Morrison Cove Water Resources Availability Study

Publication No. 277 *December 31, 2011*

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**Statutory Citations: Federal – Pub. L. 91-575, 84 Stat. 1509 (December 1970); Maryland – Natural Resources Sec. 8-301 (Michie 1974); New York – ECL Sec. 21-1301 (McKinney 1973); and Pennsylvania – 32 P.S. 820.1 (Supp. 1976).*

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EXECUTIVE SUMMARY

The objectives of the Morrison Cove Water Resources Availability Study were to assess existing water resources, establish an estimated sustainable yield from the constituent watersheds, inventory current water uses, and evaluate water quantity and quality issues in the study area. Morrison Cove includes an area identified by the Susquehanna River Basin Commission (SRBC) as a "Potentially Stressed Area" and has a long history of agriculture-related water quality issues. A lack of flow data from USGS gaging stations within Morrison Cove has precluded quantitative water resource assessment.

The Morrison Cove study area encompasses about 185 square miles in portions of Blair and Bedford counties, Pennsylvania. The predominant land uses, by area, are agricultural (55 percent) and forested (40 percent). Developed land use (including industrial, commercial, municipal, and residential) covers approximately 1 percent. Major population centers include the boroughs of Roaring Spring, Martinsburg, and Williamsburg.

Morrison Cove, located within the Ridge and Valley physiographic province, is an intermontane valley about 30 miles long and five to eight miles wide. The underlying bedrock is predominantly siliciclastics (primarily sandstone) in the ridges, and carbonates in the enclosed valley. The carbonates have solutionally enlarged fractures and conduits which substantially increase aquifer permeability. As a result, relatively high well yields are widely available within the valley portion of the study area for wells sited along major fractures and fracture traces.

A substantial amount of field work and analysis by SRBC and Meiser & Earl, Inc., as well as literature review and Geographic Information Systems (GIS) mapping of previous study results, was conducted as part of the study. From spring through winter 2009, field work included: (1) establishing temporary gaging stations near the mouth of each major watershed and developing rating curves; (2) continuously monitoring streamflows, including a wide range of seasonal flows; (3) measuring over 200 groundwater levels for a water table contour map; (4) performing seepage runs to obtain a snapshot of contributing flows within each major watershed; and 5) obtaining select water chemistry data and evaluating aquatic habitat at each seepage run station.

A detailed water availability analysis allowed SRBC to establish the amount of groundwater and surface water base flow currently available on a sustainable basis for use in each major watershed. For the purposes of this study, the sustainable limit of consumptive use is approximated by the 10-year base flow. The use of water utilization data representing the maximum approved or permitted daily use ensures a worse-case evaluation, and a conservative estimate of water availability.

The water resources in the Yellow Creek, Piney Creek, and Clover Creek Watersheds, and in the northern Gatesburg groundwater basin, are largely undeveloped. However, the amount of water currently withdrawn from the Roaring Spring exceeds the amount of water available on a sustainable basis. The amount of water currently consumptively withdrawn from the Halter Creek Watershed represents 87 percent of the 10-year base flow. Approximately 11 percent of the 10-year base flow is currently being utilized in the Plum Creek Watershed.

The Morrison Cove Watersheds were screened for potential designation as Pa. Act 220 Critical Water Planning Areas (CWPAs). The consumptive use in each watershed was compared to the appropriate Initial Screening Criterion (ISC). Consumptive use exceeded the ISC in the Halter Creek and Plum Creek Watersheds. However, the consumptive use in these watersheds is due to a few relatively stable, high volume withdrawals, and both watersheds support high quality aquatic habitat downstream of the withdrawal locations. Water use in Halter Creek and the Roaring Spring is largely driven by industrial use. Municipal and residential consumptive use is a small fraction of total use. Therefore, water use is not a function of population growth. Available data for industrial water use suggest overall stability, with no net increases in water demand in recent years. Designation of these watersheds as CWPAs does not appear to be warranted.

The greatest challenges for water supply in the Morrison Cove Study area are: (1) the concentration of major withdrawals in the Roaring Spring area, and (2) the widespread contamination of surface water and groundwater by agricultural activities. Under existing conditions, water demand exceeds available flow from the Roaring Spring during some summer and fall months in moderate drought years. In years with average hydrologic conditions, about 1-3 cubic feet per second (cfs) of flow leaves the spring pool. This flow of high quality water is critical to the aquatic habitat in downstream reaches of Halter Creek.

The study identified two unusually permeable hydrogeologic terrains as Critical Aquifer Recharge Areas (CARAs). The central portions of the study area are underlain by highly permeable sandy carbonates and sandstones of the Gatesburg Formation (Gatesburg Terrain). These are overlain by a relatively thick mantle of weathering residuum composed largely of fine sand. The sandy residuum has a very high infiltration rate and correspondingly low runoff rate, and is a nearly ideal medium for maximizing and storing recharge. The Gatesburg Terrain provides groundwater to the largest springs in the study area. The Gatesburg Terrain also provides the only water in the valley that is relatively low in agrichemical constituents. The second unusually permeable terrain consists of a narrow belt of highly soluble limestones situated along the toeslope of the surrounding ridges. The ridges provide relatively acidic, but otherwise high quality, groundwater and surface water runoff to the soluble limestones where extensive strike-oriented karst conduits have developed. These conduits convey most of the local and mountainside recharge to springs and seeps located in the downstream reaches of the watersheds. They are largely responsible for the generally high quality aquatic habitat available in the downstream reaches of the ridge-parallel streams.

Nitrate levels in the base flow of streams were generally below state and federal drinking water standards, in contrast to the surrounding groundwater. This was taken to be the result of nitrogen uptake in riparian zones. Until the elevated nitrate levels in the groundwater of the

Interior Carbonate Terrain are addressed, the stream water may be a viable alternative water supply source for some uses. Surface water withdrawals from the downstream reaches of the Yellow Creek, Piney Creek, and Clover Creek Watersheds could supply water needs with minimal impacts to existing users and aquatic habitat. Stream water quality may be further improved by restoration of riparian zone vegetation. The resulting improvements would include water quality, aquatic habitat, and channel stabilization.

RECOMMENDATIONS

In light of the study findings, SRBC has developed the following recommendations to help secure adequate yields, ensure the protection of current uses and aquatic and riparian needs, and help prevent adverse impacts to the water resources and aquatic habitat of Morrison Cove:

- Manage withdrawals from the Roaring Spring to ensure their sustainability, and to maintain and protect aquatic habitat in Halter Creek.
- Focus groundwater development for municipal grade wells on the aquifers having both high quality water and sufficient permeability to allow high production rates (i.e., the Gatesburg Terrains).
- Locate municipal-grade surface water withdrawals at downstream locations where the maximum amount of water is available and where impacts to existing users and the environment would be minimized.
- Locate large groundwater withdrawals in the downgradient portions of major recharge areas, where more water is available.
- Locate large groundwater withdrawals within watersheds in the downstream reaches to minimize the stream miles with reduced base flow and altered flow regime.
- Protect water quality in the two major Critical Aquifer Recharge Areas (CARAs): the Gatesburg North and South Terrains through use of appropriate Best Management Practices (BMPs).
- Protect water quantity in the Gatesburg Terrain areas (north and south) through use of Stormwater and Development BMPs, to minimize impervious cover.
- Treat waters for nitrate levels which exceed federal Safe Drinking Water standard (10 mg/l), as is typical in the Interior Carbonates Terrain.
- Develop and implement methods to eliminate surplus manure.
- Encourage the restoration of riparian vegetation to increase the natural treatment of water and to improve aquatic habitat.
- Measure and record flow through the existing weirs on Plum and Halter Creeks, and on the Roaring Spring pool discharge on a daily basis.
- Continue and expand the collection of reported water use data.

1.0 INTRODUCTION

1.1 Purpose and Objectives

SRBC identified the need for a thorough assessment of the available water resources of the Morrison Cove area in the southwestern portion of the Susquehanna River Basin. Developed areas in Morrison Cove (Martinsburg and Roaring Spring) have experienced conflicts among the various water users. Additionally, Morrison Cove has a long history of elevated nitrate levels in groundwater which poses a health risk and potentially limits available resources for development. The Roaring Spring area in Morrison Cove is one of eight Potentially Stressed Areas (PSAs) within the Susquehanna River Basin (Figure 1-1) identified by SRBC in 2005. PSAs are areas where the demand for and use of water resources is potentially approaching or has exceeded the sustainable limit. Roaring Spring was included due to: (1) stresses on groundwater resources during the severe droughts in 1999 through 2002; (2) indications that withdrawals within the groundwater basin exceed the recharge anticipated during a 1-in-10-year average annual drought (i.e., the 10-year base flow); and (3) the increasing demands for water due to recent industrial and commercial growth. In addition to instream and other naturally occurring water needs, the water supplies in the area must meet the needs of communities, industrial and commercial enterprises, agricultural operations, and mining and natural gas development.

The objectives of the Morrison Cove Water Resources Availability Study were to assess existing water resources, establish an estimated sustainable yield from the constituent watersheds, inventory current water uses, and evaluate quantity and quality issues in the study area. The assessment of existing water resources includes a characterization of the Roaring Spring and its sustainable capacity.

SRBC plans to use the findings of this study, within the framework of the Susquehanna River Basin Compact and in cooperation with the Commonwealth of Pennsylvania, to guide future regulatory and planning decisions affecting the Morrison Cove area. To the extent that the study provides a detailed investigation of water availability and current demands for water, focuses on key issues used in the identification of the Pennsylvania Department of Environmental Protection's Critical Water Planning Areas (CWPA), and proposes alternative measures and actions to address these problems, it supports the requirements for a Critical Area Resource Plan (CARP) under The Water Resources Planning Act of 2002 (P.L. 1776, No. 220), 27 Pa. C.S. §3101 et. Seq., referred to herein as Act 220.

Information, recommendations, and guidance for sustainable management and development of water resources will be of value to local government, water resource development consultants, and water users.

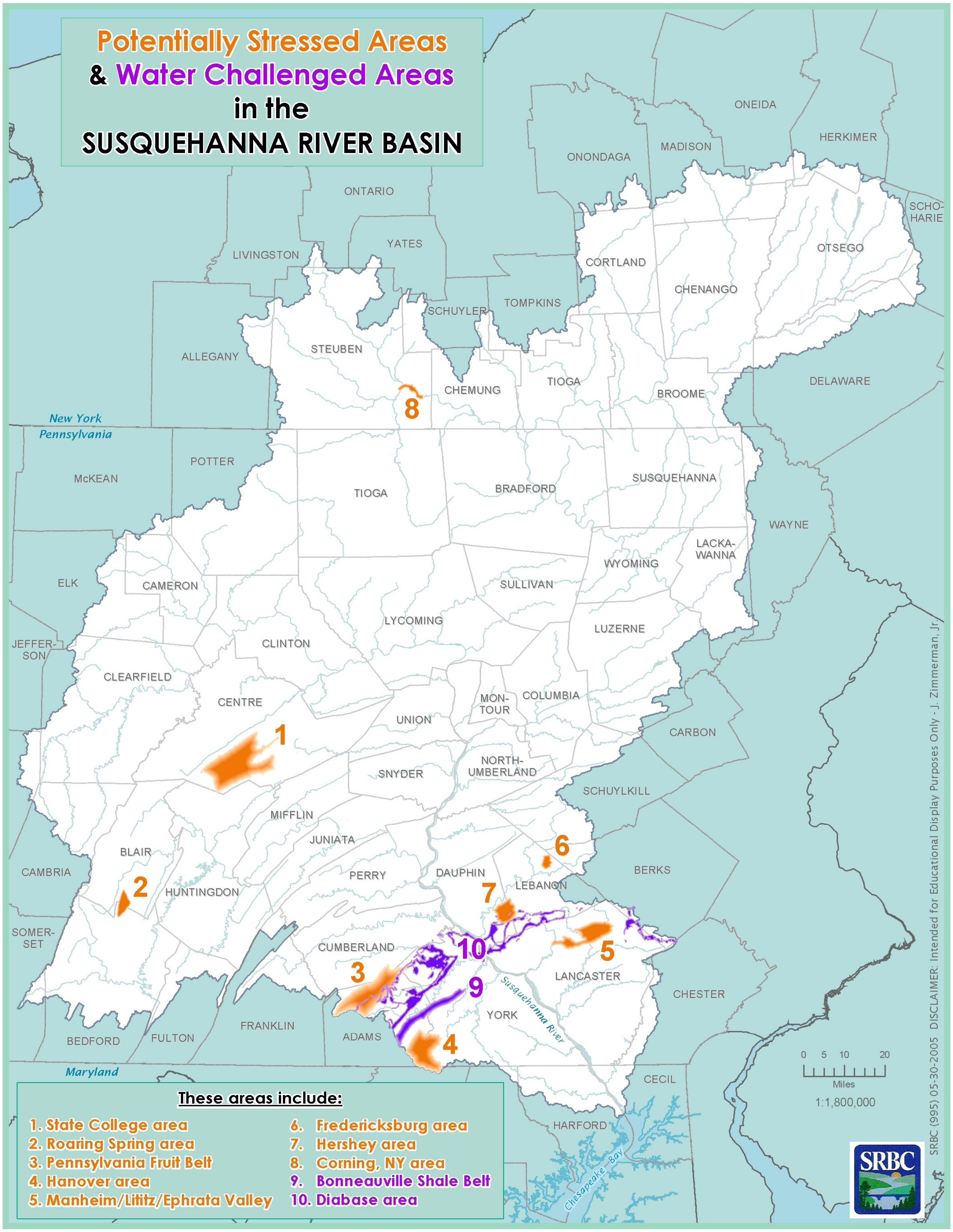

Figure 1-1. SRBC Potentially Stressed Areas (The Roaring Spring area is identified as Potentially Stressed Area Number 2.)

1.2 Study Methodology

SRBC contracted with Meiser & Earl, Inc. to conduct multiple tasks to assist in characterizing the water resources of Morrison Cove, including literature review, area reconnaissance, stream and spring flow gaging and monitoring, interpretation of groundwater elevations, and the summary and interpretation of collected data. Data and draft text and figures prepared by Meiser & Earl, Inc. are incorporated into this final report by SRBC staff.

SRBC staff developed the overall plan of investigation and performed a number of activities for the assessment of water resources, including the selection of key monitoring and sampling locations, field data collection and interpretation, performance of seepage runs, creation of base maps, water quality sampling, habitat evaluation, groundwater level measurements, overall hydrologic and hydrogeologic analyses, stakeholder meetings, and preparation of the final report and recommendations for action.

Tasks related to the study included the following:

1) Reviewed water quality and quantity literature for the Morrison Cove area.

2) Obtained several months (typically June through December 2009) of onsite streamflow data for the five major watersheds (Halter, Plum, Piney, Clover, and Yellow Creeks).

3) Obtained several months (typically June through December 2009) of onsite springflow data for the two major karst springs (Roaring Spring and Williamsburg Spring).

4) Measured water levels in water supply wells during the week of October 5, 2009, and created a water table map.

5) Sampled surface water (streams and springs) to complement the large body of existing groundwater water quality data during October 2009.

6) Evaluated aquatic and riparian habitat during October 2009.

7) Performed a base flow seepage run on all five major watersheds during the week of October 5, 2009. Multiple teams were employed to complete a seepage run of each watershed within a 24–hour period.

8) Developed flow statistics for the five major watersheds in Morrison Cove.

9) Developed a water budget for the base flow watersheds in Morrison Cove. This essentially subtracts consumptively used water from the naturally produced water, providing a status check of the level of water resource development in each base flow watershed.

2.0 GEOGRAPHIC SETTING

The Morrison Cove study area encompasses about 185 square miles in portions of Blair and Bedford counties, Pennsylvania. The study area is located in the Juniata River Subbasin and is comprised of a valley largely bounded by mountain ridges (Figure 2-1). The major population centers include the boroughs of Roaring Spring, Martinsburg, and Williamsburg. The study area is approximately 10 miles southeast of Altoona.

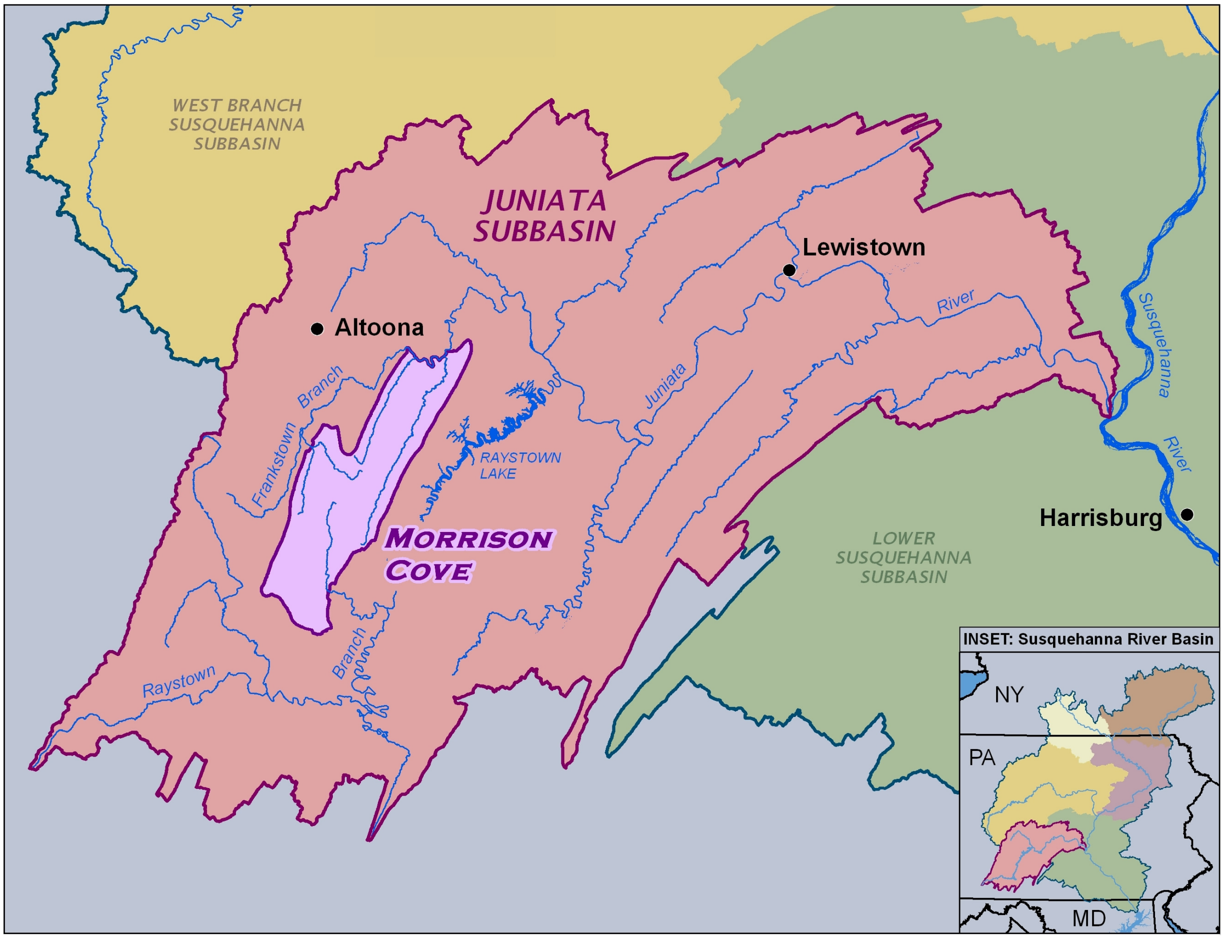

Figure 2-1. Location of Morrison Cove in the Juniata Subbasin of the Susquehanna River Basin

The predominant land uses (Figure 2-2) are agricultural (55 percent) and forested (about 40 percent). Developed areas (urban, commercial, and industrial) cover approximately 1 percent of the valley. The economy is largely agricultural, but also includes mineral extraction at a large limestone quarry and a paper mill.

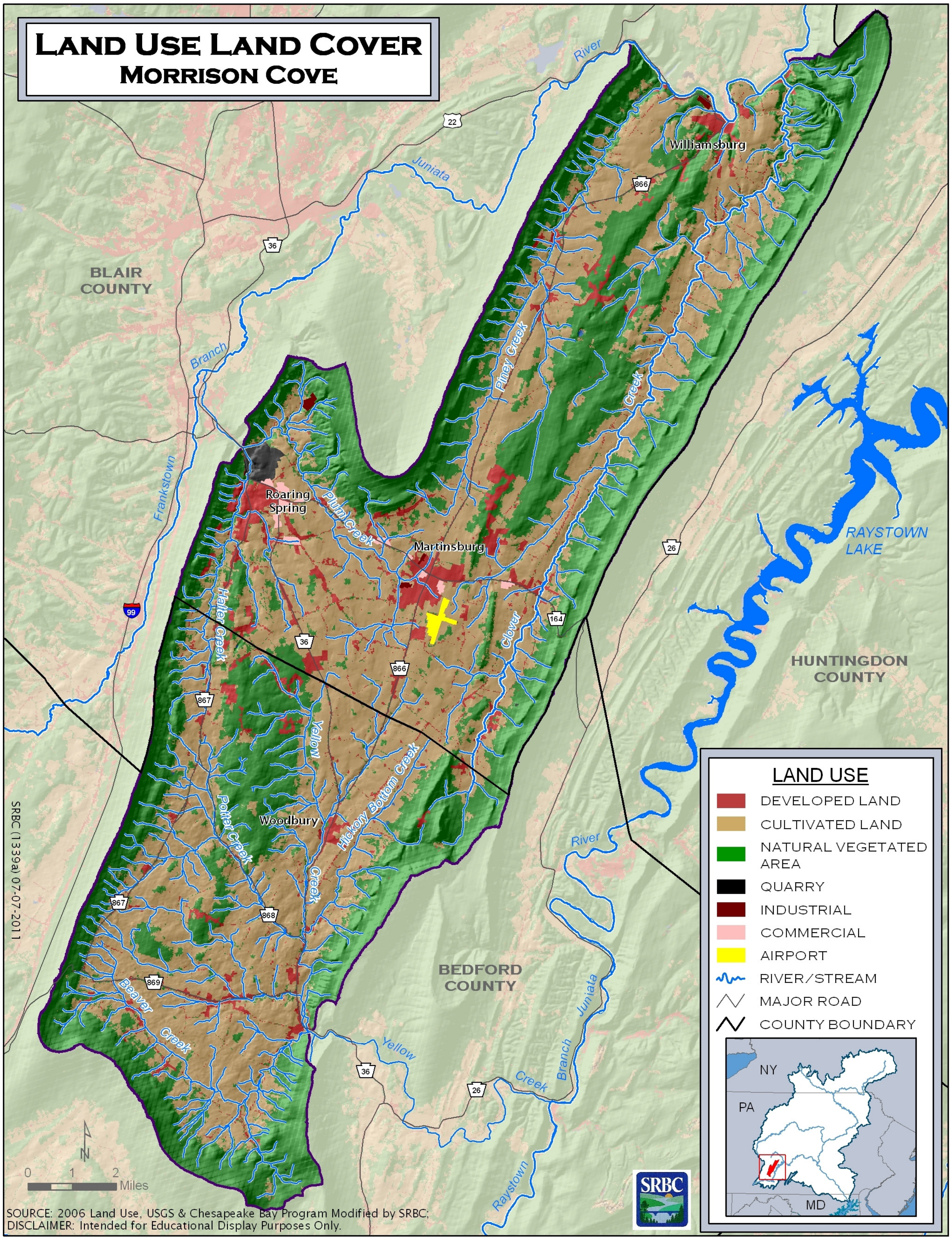

Figure 2-2. Land Use in Morrison Cove

The study area is located entirely within the Ridge and Valley physiographic province, a region characterized by sub-parallel, locally sinuous mountain ridges and broad intervening valleys. Morrison Cove is the southernmost part of an intermountain valley complex more than 100 miles in length that extends northeastward to the State College area, where it splits into Nittany Valley and Penns Valley. The Frankstown Branch Juniata River forms the northern boundary of the Morrison Cove.

Morrison Cove is an elongate valley, approximately 30 miles long and five to eight miles wide. Local relief between the mountain ridges and the adjacent valley typically ranges from 600 to 1,200 feet. Local relief in the central valley ranges from 80 to 300 feet. Mountain crest elevations range from 1,800 feet to approximately 2,560 feet (junction of Dunning and Evitts mountains, at the southwest corner of Morrison Cove). Summit elevations in the hilly terrain of the interior valley range from approximately 900 feet in the northern portion of the Morrison Cove to 1,700 feet in the south.

2.1 Surface Water Drainage

Streams in the northern and central portions of Morrison Cove drain to the Frankstown Branch Juniata River. Streams in the southern portion of Morrison Cove drain to the Raystown Branch Juniata River. Morrison Cove is drained by four major streams: Halter, Yellow, Clover, and Piney Creeks. In addition to the four major streams listed above, Schmucker Run and three unnamed tributaries discharge directly into the Frankstown Branch Juniata River.

The streams exhibit two distinctive patterns; one characterized by trunk streams that flow parallel to the adjacent mountain ridges (called strike-parallel) and a second where streams flow across the valley (called cross-strike). Examples of the strike parallel type include Halter Creek, Plum Creek, Clover Creek, Piney Creek, Hickory Bottom Creek, and Beaver Creek. Yellow Creek (excluding Beaver Creek and Hickory Bottom Creek) flows across the valley to the water gap at Loysburg, where it leaves Morrison Cove before its confluence with the Raystown Branch Juniata River.

The streams (including the Frankstown Branch Juniata River) pass through water gaps in the surrounding mountain ridges. Gap elevations generally decrease from south to north. Yellow Creek exits Morrison Cove through the Loysburg water gap at an elevation of approximately 1,110 feet. Halter and Plum Creeks exit Morrison Cove through the gap northwest of Roaring Spring at an elevation of 1,060 feet. Piney Creek and Clover Creek exit the Cove at their confluence with the Frankstown Branch of the Juniata. The mouth of Piney Creek is at an elevation of approximately 850 feet. The mouth of Clover Creek is at an elevation of approximately 805 feet. These elevations establish both erosional base level and the lowest groundwater head in each watershed. Surface water and groundwater are graded to these elevations.

3.0 HYDROGEOLOGIC SETTING

Morrison Cove is hydrogeologically isolated from surrounding areas by mountain ridges, which act as strong surface water and groundwater divides. Surface runoff and groundwater runoff originate as precipitation within Morrison Cove, and leave Morrison Cove as surface water discharge (i.e., streamflow) through the water gaps, or via groundwater discharge from seeps and springs discharging directly into the Frankstown Branch Juniata River.

The hydrogeologic setting of Morrison Cove incorporates aspects of bedrock geology, structural geology, hydrogeology, and other factors. These are addressed below in separate sections.

3.1 Bedrock Geology

The bedrock consists of sedimentary rocks of marine and marginal marine origin. The rocks themselves are of differing types, with quartz-rich sandstones and carbonates being the most common. The rocks were deposited in horizontal layers (beds), and deformed into a series of complex folds with associated faulting during the formation of the ancestral Appalachian Mountains. The current mountains are the result of erosion of a folded bedrock terrain with formations of differing resistance to erosion (i.e., differential erosion). Over geologically long periods of time, the less resistant carbonates were eroded relatively quickly and formed valleys, while the sandstones tended to resist erosion and form high ridges.

The distribution of geologic formations that crop out in Morrison Cove is shown in Figure 3-1. Their lithologic characteristics are summarized in Appendix A. The stratigraphic sequence (order of deposition in geologic time) can be summarized as follows: Cambrian dolostones with interbedded sandy dolostone, sandstone, siltstone, and shale give rise to Lower Ordovician dolostones and minor limestones, which have much less sand, silt, and clay. The dolostones rapidly transition into Middle Ordovician limestones with minor dolostones. These transition into a sequence of siliclastics of late Ordovician to Early Silurian age. These exhibit an overall coarsening upward trend, starting with organic-rich shale (Antes) at the base, and culminating with the Bald Eagle and Tuscarora sandstones. For detailed discussions of the bedrock geology and stratigraphy of the Morrison Cove area, the reader is referred to the relatively extensive previous work on this subject (Berkheiser, 1986; Butts, 1939 and 1945; Harper and Laughrey, 1996; Kay, 1944; Rones, 1969; Wilson, 1952).

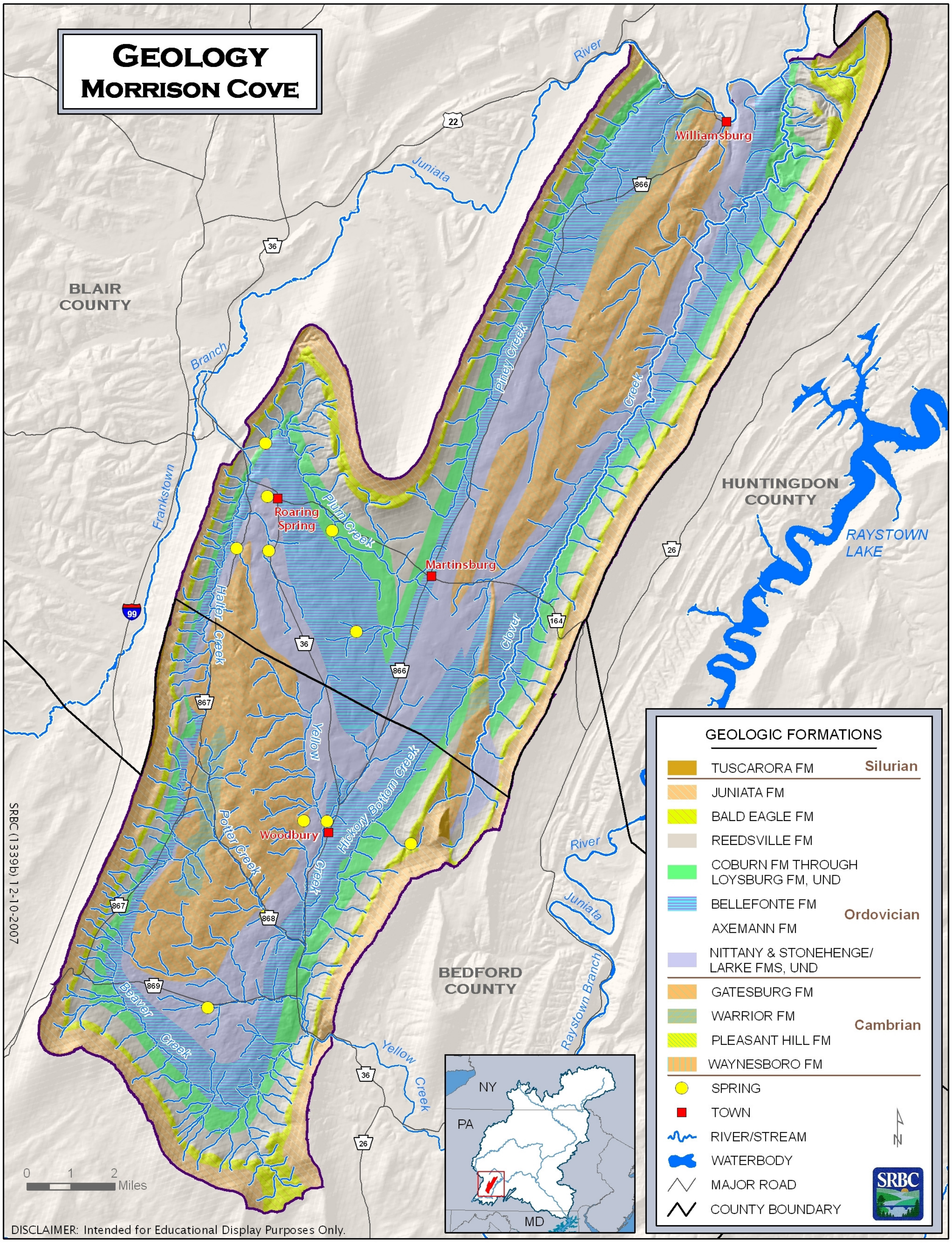

Figure 3-1. Geologic Formations in Morrison Cove (after Berg et al., 2001)

3.2 Structural Geology

The geologic formations discussed under 'Bedrock Geology' were deposited as flat (tabular or prismatic), horizontal bodies of sediment. These rock bodies were complexly folded and faulted during the formation of the ancestral Appalachian Mountains. The major geologic structure in Morrison Cove is the Nittany Anticlinorium, a large anticline with superimposed secondary folds and faults. This feature is more than 130 miles long, and extends from several miles southwest of Morrison Cove, northeast to the vicinity of Williamsport. Although the resulting geologic structure is relatively complex, it can be simplified with little disservice to the goals of this study. The simplified geologic structure is that of a simple anticline, the crest of which is oriented northeast-southwest. The anticline is slightly asymmetric, with the northwest side being steeper than the southeast side. Rock beds on the northwest side are nearly vertical, while those on the southeast side dip (i.e., slope) 50-70 degrees away from the center (Figure 3-2). Beds of sedimentary rock tend to occur as bands that parallel the nearest mountain ridge. Beds are nearly horizontal along the axis of the fold. A more detailed discussion of the structural geology of the Morrison Cove region can be found in Canich and Gold (1985), Parizek and White (1985), and Butts (1939), while a useful overview is provided by Faill and Nickelsen (1999).

Figure 3-2. Roadcut in Loysburg Water Gap, Yellow Creek, Showing Sandstone Beds in the Bald Eagle Formation Dipping at Approximately 50 Degrees to the Southeast

Uplift and differential erosion of the Nittany Anticlinorium has resulted in an elongate valley underlain by carbonates, and bounded by a wall (mountain ridge) of sandstone (Figure 3-3). This intermontain valley complex is over 100 miles in length and extends from Morrison Cove northeastward to the State College area, where it splits into Nittany Valley and Penns Valley. Morrison Cove is the southernmost portion of this intermontain valley. Morrison Cove is approximately 30 miles long and varies from five to eight miles in width.

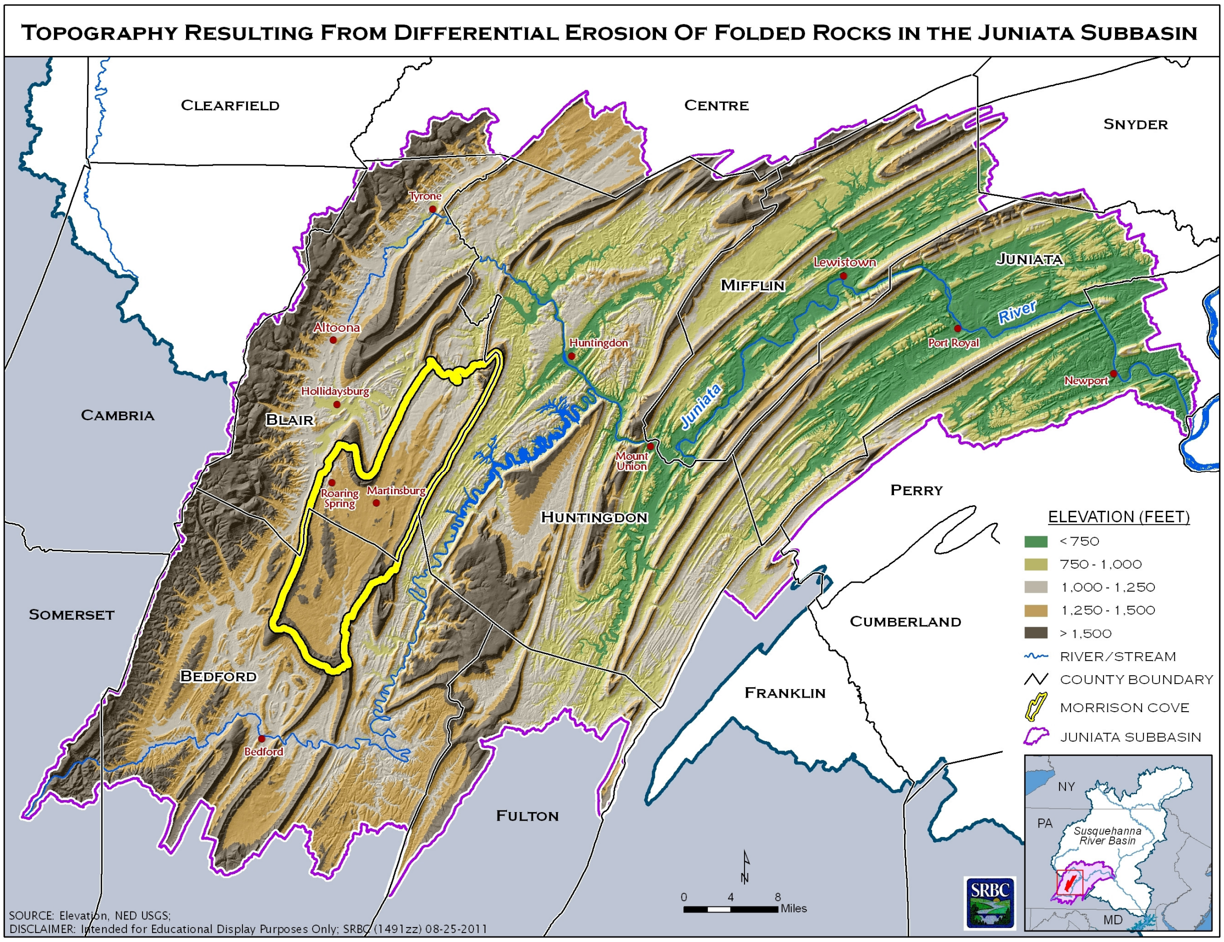

Figure 3-3. Topography Resulting from Differential Erosion of Folded Rocks with Differing Resistance to Erosion

3.3 Hydrogeology

The ability of subsurface materials to store and transmit water (called permeability) depends on the amount of open (pore) space in the rock, and how well the space is interconnected. Primary porosity consists primarily of inter-granular space (for example, the open spaces between adjacent sand grains). Becher (1996) summarizes the water-bearing characteristics and water quality of the individual formations that are stratigraphically below the Bald Eagle Formation (i.e., the formations that underlie the valley). The hydraulic parameters derived from aquifer tests in the Nittany Valley are reviewed and summarized in Fulton et al. (2005).

3.4 Hydrogeologic Terrains

Hydrogeologic terrains are geographic regions that are characterized by their groundwater flow systems. A hydrogeologic terrain includes all the land area contributing surface water and groundwater to the underlying aquifers, as well as the discharge areas. They may contain multiple aquifers and diverse topography, but are related by the flow of groundwater. Small watersheds may serve a single hydrogeologic terrain, but larger watersheds usually contain multiple hydrogeologic terrains. There are three distinct hydrogeologic terrains in the Morrison Cove study area (Figure 3-4) and they are discussed below.

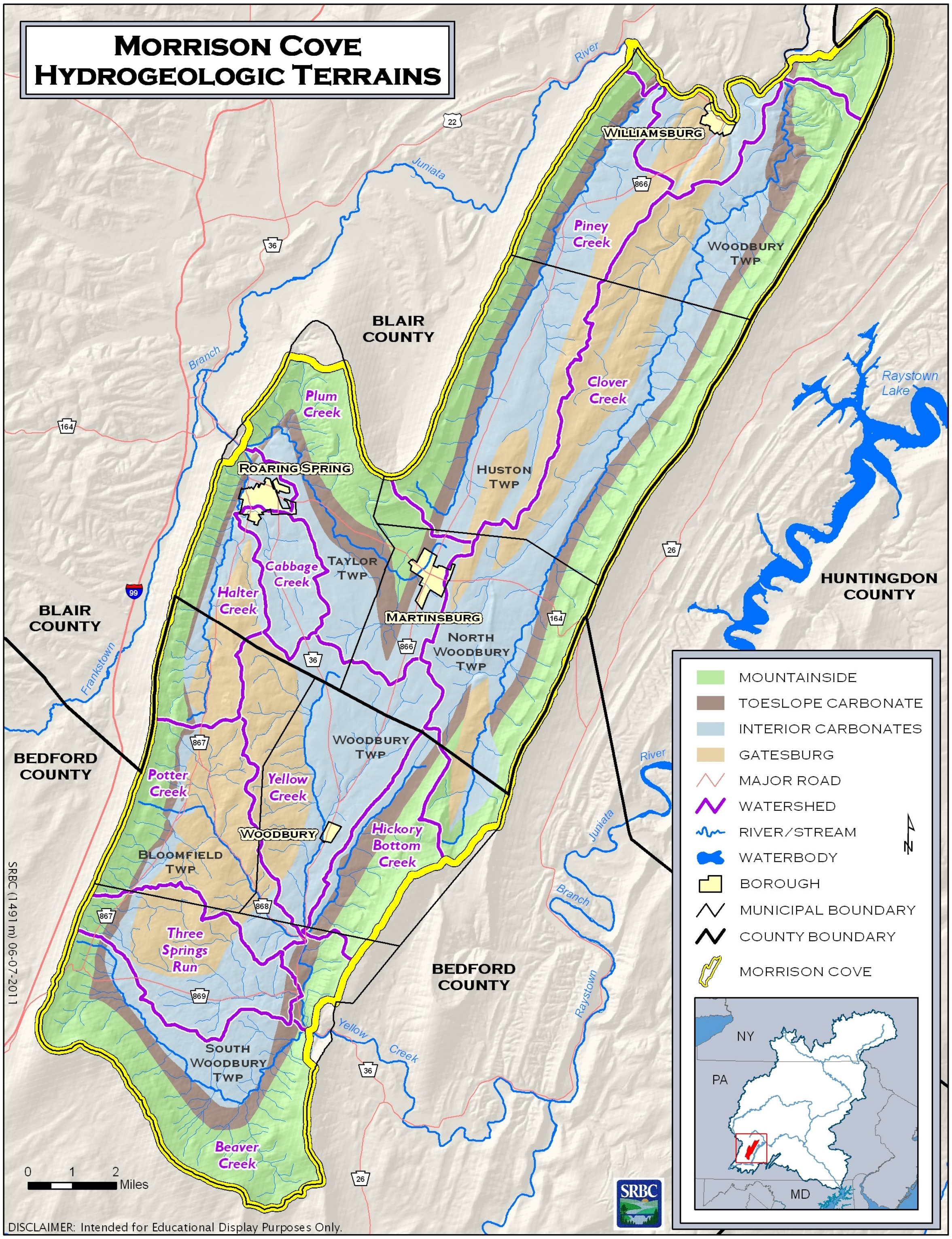

Figure 3-4. Hydrogeologic Terrains and Secondary Watersheds in Morrison Cove

3.4.1 Mountainside/Toeslope Carbonates Terrain

The hydrogeologic characteristics associated with the Mountainside/Limestone Valley Terrain have been studied in Nittany Valley where they are well-developed (Konikow, 1969; Parizek, 1971; Parizek and White, 1985). In the Mountainside/Toeslope Carbonates Terrain, the siliciclastic aquifers underlie a mountainside and contribute acidic groundwater to limestone aquifers in the adjacent valley. Acidic surface water flowing down the mountainside is captured by infiltration and by sinkholes at the base of the mountain, as the streams pass from siliciclastic to limestone bedrock. The acidic water causes the development of the karst conduits in the limestones underlying the valley. The limestone formations occur in a narrow band that parallels the mountain ridge, so the conduits do as well. In essence, the strike parallel conduits in the limestones at the foot of the mountain ridges collect acidic groundwater and surface water runoff from the siliciclastic mountain ridges. The strike-parallel conduits convey this water down gradient and along strike until it emerges as spring flow or discharge beneath stream alluvium. The permeability of the limestones “outside” of the conduit system is essentially that of a fractured bedrock aquifer with localized, poorly-integrated karst. The limestone portion of this terrain includes the following formations: Loysburg, Hatter, Snyder, Linden Hall, Nealmont, Salona, and Coburn. The total thickness of the limestones is approximately 600 feet (Canich and Gold, 1985). The siliciclastic portion of this terrain includes the following formations: Tuscarora, Juniata, Bald Eagle, and Reedsville. The total stratigraphic thickness of the mountainside siliciclastics is approximately 3,700 feet (Canich and Gold, 1985).

3.4.2 Interior Carbonates Terrain

The Interior Carbonates Terrain corresponds to a belt of dolostones and minor limestones of Lower Ordovician age that underlie much of the interior of Morrison Cove. It includes the Stonehenge/Lark, Nittany, Axemann, and Bellefonte Formations, with a total stratigraphic thickness of approximately 3,400 feet. Groundwater flows from hilly uplands to nearby streams. Aquifers in this terrain are of low (Bellefonte Formation) to moderately high (Nittany Formation) permeability. Karst is locally developed and greatly increases permeability.

In Morrison Cove, the Bellefonte Formation is a medium to thick bedded, dark gray dolostone that is rich in silt and organics. These impurities inhibit carbonate dissolution along fractures and bedding partings. As a result, this formation has relatively low permeability. The Bellefonte Formation acts as an aquitard, and forms a discontinuous groundwater flow boundary between the Mountainside/Toeslope Carbonates Terrain and the Interior Carbonates Terrain. The New Enterprise Stone and Lime quarry at Roaring Spring is an approximately 900 by 2,200 foot open pit excavated into the Bellefonte Formation to a depth of over 150 feet below Halter Creek as it flows over the high permeability limestone belt of the adjacent Mountainside/Toeslope Carbonates Terrain. The quarry highwalls exhibit minimal weeping from fractures, and a lack of conduits. Groundwater pumping to maintain dry working conditions is remarkably low, averaging 174,000 gallons per day (121 gpm average for 2006 through 2009: NESL, 2010). The Bellefonte Formation locally forms a low ridge approximately equal in width to its thickness in the western side of Morrison Cove, where the beds are nearly vertical.

In the lower reach of Cabbage Creek, the Bellefonte Formation forms a strong nickpoint on Cabbage Creek as it leaves the Interior Carbonates Terrain, and appears to form a groundwater dam. Behind the dam, the valley is filled with springs. A number of springs and spring fields in the Yellow Creek Watershed likely have a similar cause.

3.4.3 Gatesburg Terrain

The Gatesburg Terrain largely corresponds to the outcrop of the Upper Cambrian Gatesburg Formation. This terrain occurs as a forested, central upland in the southern half of Morrison Cove and as two elongate belts in the northern half, between Martinsburg and Williamsburg. The majority of this terrain is underlain by interbedded dolostone, sandy dolostone, and quartz sandstone that comprise the Upper Sandy and Lower Sandy members of the Gatesburg Formation. The terrain is deeply weathered, with a residuum of silty quartz sand that is typically several tens of feet thick (Parizek and White, 1985). The substantial thickness and relatively high permeability of the residuum make it a nearly ideal recharge material. It can accept water at a high rate and has a large storage capacity. The unusually high capacity of the residuum to accept precipitation and snowmelt is seldom exceeded. As a result, most of the first and second order streams are ephemeral, and there is very little rejected recharge.

The Gatesburg Terrain locally includes the neighboring portions of the Interior Carbonates (Stonehenge/Lark Formations and lowermost Nittany Formation) where these are interpreted to contribute groundwater flow to the Gatesburg Terrain. This may occur where the lowermost Interior Carbonates "overhang" the Gatesburg Formation at shallow depths. Groundwater in these overhung fractured and solutioned carbonates flows into the subjacent Gatesburg Formation, where the hydraulic head is generally lower during extended periods of base flow. Such conditions are common during the months of July through October. These "annexed" contributing areas are especially apparent in the Northern Gatesburg Terrain, where the groundwater flow from two unnamed tributary watersheds appears to be captured. They flow from the interior of the Northern Gatesburg Terrain out onto "overhung" portions of the Interior Carbonates Terrain, and were observed to be dry during the seepage run.

Other formations (the Warrior and Pleasant Hill Formations) that occur in the "interior" of the Gatesburg Formation, along the crest of the Nittany Anticlinorium, have been included in this hydrogeologic terrain, but comprise less than 5 percent of its areal extent. The upper (Mines), middle (Ore Hill), and lower (Stacy) members of the Gatesburg Formation are also included. Together they comprise about one-third of the Gatesburg Formation, but do not share the lithologic and hydrogeologic characteristics of the upper and lower sandy members (see Appendix A). The members of the Gatesburg Formation are generally not mapped separately.

The Gatesburg Terrain is usually structurally complex, so the total stratigraphic thickness is less certain than the other terrains. The stratigraphic thickness of the Gatesburg Formation (by itself) is approximately 1,900 feet (Canich and Gold, 1985). The Upper Sandy member is approximately 500 feet thick. The Lower Sandy member is approximately 700 feet thick (Parizek and White, 1985). They are separated by the Ore Hill member, which is approximately 260 feet thick (Parizek and White, 1985).

4.0 HYDROGEOLOGIC ANALYSIS

4.1 Water Table Mapping

Groundwater level measurements were made at more than 200 locations during the week of October 5, 2009. The locations were documented using GPS and mapped in GIS. Lines of equal water table elevation were hand-contoured (Figure 4-1).

The data were collected toward the end of a dry season of four months duration, and will portray the water table configuration under broadly similar conditions reasonably well. During wet periods (typically March through June), the water table will be somewhat higher than is indicated, especially beneath hills. However, the overall configuration is likely to be similar to that portrayed on the map.

The contouring is based on a porous media interpretation, with linear interpolations between data points, and some adjustments made for topography. No compensation was made for known relative differences in aquifer permeability. Among the most important heterogeneities are karst conduits, bedding partings, and fracture traces. The chances of these being reflected on the water table map are extremely low. Locally, these features may account for more groundwater flow than much of the surrounding area.

To properly use the water table map, information on its construction and potential limitations of the data should be considered. The data points are largely residential water supply wells. They are generally shallow, so they provide a good basis for mapping the elevation of the top of the saturated zone (i.e., the water table). Field crews attempted to acquire evenly distributed data. However, the residential wells were frequently in clusters, resulting in some areas with sparse data. There are, on the average, fewer than two data points per square mile. Some water levels from high relief areas may have reflected confined or leaky confined conditions. Insufficient data were available to check for this potential source of error. Overall, the interpolation between widely spread data points (locations), often across aquifers of differing permeability, is probably the most significant error to consider when interpreting the water table contour map. The water table map has been used, along with other data, to broadly interpret groundwater flow patterns in this section.

4.2 Seepage Run

A seepage run provides a snapshot of the streamflows at various locations in a watershed. In hydrological studies, seepage run data can be used to provide insight into the relative contributions of tributaries within a watershed, and allow the delineation of gaining and losing reaches when the flow is broadly similar to that during the seepage run. Seepage runs were performed on major watersheds in Morrison Cove during the week of October 5, 2009 (Figure 4-1). This was during a period of base flow recession, with somewhat higher than normal flows, and with no significant precipitation or runoff events (Figure 4-2). The late summer through mid-fall is typically dominated by a base flow recession. The vertical red line marks the week during which the seepage run was performed. Note that this was a ‘wetter’ than normal year. The flows measured during the seepage run were exceeded by only about 20 percent of the flows for this time of year. During periods of base flow recession, stream flow rates decline very slowly. The results are indicative of relative (groundwater) flow contributions from tributaries (subwatersheds) during periods of base flow.

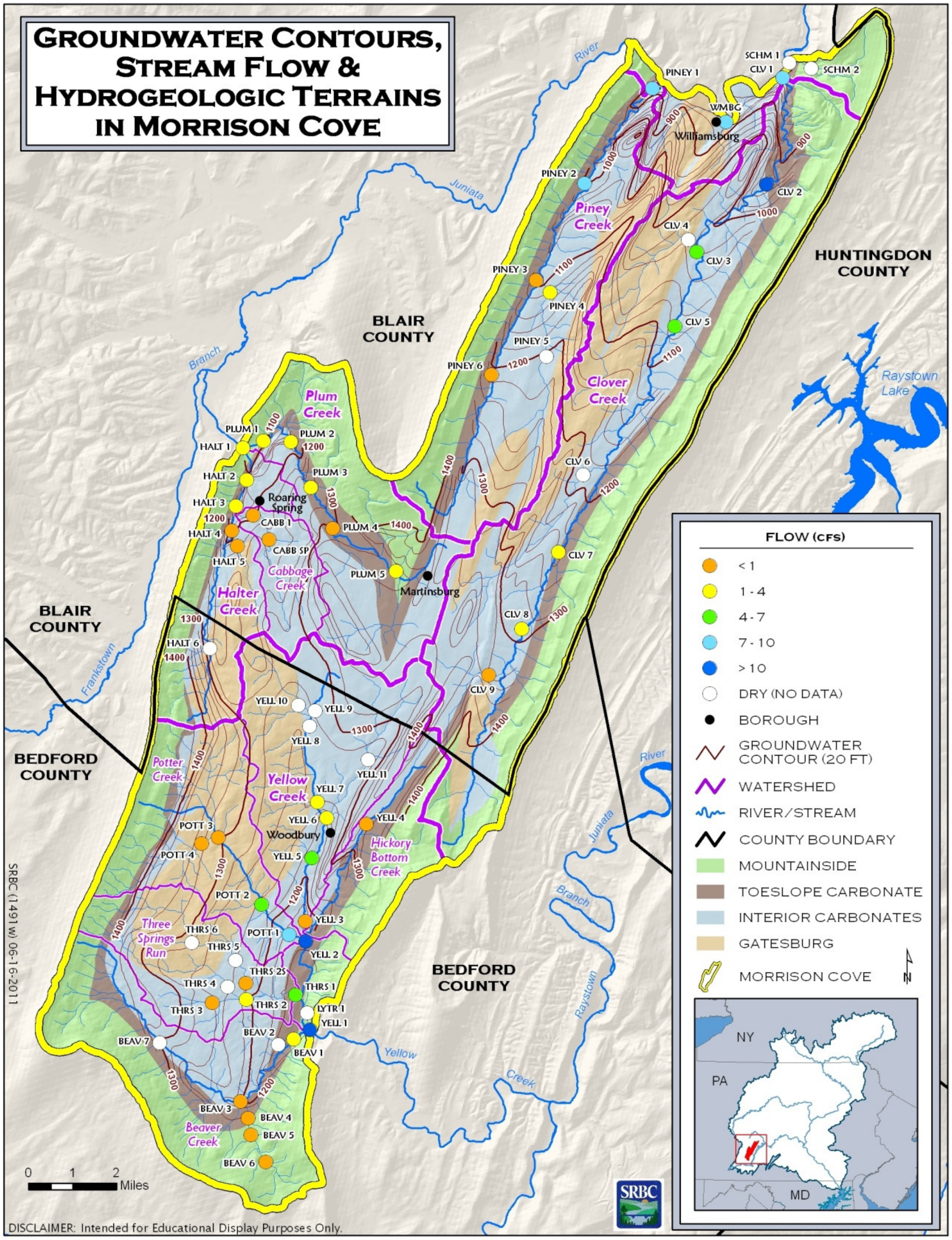

Figure 4-1. Water Table Contours, Hydrogeologic Terrains, and Seepage Run Sites

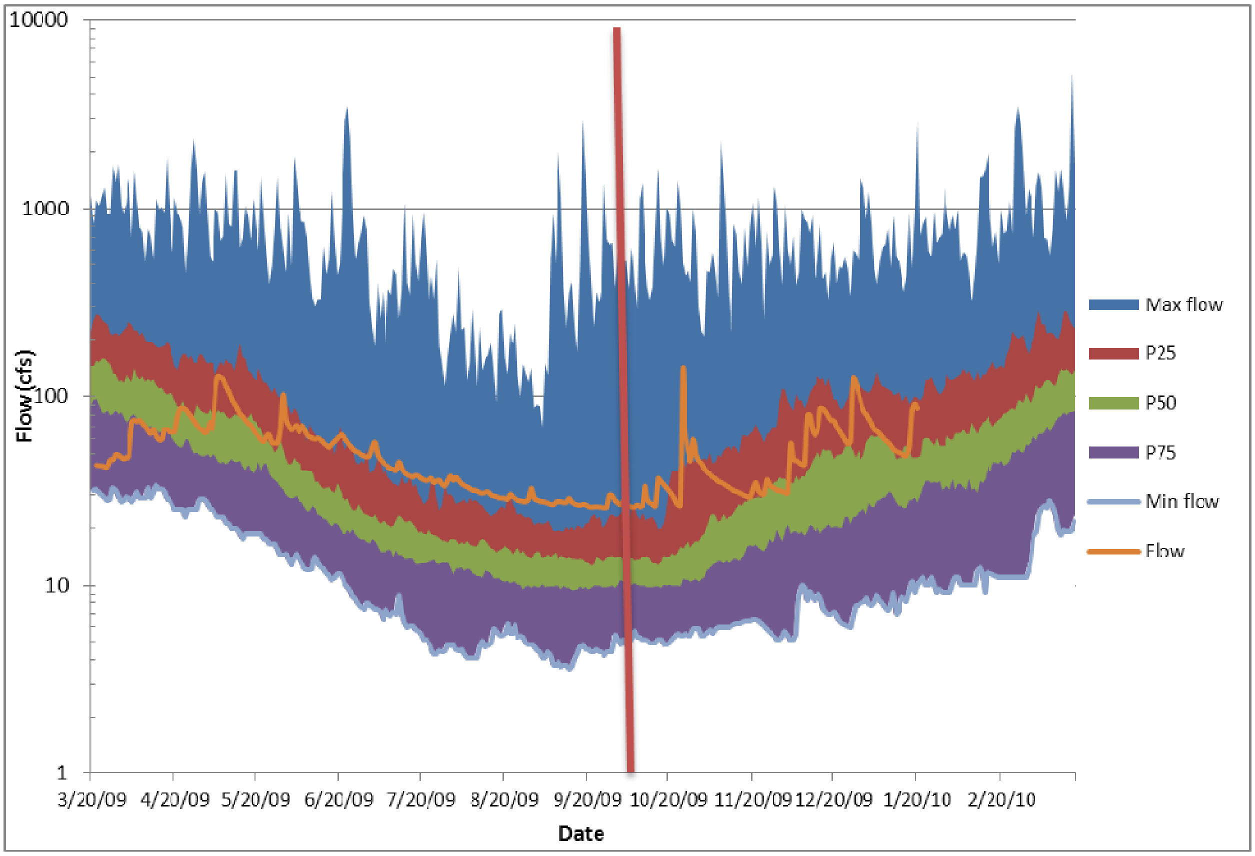

Figure 4-2. Hydrograph for Yellow Creek Where it Leaves Morrison Cove (SRBC, 2009)

4.3 Mountainside/Toeslope Carbonates Terrain

The results of the seepage run for an unnamed tributary to Beaver Creek and trunk reaches on Beaver Creek and Yellow Creek are graphed in Figure 4-3. For a watershed with a uniform, porous media aquifer, the graph of discharge versus upgradient watershed area should be a straight line, because flow should be directly proportional to area. The graph for Yellow Creek (Figure 4-3, Top) comes close to this ideal. However, the graph for the trunk reach on Beaver Creek shows a deficit of flow in the upstream reach. It receives the majority of its flow in the downstream portion of the watershed. The graphs for Piney Creek, Clover Creek, Halter Creek, and Plum Creek (Appendix B) are similar to that of Beaver Creek (Figure 4-3, Middle). These are all strike-parallel streams flowing along the base of the nearest mountain. This is most likely due to the Mountainside/Toeslope Carbonates Terrain conduits system capturing much of the upstream flow, conveying and discharging in the downstream reaches of these watersheds. The graph of flow versus upgradient watershed area for a small, unnamed tributary to Beaver Creek (Figure 4-3, Bottom), located in the southeast corner of Morrison Cove, illustrates how the flow developed on the mountainside siliciclastics is diverted to the subsurface as the streamflows across the siliciclastic-carbonate boundary. Most of the tributaries feeding the Mountainside/Toeslope Carbonates Terrain conduit system are ephemeral and contribute flow only during runoff events. Groundwater seepage from the fracture network in the toeslope carbonates and the mountainside colluvium occurs well into the dry summer months, when it likely provides a gradually declining base flow to the conduit system.

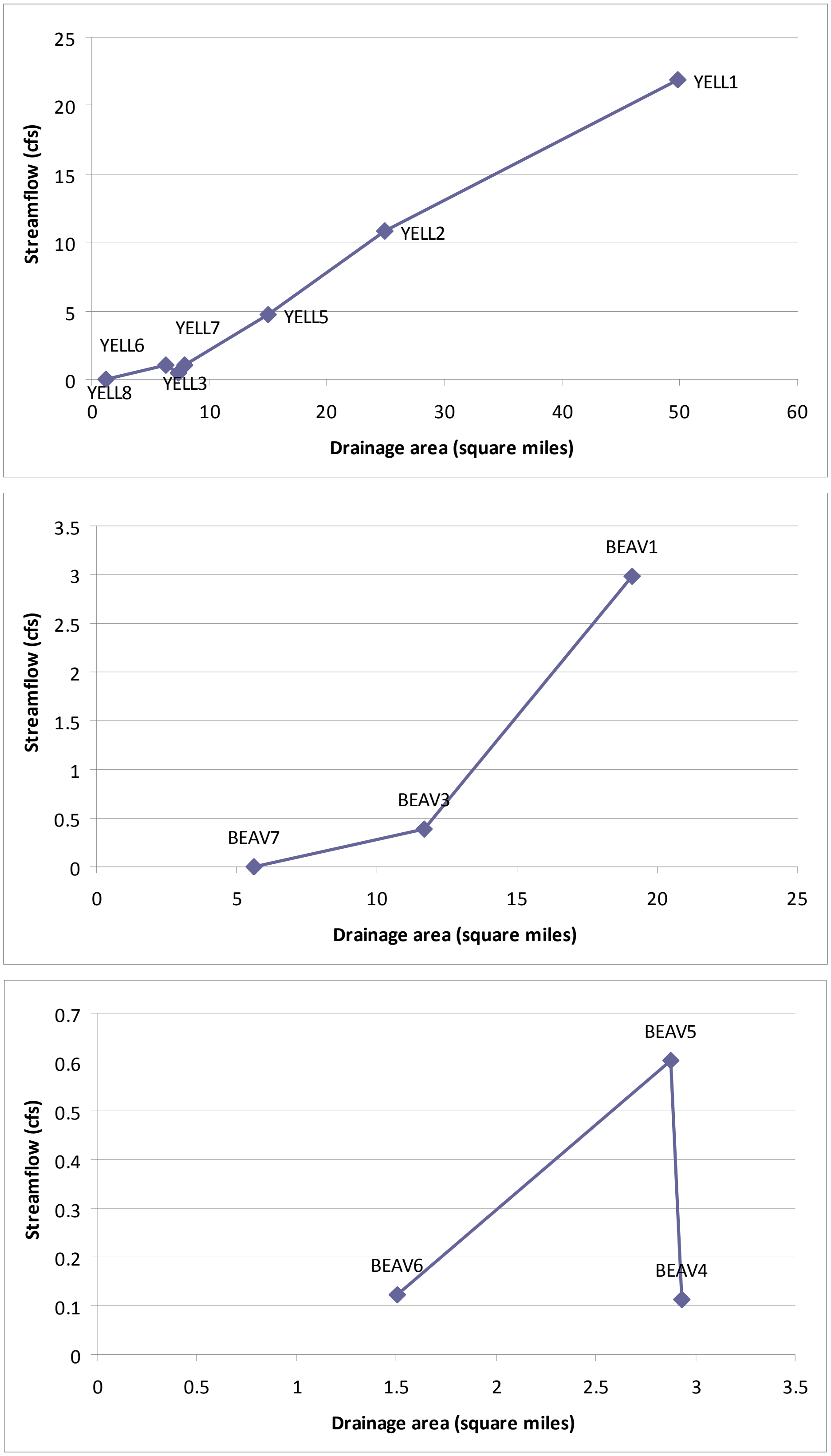

Figure 4-3. Relationship of Streamflow to Drainage Area Using Seepage Run Data (Top: Nearly linear relationship for Yellow Creek. Middle: Strongly non-linear relationship in Beaver Creek. Bottom: Loss of flow in downstream reach of a mountainside stream (an unnamed tributary of Beaver Creek) as it crosses the toeslope carbonates belt.)

4.4 Northern Gatesburg Terrain and Base Flow Basins

The topographically delineated watershed divide between the Piney Creek and Clover Creek Watersheds is located within the Northern Gatesburg Terrain. Examination of a map showing seepage run flows, hydrogeologic terrains, and groundwater contours (Figure 4-1) provides some insight into the flow of groundwater and surface water in the Northern Gatesburg Terrain. There is a groundwater trough corresponding to the axis of the Northern Gatesburg Terrain, indicating that this area is internally drained with respect to groundwater during periods of low flow. This is further suggested by the seepage run results, which show the lack of surface water in tributaries to Piney Creek and Clover Creek as “dry.” It is evident that during periods of base flow (typically July through October), groundwater from the Northern Gatesburg Terrain drains internally, parallel to the axis of the Gatesburg outcrop belt, discharging to the Williamsburg Spring, and directly to the Frankstown Branch Juniata River. During such times, the Northern Gatesburg Terrain acts as an internally drained groundwater basin between the Piney and Clover Creek Watersheds (Figure 4-4), herein termed the Northern Gatesburg Base Flow Basin. During wet periods or after extreme precipitation events, some surface water and groundwater (as base flow) drains (as ‘overflow’) from the Northern Gatesburg Base Flow Basin into the adjacent Piney Creek and Clover Creek Watersheds. At such times, groundwater flow is divided into an internally drained component and a secondary component that contributes base flow to the adjacent watersheds. As a result, the Piney Creek and Clover Creek Watersheds have dynamic watershed boundaries. During periods of base flow (typically July through October), their areas are substantially smaller than during periods with medium to high flows.

The evaluation of sustainability in this report is based on the estimated 10-year base flows and the contributing area to those flows. The contributing area is normally equated to a topographically delineated watershed. For periods of low base flow, the contributing areas for Piney Creek and Clover Creek are somewhat less than their watershed areas because the groundwater flow in the area along their shared watershed boundary, the Northern Gatesburg Terrain, is internally drained. Precise boundaries between these are not possible as the boundaries shift in response to aquifer recharge. In Figure 4-4, contributing areas have been located based on the water table mapping, geologic mapping, seepage run results, and known differences in relative permeability. The base flow drainage areas are herein referred to as *base flow basins*. The base flow basins were used in the water availability analyses (Chapter 6.0).

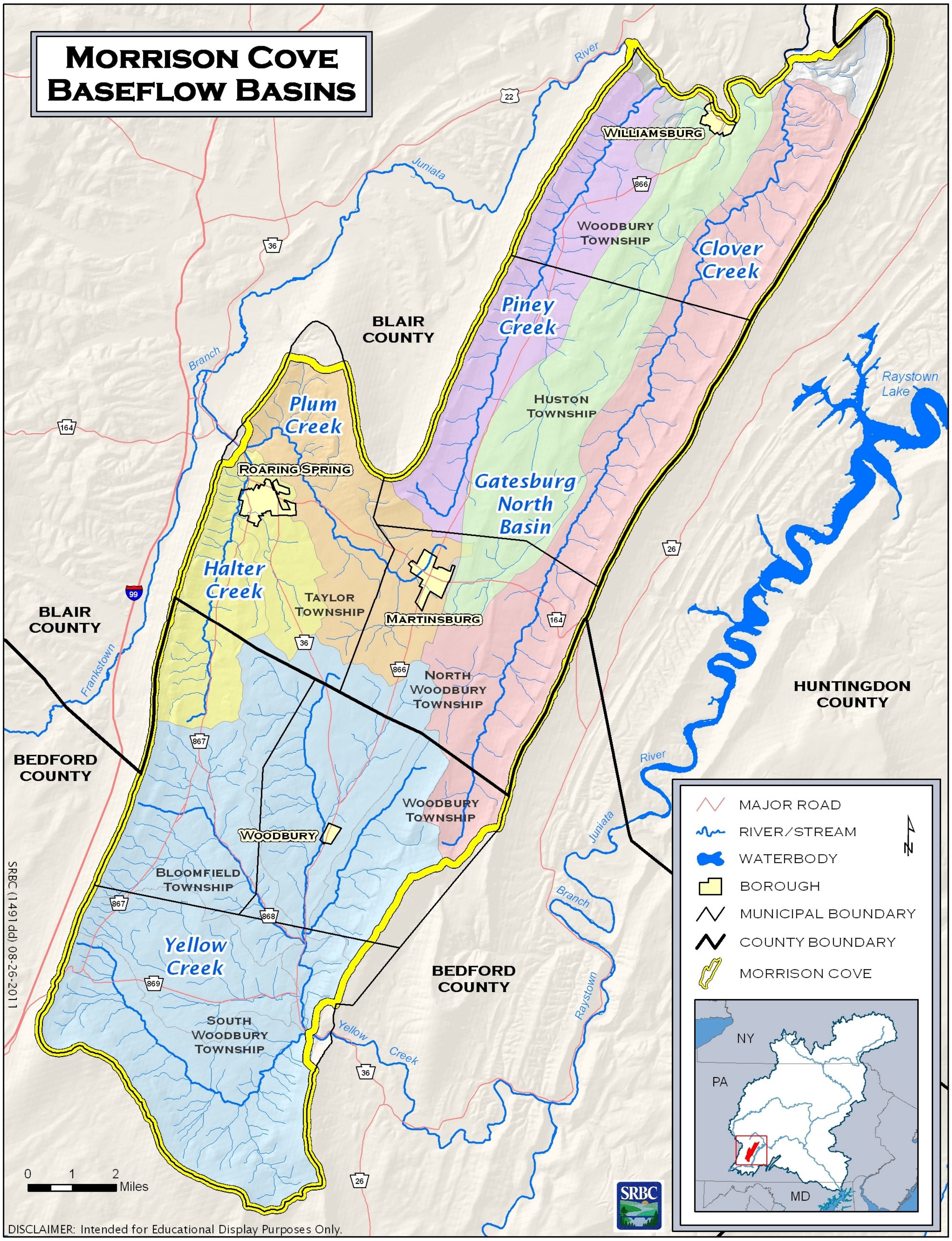

Figure 4-4. Base Flow Basins: Contributing Areas to Surface Water Flow during Periods of Low Base Flow

The Northern Gatesburg Terrain has an area of approximately 23 square miles. The only perennial outflow from the Northern Gatesburg Terrain is the Williamsburg Spring. Spring flow was monitored continuously from May 26, 2009, through January 20, 2010. During that period, the average flow was 8.1 cfs (5.2 mgd) and ranged from 7.7 cfs (5 mgd) to 8.7 cfs (5.6 mgd). Flow variations were poorly correlated with precipitation events (see hydrograph for Williamsburg Spring in Appendix C). The Northern Gatesburg Terrain is erosionally truncated by the Frankstown Branch Juniata River. Very likely, much of the groundwater flow from this terrain discharges directly to the Frankstown Branch Juniata River. Therefore, the flow from the Williamsburg Spring is likely only a moderate fraction of the total groundwater flow from this area. The average annual (2-year base flow) recharge rate for the Gatesburg Formation was estimated to be 1.2 mgd per square mile (Taylor 1997) and 0.98 mgd per square mile for the 10-year base flow (Chapter 5, this report). The Northern Gatesburg Terrain has 16 square miles of Gatesburg Formation outcrop, yielding an average annual recharge of 19.2 mgd, and a 10-year base flow of 15.7 mgd. Actual flow would be somewhat greater due to contributions from the neighboring Interior Carbonates Terrain. Flow from the Williamsburg Spring accounts for approximately one-third of the 10-year base flow from the Northern Gatesburg Terrain. The estimated groundwater discharge from the Williamsburg Spring and the truncated outcrop belt along the Frankstown Branch Juniata River would be somewhat less than these estimates due to base flow contributed to tributaries of the neighboring Piney Creek and Clover Creek Watersheds during wet periods.

4.5 Southern Gatesburg Terrain

Examination of a map showing seepage run flows, hydrogeologic terrains, and groundwater contours (Figure 4-1) provides some insight into the flow of groundwater and surface water in the Southern Gatesburg Terrain. Groundwater contours are parallel to the western mountain ridge (Dunning Mountain) and decrease in elevation from west to east across the central Yellow Creek Watershed. This suggests that groundwater flows generally from west to east across the central portion of the Southern Gatesburg Terrain. The gently sloped water table is little influenced by local topography, as it passes beneath some of the highest hills in the Morrison Cove valley. This is typical of high permeability aquifers. The water table is graded to the downgradient stream elevations as they leave the Southern Gatesburg Terrain.

During the seepage run, very little surface water flow was measured leaving the Southern Gatesburg Terrain. There was some flow from the upper reaches of Yellow Creek (location Yell 7, 1.0 cfs), but the upgradient watershed includes some Interior Carbonates Terrain. A similar flow (1.0 cfs) was measured at a small, nearby tributary to Yellow Creek (location Yell 6), which entirely drains the Interior Carbonates Terrain. Therefore, it is likely that some, if not most, of the flow at Yellow Creek location Yell 7 was from the Interior Carbonates Terrain. There was minimal surface water flow from the southern portion of the Southern Gatesburg Terrain, as evidenced by the lack of flow at Three Springs Run tributaries draining that area (Three Springs Run locations THRS 4, THRS 5, and THRS 6). Similarly, there was minimal surface water flow from the northern portion of the Southern Gatesburg Terrain, as evidenced by the lack of flow at Yellow Creek tributaries draining that area (Yellow Creek locations Yell 8 and Yell10). The largest and perhaps only surface water flow from the Southern Gatesburg Terrain during the seepage run was from Potter Creek (location Pott 2, 5.6 cfs). Potter Creek is more deeply incised into the downstream edge of the Southern Gatesburg Terrain than the other streams. There was likely some groundwater leaving the Southern Gatesburg Terrain beneath stream valleys along its eastern, downgradient edge. This flow was not measured, and would contribute base flow to streams as they crossed the Interior Carbonates Terrain.

The average annual (two-year base flow) recharge rate for the Gatesburg Formation was estimated to be 1.2 mgd per square mile (Taylor, 1997) and 0.98 mgd per square mile for the 10-year base flow (Chapter 5.0). The Southern Gatesburg Terrain has 19 square miles of Gatesburg Formation outcrop, yielding an average annual recharge of 22.8 mgd, and a 10-year base flow of 18.6 mgd. Actual flow would be somewhat greater due to contributions from the neighboring Interior Carbonates Terrain, and from the Mountainside/Toeslope Carbonates Terrain along the foot of Dunning Mountain. Flow from the Roaring Spring (5–6 mgd) accounts for about one-third of the base flow from the Southern Gatesburg Terrain during periods of low base flow.

4.6 Roaring Spring

The Roaring Spring is a large spring issuing from the base of a steep hillside in the borough of Roaring Spring. The spring is located beneath a building housing water intakes. It flows into a bermed spring pool, over a weir, and into a culvert, which conveys the spring pool overflow to Halter Creek. The spring pool overflow consists of the spring flow remaining after industrial, commercial, and municipal withdrawals has been monitored at the weir on a daily basis since 2001 (see Figure C4, Appendix C), as have the withdrawals. The total estimated spring flow is equal to the total of the withdrawals (approved or permitted quantities) and the spring pool outflow. Flow statistics were calculated from permitted, approved, and grandfathered water use and are presented elsewhere (Chapter 6.0) in this report.

The estimated flow is remarkably steady, with a narrow range of flow (Figure 4-5). There is a seasonal variation in flow (Figure C1, Appendix C), but it is frequently out of step with that for the streams in the Morrison Cove region, which exhibit a seasonal high flow corresponding to the high precipitation received during the spring months, and a seasonal low during July through October, a period of low average precipitation. Additionally, the flow from Roaring Spring does not respond to major precipitation events (Figures C1 and C2, Appendix C). The water chemistry is non-unique with respect to contributing terrain, and is likely a blend of water from multiple hydrogeologic terrains.

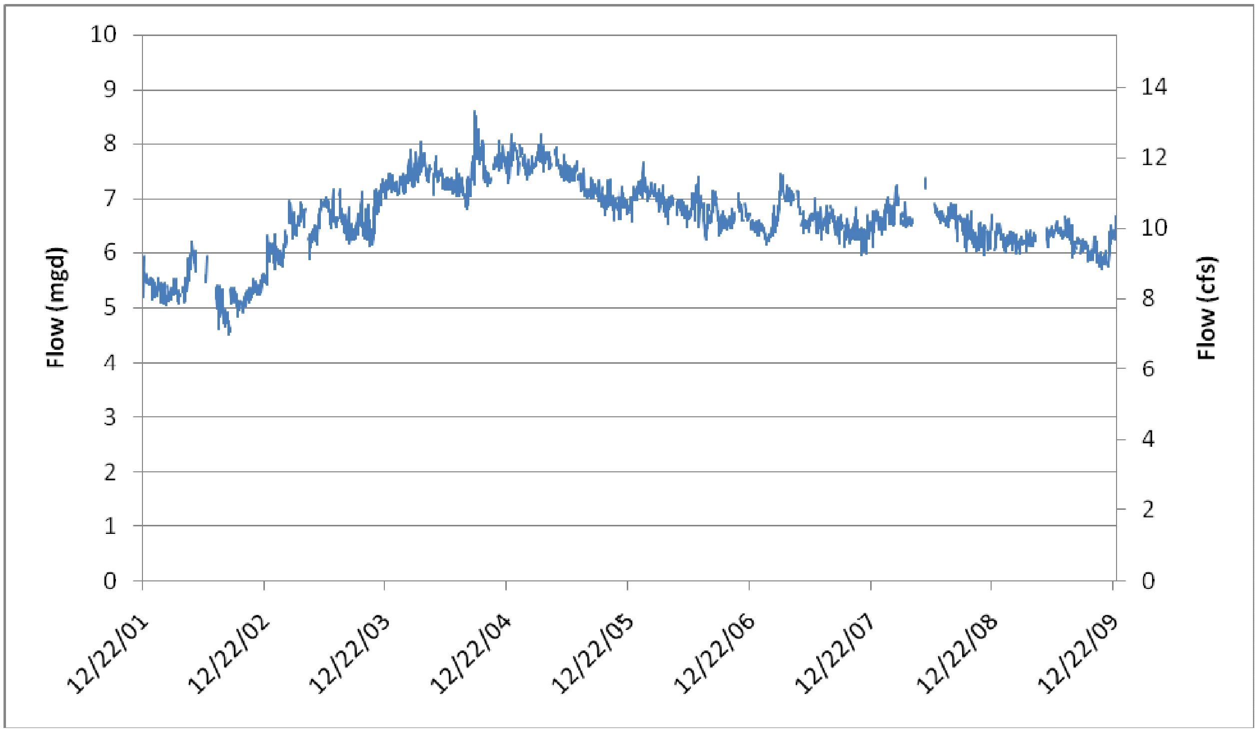

Figure 4-5. Hydrograph of Flow from the Roaring Spring for the Period of Record (Eight Years)

The flow rate for the Roaring Spring during SRBC's seepage run (week of October 5, 2009) was approximately 9.1 cfs (5.9 mgd). This is more than 2.5 times as much flow as was measured in the remaining 14.7 square miles of the Halter Creek Watershed (3.6 cfs). Therefore, additional contributing area outside of the Halter Creek Watershed is required. Given the need for a substantial recharge area with high permeability, the source of the spring water is likely the Gatesburg Formation in the Southern Gatesburg Terrain. The spring is located on the axis of prominent structural trend extending northward from the Southern Gatesburg Terrain. The lowest surface water outlet for the Southern Gatesburg Terrain has an elevation of approximately 1,240 feet, and the entire area of the Southern Gatesburg Terrain has water table elevations well above the spring pool elevation of 1,197 feet. The portion of the Southern Gatesburg Terrain nearest to the Roaring Spring is most likely the major contributing area. This area is mapped (Figure 4-1) as a groundwater mound approximately five square miles in area, and is separated from the much larger (approximately 16-square-mile) remaining Southern Gatesburg Terrain by a shallow saddle in the water table. However, some contribution from the remaining Southern Gatesburg Terrain is likely for the following reasons:

1) The northern five-square-mile portion is hydraulically connected to the remaining 16-square-mile portion.

2) The estimated two-year and 10-year base flows for the five-square-mile portion, based on Taylor (1997) and SRBC (Chapter 6.0) are 6.0 mgd and 4.9 mgd, respectively. The documented spring discharge appears to exceed the estimated one

in two year recharge from the five-square-mile area for seven of the eight years of flow record.

3) The five-square-mile portion is also mapped as a groundwater mound. This is a highly unlikely water table configuration for an area supplying virtually all of its recharge to a spring.

4.7 Underdrained Interior Carbonates Terrain; Yellow Creek and Plum Creek Watersheds

The seepage run flows measured in the Yellow Creek Watershed upstream of the village of Woodbury are low for the area drained, with the most upstream locations (Yellow 8, 9, and 10) being recorded as "dry." A small area in the extreme headwaters of the neighboring Plum Creek Watershed appears to be underdrained, with groundwater flowing into the headwaters of Yellow Creek. The groundwater flow from these two areas discharges to the trunk of Yellow Creek, upstream of seepage run location Yellow 5, in the vicinity of the village of Woodbury.

5.0 HYDROLOGIC ANALYSIS

The total area of Morrison Cove is approximately 185 square miles. There are four major watersheds in Morrison Cove, which include Piney Creek, Clover Creek, Halter Creek, and Yellow Creek (Table 5-1, Figure 5-1). Additionally, Schmucker Run and three unnamed tributaries discharge directly into the Frankstown Branch Juniata River. The characteristics of the major watersheds within Morrison Cove are summarized in Table 5-1. Streams are preferentially oriented along the bedrock strike throughout most of Morrison Cove.

Table 5-1. Major Watersheds in Morrison Cove

Major Watersheds	Outlet Elevation[1] (Feet)	Drainage Area (sq mi)
Piney Creek	850	25.4
Clover Creek	805	50.1
Halter Creek	1,060	32.1
Yellow Creek	1,110	69.2
Schmucker Run	800	2.6
Drainage to Frankstown Branch Juniata River		5.6

[1] Outlet elevations are based on USGS topographic maps and measured at the location where the stream leaves Morrison Cove.

Halter Creek has two tributaries within Morrison Cove, which include Cabbage Creek and Plum Creek. Yellow Creek has four tributaries within Morrison Cove, which include Hickory Bottom Creek, Beaver Creek, Three Spring Run, and Potter Creek. The areas of the tributaries were presented in Table 5-2 and shown graphically in Figure 5-2.

Table 5-2. The Secondary Watersheds in the Halter Creek and Yellow Creek Watersheds and Their Drainage Areas

Major Watersheds	Secondary Watersheds (Tributaries)	Drainage Area (sq mi)
Halter Creek	Cabbage Creek	4.0
	Plum Creek	17.4
Yellow Creek	Hickory Bottom Creek	7.3
	Beaver Creek	19.1
	Three Spring Run	9.8
	Potter Creek	13.3

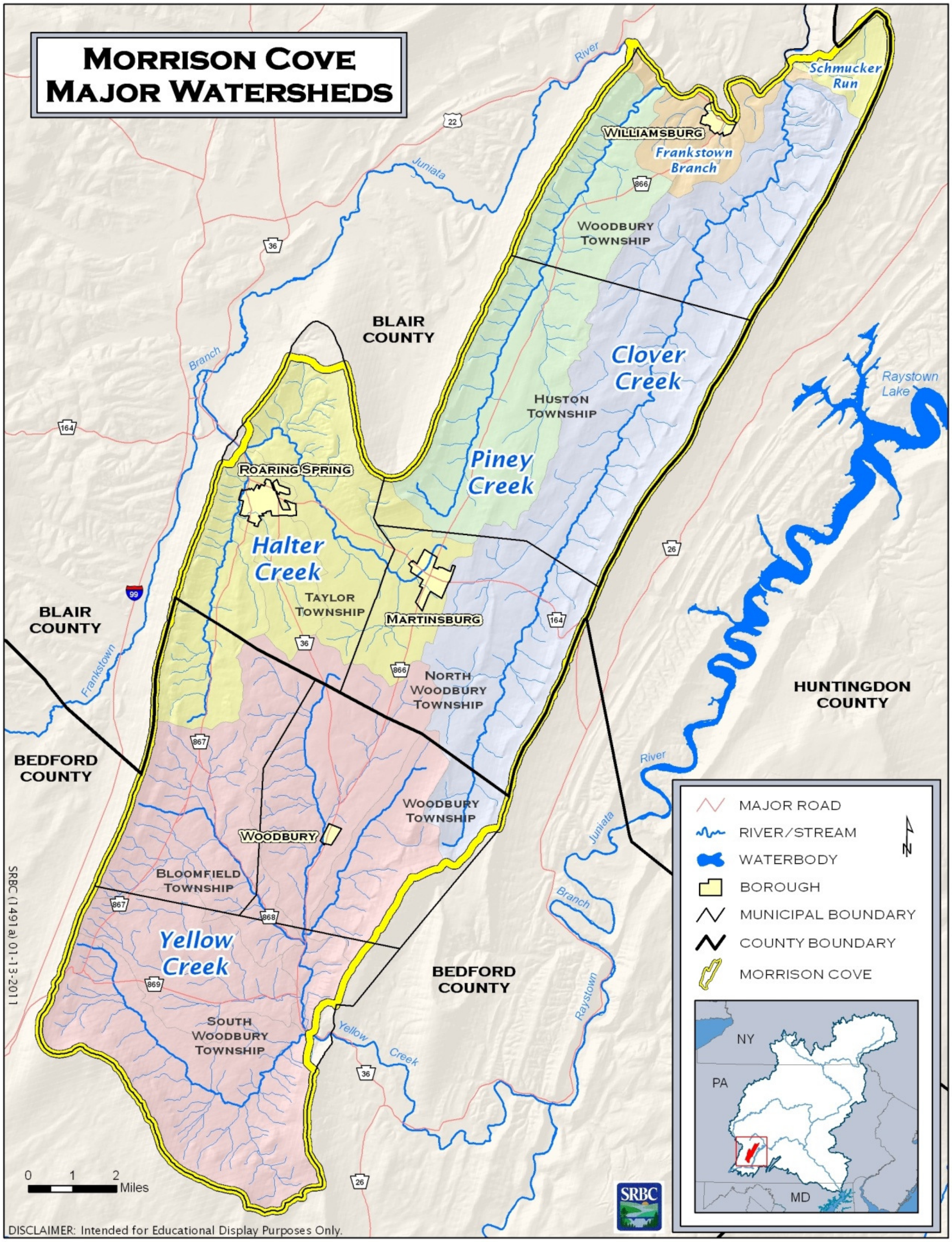

Figure 5-1. Major Watersheds in Morrison Cove

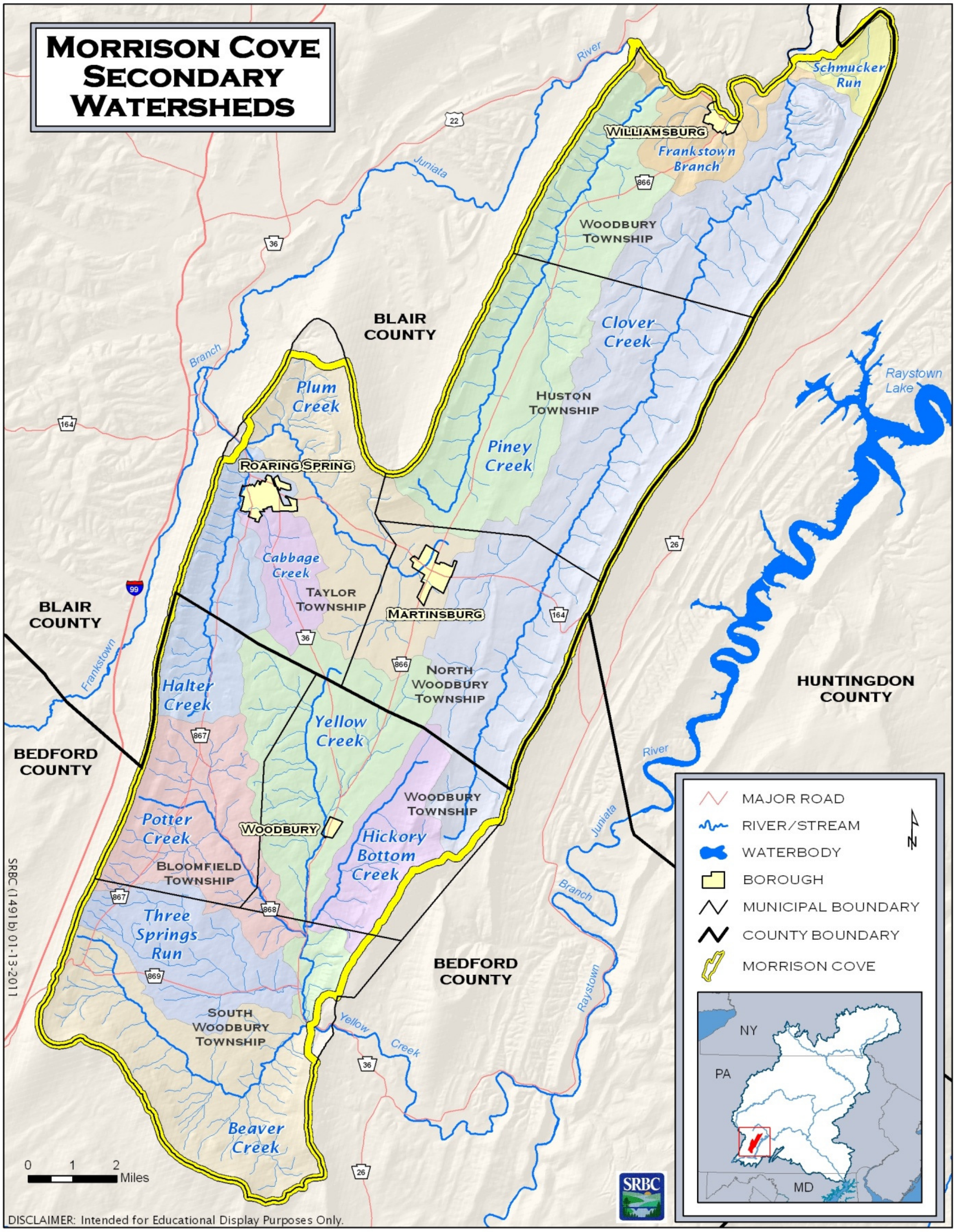

Figure 5-2. Secondary Watersheds in Morrison Cove

5.1 Streamflow Statistics

The outlets of three major watersheds, Piney Creek, Clover Creek, and Yellow Creek, were gaged to assess streamflow in the Morrison Cove area. Halter Creek was gaged upstream of the confluence of Halter Creek and Plum Creek. Plum Creek was also gaged. In addition, HC-PC-Reservoir UNT, an unnamed tributary near Martinsburg, was monitored to provide information on streamflow from the Bald Eagle, Juniata, and Tuscarora Formations. The locations of the aforementioned temporary gages are shown in Figure 5-3. Stream stages and temperatures were measured at 10-minute intervals continuously, from April 2009 through December 2009, at each temporary gage. It should be noted that although the monitoring interval at Halter Creek was 10-minute, only daily flows were obtained at this gage. This is because flow from Roaring Spring was primarily consumptively used which was only available on a daily basis. The daily consumptive use was added back to calculate flow at Halter Creek. The exact monitoring period and number of observations vary for each temporary gage due to site vandalism and equipment malfunctions. Rating curves were developed based on streamflow gaging at various stages for each temporary gage. All data were reviewed for accuracy and suspect data points were removed from the data. Daily mean flows were then calculated. Information of the temporary gage records is shown in Table 5-3 and summarized below.

Table 5-3. Information for the Temporary Gage Records

Temporary Gage	Period of Record	Monitoring Interval	Number of Observations
Piney Creek	Jun. 10, 2009 to Dec. 15, 2009	10 minutes	25,787
Clover Creek	Apr. 1, 2009 to Dec. 15, 2009	10 minutes	33,473
Halter Creek	Apr. 1, 2009 to Dec. 15, 2009	Daily	259
Plum Creek	Apr. 1, 2009 to Dec. 15, 2009	10 minutes	35,755
Yellow Creek	Apr. 1, 2009 to Dec. 15, 2009	10 minutes	35,306
HC-PC-Reservoir UNT	Apr. 30, 2009 to Dec. 15, 2009	10 minutes	29,661

Piney Creek (PC-1)

Piney Creek stilling well was located on the eastern abutment of Blair County Bridge 20 on Wertz Road. The start of PC-1 flow monitoring was delayed until June 10, 2009, due to site vandalism.

Clover Creek (CC-1)

Clover Creek stilling well was located on the Cove Forge Church property, east of Williamsburg.

Halter Creek (HC-1)

Halter Creek flows were measured in a stilling well in the pool behind a permanent, 14-foot-wide sharp-crested weir. The weir was located approximately 100 feet above the confluence of Halter Creek and Plum Creek. This temporary gage has been operated on a monthly basis since 1995. The 10-minute interval monitoring started on March 20, 2009 and ended on January 20, 2010. More than 80 percent of Roaring Spring flow was not accounted for by the HC-1 weir due to the combination of consumptive use by the Roaring Spring Bottling Company and Appleton Paper Company and discharge of Appleton Paper Company wastewater into the Frankstown Branch Juniata River.

Plum Creek (HC-PC-1)

Plum Creek joins Halter Creek as it exits Morrison Cove at McKee Gap. Plum Creek is entirely contained within Morrison Cove. Plum Creek flows were measured in a stilling well in the pool behind a permanent, 15-foot-wide sharp-crested weir. The weir at HC-PC-1 was about 100 feet above the confluence of Halter Creek and Plum Creek. Monthly measurements started in 1995. The 10-minute interval monitoring started on March 20, 2009 and ended on January 20, 2010.

Yellow Creek (YC-1)

The Yellow Creek stilling well was located on the Randy and Gloria Smith property in Loysburg within the Loysburg Gap. YC-1 flow monitoring started on March 20, 2009 and ended on January 20, 2010.

HC-PC-Reservoir UNT

Flow at HC-PC-Reservoir UNT went through a concrete culvert. The water level and specific conductance were monitored above the culvert. The monitoring started on April 30, 2009 and ended on December 15, 2009.

The daily average flows at the six temporary gages were then computed based on the recorded measurements (Figure 5-4). It should be noted that the y-axis of the sub-plots of Figure 5-4 has a different scale due to the different flow ranges at various temporary gages. The x-axis was the same for all the sub-plots. The daily average flows in cubic feet per second per square mile (csm), are shown in Figure 5-5. While the flow records did not cover a complete year (either water year or calendar year), the records spanned the high flow months of March through June, and the low flow months of July through October. Therefore, the streamflow statistics computed from the field data were determined to be representative of hydrologic conditions in 2009 within Morrison Cove. Table 5-4 summarizes streamflow statistics computed from the temporary gage data.

Table 5-4. Streamflow Statistics Computed From Temporary Gage Data (cfs)

Temporary Gage	Average	Standard deviation	Minimum	Median	Maximum
Piney Creek	16.2	7.1	9.5	14.0	66.4
Clover Creek	33.2	16.5	11.2	31.7	97.0
Halter Creek	17.4	6.2	10.8	15.4	49.6
Plum Creek	13.8	12.3	1.8	8.9	61.8
Yellow Creek	50.6	22.6	25.9	45.8	140.5
HC-PC_ReservoirUNT	0.23	0.21	0.03	0.15	1.31

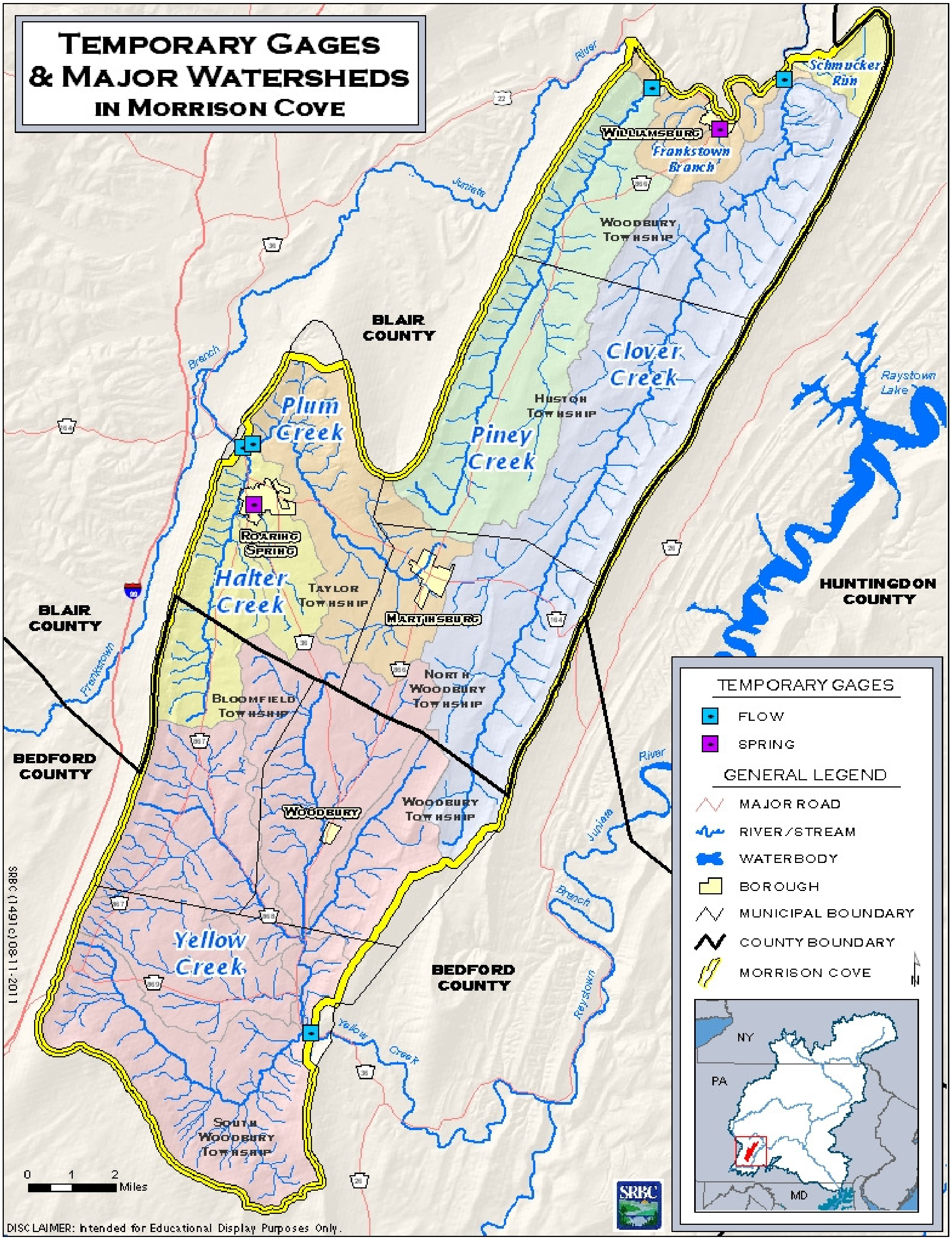

Figure 5-3. Locations of Morrison Cove Temporary Gages

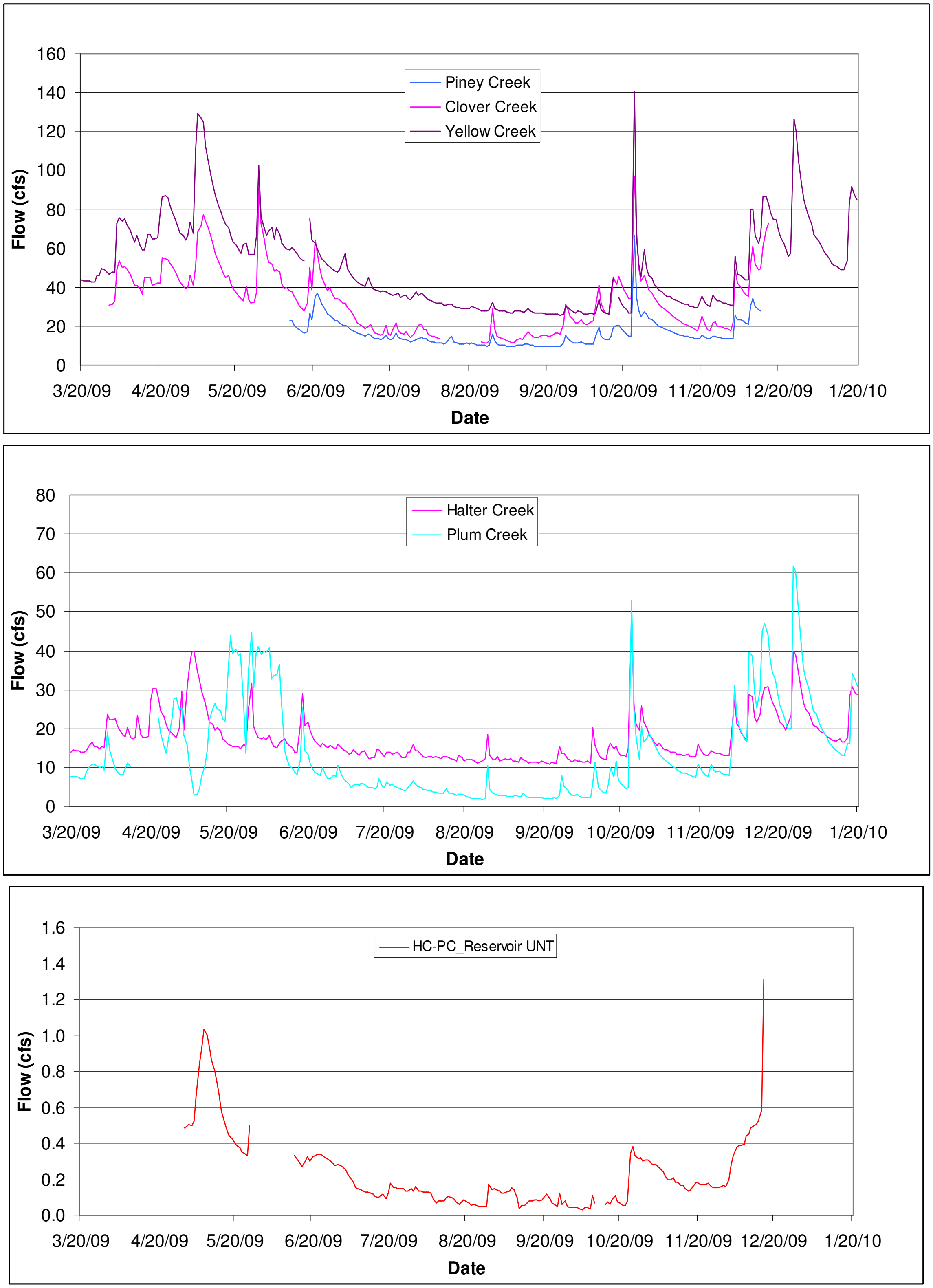

Figure 5-4. The Daily Average Flow in the Temporary Gages

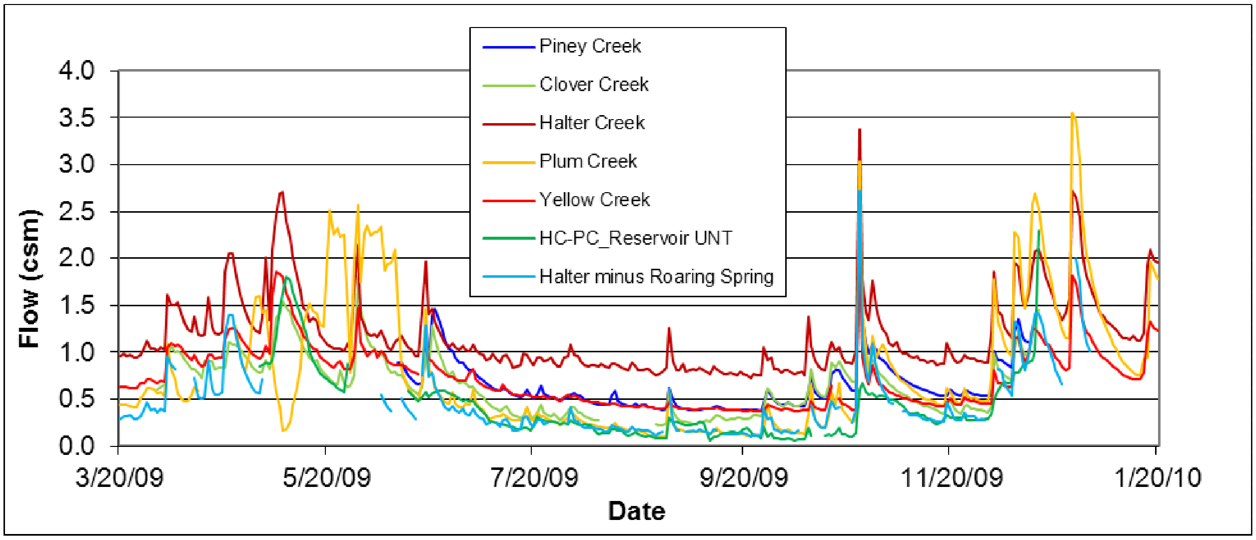

Figure 5-5. Comparison of Daily Average Flow in csm at the Temporary Gages

5.2 Recurrence Interval Analysis

SRBC employs various streamflow statistics for a wide range of purposes for water resources management and planning (SRBC, 2006; Zhang et al., 2010). The commonly used statistics include the monthly exceedance percentiles, 10-year base flow, 7Q10, and average daily flow (ADF) (Pyrce, 2004). The monthly exceedance percentiles estimated in this study included P95, P90, P85, P80, P75, P70, P65, P60, and P50. For example, monthly P90 is the streamflow that is exceeded 90 percent of the time for the month. The 10-year base flow is the 10-year recurrence interval minimum base flow. 7Q10 is the tenth percentile of the distribution of annual minimum 7-day average flows, i.e., the recurrence interval is 10 years (Riggs, 1980).

Typically, at least 10 years of continuous daily streamflow records are required to reliably estimate low flow statistics, such as 7Q10 and the 10-year base flow, using frequency analysis (Riggs, 1972). The records from the six temporary gages in Morrison Cove were less than one year, and thus were not sufficient to estimate low flow statistics with frequency analysis. Low flow statistics could be accurately estimated if continuous operation at the six temporary gages were to continue for a long time period. However, for the purpose of this study, the information was needed sooner. One common solution to this dilemma is the use of information transfer techniques to estimate low flow statistics for the streams in Morrison Cove. These information transfer techniques relate streamflow measurements during base flow conditions at the temporary gages without long-term continuous records with concurrent streamflow measurements at selected nearby gages with long-term continuous records. The temporary gages without long-term continuous records are often referred to as low-flow partial-record stations. The selected nearby long-term gages are referred to as reference gages (or index gages).

Commonly used information transfer methods for estimating low flow statistics for low flow partial-record stations include the base flow correlation method proposed by Stedinger and

Thomas (1985) and the flow ratio approach (Q-ratio) suggested by Potter (2001). The base flow correlation method was recommended by the U.S. Geological Survey (USGS) Office of Surface Water (1985). The Q-ratio method was initially developed by Potter (2001). Ries and Eng (2010) employed a modified Q-ratio method.

Generally, about 10 streamflow measurements during base flow conditions at the low flow partial-record stations over a period of three years are preferred for the base flow correlation method (Riggs, 1972; Zhang and Kroll, 2007). In this study, temporary gages were operated continuously. Although there was only one year of record, sufficient number of base flow measurements were obtained to permit the estimation of low flow statistics. Six candidate reference gages were used and are shown in Table 5-5. Commonly used statistics including ADF, 7Q10, 10-year base flow, and various monthly percentiles were estimated in this study. The estimated ADF, 7Q10, and 10-year base flow at the temporary gages in Morrison Cove are shown in Table 5-6. Figure 5-6 shows an example of the monthly streamflow percentiles for Clover Creek. The monthly percentiles for other streams are included in the appendix.

Table 5-5. Reference Gages Used in the Study

USGS #	Gage Name	Drainage Area (sq mi)	Record
01556000	Frankstown Br Juniata River at Williamsburg, PA	291	1916-current
01557500	Bald Eagle Creek at Tyrone, PA	44	1944-current
01558000	Little Juniata River at Spruce Creek, PA	220	1938-current
01559000	Juniata River at Huntingdon, PA	816	1941-current
01560000	Dunning Creek at Belden, PA	172	1939-current
01562000	Raystown Branch Juniata River at Saxton, PA	756	1911-current

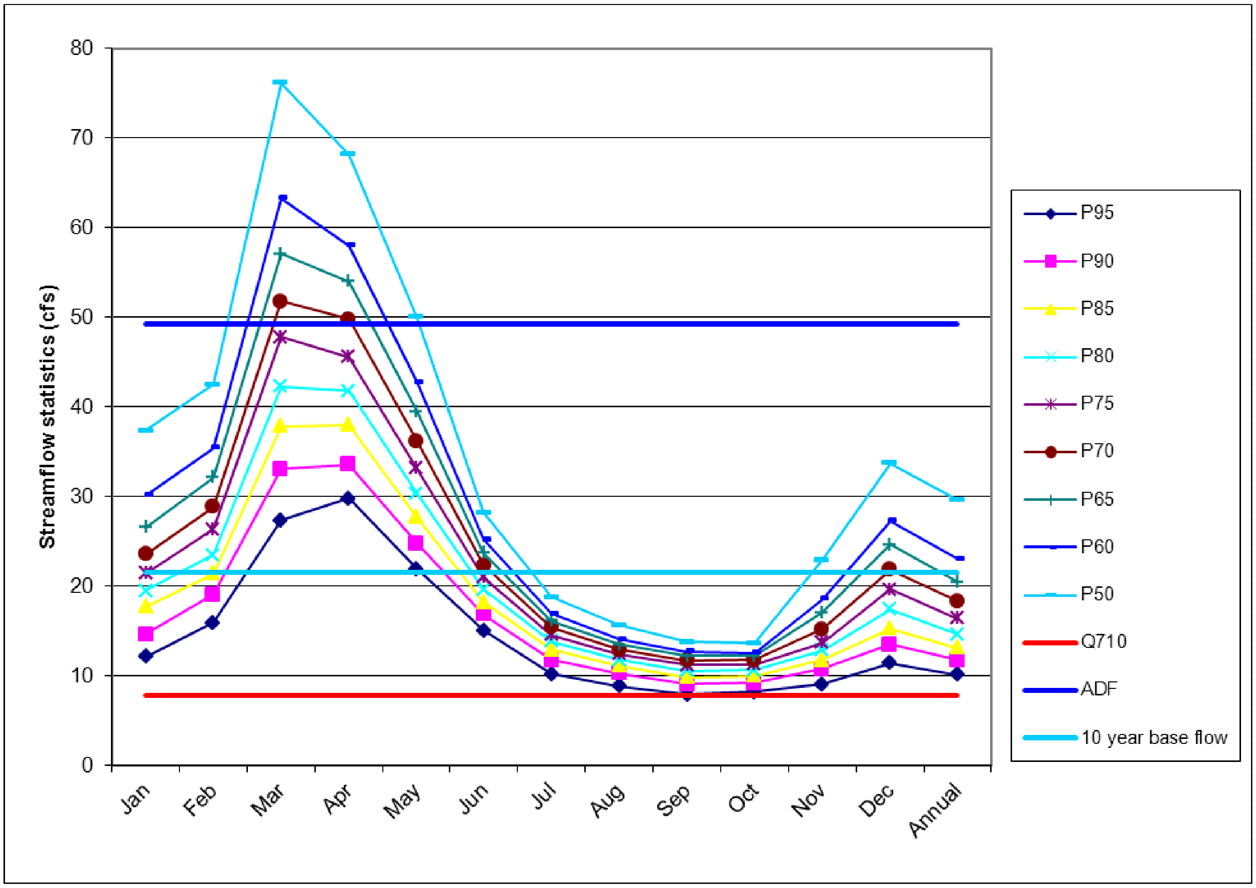

Figure 5-6. Estimate of Selected Streamflow Statistics for Clover Creek

Table 5-6. Estimate of Selected Streamflow Statistics for the Temporary Gages

Temporary Gage	Reference Gage	Concurrent Streamflows	Correlation Coefficient	7Q10 (cfs)	ADF (cfs)	10-year Base Flow (cfs)
Halter Creek	01556000	10	0.915	3.3	27.3	10.6
Plum Creek	01556000	13	0.931	2.2	17.9	6.9
Piney Creek	01558000	5	0.991	6.2	39.9	19.6
Clover Creek	01559000	7	0.966	7.8	49.2	21.5
Yellow Creek	01562000	14	0.920	10.2	140.7	46.8
HC-PC-Reservoir	01556000	5	0.995	0.07	0.56	0.22

6.0 WATER AVAILABILITY

To assess the availability of water resources in Morrison Cove for existing and future allocation and use, water budget analyses for each base flow basin were developed. The analyses are conservative and designed to support sustainable development of water resources. The assumptions used in the analyses include the following:

- For development to be sustainable, water demands should be satisfied not only during average hydrologic conditions but also during 'moderate' drought years. SRBC has defined the sustainable limit of water resource development as the average annual base flow (recharge) available in the "local" watershed during a 1-in-10-year average annual drought; the selection of the 1-in-10-year drought recharge standard strikes a balance among resource conservation, environmental needs, regulatory restriction of growth and development, and the need for adequate and often expensive constructed water storage facilities (SRBC, 2005). Therefore, recharge available during a 1-in-10-year drought (or a 10-year base flow) was used.
- Limiting water use to sustainable levels will also protect water quality, downstream uses, and ecosystem needs.
- Base flow basins (as opposed to surface watersheds) were used in the analyses to account for the importance of the water resources available in the Gatesburg Formation, and to recognize the watershed areas during low flow periods rather than medium and high flows.
- Water use values represent the quantities of water consumptively used within Morrison Cove. Much of the water withdrawn is eventually returned through wastewater discharges or via on-lot septic systems. SRBC defines consumptive use as that quantity of water not returned to the water resources of the basin, or in this case, to a base flow basin. Examples of consumptive use include evaporation, incorporation into products, direct exports or diversions, and transpiration through irrigation.
- Water availability is derived solely from base flow rather than total flow (which would include surface runoff), even though thunderstorms and other rainfall events may temporarily increase streamflows. However, this water is not considered to be significant or reliable, and is therefore not included in the overall analysis.

For purposes of these analyses, the maximum amount of water available for future use was calculated to be the portion of the 10-year base flow remaining after existing consumptive uses are taken into account. The following sections summarize the streamflow statistics previously derived (Chapter 5.0) that would be used as the basis for quantifying water use and water availability for each base flow basin.

6.1 Flow Statistics

Base flow basins were delineated for the Morrison Cove study area (Figure 4-4). These include Clover, Halter, Piney, Plum, and Yellow Creeks, and the Gatesburg North base flow basins. The flow statistics used in the analyses are shown in Table 6-1.

Ten-year base flows for the Piney Creek, Clover Creek, Yellow Creek, Plum Creek, and Halter Creek base flow basins (as presented in Chapter 4.0, Figure 4-4) are based on actual measurements of groundwater contribution to the basins, and are used in the water availability analyses.

The Gatesburg North Base Flow Basin does not have a corresponding surface watershed that could be monitored directly. However, because the basin is underlain, as a whole, by the Gatesburg Formation, the recharge rate derived by Taylor (1997) was used to estimate 10-year base flow.

Table 6-1. Ten-year Base Flows for Morrison Cove

Base Flow Basin	10-Year Base Flow (cfs)
Piney Creek	19.6
Clover Creek	21.5
Gatesburg North	27.8
Yellow Creek	46.8
Plum Creek	6.9
Halter Creek*	10.6
Roaring Spring	8.3

*The Roaring Spring is included in Halter Creek base flow basin.

Some clarifications need to be made regarding the base flow basins. The first is that the Gatesburg South Terrain, not listed in Table 6-1, drains at a ratio of approximately 40 percent to the Yellow Creek base flow basin and 60 percent to the Roaring Spring and Halter Creek base flow basin. These percentages were determined based on flow measurements made during the seepage run. As stated in Chapter 4.0, the total flow from the Gatesburg South Terrain measured during the seepage run was approximately 14.7 cfs. Based on observations of Yellow Creek and the Roaring Spring, approximate outflows were 5.6 cfs and 9.1 cfs, respectively. Yellow Creek outflow (5.6 cfs) is equal to approximately 40 percent of the total flow (14.7 cfs) from the Gatesburg South Terrain, and the Roaring Spring outflow (9.1 cfs) is equal to approximately 60 percent of the total flow (14.7 cfs). The second clarification is that the Roaring Spring discharges groundwater from the Southern Gatesburg Terrain to the Halter Creek base flow basin.

6.2 Water Use

Water use was grouped by base flow basin and categorized by water use type. Water users located within each base flow basin were determined using records from SRBC and PADEP water use databases and GIS spatial analyses. PADEP water use data were used to supplement SRBC data.

SRBC data include consumptive use and surface water and groundwater withdrawal approvals, current as of June 2011. The quantities used in the analyses are based on approved quantities (peak day for consumptive water use and surface water withdrawals and 30-day averages for groundwater withdrawals) and not reported use quantities.

Two additional datasets were used to supplement SRBC data, which included PADEP user registration data and USGS Water-Analysis Screening Tool (WAST) data. All public water agencies and hydropower facilities, as well as those users withdrawing or using greater than 10,000 gallons per day averaged over a 30-day period, are required to register their water use with PADEP. PADEP user registration data are reported withdrawal data through the year 2010 and were normalized to an average annual use quantity.

Use quantities from the WAST data from 2003 were determined based on actual days used rather than average annual use (Stuckey, 2008). Several water use categories were known to be underrepresented. These include unregistered withdrawals, irrigation, livestock, and golf course irrigation. Gaps for residential and non-residential use were filled with estimated data (Stuckey, 2008). Details on how the residential and non-residential information were calculated can be found in the USGS Open-File Report 2008-1106, "Development of the Water-Analysis Screening Tool Used in the Initial Screening for the Pennsylvania State Water Plan Update of 2008."

Agricultural consumptive use was based on estimates for the Juniata Subbasin by Jarrett and Hamilton (2002). The Jarrett and Hamilton (2002) study was performed under contract to SRBC and was the basis for estimating agricultural consumptive use in SRBC's Pennsylvania Agricultural Consumptive Use Study (Dehoff et al., 2005). For purposes of these analyses, it was assumed that the amount of consumptive use is directly proportional to agricultural land use area in each base flow basin.

Consumptive water use was taken directly from SRBC-approved quantities. For PADEP registration data, consumptive water use was determined as the difference between a project's withdrawal and wastewater discharge. WAST estimated residential withdrawals were adjusted with the assumption that 90 percent of the water is returned to the system and only 10 percent is consumptively used; all other WAST data were assumed to have 100 percent consumptive use (Stuckey, 2008).

Water use was divided between base flow basins to account for groundwater flow paths. Groundwater in the Southern Gatesburg Terrain discharges to both the Yellow Creek and Halter Creek base flow basins. The percentage of flow is equal to an approximate 40 percent flow to Yellow Creek base flow basin and an estimated 60 percent flow to the Halter Creek base flow basin during periods of base flow. Similarly, because the Roaring Spring contributes flow to the Halter Creek base flow basin, 60 percent of the water use in the Southern Gatesburg Terrain was incorporated into the water use values for the Halter Creek base flow basin.

Water use values, separated by sector, have been determined for each base flow basin and are listed in Table 6-2. All values have been rounded to the nearest hundredth place.

Table 6-2. Water Use by Sector and Base Flow Basin

Base Flow Basin	Water Use by Sector (mgd)							Total Water Use (mgd)	Total Water Use as a Percent of 10-Year Base Flow
	Agricultural	Residential	Municipal	Commercial	Industrial	Recreational	Mining		
Piney	0.10	0.01	---	---	---	---	---	**0.10**	**0.8**
Clover	0.17	0.01	0.04	0.01	0.26	---	---	**0.49**	**3.5**
Gatesburg North	0.10	0.01	0.29	0.01	0.24	---	---	**0.65**	**3.6**
Yellow	0.36	0.03	0.26	0.01	0.23	0.11	---	**0.99**	**3.3**
Plum	0.11	0.01	0.16	<0.01	---	---	0.20	**0.48**	**10.8**
Halter*	0.12	0.02	0.41	0.03	5.75	0.16	---	**6.49**	**87.2**
Roaring Spring	0.07	0.01	0.41	<0.01	5.13	0.16	---	**5.78**	**108**
Total Water Use (mgd)**	**0.96**	**0.08**	**1.16**	**0.06**	**6.48**	**0.26**	**0.20**		

Note:
*The Roaring Spring use is included in the Halter Creek base flow basin.
**The Roaring Spring use is excluded from the water use by sector totals.

6.3 Water Availability

For each base flow basin, the water use was compared to the estimated 10-year base flow to determine the water available for future development.

As described previously in Chapter 3.0, there may be an amount of flow from the Southern Gatesburg Terrain leaving as underflow. This sub-surface flow path moves roughly 50 percent of the 10-year base flow from the Southern Gatesburg Terrain to the Northern Gatesburg Terrain. This underflow component is not well documented. Including the underflow could result in an overestimation of the water availability, potentially resulting in overallocation. Therefore, the underflow was not taken into consideration in the analysis.

The water use for each base flow basin has been calculated as both total water use and as a percentage by water use type. The results of the water availability analysis for each base flow basin are presented in the following series of pie charts (Figures 6-1 through 6-7).

Based on the water availability analyses, the base flow basins of Piney Creek, Clover Creek, Gatesburg North, and Yellow Creek have less than 10 percent of the 10-year base flow currently being consumptively used (Figures 6-1, 6-2, 6-3, and 6-4, respectively). Less than 1 percent of the 10-year base flow is consumptively used in Piney Creek, with the largest water use sector in Piney Creek being agriculture.

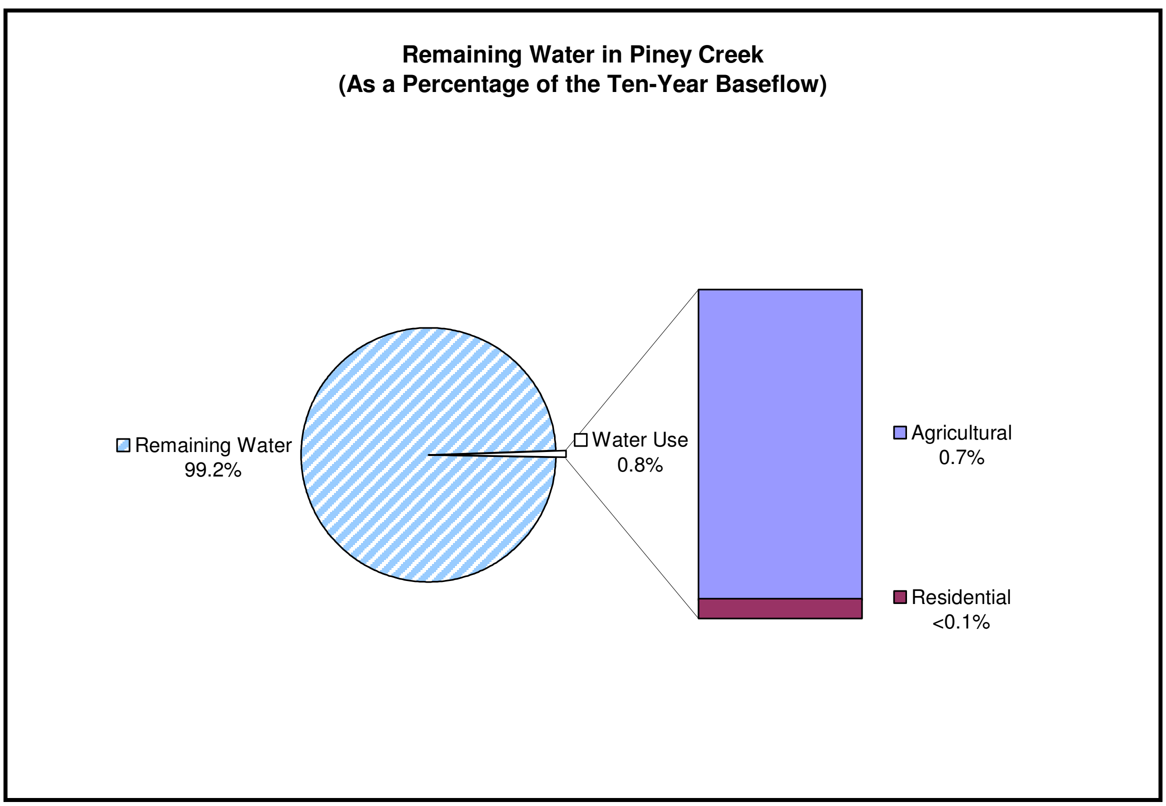

Figure 6-1. Remaining Water in Piney Creek

As indicated in Figure 6-2, approximately 3.5 percent of the 10-year base flow is consumptively used in the Clover Creek base flow basin. Water use primarily resides in the industrial and agricultural sectors with these sectors' consumptive use equaling about 1.9 percent and 1.2 percent, respectively.

The Northern Gatesburg base flow basin has approximately 96.4 percent of the 10-year base flow remaining after considering water use. The top two water use sectors are municipal and industrial, which account for an estimated 1.6 and 1.3 percent of total use, respectively.

Water use within the Yellow Creek base flow basin is approximately 3.3 percent of the 10-year base flow. The largest water use sectors in this basin are agricultural, municipal, and industrial. About 96.7 percent of the 10-year base flow remains in this basin.

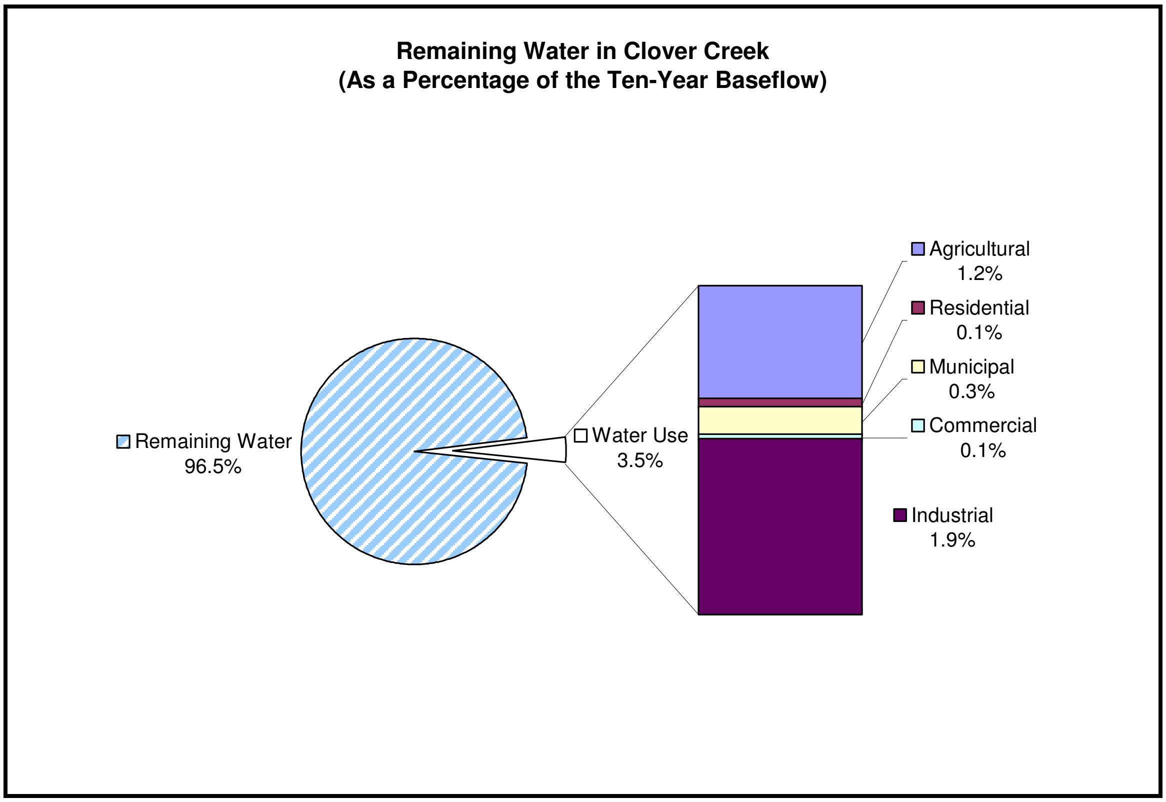

Figure 6-2. Remaining Water in Clover Creek

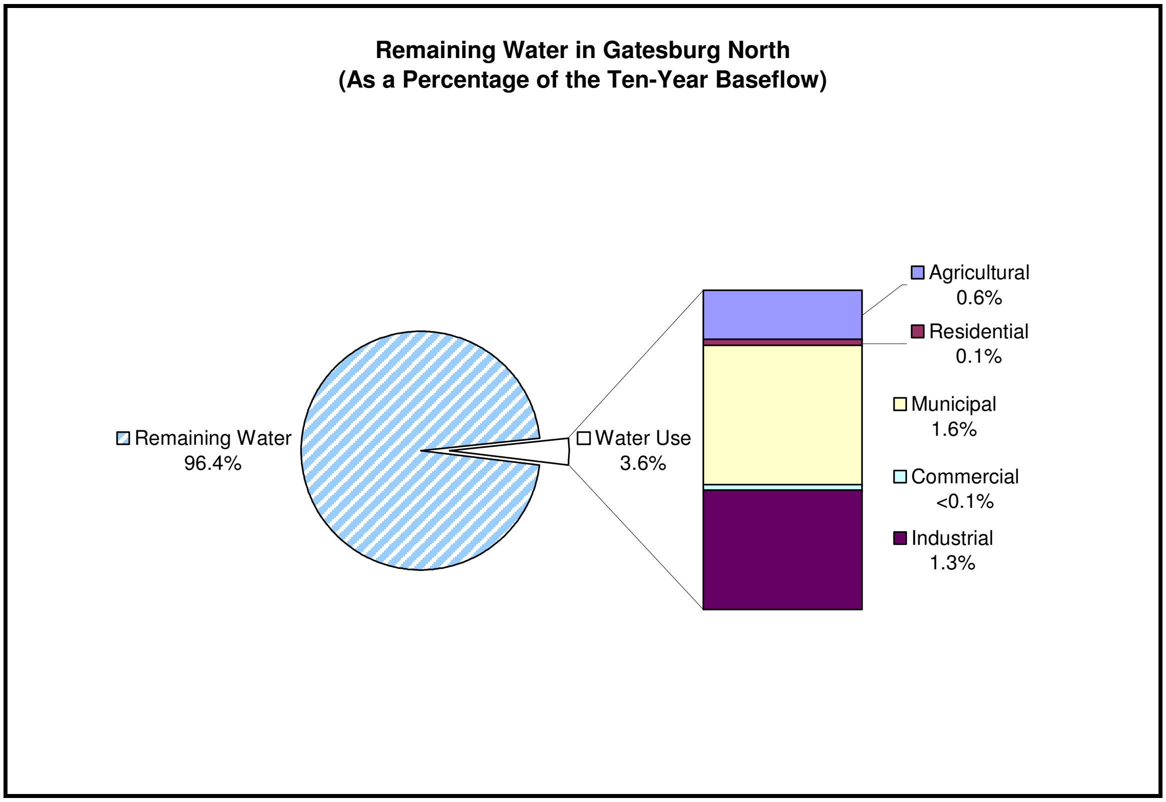

Figure 6-3. Remaining Water in Gatesburg North

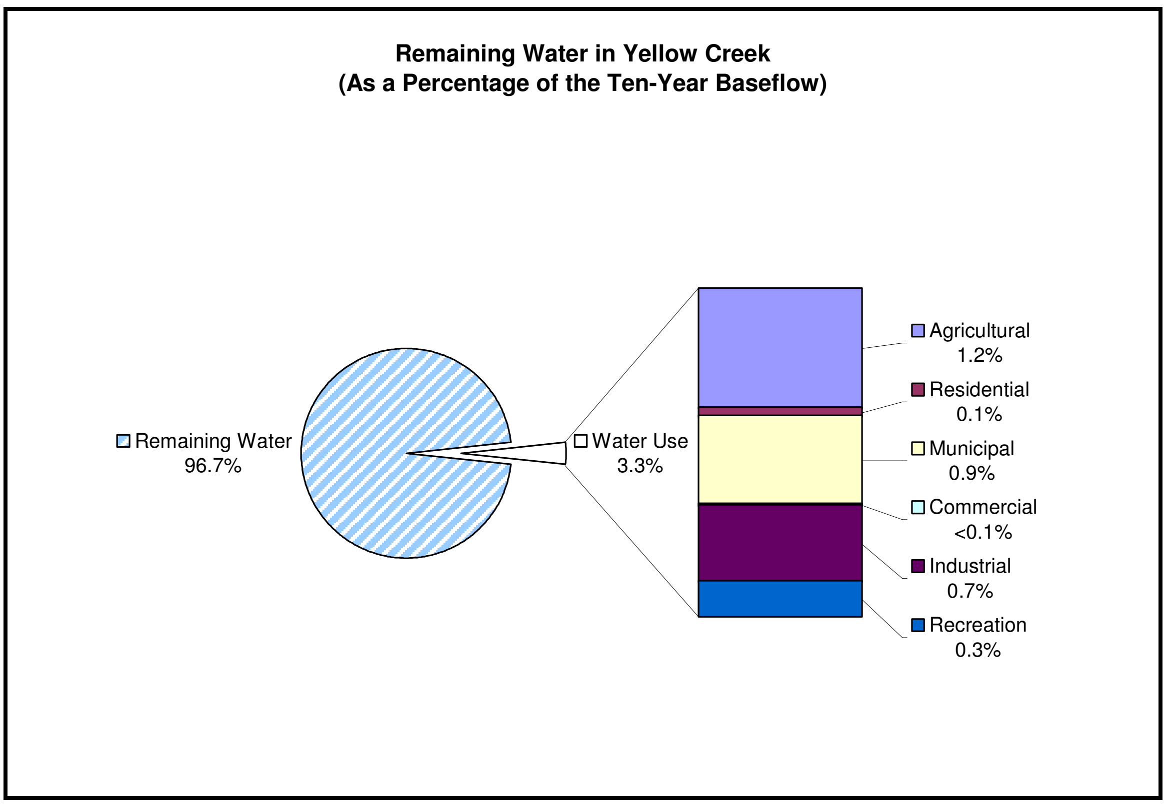

Figure 6-4. Remaining Water in Yellow Creek

Consumptive water use in Piney Creek, Clover Creek, Gatesburg North, and Yellow Creek base flow basins is less than 10 percent of the 10-year base flow. Consumptive water use in Plum Creek, Halter Creek, and the Roaring Spring base flow basins accounts for more than 10 percent of the 10-year base flow. The pie charts for these basins are depicted in Figures 6-5, 6-6, and 6-7.

Approximately 10.8 percent of the 10-year base flow has been used upgradient of the outlet of Plum Creek. The major water use types or sectors include mining, municipal, and agricultural, with mining being the largest use sector at about 4.4 percent of the total water use.

Halter Creek has a considerable amount of consumptive water use, as approximately 87.2 percent of the 10-year base flow is currently being utilized upgradient of the outlet of Halter Creek. The largest water use sector in Halter Creek is industrial. The amount of water currently being used indicates that any new or existing water use approvals within the Halter Creek base flow basin should be conditioned to provide low flow protection for downstream uses.

Results of the water availability analysis indicate that water use at the Roaring Spring is greater than the sustainable 10-year base flow. The peak approved water use exceeds 100 percent of the available water upgradient of the outlet. The major water use in this base flow basin is industrial, as this sector comprises more than 92 percent of the total water use from the Roaring Spring.

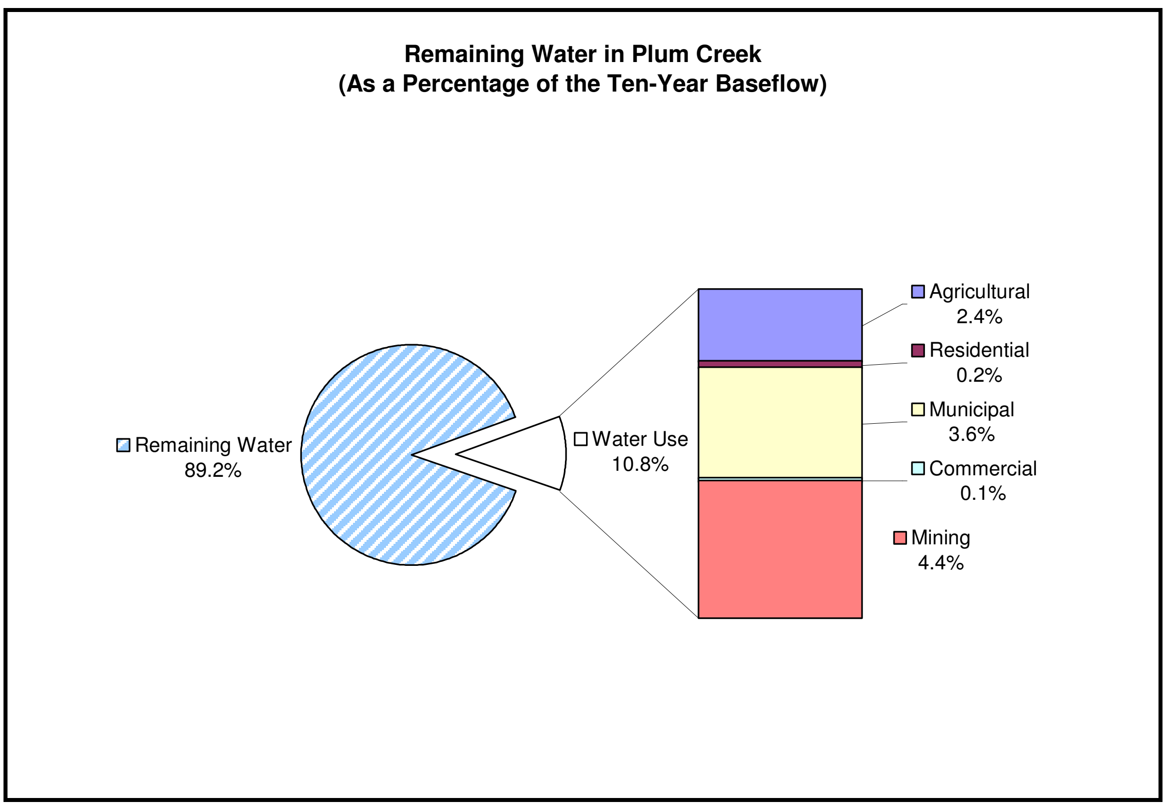

Figure 6-5. Remaining Water in Plum Creek

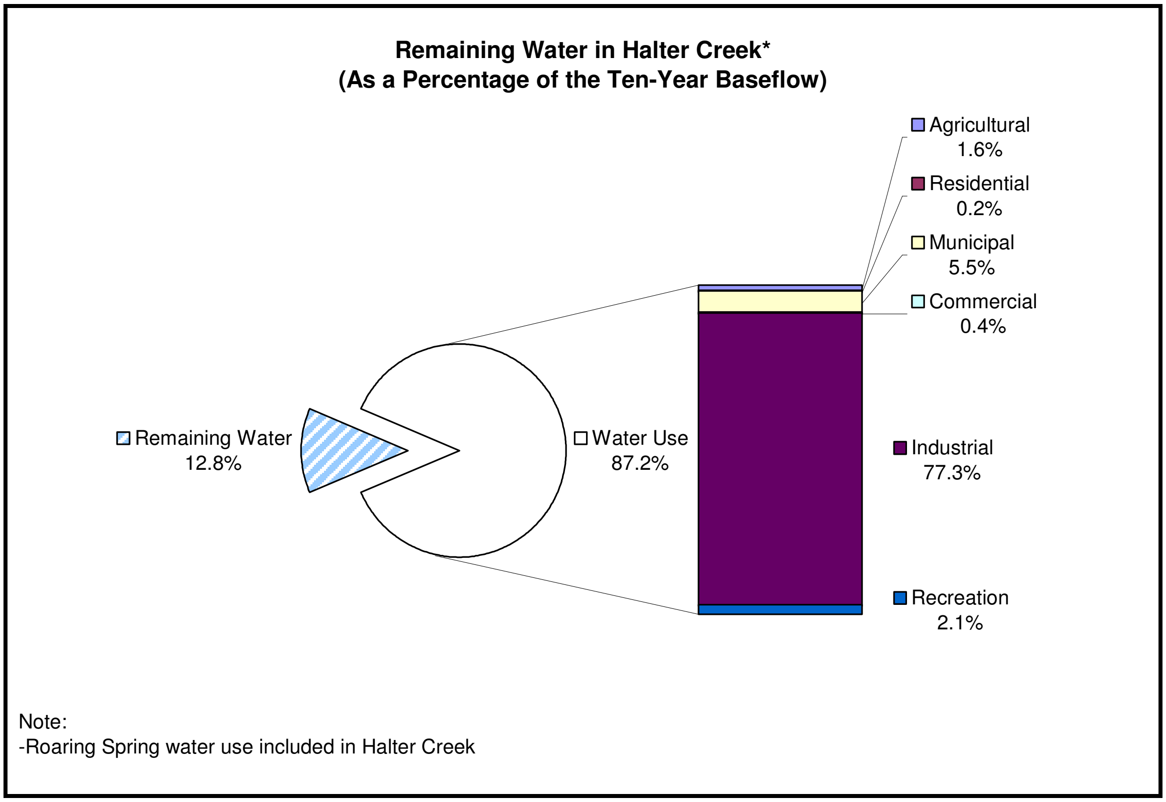

Figure 6-6. Remaining Water in Halter Creek

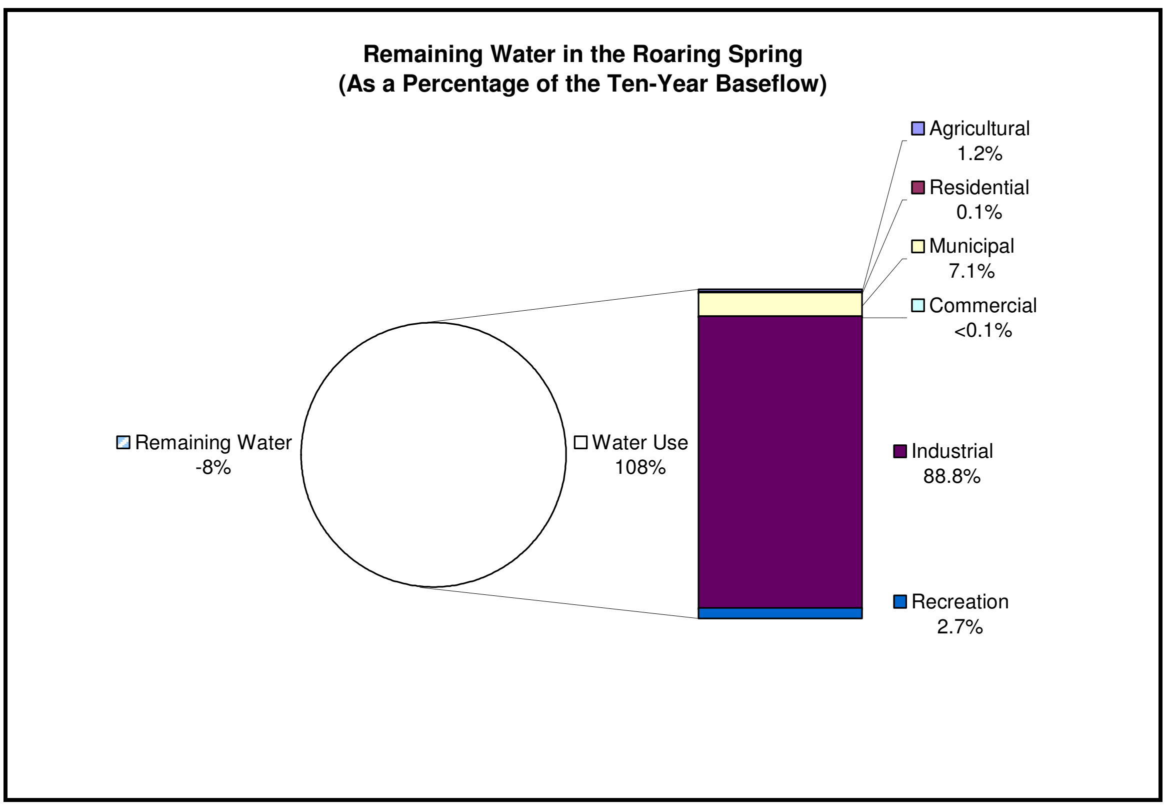

Figure 6-7. Remaining Water in the Roaring Spring

6.4 Screening for Identification of Critical Water Planning Areas (CWPAs)

The major watersheds in Morrison Cove were screened according to guidelines for identification of CWPAs (Stuckey, 2008). The consumptive use in each major watershed was compared to the appropriate ISC, which is 50 percent of the 7Q10 flow for all streams, except those designated as Class A trout streams in areas of carbonate bedrock, where 30 percent of the 7Q10 flow was used. The streams of Morrison Cove, with the exception of Halter Creek, meet the criteria for evaluation as 30 percent of the 7Q10 flow, rather than 50 percent of the 7Q10 flow. This determination was made in conjunction with information presented in Chapter 7.0. Based on field observations, Halter Creek is functioning as a Class A stream; however, the stream is not currently classified with this designation. For the purposes of this analysis, Halter Creek will be screened using both the 30 percent and the 50 percent criteria.

As shown in Table 6-3, consumptive use exceeded the ISC of 30 percent of 7Q10 in the Plum Creek Watershed and exceeded the ISC of both 30 percent and 50 percent of the 7Q10 in the Halter Creek Watershed. These watersheds meet the ISC for consideration as potential CWPAs. However, the consumptive use in these watersheds is due to a few relatively stable, long-established, high volume withdrawals, and both watersheds currently support high quality aquatic habitats downstream of the withdrawal locations. Water use in Halter Creek and the Roaring Spring is largely driven by industrial use. Municipal and residential consumptive use is a small fraction of total use. Therefore, water use is not a function of population growth. Available data for industrial water use suggest overall stability, with no net increases in water demand in recent years. Designation of these watersheds as CWPAs does not appear to be warranted.

Table 6-3. Screening for Critical Water Planning Areas (CWPAs)

Watersheds	Water use (mgd)	ISC of 30% of 7Q10		ISC of 50% of 7Q10	
		30% of 7Q10 (mgd)	ISC Met (Yes/No)	50% of 7Q10 (mgd)	ISC Met (Yes/No)
Piney Creek	0.10	1.20	No	---	---
Clover Creek	0.49	1.51	No	---	---
Yellow Creek	0.99	1.98	No	---	---
Plum Creek	0.48	0.43	Yes	---	---
Halter Creek	6.49	0.64	Yes	1.07	Yes

6.5 Conclusions

The findings of the water availability analyses for Morrison Cove demonstrate that Piney Creek, Clover Creek, Northern Gatesburg, and Yellow Creek base flow basins have a small percentage of existing water use (i.e., less than 5 percent) as compared to the 10-year base flow. Substantial water is available in these areas for future development. Plum Creek base flow basin currently has a moderate water use of approximately 10.8 percent of the 10-year base flow and development is unlikely to be constrained by water availability.

Comparisons of water use and water availability indicate that water use in the Halter Creek base flow basin nearly equals the quantity of water available for development and that current consumptive water use exceeds the sustainable 10-year base flow at the Roaring Spring. These base flow basins may exhibit supply shortages under drought conditions. Extreme caution should be taken in the review of any requests for new or increased water use within these two base flow basins. Withdrawals may be interruptible for downstream resource protection. In addition, the potential effects of cumulative water use in the Halter Creek and Plum Creek base flow basins on the aquatic habitat in the reach downstream of their confluence has to be taken into account. This may considerably reduce the water availability for the Plum Creek base flow basin.

The available water for future development estimated in this study is conservative considering 100 percent of the 10-year base flow is allowed to be used. Severe droughts and increased water use potentially could create serious deficits that may jeopardize environmental needs and should be taken into consideration for water resource planning.

According to guidelines for identification of CWPAs, consumptive water use values in Piney, Clover, and Yellow Creeks are less than the ISC of 30 percent of 7Q10. Consumptive use exceeded the ISC of 30 percent of 7Q10 in the Plum Creek Watershed and exceeded the ISC of both 30 percent and 50 percent of the 7Q10 in the Halter Creek Watershed. Plum and Halter Creek Watersheds are not recommended for nomination as CWPAs, because of the nature of the withdrawals and the high quality aquatic habitat they support.

7.0 WATER QUALITY AND AQUATIC HABITAT

7.1 Water Quality

Water quality and water quantity are interrelated and an assessment of water quality issues that have a direct and substantial effect on water resource availability is critical in the evaluation of a potentially water-stressed area. As such, an assessment of relevant water quality monitoring reports, projects, and studies on the streams in Morrison Cove was completed. These data were compiled and analyzed to provide a summary of water quality issues and concerns in each of the major watersheds within the region.

Historically, the most significant water quality issue in Morrison Cove is the high concentrations of nitrate in the groundwater. In 2004, the USGS completed an extensive study on the sources of water and contaminants to water supply wells in the Martinsburg area. This was done using geochemical indicators, analysis of anthropogenic contaminants, and simulation of groundwater flow.

Groundwater is an essential resource for this rural area as it is the main drinking water source for more than 3,000 people. Martinsburg has four wells in the carbonate-bedrock aquifer that supply the drinking water. The quantity of water from these wells is not a concern but the quality of the water definitely is. Concentrations of nitrate in the well water have exceeded the Maximum Contaminant Level (MCL) of 10 mg/l numerous times. High concentrations in groundwater are not limited to Martinsburg; a Pennsylvania Department of Agriculture study reported that water from 35 percent of wells sampled in the Morrison Cove Valley exceeded the MCL for nitrate. The Martinsburg project provides an excellent case study about the issues related to nitrogen-contaminated groundwater.

Potential sources of groundwater contamination can be directly correlated to land use types. The land within the groundwater boundaries for the Martinsburg wells falls into three major land use categories: forested, agricultural, and low density residential. The forested areas (17 percent) provide no source of nitrogen other than precipitation, the agricultural areas (80 percent) contribute nitrogen from numerous sources including manure and fertilizers, and the low density residential areas (2.5 percent) present the possible sources of leaking sewer lines, on-lot septic systems, and lawn fertilizers.

Lindsey and Koch (2004) collected field data to provide streamflow information as well as data on groundwater levels in order to delineate the areal extent of the zone of contribution to the Martinsburg wells. Water quality data were also gathered to determine the source of contamination to the wells. Eight private wells, two municipal wells, one spring, and four streams were sampled. The water samples were analyzed for major ions, nutrients, nitrogen isotope ratios, wastewater compounds, and bacteria. Numerous methods were used to determine potential sources of contaminants to the wells, including geochemistry, anthropogenic contaminants, bacterial source tracking, and a groundwater model. Nitrogen isotopic ratios are used to determine sources of nitrogen because chemical fertilizers have a distinctly different isotope ratio for nitrogen than organic waste, such as manure, does. Microbial source tracking was used to further differentiate between human, livestock, and other possible bacterial sources.

The results from this study shed some light on the sources of contamination and provided useful information for moving forward to resolve the issues. The primary form of nitrogen detected in the groundwater, as expected, was nitrate, with concentrations ranging from 5.7 to 36 mg/l. The municipal supply wells had concentrations of 8.9 and 9.1 mg/l, which was consistent with what was routinely measured by Martinsburg Borough in these wells. The nitrogen isotope signatures results were not very clear, in that the ranges indicated sources likely to be from manure, human sewage, or chemical fertilizers, but more likely a mixture of the three. Wastewater analysis pointed to human sewage not being the likely nitrogen source. Fecal coliform bacteria were detected in all wells and streams sampled; four stream samples were traced by microbial methods to dairy cattle sources. Three wells and the one spring were also linked through bacteria to dairy cattle.

Multiple lines of evidence were used in this study. Because of the complexities of modeling in carbonate terrain, geochemical, anthropogenic, and microbial analyses were used in combination to assess the validity of model simulation results. Combining the geochemical data with the output from the model concerning the areal extent of contribution zones for each well field led to the following major conclusion: the primary source of nitrate groundwater is from agricultural activity and not human sewage. Since agricultural sources such as manure and crop fertilizers are a central component of the livelihood of many of the residents in the Martinsburg area, nitrate contamination from agricultural practices is not something that can be eliminated easily.

7.2 Riparian Areas and Aquatic Habitat

Intact riparian areas provide numerous functions and benefits to streams in the following three categories: 1) hydrology and sediment dynamics; 2) biogeochemistry and nutrient cycling; and 3) habitat and food web maintenance. Functions related to hydrology and sediment dynamics include storage of surface water and sediment, which reduces damage from floods downstream from the riparian area. Riparian areas intercept, cycle, and accumulate chemical constituents in shallow subsurface flow, thus filtering out pollutants from overland flow and shallow groundwater that might otherwise contaminate adjacent water bodies. Riparian vegetation provides streams (and dependent aquatic communities) with microclimate modification and shade, organic litter and wood inputs, nutrient retention and cycling, streambank stability, and control of sedimentation. Maintaining biodiversity is a major ecosystem function that riparian areas provide and is the basis for fisheries in addition to providing bird and wildlife habitat. Riparian areas host numerous invertebrates, almost all local amphibian species and reptiles, a majority of bird species, and many mammal species.

Activities that disrupt riparian vegetation result in an increase in the amount of solar radiation that reaches a stream, thereby resulting in higher stream temperatures and affecting aquatic primary production. Removal of riparian vegetation also results in a decreased ability to retain water, sediment, and excess nutrients (e.g., nitrogen and phosphorus) during overland flows or flood events. In areas where riparian buffers have been disrupted or removed, overland flow or flood events result in increased erosion rates and inundate riparian areas and floodplains with sediment limiting their filtering functions. Silt and sediment loads cover riffle areas, which are critical habitat for benthic macroinvertebrates and fish eggs. Silt and sediments can also become embedded among the coarser substrate materials in a stream, thereby eliminating hyporheic habitat and preventing the exchange of oxygen to any benthic organisms or eggs within the substrate. Removal of riparian areas is particularly damaging in agricultural lands where upslope chemicals and excess fertilizers can flow unimpeded into streams, thereby negatively impacting aquatic communities. Excess nutrients can lead to excessive aquatic macrophyte and algal growth, which can choke a slow-moving stream and deplete streams of oxygen as it decomposes. Without riparian areas present to reduce flow velocities, stream channels accommodate these flow events by increasing their cross-sectional area through channel widening or streambed downcutting. Livestock grazing in agricultural areas can result in the removal and trampling of riparian vegetation, sloughing of banks, compaction of riparian soils, and dispersal of exotic or non-native plant species and pathogens. Because livestock tend to congregate in these areas, their impact on riparian areas can be disproportionately large.

There is a direct link between riparian buffers and water quality. Because of the geology of the Morrison Cove region, there is a high degree of interaction between surface water and groundwater. Thusly, elevated surface water nitrate concentrations likely reflect groundwater concentrations. Forested riparian buffers can have a significant impact on reducing the concentration of nitrate in groundwater. One study (Schoonover and Willard, 2003) showed a 61 percent reduction with just a 10-meter buffer and another showed a 78 percent reduction in nitrate concentration through a 38-meter forested buffer. Wider riparian buffers generally remove more nitrate. From all studies compiled by the United States Environmental Protection Agency (USEPA) (2005), the mean nitrate removal effectiveness was 74 percent, with predicted removal rates of 50 percent with a 3-meter buffer, 75 percent with a 28-meter buffer, and 90 percent effectiveness with a 112-meter buffer. This paper also discusses the effectiveness of grasses as riparian buffers, which is less than forested but still provides some nitrate removal.

Nitrate in groundwater and surface water is a threat to the waters of Morrison Cove. Planting riparian buffers may be the simplest answer to reducing the concentration of nitrate. While there are certain types of riparian buffers that may be more ideal and effective, the USEPA review paper demonstrates that a buffer of nearly any width and made up of any combination of trees, shrubs, and grasses can be a very effective in the removal of nitrate.

7.3 Methods for Water Quality Evaluation

SRBC has been involved in numerous efforts and projects that have included monitoring the water quality of streams in Morrison Cove prior to the start of the current study. One has involved more long-term sampling at sites throughout the Juniata Subbasin in 1995, 2004, and 2010. Another was a year-long quarterly monitoring project at 33 sites within Morrison Cove in 2005. The parameters of interest for this study included those most closely with agriculture (i.e., nutrients and sediment), ones that reflect underlying geology (i.e., calcium, magnesium), and those that are associated with urbanization (i.e., chloride, sodium). Instream flow measurements were also taken during each seasonal sample, which provides an illustration of the potential fluctuations in stream discharge. In October 2009, concurrent with the seepage run, SRBC staff also documented field chemistry and nitrate concentrations at the same 45 sites, although one-third of the proposed sites were dry when the sampling was conducted. Also in October 2009, Meiser & Earl, Inc. completed a monitoring survey of 40 stream and spring locations throughout Morrison Cove. In addition to in-situ field parameters, a laboratory chemical analysis for parameters of interest was also completed which included nitrate, sulfate, chloride, alkalinity, and sodium.

In addition, other agencies and groups have done water quality surveys on smaller scales throughout portions of Morrison Cove. From 2002 through the present, the Western Pennsylvania Conservancy (WPC) has been involved in water quality monitoring in the Morrison Cove region. Their work primarily revolves around the implementation of streambank fencing on farms to improve water quality by excluding livestock. Samples were collected at farms along Piney, Clover, Beaver, and Hickory Bottom Creeks and Three Springs Run. These samples were analyzed with field test kits but generally were in agreement with all other data for these watersheds. This project extends beyond Morrison Cove and is ongoing. Preliminary findings are showing benefits of streambank fencing and improved water quality.

In 2004-2005, the Blair County Conservation District (BCCD) completed a Piney Creek Watershed Assessment and Conservation Plan. Included in this assessment was water quality sampling at five stream locations. The Piney Creek assessment also pointed to some familiar solutions: streambank fencing, septic upgrades, and improvements to manure management. Then in 2010, BCCD published a Plum Creek Watershed Assessment, Restoration, and Preservation Plan. This study concluded that Plum Creek is one of the few high quality cold water fishery (HQ-CWF) streams in Blair County, and while agriculture has protected the stream from urban impacts, it also has had a negative effect. Data from BCCD were in agreement with all other available data indicating elevated nitrate concentrations throughout Piney Creek and Plum Creek Watersheds.

The Bedford County Conservation District completed a Coldwater Heritage Watershed Assessment for Potter Creek in 2005. Water quality and macroinvertebrate samples were collected at five locations throughout Potter Creek Watershed. Water quality data were in agreement with all other data collected for Potter Creek, showing elevated nitrate concentrations and high alkalinity values associated with limestone streams. Sedimentation and erosion were listed as major issues in Potter Creek.

Each of these projects, whether focused on one stream or broadly across Morrison Cove, points to the same basic issues and concerns. Nitrogen (mostly as nitrate) is the single biggest water quality concern. Additionally, sedimentation has far-reaching impacts on water quality, habitat, and biota. The lack of riparian buffer corridors along the streambanks is also a common theme throughout all the above studies.

An evaluation of the water quality data from each of these individual projects was completed and results were compiled and discussed below for each watershed in Morrison Cove. Water quality results discussed as mean values are given for sites where there were at least five samples taken by some agency at the same location. Other results and values are noted as anecdotal and supporting data. Table 7-1 displays the water quality criteria used for evaluating the water quality data. Figure 7-1 depicts the stream segments in Morrison Cove that are on the 303(d) List of Impaired Waters.

Table 7-1. Water Quality Criteria and Reference Values with Source

Parameter	Water Quality Criteria or Reference Value	Reference
Temperature	> 20º C	PA Code for CWF
Dissolved Oxygen	< 5 mg/l	PA Code for CWF
pH	< 6	PA Code
pH	> 9	PA Code
Alkalinity	< 20 mg/l	PA Code
Nitrite + Nitrate	> 10 mg/l	PA Code, drinking water
Nitrate	> 1.0 mg/l	USGS, background with no anthropogenic influence
Nitrate	> 2.3 mg/l	SRBC archived data, 75^{th} percentile
Nitrate	> 6.16 mg/l	SRBC archived data, 95^{th} percentile
Phosphorus	> 0.1 mg/l	USGS, background with no anthropogenic influence
Sodium	> 20 mg/l	NY groundwater
Chloride	> 250 mg/l	PA Code, drinking water
Sulfate	> 250 mg/l	PA Code, drinking water
Chlorine	0.019 mg/l	PA, one hour average

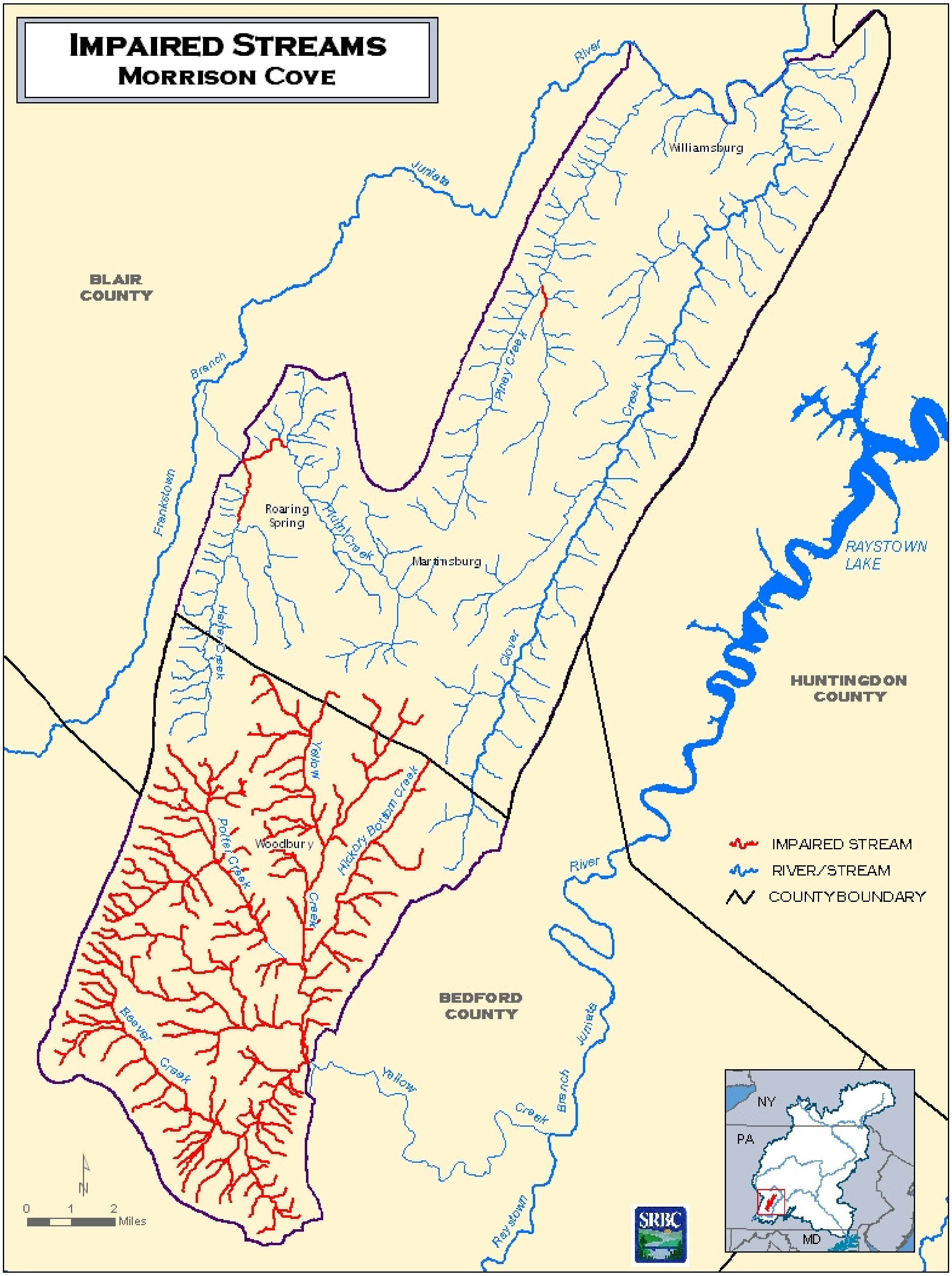

Figure 7-1. Impaired Streams in Morrison Cove

7.4 Watershed Evaluations

7.4.1 Clover Creek

The Clover Creek (WBD 0205030203) Watershed drains 50 square miles and makes up about 27 percent of Morrison Cove. It flows northeast, nearly parallel to Piney Creek (Figure 7-2). The main channel of Clover Creek flows through primarily agricultural land and is influenced by ridge geology from tributaries and by the carbonate valley between the ridges. Clover Creek has a PADEP Chapter 93 Designated Use Classification of High Quality Cold Water Fishery (HQ-CWF). It drains north-northeast to the Frankstown Branch of the Juniata River. The headwaters of the Clover Creek mainstem originate on the slopes of Tussey Mountain. Land use is over 54 percent forested and 42 percent agriculture.

Water Quality

Clover Creek is the only major subwatershed in the Cove that does not have any segments or tributaries listed in the 303(d) list of stream impairments. There were two sites on Clover Creek that had at least five data points, and there were minimal differences in the water quality at the upstream and downstream two locations. Nitrates averaged about 5.0 mg/l at the downstream site and about 6.0 mg/l at the upstream site. Based on molar ratios of Ca/Mg less than 1.6, much of the water in Clover Creek originates from a dolomite-based groundwater system. Hardness, pH, and conductivity are also typical for these types of waters.

Sodium, chloride, and sulfate are all in the low range, meaning there are likely no significant anthropogenic sources of these ions in Clover Creek Watershed. There were numerous other one-time grab samples taken throughout Clover Creek, which provided a few other anecdotal pieces of information.

The most upstream sampling location had lower alkalinity, magnesium, chloride, and nitrate concentrations, which may point to the headwaters being more influenced by the tributaries that come off the ridge and have markedly different water chemistry.

Riparian Area Condition

The headwaters of Clover Creek are located in heavily forested lands, with riparian areas almost entirely intact. Along the lower headwater segments, at the beginning of the mainstem Clover Creek, riparian areas appear to have been cleared along agricultural lands bordering the stream (Figure 7-3). For the majority of the stream channel flowing along the valley floor through agricultural lands, most riparian areas have been cleared, or where existing, consist of marginal grasses.

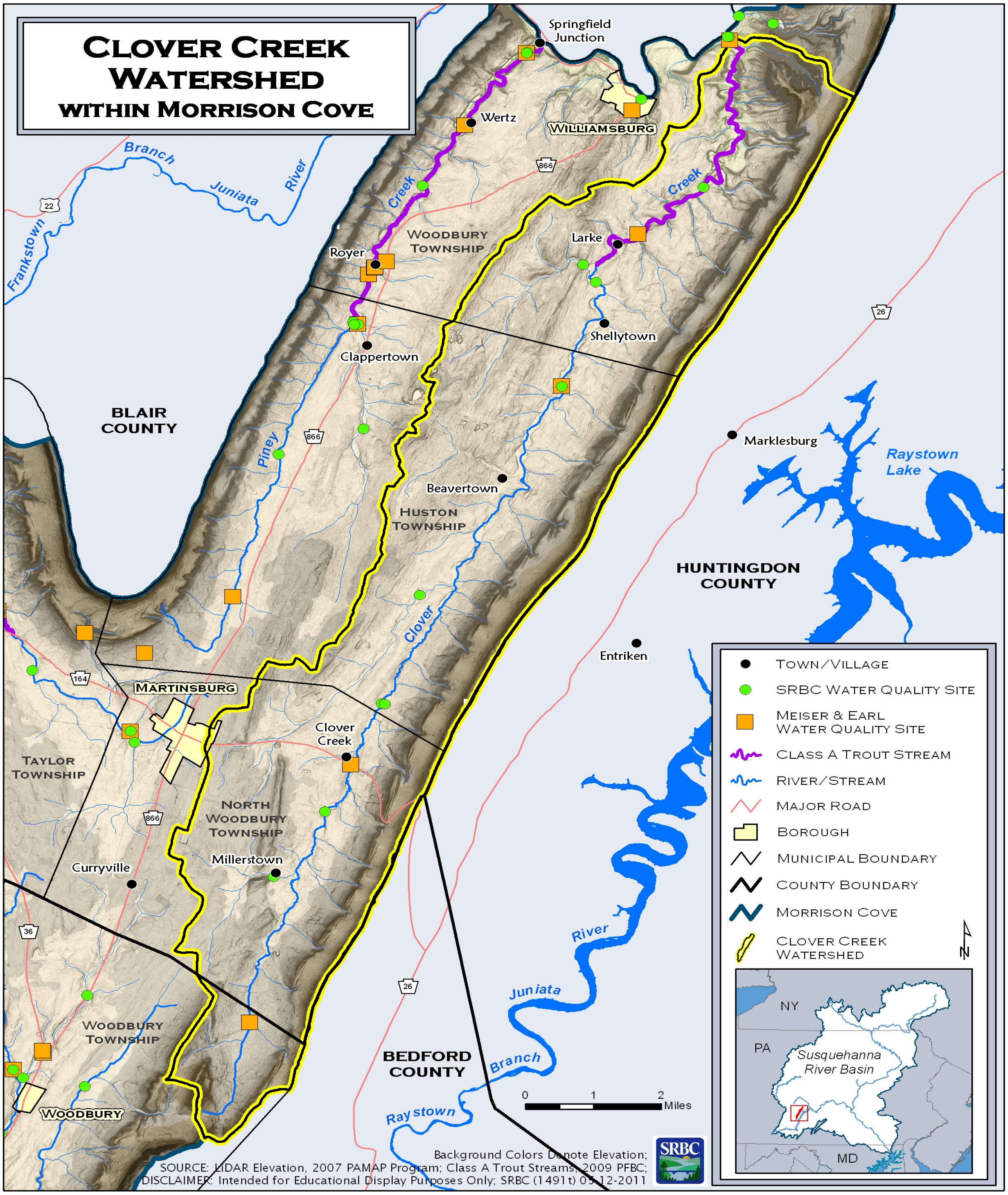

Figure 7-2. Clover Creek Watershed

Figure 7-3. Example of Lack of Riparian Buffer and Agriculture along Clover Creek

Aquatic Habitat Condition

Visual aquatic habitat assessments were performed by SRBC staff at nine sampling points along Clover Creek in October 2009.

The nine sampling points along the Clover Creek were called Clover 9–Clover 1 (upstream–downstream, respectively), and represented a variety of instream habitats. Clover 9, Clover 7, and Clover 6 were located in lands dominated by cropland and pasture, where riparian areas had been removed. Instream habitat at these sample points was relatively marginal in terms of epifaunal substrate, instream cover, embeddedness, diminishing available fish cover habitat, and interstitial habitat for benthic macroinvertebrates. Sampling points Clover 8, Clover 5, Clover 4, and Clover 2 were also primarily located in agricultural or residential lands and had minimal riparian areas with extremely limited tree cover and narrow grass buffers. Instream habitat at these sample points was suboptimal in terms of epifaunal substrate, instream cover, embeddedness, and channel alteration. Marginal scores resulted for instream habitat parameters as related to sedimentation deposition and frequency of riffles. Sampling points Clover 3 and Clover 1 had higher quality riparian areas along the sampled stream length, consisting of more vegetative cover and more stable streambanks. The instream habitat condition also presented as higher quality overall than all other sample points.

Subwatershed Stream Condition and Recommendations

The entire subwatershed is listed on PADEP's 303(d) list as attaining for supporting aquatic life use (Figure 7-2). It is likely that the intact forested lands surrounding Clover Creek's headwaters are protecting these systems in terms of water quality and quantity, thus contributing natural flows to the downstream reaches of Clover Creek. Water quality supplied from these source headwaters, and all contributing headwater tributaries, must be of such high quality that they are able to support aquatic life use along Clover Creek. This trend stands out in light of the large portion of the stream surrounded by agricultural lands in areas in which riparian areas have been thinned, modified, or removed. Instream habitat results indicate a connection between the quality and extent of riparian areas and the quality of habitat present within a sampled reach. Sites with increased habitat scores for riparian cover and bank stability showed corresponding higher scores for instream habitat parameters such as instream cover and epifaunal substrate.

Recommendations for maintaining the stream classification in this subwatershed include maintaining all existing forested riparian buffers. Further removal of existing forested riparian areas would enhance erosional activities and increased bank instability, thereby resulting in a degradation of the stream's water quality. Maintaining these riparian areas is especially critical in the subwatershed's headwaters, as the majority of the riparian areas are surrounded by mostly intact forested lands functioning to protect the natural form and function of these systems. These lands should be prioritized for preservation to maintain the higher quality instream habitat and riparian areas associated with these stream segments.

7.4.2 Piney Creek

Piney Creek Watershed (WBD 0205030203) has similar land use and water chemistry as Clover Creek but has only about half the drainage area (25 square miles), making up about 14 percent of Morrison Cove. Piney Creek has a PADEP Chapter 93 Designated Use Classification of HQ-CWF). It drains north-northeast to the Frankstown Branch of the Juniata River (Figure 7-4). The headwaters of the Piney Creek mainstem originate on the eastern slopes of Lock Mountain. The Piney Creek mainstem flows through a mixture of agricultural and forested lands. There are numerous headwater tributaries located along the western portion of Piney Creek's drainage basin. These headwaters originate within the forested ridgelines and slopes of Lock Mountain, likely providing the Piney Creek receiving waters with cool waters, stable sediment loads, and a sustainable energy source to downstream aquatic and terrestrial food webs. The lower gradient valley bottom portions of the subwatershed are dominated by agricultural land use. Overall, agricultural lands account for 44 percent of the subwatershed. Forested lands account for approximately 51 percent of the subwatershed. Developed lands constitute a marginal portion of the subwatershed, accounting for 5 percent of land use.

Water Quality

Only one small unnamed tributary is on the 303(d) list of impaired waters (Figure 7-1). Two sites on Piney Creek had at least five data points, one near the mouth and one about halfway up the stream. Nitrate levels in Piney Creek are similar to Clover Creek but a little higher on average at both upstream and downstream locations (6.9 and 6.1 mg/l, respectively). Like Clover Creek, Ca/Mg ratios suggest a dolomite water source although the most upstream sites had a higher ratio suggesting perhaps some limestone influence. Chloride, sodium, and sulfate were all low and very similar to Clover Creek. Hardness, pH, and conductivity were normal and consistent throughout the watershed. In addition, Blair County Conservation District (BCCD) completed a full watershed assessment on Piney Creek in 2005. Their nitrate results were in line with the findings of SRBC and Meiser & Earl, Inc., with average concentrations of 6.3 mg/l (BCCD, 2005).

Riparian Area Condition

Riparian areas are comparably intact in the lower portions of the subwatershed as compared to the upgradient headwaters areas. The source headwater areas located on the slopes of Lock Mountain include intact forested riparian areas. As the headwaters transition downslope to the valley floor, riparian areas are no longer present along much of these waters. As Piney Creek flows through the agricultural lands that dominate the valley floor, most riparian areas have been removed, thinned, or disturbed. A fairly substantial forested riparian area exists along the mainstem Piney Creek in the middle portion of the subwatershed, and remains intact for most of the stream's length to its confluence with the Frankstown Branch of the Juniata River.

Aquatic Habitat Condition

Visual aquatic habitat assessments were performed by SRBC staff at five sampling points along Piney Creek in October 2009. The habitat assessment methodology focuses on instream parameters (e.g., epifaunal substrate, instream cover, channel alteration, streambank condition). A site-specific score is generated from the assessment and can be used to make general observations (e.g., optimal, suboptimal, marginal, poor) about habitat at that location.

The five sampling points along Piney Creek, called Piney 6–Piney 1 (upstream-downstream, respectively), represented a variety of instream habitats. Piney 6 was surrounded by agricultural lands. The riparian area scored suboptimal for width and vegetative cover. Instream habitat parameters scored suboptimal for a few instream habitat parameters (epifaunal substrate, channel alteration) and marginal for instream cover, embeddedness (e.g., the amount of fine sediments surrounding substrate materials), and sediment deposition. A riparian area does not exist at this sample point, so stormwater runoff from the surrounding fields likely flows unimpeded into the stream, thus impacting the habitat quality. Piney 5 had no data collected due to lack of flow at the site. Piney 4 had a close-cropped riparian area with minimal vegetative cover. Instream habitat parameters were marginal at this site, except for embeddedness and channel alteration, which presented suboptimal scores. Field notes indicate livestock were not restricted from the riparian area or stream and that severe sedimentation was noted. Piney 3 had a forested riparian area coupled with optimal channel form and instream habitat parameters. Piney 2 was noted as having an impacted, narrow riparian area with minimal vegetative cover, and scored suboptimal for all instream habitat parameters. Piney 1 was located at the farthest downstream point in the subwatershed and presented the highest, site-specific habitat score. Field notes by SRBC staff indicated this site had an intact forested riparian area coupled with optimal channel form and suboptimal instream habitat parameters.

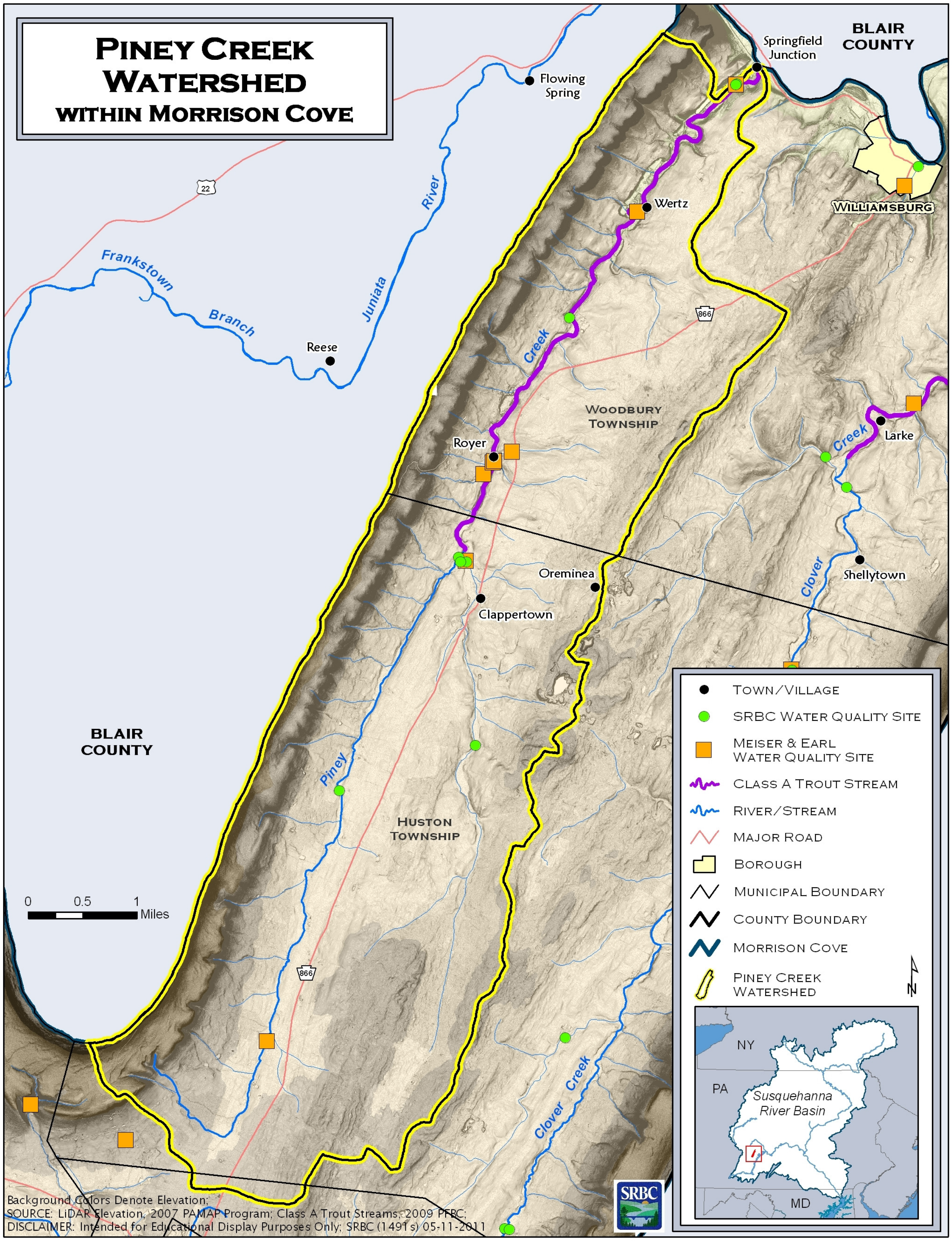

Figure 7-4. Piney Creek Watershed

Subwatershed Stream Condition and Recommendations

It is likely that the relatively intact forested lands along the ridgelines and slopes of Lock Mountain support the many functions provided by the associated headwater tributaries draining along the western portion of Piney Creek. The PADEP Designated Use Classification of HQ-CWF for Piney Creek (and all contributing tributaries) bespeaks a functioning stream ecosystem in which the aquatic community is supported by water quality not significantly impaired by the agricultural land use surrounding the headwaters and upgradient portions of the mainstem Piney Creek. Instream habitat assessments show a clear link between adjacent riparian buffer condition and channel form/instream habitat parameters. Sites with increased habitat scores for riparian cover, bank stability, and width showed corresponding higher scores for instream habitat parameters.

Recommendations for maintaining the stream classification in this subwatershed include maintaining all existing vegetative riparian buffers. Further removal of existing riparian areas would enhance erosional activities and increase bank instability, thereby resulting in degradation of the stream's water quality.

7.4.3 Halter Creek

The Halter Creek (WBD 0205030201) Watershed is the most developed watershed within Morrison Cove and as such, has additional water quality issues on top of the agriculturally-based ones discussed for the surrounding watersheds. Currently, Halter Creek has a PADEP Chapter 93 Designated Use Classification of Warm Water Fishery (WWF), although that is under review; the current existing use for a large portion of the stream is Cold Water Fishery (CWF). Additionally, the final 2.3 miles of Halter Creek, downstream of its confluence with Plum Creek, have recently been designated as Class A Trout Waters by the Pennsylvania Fish and Boat Commission (PFBC). Halter Creek drains northwest to its confluence with the Frankstown Branch Juniata River (Figure 7-5). The lower three miles of Halter Creek are listed on the 303(d) list as impaired waters for total suspended sediment due to urban runoff and storm sewers (Figure 7-1). There are numerous headwater tributaries draining off the forested hillslopes west of the Halter Creek mainstem. The land use surrounding Halter Creek headwaters is agricultural and residential. As Halter Creek flows through the subwatershed, it is primarily surrounded by agricultural lands, with forested hillslopes located along the entire western section of the subwatershed. The borough of Roaring Spring is situated in the lower portion of the subwatershed, near the confluence of Halter Creek and Plum Creek. The Roaring Spring (Figure 7-6), in the town with the same name, is of vital importance to the local economy, as much of the industry is dependent on that water source. Overall, agricultural lands account for approximately 49 percent of the subwatershed. Forested lands account for approximately 34 percent of the subwatershed. Developed lands account for 17 percent of land use.

Cabbage Creek is a small tributary to Halter Creek and accounts for approximately four square miles in drainage area. Cabbage Creek has a PADEP Chapter 93 Designated Use Classification of WWF. The primary land use surrounding Cabbage Creek headwaters is agricultural. Overall, agricultural lands account for approximately 70 percent of the subwatershed. Forested lands account for approximately 11 percent of the subwatershed.

Developed lands constitute a relatively large portion of the watershed, at 19 percent. As Cabbage Creek flows through the southern outskirts of the Borough of Roaring Spring, minimal riparian areas are present (Figure 7-7). At the confluence of Cabbage Creek and Halter Creek, there is a small portion of forested land that does include vegetated riparian areas. It is in this most downstream reach that riparian cover, bank condition, and vegetative zone width were highest.

Plum Creek is the other significant tributary to Halter Creek and it drains 17.4 square miles. Currently, Plum Creek has a PADEP Chapter 93 Designated Use Classification of WWF, although that is under review and the current existing use is HQ-CWF. In addition, from the confluence of Plum Creek and Halter Creek, to a distance of 3.4 miles upstream, the stream has been classified by PFBC as a Class A Wild Trout Stream. The land use surrounding Plum Creek headwaters is a mixture of urban developed and agricultural. The Plum Creek mainstem flows through primarily agricultural lands. There are numerous headwater tributaries located along the northeastern portion of Plum Creek's drainage basin, flowing from forested upgradient hillslopes on the western slopes of Lock Mountain. The lower gradient valley bottom portions of the subwatershed are dominated by agricultural land use and urban developed land use surrounding the town of Martinsburg. Overall, agricultural lands account for approximately 54 percent of the subwatershed. Forested lands account for approximately 32 percent and developed lands account for 14 percent of land use. The final 1.4 miles of Plum Creek are listed on the 303(d) list of Impaired Waters for siltation due to road runoff and bank modification (Figure 7-1).

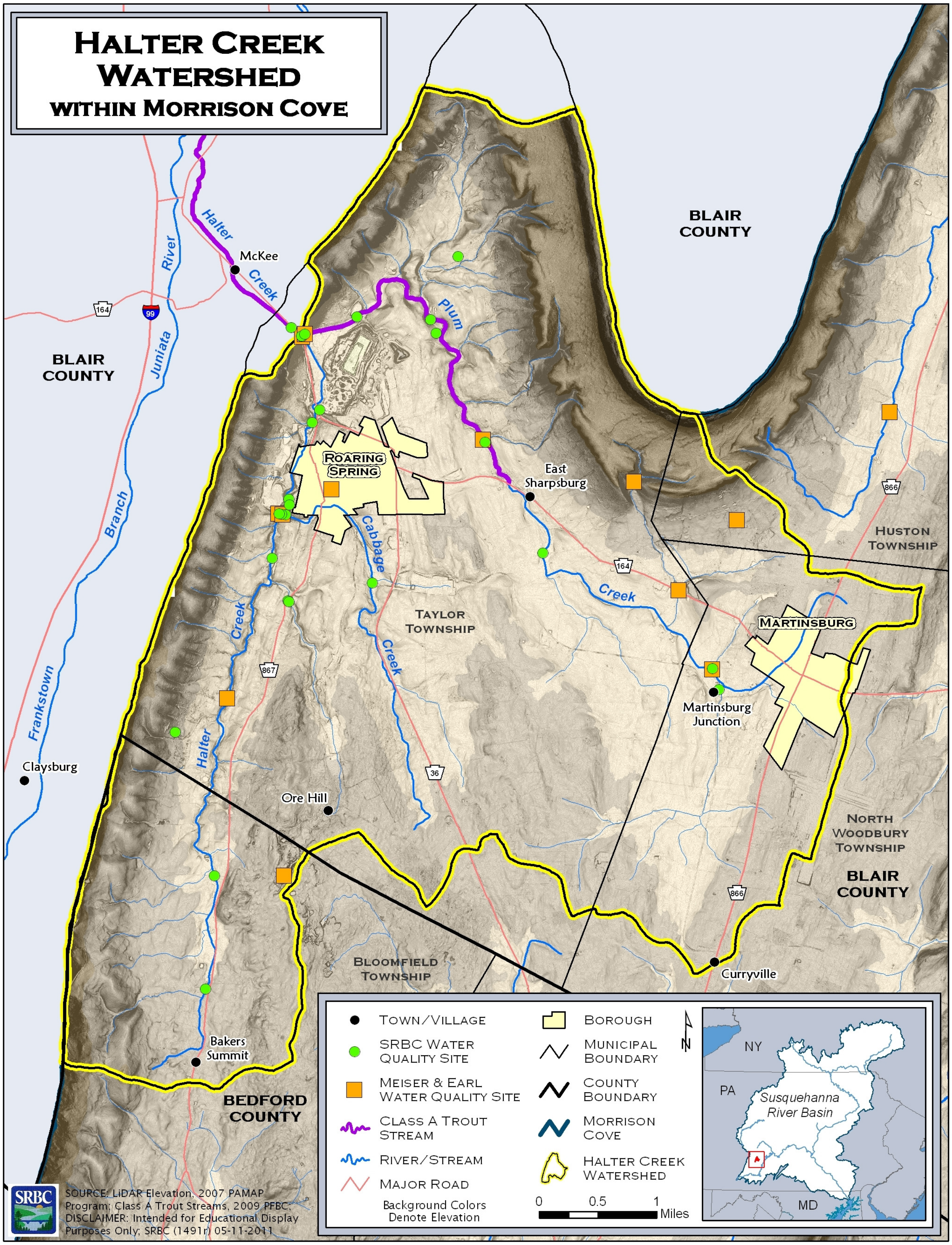

Figure 7-5. *Halter Creek Watershed*

Water Quality

Within the 32-square-mile drainage of Halter Creek, numerous springs help provide consistent base flow, but also input excess nutrients into the surface water. Due to issues of ongoing development and the critical importance of water, SRBC sampled the Halter Creek Watershed more intensely. As a result, a more spatially robust dataset (six sites on Halter Creek, two sites on Cabbage Creek, and three sites on Plum Creek) is available for this watershed. The headwaters of Halter Creek have a different chemical signature than the remaining sections of the watershed. These headwaters are likely influenced prominently by the ridge geology as the water chemistry signals do not reflect carbonate valley geology. Alkalinity, hardness, and conductivity are much lower and nitrate concentrations are less than 1 mg/l. Upstream of the confluence of Cabbage Creek, Halter Creek has more typical water chemistry for Morrison Cove. Nitrate concentrations above the confluence with Cabbage Creek average 2.8 mg/l. Cabbage Creek is a small drainage but it has a great influence on Halter Creek, raising the nitrate concentrations by nearly 2 mg/l. Cabbage Creek originates in a spring complex (Figure 7-8) and numerous samples from these springs were analyzed. Nitrate concentrations were consistently greater than 10 mg/l. Downstream of Cabbage Creek but upstream of the Town of Roaring Spring, water quality is similar to the site upstream of Cabbage with the exception of nitrate, which averaged 4.6 mg/l.

Figure 7-6. Roaring Spring Outflow (Instrumented weir provided daily flow measurements for use in this study.)

Figure 7-7. ***Cabbage Creek Flowing under the Driveways of Homes in Roaring Spring (The plant growth in the stream is predominantly watercress.)***

Figure 7-8. ***Spring Complex along Cabbage Creek***

On Halter Creek, downstream of the wastewater treatment plant, nitrate levels remain unchanged but a noticeable spike in chloride is evident. Further downstream, below the quarrying operation, nitrates remain constant but the chloride concentrations spike again and there is a dramatic increase in sulfate. Above Roaring Spring, chloride concentrations average 16 mg/l, and below the wastewater treatment plant and quarry, the average is 48 mg/l. These chloride levels are well below the water quality standard of 250 mg/l but the spike is worth noting nonetheless. Similarly, sulfate concentrations below the quarry are nearly three times higher than just a mile upstream. Again, sulfate does not violate water quality standards, but it is worth noting. Halter and Cabbage Creek both have a Ca/Mg ratio of about 1.3, which indicates a dolomite source.

Plum Creek joins Halter Creek just below the quarry in Roaring Spring (Figure 7-9). Plum Creek has its own unique set of water quality issues. Plum Creek has nitrate concentrations above 5 mg/l and as high as 8 mg/l throughout the watershed. Additionally, chloride concentrations are five to ten times higher in Plum Creek than in any other stream in Morrison Cove. In the headwaters of Plum Creek, concentrations were routinely more than 100 mg/l, and the other sites on the stream had an average chloride concentration of more than 45 mg/l. This is likely due to effluent from the Martinsburg Wastewater Treatment Plant. Although Plum Creek is highly spring-fed (Figure 7-10), flow measurements indicate a likely natural decrease of up to 90 percent between spring and fall.

Figure 7-9. Within the High Quality–Cold Water Fishery Section of Plum Creek

Figure 7-10. Outflow from Spring Complex near the Mouth of Plum Creek (Green vegetation in stream is watercress.)

Finally, the northern exit point of Morrison Cove is Halter Creek about two miles before it empties into the Frankstown Branch Juniata River. The water quality at this site is better because the high sulfate concentration of Halter is diluted by the added flow from Plum Creek, and the high chlorides in Plum are diluted by the added flow of Halter Creek. However, the nitrate concentrations remain fairly high with an average value of 5.4 mg/l.

Riparian Area Condition

The headwaters of Halter Creek are located in transitional lands partly forested and partly agricultural, with marginal forested riparian areas located only in the uppermost section of the headwaters. Along the lower headwater segments, at the beginning of the mainstem Halter Creek, riparian areas appear to have been cleared along agricultural lands bordering the stream. For the majority of the stream channel flowing along the valley floor through agricultural lands, most riparian areas have been cleared, or where existing, consist of marginal grasses. Field notes by SRBC staff indicate livestock have unrestricted access to streambanks in various agricultural lands along Halter Creek. In the middle portion of the subwatershed, intact forested riparian buffers are present for approximately two miles until the stream reaches the outskirts of Roaring Spring, where developed lands replace vegetated riparian areas. Halter Creek flows through the lands owned by New Enterprise Stone & Lime Company, adjacent to the New Enterprise Stone Roaring Spring Quarry. The riparian area appears to consist of a narrow grass filter strip in this area.

Aquatic Habitat Condition

Visual aquatic habitat assessments were performed by SRBC staff at five sampling points along Halter Creek, two points along Cabbage Creek, and five points along Plum Creek in October 2009.

The five sampling points along Halter Creek were named Halter 5–Halter 1 (upstream-downstream, respectively), and presented a relatively stable series of instream habitats. Halter 5 was located in the most upstream portion of the subwatershed, with all subsequent sampling points located downstream. Sampling point Halter 5 was surrounded by mixed land use (residential, forested, agriculture) and was located adjacent to a paved road. Instream habitat parameters (cover and epifaunal substrate) scored poor for this site relative to all other Halter Creek sample points, diminishing available fish cover habitat and interstitial habitat for benthic macroinvertebrates. Additional instream habitat parameters (sediment deposition, embeddedness, channel alteration) scored suboptimal for the sample point. This indicates stormwater runoff is likely eroding streambanks and depositing fine sediments on the channel bottom. Halter 4 was located downstream of a paved road and a farm, along a reach entirely surrounded by a forested riparian area. It scored optimal for riparian cover, vegetation, and bank condition. Instream habitat was suboptimal (epifaunal substrate, instream cover, embeddedness, sediment deposition, channel alteration).

Halter 3 was located immediately upstream of an impounded section of the stream, in a section of the subwatershed with forested riparian areas. It scored optimal for riparian cover, vegetation, bank condition, and channel alteration. Instream parameters for epifaunal substrate, instream cover, and sediment deposition scored suboptimal. Sampling point Halter 2 was located in a small but well-forested riparian area with moderate residential land use and a highway adjacent to it. Roaring Spring Sewage Treatment Plant discharges to Halter Creek, 230 feet upstream of the sample point. Despite its proximity to the discharge point, the sample site presented high quality instream habitat parameters. Alternatively, the site had poor to marginal riparian areas, likely remnant of road construction in the area. Sampling point Halter 2 was located approximately 150 feet downstream of New Enterprise Stone Roaring Spring Quarry, near the confluence of Halter Creek with the Frankstown Branch Juniata River. Typical of developed areas, the riparian area along this stretch of stream had been removed (scoring poor for vegetative cover and riparian width). Epifaunal substrate scored optimal as an instream parameter but all other parameters scored suboptimal.

The two sampling points along Cabbage Creek, called Cabbage 1 and Cabbage 2, respectively, presented varying instream habitats. Cabbage 2 was located at the confluence of the two headwater tributaries, at a point along a roadside ditch section of Cabbage Creek. Sampling point Cabbage 1 was located near the confluence with Halter Creek, at the most downstream portion of the subwatershed, and was entirely surrounded by forested lands. Cabbage 2 included instream rip rap and artificial substrate. One streambank was concrete, gravel, and stone, leading up to a paved road. The opposite streambank had minimal riparian vegetation. The site scored poorly for nearly all instream parameters, including instream cover, embeddedness, sediment deposition, and channel alteration. Thus, available fish cover habitat and interstitial habitat for benthic macroinvertebrates were nearly nonexistent. Cabbage 1 had higher quality riparian areas (optimal scores) along the sampled stream length for vegetative cover (forested), stable streambanks, and riparian widths. The instream habitat condition also presented optimal for nearly every parameter for this sample point.

The five sampling points along Plum Creek, called Plum 5–Plum 1 (upstream-downstream, respectively), presented a more stable series of instream habitats. Plum 5 was located in the most upstream portion of the subwatershed, with all subsequent sampling points located downstream. Plum 5 was surrounded by agricultural crop lands, although it appeared to have a small forested buffer located at the sample point. This forested buffer is the likely reason that this sample point scored higher for both riparian protective cover and condition of streambanks. However, instream habitat parameters (cover and epifaunal substrate) and sediment deposition scored poor for this site relative to all other Plum Creek sample points, diminishing available fish cover habitat and interstitial habitat for benthic macroinvertebrates. There is a NPDES discharge point (Martinsburg Sewer Treatment Plant) located 570 feet upstream of Plum 5, which is the likely cause of the relatively degraded instream habitat parameters at this sample point. Plum 4 was located in Plum Creek along a reach entirely dominated by cropland. It appeared that this stream reach had a grass riparian area intact, resulting in relatively optimal scores for riparian cover and bank condition. Riparian area width scored poor, as evidenced by a narrow strip buffer in place at the site. Instream habitat scored a mixture of marginal (epifaunal substrate, frequency of riffles) and suboptimal (instream cover, embeddedness, sediment deposition, channel alteration). Plum 2 was located in a section of the subwatershed that included a moderate forested riparian area on its west bank, but was located downslope of a farm on its eastern bank, with no intervening riparian area to filter runoff. Instream parameters for embeddedness, sediment deposition, and riparian areas scored suboptimal for the sample point, whereas nearly all other instream parameters scored optimal. Sampling points Plum 3 and Plum 1 had higher quality riparian areas (optimal scores) along the sampled stream length, consisting of increased vegetative cover (both grass strips and forested), stable streambanks, and increased riparian widths. The instream habitat condition was also optimal for nearly every parameter for these sample points.

Subwatershed Stream Condition and Recommendations

Other than for a small section of Halter Creek near the terminus of the subwatershed, the entire subwatershed is listed on PADEP's 303(d) list as attaining for supporting aquatic life use. The impaired sections of Halter Creek are listed as impaired by suspended solids from urban runoff/storm sewers (Figure 7-1). Relatively simple vegetated retention buffers or swales could be installed at, or immediately downstream of, the discharge points in an effort to promote discharge retention and filtering.

Riparian cover at Halter 5 and Halter 4 was completely different, yet instream habitat parameters indicate similar quality. This indicates that upstream flows and sediment loads likely dictate instream habitat quality through this section of the Halter Creek mainstem despite the presence of an intact forested riparian buffer at Halter 4. This would suggest that restoring riparian buffers adjacent to the stream, along the entire section of Halter Creek as it flows through agricultural lands in the subwatershed, would be beneficial to improve instream habitat quality. The downstream sample points (Halter 3 and Halter 2) were located in areas surrounded by residential land use and included higher quality riparian areas.

The entire Cabbage Creek subwatershed is listed on PADEP's 303(d) list as attaining for supporting aquatic life use. Urban BMPs should be considered for the developed lands in and around Roaring Spring as related to stormwater runoff into Cabbage Creek, especially in sections of the stream adjacent to roadways. Stormwater runoff from impervious cover increases runoff rates, thereby transporting larger volumes of water to streams. This results in flashy flow events that erode and destabilize streambanks. Increased stormwater runoff where riparian areas are absent leads to decreased infiltration and retention rates of stormwater, with all its pollutants, and sediment. These substances are transported directly into Cabbage Creek, resulting in impaired instream habitat and aquatic communities. Forested lands surrounding tributary headwaters and downstream reaches of Cabbage Creek should be prioritized for preservation to maintain the higher quality instream habitat and riparian areas associated with these stream segments.

Other than for a small section of Plum Creek near the mouth of the creek, the entire subwatershed is listed on PADEP's 303(d) list as attaining for supporting aquatic life use. The impaired reaches of Plum Creek adjacent to the quarry are listed as impaired by siltation from bank modification and road runoff. The NPDES discharge point located just upstream of Plum 5 is likely impacting this reach of Plum Creek. Stormwater BMPs outlined by the USEPA could be installed and implemented such that the discharge points at multiple sites along Plum Creek are managed in a way to promote retention and infiltration. Similarly, urban BMPs should be considered for the developed lands in and around Martinsburg as related to stormwater runoff into the Plum Creek headwaters.

For sections of Plum Creek classified as a Class A Wild Trout Stream, riparian restoration efforts should be considered in an effort to protect cool water temperatures in this high quality stream. Forested lands surrounding tributary headwaters and downstream reaches of Plum Creek should be prioritized for preservation in order to maintain the higher quality instream habitat and riparian areas associated with these stream segments.

7.4.4 Yellow Creek

The Yellow Creek (WBD 0205030306) Watershed is a larger (85 square miles, 70 square miles within Morrison Cove) and more complex watershed than either Clover or Piney Creek and makes up 30 percent of Morrison Cove (Figure 7-11). There are four major tributaries to Yellow Creek: Hickory Bottom Creek, Potter Creek, Three Springs Run, and Beaver Creek. Between all these major tributaries and small feeder tributaries, 174 stream miles are impaired by nutrients and/or sediment in the Yellow Creek Watershed. This accounts for more than 98 percent of all the impaired stream miles in Morrison Cove. Possible sources for excessive nitrate concentrations in Yellow Creek Watershed include a range of agricultural activities present within the watershed. These include crop and grazing-related agriculture, as well as animal feeding operations. Nearly the entire portion of the Yellow Creek Watershed located within Morrison Cove is listed as impaired for aquatic life (Figure 7-1). Land use in the portion of Yellow Creek within the Cove is 41 percent forested, 54 percent agriculture, and just 5 percent developed land.

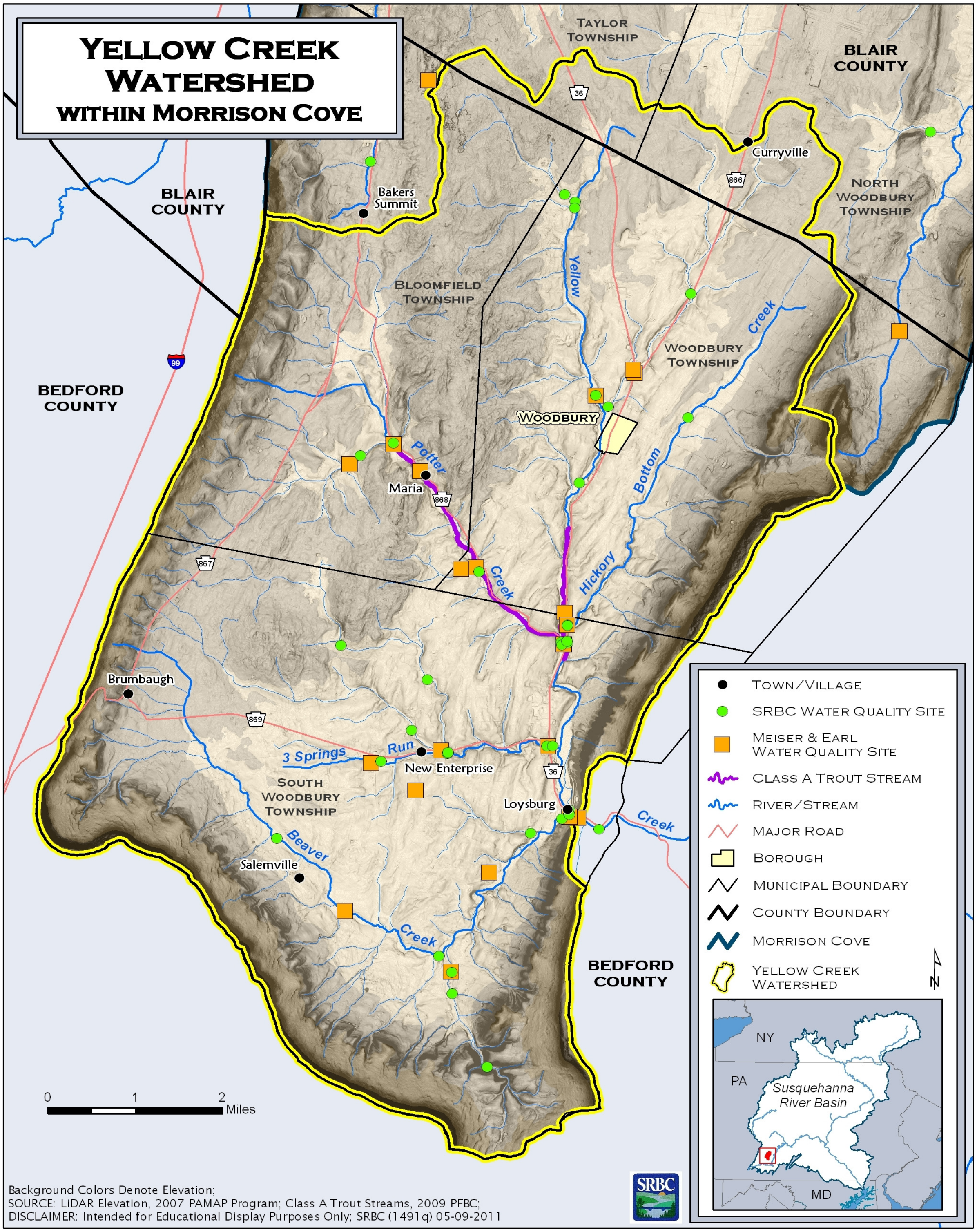

Figure 7-11. Yellow Creek Watershed

Two sites on Yellow Creek (one above Potter Creek and one near where the stream exits Morrison Cove) have at least five sampling data points, as does one site at the mouth of each of the major tributaries. Hickory Bottom has a PADEP Chapter 93 Designated Use Classification of HQ-CWF. Many other sites on Yellow Creek and its tributaries were sampled one time, and these data provide added spatial context to some of the data results. In the Yellow Creek Watershed, the mainstem of Yellow Creek and all major tributaries except Hickory Bottom Creek show a dolomite signature with Ca/Mg ratios less than 1.6. Hickory Bottom seems to originate from a more limestone-based geology with a Ca/Mg ratio of 2.6. A majority of the flow into Hickory Bottom Creek, especially in the summer and fall months, comes from an outflow of Hipple's Cave (Figure 7-12).

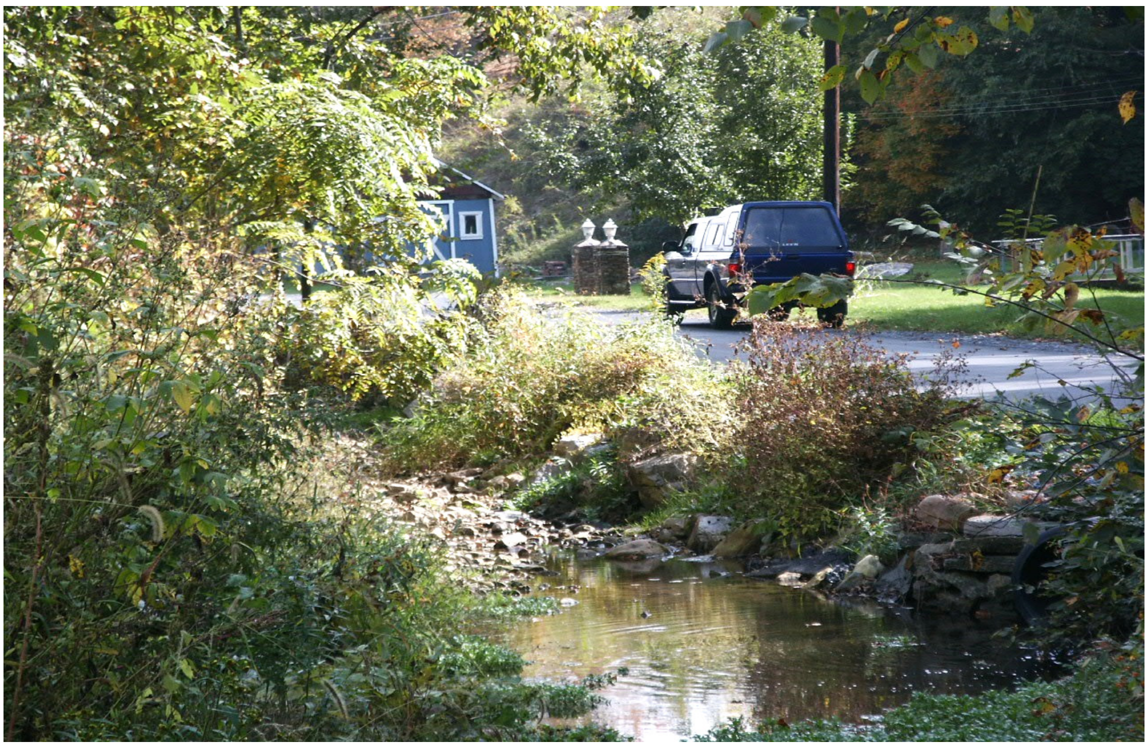

Figure 7-12. Hickory Bottom Creek (Note all flow is coming from Hipple's Cave, a conduit in the toeslope carbonates, under the road and to the right. Hickory Bottom Creek above this point was dry (channel diverging to the left).)

The upstream site on Yellow Creek showed elevated nitrates with an average concentration greater than 8.0 mg/l. Two springs were sampled above this site, one by SRBC and one by Meiser & Earl, Inc., and both had nitrate concentrations of more than 12 mg/l, which is contributing to the elevated nitrate in the upstream reaches of Yellow Creek. The downstream site, near the exit point of the stream out of the Cove, has a nitrate concentration that is 2 mg/l less than the upstream site. Sodium, sulfate, and chloride concentrations were all low and similar to Piney and Clover Creeks. Flows can decrease about 80 percent in Yellow Creek from spring to fall.

Hickory Bottom Creek (a seven-square-mile drainage area) enters Yellow Creek from the east and has the lowest nitrate concentrations of anywhere in Yellow Creek; it is also the smallest of the major tributaries. Nitrate at the mouth of Hickory Bottom Creek averages 4.9 mg/l. Streamflow in the dry summer and fall months is commonly less than one cfs and can decrease as much as 90 percent from spring to fall. Numerous observations have been made that above the confluence with the Hipple's Cave inflow, Hickory Bottom Creek is often dry during September and/or October. Three of the seven farms where WPC was working on streambank fencing projects were in the Hickory Bottom Creek Watershed.

7.4.5 Potter Creek

Potter Creek is the next downstream tributary in the Yellow Creek basin. It enters from the west and drains 13 square miles. Potter Creek has a PADEP Chapter 93 Designated Use Classification of HQ-CWF. It drains southeast to its confluence with Yellow Creek. The entire mainstem of Potter Creek has been classified as a Class A Wild Trout Stream. As Potter Creek flows through the subwatershed, it is primarily surrounded by agricultural lands, with forested hillslopes and ridgelines located along the western and northern portions of the subwatershed. Overall, agricultural lands account for approximately 53 percent of the subwatershed. Forested lands account for approximately 45 percent of the subwatershed. Developed lands constitute a small portion of the subwatershed, accounting for only 2 percent of land use.

Water Quality

At the mouth, nitrate concentrations average almost 5.5 mg/l. Streamflows remained more constant in Potter Creek than other tributaries due to the influence of numerous large springs coming into the stream along its entire length. Four springs that feed Potter Creek were sampled. The more upstream spring locations had nitrate concentrations that were more than two times lower than the most downstream spring sampled by SRBC, which averaged more than 13.5 mg/l. Hardness and conductivity were also much higher in this downstream spring, located along Rt. 868. Potter Creek is one of the most highly-used recreational trout fishing streams within the Yellow Creek Watershed.

Riparian Area Condition

All three main headwater areas draining to the mainstem of Potter Creek are located in heavily forested lands, primarily hillslopes or ridgelines, with riparian areas almost entirely intact. All other headwater tributaries draining off Dunning Mountain appear to include intact forested riparian areas. Along the Potter Creek mainstem, riparian areas appear to have been maintained along limited portions of the stream and cleared along many of the agricultural lands bordering the stream (Figure 7-13).

Figure 7-13. Lack of Riparian Vegetation and Channel Cover along Potter Creek

<u>Aquatic Habitat Condition</u>

Visual aquatic habitat assessments were performed by SRBC staff at four sampling points along Potter Creek in October 2009.

Potter 4 through Potter 1 were sample points in this subwatershed. Potter 4 was located in the most upstream portion of the subwatershed. Potter 3 was also located in the upper portion of the watershed. Potter 2 and Potter 1 were located downstream from Potter 3. Potter 4 was surrounded by mixed land use (transitional, agricultural, and residential) and included a marginal forested riparian area. Instream habitat parameters (epifaunal substrate, cover sediment deposition) generally scored poorly. Because this site had a marginal riparian buffer, it is likely that stormwater runoff from the surrounding lands impacted the habitat quality at this sample point. Land use surrounding Potter 3 was similar to Potter 4. A minimal forested riparian area was present at the sample point. The sample point scored optimal for instream habitat parameters as related to sedimentation and suboptimal for habitat substrate and cover, suggesting the riparian buffer is functioning to filter out excess sediment loads either from overland flow or storm pulse events. Potter 2 was surrounded by agricultural fields and was just upstream of a farm. There was no intact riparian area present at the site, but a large, 21-acre palustrine/emergent wetland complex was located just upstream of the sample point. Instream habitat parameters (embeddedness, channel alteration, channel flow) scored optimal while epifaunal substrate, cover, channel alteration, and sediment deposition scored suboptimal. Potter 1 was located in a residential area that included no riparian area. Despite the lack of riparian area, the site scored optimal for nearly all instream habitat parameters other than those related to riparian zone width.

Subwatershed Stream Condition and Recommendations

The sites in this subwatershed presented data generally indicating that the Potter Creek Watershed provides supporting habitat. It seems the numerous forested headwaters draining off Dunning Mountain are contributing stable flows and high quality water to the Potter Creek mainstem. These forested lands, beyond those protected in the State Game Lands, surround the tributary headwaters and should be prioritized for preservation.

Recommendations for maintaining the HQ-CWF stream classification in this subwatershed include maintaining all existing vegetative riparian buffers. Further removal of existing riparian areas would enhance erosional activities and increase bank instability, thereby resulting in a degradation of the stream's water quality.

However, almost the entire subwatershed is listed on PADEP's 303(d) list as impaired by agriculture in terms of siltation. This has resulted in a non-attaining status for supporting aquatic life for the majority of streams in the subwatershed. To remediate excess siltation events that have contributed to the subwatershed's impaired waters, riparian areas need to be restored or reestablished where missing. Streambank fencing and cattle exclusion would also be beneficial in this watershed. For sections of Potter Creek classified as a Class A Wild Trout Stream, riparian restoration efforts should be considered in an effort to protect cool water temperatures in this high quality stream.

7.4.6 Three Springs Run

Three Springs Run also comes into Yellow Creek from the west and is similarly influenced by the influx of numerous springs, although it has a smaller drainage area (9.7 square miles). Three Springs Run has a PADEP Chapter 93 Designated Use Classification of HQ-CWF. It drains east to its confluence with Yellow Creek. Three Springs Run derives its name from the three main headwater springs draining to form the mainstem. The two northern-most headwaters are located in the upper western reaches of the subwatershed and include numerous tributaries originating from the forested hillslopes of Dunning Mountain. As Three Springs Run flows through the subwatershed, it is primarily surrounded by agricultural lands, with intermittent forested riparian areas along the channel. Overall, agricultural lands account for approximately 76 percent of the subwatershed. Forested lands account for approximately 18 percent of the subwatershed. Developed lands constitute a small portion of the subwatershed, accounting for only 6 percent of land use.

Water Quality

Nitrate concentrations at the mouth of Three Springs Run averaged 8.8 mg/l, which is the highest of any of the Yellow Creek tributaries. Conductivity and hardness are also considerably higher than the other tributaries. Upstream grab samples for nitrate showed lower concentrations upstream. Streamflows do not fluctuate as much as in some other Morrison Cove streams, which is likely due to the high groundwater contribution. Two springs were sampled in the Three Springs Run Watershed, both of which showed nitrate levels of about 8 mg/l.

Riparian Area Condition

All three main headwater areas draining off Dunning Mountain are located in heavily forested lands, primarily hillslopes or ridgelines, with riparian areas almost entirely intact. All other headwater tributaries draining off Dunning Mountain appear to include intact forested riparian areas. As these headwaters reach the valley floor, riparian areas become less prevalent as most land use is agricultural up to the streambanks (Figure 7-14). However, there are many stream segments with intact riparian buffers, and overall, there appears to be more riparian areas in this subwatershed than in many of the other subwatersheds comprising Morrison Cove.

Figure 7-14. Siltation Fencing and Constructed Banks along a Reach of Three Springs Run

Aquatic Habitat Condition

Visual aquatic habitat assessments were performed by SRBC staff at six sampling points along Three Springs Run in October 2009; however, the three most upstream sites (THRS 6-4) were dry at the time of assessment.

Three of the six sampling points had flow (THRS 3–THRS 1) and were included in the habitat assessment. THRS 3 was located in the most upstream portion of the subwatershed on the southern headwater branch draining to the Three Springs Run mainstem. Land use surrounding THRS 3 consisted of residential and agricultural. Field notes indicate no riparian cover was present at this sample point. With no riparian area to buffer runoff events from surrounding lands, instream habitat parameters were likely impacted, as reflected in marginal scores for instream cover, epifaunal substrate, sedimentation, and channel alteration. Marginal scores for these parameters indicate that high flow events are likely flashing through the channel unabated. Riparian area vegetation would serve to slow down stormflows and filter pollutants. THRS 2 was located at the confluence of the headwaters to form the mainstem Three Springs Run. Land use surrounding the sample point consisted of agricultural fields, farms, residential areas, and minimal forest cover. Field notes indicate heavy sedimentation immediately upstream of THRS 2. The sample point scored poor for embeddedness and sedimentation, effectively eliminating available interstitial habitat availability for benthic macroinvertebrates. THRS 1 was located the farthest downstream, near the confluence with Yellow Creek. The sample point was just upstream of a paved road, and surrounded by agricultural lands, commercial development, and a farm. A forested riparian area was present on the southern bank of the stream. The site scored suboptimal for most instream habitat parameters except for sedimentation, which scored marginal. The higher instream scores are likely due to the presence of a fairly intact forested riparian area. Instream cover (fish cover) and bank stability both scored well for all three sites.

<u>Subwatershed Stream Condition and Recommendations</u>

The sample points in this subwatershed presented data generally indicating that supporting habitat was available throughout the watershed. Much like in the Potter Creek subwatershed, it seems the numerous forested headwaters draining off Dunning Mountain are contributing stable flows and high quality, spring-fed water to the Three Springs Run mainstem. These forested lands should be prioritized for preservation.

Recommendations for maintaining the HQ-CWF stream classification in this subwatershed include maintaining all existing vegetative riparian buffers. Further removal of existing riparian areas would enhance erosional activities and increase bank instability, thereby resulting in a degradation of the stream's water quality. However, the entire subwatershed is listed on PADEP's 303(d) list as impaired by agriculture in terms of siltation. This has resulted in a non-attaining status for supporting aquatic life for all streams in the subwatershed. To remediate excess siltation events that have contributed to the impaired stream reaches, riparian areas need to be restored or reestablished where missing.

7.4.7 Beaver Creek

Beaver Creek is the last named tributary to enter Yellow Creek within the confines of Morrison Cove and forms the southern boundary of Morrison Cove region. It is also the largest tributary to Yellow Creek, draining 19 square miles. Beaver Creek has a PADEP Chapter 93 Designated Use Classification of HQ-CWF. It drains south and east to its confluence with Yellow Creek. Beaver Creek has numerous headwaters originating on the forested slopes of Dunning Mountain, in the western portion of the subwatershed. As Beaver Creek flows through the subwatershed, it is primarily surrounded by agricultural lands, with intermittent forested riparian areas along the channel. Forested hillslopes form the western and southern boundaries of the subwatershed, from which numerous headwater tributaries drain to the Beaver Creek mainstem. Overall, agricultural lands account for approximately 42 percent of the subwatershed.

Forested lands account for approximately 55 percent of the subwatershed. Developed lands constitute a small portion of the subwatershed, accounting for only 3 percent of land use.

Water Quality

Beaver Creek is unique in that aside from the sampling location at the mouth, which does have a high nitrate concentration (5.6 mg/l), the rest of the upstream locations showed nitrates levels of less than 1.5 mg/l. It is likely that the majority of the nitrate problem is coming from numerous springs in the lower portion of the watershed. One of these springs was sampled by Meiser & Earl, Inc. in October 2009, and had a nitrate concentration of 14.6 mg/l. It is likely that other nearby springs contain similar nitrate concentrations. All samples taken in the upstream portion of the watershed have little to no nitrate above background levels of 1 mg/l. In all the tributaries of Yellow Creek, sulfate, chloride, and sodium were very low and were not water quality issues at all.

Riparian Area Condition

Riparian area condition is similar to that in Three Springs Run subwatershed to the north. All headwater areas draining off Dunning Mountain are located in heavily forested lands, primarily hillslopes or ridgelines, with riparian areas almost entirely intact. As these headwaters reach the valley floor, riparian areas become less prevalent as most land use is agricultural up to the streambanks. The Beaver Creek mainstem flows through agricultural lands across which most riparian areas have been converted, thinned, or removed entirely.

Aquatic Habitat Condition

Visual aquatic habitat assessments were performed by SRBC staff at seven sampling points along Beaver Creek in October 2009; however, two sites (Beaver 7 and Beaver 2) had no flow at the time of assessment.

Five of the seven sampling points had flow (Beaver 6–Beaver 3 and Beaver 1) and were included in the habitat assessment. All five sampling points were located in the lower half of the subwatershed. Land use surrounding Beaver 6 consisted of intact forested lands. The site scored optimal for all habitat parameters except channel flow status. However, given the intact lands surrounding this headwater channel, it seems channel flow was probably just part of the natural hydrologic regime for the October sampling time period. Beaver 5 was surrounded by a farm, a pond, and agricultural fields. A narrow forested riparian area was present at the site. Instream habitat parameters scored suboptimal for sediment deposition and embeddedness, indicating higher sediment loads occurring along this segment of the stream. Streambanks scored optimal in terms of stability, as did epifaunal substrate, instream cover, channel flow, channel alteration, and riparian vegetative cover.

Beaver 4 was located just downstream of Beaver 5 and included similar surrounding land use. Instream habitat parameters and riparian area also mirrored those at Beaver 5. The only noted difference was that instream cover scored marginal for this site. The sample point was located just below an access road, and as such, instream cover may have been marginal due to historic stream alteration from constructing the access road. Beaver 3 was located adjacent to a farm, and surrounded by agricultural fields. Field notes by SRBC staff indicate limited riparian area at Beaver 3 with livestock accessing the stream during the time of sampling. Excessive sedimentation was also noted at this sample point (Figure 7-15). With no riparian area to buffer runoff events from surrounding lands, instream habitat parameters were likely impacted, as reflected in marginal scores for embeddedness and sedimentation, thereby diminishing available interstitial habitat for benthic macroinvertebrates. All other instream habitat parameters presented suboptimal scores. Beaver 1 was located at the lower end of the subwatershed, near the confluence with Yellow Creek. Land use surrounding this sample point was primarily residential. No riparian area existed at the site. Instream parameters scored suboptimal (instream cover, embeddedness, sediment deposition, channel alteration) and optimal for epifaunal substrate, channel flow status, and frequency of riffles.

Figure 7-15. Erosion and Sedimentation along a Meander on Beaver Creek near the Mouth

<u>Subwatershed Stream Condition and Recommendations</u>

Similar to the data gathered for the adjacent Three Springs Run subwatershed, the sample points in this subwatershed indicate supporting habitat is present. The numerous forested headwaters draining off Dunning Mountain are likely contributing stable flows and high quality water to Beaver Creek. These forested lands should be prioritized for preservation.

Recommendations for maintaining the HQ-CWF stream classification in this subwatershed include maintaining all existing vegetative riparian buffers. Further removal of existing riparian areas would enhance erosional activities and increase bank instability, thereby resulting in a degradation of the stream's water quality.

However, the entire subwatershed is listed on PADEP's 303(d) list as impaired by agriculture in terms of excess nutrients and siltation. This has resulted in a non-attaining status for supporting aquatic life for all streams in the subwatershed. To remediate agricultural runoff events that have contributed to the subwatershed's impaired waters, riparian areas need to be restored or reestablished where missing. Streambank fencing for the purpose of livestock exclusion would also be beneficial in Beaver Creek Watershed.

7.5 Conclusions

Watersheds and subwatersheds include all lands that drain water to the stream network that lies therein. Thus, land use condition within a watershed has direct bearing on the condition of the streams within that setting. Forested lands surrounding streams provide numerous functions to protect high water quality and quantity, in addition to a host of ecosystem services. Agricultural lands, while important to the local economies, can often result in stream impairment from removal of streamside riparian areas. Targeting intact forested lands for preservation or protection will ensure protection of a watershed's streams. Focusing restoration efforts on riparian areas in agricultural and urban areas can often enhance stream channel and bank stability, cool stream temperatures, and provide high quality food sources to instream aquatic communities and habitat to terrestrial wildlife communities.

This chapter has presented factors that contribute to the water quality degradation of the streams in Morrison Cove. Agriculture is the most likely source for the elevated nitrate concentrations throughout the Cove, as it is the dominant land use. Common sources of nitrate are manure, fertilizers, and animal feedlots. Some efforts have been made to address the nitrate problem, including a regional manure digester and working with local farmers to implement BMPs, such as streambank fencing and increased riparian buffers along streams.

Besides the potential impact on human health through drinking water, high concentrations of nutrients can also have negative impacts on stream biota, aesthetics, and recreation opportunities. Eutrophication is defined as a condition in which a body of water has an excess of nutrients, frequently due to runoff from the land, which causes a dense growth of plant life and can lead to oxygen depletion, fish kills, and a loss of biodiversity.

In an effort to reduce nitrate concentrations in the waters of Morrison Cove, the Cove Area Regional Digester (CARD) project was founded. The purpose of this project is to turn the excess manure from surrounding dairy farms into usable products. Many beneficial end results are expected: a reduction in nutrient loading of nitrogen and phosphorus to groundwater and streams, reduction of ammonia gas emissions, an outlet for local manure disposal, and two practical products for re-sale: soil amendment material and power. The Morrison Cove area is home to over 25,000 head of dairy cattle which produce an estimated 200 tons of manure daily. Funding was recently secured for the full implementation of this project. Construction is slated to start in late 2011 with commercial operation beginning in late 2012.

The cause of the increased concentrations of chloride in the lower reach of Halter Creek and all of Plum Creek is likely due to the effluent from sewage treatment plants. The elevated sulfate concentrations in the lower reaches of the watershed are likely related to the adjacent quarry. The cause is the occurrence of evaporitic minerals (chiefly, the minerals anhydrite and gypsum, which are composed of calcium sulfate and hydrated calcium sulfate, respectively) in the formation being quarried (Bellefonte Formation) in the lower portion of the watershed. Particles of this mineral are released by the crushing and washing of the bedrock to make various grades of aggregate. These particles are then washed or blown into the stream. Chloride shows a seasonal trend; concentrations are much higher in the summer and fall months when streamflow is at its lowest, so the dilution factor is decreased considerably. Then the higher flows of winter and spring dilute the chloride, and concentrations are lower, although still higher than the rest of Morrison Cove streams.

Overall, the streams in Morrison Cove are productive and maintain thriving fish communities and adequate macroinvertebrate communities. However, dramatic seasonal declines in streamflow and the region-wide nitrate problem are important issues to consider. Given the low amount of water availability in Halter Creek, this could potentially be a problem in the designated Class A Trout Stream reach of Halter Creek, downstream of the confluence of Plum Creek. However, the importance of the large influx of colder groundwater from springs cannot be understated when it comes to sustaining excellent trout fisheries. The biggest detriment to macroinvertebrate communities in Morrison Cove is siltation, as fine sediment often compromises the quality of macroinvertebrate habitat.

Streamflow in most of the streams in Morrison Cove drops dramatically in the late summer and fall months and many headwater reaches and tributaries frequently go dry. Besides the nitrate issue, the water quality in these streams is fairly good but the elevated nitrate threatens the water resources of the region and should not be taken lightly. Because of the high degree of interaction between surface water and groundwater, elevated surface water nitrate concentrations reflect groundwater concentrations. This poses a real problem since groundwater is the primary source of drinking water for a majority of the region.

The data from this study linked with other surface water data from various places, including SRBC, seem to show that the nitrate concentrations in the groundwater are higher than those in the surface water, even during low base flow conditions. This leads to the conclusion that nitrate in the groundwater is being removed by some mechanism–possibly riparian corridors. Perhaps focusing efforts on restoring riparian buffer zones along the streams in Morrison Cove would not only reduce nitrogen inputs through overland flow but would also act as a filter for groundwater that is feeding these streams.

At a watershed or subwatershed scale, Morrison Cove presents a setting where land use is a mixture of ridges and valleys that support both intact, forested lands and agricultural areas. Developed or urban areas are sparse throughout the watershed, with the exception of the towns of Roaring Spring and Martinsburg. Subwatershed assessments within Morrison Cove indicate that there are numerous forested headwaters draining off the area's ridgelines. These forested headwaters typically have intact riparian areas, and contribute stable flows and high quality water to several streams located downstream in a subwatershed. Riparian areas, including those in forested headwater settings, function to store surface water and sediment runoff that occur during storm events, which reduces flood damage downstream. Riparian areas intercept, cycle, and accumulate chemical constituents in shallow subsurface flow, thus filtering out pollutants from overland flow and shallow groundwater that might otherwise contaminate adjacent waterbodies. Riparian vegetation provides streams (and dependent aquatic communities) with microclimate modification and shade, organic litter and wood inputs, nutrient retention and cycling, streambank stability, and control of sedimentation. Maintaining biodiversity is a major ecosystem function that riparian areas provide and is the basis for fisheries in addition to providing bird and wildlife habitat.

8.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter highlights significant findings and water resource management issues, along with recommendations. The water availability findings are useful as a basis for decision making by regulatory agencies, for planning by local communities for sustainable growth, and as a guide for water resource consultants. The recommendations are intended to address critical needs for improvement or protection. In some cases, the recommended actions are not covered under existing SRBC, state, and federal programs. If they are to be implemented, the stakeholders in Morrison Cove, including municipalities, major industries, and conservation and sporting groups, must do so. With the exception of local zoning and development codes, the implementation of most of the recommendations will require some funding. Specific recommendations regarding funding sources are beyond the scope of this study. However, state and federal grants and matching funds will likely be required. Up-to-date information is available from the state and federal regulatory agencies.

8.1 Water Availability Conclusions and Recommendations

Currently permitted, registered, and approved water use from the Roaring Spring exceeds SRBC's 10-year base flow sustainability limit. This indicates that on an infrequent basis, once every 10 years on average, water use will approach and possibly exceed the amount of natural aquifer recharge received. If the preceding few years have been wetter than normal, adverse impacts will be minimal. However, if the preceding few years have been dryer than normal, then noticeable impacts and water shortages are likely. Additional water resource development would likely result in more frequent and more severe periods of potential water shortage.

Current permitted, registered, and approved water use in the Halter Creek Watershed is approximately 87 percent of SRBC's 10-year base flow sustainability limit. Once the remaining 13 percent are utilized, additional water will have to be sourced from outside the Halter Creek Watershed.

Water resources are largely undeveloped in the Yellow Creek, Clover Creek, and Piney Creek Watersheds, and in the Northern Gatesburg Terrain. Current permitted, registered, and approved water use in these basins is a small fraction of SRBC's 10-year base flow sustainability limit. In order to ensure development in a sustainable manner and with minimal environmental impact, the following recommendations are suggested:

1) Groundwater withdrawals should be located such that the strike of potential water-bearing-zones does not intercept a perennial stream located within one mile of the well. This will help prevent the direct dewatering of streams and help to ensure that the water quality is not compromised by the surface water contribution.

2) Groundwater withdrawals should be located in the downstream reaches of the watersheds. This helps ensure that there is adequate contributing area, minimizes flow-depleted stream reaches, and minimizes alteration of the natural flow regime.

3) Flows should be routinely measured and recorded at the downstream ends of the Halter Creek, Plum Creek, Clover Creek, and Piney Creek Watersheds, and at the outlets of the Roaring Spring and Williamsburg Spring. This information will allow refinement of the streamflow statistics developed in this report, and will provide a basis for evaluating the impact of future withdrawals and land use changes.

8.2 Recommendations for the Management of the Gatesburg Terrain CARAs

The Gatesburg Terrain CARAs (Critical Aquifer Recharge Areas) contain the greatest quantity and quality of groundwater available for development in the Morrison Cove. They should be managed in a manner that safeguards the quantity and quality of water available from these remarkable resource repositories. The following recommendations will help to ensure the fulfillment of these goals.

1) The quantity of water available from the Gatesburg Terrains is directly related to the amount of recharge they receive. Water resource availability in the Gatesburg Terrains should be protected through the use of development BMPs, which minimize impervious cover, and stormwater management BMPs, which address the recharge of stormwater.

2) Land use and water use in the Southern Gatesburg Terrain needs to be carefully managed in order to minimize impacts to water quality. The land in these areas is not generally suitable for agricultural activities so nitrate contamination is not a likely issue. The soil and residuum readily absorb precipitation, maximizing groundwater recharge, but provide minimal protection from surface spills.

3) Water quality in the Gatesburg Terrains should be protected by discouraging additional/new land use and activities requiring the routine use of potential chemical contaminants, and by carefully managing the existing use of potential contaminants to avoid over-application or unintended release.

4) The amount of water available for development from the Southern Gatesburg Terrain is limited by potential habitat impacts to tributaries of Yellow Creek. These are fed by 'overflow' from the Southern Gatesburg Terrain and have a designated use of HQ. When the total of all of the SRBC-approved withdrawals equals or exceeds 10 percent of 7Q10 (for each draining tributary), a passby will be required. Such water sources are then, by definition, interruptible. Passbys are used by SRBC to protect the aquatic habitat and downstream users.

8.3 Recommendations for the Management of the Roaring Spring

Current permitted, registered, and approved water use from the Roaring Spring exceeds SRBC's 10-year base flow sustainability limit. This indicates that on an infrequent basis, once in 10 years on average, water use will approach and possibly exceed the amount of natural aquifer replenishment received. If the preceding few years have been wetter than normal, adverse impacts will be minimal. However, if the preceding few years have been dryer than normal, then noticeable impacts and water shortages are likely. Additional water resource development would likely result in more frequent and more severe periods of potential water shortage. Future water demands will need to be met from additional sources because the Roaring Spring is fully subscribed with respect to SRBC's sustainable withdrawal limit (10-year base flow).

The Roaring Spring is hydrologically connected to the Southern Gatesburg Terrain and the Yellow Creek Watershed. It represents a "natural" withdrawal (a groundwater discharge) from the Yellow Creek Watershed. Following recommendations made for protection of the Gatesburg Terrain CARAs (Section 8.2, above) will help to ensure sustainable water supplies and high quality aquatic habitat.

Care should be taken to avoid high volume withdrawals in the Gatesburg Formation outcrop area nearest the Roaring Spring in order to minimize the potential for impacting spring flow.

8.4 Recommendations for Mitigation of Nitrate Contamination

Nitrate contamination of groundwater is a major issue in the 55 percent of Morrison Cove that is dominated by agricultural land use. This longstanding problem has not been resolved through existing agricultural BMPs and manure management planning. Reduction of nitrate concentrations in the groundwater will require reduced application of manure on the land surface, either through reduced fertilization, by exporting it outside Morrison Cove, or by processing in a manure digester. Although it includes significant capital costs, the manure digester project is a long-term viable solution with many beneficial end results expected, including a reduction in nutrient loading of nitrogen and phosphorus to groundwater and streams, reduction of ammonia gas emissions, an outlet for local manure disposal, and two practical products for re-sale: soil amendment material and power.

Instream nitrate concentrations in Morrison Cove are generally below the safe drinking water standard (10 mg/l). However, all sampled streams had nitrate concentrations greater than the 75th percentile (2.3 mg/l) for all nitrate samples taken within the Susquehanna River Basin in the last five years, and a majority of nitrate concentrations are greater than the 95th percentile value (6.2 mg/l). For both groundwater and surface water, reduced nitrate concentrations and improved water quality in general not only benefit aquatic life and improve stream aesthetics through limiting excessive plant growth, but also lower water treatment costs for water suppliers. There is an effective, low cost approach to reduction of nitrate concentrations in surface waters that is neither widely used nor widely appreciated in the Morrison Cove area. The widespread use of riparian buffers would improve both stream water quality (through nitrate uptake) and benefit aquatic habitat.

Halter Creek and Plum Creek are the only two streams that have other water quality concerns in addition to the ubiquitous nitrate problem. Plum Creek and Halter Creek both have elevated concentrations of chloride, which likely result from the wastewater treatment plants within each catchment. The lower reaches of Plum Creek also have elevated sulfate concentrations believed to be related to the large quarry that is adjacent to and along the lower mile of the stream. Additional water withdrawals would only exacerbate the concentrations of these two pollutants and as such, to protect water quality, caution should be taken when considering new withdrawal requests.

In November 2010, PADEP amended its Chapter 102 regulations in regards to stormwater management, agricultural planning, erosion and sedimentation control requirements, and riparian buffer provisions. Strengthening planning and implementation of nutrient management plans and farm conservation plans in light of these new regulations would also be beneficial in addressing the major sources of nitrate with Morrison Cove.

8.5 Recommendations for the Protection and Restoration of Stream Quality and Aquatic Habitat

In order to protect and improve the quality of the streams in Morrison Cove, the upgradient forested riparian areas surrounding headwaters should be prioritized for minimal disturbance and preservation, or targeted for protection with a set-back ordinance. A setback distance of 100-300 feet (from the streamway) is recommended (PADEP, 2010; USEPA, 2005) for optimum nitrate uptake and protection/restoration of aquatic habitat. While all of the subwatersheds in Morrison Cove have multiple reaches where the lack of riparian buffer is a detriment, the Clover Creek and Yellow Creek subwatersheds seem to have more continuous reaches of stream that flow directly through agricultural lands with little or no buffer. In these watersheds, the implementation of riparian buffer vegetation in any combination of trees, shrubs, or unmowed grasses will improve bank stability, increase flood plain connectivity and habitat, decrease scouring and erosion, and improve stream cover for biota.

Riparian areas in downstream reaches are also critical to providing form and function to stream channels, banks, flood attenuation, and the aquatic ecosystem. Riparian buffers not only act as filters along streambanks for nutrient uptake, but they also provide many other additional benefits. They help stabilize streambanks, which reduces erosion and leads to a decline in downstream sedimentation. Excessive sedimentation is detrimental to both macroinvertebrate and fish communities. All Morrison Cove streams support some level of a trout fishery, including some HQ-CWF and some reaches of Class A Trout Waters. To maintain the high quality and/or cold water fishery designations of several streams in the watershed, intact streamside riparian areas must be maintained and inadequate riparian areas should be improved. Trout communities and other cold water fish species would greatly benefit from riparian buffers as they facilitate cooler stream temperatures through shading and often provide increased instream cover via woody debris, leaf packs, and root wads. Yellow Creek in particular is well known regionally as one of the best recreational trout fishing streams in central Pennsylvania. This status could only be improved through the addition of riparian buffers along stream channels. A set-back ordinance prohibiting development within 100-300 feet of an intact riparian area should be considered for the areas where intact riparian areas remain (PADEP, 2010; USEPA, 2005). Further removal of existing riparian areas should be discouraged or prohibited.

Many valley bottom areas within Morrison Cove include lands under agricultural development. For those lands where riparian areas remain intact, streambank fencing to keep livestock out of the stream would result in protection of these areas and the functions they provide. However, site visits have noted that many riparian areas in this setting have been cleared or thinned throughout these lands. As riparian areas are lost, the functions and benefits they provide are lost. In agricultural lands, the most significant results of riparian area loss are increased streambank instability, flooding, dissolved nutrients, turbidity, and siltation.

Several Morrison Cove subwatersheds are listed on PADEP's 303(d) list as impaired by agriculture in terms of siltation, primarily in the Yellow Creek subwatershed. This has resulted in a non-attaining status for supporting aquatic life for the majority of streams in the subwatershed. To remediate excess siltation events that have contributed to the subwatershed's impaired waters, riparian areas need to be restored or reestablished where missing. Land owners could pursue coordination with the county conservation district or a local Farm Service Agency representative regarding the state's CREP for installing conservation practices on their land. Such conservation measures could include the creation of forested riparian buffers, wetland restoration, planting of native trees, shrubs, and grasses along streams, and installation of streambank fencing to prevent grazing and trampling by livestock.

8.6 Recommendations for Development of Municipal Grade, Potable Water Supplies from Groundwater in the Carbonate Aquifers of Morrison Cove

Groundwater exploration efforts should focus on the aquifers having both high quality water and sufficient permeability to allow high production rates. The aquifers in the Interior Carbonates Terrain, with the exception of the Bellefonte Formation and the toeslope carbonates of the Mountainside/Toeslope Carbonates Terrain, are capable of relatively high yields from properly sited wells. These areas are extensively developed for agricultural use, and nitrate levels have historically been high, often exceeding the federal safe drinking water standard (10 mg/l). This water will most likely require treatment for nitrates and other agricultural chemicals. Sinkholes may be activated by the drilling, developing, and testing phases, or by the drawdown during well use months or years after drilling. These may cause subsidence damage to buildings and infrastructure (roads, water mains, etc.), or capture and divert local streamflow. The success of a program to develop a high capacity well in the karst-prone carbonates in the Interior Carbonates Terrain and in the Mountainside/Toeslope Carbonates Terrain is highly dependent on the services of a hydrogeologist and a driller with extensive experience in the development of high capacity wells in karst.

8.7 Recommendations for Development of Municipal Grade, Potable Water Supplies from Groundwater in the Gatesburg Formation

In the Morrison Cove study area, the Gatesburg Formation has both high quality water and sufficient permeability to allow the development of high capacity production wells. Gatesburg wells are best located in the interior of the Gatesburg Terrains to avoid drawing agricultural contaminants from the neighboring Interior Carbonates Terrain into the Gatesburg aquifer. Gatesburg wells will typically require a relatively long length of casing (100–300 feet) due to the deep weathering of the formation. Flowing sand and weak rock, often encountered in the Gatesburg, can increase drilling time and expense. Gatesburg wells frequently require screening to keep sand out of the well. Specialized drilling methods are generally employed due to the subsurface conditions encountered in the Gatesburg. These include cable tool drilling and various modified air rotary methods. The success of a program to develop a high capacity well in the Gatesburg Formation is highly dependent on the services of a hydrogeologist and a driller with extensive experience in the development of high capacity wells in unstable formations.

8.8 Optimum Well Locations

High rate withdrawals from aquifers within a given watershed will require an area of contribution of sufficient size to support the withdrawal on a sustainable basis. Large groundwater withdrawals are best located downgradient of major recharge areas, where the area of contribution is large and more water is available. Headwater watersheds generally do not have sufficient area to support high rate withdrawals. High rate withdrawals will reduce the base flow in a watershed. This will be especially evident during low base flow periods, when the flow is almost entirely from groundwater discharge. A downgradient location provides a relatively large area of contribution, and minimizes the stream miles with reduced base flow and modified flow regime. Well locations too close to a stream may result in streambed sinkholes and/or in a determination of 'surface water influence' due to poor filtration of stream water being drawn into the aquifer.

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Appendix A

Geologic Formations in the Morrison Cove Study Area

LOWER SILURIAN

Tuscarora Formation (400 feet):

Light to medium-gray sandstone and minor interbedded shale.

UPPER ORDOVICIAN

Juniata Formation (1250 feet):

Brownish to grayish-red sandstone, some siltstone, and shale.

Bald Eagle Formation (800 feet):

Gray to olive-gray and grayish-red, fine to course-grained sandstone, and some conglomerate.

Reedsville Formation (1250 feet):

Mainly dark gray to black shale, with interbeds of buff siltstone; increasingly more carbonaceous, with calcareous interbeds near the base (Antes Member). A cleavage, both fracture and slaty, may be developed locally. Becomes olive-gray higher in the section.

MIDDLE ORDOVICIAN

Loysburg-Coburn Formations (undifferentiated: 600 feet):

Coburn: Thin interbeds of dark gray argillaceous limestone and calcareous shale.

Salona: Thin (5-15 cm) beds of gray limestone with shaly partings; weathers to platy slabs.

Nealmont: Thick (91-2 m) interbeds of mottled gray, bioturbate limestone, and dove-gray micritic limestones.

Linden Hall: Thick interbeds of bioturbated limestone and gray micritic limestone.

Snyder: Finely laminated and relatively thinly bedded limestone and Mg-limestones, with local thin rip-up-clast conglomerates.

Hatter: Cycles of micritic dark gray limestone with bioclastic interbeds.

Loysburg: Interbeds of dove-gray limestone and limy dolostones; tiger-striped (1-2 cm) layering near base.

LOWER ORDOVICIAN

Bellefonte Formation (1200 feet):

Cycles of light gray, medium to thick bedded limy dolostones (packstones) capped with finely laminated micritic and locally algal dolostone. Three thick (1-3m) “beds” of chert, both massive white, and vemicular black (replaced bioturbation burrows) occur as regional markers. Elsewhere, chert is developed as rare nodules and thin (11-2 cm) beds. Dark gray to black mottled “pisolitic” beds occur in the cycles near the base.

Axemann Formation (180 feet):

Cycles of course bioclastic limestone capped by finely laminated, light gray to buff dolostone occur interlayered with dominantly fine-grained to micritic dolostones on a 10-meter scale.

Nittany Formation (1200 feet):

Mainly dark gray to mauve, medium-grained crystalline dolostone, with cycles of mottled dark and light gray dolostone, medium-grained crystalline dark gray dolostone, and cream to buff weathered, laminated, argillaceous dolostone. Nodules of dark gray and massive oolitic white chert are common, particularly near the base. In places cherty ridges are apparent in the float that are transverse to strike. Oolitic white chert is common. Some sandy (quartz-rich) lenses occur in the lower middle part of the section.

Stonehenge/Larke Formation (100 feet):

Interbeds of tan crystalline dolostone, finely laminated dolostone, coarse crystalline vuggy dolostone, and fine-grained, dark gray limestone. Some oolitic and pelletal dolostone near top.

CAMBRIAN

Gatesburg Formation (2000 feet):

Mines Member:	Medium and dark gray, medium crystalline dolostone, with abundant dark gray to black chert nodules, some of it algal and oolitic. (600 feet)
Upper Sandy Member:	Cycles of algal dolostone, mottled gray bioturbated crystalline dolostone, platy weathered laminated dolostone, and cross-bedded sandstone, with rare limestone interbeds and flat pebble conglomerates. (500 feet)
Ore Hill Member:	Mainly wavy-bedded, dove-gray micritic limestone, local bioclastic lenses. (120 feet)
Lower Sandy Member:	Similar to Upper Sandy units. Cycles of algal dolostone, mottled gray, bioturbated crystalline dolostone, platy weathered laminated dolostone, and cross-bedded sandstone. (700 feet)
Stacey Hill Member:	Dark gray, medium to coarse crystalline dolostone, interbedded with medium crystalline algal and oolitic dolostone (unknown thickness, but probably included in the basal portion of the Lower Sandy)

Warrior Formation (1200 feet):

Thinly interbedded limestone and calcareous shale, grading downward into crystalline dolostone with interbeds of sandstone up to 3-meters thick.

Pleasant Hill Formation (200 feet):

Gray, thin-bedded limestone interbedded with shale, siltstone, and sandstone.

Waynesboro Formation (unknown thickness, incomplete exposure):

Greenish-gray and grayish-purple shale interbedded with greenish-gray sandstone and conglomerate.

(from: Gold and Doden, 2002; Canich and Gold, 1985; and Taylor et al., 1982)

Appendix B

Graphs of Discharge vs. Watershed Area in the Major Watersheds of Morrison Cove

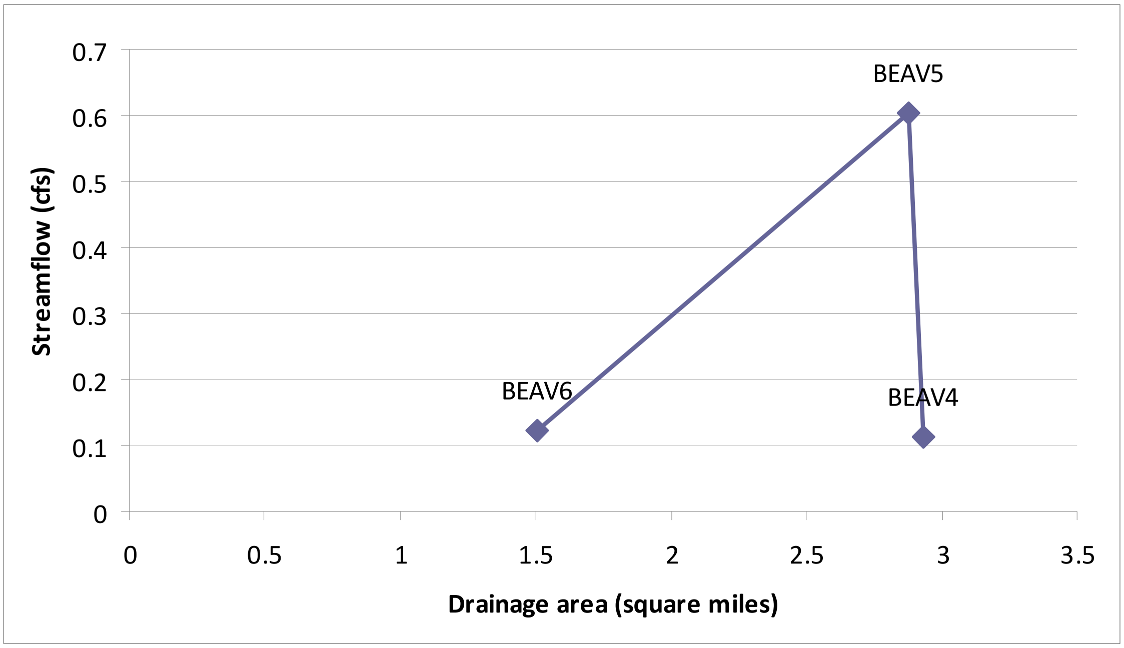

Figure B1. ***An Unnamed Mountainside Tributary to Beaver Creek (It picks up water in the mountainside siliciclastics, but abruptly loses it downstream of BEAV5.)***

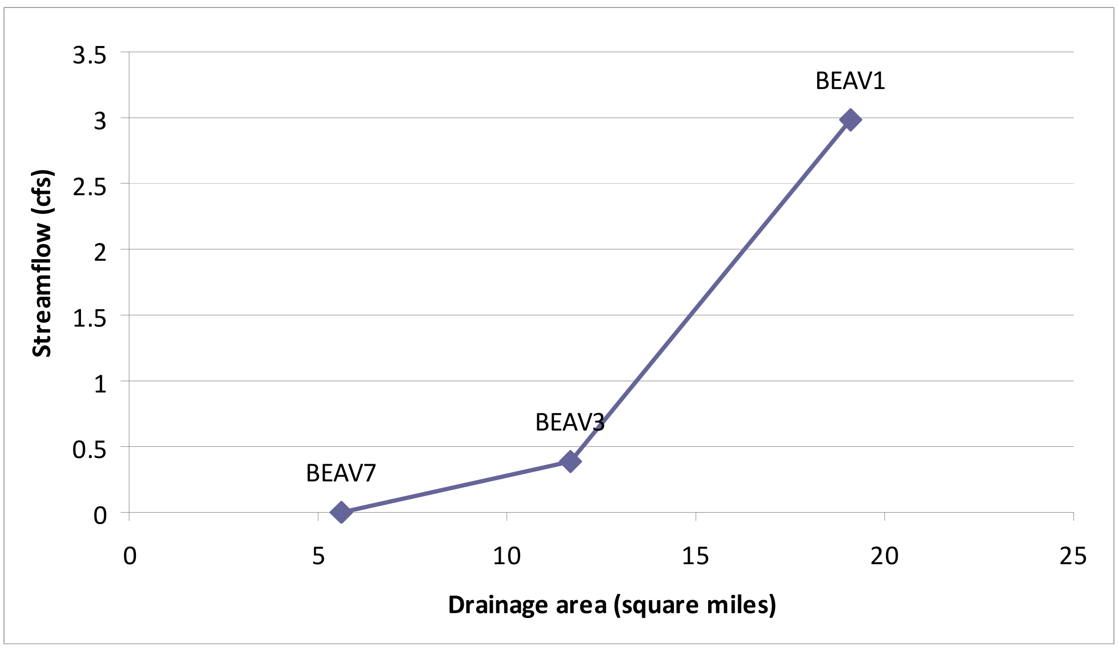

Figure B2. ***Beaver Creek Rapidly Picking up Water between BEAV1 and BEAV3***

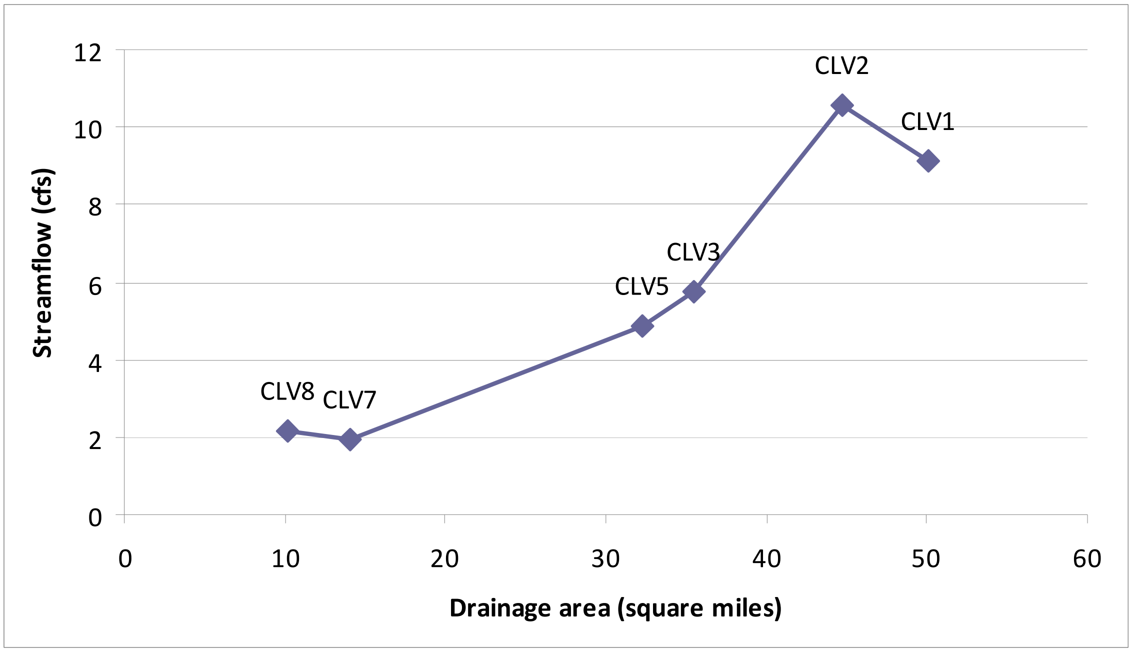

Figure B3. Clover Creek Picking up Flow Gradually between CLV2 and CLV 7 (although still below the trend from CLV2 through CLV8)

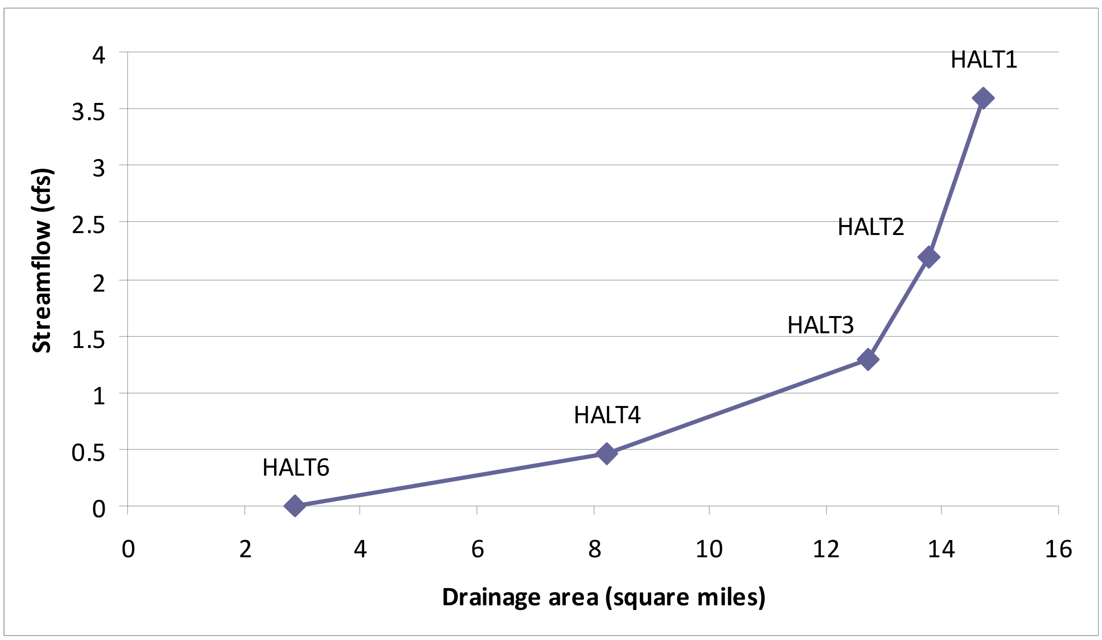

Figure B4. Halter Creek Picking up Most of Its Water Downstream of Halt3

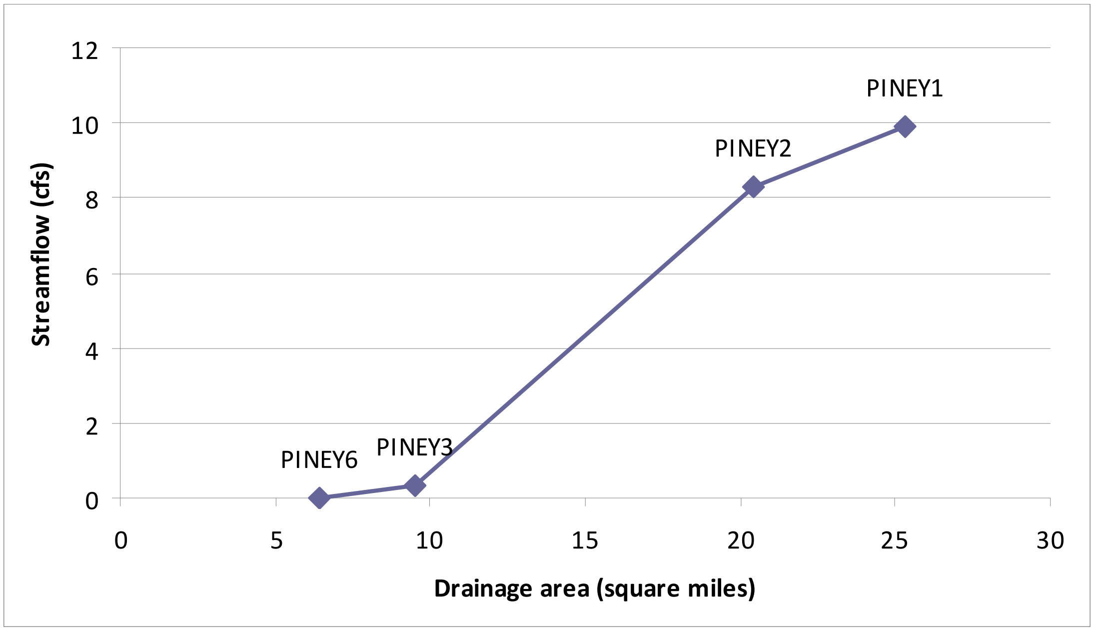

Figure B5. Piney Creek Picking up Most of Its Flow between Piney 2 and Piney 3

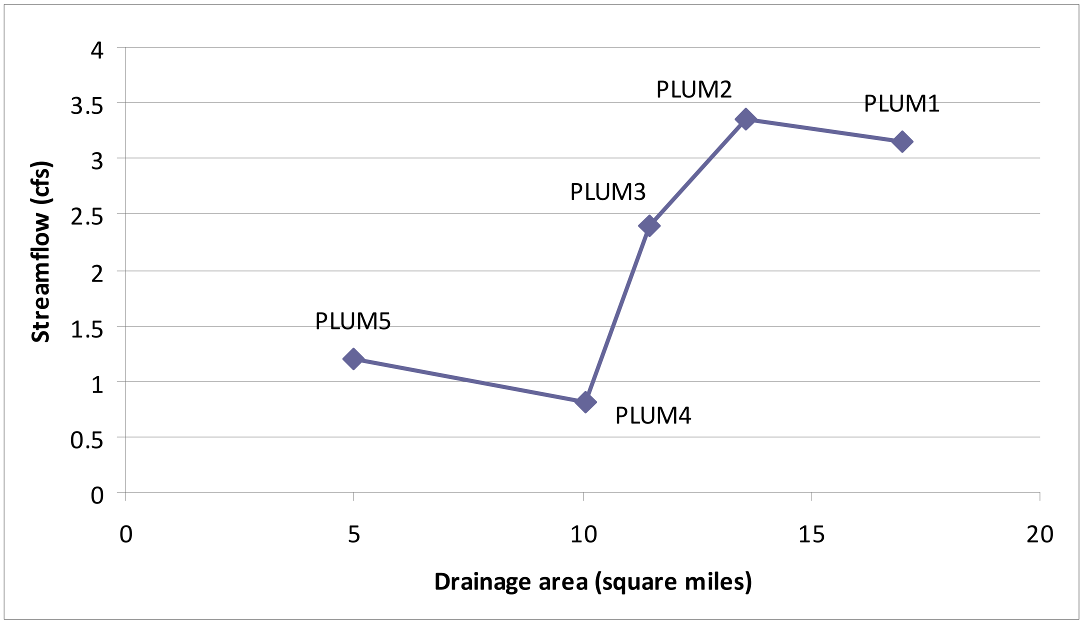

Figure B6. Plum Creek Picking up Spring Flow between Plum 3 and Plum 2

Appendix C

Hydrographs of the Roaring Spring and the Williamsburg Spring

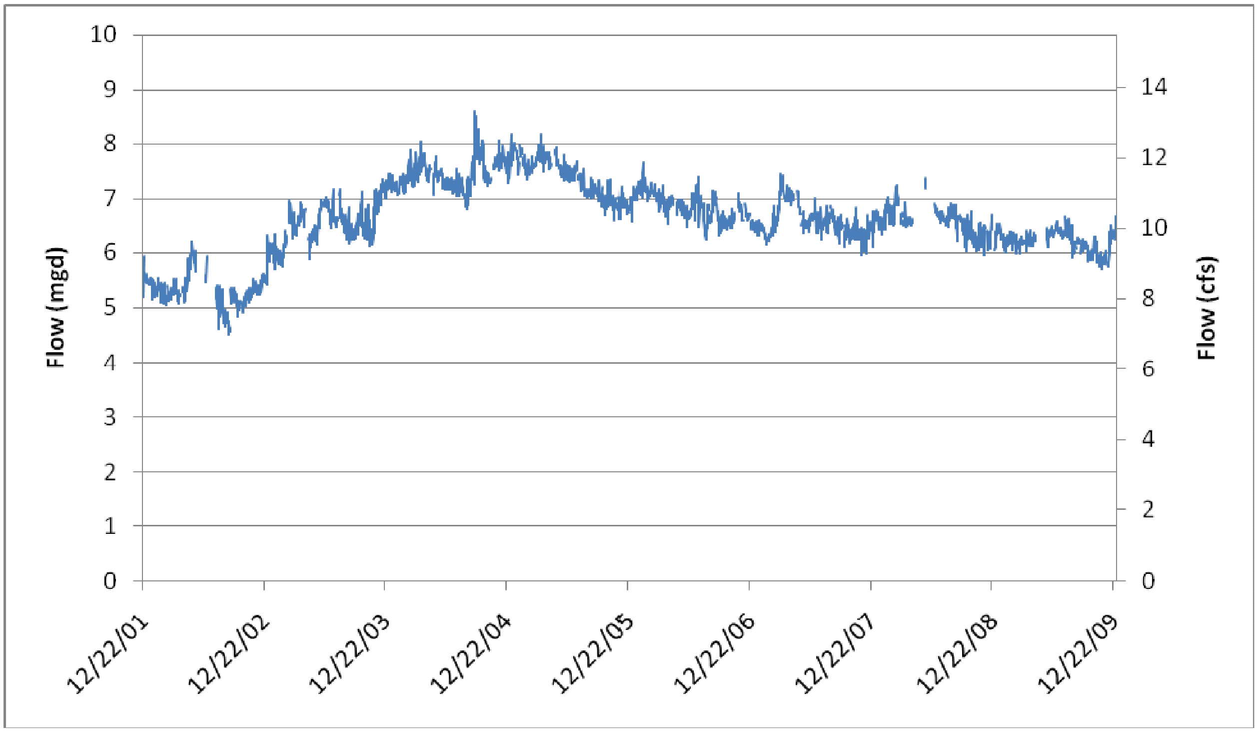

Figure C1. Hydrograph for the Roaring Spring

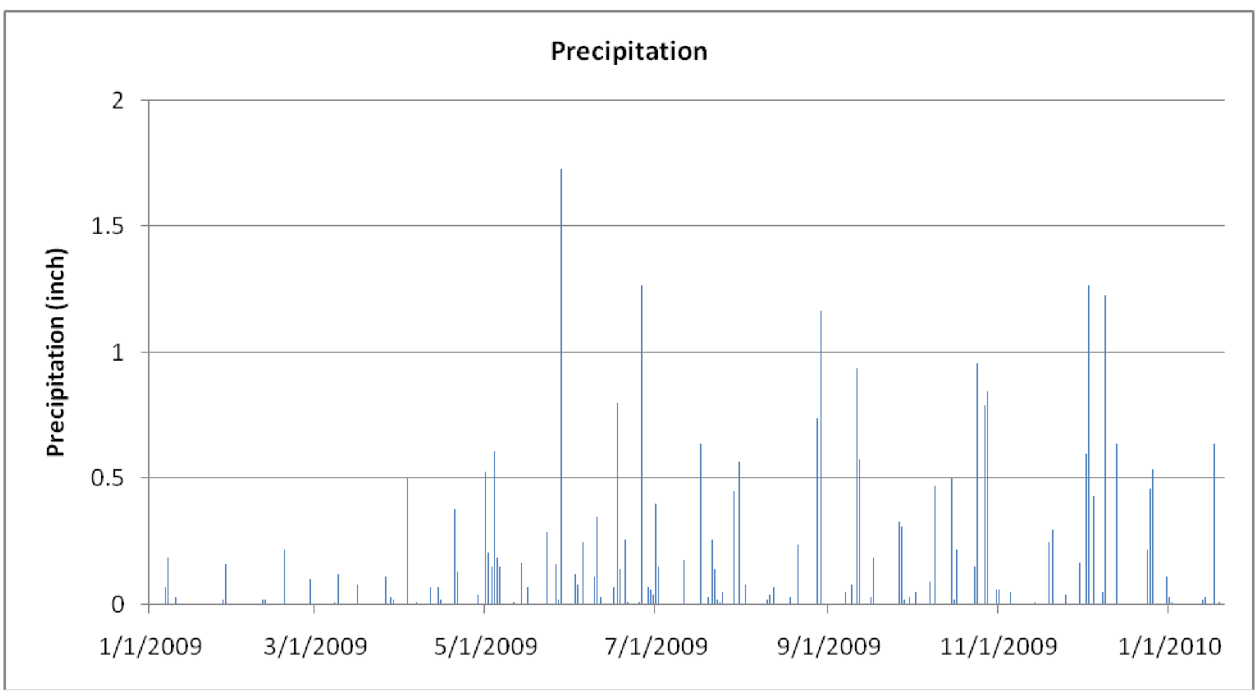

Figure C2. Precipitation at Martinsburg Airport during the Temporary Monitoring Period

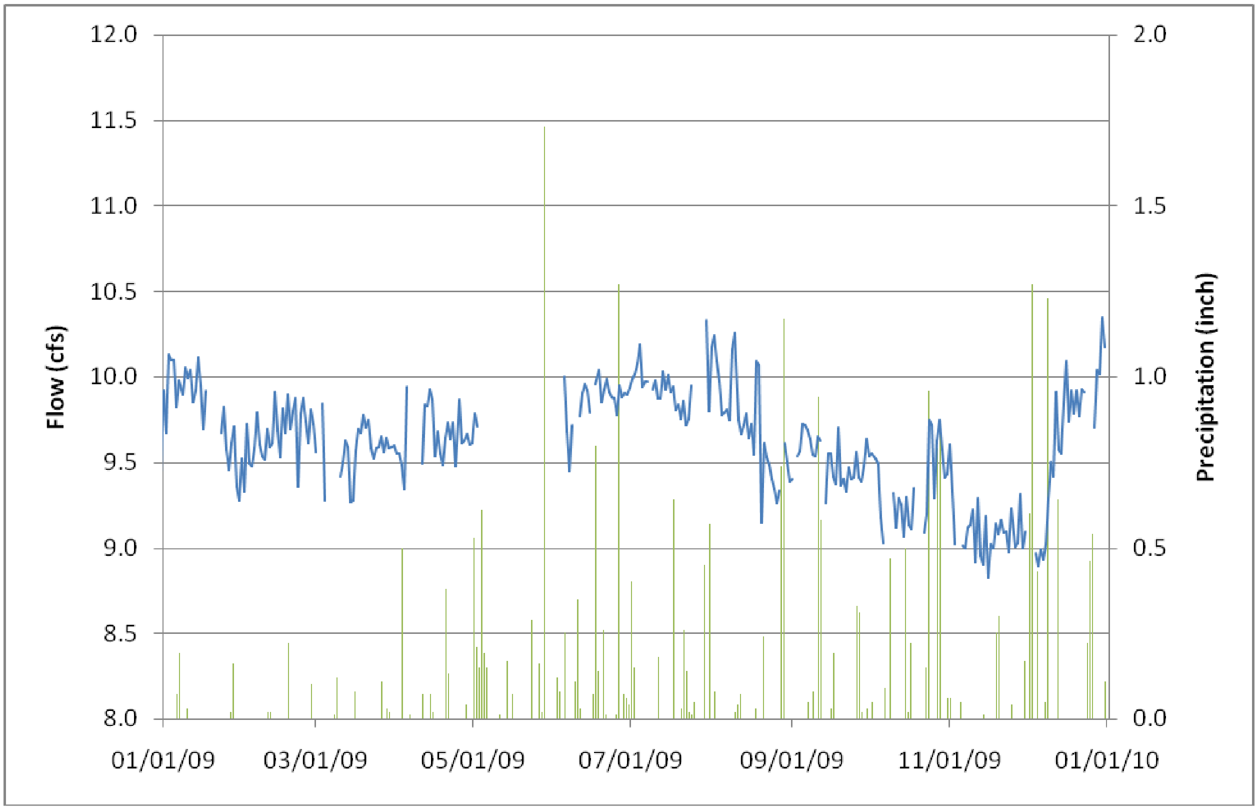

Figure C3. Hydrograph and Precipitation for the Roaring Spring during Temporary Monitoring Period (Note lack of correspondence between spring flow and precipitation.)

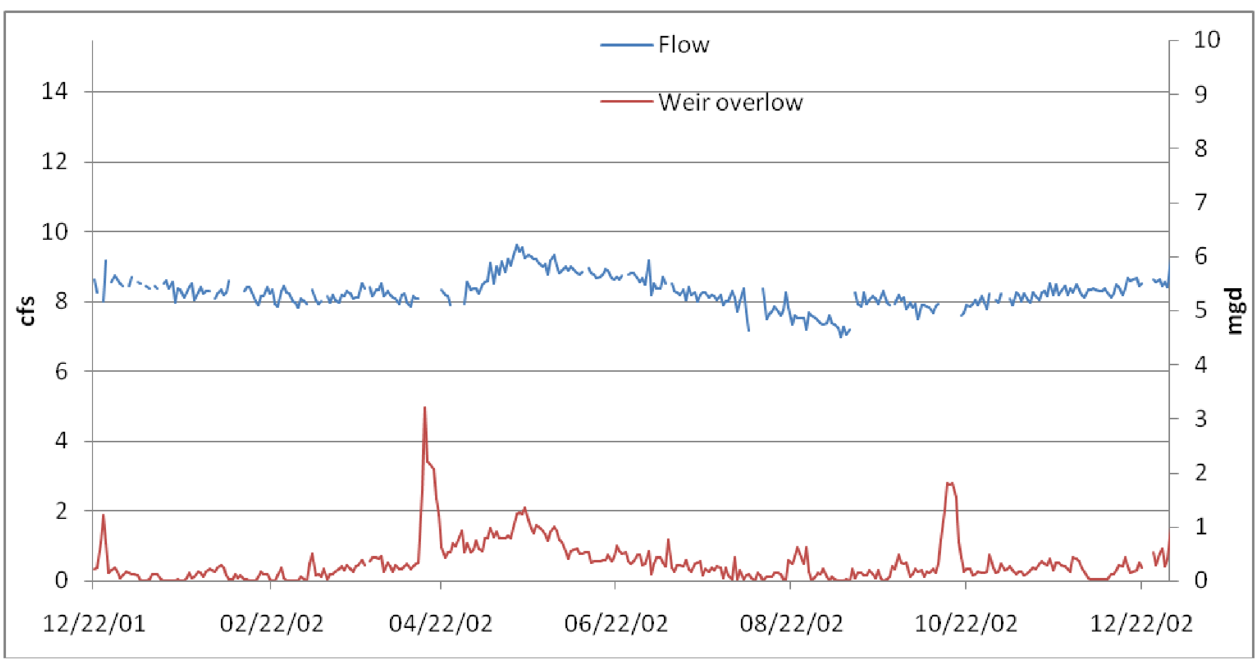

Figure C4. Hydrograph of Spring Flow and Spring Pool Discharge for the Roaring Spring

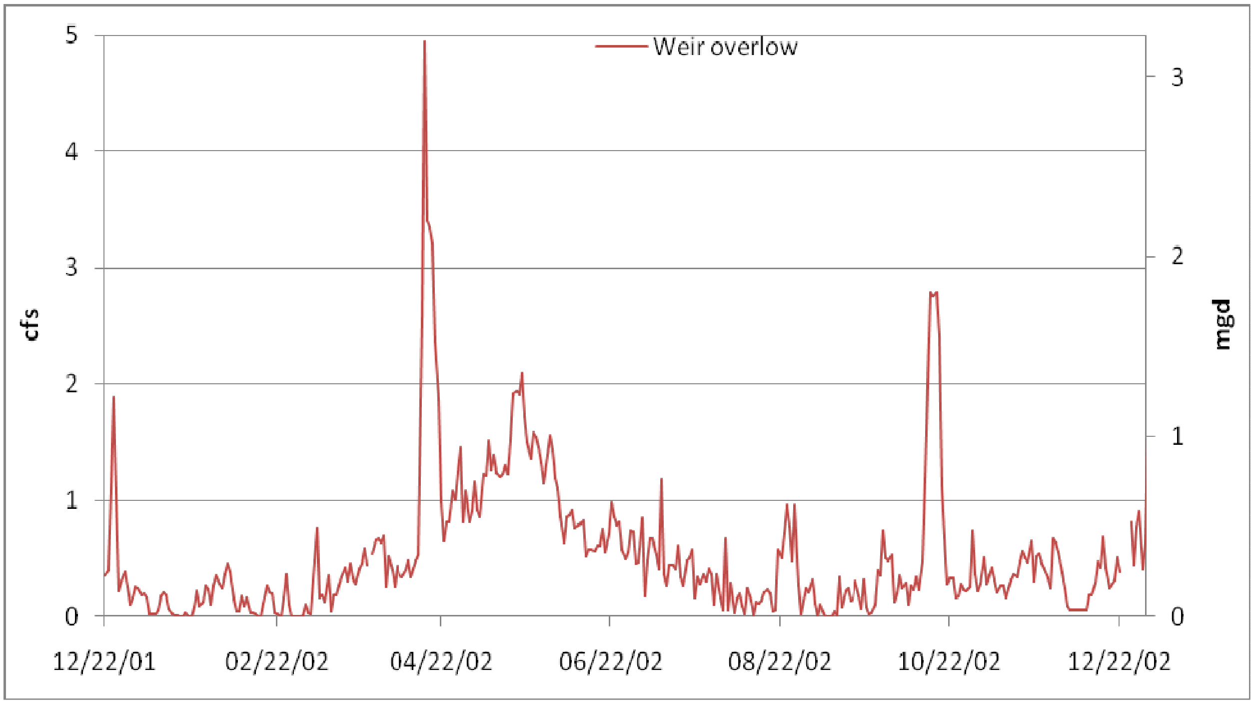

Figure C5. Hydrograph of the Spring Pool Discharge at the Roaring Spring during the 2002 Drought (Note several short periods of zero or near zero flow leaving the spring pool.)

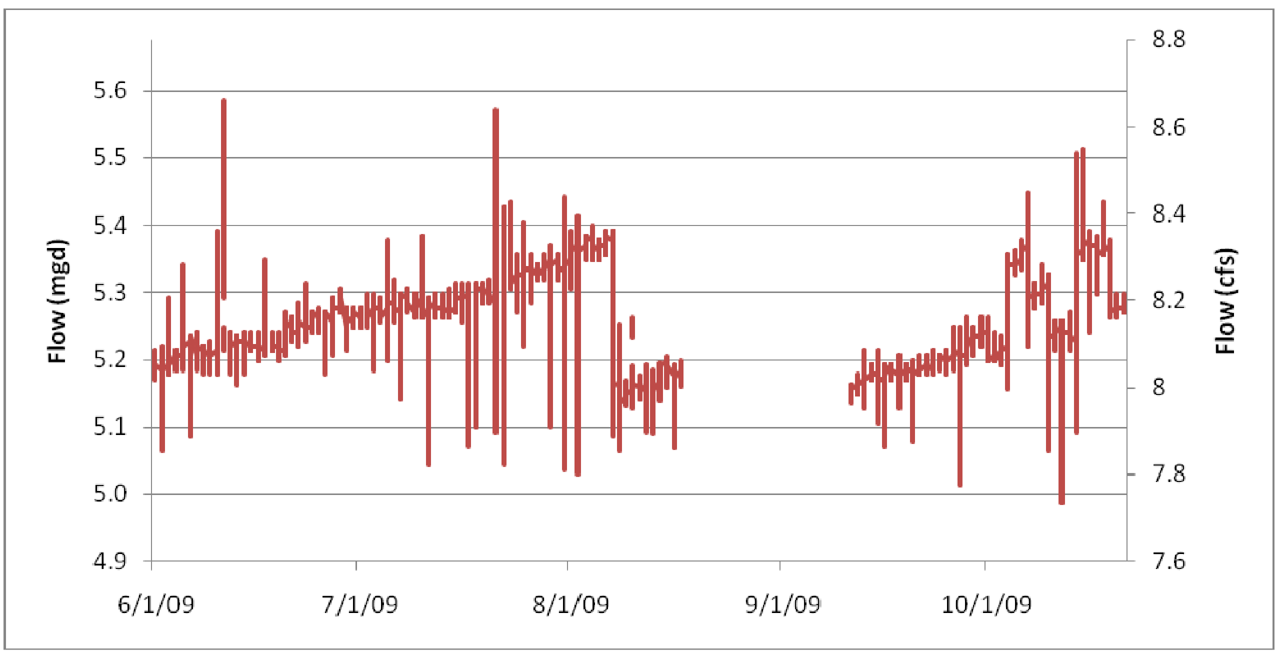

Figure C6. Hydrograph of Flow from the Williamsburg Spring during the Temporary Monitoring Period (Vertical scale choice intended to emphasize variability. All flow values were within the range of 7.7 to 8.6 cfs (4.9 – 5.6 mgd).)

Appendix D

Major Watershed Flow Statistics

Table D1. Estimate of Monthly Percentiles for Clover Creek (cfs)

Month	P95	P90	P85	P80	P75	P70	P65	P60	P50
Jan	12.1	14.6	17.7	19.5	21.4	23.6	26.6	30.1	37.4
Feb	15.9	19.0	21.4	23.5	26.3	28.9	32.1	35.4	42.5
Mar	27.4	33.1	37.9	42.3	47.8	51.8	57.1	63.3	76.2
Apr	29.8	33.6	38.0	41.8	45.6	49.8	54.0	58.0	68.2
May	21.9	24.8	27.7	30.4	33.2	36.2	39.5	42.8	50.0
Jun	15.1	16.8	18.2	19.7	21.0	22.4	23.7	25.2	28.2
Jul	10.2	11.8	12.9	13.8	14.6	15.4	16.1	16.9	18.8
Aug	8.9	10.3	11.2	11.8	12.4	12.9	13.5	14.1	15.6
Sep	7.9	9.0	9.8	10.5	11.2	11.7	12.2	12.7	13.7
Oct	8.2	9.2	10.0	10.6	11.2	11.7	12.2	12.6	13.6
Nov	9.1	10.8	11.7	12.8	13.7	15.2	17.0	18.6	22.9
Dec	11.4	13.5	15.3	17.4	19.7	21.8	24.7	27.3	33.7
Annual	10.1	11.8	13.1	14.6	16.4	18.4	20.5	23.1	29.6

Table D2. Estimate of Monthly Percentiles for Halter Creek (cfs)

Month	P95	P90	P85	P80	P75	P70	P65	P60	P50
Jan	5.5	7.0	8.3	9.7	10.8	11.9	13.2	14.9	18.3
Feb	7.2	8.9	10.2	11.9	13.4	15.0	16.6	18.6	23.2
Mar	15.0	18.1	21.0	23.6	26.0	29.0	32.1	35.9	43.2
Apr	14.7	16.9	18.9	21.3	23.9	26.2	28.7	31.2	37.2
May	9.7	11.5	12.8	14.0	15.5	17.0	18.8	20.5	24.5
Jun	6.4	7.1	7.7	8.3	8.9	9.5	10.2	11.1	12.7
Jul	4.4	5.0	5.4	5.9	6.3	6.6	7.0	7.3	8.2
Aug	3.9	4.3	4.6	4.8	5.1	5.3	5.6	5.9	6.7
Sep	3.4	3.9	4.2	4.4	4.7	4.9	5.1	5.3	5.9
Oct	3.7	4.2	4.4	4.6	4.8	5.0	5.2	5.5	6.2
Nov	4.1	4.6	5.0	5.6	6.1	6.7	7.4	8.3	10.5
Dec	4.6	5.3	6.5	7.7	8.8	10.2	11.4	12.8	17.0
Annual	4.3	5.0	5.6	6.3	7.2	8.1	9.3	10.8	14.3

Table D3. Estimate of Monthly Percentiles for HC-PC-Reservoir UNT (cfs)

Month	P95	P90	P85	P80	P75	P70	P65	P60	P50
Jan	0.11	0.14	0.17	0.20	0.22	0.25	0.27	0.31	0.38
Feb	0.15	0.18	0.21	0.24	0.28	0.31	0.34	0.38	0.48
Mar	0.31	0.37	0.43	0.49	0.54	0.60	0.66	0.74	0.89
Apr	0.30	0.35	0.39	0.44	0.49	0.54	0.59	0.64	0.77
May	0.20	0.24	0.26	0.29	0.32	0.35	0.39	0.42	0.50
Jun	0.13	0.15	0.16	0.17	0.18	0.20	0.21	0.23	0.26
Jul	0.09	0.10	0.11	0.12	0.13	0.14	0.14	0.15	0.17
Aug	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.12	0.14
Sep	0.07	0.08	0.09	0.09	0.10	0.10	0.11	0.11	0.12
Oct	0.08	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.13
Nov	0.08	0.10	0.10	0.11	0.13	0.14	0.15	0.17	0.22
Dec	0.10	0.11	0.13	0.16	0.18	0.21	0.23	0.26	0.35
Annual	0.09	0.10	0.12	0.13	0.15	0.17	0.19	0.22	0.30

Table D4. Estimate of Monthly Percentiles for Piney Creek (cfs)

Month	P95	P90	P85	P80	P75	P70	P65	P60	P50
Jan	9.8	11.7	13.6	15.8	17.4	18.9	20.6	22.8	28.0
Feb	13.2	15.6	17.1	18.6	20.7	23.1	25.4	28.0	34.2
Mar	23.4	28.1	31.7	35.4	39.4	43.6	48.0	52.4	62.2
Apr	23.4	27.3	31.2	35.1	38.3	41.6	45.5	49.3	56.2
May	17.0	20.1	22.4	24.3	26.5	28.9	31.8	34.2	40.2
Jun	11.3	12.3	13.5	14.9	16.1	17.3	18.5	19.8	22.6
Jul	8.5	9.1	9.7	10.2	10.7	11.3	11.8	12.5	13.7
Aug	7.3	7.8	8.1	8.7	9.0	9.4	9.7	10.1	11.0
Sep	6.8	7.1	7.5	7.8	8.0	8.5	8.8	9.1	10.0
Oct	6.9	7.5	7.8	8.2	8.7	8.9	9.2	9.6	10.5
Nov	7.6	8.3	8.9	9.4	10.1	11.4	12.8	14.5	19.1
Dec	8.3	10.2	12.3	14.5	16.2	18.1	20.3	22.6	27.8
Annual	7.8	8.8	9.7	10.9	12.1	13.7	15.8	18.2	23.7

Table D5. Estimate of Monthly Percentiles for Plum Creek (cfs)

Month	P95	P90	P85	P80	P75	P70	P65	P60	P50
Jan	3.6	4.6	5.5	6.4	7.1	7.9	8.7	9.8	12.1
Feb	4.8	5.8	6.7	7.8	8.8	9.9	10.9	12.3	15.3
Mar	9.9	11.9	13.8	15.5	17.1	19.1	21.1	23.6	28.4
Apr	9.6	11.1	12.5	14.0	15.7	17.2	18.9	20.5	24.5
May	6.4	7.6	8.4	9.2	10.2	11.2	12.4	13.5	16.1
Jun	4.2	4.7	5.1	5.5	5.8	6.3	6.7	7.3	8.4
Jul	2.9	3.3	3.5	3.9	4.1	4.4	4.6	4.8	5.4
Aug	2.6	2.8	3.0	3.2	3.4	3.5	3.7	3.9	4.4
Sep	2.2	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.9
Oct	2.4	2.7	2.9	3.0	3.1	3.3	3.5	3.6	4.1
Nov	2.7	3.1	3.3	3.7	4.0	4.4	4.9	5.5	6.9
Dec	3.1	3.5	4.3	5.1	5.8	6.7	7.5	8.4	11.2
Annual	2.8	3.3	3.7	4.2	4.7	5.3	6.1	7.1	9.4

Table D6. Estimate of Monthly Percentiles for Yellow Creek (cfs)

Month	P95	P90	P85	P80	P75	P70	P65	P60	P50
Jan	21.1	28.9	36.2	42.6	49.4	56.3	63.9	71.5	92.2
Feb	31.2	39.6	47.2	57.8	66.9	76.1	85.2	97.2	122.0
Mar	64.1	79.6	94.9	108.6	124.2	138.6	156.7	175.0	216.1
Apr	60.6	72.5	82.8	94.3	105.7	117.9	131.0	144.5	175.0
May	41.7	48.7	54.8	61.9	69.7	76.5	84.9	94.3	117.9
Jun	23.1	27.4	30.6	33.9	36.8	39.4	42.6	46.7	56.1
Jul	15.2	17.5	19.6	21.6	23.1	25.1	27.2	29.2	33.3
Aug	11.9	14.1	15.4	16.7	18.3	19.6	21.3	22.8	26.5
Sep	10.3	12.5	13.8	15.2	16.4	17.5	18.6	20.1	23.0
Oct	12.8	14.1	15.4	16.1	16.7	17.8	18.9	20.2	23.9
Nov	14.5	16.4	18.6	21.5	23.6	26.8	29.8	33.5	42.8
Dec	17.6	22.1	25.9	29.8	33.8	38.3	46.9	56.0	75.8
Annual	14.9	17.8	21.3	24.6	28.6	33.5	38.8	45.9	65.1