station, located on Slab Cabin Run downstream of Millbrook Marsh, was added in 2005 to assess the marsh's ability to control stormwater impacts from downtown State College and University Park. The final three sites currently monitored are located in the Walnut Springs subbasin in State College Borough to monitor stormwater impacts.

WRMP monitoring station on Walnut Springs.

Groundwater Monitoring Stations

The WRMP monitored water levels at three wells in 2011 (**Figure 3**). These wells were selected because they are not subject to frequent fluctuations caused by external factors such as high-yield pumping, stormwater, artificial groundwater recharge, or surface water discharges. In addition, the WRMP analyzes publically available data from two USGS monitoring wells (**Figure 3**). When considered together, the five wells provide a picture of representative groundwater conditions across the Spring Creek Watershed.

Spring Monitoring Stations

Spring monitoring became part of the WRMP in 2005 with the addition of water quality monitoring at seven spring stations (**Figure 3**). Like the stream and groundwater sites, these springs were chosen to be representative of various land use, geologic, and hydrologic conditions encountered in the Spring Creek Watershed.

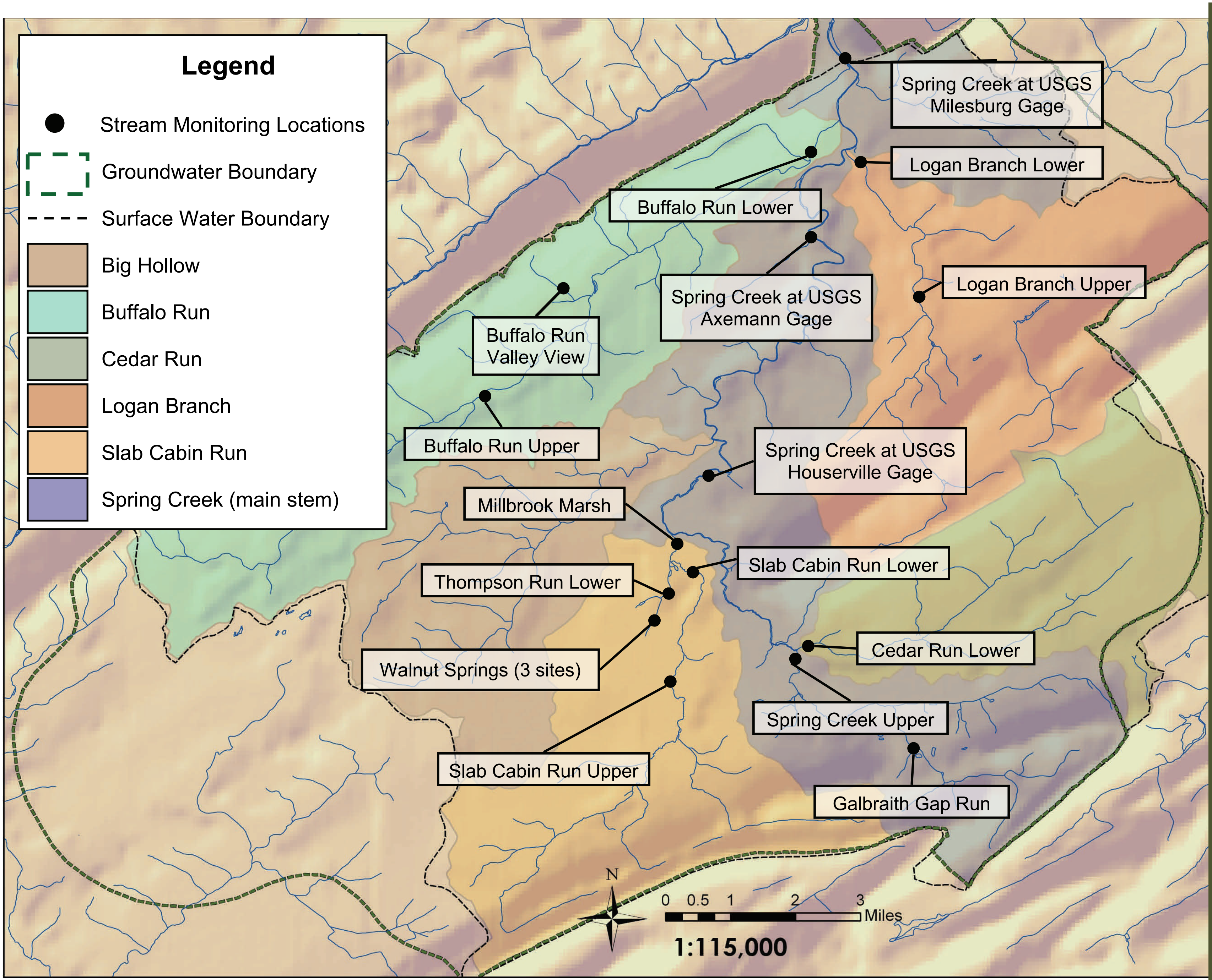


Figure 2: Stream sampling sites surveyed in 2011 as part of the Water Resources Monitoring Project. and USGS stream gages.

Monitoring Stations

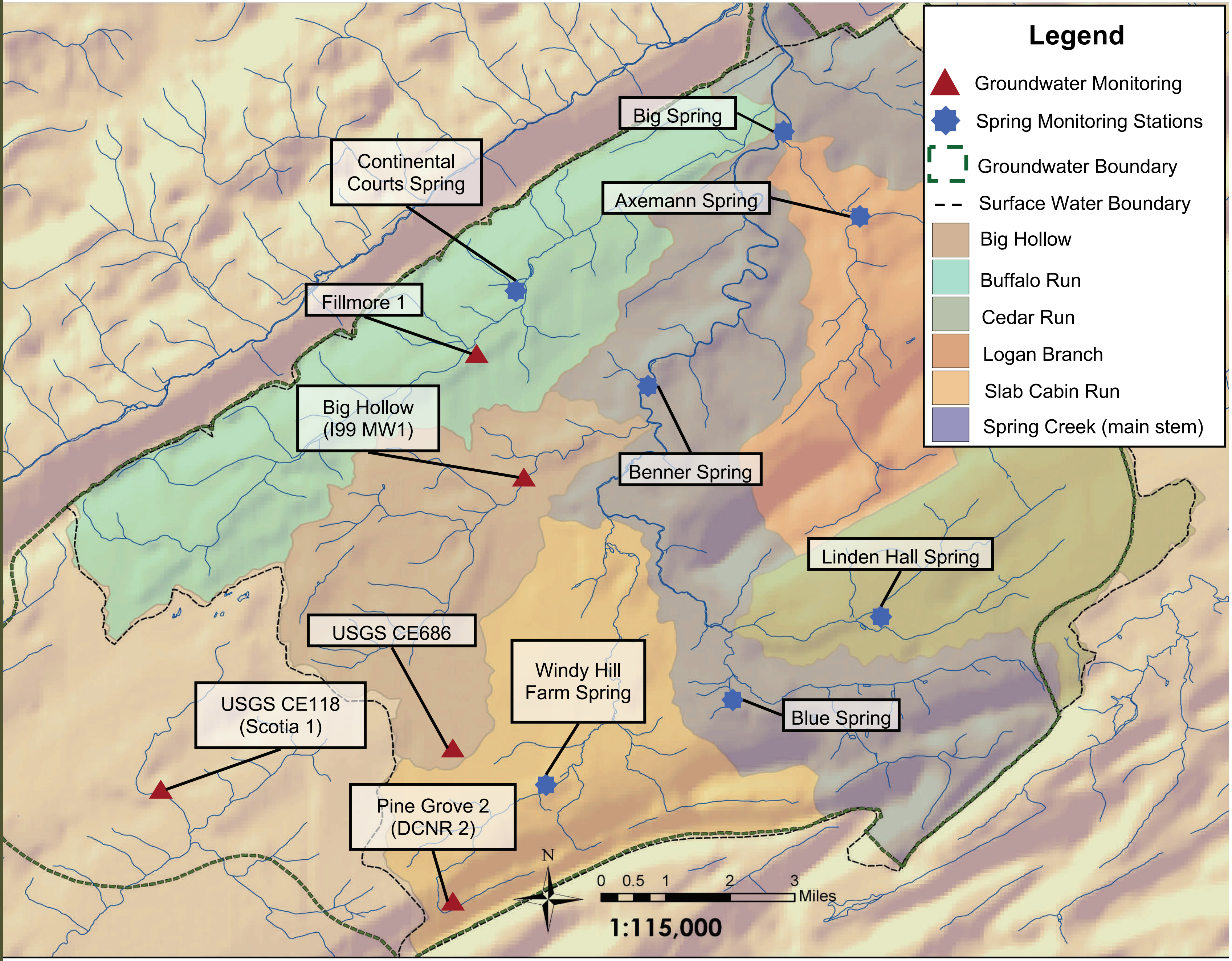


Figure 3: Groundwater and spring stations surveyed in 2011 as part of the Water Resources Monitoring Project and USGS groundwater monitoring wells.

Water Quality Monitoring

WRMP staff and volunteers collected water samples from fifteen stream sites and seven springs in 2011. Sampling took place on a quarterly basis (in May, August, November and December) when streams were at baseflow conditions. The water samples were analyzed for chemical and nutrient content by the PADEP Analytical Laboratories. Coliform analysis of spring samples was conducted by the University Area Joint Authority laboratory. **Appendices 4** and **5** summarize the results of the 2011 water quality analysis.

Continuous Measurements

Thirteen stream stations were equipped with instruments to continuously monitor stream stage. Thirteen of these were maintained by the WRMP and outfitted with one of three types of pressure transducer: Design Analysis Associates, Inc. DH-21 pressure transducers; Solinst, Inc. Levelogger Gold pressure transducer, or; Solinst, Inc. Levelogger Edge pressure transducer. Both types of Solinst transducer are non-vented and were coupled with a Solinst Barologger Edge or Barologger Gold to compensate for atmospheric pressure. Stream stage was recorded every 30 minutes for all stations except Lower Thompson Run and the three stations on Walnut Springs, where stream stage was recorded every 5 minutes. Readings were taken more frequently at these stations because past data have shown that flow in Thompson Run and Walnut Springs can fluctuate rapidly in a short period of time during storm events.

The other three stream monitoring stations are the stations maintained by the USGS.

WRMP volunteer Dan Delotto conducting a site survey.

Water temperature was measured hourly at 14 stream stations using Onset Computer Corporation Optic Stowaway TidBitv2 data loggers. At the Thompson Run station and Middle Walnut Springs station, the temperature data logger was set to record temperature every 5 minutes instead of every hour. Again, readings were taken more frequently at these stations because, as with flow, past data have shown that temperatures in Thompson Run and Walnut Springs can fluctuate rapidly in a short period of time during storm events. Water temperature data summaries for 2011 are presented in **Appendix 7**.

Water surface elevation was recorded every 3 hours at the five wells comprising the groundwater monitoring network. WRMP staff and volunteers maintained the monitoring instruments at three of the five wells, which were equipped with InSitu miniTROLL pressure transducers. The other two wells, CE118 and CE686, were maintained by the USGS. **Appendix 8** summarizes the groundwater elevation data for 2011.

Discharge Measurements

Data from the WRMP stream gages are collected as stream water level (or stage) data. In order to better understand the behavior of the streams, the data needs to be expressed as stream flow, or discharge. A rating table or curve is a relationship between stage and discharge at a cross-section of a stream. To develop a rating curve the Water Resources Coordinator and volunteers make a series of discharge measurements using a hand-held current meter (Marsh-McBirney FlowMate). These discharge points are plotted versus their accompanying stage, and a curve is drawn through the points (**Figure 4**). There can be significant scatter around this curve. Because of this, it is good to keep in mind that the discharge values provided by WRMP are estimates of the most likely discharge value. Also, wading into the stream to collect discharge measurements during high flows is not safe. Therefore, WRMP discharge values at high flows are calculated by extrapolating the rating curve to higher stages. As a result, there can be significant errors in the rating curves at higher flow levels. Estimated discharges are indicated by the use of dashed lines in the graphs of WRMP flow data.

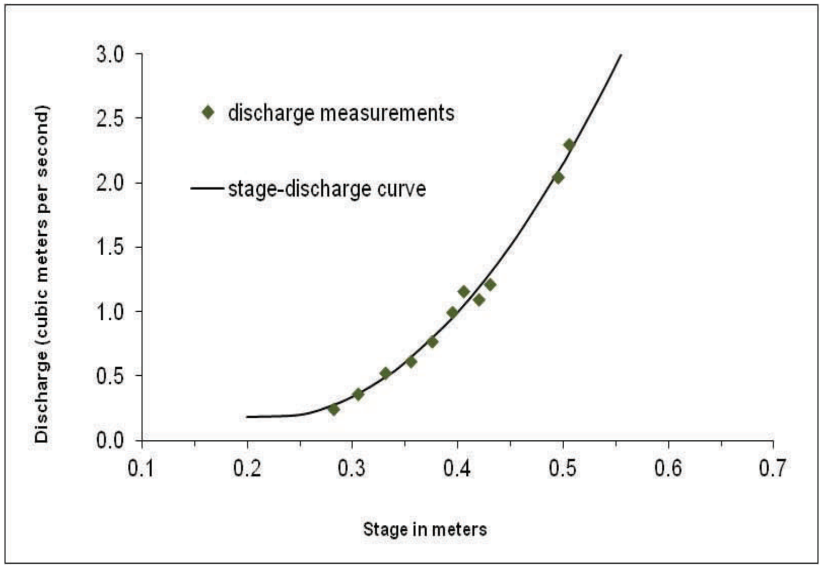


Figure 4. Stage-discharge relationship for the WRMP gaging station on Buffalo Run at Coleville.

Discharge measurements are made at each gaging station throughout the year to ensure the validity of the rating curves. Sometimes, stream channel dimensions at the gage site may change due to processes such as sediment erosion or deposition. The Water Resources Coordinator and the technical subcommittee of the Water Resources Monitoring Committee periodically review the rating curves and revise them as needed.

The data for the USGS-operated stream gages is also collected as stage data. Rating curves for these stations are maintained by the USGS. The USGS is equipped to measure discharge at higher flows to produce reliable rating curves at high stages.

Appendix 6 summarizes the stream discharge data for 2011.

Data Quality

To assure the consistency and quality of data collected as part of the WRMP, the WRMC developed a set of standardized procedures for data collection, sample processing and database maintenance. A detailed description of these methods can be found in the Spring Creek Watershed Water Resources Monitoring Protocol. To review this document, please contact Nick Schipanski at (814) 237-0400.

In addition to periodic review of rating curves, the Water Resources Coordinator and the WRMC also reviews operational procedures and equipment used in the monitoring program. In 2011, the WRMP discontinued the use of the type of pressure transducer used to record stream stage since the programs' inception in 1998 due to increasingly frequent unit failures. By the end of 2011, all stream monitoring stations were equipped with other pressure transducers considered more reliable. As a result of these changes, data logger reliability has greatly improved while operational costs have decreased.

Appendix 3 provides detailed summaries of the monitoring and data collected at each WRMP location.

WRMP monitoring location on Spring Creek in Oak Hall.

Monitoring Results: Comparing 2011 and 2012

The Spring Creek Watershed experienced two very different precipitation patterns in 2011 and 2012 (to date). Using data collected at the University Park campus of The Pennsylvania State University, above average monthly totals in the spring and fall of 2011 gave way to dry conditions beginning in February of 2012 that continued through the summer (**Figure 5**).

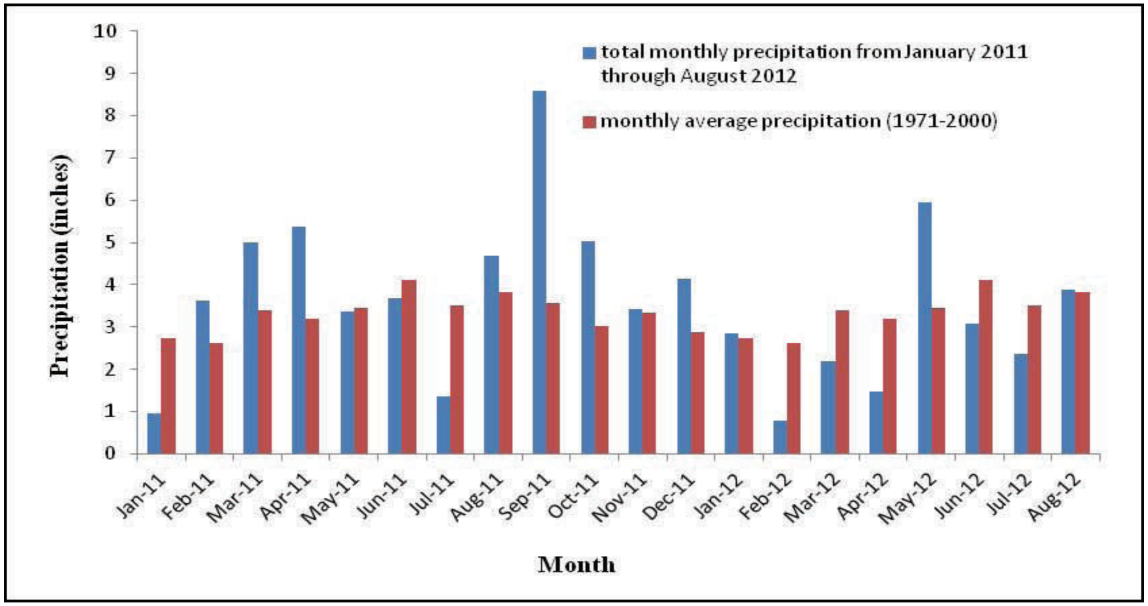


Figure 5. Monthly precipitation in State College from January 2011 through August 2012. Total monthly precipitation and average monthly values are from the PA State Climatologist, available at http://climate.met.psu.edu/www_prod/ida/index.php?t=3&x=shef&id=STCP1

On a calendar year basis, 2011 had 124% of average annual precipitation and 2012 is at 79% of normal through the end of August (**Figure 6**).

One way of looking at the impact of changes in precipitation on a watershed is to calculate a **water budget** and an understanding of water budgets is a foundation for effective resource management. Water budgets provide a way to measure availability and sustainability of a water supply. A water budget states that the rate of change in a watershed is balanced by the rate at which water flows into and out of the watershed. The inset “What is a Water Budget” beginning on page 12 offers a more detailed description about calculating water budgets.

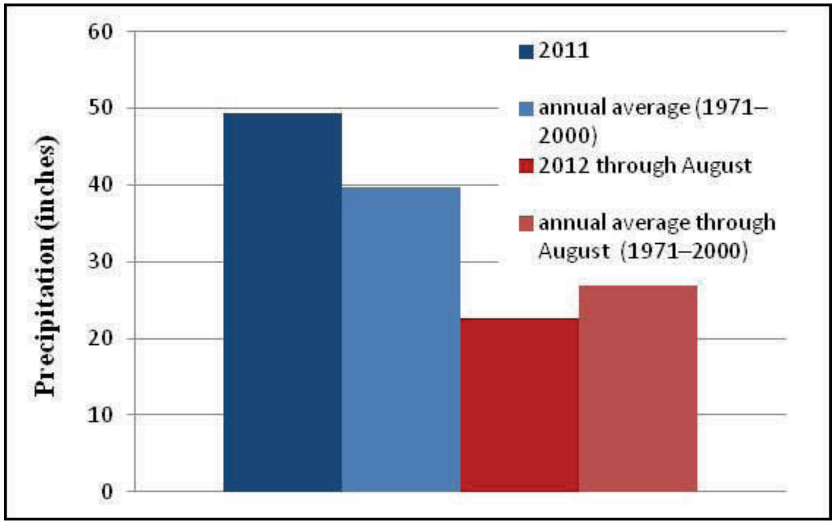


Figure 6. Annual precipitation totals by calendar year. Total annual precipitation and annual average precipitation values are from the PA State Climatologist, available at http://climate.met.psu.edu/www_prod/ida/index.php?t=3&x=shef&id=STCP1

Human activities affect the natural hydrologic cycle in many ways. Modification of landscapes to accommodate agriculture (drainage and irrigation systems) alters infiltration, runoff, and evapotranspiration rates. Urban development, and the roads, buildings and parking lots that accompany it, increase runoff and decrease infiltration. Water budgets provide a basis for assessing how natural or human-induced changes in parts of the hydrologic cycle may impact other aspects of the cycle.

The Water Budget and the Water Year

The most recent water budgets for the Spring Creek watershed were prepared for the Centre Region Council of Governments by the Susquehanna River Basin Commission (SRBC) in 1997[1]. This report will be referred to as the SRBC report. Data for the water budgets between 1968 and 1993 at the Milesburg USGS gaging station are summarized in **Table 2** on page 18.

As Dr. Giddings discusses in his description of water budgets, changes in the amount of water stored as groundwater and soil moisture are difficult to measure and calculate. Therefore, the SRBC calculated the water budgets for a period of time in which the beginning and end quantity of water stored as

continued on page 17

What is a Water Budget?

by

Todd Giddings, Ph.D., P.G.

A **water budget** is the scientific method for measuring the amount of water entering, stored within, and leaving a watershed, and it is also called a hydrologic budget or a water balance. The water budget for a watershed is directly analogous to a household financial budget, where:

Total Household Income = Expenditures for Taxes + Savings + Food + Housing + Clothing + Recreation.

People do household budgets so they can live within their means, and a water budget will tell us if we are "living within our means" in the Spring Creek Watershed. There is an axiom for water resources that states: ***"You can't manage what you don't measure."*** The water budget for the Spring Creek Watershed will answer these three key questions: **How much water do we have? How much water are we using?** and **How much water do we need?**

Precipitation is analogous to the **Household Income**. A household may receive income from salaries, wages, gifts, stock dividends, or inheritances. A watershed receives precipitation "income" in the form of rain, hail,

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[1] Taylor, L.E. 1997. *Water Budget for the Spring Creek Basin.* Susquehanna River Basin Commission Technical Report Number 184, Harrisburg, PA.

sleet, and snow. We measure the household income in dollars, and we measure the watershed precipitation income in inches of water depth over the entire area of the watershed. The frozen precipitation income, such as snow and sleet, we melt and express as its water-equivalent in inches, just as if it occurred as rainfall. Thus 10 inches of fluffy, powder snow would have a water-equivalent of approximately 1 inch of liquid when melted. One inch of rain over a one-acre area is 27,152 gallons of water.

Now let's look at our "expenditures" for the Spring Creek Watershed water budget. A major watershed "expenditure" is evapotranspiration, which is analogous to taxes, because like taxes, evapotranspiration is a major item in the water budget. Evapotranspiration is not easily seen, just like some taxes. When rainfall reaches the ground, it infiltrates into the soil and becomes available for use by grasses, crops, shrubs and trees. All vegetation transpires (breathes out) water vapor (an invisible gas) from pores in its leaves, and this natural process is called transpiration. Some of the rain that falls on vegetation (on leaves or blades of grass) and on the soil and pavement evaporates back into the air, and this process is called evaporation. In the late spring, summer, and early fall, when temperatures are warm or hot, and when vegetation is growing (and transpiring), more than two-thirds of rainfall is returned to the atmosphere by evapotranspiration (the combined effect of evaporation and transpiration) and this water never has a chance to percolate down through the soil to the water table and recharge ground-water.

So far the watershed water budget is:

Precipitation = Evapotranspiration +….

The next watershed "expenditure" of our precipitation "income" is stream Runoff. Runoff is a major watershed "expenditure" in the water budget and is analogous to the rent or mortgage payments we pay for housing. Runoff from the Spring Creek Watershed is measured continuously by a stream gage located at the mouth of the watershed, just downstream from the McCoy Dam in the mountain gap between Bellefonte and Milesburg. The U.S. Geological Survey maintains this stream gaging station, and you can view a hydrograph of the flow of Spring Creek at this Milesburg stream gage on the U.S.G.S. Web site by clicking here. Note that the flow of Spring Creek is measured in cubic feet of water per second flowing in the stream channel. (One cubic foot per second of water flow is equal to 449 gallons per minute.) This flow in cubic feet per second is added up for all the seconds in one year to calculate the total annual flow (runoff) of Spring Creek. To use this total annual runoff in the water budget, the total annual cubic feet of runoff are converted into the equivalent inches of water depth, as if the total annual volume of runoff was spread evenly over the 175 square mile area of the Spring Creek Watershed. This conversion of water measurement units is analogous to converting euros into dollars for our household budget calculations.

The water budget is now:

Precipitation = Evapotranspiration + Runoff + …

The next “expenditure” of the precipitation “income” to the watershed is Soil Moisture. The soil in the Spring Creek Watershed holds moisture (water) and is analogous to a savings account that holds dollars. Accurately measuring the amount of moisture held in the soil throughout the entire Spring Creek Watershed is a technically impossible task. One way to avoid the need to have accurate soil moisture measurements is to calculate the water budget of the watershed on an annual basis. We assume that the amount of water stored in the soil on December 31st is the same at the end of each year, and so we don’t have to measure it. This is analogous to a savings account that has the same balance at the end of each household budget year. Soil moisture is so difficult to measure accurately over an entire watershed that the usual procedure for calculating annual watershed budgets is to end the budget year during a period of negligible evapotranspiration. Then it can be assumed that the soil moisture is not significantly different than at the end of other budget years.

The water budget is now:

Precipitation = Evapotranspiration + Runoff + ∆Soil Moisture +...

The “∆” symbol stands for “change in”, so ∆Soil Moisture reads as Change in Soil Moisture. Because we calculate the annual budget to date when the soil moisture storage is assumed to be the same as the soil moisture storage on that date a year ago, the change in soil moisture storage is zero, and the ∆Soil Moisture value in our water budget equation is 0.

The next term in our water budget is Change in Surface Water, expressed as ∆Surface Water. The Spring Creek Watershed does not contain any lakes or large reservoirs that store surface water, and the ponds are so small that they do not affect the budget calculation for the entire watershed. It is assumed that the volume of water contained in the stream channels is the same at the end of each annual water budget period, and therefore the ∆Surface Water term in the annual water budget is 0.

Our water budget is now:

Precipitation = Evapotranspiration + Runoff + ∆Soil Moisture + ∆Surface Water + …

The last “expenditure” of the precipitation “income” in the water budget is Change in Ground-Water Storage, expressed as ∆Ground Water. Ground water is stored throughout the Spring Creek Watershed in the sandstone, shale, limestone, and dolomite bedrock formations beneath the soil cover layer. The ground water is stored in the spaces between rock grains, and in the fractures, bedding planes, and solution openings (caverns) within the bedrock. These openings are called the porosity of the bedrock, and porosity is a measure of the water-holding capacity of subsurface bedrock. With respect to ground water movement, it is not just the total magnitude of porosity that is important, but also the size of the voids and the extent to which they are interconnected, as the pores in a bedrock formation may be open and interconnected, or closed and isolated. A bedrock formation that stores and transmits water, such as to wells and springs is called an aquifer. Use of the term aquifer is often restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply.

The change in ground-water storage is calculated by using water-table levels in several monitoring wells located throughout the watershed. If the average water-table level is lower at the end of the water budget period, then there was a reduction in the amount of ground water stored in the watershed during the budget period. The household budget analogy is a lower savings account balance at the end of the budget period, indicating a decrease in savings. If the household income were temporarily reduced, then to pay for rent and food expenses the family would use some of their savings. When the Spring Creek Watershed received 18% less than average precipitation (income) in year 2000, to meet the evapotranspiration and runoff “expenditures”, the “savings” in ground water storage were “spent”, and the average water-table level in the watershed at the end of 2000 was significantly lower than on January 1, 2000.

The complete water budget equation is:

Precipitation = Evapotranspiration + Runoff + ∆Soil Moisture + ∆Surface Water + ∆Ground Water

For the Spring Creek Watershed in 1968, the values (in inches) for the water budget equation were:

33.51 Precipitation = 21.87 Evapotranspiration + 12.14 Runoff + 0 ∆Soil Moisture + 0 ∆Surface Water -0.5 ∆Ground Water

The -0.5 ∆Ground Water means that one-half inch less ground water was in the watershed at the end of 1968. Remember we are expressing all of the water amounts as a depth in inches over the entire 175 square mile area of the Spring Creek Watershed. The 33.51 inches of precipitation were 14 % below normal in 1968, and ground water discharge sustained the flows of the springs and streams.

The Spring Creek Watershed has several unique hydrologic characteristics. Some of these unique characteristics are evident by comparing the water budget characteristics of the Spring Creek Watershed to three other watersheds that do not contain 80 % of their total area in limestone and dolomite aquifers in their valleys.

The key role of ground-water recharge, storage, and discharge in the Spring Creek Watershed is demonstrated by the 86.1 percent of total annual runoff that is ground water. Beaverdam Creek Watershed, composed of sand and gravel on the coastal plain of New Jersey, is a distant second at 72%. Notice that evapotranspiration removes two-thirds of the total annual precipitation that falls in the Spring Creek Watershed.

Watershed Name:	**Spring Creek**[1]	**Hadley Creek**[2]	**Beaverdam Creek**[3]	**Pomperaug River**[4]
Location	Pennsylvania	Illinois	Maryland	Connecticut
Date of Budget	1968	1957	1951	1913
Area in Sq. Miles	175	73	20	89
Physiography	Valley & Ridge	Till Plains	Coastal Plain	Highlands
Principal Aquifers	Carbonate Rocks & Clastic Rocks	Glacial Till over Shale	Silt, Sand, and Gravel	Till over Crystalline Rocks
Average Depth to Water Table - feet	89	10	8	17
Total Annual Precip. - inches	33.5	39.7	41.4	44.4
Ground Water percent of Total Runoff	86.1	13.8	72.0	42.0
Values below are expressed as a **percent** of total annual precipitation.				
Total Runoff	36.3	35.0	36.1	46.4
Groundwater Runoff	31.2	4.8	25.9	19.6
Total Evapotranspiration	65.5	62.0	60.7	52.2
Groundwater Evapotranspiration	2.8	2.5	23.5	14.0
Groundwater Recharge	33.2	10.1	51.5	35.0

1 Giddings, M.T. 1974. Hydrologic Budget of the Spring Creek Drainage Basin, Pennsylvania. Doctoral Dissertation, The Pennsylvania State University, 76 pp.
2 Schicht, R.J. and W.C. Walton. 1961. Hydrologic Budgets for Three Small Watersheds in Illinois. Illinois State Water Survey Report of Invest. 40, 40 pp.
3 Rasmussen, W.C. and G.E. Andreason. 1959. Hydrologic Budget of the Beaverdam Creek Basin, Maryland. U.S. Geological Survey Water Supply Paper 1472, 106 pp.
4 Meinzer, O.E. and N.O. Stearns. 1929. A study of ground water in the Pomperaug Basin, Connecticut, with special reference to intake and discharge. U.S. Geological Survey Water Supply Paper 597-B, pp. 73-146.

groundwater, soil moisture and within stream channels is assumed to be approximately equal so that these storage factors can also be ignored. (Recall that the Spring Creek Watershed does not have significant lakes or reservoirs than can impact surface water storage and the ponds and wetlands present are assumed to have an insignificant impact on the overall water budget of the Watershed).

The time period used is the **water year**, which is a 12-month period beginning October 1 of one year and ending September 30 of the next year. For example, the 2011 water year started on October 1, 2010 and ended on September 30, 2011. This time period has been adopted by the USGS and other hydrologists because hydrological systems in the northern hemisphere are typically at their lowest levels near October 1.

Using these assumptions, the water budget equation used in the SRBC report is:

Precipitation = Total Runoff + Evapotranspiration

Precipitation and total runoff are known variables. Precipitation data, for example, is collected at the University Park campus at The Pennsylvania State University and can be assumed to apply equally to the entire watershed. Total runoff values for the Spring Creek Watershed can be derived from discharge values measured continuously by the USGS stream gage at Milesburg, located near the mouth of the watershed on Spring Creek just upstream of the borough of Milesburg. Evapotranspiration is simply calculated as the residual of precipitation minus runoff.

The area of the drainage basin is also an important factor in calculating a water budget for a particular stream. In many cases the area of the basin above a stream gage is used in the calculation because the surface water and groundwater basins are the same. However, for the Spring Creek Watershed the sur-

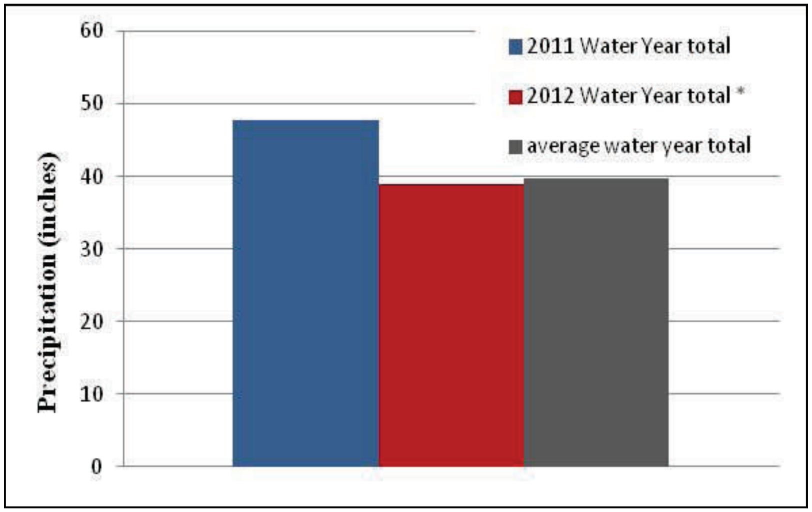


Figure 7. Annual precipitation totals for the Spring Creek Basin by water year. Total annual precipitation and annual average precipitation values are from the PA State Climatologist, available at http://climate.met.psu.edu/www_prod/data/ .

* 2012 water year total was calculated using actual recorded values for October 2011 through August 2012 and assumed average precipitation for September 2012.

Water Year	Precipitation		Total Runoff		Evapotranspiration	
	(billions of gallons)	(% of 1968-1993 mean)	(billions of gallons)	(% of 1968-1993 mean)	(billions of gallons)	(% of 1968-1993 mean)
Mean (1968-1993)	111.4[@]		54.3[@]		57.1[@]	
2011	137.2 [#]	123.2%	66.9 [#]	122.3%	70.3	121.4%
2012	111.9 [#]	100.4%	63.0 [#] [*]	115.4%	48.9	84.1%

Table 2. Mean values for precipitation, total runoff and evapotranspiration in water budgets for the Spring Creek Basin at the USGS Milesburg gage for 1968 through 1993 and water budgets for water years 2010 and 2011.

@ Water budget data for 1968 through 1993 are from *Taylor, L.E. 1997. Water Budget for the Spring Creek Basin. Susquehanna River Basin Commission Technical Report No. 184.* Data reported in inches converted to total gallons per year.

Water Year 2012 precipitation and total runoff values were calculated using recorded precipitation and flow values from October 2011 through August 2012 and assumed average monthly precipitation and flow values for September 2012. Precipitation values for STCP1 on the University Park campus for 2011 and 2012 were from PA State Climatologist, available at http://climate.met.psu.edu/www_prod/ida/index.php?t=3&x=shef&id=STCP1 . Data were in inches and converted to gallons across entire Basin per year. Flow data at the USGS Milesburg gage for 2011 and 2012 were from the USGS, available at http://waterdata.usgs.gov/usa/nwis/uv?01547100 . Data were in cubic feet per second and converted to total gallons per year.

* USGS flow data for 2012 is provisional and subject to revision.

face water and groundwater basins are not the same size. For the water budget calculations summarized in Table 2, the SRBC report assumed a groundwater basin of 165.6 square miles, as measured from the USGS gage at Milesburg.

For comparative purposes, the water budgets for the Spring Creek Watershed for 2011 and 2012 were calculated using similar methodology and assumptions used in the 1997 SRBC report. Precipitation in the 2011 and 2012 water years was 123.2% and 100.4%, respectively, of the 1968-1993 median of 111.4 billion gallons (**Table 2**). Total runoff in 2011 and 2012 water years as measured at the Milesburg USGS gage was 122.3% and 115.4%, respectively, of the 1968-1993 mean of 54.3 billion gallons (**Table 2** and **Figure 8** on page 19). Far from being "dry", 2011 was (on a water year basis) slightly above the norm for both precipitation and total runoff.

Groundwater

As noted above, one assumption used in the SRBC methodology for calculating the Spring Creek Basin water budgets is that the quantity of water stored as groundwater is equivalent at the beginning and end

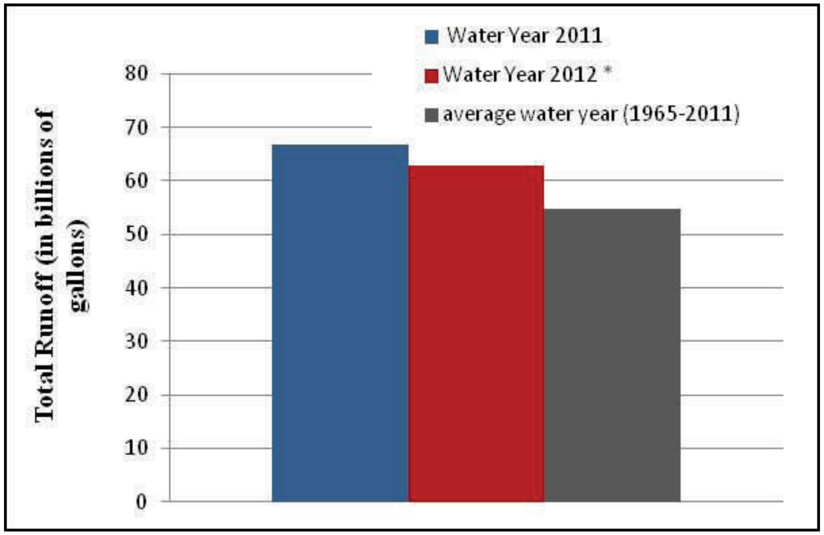


Figure 8. Annual runoff totals at the USGS Milesburg stream gage by water year. Total annual runoff and annual average runoff values are derived from USGS stream discharge values, available at http://waterdata.usgs.gov/usa/nwis/uv?01547100 . Data reported in cubic feet per second and converted to gallons per year.
* 2012 water year total was calculated using actual recorded values for October 2011 through August 2012 and assumed average discharge values for September 2012.

of each water year. The USGS and WRMP maintain several water level monitoring wells within the Watershed (see **Figure 3** on page 7). Review of USGS well CE118 water level data on or near September 30 going back to 1968 clearly indicates that water table elevation, and therefore the quantity of water stored in our aquifers, on September 30 is not constant from year to year (**Figure 9** on page 20).

Groundwater is a significant contributor to stream flow in the Spring Creek Watershed. The many springs that discharge into Spring Creek and its tributaries contribute to healthy flows even during dry periods. There are at least seven springs in the watershed with an outflow of at least 1 million gallons per day[2]. Big Spring in Bellefonte drains the productive Gatesburg formation and has a outflow of approximately 15 million gallons per day [3]. The benefit of this robust baseflow contribution from our groundwater aquifers is evident in the maintenance of stream flows in the watershed even during periods of drought or prolonged dry conditions.

The 1997 SRBC report calculated the percentage of total flow at Milesburg that was due to groundwater baseflow. Taylor calculated that over a 25-year period between 1968 and 1994, groundwater baseflow at Milesburg averaged 88% of the total flow. Giddings estimated that for 1968 and 1969 approximately 86% of the stream flow in the Spring Creek Basin was groundwater baseflow (See *What is a Water Budget?* on page 12). Giddings compared this baseflow to the groundwater baseflows in other, non-carbonate watersheds in Illinois, Maryland and Connecticut and found Spring Creek's groundwater baseflow to be significantly higher .

[2] Carline, R.F., Dunlap, R.L., Detar, J.E. and B.A. Hollendar. 2011. *The Fishery of Spring Creek– A Watershed Under Siege.* Pennsylvania Fish and Boat Commission Technical Report Number 1, Harrisburg, PA.

[3] The Bellefonte Borough Water System. 2011. *Water Quality Report* . Online at http://bellefonte.net/wp-content/uploads/2011/06/Bellefonte-Water-Report-2011-Calendar-Year.pdf . Retrieved September 17, 2012.

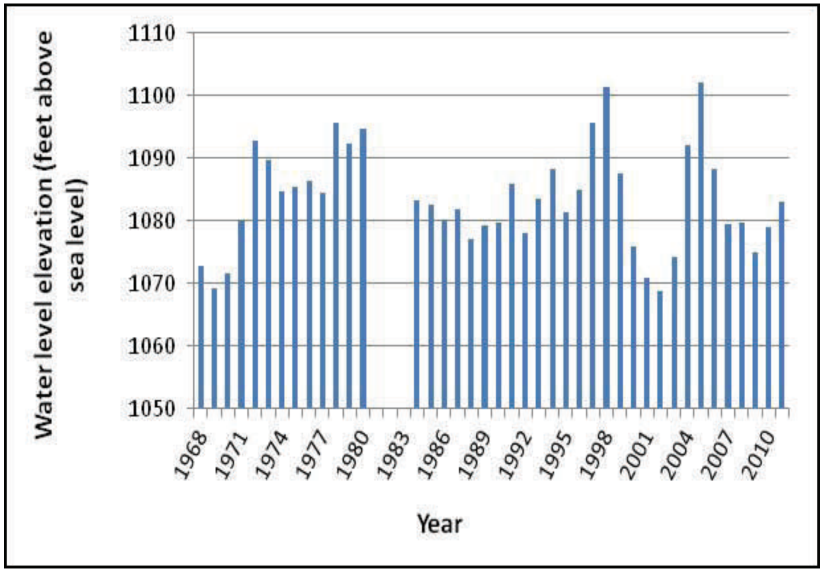


Figure 9. Groundwater elevations at USGS Centre County observation well CE118 . Groundwater elevation on or near September 30 for the years 1968 to 2011. Measurements converted to elevation above sea level from depth-to-groundwater data provided by the USGS at http://nwis.waterdata.usgs.gov/nwis/dv?referred_module=gw&site_no=404518077575501

Different precipitation patterns can have significant impacts on the recharge of groundwater storage. Snow melt and rainfall typical of late winter and early spring replenish aquifers. This replenishment was absent in 2012 due to the lack of snow melt and dry conditions through the spring (**Figure 10**).

Stream Discharge

Stream discharge data shown in **Figure 11** on page 21, from the USGS gage on Spring Creek at Milesburg for water years 2011 and 2012, is representative of flows in Spring Creek and its tributaries. In general, baseflows were above the historic median during the spring, fall and early-winter of 2011 in response to precipitation received in those months. Flows fell below historic median flows in late winter and spring of 2012 as a dry cycle kicked in. Although stream flows through early spring of 2012 at the Milesburg USGS gage were below the historic median, summer flows have been at or near median daily flows (**Figure 12** on page 21). Monthly precipitation during the 2012 summer have been closer to historic averages (**Figure 5** on page 11). Also, summer baseflows are typically supported by groundwater, and the Milesburg gage is downstream of the

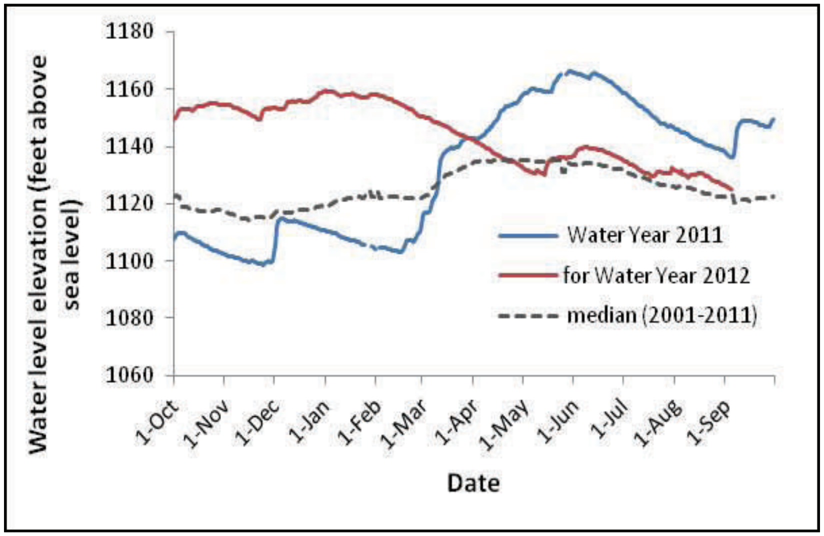


Figure 10. Groundwater elevations at USGS Centre County observation well CE686 for water years 2011 and 2012. Water level elevation data from the USGS at http://waterdata.usgs.gov/nwis/dv/?site_no=404556077525101&agency_cd=USGS&referred_module=sw

very productive Gatesburg-draining springs such as Big Spring. This data shows how effectively groundwater reserves maintain summer base flows in the spring Creek Watershed, even in periods of below normal precipitation.

Slab Cabin Run in State College between South Atherton Street and Millbrook Marsh does not receive significant inputs from springs. Portions of the channel in this reach of Slab Cabin Run often run dry or become standing pools during late summer and early fall. The average daily discharge at Slab Cabin Run at East College Avenue during the summer of 2012 is near the historic median flows, although lower than flows at this location in 2011 (**Figure 13** on page 22).

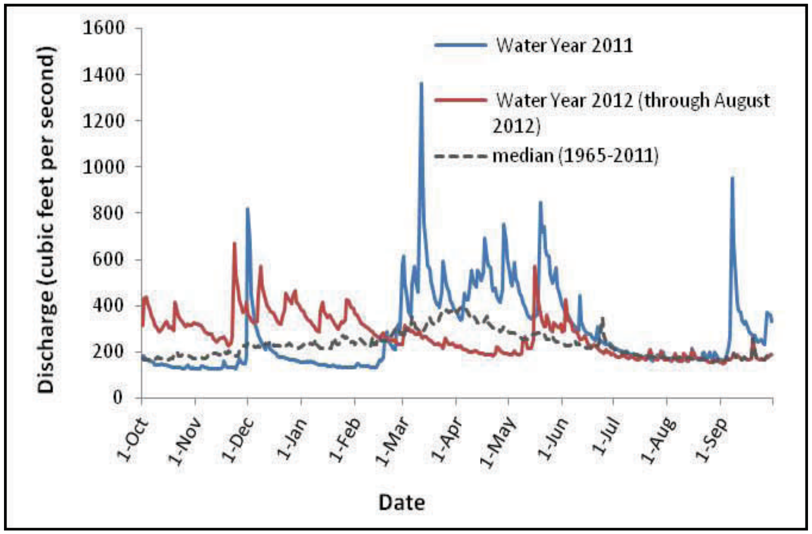


Figure 11. Average daily discharge at the USGS Milesburg stream gage for water years 2011 and 2012. Discharge data is from the USGS at http://waterdata.usgs.gov/usa/nwis/uv?01547100 .

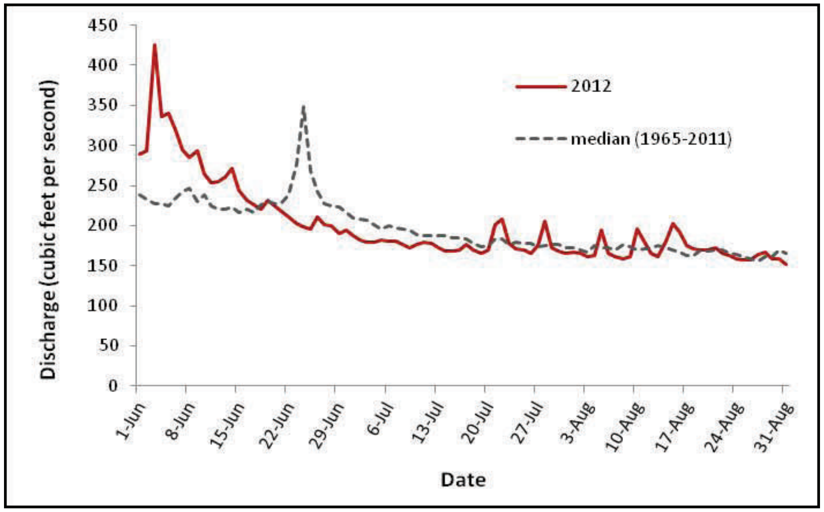


Figure 12. Average daily discharge at the USGS Milesburg stream gage from June 1, 2012 through August 31, 2012. Discharge data is from the USGS at http://waterdata.usgs.gov/usa/nwis/uv?01547100 .

As noted above, during late winter and early spring of 2012 daily flows at the USGS Milesburg gage on Spring Creek were somewhat lower than the historical daily flow values. The same held true for this time period at most monitoring stations in the watershed.

A few stations, as typified by the discharge record for the USGS Axemann gage located below Fisherman's Paradise on Spring Creek recorded late-winter to spring flows virtually identical to the median daily flows (**Figure 14** on page 22). However, all stream monitoring station discharges during the late winter, spring and summer of 2012 were lower when compared to the same period in 2011.

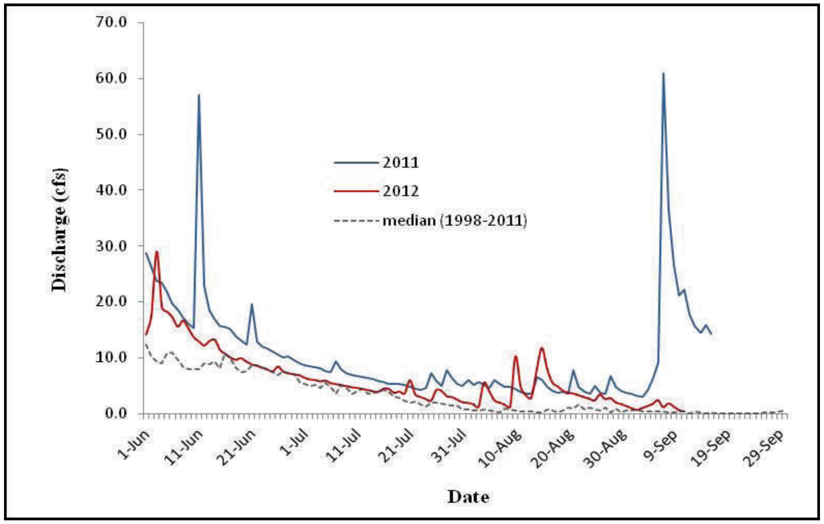


Figure 13. Average daily discharge on Slab Cabin Run at E. College Avenue in 2011 and 2012 from June 1 through September 12.

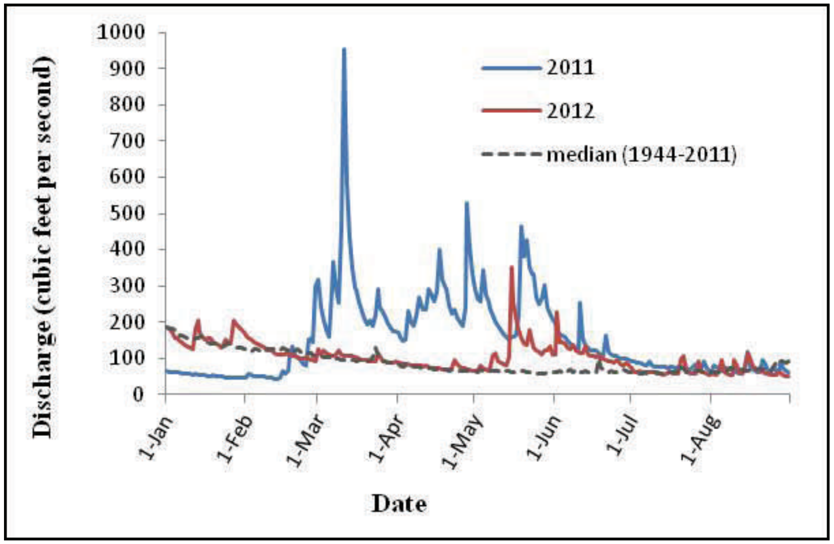


Figure 14. Average daily discharge at the USGS stream gage at Axemann in 2011 and 2012 for the period between January 1 and August 31. Data from the USGS at http://waterdata.usgs.gov/usa/nwis/uv?site_no=01546500

Stream Temperature

High summer air temperatures can cause stream water temperatures to reach or exceed the lethal temperature threshold for trout (24^0 C). Also, surface runoff from hot impervious surfaces during summer months can enter streams and cause water temperatures to increase. During the period of record for the WRMP (1998 to present), average and maximum

continued on page 24

The Biological Impacts of Stream Discharge Variations

By

Robert Carline, Ph.D.

Variations in flow exert an enormous effect on the plants and animals in a stream. To illustrate some of these effects on the fauna of Spring Creek, consider these conditions: (1) modest deviations (e.g., ± 30%) from average flows; (2) drought flows; and (3) catastrophic high flows.

During years of above average (modest deviations) flow, we find more pollution intolerant invertebrates than during years of low flow. The most common sensitive or pollution intolerant groups include stoneflies, mayflies, caddisflies and amphipods or scuds. These organisms favor coarser substrates, and when stream flows are above normal, fine sediment is transported downstream, rather than depositing on the stream bottom. Likewise, trout respond favorably to above normal flows, and there are a host of reasons why.

Above normal flows provide more living space for trout in addition to increased food supply. Higher flows are particularly important for brown trout reproduction. During wet years we find more suitable spawning substrates, which are often in short supply, particularly during dry years. Above normal flows are very important for incubation of trout embryos. Trout deposit their eggs in shallow nests and then cover the eggs with gravel. The eggs remain in the gravel from November until March. The nests are located in areas of the streambed where surface water infiltrates into the gravel, bringing oxygen to the eggs and carrying away waste products and carbon dioxide. Below normal flows result in deposition of silt on these nests, a reduction in infiltrating water, and much reduced survival of embryos.

Trout redd. Photo courtesy of Bob Donaldson.

During prolonged periods of drought, stream flows become dangerously low. Available habitat for invertebrates and fish is much reduced, and mortality rates of fish increase. Low flows are often associated with above normal water temperatures, which may reach lethal levels for trout or put them under a great deal of stress. When stressed, trout become more susceptible to diseases. Low flows favor avian predators like the great blue heron, whose effectiveness increases substantially when streams are low and clear.

At the other extreme, catastrophic flows can devastate invertebrate and fish life in streams. In the Spring Creek watershed, catastrophic flows may result from heavy rains falling on deep snow or from excessive rainfall owing to hurricanes. These extremely high flows can move rocks the size of bowling balls. As these rocks roll along the bottom, they crush nearly every living thing in their path. Fishes may survive by moving to the water edges, but invertebrates are not nearly so mobile. If floods occur when trout eggs are incubating in the streambed, all of these eggs will be destroyed. This is a common phenomenon in high gradient mountain streams, but it occurs less frequently in low gradient streams like Spring Creek.

Stream flow, which is dictated by rainfall trends, tends to be cyclic. Several years of above normal flows without catastrophic flows results in high trout densities. These large populations can crash quickly, if drought conditions follow. Hence, these seemingly erratic changes in annual trout numbers are simply the result of variations in rainfall.

daily stream temperatures approaching or exceeding 24⁰ C has only been observed in urbanized portions of the watershed.

Water temperature data from Slab Cabin Run at East College Avenue is typical of 2011 and 2012 data from other WRMP stations located in urbanized areas (**Figure 15** and **Figure 16**). Average daily and maximum daily water temperatures in 2012 were slightly above 2011 values early in the summer.

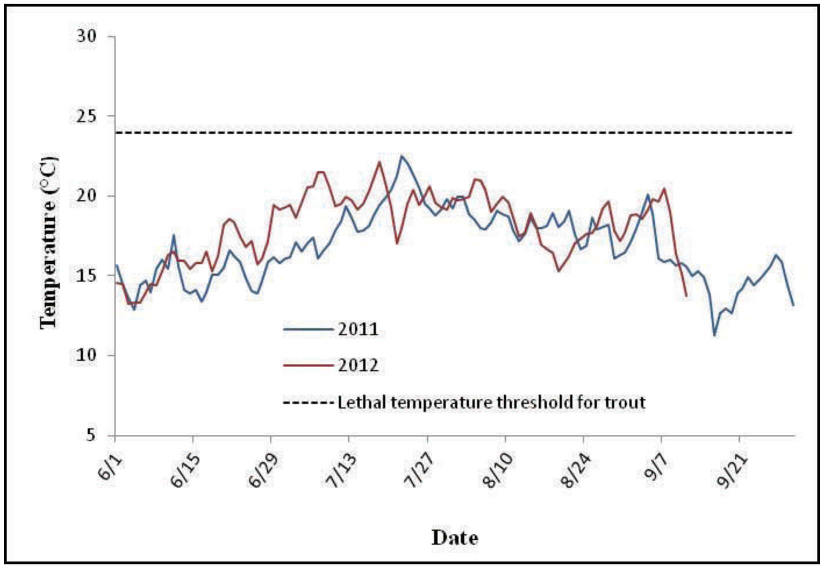


Figure 15. Average daily water temperature on Slab Cabin Run at E. College Avenue during summer 2011 and 2012.

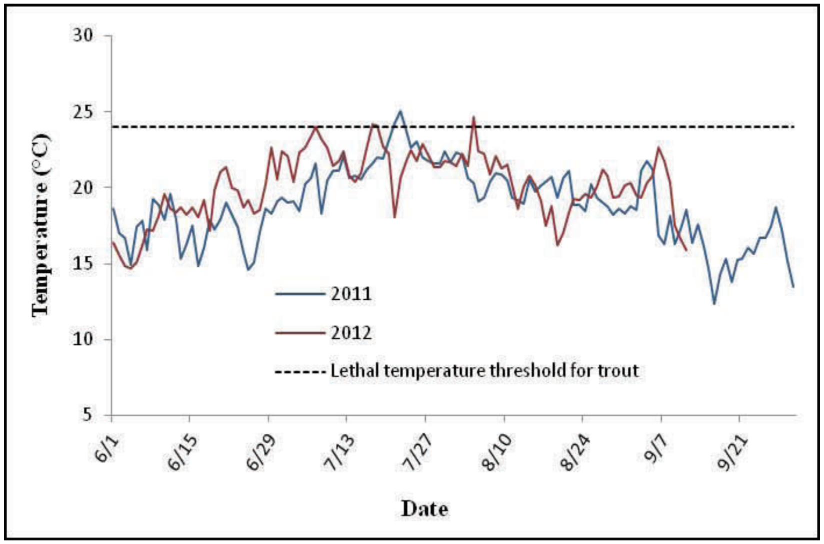


Figure 16. Maximum daily water temperature on Slab Cabin Run at E. College Avenue during summer 2011 and 2012.

Since late-July, there are no notable temperature trends distinguishing one year from the other.

Water Quality

Water quality was assessed in May, August, October and December 2011 during baseflow conditions at fifteen stream and seven spring stations across the Spring Creek Watershed. WRMP water samples were evaluated for a number of common organic and inorganic pollutants (**Appendix 1**). A summary of water resource management issues for each municipality in the Spring Creek Watershed can be found in **Appendix 2**.

Trends in concentrations of the various parameters were generally similar to those observed for previous years' samples. The 2012 water quality sampling is on-going and comparisons between 2011 and 2012 water years were not performed. **Appendices 4** and **5** show the median concentrations of all parameters analyzed in 2011 at each of the stream and spring sites, respectively. Here are some generalizations:

- Only one site featured atypical sampling results in 2011: the Buffalo Run Valley View site. This site samples a small unnamed tributary to Buffalo Run and is collected at the intersection of North Fillmore Road, Purdue Mountain Road and Valley View Road. Concentrations of several metals were elevated during the May and August sampling, resulting in median levels for 2011 to be elevated over historic median values (**Table 3** on page 26). During past years, many of these metals were typically below detection limits in our sampling.
- At most non-headwater stream sites in 2011, the concentration of nitrate nitrogen (a common pollutant of treated wastewater and agricultural runoff) was detected at higher levels relative to the two headwater stream sites at Buffalo Run Valley View and Galbraith Gap Run. However, these nitrate nitrogen concentrations were similar to those in previous years. Nitrate levels were also high at Axemann Spring, Benner Spring, Linden Hall Spring and Windy Hill Farm Spring. These concentrations were also similar to past years' sampling results.
- Orthophosphorus, a pollutant commonly associated with agriculture, was present at low levels (near the detectable limit) at all of the stream sites. Orthophosphorus was also detected at low levels at Benner Spring and Windy Hill Farm Spring. The 2011 orthophosphate results were consistent with those from previous years.
- Chloride concentrations were similar to those observed over the history of the WRMP. Elevated chloride concentrations indicates impacts from urbanization and waste water treatment processes. Consistent with an urban impact, the highest chloride concentrations were measured at

Metal		**Sampling Date**					**Median for period of record (2004-2011)**	Detection limit **(µg/L)**
		May 2011	**Aug 2011**	**Oct 2011**	**Dec 2011**	**2011 median**		
Aluminum (µg/L)	Total	178.0	496.0	150.0	28.4	164.0	59.5	10.0
	Dissolved	30.1	97.2	111.0	ND	63.7 *	Below detection limit	10.0
Chromium (µg/L)	Total	11.3	15.4	ND	ND	6.7 *	Below detection limit	4.0
	Dissolved	10.4	13.4	ND	ND	6.2 *	Below detection limit	4.0
Manganese (µg/L)	Total	31.7	137.0	70.3	21.3	51.0	34.8	2.0
	Dissolved	8.8	31.3	26.8	16.4	21.6	20.3	2.0
Nickel (µg/L)	Total	8.8	7.5	ND	ND	4.6 *	Below detection limit	4.0
	Dissolved	8.1	5.8	ND	ND	3.9 *	Below detection limit	4.0

Table 3. Buffalo Valley View water quality results for select parameters.

* At least one sample had an undetectable concentration so a concentration of 1/2 detection limit was set as concentration for calculations.

ND Below detection limit

two sites surrounded by extensive urban development: Slab Cabin Run at Millbrook Marsh and Thompson Run.

- In addition to the Buffalo Run Valley View site discussed above, total aluminum concentrations at Logan Branch near Pleasant Gap were also elevated over historic levels. Otherwise, total aluminum was detected at low levels at other sites in 2011. Dissolved aluminum concentrations were near or below the detection limit at all sites besides Buffalo Run Valley View.
- Iron was detected at all stream sites and at low levels at Benner Spring, Blue Spring and Windy Hill Farm Spring in 2011. As in past years, total iron concentrations were highest at Logan Branch near Pleasant Gap and Buffalo Run Valley View. The Logan Branch site typically demonstrates high iron levels, perhaps a legacy of a long industrial history in this sub-watershed. Elevated dissolved iron concentrations at Buffalo Run Valley View are also typical of this site.

- Fecal coliform bacteria were detected at all springs except Continental Courts Spring. Windy Hill Farm Spring had the highest concentration of fecal coliforms; however, none of the observed concentrations exceeded the PADEP bathing standard (200 colonies/100 ml).

Biological Monitoring

The WRMP initiated biological monitoring of the Spring Creek Watershed in 2011. This biological monitoring samples stream bed macroinvertebrates. Macroinvertebrates are animals that have no backbone and are visible without magnification. Benthic macroinvertebrates (i.e. macroinvertebrates that live on a stream bed or lake bottom) include such animals as insect larvae, crayfish, mussels, aquatic snails and aquatic worms.

Benthic macroinvertebrates are a vital link in the aquatic food chain. The energy stored by plants is available to animal life either in the form of leaves that fall in the water or in the form of algae that grows on the stream bottom. The algae and leaves are eaten by macroinvertebrates. These macroinvertebrates are then a main food source for larger animals such as fish.

Some benthic macroinvertebrates cannot survive in polluted water, while others can. In a healthy stream, the benthic community will include a variety of pollution-sensitive macroinvertebrates. In an unhealthy stream, there may be only a few or no pollution-sensitive types present.

Analyzing a water sample for chemical pollutants only provides information about the water quality at the time of sampling. Fish can move away to avoid polluted water and then return when conditions improve. However, benthic macroinvertebrates cannot easily move to avoid pollution. In addition, macroinvertebrate data are easy to collect without expensive equipment. The data obtained by macroinvertebrate sampling can indicate the need for additional data collection such as water quality analysis and/or fish sampling.

The WRMP has adopted the methodology developed by PADEP for limestone streams. This monitoring methodology utilizes benthic macroinvertebrates to establish an Index of Biological Integrity (IBI) for each location sampled. Sampling was conducted in March of 2012 and sample analysis is ongoing. Results will be fully detailed in the 2012 State of the Water Resources Report.

Closing

We hope that you found this year's report on the State of the Water Resources both interesting and informative. Residents of Spring Creek Watershed currently enjoy better water quality than the region has seen in nearly 100 years. Without quality long-term water level, discharge, and water chemistry data sets like those being maintained by the WRMP, it would be difficult to understand how our water resource is changing and why.

The Water Resources Monitoring Project, which has been in place for over 13 years, provides vital long-term data that can be used by local planning officials to make sound land use decisions. Your continued support will help this project maintain the ability to respond to new information needs and provide quality data to monitor changes within the watershed as our community continues to grow.

Daily stream flow and water temperature data, as well as quarterly water quality data, are available upon request by contacting the WRMP Water Resources Coordinator, Nick Schipanski, at (814) 237-0400.

Appendices

Appendix 1	Water Quality Parameters
Appendix 2	Summary of monitoring sites and management issues in their vicinity by municipality
Appendix 3	Monitoring summary by location
Appendix 4	Stream Water Quality Results
Appendix 5	Spring Water Quality Results
Appendix 6	Daily Stream Flows
Appendix 7	Daily Stream Temperatures
Appendix 8	Daily Groundwater Elevations

Appendix 1: Water Quality Parameters

Parameter	Description	Sources	Environmental Effects	Baseflow Monitoring	Spring Monitoring
Aluminum	The most abundant element on Earth	Urban runoff, industrial discharges, and natural sources	May adversely affect the nervous system in humans and animals	X	X
Cadmium	Natural element found in the Earth's crust	Industrial sources and urban sources including fertilizer, non- ferrous metals production, and the iron and steel industry	Toxic to humans and aquatic life	X	X
Chloride	The concentration of chloride salt ions dissolved in the water	Washes off roads where used as a deicing agent	Very high chloride concentrations can be toxic to macroinvertebrates and limit osmoregulatory capacity of fishes	X	X
Chromium	A trace element essential for animals in small quantities	Found in natural deposits of ores containing other elements	Toxic to humans and aquatic life if present in excess	X	X
Conductivity	Measure of the water's ability to conduct electricity. Proportional to the amount of charged ions in the water	Sources of ions are both naturally occurring and anthropogenic in origin. Include soil, bedrock, human and animal waste, fertilizers, pesticides, herbicides, and road salt	Suspended solids clog fish gills and alter stream-bed habitat upon settling. Dissolved materials limit theosmoregulatory ability of aquatic animals	X	X
Copper	A heavy metal less common than lead and zinc in nature	Used in wiring, plumbing, and electronics. Also used to control algae, bacteria, and fungi	Toxic to humans and aquatic life. Solubility is effected by water hardness	X	X
Dissolved Oxygen	The amount of oxygen gas dissolved in the water, saturation inversely related to temperature	Dissolved oxygen is depleted by respiration and microbial breakdown of wastes. It is restored by photosynthesis and physical aeration	Low levels of dissolved oxygen are harmful to aquatic animals. This is usually the result of organic pollution or elevated temperature	X	X
Coliform Bacteria	Common intestinal bacteria of warm and cold-blooded animals	Animal wastes and sewage contamination	Pathogenic to humans		X
Iron	Common element found in the Earth's crust	Urban runoff, industrial discharges, and natural sources	Toxic to humans and aquatic life	X	X
Lead	A heavy metal that occurs naturally as lead sulfide but may exist in other forms	Urban and industrial uses include gasoline, batteries, solder, pigments, and paint	Toxic to humans and aquatic life. Solubility is effected by water hardness.	X	X
Manganese	Common element found in the Earth's crust	Urban runoff, industrial discharges, and natural sources	Toxic to humans and aquatic life	X	X
Nickel	A trace element essential for animals in small quantities	Industrial wastewaters	Toxic to humans and aquatic life if present in excess	X	X
Nitrate (NO3)	One of three forms of nitrogen found in water bodies, this form is used by plants. Organic nitrogen is converted to nitrate by bacteria	Any nitrogen-containing organic waste, including sewage from treatment plants and septic systems and runoff from fertilized lawns, farms, and livestock areas	High nitrate levels promote excessive plant growth and eutrophication. Excess nitrate in drinking water can cause illness or death in infants	X	X
Orthophosphate	The form of inorganic phosphorus required by plants. Often the limiting factor in plant growth	Rocks and minerals provide low natural levels. Human sources include commercial cleaning products, water treatment plants, and fertilized lawns and farmland	A small increase in orthophosphorus can cause eutrophication, the loss of dissolved oxygen through the stimulation and decay of excessive plant growth	X	X
pH	A measure of the acidity of water on a logarithmic scale of 1 to 14 with 7 being neutral, below 7 acidic, and above 7 alkaline	Alkaline conditions can be a result of carbonate bedrock geology. Acidic conditions could be caused by acid deposition and pyritic reactions associated with acid mine drainage	Extreme acidity or alkalinity can inhibit growth and reproduction in aquatic organisms. Acidic waters also increase the solubility of metals from the sediment	X	X
Sodium	Soft metal commonly found in nature	Various salts of sodium occur in considerable concentrations in the Earth's crust	There is some evidence to suggest that these high levels of sodium are toxic to some plants	X	X
Total Suspended Solids	Any particles carried by the water including silt, plankton, organic stream matter, industrial waste, and sewage	Include urban runoff, wastewater treatment plants, soil erosion, and decaying plant and animal material	Suspended solids clog fish gills and alter stream-bed habitat when settled. Particles may carry bound toxic compounds or metals	X	X
Turbidity	A measure of water clarity expressed as the amount of light penetrating the water. It is relative to the amount of suspended material in the water	While in some cases high turbidity is natural, it is usually the result of earth-moving activities, urban runoff, and erosion	High turbidity blocks light from the water column, inhibiting productivity of aquatic plants and periphyton. These particles also absorb sunlight and increase temperature. Also, particles will eventually come out of suspension and cause sedimentation	X	X
Zinc	A heavy metal commonly found in rock-forming minerals	Urban runoff, industrial discharges, and natural sources	Somewhat toxic to humans and aquatic life. Solubility is affected by water hardness	X	X

Appendix 2: Summary of monitoring sites and management issues in their vicinity by municipality

Municipality	Monitoring sites within the municipality	Other sites influenced by activities within the municipality	Water resources management issues
Benner Township	Unnamed tributary to Buffalo Run (BVV) Continental Courts Spring (COS) Fillmore Well Benner Spring (BES) Spring Creek at Axemann (SPA)	Buffalo Run near Coleville (BUL) Spring Creek at Milesburg (SPM) Logan Branch near Pleasant Gap (LOU)	Agricultural practices (ground and surface water) Urbanization/Suburbanization (storm-water and water supply)
Boggs Township	Spring Creek at Milesburg (SPM)		
College Township	Spring Creek at Houserville (SPH) Slab Cabin Run at Millbrook Marsh (MIL) Slab Cabin Run at East College Avenue (SLL) Thompson Run (THL) Spring Creek at Oak Hall (SPU) Cedar Run at Oak Hall (SPU) Big Hollow/ I-99 Well		Urbanization/Suburbanization (storm-water and water supply) Agricultural practices (upstream areas)
Ferguson Township	Windy Hill Farm Spring (WIS) DCNR/Pine Grove Mills Well USGS CE686 Monitoring Well USGS CE118 Monitoring Well	Thompson Run (THL)	Urbanization/Suburbanization (storm-water and water supply) Agricultural practices
Halfmoon Township		Buffalo Run near Fillmore (BUU) Big Spring (BIS)	Agricultural practices Suburban development
Harris Township	Blue Spring (BLS) Linden Hall Spring (LIS) Galbraith Gap Run (GGU)	Slab Cabin Run at South Atherton Street (SLU) Spring Creek at Oak Hall (SPU) Cedar Run at Oak Hall (CEL)	Agricultural practices (surface and groundwater) Suburban development
Patton Township	Buffalo Run near Fillmore (BUU)		Agricultural practices/suburbanization
Potter Township			Agricultrual practices
Spring Township	Logan Branch near Pleasant Gap (LOU) Axemann Spring (AXS) Buffalo Run near Coleville (BUL)	Logan Branch at Bellefonte (LOL) Spring Creek Milesburg (SPM)	Agricultural practices (surface and groundwater) Suburban development Industrial water usage
Walker Township			Agricultural practices/ suburbanization
Bellefonte Borough	Logan Branch in Bellefonte (LOL) Big Spring (BIS)	Spring Creek at Milesburg (SPM)	Urbanization/Suburbanization (storm-water)
Centre Hall Borough			Agricultural practices in surrounding areas
Milesburg Borough		Spring Creek at Milesburg (SPM)	Urbanization (storm-water)
State College Borough	Slab Cabin Run at South Atherton Street (SLU) Walnut Spring (WAU, WAM, WAL)	Thompson Run (THL) Slab Cabin Run at East College Avenue (SLL) Slab Cabin Run at Millbrook Marsh (MIL)	Urbanization/Suburbanization (storm-water)

Appendix 3: Monitoring summary by location

Site Type	Site Name (Code)	Monitoring Type	Current Data Collection Interval	Period of Record
Stream	Buffalo Run Lower (BUL)	Discharge	30 min	1999 - present
		Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Buffalo Run Upper (BUU)	Discharge	30 min	1999 - present
		Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Buffalo Run Valley View (BVV)	Baseflow water quality	quarterly	2007 - present
	Cedar Run Lower (CEL)	Discharge	30 min	1998 - present
		Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Galbraith Gap Run (GGU)	Baseflow water quality	quarterly	2008 - present
	Logan Branch Lower (LOL)	Discharge	30 min	1999 - present
		Water temperature	1 hr	2000 - present
		Baseflow water quality	quarterly	2007 - present
	Logan Branch Upper (LOU)	Discharge	30 min	1999 - present
		Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Slab Cabin Run at Millbrook (MIL)	Discharge	30 min	2005 - 2006 ; 2009 - present
		Water temperature	1 hr	2008 - present
		Baseflow water quality	quarterly	2007 - present
	Slab Cabin Run Lower (SLL)	Discharge	30 min	1999 - present
		Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Slab Cabin Run Upper (SLU)	Discharge	30 min	1998 - present
		Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Spring Creek Upper (SPU)	Discharge	30 min	1998 - present
		Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present

Appendix 3: Monitoring summary by location

Site Type	Site Name (Code)	Monitoring Type	Current Data Collection Interval	Period of Record
Stream	Spring Creek Axemann (SPA)	Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Spring Creek Houserville (SPH)	Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Spring Creek Milesburg (SPM)	Water temperature	1 hr	1999 - present
		Baseflow water quality	quarterly	2007 - present
	Walnut Springs Middle (WAM)	Water level *	5 min	2008 - present
		Water temperature	5 min	January, 2012 - present
	Walnut Springs Lower (WAL)	Water level *	5 min	2008 - present
	Walnut Springs Upper (WAU)	Water level *	5 min	2008 - present
	Thompson Run Lower (THL)	Discharge	5 min	1999 - present
		Water temperature	5 min	1999 - present
		Baseflow water quality	quarterly	2007 - present
Groundwater well	Big Hollow (I-99)	Water surface elevation	3 hr	2003 - present
	Fillmore 1	Water surface elevation	3 hr	2003 - present
	Pine Grove Mills/DCNR	Water surface elevation	3 hr	2003 - present
Spring	Axeman Spring (AXS)	Baseflow water quality	quarterly	2007 - present
	Benner Spring (BES)	Baseflow water quality	quarterly	2007 - present
	Blue Spring (BLS)	Baseflow water quality	quarterly	2007 - present
	Big Spring (BIS)	Baseflow water quality	quarterly	2007 - present
	Continental Courts Spring (COS)	Baseflow water quality	quarterly	2007 - present
	Linden Hall Spring (LIS)	Baseflow water quality	quarterly	2007 - present
	Windy Hill Farm Spring (WIS)	Baseflow water quality	quarterly	2007 - present

* Stage discharge rating curves for the Walnut Spring s stream discharge monitoring stations are in development.

Appendix 4: Median Stream Water Quality Results (Metals) for 2011

		Aluminum (µg/L)		Cadmium (µg/L)		Chromium (µg/L)		Copper (µg/L)		Iron (µg/L)	
Site Name	**Abbrev**	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Galbraith Gap Run	GGU	7.7*	38.4	ND	ND	2.0*	2.0*	ND	ND	ND	45.5
Cedar Run - Lower	CEL	ND	45.1	ND	ND	ND	ND	ND	ND	ND	83.0
Slab Cabin Run - Upper	SLU	5.0*	52.0	0.1*	ND	2.0*	ND	2.0*	ND	10.0*	108.5
Slab Cabin Run - Lower	SLL	5.0*	36.9	ND	ND	ND	ND	ND	ND	ND	58.5
Slab Cabin Run - Millbrook	MIL	5.0*	49.8	ND	ND	ND	ND	ND	ND	ND	119.5
Thompson Run - Lower	THL	5.0*	29.2	ND	ND	ND	ND	ND	ND	ND	30.5*
Buffalo Run - Upper	BUU	5.0*	73.8	ND	ND	2.0*	2.0*	ND	ND	19.0*	148.5
Buffalo Run - Valley View	BVV	63.7*	164.0	ND	ND	6.2*	6.7*	ND	ND	35.5	424.5
Buffalo Run - Lower	BUL	5.0*	51.2	ND	ND	2.0*	2.0*	ND	ND	ND	98.5
Logan Branch - Upper	LOU	5.0*	171.0	ND	ND	ND	ND	ND	ND	ND	225.5
Logan Branch - Lower	LOL	ND	55.3	ND	ND	ND	ND	ND	ND	ND	84.0
Spring Creek - Upper	SPU	ND	37.1	ND	ND	ND	ND	ND	ND	ND	66.5
Spring Creek - Houserville	SPH	5.0*	54.6	ND	ND	ND	ND	ND	ND	10.0*	108.0
Spring Creek - Axemann	SPA	5.0*	83.2	ND	ND	2.0*	2.0*	ND	ND	ND	78.0
Spring Creek - Milesburg	SPM	7.7*	38.4	ND	ND	ND	ND	ND	ND	10.0*	63.0*

		Lead (µg/L)		Manganese (µg/L)		Nickel (µg/L)		Sodium (mg/L)		Zinc (µg/L)	
Site Name	**Abbrev**	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Galbraith Gap Run	GGU	ND	ND	1.0*	7.5	2.0*	2.0*	0.6	0.6	ND	ND
Cedar Run - Lower	CEL	ND	ND	2.7	5.4	ND	ND	6.3	6.4	ND	ND
Slab Cabin Run - Upper	SLU	0.05*	ND	6.9	13.6	ND	ND	10.1	10.3	ND	ND
Slab Cabin Run - Lower	SLL	ND	ND	2.4*	4.5	ND	ND	16.2	16.2	ND	ND
Slab Cabin Run - Millbrook	MIL	ND	ND	8.8	12.9	ND	ND	23.9	24.0	ND	ND
Thompson Run - Lower	THL	ND	0.05*	5.1	8.2	ND	ND	30.4	31.1	ND	ND
Buffalo Run - Upper	BUU	ND	ND	3.9	8.6	2.0*	2.0*	12.2	12.8	ND	ND
Buffalo Run - Valley View	BVV	ND	ND	21.6	51.0	3.9*	4.6*	7.5	7.7	ND	ND
Buffalo Run - Lower	BUL	ND	ND	5.1	8.1	2.0*	2.0*	9.7	10.0	ND	ND
Logan Branch - Upper	LOU	ND	0.63*	4.7	12.4	ND	ND	13.7	14.3	ND	ND
Logan Branch - Lower	LOL	ND	0.05*	1.0*	3.6*	ND	ND	12.8	13.0	ND	ND
Spring Creek - Upper	SPU	ND	ND	2.5*	4.6	ND	ND	8.0	7.9	ND	ND
Spring Creek - Houserville	SPH	ND	ND	4.4	7.3	ND	ND	15.8	15.6	ND	ND

*	At least one sample had an undetectable concentration so a concentration of 1/2 detection limit was set as concentration for calculations.
ND	All concentrations for all sampling events were below detection limits so no value was assigned for concentrations

Appendix 4: Median Stream Water Quality Results (Nutrients & Physicochemical) for 201

		Calcium (mg/L)	**Magnesium** (mg/L)	**Hardness** (mg/L)	**Chloride** (mg/L)	**Sulfate** (mg/L)	**Suspended Solids** (mg/L)
Site Name	**Abbrev**	Total	Total	Total	Total	Total	Total
Galbraith Gap Run	GGU	3.0	1.5	13.0	1.2	ND	1.0*
Cedar Run - Lower	CEL	77.7	23.1	289.0	13.8	17.5	1.0*
Slab Cabin Run - Upper	SLU	39.5*	14.9*	160.5	26.0	10.0*	8.0*
Slab Cabin Run - Lower	SLL	53.5	21.0	220.0	31.2	18.7	3.5*
Slab Cabin Run - Millbrook	MIL	60.7	24.6	253.0	51.3	19.6	1.0*
Thompson Run - Lower	THL	72.0	29.4	302.0	73.4	18.3	1.0*
Buffalo Run - Upper	BUU	60.9	19.4	232.0	22.8	27.0	8.0*
Buffalo Run - Valley View	BVV	23.0	3.4	71.5	7.9	10.0*	36.0
Buffalo Run - Lower	BUL	61.6	21.1	244.5	18.8	32.9	7.0*
Logan Branch - Upper	LOU	64.8	16.4	229.5	27.5	49.6	15.0
Logan Branch - Lower	LOL	54.5	19.2	214.0	27.0	34.2	3.5*
Spring Creek - Upper	SPU	46.3	13.9	173.0	16.9	14.0*	3.5*
Spring Creek - Houserville	SPH	63.3	21.1	245.0	33.6	19.8	3.5*
Spring Creek - Axemann	SPA	62.4	21.9	246.5	41.1	21.5	3.5*
Spring Creek - Milesburg	SPM	57.3	20.4	227.0	36.0	28.4	3.5*

		pH	**Diss. Oxygen** (mg/L)	**Temperature** (°C)	**Conductivity** (mS)	**Nitrate-N** (mg/L)	**Orthophosphorus** (mg/L)
Site Name	**Abbrev**						Total
Galbraith Gap Run	GGU	7.9	10.61	11.2	37.3	0.09	0.008*
Cedar Run - Lower	CEL	8.3	10.93	11.8	559.0	4.37	0.012*
Slab Cabin Run - Upper	SLU	8.1	10.62	12.0	300.2	3.06	0.015
Slab Cabin Run - Lower	SLL	8.1	11.15	12.2	503.2	2.95	0.011
Slab Cabin Run - Millbrook	MIL	8.1	10.61	12.3	611.5	3.20	0.015
Thompson Run - Lower	THL	8.1	10.73	12.2	672.0	3.65	0.016*
Buffalo Run - Upper	BUU	8.2	10.63	12.5	577.5	1.09*	0.016*
Buffalo Run - Valley View	BVV	7.9	10.41	12.9	179.4	0.18	0.030
Buffalo Run - Lower	BUL	8.3	11.24	12.9	517.5	1.51	0.013*
Logan Branch - Upper	LOU	7.9	10.64	12.8	512.4	2.76*	0.028
Logan Branch - Lower	LOL	8.1	10.92	11.7	481.3	1.54	0.015*
Spring Creek - Upper	SPU	7.8	10.35	12.0	382.0	1.76	0.008*
Spring Creek - Houserville	SPH	8.3	10.48	12.3	540.5	2.92	0.011*

*	At least one sample had an undetectable concentration so a concentration of 1/2 detection limit was set as concentration for calculations.
ND	All concentrations for all sampling events were below detection limits so no value was assigned for concentrations

Appendix 5: Median Spring Water Quality Results (Metals) for 2011

		Aluminum (µg/L)		**Cadmium (µg/L)**		**Chromium (µg/L)**		**Copper (µg/L)**		**Iron (µg/L)**	
Site Name	**Abbrev**	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Axemann	AXS	ND	ND	ND	ND	2.0*	2.0*	ND	ND	ND	ND
Benner	BES	5.0	43.1	ND	ND	ND	ND	ND	ND	10.0*	102.0
Big Spring	BIS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Blue Spring	BLS	ND	16.0	ND	ND	ND	ND	ND	ND	ND	31.5*
Continental Courts	COS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Linden Hall	LIS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Windy Hill	WIS	5.0*	94.5	ND	ND	ND	ND	ND	ND	ND	124.0

		Lead (µg/L)		**Manganese (µg/L)**		**Nickel (µg/L)**		**Sodium (mg/L)**		**Zinc (µg/L)**	
Site Name	**Abbrev**	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Axemann	AXS	ND	ND	ND	1.0*	2.0*	2.0*	16.1	16.6	ND	ND
Benner	BES	ND	0.5*	ND	13.1	ND	ND	25.1	26.1	ND	ND
Big Spring	BIS	ND	ND	ND	ND	ND	ND	9.8	9.9	ND	ND
Blue Spring	BLS	ND	0.5	ND	ND	ND	2	3.0	3.0	ND	ND
Continental Courts	COS	ND	ND	ND	ND	2	2.0*	8.8	9.5	ND	ND
Linden Hall	LIS	ND	ND	ND	ND	ND	ND	2.8	2.9	ND	ND
Windy Hill	WIS	ND	0.5*	3.8*	8.8*	ND	ND	13.2	12.9	ND	ND

*	At least one sample had an undetectable concentration so a concentration of 1/2 detection limit was set as concentration for calculations.
ND	All concentrations for all sampling events were below detection limits so no value was assigned for concentrations

Appendix 5: Median Spring Water Quality Results (Nutrients & Physicochemical) for 2011

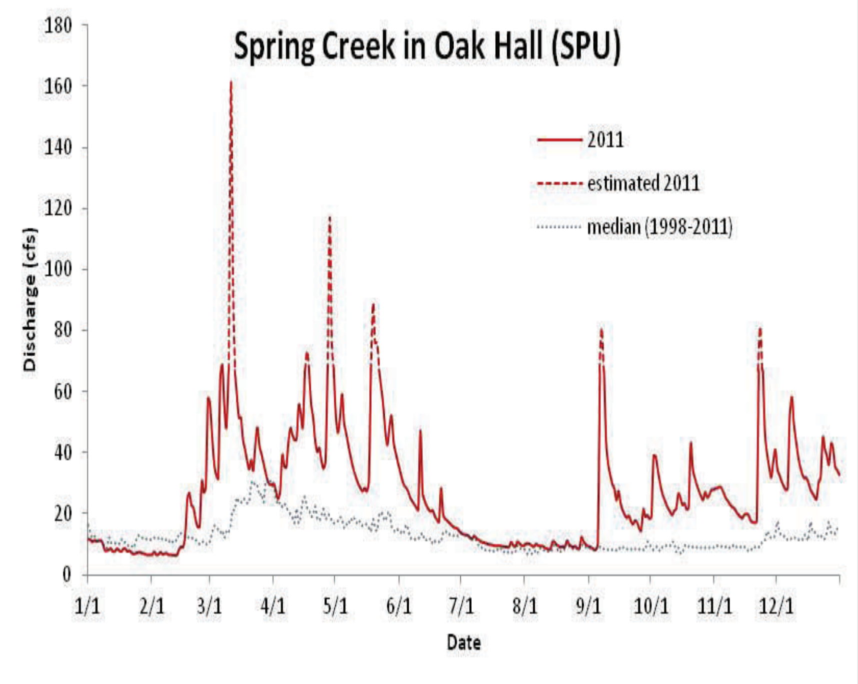
Site Name	Abbrev	Calcium (mg/L) Total	Magnesium (mg/L) Total	Hardness (mg/L) Total	Chloride (mg/L) Total	Sulfate (mg/L) Total	Suspended Solids (mg/L) Total	Turbidity (NTU)
Axemann Spring	AXS	80.9	32.5*	340.5	41.2	27.4*	ND	ND
Benner Spring	BES	65.7	17.5	251.0	57.3	13.5*	7.0*	2.02
Big Spring	BIS	32.8	16.5	150.0	20.6	ND	ND	ND
Blue Spring	BLS	34.2	16.3	152.0	5.6	ND	1.0*	ND
Continental Courts Spring	COS	59.2	26.3	256.5	21.0	ND	1.0*	ND
Linden Hall Park Spring	LIS	75	30.1	311.0	7.7	18.6*	ND	ND
Windy Hill Farm Spring	WIS	56.0	26.1	247.0	21.8	13.2*	16.0*	5.09*

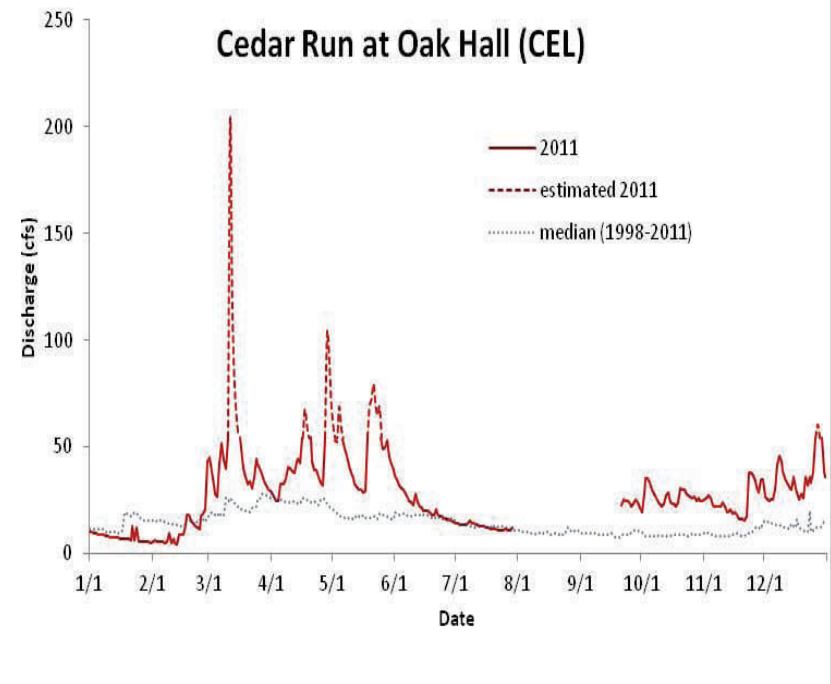
Site Name	Abbrev	pH	Diss. Oxygen (mg/L)	Temperature (°C)	Conductivity (mS)	Nitrate-N (mg/L)	Orthophosphorus (mg/L) Total	Fecal Coliforms (#col/ 100mL)
Axemann Spring	AXS	7.4	9.86	10.4	717.0	5.93	ND	2.7
Benner Spring	BES	7.4	10.21	10.6	550.5	3.68	0.005*	3.7
Big Spring	BIS	8.0	10.82	10.4	341.9	1.93	ND	4.7
Blue Spring	BLS	7.7	7.56	10.6	296.7	1.58	0.008*	2.0
Continental Courts Spring	COS	7.4	7.85	10.5	512.0	2.24	ND	ND
Linden Hall Park Spring	LIS	7.4	7.45	10.0	608.5	4.39	ND	2.5
Windy Hill Farm Spring	WIS	7.6	6.10	11.8	530.5	4.08	0.013*	11.0

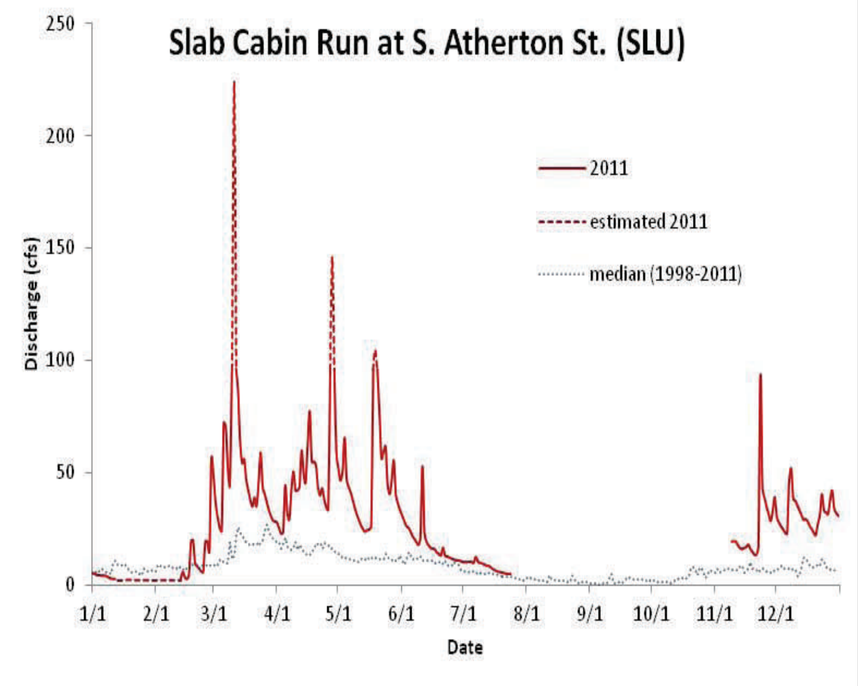
*	At least one sample had an undetectable concentration so a concentration of 1/2 detection limit was set as concentration for calculations.
ND	All concentrations for all sampling events were below detection limits so no value was assigned for concentrations

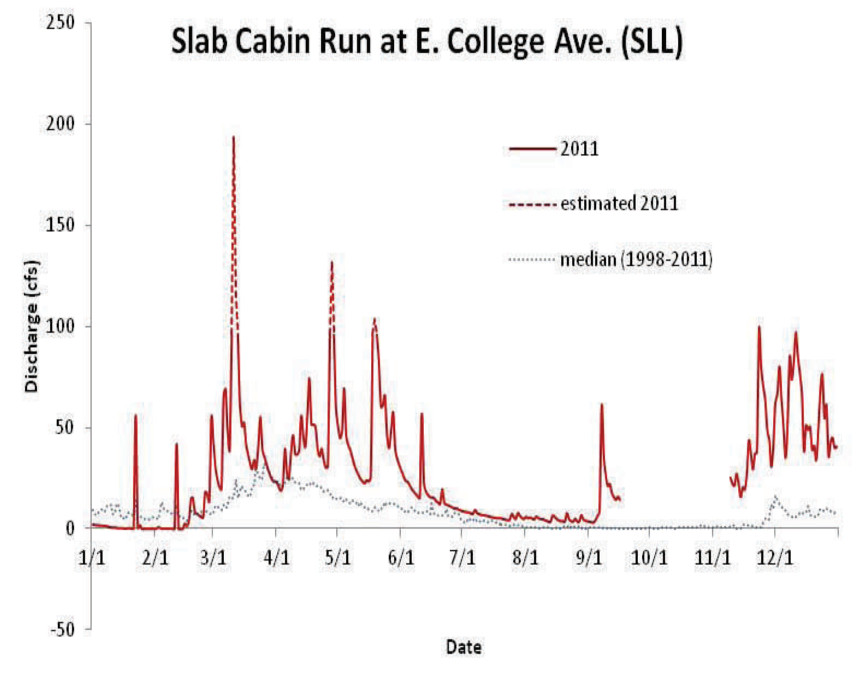
Appendix 6: Daily Stream Flow for 2011

Flow data from WRMP gaging stations within the Spring Creek Watershed.

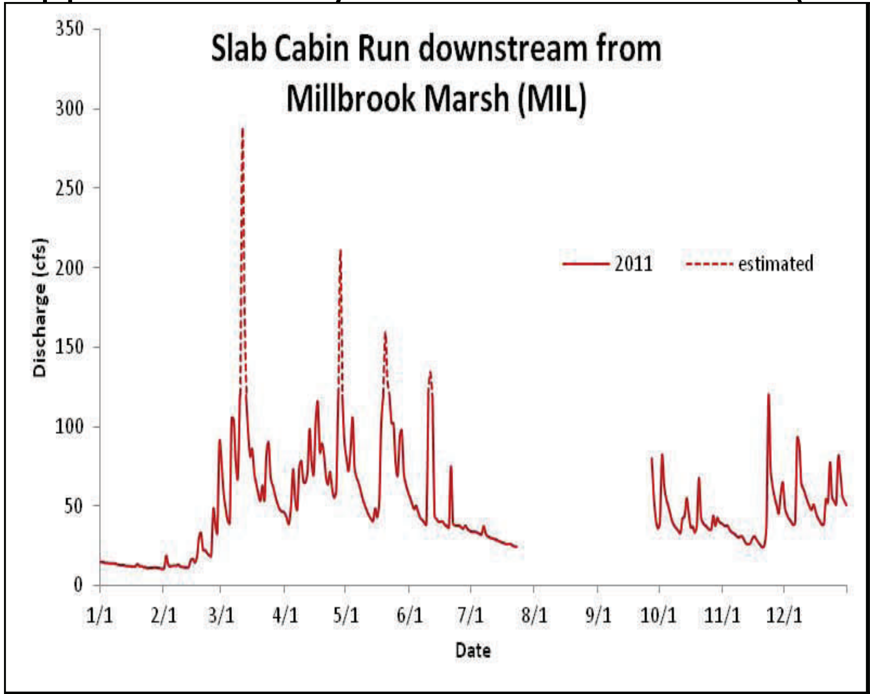




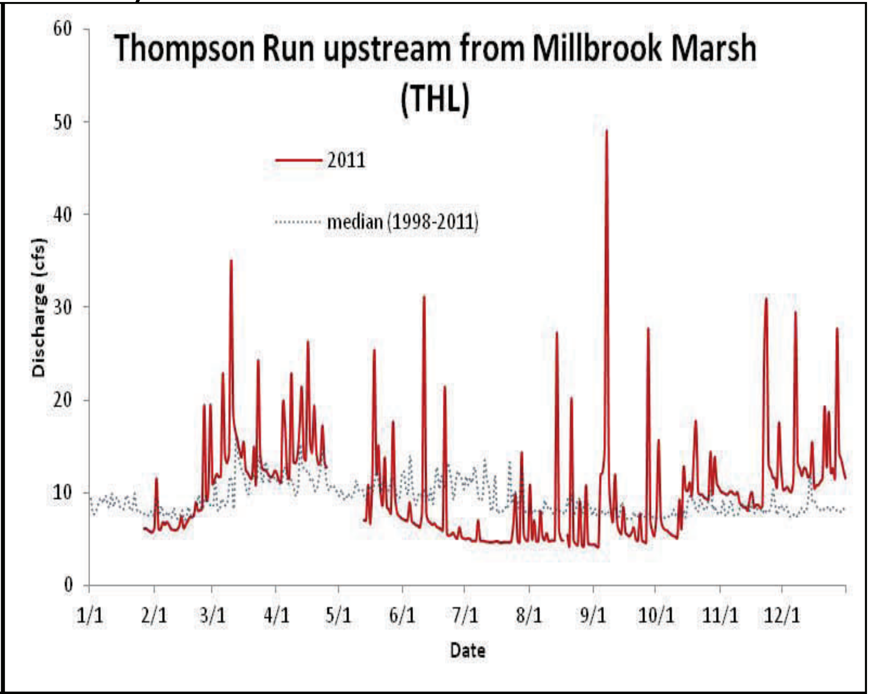




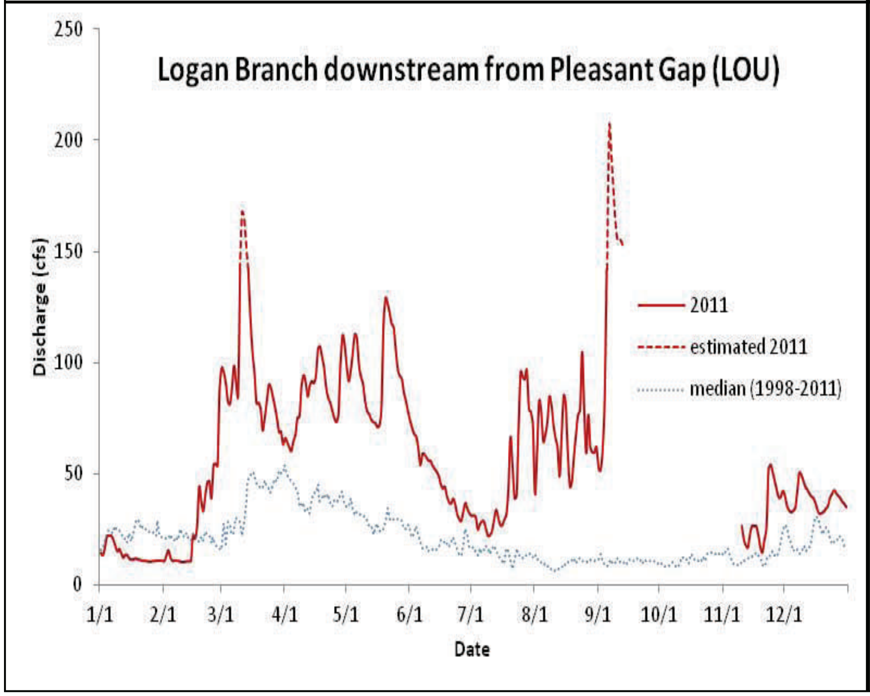
Appendix 6: Daily Stream Flow for 2011 (*continued*)



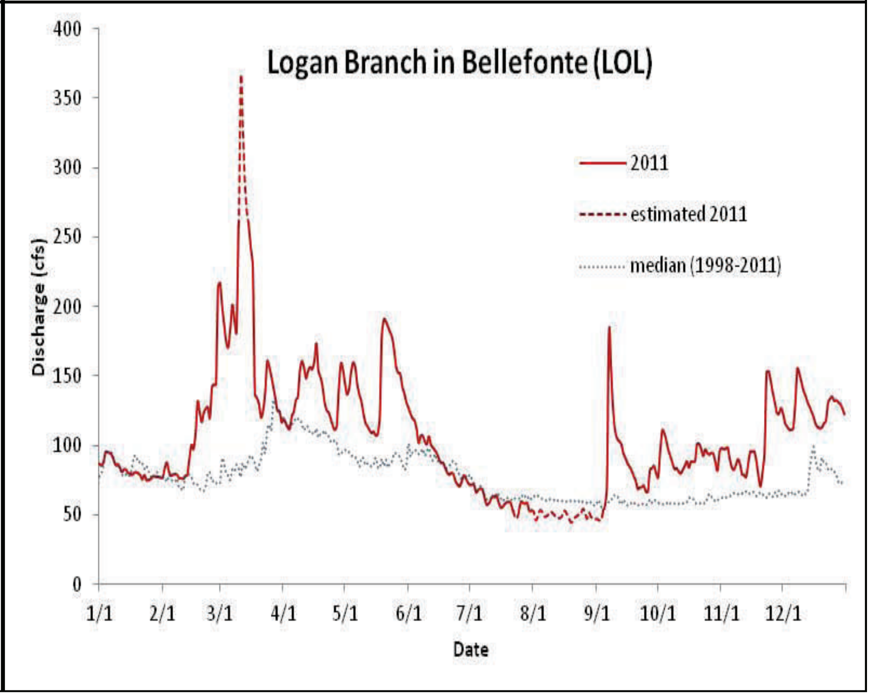
Slab Cabin Run downstream from Millbrook Marsh (MIL)



Thompson Run upstream from Millbrook Marsh (THL)

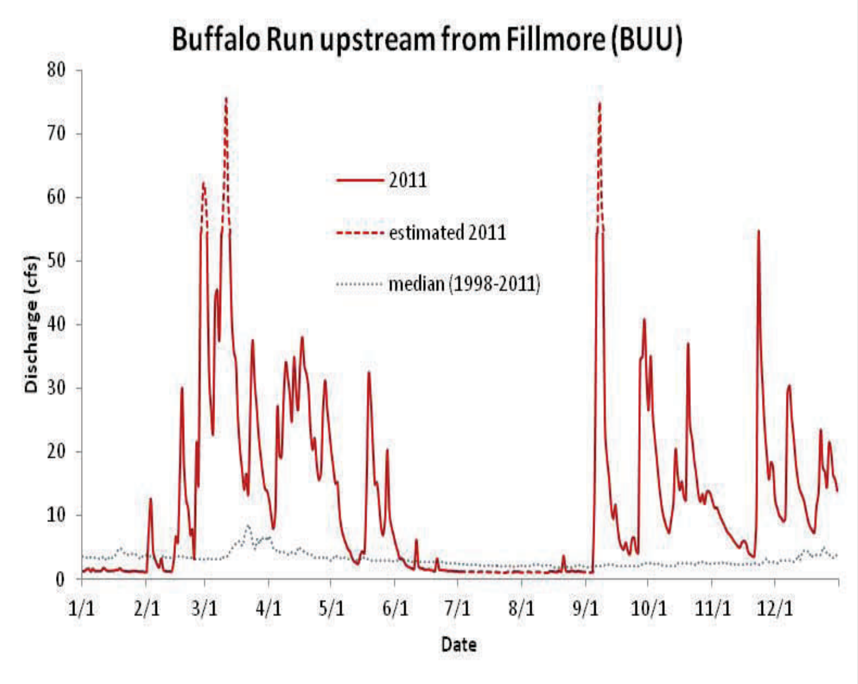


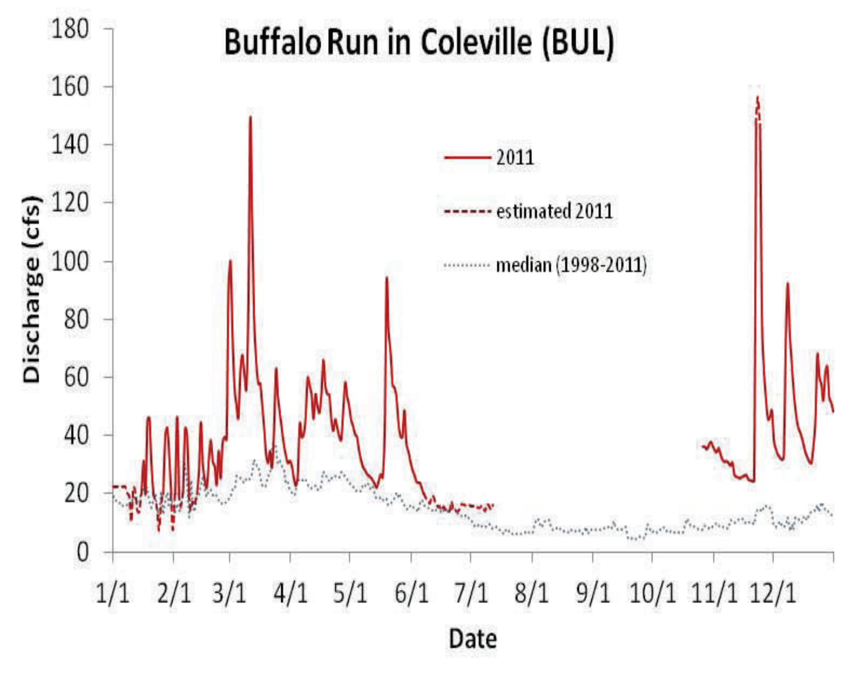
Logan Branch downstream from Pleasant Gap (LOU)



Logan Branch in Bellefonte (LOL)

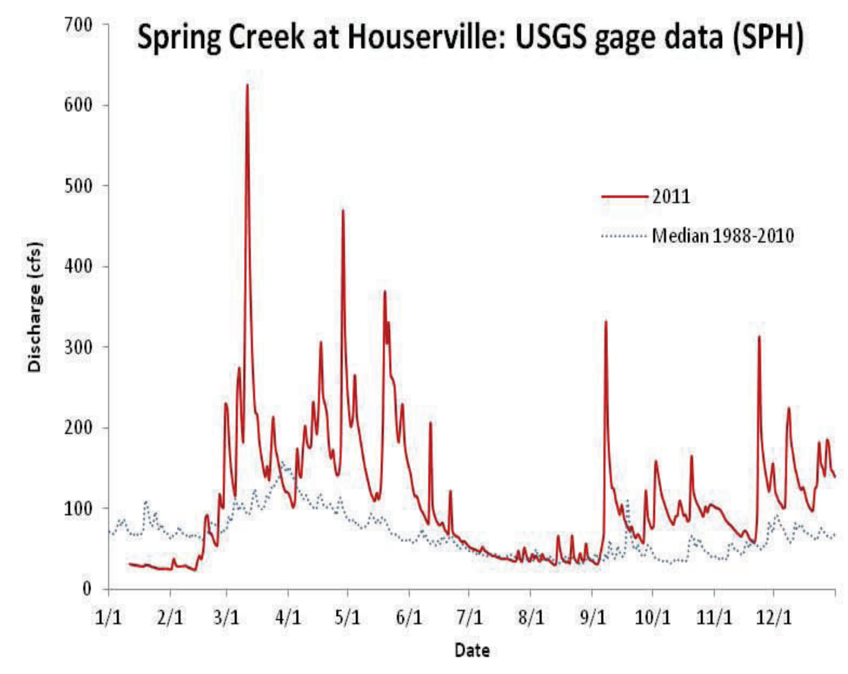
Appendix 6: Daily Stream Flow for 2011 (*continued*)



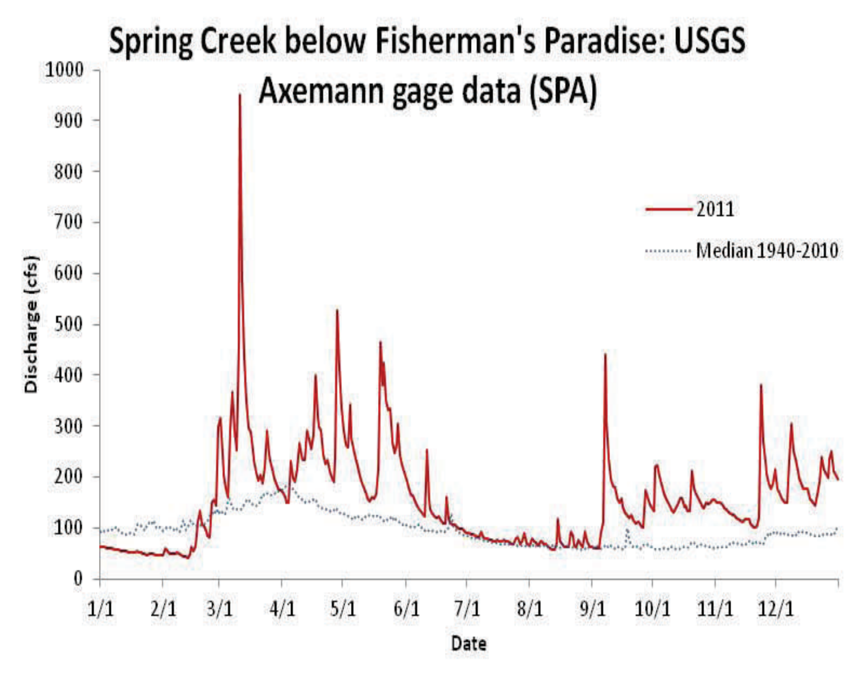


Appendix 6: USGS Spring Creek flow data (*continued*)

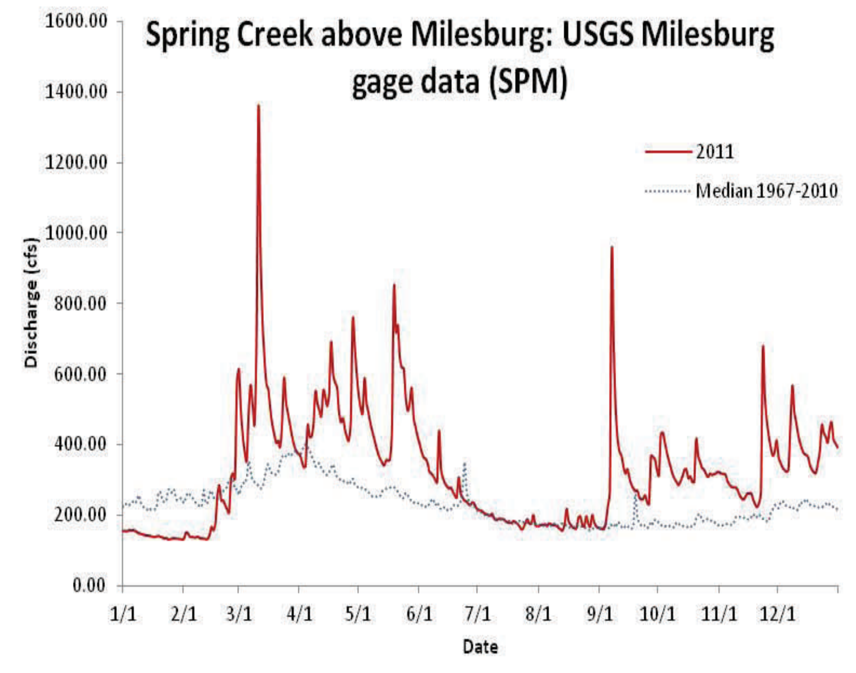
Flow data from the U.S. Geological Service gaging stations on Spring Creek from http://waterdata.usgs.gov/nwis/rt



Spring Creek at Houserville: USGS gage data (SPH)



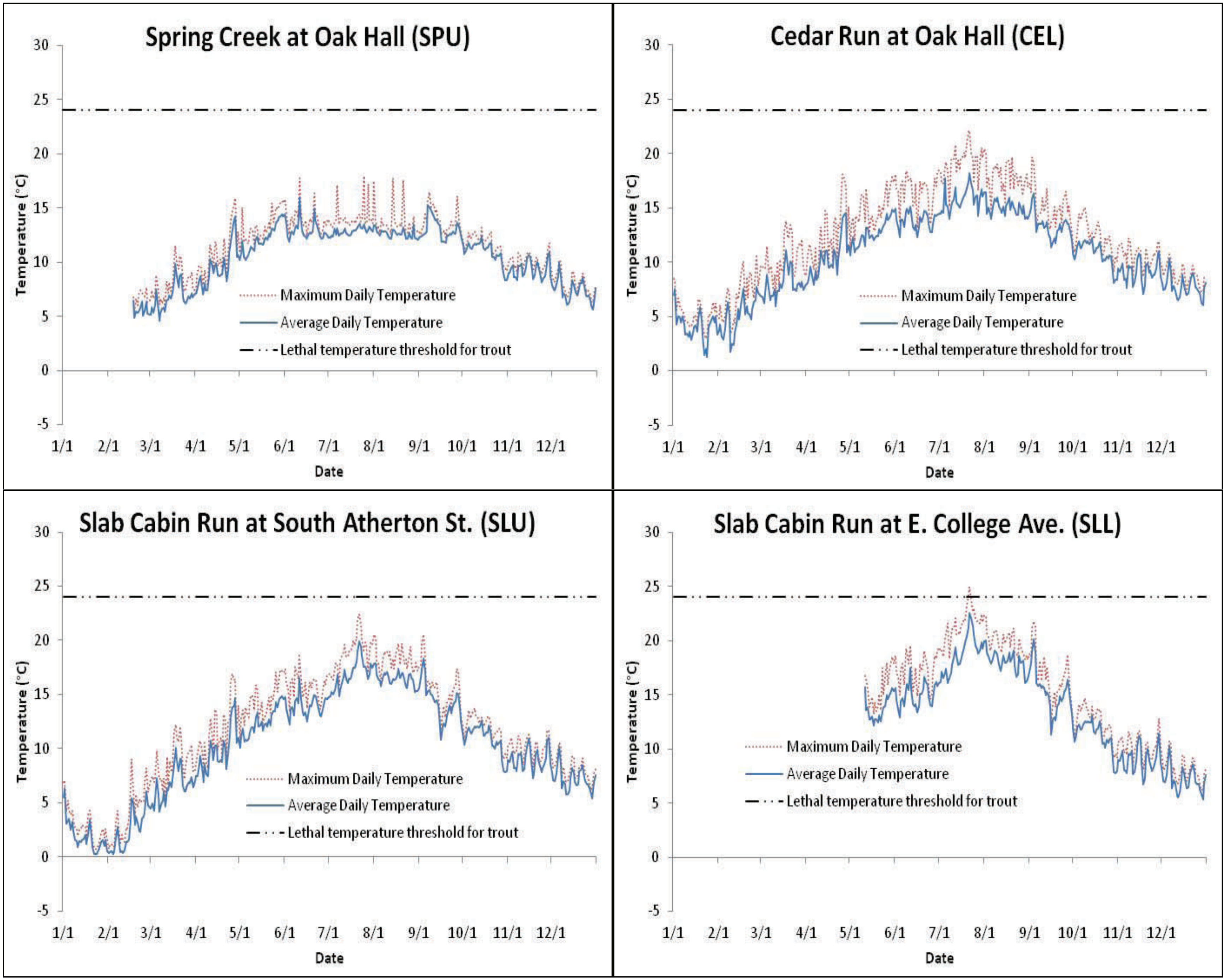
Spring Creek below Fisherman's Paradise: USGS Axemann gage data (SPA)



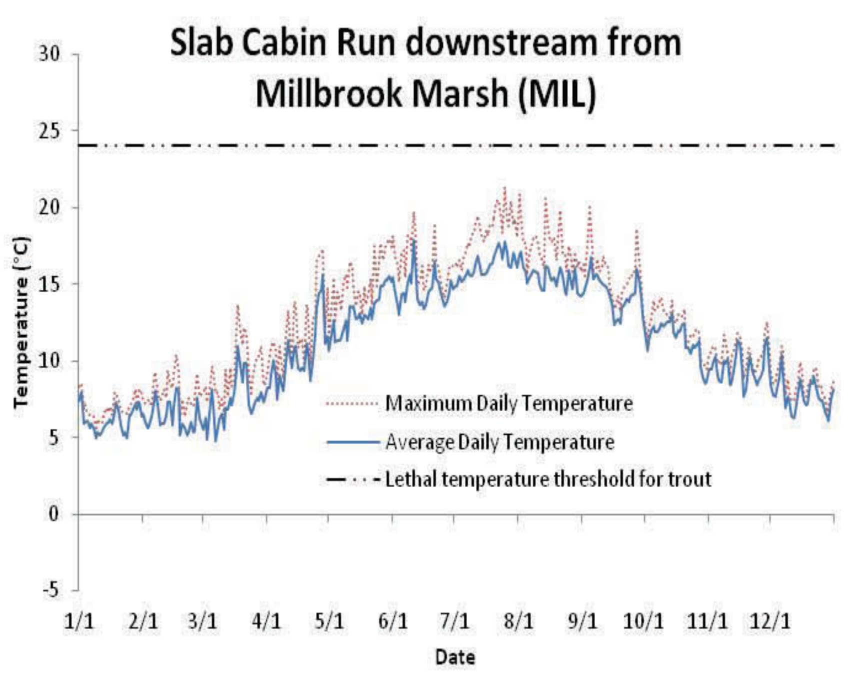
Spring Creek above Milesburg: USGS Milesburg gage data (SPM)

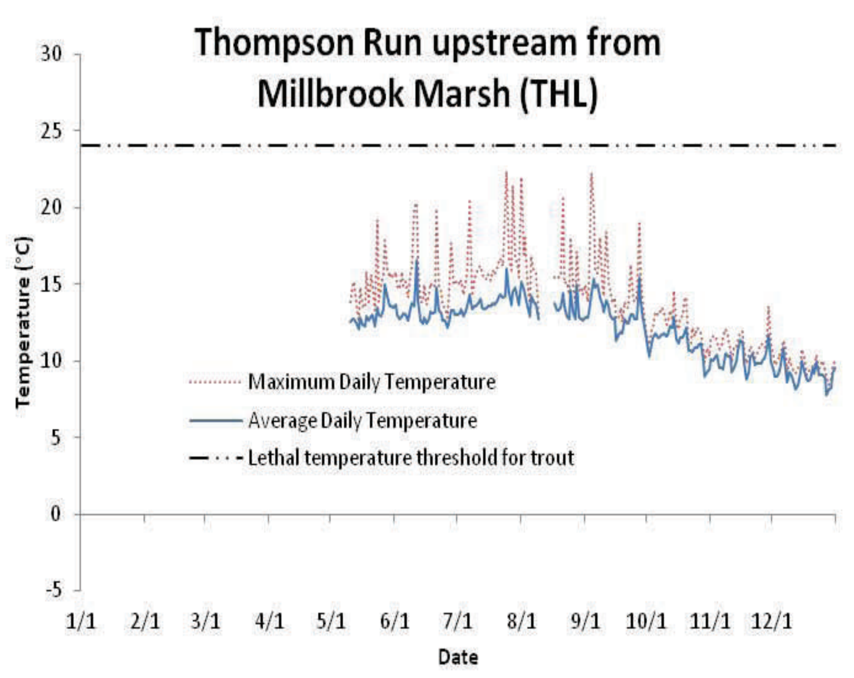
Appendix 7: Daily Stream Temperatures for 2011

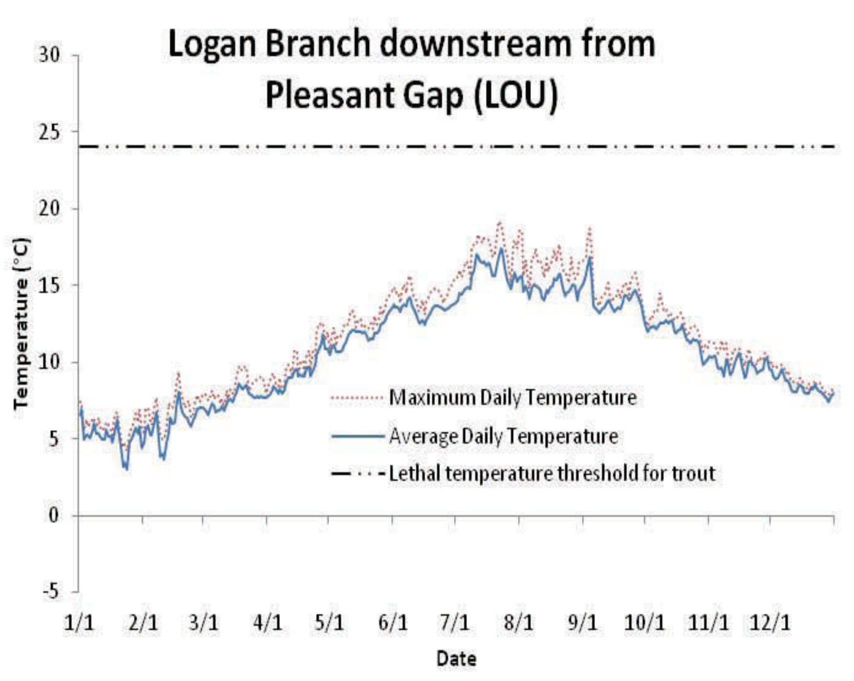
Average daily stream temperature and maximum daily stream temperature for 12 locations in the Spring Creek Watershed.

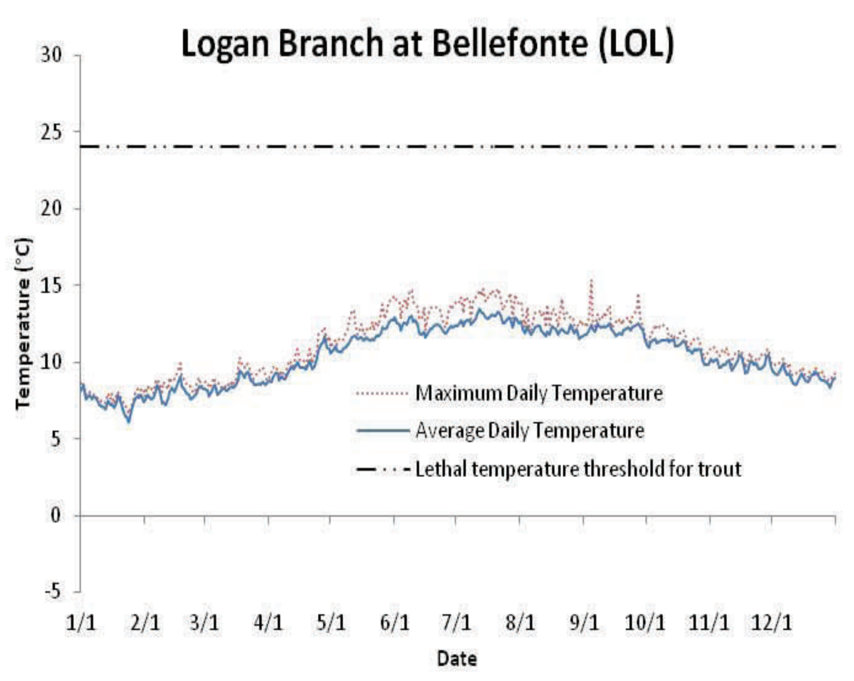


Appendix 7: Daily Stream Temperatures for 2011 (*continued*)

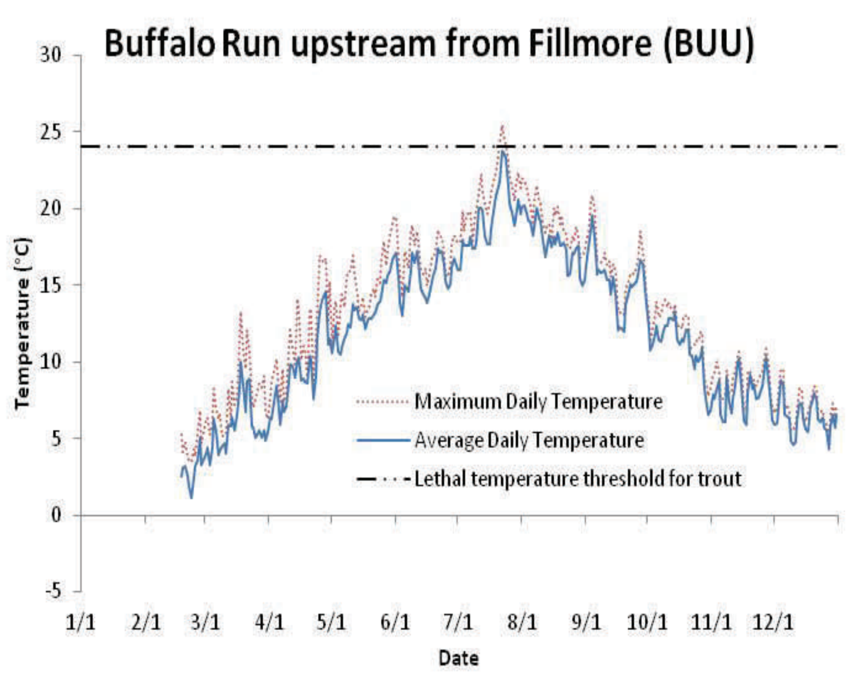


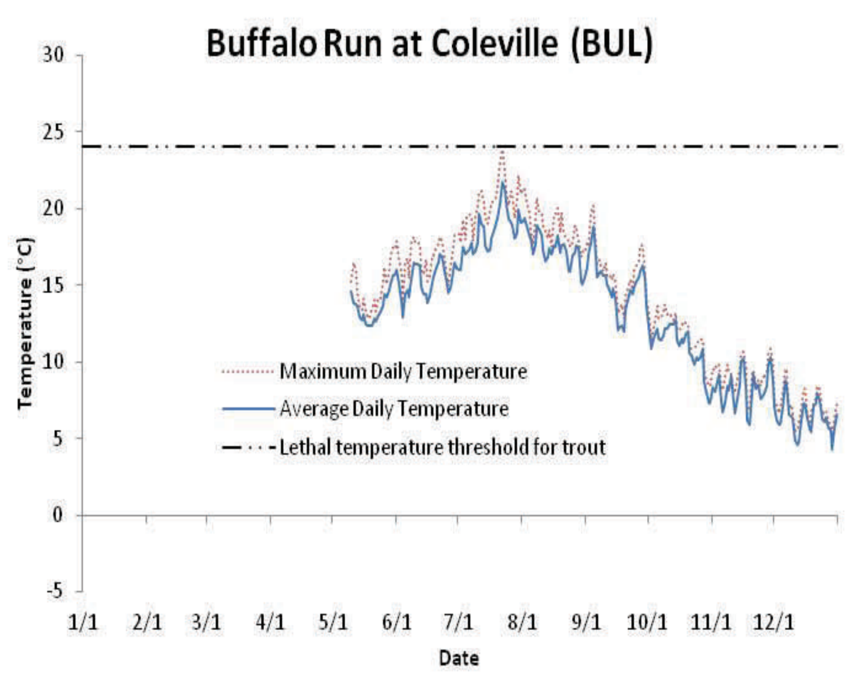


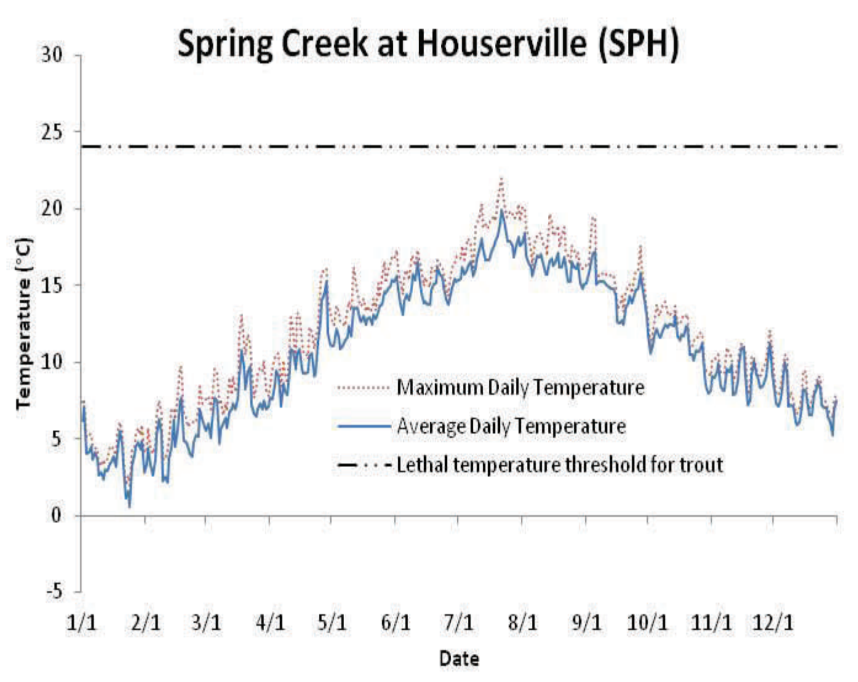


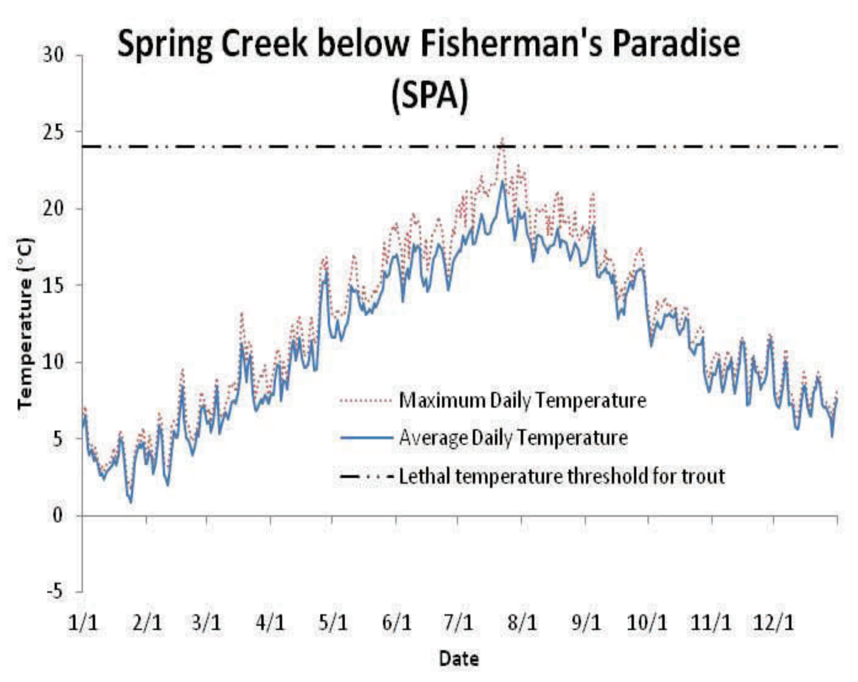


Appendix 7: Daily Stream Temperatures for 2011 (*continued*)

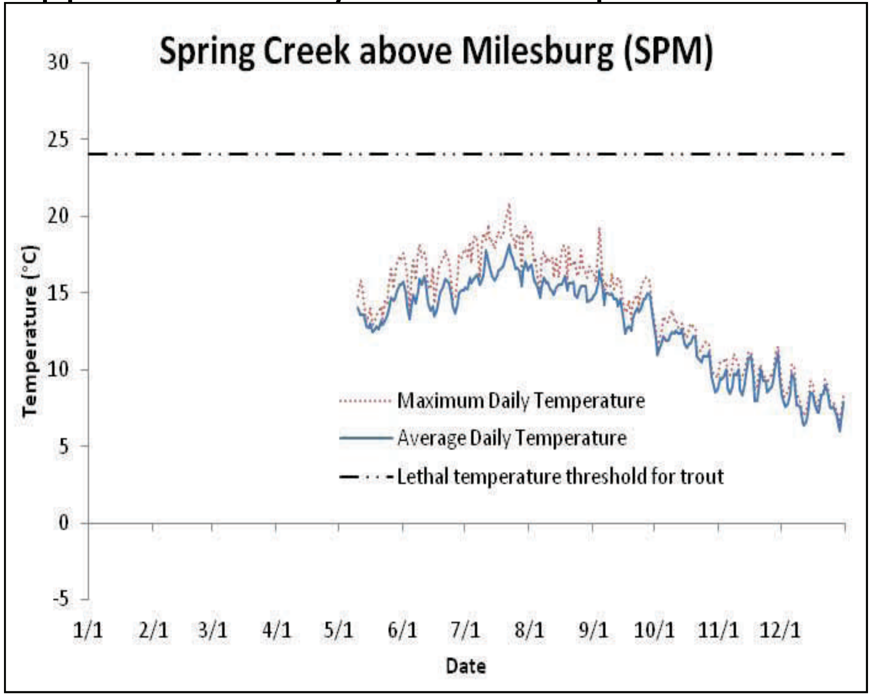

Buffalo Run upstream from Fillmore (BUU)


Buffalo Run at Coleville (BUL)


Spring Creek at Houserville (SPH)

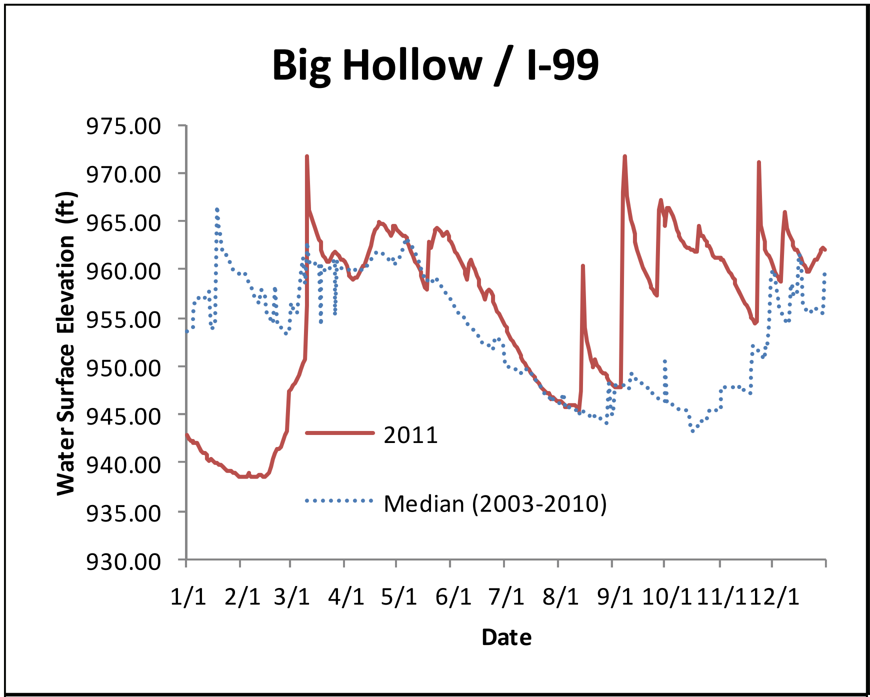

Spring Creek below Fisherman's Paradise (SPA)

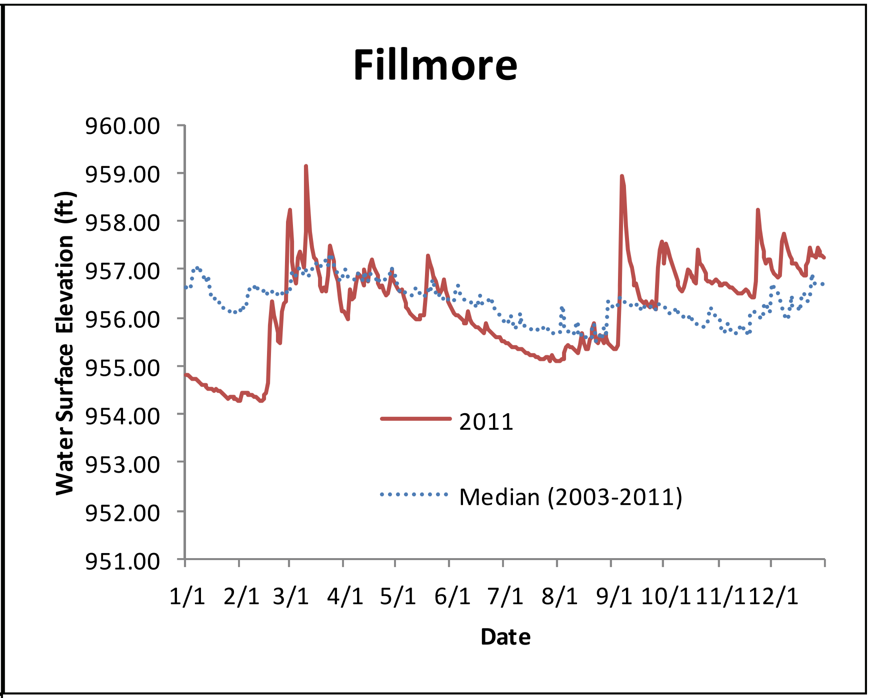
Appendix 7: Daily Stream Temperatures for 2011 (*continued*)

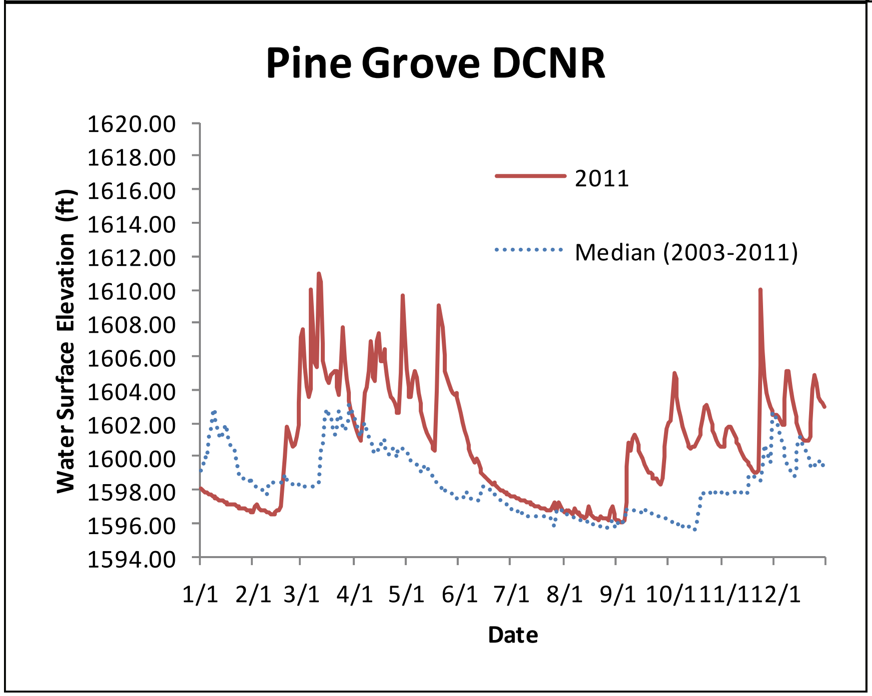


Appendix 8: Daily Groundwater Elevations for 2011

Groundwater elevations from groundwater monitoring wells within the Spring Creek Watershed.







Appendix 8: Daily Groundwater Elevations for 2011 (*continued*)

Water elevation data from the U.S. Geological Service from http://waterdata.usgs.gov/nwis/rt