sources of nitrate that cause concentrations to be elevated and approach or exceed the 10 mg/l MCL (Lindsey and Koch, 2004). A study by the Pennsylvania Department of Agriculture reported that about 35 percent of the wells sampled in the Morrison Cove valley had nitrate levels exceeding the MCL of 10 mg/l (Lindsey and Koch, 2004).

HABITAT

The habitat assessment in Morrison Cove showed some general trends among many of the streams. The biggest habitat problems throughout the Cove were channel alteration, sedimentation, and a lack of riparian zone and vegetative bank cover. The upstream sites on both Halter and Plum Creeks had the poorest habitat rating, while the middle reaches on both these streams tended to have higher habitat scores. In Yellow Creek Watershed, habitat scores varied greatly due to differences in riparian buffers, severity of sedimentation, and availability of epifaunal substrate. Piney and Clover Creeks generally had good habitat assessments, although riparian buffers were lacking at both upstream sites.

Halter Creek

The Halter Creek Watershed accounts for about 30 percent of the Morrison Cove region. The entire watershed currently is designated as Warm Water Fishes (WWF) by the Commonwealth of Pennsylvania (PA Code, Chapter 93.9n). The land use in the upper reaches of Halter Creek is primarily agricultural crop land. The land use surrounding the lower reaches of Halter Creek is mainly developed land: residential, commercial, and industrial. This includes a paper mill, a wastewater treatment plant, a water bottling company, and a quarrying operation. The town of Roaring Spring is the largest municipality in the Halter Creek Subbasin. The middle reaches of Halter Creek are the most protected sections of the stream with more extensive forested riparian buffers.

Within the boundaries of Morrison Cove, the downstream two miles of Halter Creek are impaired due to urban and industrial runoff and storm sewer problems. Halter Creek was placed on the Section 303(d) list of impaired waters in 1998 (PADEP 2004). The water chemistry in upstream reaches of Halter Creek was different than that in downstream reaches due to differences in adjacent and upstream geology and land use. Of the macroinvertebrate communities sampled in the Halter Creek Watershed, six were nonimpaired sites, five were slightly impaired sites, and one was moderately impaired.

Confluence of Plum Creek with Halter Creek.

The water quality in the headwaters (H6) of Halter Creek was greatly influenced by the tributaries coming off of the western sandstone ridge. This water was characterized by low alkalinity, low hardness, and low conductivity. Among the parameters that were analyzed for this project, H6 had no values exceeding water quality standards and was classified as "higher" water quality. However, the habitat condition was determined to be non-supporting with a biological condition of slightly impaired. This site was highly dominated by Chironomidae and had a very low percentage of Ephemeroptera. The land use in the area was predominantly agriculture, and there was no protective vegetative riparian zone surrounding the stream. The lack of suitable habitat had a negative effect on the macroinvertebrate community despite suitable water quality.

Numerous tributaries come into Halter Creek off the western ridge. One of these tributaries (T2) was sampled, and biological and habitat conditions were both ranked at the highest level, nonimpaired and excellent, respectively. The biological community had a high diversity with an excellent representation of mayflies and stoneflies. The water quality was classified as "middle" quality, due primarily to low alkalinity. However, this is not unusual for streams coming off sandstone ridges.

An unnamed tributary (T1) comes into Halter Creek above H5 and flows from the carbonate valley that makes up the center part of Morrison Cove. The water chemistry at T1 was "middle" quality and was generally representative of the dolomite geology from which it originated, specifically having high hardness and high magnesium concentrations. Nitrates also were elevated at this site. The habitat was rated as supporting with a slightly impaired biological condition. T1 is a limestone stream and was highly dominated (71.7 percent) by *Gammarus*. This tributary is quite small and its streambed is comprised mostly of sand. The riparian buffer around the sampling site was good, but upstream it flowed through multiple residential lawns.

The next downstream site on the mainstem of Halter Creek was H5, which was upstream of the confluence of Cabbage Creek with Halter Creek. The water chemistry at this site was rated as "higher" quality. There was also excellent habitat and a nonimpaired macroinvertebrate community. This site had six taxa of mayflies with *Baetis* being the dominant taxa in the sample. It was ranked the highest of all the Halter Creek sites.

Originating in the dolomite geology, Cabbage Creek (H7) contributed high hardness and magnesium to Halter Creek. However, H7 also provided an increase in nitrates, chloride, and conductivity, all of which are associated with anthropogenic activity. As a result, Cabbage Creek was classified as having "lower" water quality. Despite the somewhat degraded water quality at the time of sampling, the biological condition was rated as nonimpaired, which was tied to its excellent habitat rating. Cabbage Creek exhibited characteristics of a limestone stream with *Gammarus* being the dominant taxa. Due to the geology of the area, there was a waterfall near the mouth where samples were taken, which is an unusual feature for a limestone stream. Three taxa of mayflies and one stonefly taxon were identified at this site. Cabbage Creek significantly changes the water chemistry of Halter Creek.

The Halter Creek site downstream of the confluence with Cabbage Creek (H4) had a drop in water quality from "higher" to "middle" quality. The biological condition remained nonimpaired. The macroinvertebrates at H4 also showed the influence of Cabbage Creek with an increase in *Gammarus* and a slight increase in stonefly taxa, possibly due to the waterfall increasing the dissolved oxygen levels in the stream. Habitat was excellent based partially on above average instream cover and riparian buffer.

The next reach of Halter Creek runs through the town of Roaring Spring. The site (H3) is downstream of a large portion of the town, as well as a small sewage treatment facility. The water quality at this site is rated as "higher" with an excellent habitat rating. Although not exceeding water quality standards, the concentration of chloride was twice what it was upstream. Additionally, the concentration of sodium doubled through this reach, and slightly exceeded the water quality standard. The biological condition at this site was determined to be slightly impaired, and taxa richness dropped from 28 at the upstream site (H4) to 14 at this site (H3). While sampling, it was noted that paper pulp was clogging the net, which may have impacted the macroinvertebrate population sample.

"The last mile of Plum Creek is impaired due to runoff and siltation and was placed on the Section 303(d) list in 2002."

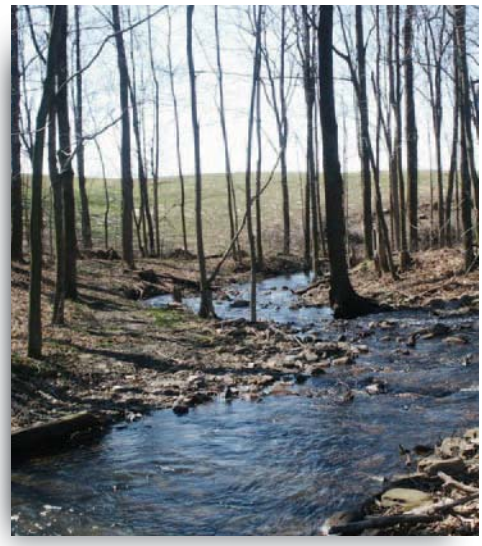
At H2, which is upstream of the confluence with Plum Creek, the water quality was similar to H3, except that the sulfate concentration tripled. The highest sulfate concentration recorded at this site was 64 mg/l in February 2006. A major highway and a large quarrying operation are located between these two sites, which may have contributed to this elevated sulfate level. Although sulfate did not exceed the water quality standard, such a large increase in a short stream reach (< 1 mile) could be cause for concern. The water quality at this site was rated as "middle" quality. There is no habitat or biological data for this location due to its close proximity to H8, as well as access problems and lack of riffle habitat. The most downstream site sampled on Halter Creek, H1, was downstream of Plum Creek and is representative of the water that is flowing out of the Morrison Cove valley and into the Frankstown Branch of the Juniata River. The water quality at H1 was determined to be "middle" quality with a supporting habitat condition. The biological community was rated as slightly impaired and was dominated by *Baetis*, had no stoneflies, and contained only two taxa of mayflies.

Plum Creek, the largest tributary to Halter Creek, enters directly below Halter Creek site H2. The upper reaches of Plum Creek are largely spring fed and flow through agricultural crop lands with a small amount of low density residential development scattered throughout. The last mile of Plum Creek is impaired due to runoff and siltation and was placed on the Section 303(d) list in 2002 (PADEP, 2004). There were three sampling sites on the mainstem of Plum Creek as well as one tributary site.

The most upstream site on Plum Creek was H10, which was located adjacent to the Borough of Martinsburg. This was the only site to receive a moderately impaired biological rating. The macroinvertebrate community was highly dominated by Planariidae (flatworms, planarians), and there were no mayflies, stoneflies, or caddisflies. The water chemistry revealed "poor" water quality, due to high conductivity and elevated concentrations of nitrate and sodium. Sodium concentrations were two times the water quality standard, with an average concentration of 41 mg/l for the year. Additionally, H10 had the highest values of any of the stream sites for a number of other parameters: calcium, chloride, hardness, and silica, as well as the lowest dissolved oxygen value. Habitat condition was rated as partially supporting due to insufficient riparian buffer, degraded bank conditions, and very mucky substrate. Site H10 also potentially was impacted by suburban and industrial run-off, as it was located downstream of residential developments and a school, and directly downstream of a book binding plant.

Downstream at H9, significant improvement was noted as the biological rating improved to nonimpaired. There were 10 taxa of mayflies, stoneflies, and caddisflies, and the sample composition was 54 percent mayflies (mostly *Baetis*). Interestingly, H10 and H9 were the only sites to have the Amphipoda taxon of *Crangonyx*, which had individuals present

in higher numbers at H10 than H9. Although the water quality did improve slightly from H10 to H9, it was still evaluated as "poor" quality, due to high concentrations of nitrate and sodium, both exceeding water quality standards. This site also had the highest values of alkalinity (334 mg/l), potassium (11.9 mg/l), and pH (8.6). However, the habitat at this site was rated as excellent, as it had a well developed riffle area and abundant instream cover.



Forested tributary to Plum Creek off the northern sandstone ridge of Morrison Cove.

Numerous tributaries enter Plum Creek from the northern, forested, shale and sandstone ridges. One of these tributaries was sampled (T3) and was ranked in the highest water quality, biological, and habitat categories. The biological condition rating for this site was nonimpaired, and the diverse community included numerous mayfly and stonefly taxa. The water quality at T3 was rated as "higher" quality and was typical for water originating from a sandstone ridge. The water chemistry was similar to the water quality of T2 on Halter Creek. The habitat at this site was rated as excellent with above average epifaunal substrate and instream cover and well-developed riffles.

The station at the mouth of Plum Creek (H8) showed some improvement in water quality but was ranked in the "lower" water quality grouping. The biological condition was rated as slightly impaired, and diversity was lower than at the upstream site (H9). The habitat was rated as excellent, although it lacked a protective riparian zone on one side where the stream was very close to the road. The last half mile of Plum Creek runs adjacent to a quarrying operation that may have an impact on water quality in Plum Creek, as well as Halter Creek. In Plum Creek, sodium, chloride, and conductivity all decreased from upstream to downstream. However, nitrate was high at all three sites. This likely was related to the amount of agriculturally based land use in the sub-watershed. Also, Plum Creek is largely a spring-fed stream, and the groundwater in the surrounding aquifers has high nitrate concentrations (Lindsey and Koch, 2004).

Clover and Piney Creeks

The watersheds of Clover and Piney Creeks make up about 27 percent and 14 percent of Morrison Cove, respectively. These two streams flow almost parallel north and empty directly into the Frankstown Branch of the Juniata River. They are both currently designated as High Quality - Cold Water Fishes (HQ-CWF) (PA Code Chapter 93.9n). The main channels flow through primarily agricultural land and are influenced by ridge geology from tributaries and by the limestone valley they share between those ridges. Both are located in very rural areas, with no large population centers. Because of these similarities, the water quality and habitat ratings at the two sites on each stream differ only slightly.

Both the upstream (P2) and downstream (P1) sites on Piney Creek were rated as having "middle" water quality, slightly impaired biological condition, and excellent habitat. The two sites on Clover Creek (C1 and C2) both had "middle" water quality and excellent habitat conditions. However, the upstream site, C2, had a slightly impaired biological condition, while the site at the mouth, C1, was determined to be nonimpaired biologically. C1 had a higher diversity and abundance of mayflies and two stonefly taxa, whereas the other sites did not contain stoneflies. The only parameter of concern in Piney and Clover Creeks is nitrate, which is likely due to the fact that the land use in these watersheds is 50 percent agriculture.

Collecting macroinvertebrates in the upstream reaches of Clover Creek.

Yellow Creek

The Yellow Creek Watershed comprises the remaining 30 percent of the Morrison Cove valley. Although some of the headwaters are located in forested areas, the mainstem of Yellow Creek flows through generally low lying agricultural land and receives water from four large tributaries. The entire Yellow Creek Basin and all the tributaries included in the Cove are currently designated as HQ-CWF. With the exception of one small segment of Potter Creek, the entire Morrison Cove portion of the Yellow Creek Basin is impaired for nutrients and siltation from agriculture. Yellow Creek and all the sampled tributaries were listed as impaired on PADEP's 2004 Integrated List of All Waters (PADEP, 2004). Two sites were sampled on the mainstem of Yellow Creek, and additional sites were sampled at the mouths of each of the four tributaries that join Yellow Creek within the Cove. The stations sampled in the Yellow Creek Watershed were all nonimpaired biologically, except for Y5 in Beaver Creek, which was rated slightly impaired.

Hickory Bottom Creek, flows into Yellow Creek from the northeast and is the smallest of the four tributaries. The water quality at the site on Hickory Bottom Creek, Y1, was rated as "middle," due to an elevated nitrate concentration. The habitat condition was classified as excellent, and the biological condition was nonimpaired. This site was dominated by the organic pollution-tolerant mayfly taxon Baetis. However, this sample also had four other mayfly taxa and two stonefly taxa. In October, the middle reaches of Hickory Bottom Creek were dry. The sampling site was downstream of a spring flowing out of Hipple's Cave, which maintained flow in the lower reach of the creek. The first site on the mainstem of Yellow Creek, Y2, was upstream of the confluence of Potter Creek, and the water quality was rated as "lower" quality. The habitat was classified as supporting, but the biological condition was nonimpaired.

Yellow Creek as it flows out of Morrison Cove, east of Loysburg.

The macroinvertebrates included a mix of pollution-sensitive mayflies, stoneflies, and caddisflies.

Potter Creek flows into Yellow Creek from the northwest with much of its headwaters flowing through state game lands. The water quality at the Potter Creek site, Y3, was rated as "middle" quality, because of the elevated concentrations of nitrate. The biological condition was nonimpaired and was dominated by *Ephemerella*, with five other mayfly taxa and one stonefly taxon. This site also had one of the highest taxonomic richness scores with 28 taxa present. The habitat of Potter Creek was rated as excellent, and the stream had more widespread riparian buffer and instream cover than many of the other tributaries to Yellow Creek. Potter Creek also had a relatively constant temperature year round, which is an indication of a spring-fed stream.

Three Springs Run, like Potter Creek, originates in the carbonate valley in the center of Morrison Cove and receives a considerable amount of its flow from springs, but there are some differences in water quality at these two locations. The Three Springs Run site, Y4, had the highest levels of nitrates of all the steam sites in the Yellow Creek Watershed, which contributed to a water quality rating of "lower" for this site. Habitat at Y4 was considered to be excellent, and the macroinvertebrate community was classified as nonimpaired. Y4 contained numerous pollution-sensitive taxa and had one of the best Hilsenhoff Biotic Index scores and one of the highest Shannon Diversity scores of all the sampled locations. There were five mayfly taxa, but no stonefly taxa at this site. It was the only valley stream site to have the caddisfly taxon *Dolophilodes*, which is very pollution sensitive.

Beaver Creek joins Yellow Creek from the southern-most portion of the Cove and has numerous smaller tributaries that enter from the southern sandstone ridge. This resulted in slightly different water chemistry than the other Yellow Creek tributaries, specifically lower alkalinity and total hardness values. Site Y5, on Beaver Creek, ranked as "middle" class for water quality. Habitat condition was rated as supporting, and the biological community was slightly impaired. This site had the lowest taxonomic richness and diversity

ratings, and the macroinvertebrate population had fewer sensitive taxa than the other sites in the Yellow Creek Watershed. Beaver Creek is heavily impacted by agriculture throughout much of its watershed.

Yellow Creek site Y6 was the last sampling location before Yellow Creek exits the southern end of Morrison Cove just east of Loysburg. The water chemistry this site was rated as "middle" quality while the habitat condition was excellent. This represents the water quality as it exits the Cove; however, Yellow Creek continues for nearly 10 miles outside the Cove before it empties into the Raystown Branch of the Juniata River. The biological condition at this site was determined to be nonimpaired and included a mix of pollution-sensitive mayflies, stoneflies, and caddisflies. This sampling location also had slightly more pollution-sensitive taxa and slightly higher diversity than the upstream site on the mainstem of Yellow Creek (Y2).

Springs

Springs are natural wells that discharge groundwater into a local stream and occur where the water table is at or above the land surface. Springs can occur in or above a stream's channel and in periods of low precipitation provide much of the flow. There are two main types of springs within a carbonate aquifer system such as Morrison Cove: diffuse and conduit. Diffuse springs are described generally as deep-moving groundwater and show little seasonal variation or response to rain events. Conduit springs arise from a shallower groundwater system, are more responsive to precipitation, and have a higher seasonal variation in discharge and water chemistry (McGinty, 2003). Ten springs were sampled at least once throughout the course of the project. The locations of these springs can be found in Figures 2 and 3.

Large spring (S10) flows into Three Springs Run.

Halter Creek Watershed Springs

The Cabbage Creek spring, S1, was a small tributary flowing out of a spring-fed area that included a pond and numerous seeps. The water quality was characterized by very high total hardness and alkalinity. The nitrate concentration in this spring was more than 10 mg/l each of the three times it was sampled. This site was dry during the October sampling period and so no sample was collected. The estimated flow ranged from 60 gallons per minute (gpm) to 220 gpm. The small spring, S2, that enters the unnamed tributary to Halter Creek, T1, was the smallest of all the springs sampled. It also was characterized by high alkalinity and hardness, as well as the highest silica concentration of any spring site. The flow from this spring was quite low at <1 gpm to 7 gpm but was flowing throughout the year.

There were three different springs sampled that flowed directly into Plum Creek. Along Weitzel Hill Road, there were two springs that converged and flowed into Plum Creek less than a mile from the mouth. The discharge from this spring complex, S3, varied greatly throughout the year, from <10 gpm to over 1,200 gpm. This spring had the highest single sample concentrations of total hardness and magnesium in February 2006. Interestingly, the sulfate concentration in this spring was three to four times higher than any other spring sampled in the Cove, with samples ranging from 64 – 77 mg/l.

The spring in the headwaters of Plum Creek, S4, was flowing only in April and January and was sampled at its emergent point near a culvert on a farm. This spring had the highest single concentration of nitrates at 16 mg/l in January. Additionally, this spring also had the highest single concentrations of chloride, potassium, and sodium and the highest conductivity of any spring sample taken during January. These high concentrations of sodium and chloride in the winter may be related to road salt application for de-icing purposes. It is probable that this spring is a shallow spring, is affected greatly by rainfall events, and responds quickly to leaching of road salts, fertilizers and manure into the ground.

The largest spring sampled was S5, which doubled the flow to Plum Creek when it entered downstream of the Brumbaugh Road crossing. This spring was very productive, discharging more than 2,200 gpm minute in January, and included a large marshy area with one distinct channel flowing into Plum Creek. This spring flows above limestone geology, which is reflected in the high concentrations of calcium in the water.

Yellow Creek Watershed Springs

The site that initially was called a spring in the headwaters of Hickory Bottom Creek, S6, is likely not an actual spring but rather a portion of an intermittent stream flowing off the sandstone ridge. It did not exhibit any of the characteristics of spring water, such as low dissolved oxygen or a consistent temperature throughout the year. However, it was sampled quarterly and provided an example of the characteristics of water flowing from sandstone and shale geology. This water was characterized by low concentrations of alkalinity, calcium, magnesium, and hardness.

Two springs flowed directly into Yellow Creek, and both were in the headwaters of the stream. One of the springs, S7, was flowing only during the April sampling event. The reason for this is unknown since it was discharging more than 200 gpm when it was sampled. The other Yellow Creek spring, S8, flowed from under a spring house about 50 yards from where the sample was collected. This spring was flowing