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.

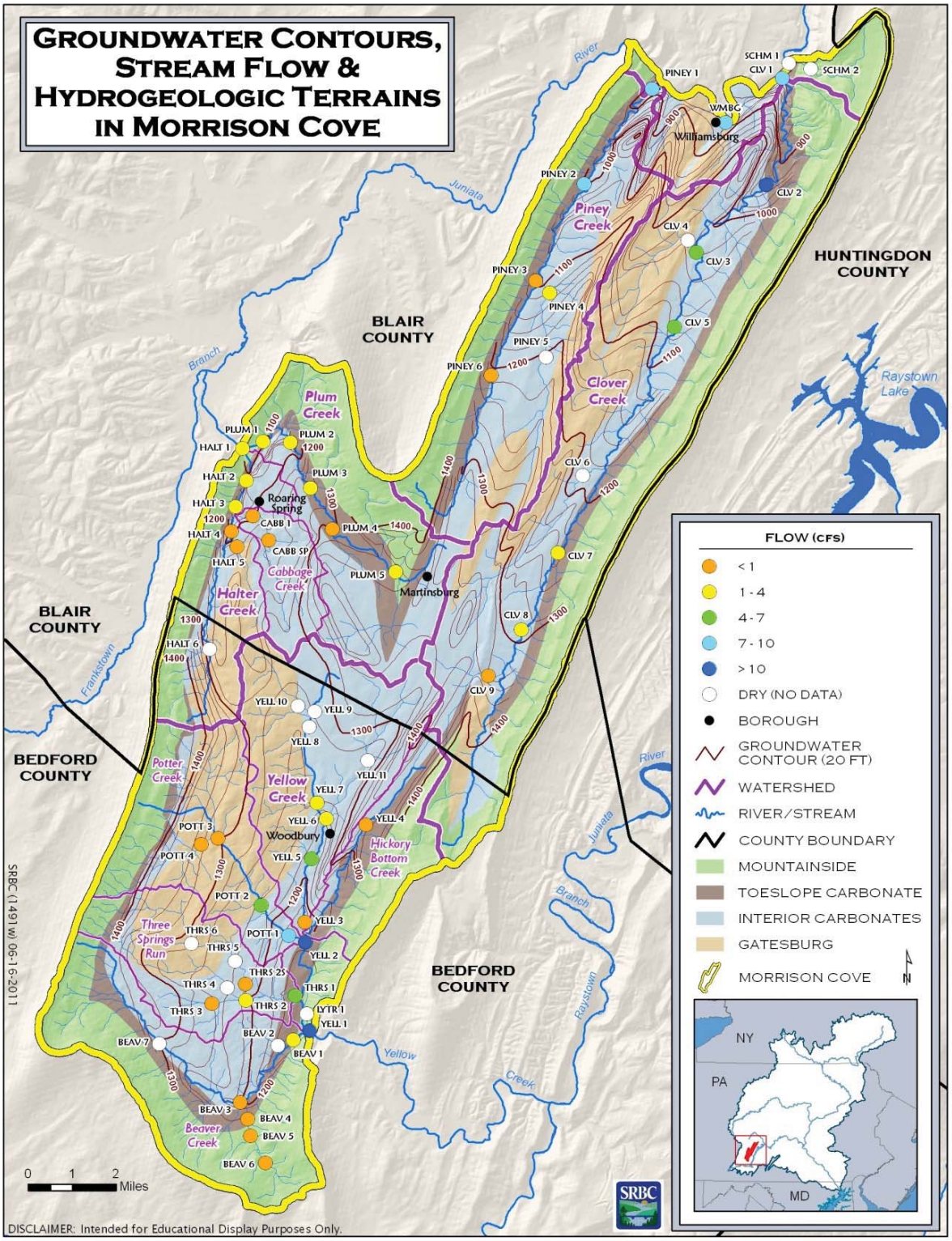

Figure 4-1. Water Table Contours, Hydrogeologic Terrains, and Seepage Run Sites

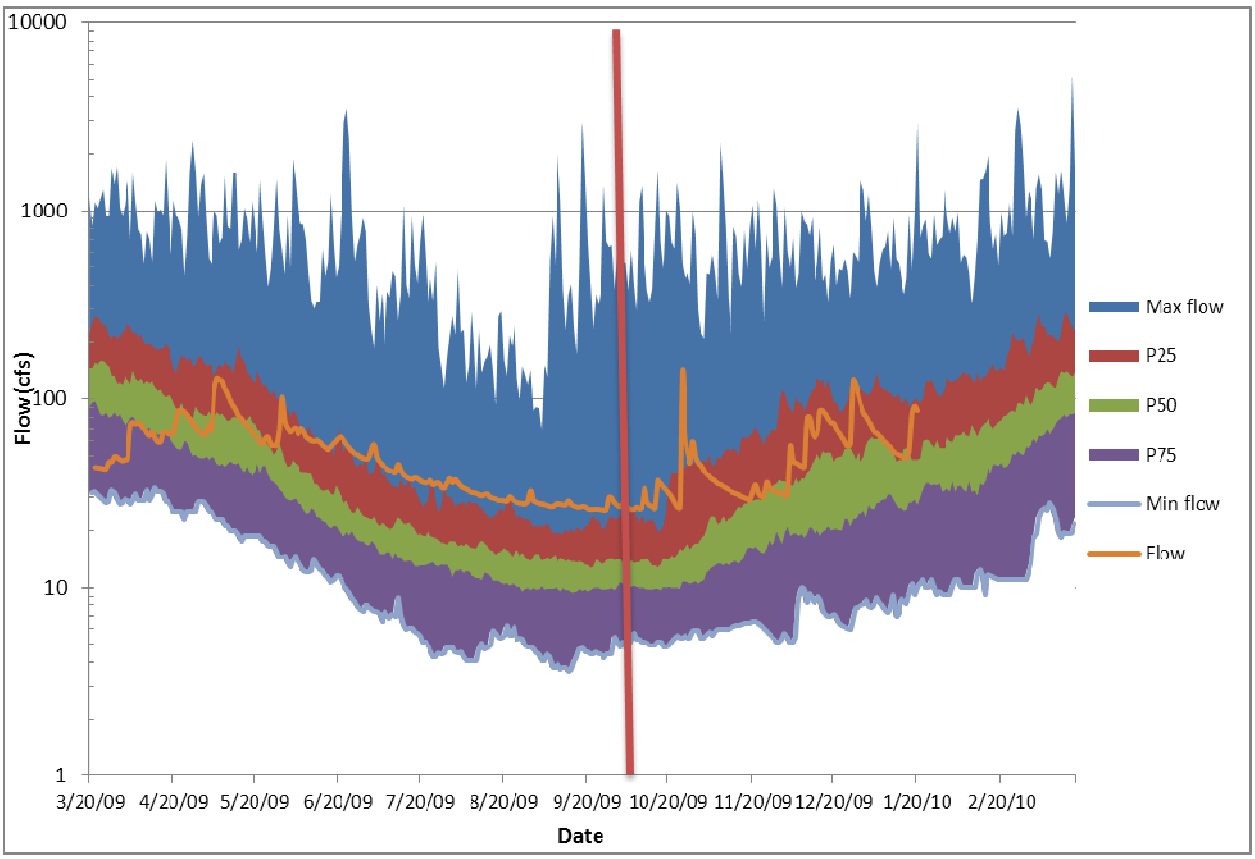

Figure 4-2. Hydrograph for Yellow Creek Where it Leaves Morrison Cove (SRBC, 2009)

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.

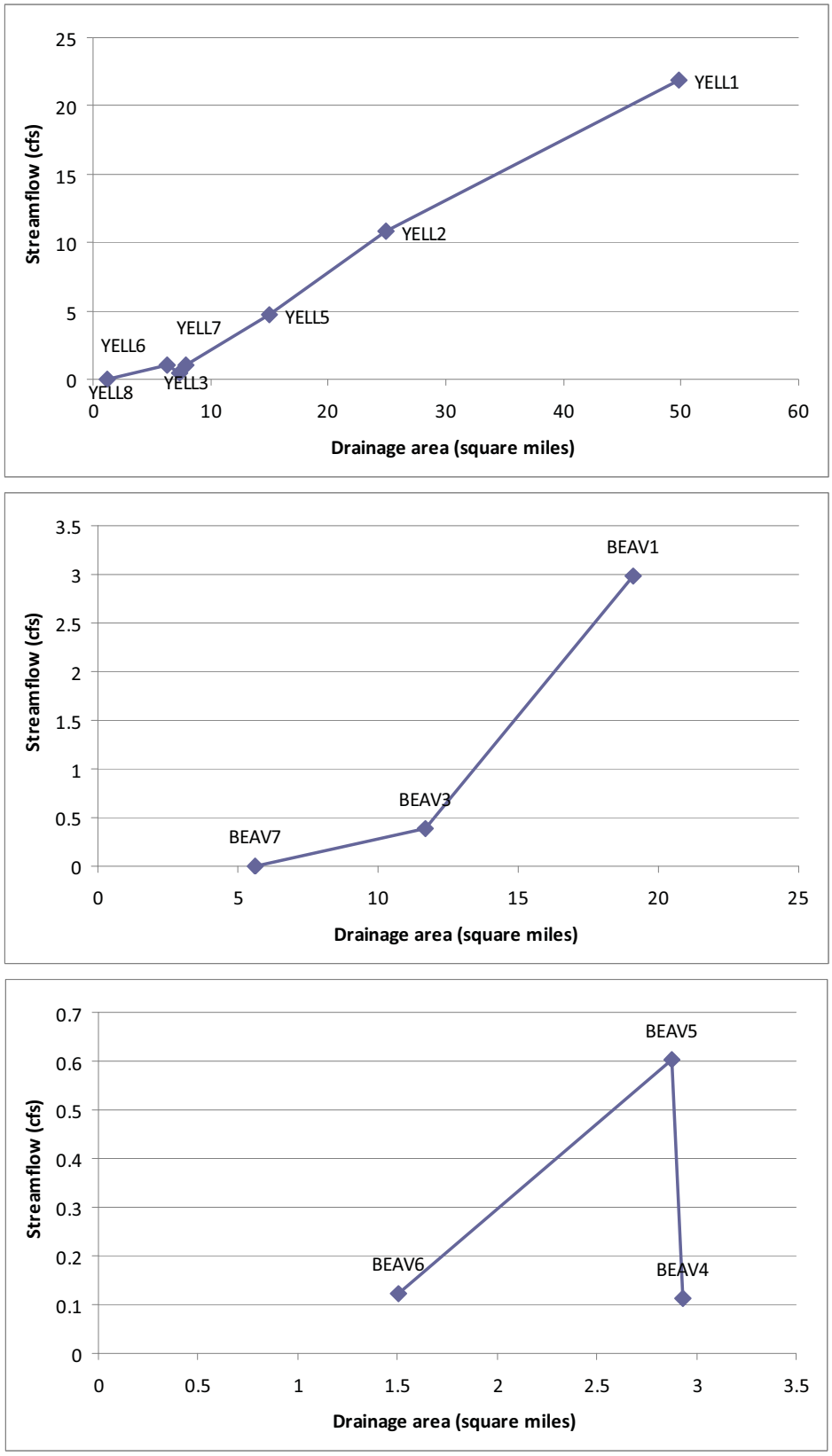

Figure 4-3. ***Relationship of Streamflow to Drainage Area Using Seepage Run Data (Top: Nearly linear relationship for Yellow Creek. Middle: Strongly non-linear relationship in Beaver Creek. Bottom: Loss of flow in downstream reach of a mountainside stream (an unnamed tributary of Beaver Creek) as it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

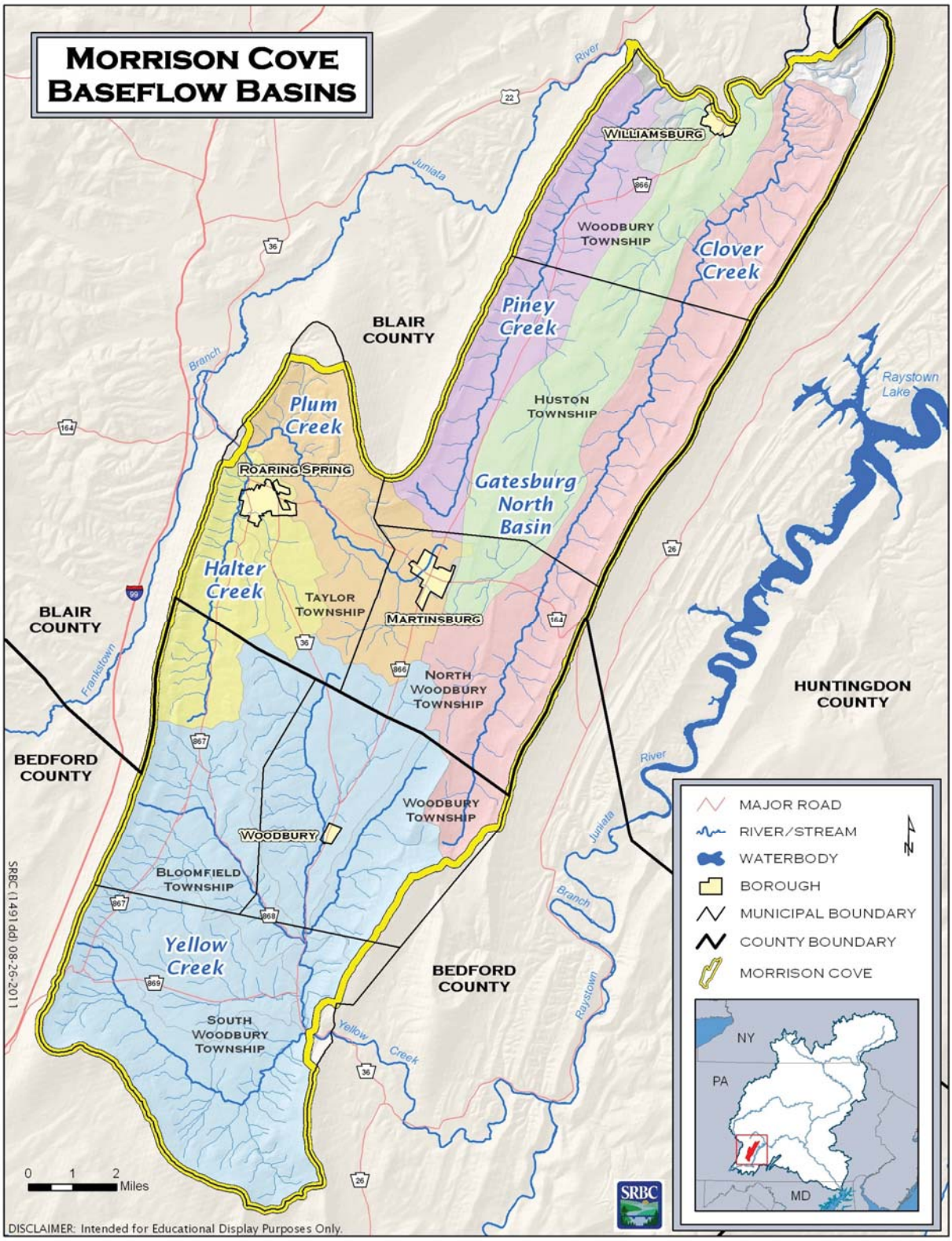

Figure 4-4. Base Flow Basins: Contributing Areas to Surface Water Flow during Periods of Low Base Flow

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.

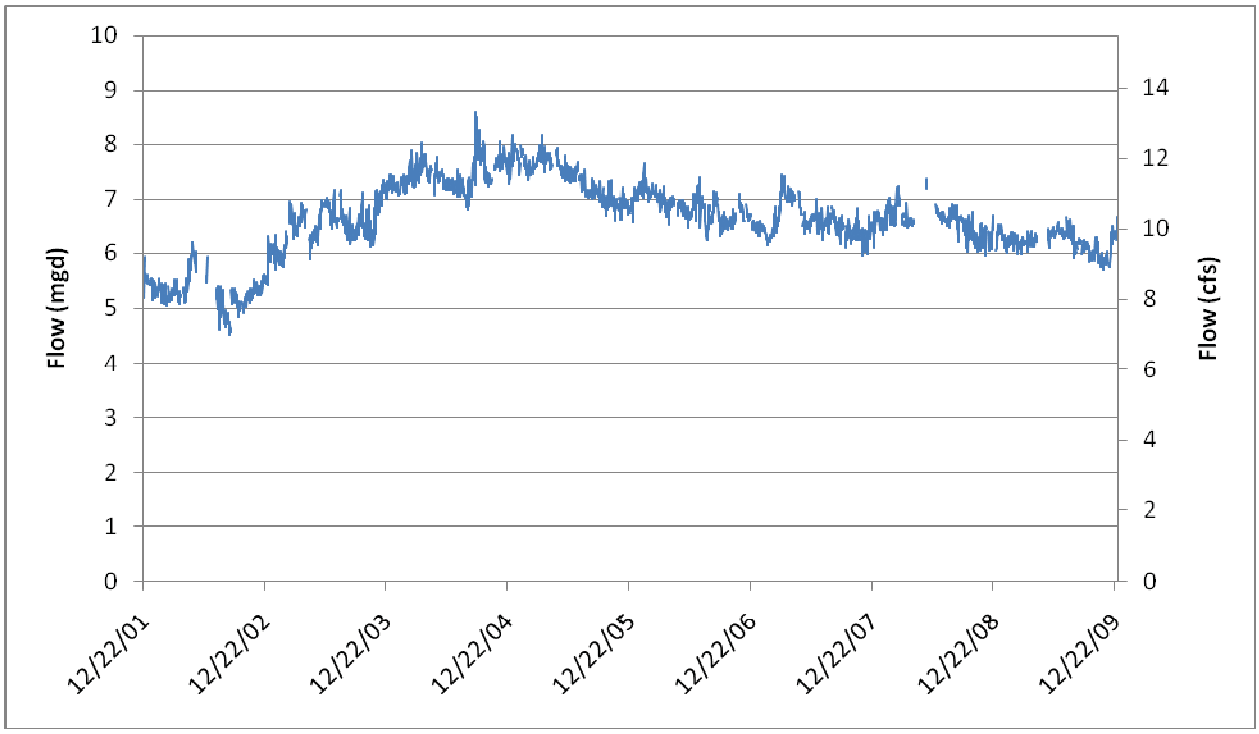

Figure 4-5. Hydrograph of Flow from the Roaring Spring for the Period of Record (Eight Years)

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.