Quittapahilla Creek Watershed Assessment
Volume 1 – Findings Report

Quittapahilla Watershed Association

August 2006

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Volume 1 – Findings Report

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1.1 – Introduction

In 2001 the Quittapahilla Creek Watershed Association was awarded an Environmental Stewardship and Watershed Protection Grant to conduct a watershed assessment and develop a restoration and management plan for the Quittapahilla Creek Watershed.

Since only a portion of the funding requested was approved under the 2001 Environmental Stewardship Grant (ME # 350428), it was necessary to reevaluate the scope of the project, and focus on those study components that could be completed with the funding provided. Based on this reevaluation, the funding provided by the approved 2001 grant was utilized to begin work in August 2001 on some of the tasks associated with the watershed assessment component of the project. The watershed assessment components funded under the 2001 Environmental Stewardship Grant were then referred to as Phase IA of the Quittapahilla Creek Watershed Project. The remaining components of the watershed assessment and developing the restoration and management plan were then referred to as Phase IB of the Quittapahilla Creek Watershed Project. In 2003 the Watershed Association was awarded a second Environmental Stewardship and Watershed Restoration and Protection Grant (ME # 3521023). This grant allowed the Watershed Association to complete the watershed assessment and develop the restoration and management plan.

The Preliminary Findings Report (Clear Creeks Consulting and Skelly & Loy, Inc, 2003), Geomorphic and Habitat Maps (Clear Creeks Consulting, et. al., 2002), and Field Reconnaissance Maps (Clear Creeks Consulting and Skelly & Loy, Inc, 2002), previously submitted, constituted the deliverables for Phase 1A and described/documented the work completed on the Quittapahilla Creek Watershed Project with the 2001 Environmental Stewardship Grant. This Final Findings Report and Restoration and Management Plan constitute the deliverables for Phase 1B and describe/document all of the work completed on the Quittapahilla Creek Watershed Project with both Environmental Stewardship Grants.

1.2 – Project Study Area and Background

The Quittapahilla Creek Watershed is situated in the Ridge and Valley and Triassic Lowland physiographic regions in Lebanon County, Pennsylvania. Quittapahilla Creek is a tributary to Swatara Creek and is part of the Susquehanna River Basin. Its headwaters begin just east of Lebanon, Pennsylvania and it enters the Swatara Creek near North Annville, Pennsylvania (Plate 1).

Although the major land use in the watershed is agricultural, there are significant areas of urbanization along the Route 422 corridor in the City of Lebanon, West Lebanon, Cleona, and Annville. In addition, new development in the watershed is replacing farms with suburban communities. Past and current land use and land management practices in the rural areas, suburban communities, and urban centers have contributed to degraded water quality, stream bank and bed erosion, sedimentation, flooding, and the loss of riparian and in-stream habitat throughout the Quittapahilla Creek Watershed.

The Quittapahilla Creek Watershed Association is particularly concerned about: channel instability caused indirectly by increased runoff from the urban centers and developing suburban areas, and the direct impacts associated with livestock grazing, the removal of riparian vegetation, and channel modifications; degraded water quality associated with sediment and nutrient loadings from upland sources (e.g., cultivated areas, parking lots, streets, highways, and rooftops) and point source discharges; and impacts to in-stream habitat resulting from sediment and nutrient loadings, and channel modifications implemented by private landowners.

Studies conducted by Pennsylvania Department of Environmental Protection (PADEP) confirm that these concerns are valid. The results of stream surveys conducted in the 1980's and 1990's clearly indicate impairment of aquatic resources in the Quittapahilla Creek Watershed. In fact, the main stem, as well as all of the major tributaries to the Quittapahilla Creek are listed as impaired in the 303(d) listings. The 2000 305(b) Report prepared by DEP indicated that there are 88.9 miles of stream in the Quittapahilla Creek Watershed. Only 1.82 miles of stream (2%) were found to support designated aquatic life uses. The identified land use activities contributing to impairment include agriculture, crop related agriculture, urban/storm sewers, and bank modification. Sources of impairment include nutrients, siltation, suspended solids, organic enrichment/low dissolved oxygen concentrations, flow alteration, and other habitat alterations.

The Total Maximum Daily Loads (TMDLs) Report (PADEP, 2000) cites excessive sediment and nutrient levels as a major water quality problem in the Quittapahilla Creek Watershed. The report indicates that these pollutants are causing increased algae growth, large accumulations of fine sediments on the streambed, and degradation of in-stream habitat. Although the report attributes the excessive sediment and nutrient levels principally to agricultural activities, these pollutants are also associated with other upland sources (e.g., urban runoff) as well as in-stream sources (e.g., stream bed and bank erosion).

Plate 1 – Watershed Map

1.3 – Project Goals and Objectives

A number of private organizations and public agencies have been working with the Quittapahilla Creek Watershed Association to improve the water quality and aquatic habitat of Quittapahilla Creek. However, there has been no comprehensive *Assessment*, nor coordinated effort to identify and prioritize water quality, habitat and stream channel stability problems throughout the watershed. As a consequence, targeting of stream reaches for improvements has been on a project-by-project basis. There is no *Master Plan* for the Quittapahilla Creek Watershed that serves to focus funding and restoration and management efforts where they are most needed.

The Quittapahilla Creek Watershed Association believes that its best chance for resolving the existing problems and avoiding future problems is to step back from the current project-based approach and develop a comprehensive plan of action based on an assessment of the entire watershed.

The Watershed Association's goals and objectives for the Quittapahilla Creek Watershed Project are presented below:

1. Establish benchmarks for evaluating and documenting changes in the watershed by assessing current hydrologic, water quality, in-stream habitat, and channel stability conditions.

2. Identify and prioritize restoration and management strategies to address existing hydrologic, water quality, in-stream habitat, and channel stability problems.

3. Determine the potential for future hydrologic, water quality, in-stream habitat, and channel stability problems.

4. Develop recommendations for management and protection strategies that will prevent and/or minimize future problems.

1.4 – Project Study Components and Methodology

The major components of this study include watershed characterization, subwatershed analysis, morphologic stream assessment, biological assessment, and water quality monitoring. The following outline describes the work involved in each component of the study.

1.4.1 – Watershed Characterization

Regional climatic conditions and watershed geology, soils, topography, land use and land cover have a significant effect on the volume, timing and routing of water and sediments

from adjacent uplands into a stream, and along the stream to the outlet of the watershed. These factors interact to profoundly affect the nature of stream systems and how resistant they are to disturbance.
Existing information was collected and compiled and additional information developed on regional weather patterns, natural watershed characteristics, and historic and current land use practices. This information was reviewed and evaluated to provide an understanding of how these characteristics may have affected or are affecting the hydrologic and sediment regime of the watershed and the water quality, habitat and channel stability of Quittapahilla Creek and its tributaries.

The types of data collected and compiled for review and evaluation included climatologic data, existing GIS databases, topographic maps, soils, geology, wetland and sensitive areas inventories, and land use maps, water quality data, biological data, hydrologic and hydraulic data, historic and recent aerial photography, as well as published and unpublished technical reports and management plans.

- Climate

Information on the regional weather patterns of the Quittapahilla Creek Watershed was obtained from the NOAA National Data Centers (NNDC) Climate Data Online.

- Watershed or Basin Morphometry

Mapping the Quittapahilla Creek Watershed was the first step in the characterization process. The watershed boundaries, drainage area, basin profile and cross-section have been determined from the Pennsylvania Spatial Data Access (PASDA) GIS Database and U.S. Geological Survey (USGS) quadrangle topographic maps at 1:24,000. The information on the Quittapahilla Creek Watershed was obtained from the Manheim, Fredericksburg, Richland, Lebanon, and Palmyra, PA quadrangles (USGS, 1995, 1994, 1974, 1995 and 1974).

- Geology

Evaluating the effects of geology on the hydrologic and sediment regime and stream channel morphology of Quittapahilla Creek began at the watershed level. The watershed map was overlain onto the geological map, noting geologic formations, where changes in rock type occur, and structural boundaries.

Mapping data on the surface geology of the Quittapahilla Creek watershed was obtained from the PASDA GIS Database. A number of references were utilized to develop a picture of the geology of the Quittapahilla Creek Watershed (Gray and Lapham, 1961; Geyer, 1970; Van Diver, 1990; and Miller, 1995).

- Soils

The soil characteristics of the Quittapahilla Creek watershed were evaluated to determine their effects on runoff, erosion hazard and the potential for unstable hillslope and channel conditions. Information on the soils of the Quittapahilla Creek watershed was obtained from the PASDA GIS Database and the Soil Survey of Lebanon County, Pennsylvania (1981).

- Land Use and Land Cover

The Quittapahilla Creek watershed was evaluated relative to historic, current, and future land use and land cover. Particular attention was focused on land use activities, vegetation changes, and channel alterations that have a significant influence on hydrologic and sediment regimes, hillslope processes and channel stability. Information on the current land use and land cover was obtained from the PASDA GIS Database and revised based on information collected during the field reconnaissance.

A history of land use activities, changes in vegetation patterns, as well as stream channel and floodplain alteration activities in Lebanon County, in general, and the Quittapahilla Creek watershed, in particular, was developed from historic aerial photographs, maps and plans obtained from records on file with the Lebanon County Board of Assessment (aerial photograph series 1936, 1967, 1984, and 1985), City of Lebanon Department of Public Works (historic survey maps 1851, 1888, 1906, and 1942).

In addition, historical references and maps from the Lebanon County Historical Society (Beers, 1875; Egle, 1883; Dundore, 1951; and Richter, et. al., 1987) and the Lebanon Valley College Library, Special Collections Section (Shay, 1949; Aungst, 1968; Carmean, 1976; and Westenberger, et. al., 1990) were consulted. These records were supplemented with anecdotal information obtained through interviews with local officials and residents.

Information on future land use was developed from zoning maps and master plans obtained from the townships and the Lebanon County Planning Office.

- Hydrology

    - U.S. Geological Survey Stream Gage Record Analysis

U.S. Geological Survey records for the USGS stream gaging station on Quittapahilla Creek near Bellegrove were analyzed to develop estimates for mean annual stream flow, characterize seasonal variability in mean monthly streamflow, and evaluate annual peak discharges for the period of record (1975 – 1994).

The most recent flood frequency analysis of the maximum annual peaks was used to develop estimates for peak discharges for the 1.25-yr, 1.5-yr, 2-yr, 10-yr, 50-yr and 100-yr recurrence interval (RI) flows.

Records for the USGS stream gaging station on Beck Creek near Cleona (1963 to 1981) were also analyzed. However, there is some concern regarding the reliability of estimates for the less frequent, higher volume storms for this gage site. The Watershed Association will be requesting that USGS evaluate any effects the peak flows recorded during Hurricane Agnes in 1972 may have had on these estimates.

- Field Calibration of Bankfull Discharge

When this study began regional regressions for estimating bankfull discharge and verifying bankfull channel geometry for Pennsylvania streams were not available. Therefore, field calibration surveys were conducted at five USGS gaging stations in the Ridge and Valley region of Pennsylvania and Maryland including Beck Creek, Quittapahilla Creek, Swatara Creek, Monocacy Creek, and Marsh Run. The watersheds draining these gages range in size from 7.87 – 116 square miles. This information was used to develop regional regression equations relating drainage area to bankfull discharge.

The Beck Creek and Quittapahilla Creek are both inactive gage sites. In order to utilize these sites for the watershed assessment, their historic rating tables had to be validated and updated. The Quittapahilla Creek Watershed Association entered into a cooperative agreement with the USGS field office in New Cumberland, PA to validate/update the rating tables. The necessary field measurements and analytical work was completed and the rating tables updated. Utilizing the new rating tables, the U.S. Fish and Wildlife Service conducted the gage calibration surveys at the five USGS gaging stations and developed the regional regressions for use in developing estimates of bankfull discharge and to verify bankfull channel indicators observed during the morphologic stream assessment. Unfortunately, the reliability of the regional regressions developed by the U.S. Fish & Wildlife Service was significantly affected by the limited number of gage sites surveyed. It was determined that these regional regressions should not be used to develop discharge estimates or verify bankfull indicators.

- U.S. Geological Survey Regional Regressions

As noted above, it was originally intended that the field calibration work conducted by the U.S. Fish & Wildlife Service would be used to develop regional regressions for estimating bankfull discharge and for use in the morphologic stream assessment. However, due to the limited number of gage sites surveyed these regional regressions were not used for this study.

The U.S. Geological Survey recently published regional regressions that were developed utilizing data from 66 gage sites in Pennsylvania and Maryland (J. Chaplin, 2005). The large data set provided curves with good predictive capability. More importantly USGS also developed regressions specific to carbonate watersheds making them both reliable and directly applicable to Quittapahilla Creek. These regressions were used as part of this study to calibrate the HEC-HMS hydrologic model, estimate bankfull discharge, and verify the data collected during the morphologic stream assessment.

- Hydrologic Modeling and Analysis

A hydrologic analysis of the Quittapahilla Creek watershed was conducted to develop estimates of the 1-, 2-, 10-, 50- and 100-year 24-hour peak discharge rates for segments along the Quittapahilla Creek mainstem and for each of its major subwatersheds.

The intent of developing this information was to characterize the existing hydrologic regime of the Quittapahilla Creek watershed. This information provided insight into how land use activities have altered peak flow characteristics and contributed to channel stability and flooding problems. In addition, the results of the hydrologic modeling were used to evaluate and select potential sites for best management practices for controlling stormwater runoff. This was accomplished by reevaluating peak discharge rate and the shape of the hydrograph for the 1-, 2-, 10-, 50- and 100-year 24-hour storms under existing and future land use conditions with and without best management practices.

The U.S. Army Corps of Engineers (ACOE) Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) computer program was selected for conducting the hydrologic modeling and analysis of the Quittapahilla Creek Watershed. Essentially, this computer program is an improved version of the ACOE HEC-1 computer program.

Several benefits are derived from the development of the Quittipahilla Watershed hydrologic model using HEC-HMS. First, peak stormwater runoff rates and hydrographs are the primary output parameters from the model. Second, the model can initially be used to evaluate and select potential sites for the construction of stormwater control facilities. Third, from the perspective of land use and stormwater management planning, the HEC-HMS model can also be used to evaluate the impact of proposed subdivisions and land developments. When a land development or subdivision plan application is submitted, the sub-area in which the proposed project is located is divided into the minimum number of smaller drainage areas that are required to accurately analyze the impact that the proposed project would have on stormwater runoff rates from the sub-area and at points of interest downstream in the watershed. Similarly, the stormwater runoff rate control provided by the stormwater management facilities proposed for the project can be analyzed.

- Mapping 100-Year Floodplains

To determine the extent of the Quittapahilla Creek watershed affected by flood flows, the approximate limits of the 100-year floodplain along the Quittapahilla Creek mainstem and its tributaries were determined from the PASDA GIS Database. In addition, historic flood studies conducted in the Quittapahilla Creek watershed were reviewed and evaluated

1.4.2 – Morphologic Stream Assessment of Quittapahilla Creek

The intent of the morphological stream assessment was: map current geomorphic features; assess current channel condition; identify factors influencing channel condition; identify the location and nature of channel stability problems; evaluate the direction, rate and nature of channel adjustments; evaluate the degree to which the existing channel conditions differ from an accepted range of morphological values for stable streams; and determine the sensitivity of the stream reaches assessed to alterations in hydrologic or sediment regime and/or direct disturbances.

Following the assessment procedures of Rosgen (1996) the Team did: characterize the current channel morphology; evaluate its departure from a potential stable form; determine the factors and processes influencing it (past and present); and determine its direction of adjustment.

- Field Calibration of Bankfull Channel Field Indicators

As indicated above, the U.S. Geological Survey recently published regional regressions that were developed utilizing data from 66 gage sites in Pennsylvania and Maryland (J. Chaplin, 2005). The large data set provided curves with very reliable predictive capability. More importantly USGS also developed regressions specific to carbonate watersheds making them both reliable and directly applicable to Quittapahilla Creek. These regressions were used as part of this study to calibrate the HEC-HMS hydrologic model, estimate bankfull discharge, and to verify channel geometry data that was based on bankfull channel indicators observed during the morphologic stream assessment.

- Level I - Geomorphic Characterization of Quittapahilla Creek

The reaches along the Quittapahilla Creek were classified into generalized categories of stream types (i.e., A, B, C, D, etc.) utilizing USGS quadrangle maps, and 1994 aerial photography.

- Geomorphic Features of Quittapahilla Creek

During Summer 2001, the geomorphic features of Quittapahilla Creek were mapped from the headwaters south of the City of Lebanon to the confluence with Swatara Creek.

The 1994 Quarter Quad aerial photographs were utilized for the geomorphic mapping in the field. The aerial photographs were developed at a scale of 1 inch = 100 feet and overlain with mylar sheets onto which the left and right stream banks of Quittapahilla Creek had been digitized. Stream channel and adjacent floodplain features were then hand drawn on these mylar base maps. Landscape features shown on the aerial photographs could be seen through the mylar sheets, thereby providing points of reference for orientation in the field.

The geomorphic mapping effort focused on verifying existing land use activities and land cover including type and condition, identifying and documenting unstable conditions in upland and riparian areas, characterizing stream channel morphology and condition, and identifying point and non-point pollution sources. Observations on riparian and stream bank vegetation, meander pattern, depositional features, debris and channel blockages, vertical stability, streambed materials, streambed features (e.g., riffles, pools, runs and glides), bank height, stream bank erosion were mapped and recorded. The location of significant points in the field (e.g., storm drain outfalls, wastewater discharge outfalls, and springs) were noted on the maps and recorded to facilitate relocation with a Garmin Hand-Held GPS Unit. The Geomorphic and Habitat Maps submitted previously document the findings of this effort.

- Morphological Description and Assessment of Stream Condition

During Spring 2003, a morphological stream assessment was conducted along the mainstem of Quittapahilla Creek. This work included the detailed levels of geomorphic assessment and was critical to evaluating the overall condition and stability of Quittapahilla Creek and completion of the geomorphic component of the watershed assessment.

Quittapahilla Creek was classified into specific categories of stream types (i.e., B4, C4, E4, etc.) and assessed for channel condition utilizing a combination of the standard field procedures and the extrapolation field procedures recommended by Rosgen (1996). Fourteen reaches along the mainstem Quittapahilla Creek were identified as being representative of stream type and stream condition along the mainstem. Detailed reach classification surveys were conducted of these fourteen representative reaches. The same reaches were assessed relative to existing channel morphology, vertical and lateral stability, sediment transport competence, and influencing factors including riparian vegetation, meander pattern, depositional pattern, debris and channel blockages, and sediment supply. In addition, all banks in meander bends and each eroding bank regardless of location along the mainstem were evaluated relative to bank erosion potential and near bank stress.

Utilizing the information developed from the geomorphic mapping, the data collected from the Level II stream classification and Level III channel condition assessment of the representative reaches was extrapolated to the other thirty-eight reaches along the mainstem Quittapahilla Creek. The information from the representative and extrapolated reaches was utilized to evaluate the current conditions of Quittapahilla Creek, and the degree to which the existing conditions of the representative reaches differ from an accepted range of morphological values documented for similar stable stream types.

- Level IV - Stream Stability Validation Monitoring**.**

Verification of the assessment data through monitoring is a critical component of the overall effort. It provided documentation of the problems along Quittapahilla Creek for state and federal permitting agencies, as well as funding agencies. It provided baseline data for evaluating restoration and management strategies. In addition, it was utilized in conjunction with water quality monitoring data to calibrate the water quality model.

In order to document channel erosion rates, and develop in-field estimates of sediment loadings from in-stream sources, twenty-five permanent cross-sections established along the Quittapahilla Creek were monitored for channel stability over a period of eighteen months. This component of the study involved the installation of permanent cross sections, surveying the cross sections, and resurveying the cross sections at the end of eighteen months. The permanent cross sections were installed and surveyed during Summer 2001. They were resurveyed during Spring 2003. The work completed was documented in the Draft Geomorphic and Habitat Maps.

1.4.3 – Subwatershed Analysis

The physical features and current conditions of each of the major subwatersheds of Quittapahilla Creek watershed were assessed. The information utilized in the assessment was gathered from existing GIS databases, topographic maps, soil surveys and maps, geologic maps and reports, land use and land cover maps, as well as historic and recent aerial photography. Conducting a Level I - Geomorphic Characterization and field reconnaissance with photographic documentation of the subwatersheds provided additional information on current conditions.

- Level I - Geomorphic Characterization of the Major Tributaries

The geomorphic characterization focused on classifying stream reaches in these subwatersheds into the generalized stream types (i.e., A, B, C, D, etc.) described in <u>A Classification of Natural</u> <u>Rivers</u> (Rosgen, 1994). The stream reaches were classified based on information gathered from USGS quadrangle maps and aerial photography. This task provided information that was useful in focusing the field reconnaissance effort. Conversely, the field reconnaissance provided verification of the initial reach classifications.

- Field Reconnaissance of the Subwatersheds

During Summer 2001, the field reconnaissance and photographic documentation was conducted to assess and document existing conditions in each of the major subwatersheds from their headwaters to confluence with Quittapahilla Creek. A total of 62 miles of tributaries including Killinger Creek, Buckholder Run, Gingrich Run, Bachman Run, Beck Creek, Snitz Creek, an Unnamed Tributary draining South Lebanon, Brandywine Creek, and Unnamed Tributary draining North Annville were reconnoitered and mapped.

The USGS 7.5-minute topographic maps were utilized as a base for the field reconnaissance maps used in the field. The field reconnaissance maps were developed at a scale of 1 inch = 660 feet to allow overlay with the Soil Survey and Conservation Plans prepared by the Lebanon County Conservation District for agricultural lands.

The field reconnaissance focused on verifying existing land use activities and land cover including type and condition, identifying and documenting unstable conditions in upland and riparian areas, characterizing stream channel morphology and condition, and identifying point and non-point pollution sources.

This information, in conjunction with information from other study components (i.e., hydrologic modeling, water quality modeling, water quality monitoring, and biological surveys) provided a basis for identifying and prioritizing problem areas in the subwatersheds.

1.4.4 – Ecological Assessment

Evaluating information and data from historic biological surveys can provide an understanding of how biological communities have changed with land use activities in a watershed. The available biological data was utilized to evaluate historic conditions and determine trends for the biological communities along Quittapahilla Creek and its tributaries.

As part of the current study, surveys were conducted to evaluate the existing habitat conditions and the biological communities in the Quittapahilla Creek watershed. Ten (10) stations were identified along the Quittapahilla Creek and its major tributaries for macroinvertebrate and fish surveys. This component of the study provided information on existing conditions that was utilized in conjunction with water quality monitoring and geomorphic assessment data to identify and prioritize problems along the main stem Quittapahilla Creek and its major tributaries. The biological surveys also established baseline conditions prior to the implementation of any restoration or management measures.

- Historic Biological Communities

The data compiled from biological surveys (macroinvertebrate and fish) conducted by various state agencies (e.g. PA Fish Commission, PA DER, etc.) from the mid-1960's through the late 1980's were reviewed and evaluated. Data compiled from other investigations were also evaluated. For example, a study conducted by Bethlehem Steel Corporation between 1975 and 1978 was part of the NPDES monitoring program at their Lebanon Plant.

More recent studies conducted by staff of the U. S. Department of Agriculture included macroinvertebrate sampling to evaluate the effects of the Watershed Association's stream bank fencing projects. As part of this effort Beck Creek, Bachman Run, Snitz Creek and locations along Quittapahilla Creek were sampled in 1999 and 2000. The most recent data available includes the results of macroinvertebrate sampling and habitat assessments conducted in Spring 2001 by Pennsylvania DEP. Data from all these investigations was reviewed and evaluated.

- Evaluation of Existing In-Stream Habitat

During Summer 2001, existing in-stream habitat along the mainstem Quittapahilla Creek was mapped. Because this part of the assessment was focused on habitat criteria for naturally reproducing trout populations, habitat parameters relevant to spawning and sustaining embryos, fry, juvenile and adult fish were emphasized in the mapping/evaluation process.

The habitat mapping effort focused on characterizing and documenting existing habitat including depth of pools and riffles/runs; percent of the total stream area that provides adequate cover for adult trout during the low flow period; an evaluation of channel substrate relative to potential spawning areas, fry and juvenile escape cover and resting areas, macroinvertebrate habitat in riffles/runs, and the % fine sediment (embeddedness) in riffles/runs; percent of stream length that is pools; a rating of the quality (i.e., size, depth, structure) of the pools; dominant stream bank vegetation; percent of the stream bank covered by vegetation; and the percent of the stream area shaded.

- Existing Biological Communities

During Winter 2003 the benthic macroinvertebrate communities were assessed along the Quittapahilla Creek and its major tributaries. The biological sampling effort utilized the U.S. EPA Rapid Bioassessment Protocol (RBP) and included field data collection at ten stations; taxonomic identification; development of Functional Group and Tolerance Indices for macroinvertebrate communities at each station; data interpretation; and data management.

The fish communities were assessed during Summer 2004. This biological sampling effort also utilized the U.S. EPA Rapid Bioassessment Protocol (RBP) and included field data collection at the same ten stations; taxonomic identification; determination of tolerance value and trophic level; and calculation of Indices of Biotic Integrity (IBI) for fish communities at each station.

1.4.5 – Water Quality Assessment

- Historic Water Quality Conditions

The data compiled from water quality monitoring conducted by various state agencies (e.g. PADEP, PADER, etc.) from the mid-1960’s through the late 1980’s were reviewed and evaluated. Data compiled from other investigations were also evaluated. For example, a study conducted by Bethlehem Steel Corporation between 1975 and 1978 was part of the NPDES monitoring program at their Lebanon Plant.

More recently, the Biology Department of Lebanon Valley College has been conducting water quality monitoring under baseflow conditions at a number of locations along Quittapahilla Creek and its tributaries since 1999. Their data was compiled, reviewed and evaluated.
The available data was utilized, to the extent practical, to evaluate historic conditions and determine trends for the water quality along Quittapahilla Creek and its tributaries.

- Total Maximum Daily Loads (TMDLs) Study

The Pennsylvania Department of Environmental Protection developed TMDLs for the Quittapahilla Creek watershed to address siltation, suspended solids, and nutrient impairments identified in Pennsylvania's 1996 and 1998 303(d) lists and 2000 305(b) report. The Total Maximum Daily Loads (TMDLs) Report (PADEP, 2000) was reviewed and evaluated to develop an initial understanding of the type and magnitude of water quality problems that exist in the Quittapahilla Creek Watershed. The findings of the report guided development of the work plan and assessment approach for the current study.

- Water Quality Modeling and Analysis

Two key issues in selecting a water quality model concern the model data requirements and the availability of these data across the watershed. The Generalized Watershed Loading Function (GWLF) model is especially suitable, both in terms of data requirements and accuracy of output. Loading functions provide a useful means for estimating nutrient and sediment loads when chemical simulation models are impractical due to funding limitations or data availability. Much of the data for the GWLF model are available through databases maintained by local, state and federal agencies. Other key input parameters can be estimated based on literature research. Recently, Pennsylvania State University has been assisting DEP in the development and implementation of the GWLF model with a GIS software (ArcView) interface (AVGWLF). AVGWLF has been selected by DEP to help support its ongoing TMDL projects within Pennsylvania.

With respect to the Quittapahilla Watershed, AVGWLF was selected to analyze water quality due to its ability to simulate nutrient and sediment loads within the impaired watershed, compare simulated loads within the impaired watershed against loads simulated for a nearby unimpaired "reference" watershed, and identify and evaluate pollution mitigation strategies (Best Management Practices – BMPs) that could be applied in the impaired watershed to achieve pollutant loads similar to those calculated for the reference watershed.

The analysis focused on identifying general areas where pollutant loadings indicate that best management practices should be implemented. In addition, the analysis evaluated the effect that implementing best management practices has on reducing pollutant loadings in the subwatersheds.

- Point Source Discharges

Information on major point source pollution discharges in the Quittapahilla Creek watershed was obtained from the PADEP's e F.A.C.T.S. Web Site. The Permit Engineer with PADEP, Water Management Program, South Central Office responsible for reviewing and monitoring NPDES permits in the Quittapahilla Creek Watershed verified the information obtained from the Web site (T. Carpenter, personal communication). The majority of the discharge outfall locations were identified and mapped during the field reconnaissance.

- Water Quality Monitoring

The Biology Department of Lebanon Valley College (LVC) has been conducting water quality monitoring under baseflow conditions at a number of locations along Quittapahilla Creek and its tributaries.

The Biology Department's water quality monitoring was conducted in 1999, 2000, and 2001 at one site on Snitz Creek (Dairy Road); four sites on Beck Creek (Bricker Lane, Royal Road, Reist Road, and Oak Street); five sites on Bachman (two sites along Rte. 241 near the headwaters, Fontana Road, Bucher Lane, and Reigerts Lane), and one site on the Quittapahilla Creek (Glen Road). The parameters monitored included temperature, pH, turbidity, nitrate-nitrogen, orthophosphate, and alkalinity.

During the Summer, Fall and early Winter, 2003 the consulting Team conducted water quality monitoring of storm flow events at ten sites along Quittapahilla Creek and its tributaries. The consultant's monitoring effort included installation of staff gauges at each site, installation of continuous-reading digital thermographs at each site; flow measurements and rating curve development for each site; sample collection and analysis for five storm events at each site. The storm water samples were analyzed for: temperature, pH, dissolved oxygen, specific conductance, total acidity, total alkalinity, biochemical oxygen demand, nitrate, orthophosphate phosphorus, total phosphorus, total dissolved solids, total Kjeldahl nitrogen, total nitrogen, total suspended solids, turbidity, hardness, copper, lead, zinc, and fecal coliform.

The additional monitoring effort allowed a baseline to be established for water quality conditions, comparison of baseflow and storm flow conditions, computation of pollutant loadings of key parameters, calibration of the water quality model to actual water quality conditions in the watershed, and establishment of a long-term monitoring program for tracking improvements in water quality as restoration and management measures are implemented.

- Evaluation of Sediment Discharge

The comprehensive watershed assessment provided much of the information needed to develop a rational, science-based plan for improving the Quittapahilla Creek. However, the initial work effort did not include a sediment-evaluation program. This gap in the assessment was considered significant because the TMDL report for Quittapahilla Creek points to sediment as a major cause of impairment. In 2003 the National Fish and Wildlife Foundation, through their Chesapeake Bay Small Watershed Grants Program, provided funding to study the sediment yield characteristics of the watershed. During the period of Fall 2003 to Spring 2005 bedload and suspended sediment load samples were collected at one station on the lower main stem Quittapahilla Creek and two tributary stations. The data was collected across a range of stream flow conditions and was used to develop a sediment rating curve for determining sediment transport and sediment yield characteristics for the system. The detailed results of the sediment discharge evaluation are presented in a separate report (Skelly & Loy, Inc. and Clear Creeks Consulting, 2005) and summarized in this document.

Because this sediment monitoring effort was a component of an overall watershed assessment, it provided information that was utilized in conjunction with the baseflow and storm flow water quality monitoring, biological survey data, and geomorphic assessment data to identify and prioritize problem areas along the mainstem of Quittapahilla Creek and its major tributaries. It established a baseline for water quality conditions, allowed computations of actual sediment loadings, provided a comparison of baseflow and storm flow conditions, evaluated the effects of land use on sediment loadings, allowed calibration of the water quality model to actual water quality conditions in the watershed, and established a long-term monitoring program for tracking improvements in water quality as restoration and management measures are implemented.

Section 2 – Watershed Characterization

2.1 – Introduction

This section summarizes the physical characteristics of the Quittapahilla Creek watershed. The information presented in this section provides an overview of the entire watershed area and a general description of Quittapahilla Creek and its major subwatersheds. Plate 1 presented a map of the Quittapahilla Creek watershed. Detailed information specific to the major subwatersheds and Quittapahilla Creek mainstem is presented in the Subwatershed Analyses, Morphologic Stream Assessment, Ecological Assessment, and Water Quality Assessment sections, respectively.

The primary focus of the watershed assessment is identifying hydrologic, water quality, in-stream habitat, and channel stability problems. Therefore the information presented in this section was utilized to evaluate how regional weather patterns, natural watershed characteristics, and historic and current land use practices may have affected or are affecting the hydrologic and sediment regime of the watershed, water quality and habitat, channel stability of Quittapahilla Creek and its subwatersheds.

The sources for the information collected included climatologic databases, hydrologic databases and technical reports, GIS databases, topographic maps, soil surveys and maps, geologic reports and maps, land use/land cover maps and historical records on land use activities, and historic and recent aerial photography.

2.2 – Physiography

The Quittapahilla Creek Watershed is situated in the Ridge and Valley and Triassic Lowland physiographic regions in Lebanon County, Pennsylvania. Quittapahilla Creek is a tributary to Swatara Creek and is part of the Susquehanna River Basin. Its headwaters begin just south of Lebanon, Pennsylvania and it enters the Swatara Creek near North Annville, Pennsylvania.

The landforms of the Ridge and Valley region are dramatic for their regularity if not for their topographic relief (Miller, 1995). Northeast-southwest trending mountains and valleys characterize the Ridge and Valley region. Folding and differential erosion of sedimentary rocks created the landforms of this region. The region was deformed and pushed westward by the Appalachian Orogeny of the Late Paleozoic Period. The less resistant rocks, such as dolomite and limestone, brought to the surface by this geologic process eroded rapidly and became lowland valleys, while the more resistant rock, such as shale and sandstone, formed the ridges and high valleys. The Quittapahilla Creek watershed is situated almost entirely in the Great Valley, one of several subregions of the Ridge and Valley characterized by broad limestone valleys. In the Lebanon County area elevations range from over 1600 feet on Second Mountain to 400 feet in the Lebanon

Valley. Typically streams in the region have a well-developed dendritic drainage network, with major streams occupying broad valleys trending northeast-southwest and minor streams flowing off the ridges and intersecting the major streams. The headwaters of the southern tributaries drain a ridgeline along the southern boundary of Lebanon County that is situated in the northern portion of the Triassic Lowlands. The Triassic Lowlands are an irregularly shaped belt that parallels the Piedmont physiographic region to its northwest. They are composed of relatively young and weak sedimentary rocks into which volcanic rock have intruded themselves. The weak sedimentary rocks of this region have developed into fertile lowlands, while the volcanic ridges resemble the more rugged landscape of the Piedmont Uplands (Miller, 1995).

2.3 – Climate

Lebanon County lies too far inland for the climate to be strongly affected by the Atlantic Ocean, and therefore, it has a humid continental climate. Most weather systems that affect the County develop in the Central United States and are modified considerably before reaching the area. The average annual precipitation of 42.3 inches is distributed throughout the year, most of which is in the form of rainfall. May – August are the periods of highest precipitation, which usually occurs as afternoon or evening showers or thunderstorms. There are about 37 thunderstorms each year, and most occur during this period. January – February are the periods of lowest precipitation. Average annual snowfall is 27 inches. The first significant snowfall is usually in December and the last snowfall normally occurs in March.

Winters are cold, but cloudiness is not persistent because of the moisture lost in the more western counties as the air masses approach. Mean daily temperatures range from 27.3 – 32.2ºF in winter. In summer, 60 percent of possible sunshine is received. Mean daily temperatures range from 67.8 – 72.2ºF in summer. Extended periods of hot humid weather occur with temperatures hotter than 90º F. Spring and fall are transition periods. High temperatures in April and October are in the 60’s.

Table 2.3.1 presents the monthly ranges and averages of temperature and precipitation in Lebanon from available records covering the last 50 years.

Parameter	**Monthly Average and Range**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temperature (F°)	27.3 (18-37)	29.9 (19-43)	39 (24-55)	49.2 (34-66)	59.0 (43-75)	67.8 (53-82)	72.2 (60-84)	70.0 (57-83)	62.6 (46-77)	51.4 (35-68.0)	41.3 (28-57)	32.2 (21-45)
Precipitation (Inches)	3.19 (1.32-6.31)	2.56 (0.88-6.68)	3.31 (0.81-8.17)	3.72 (1.41-7.84)	4.61 (1.47-8.02)	4.04 (0.73-9.07)	4.57 (0.86-10.29)	3.48 (1.25-11.12)	4.08 (0.41-8.21)	3.32 (0.60-8.50)	3.62 (0.90-5.96)	3.19 (1.27-7.40)

Table 2.3.1 – Monthly ranges and averages of temperature and precipitation in Lebanon, PA

2.4 – Basin Morphometry

The Quittapahilla Creek watershed area is 77.3 square miles (49,472 acres). It is an oblong basin, about 14.8 miles long by 8.3 miles wide at its widest point. The subwatershed areas of its eight largest tributaries, Killinger Creek, Snitz Creek, Unnamed Tributary South, Beck Creek, Bachman Run, Gingrich Run, Brandywine Creek and Buckholder Run are 14.28, 11.25, 9.45, 8.17, 8.16, 4.99, 3.25, and 0.9 square miles, respectively. Plate 2 shows the major subwatersheds.

From its headwaters south of the City of Lebanon (elevation 500 feet) Quittapahilla Creek flows approximately 22 stream miles to its confluence with Swatara Creek in the North Annville Township (elevation 350 feet). The average slope of the mainstem is 0.13%. The high point of the watershed is situated at Furnace Hills in Cornwall Township (elevation 1120 feet), giving the basin an average longitudinal gradient of 1.0%.

The southern boundary of the watershed divide includes numerous ridges and knobs with elevations ranging from 700 to 960 feet. The steeper headwater areas of the tributaries draining these southern ridges range in slope from 2 to 4%. After flowing off the ridges these tributaries meander for several miles across the valley floor before reaching the mainstem. As a consequence, the gradients of their lower reaches are much flatter, with average slopes ranging 0.1 to 0.5%. Most ridges and knobs along the northern boundary of the watershed are less than 600 feet in elevation. With the exception of Brandywine Creek, these northern tributaries flow off the ridges directly into the mainstem. The average slopes of these tributaries range from 1.0 to 2.0%. Plate 3 presents a map of the Quittapahilla Creek watershed topography.

2.5 – Geology and Soils

Plates 4 – 7 present maps of the soils and geology of the Quittapahilla Creek watershed. As mentioned previously, the headwaters of the southern tributaries drain a ridgeline along the southern boundary of Lebanon County that is situated in the northern portion of the Triassic Lowlands. This area is underlain by Triassic sandstone, conglomerate, and diabase. The Triassic diabase intrusion has been mined for iron ore. The Cornwall mines, the oldest continuously operated mines in the Western Hemisphere, were important producers of high-grade ore from 1742 until 1972.

The majority of the land area in the watershed is situated in the Great Valley section of the Ridge and Valley region. This area is underlain by bedrock of Lower Paleozoic shale, limestone, and dolomite formations. The upper and middle reaches of the mainstem Quittapahilla Creek as well as the middle and lower reaches of the major tributaries flow across the carbonate rocks of the valley. Sinkholes and solution cavities are common in these carbonate rocks. Quarries in the carbonate rock are mined for concrete aggregate, cement, flux stone, and paint filler.

The lower reaches of the mainstem Quittapahilla Creek, as well as the headwaters of the northern tributaries, are underlain by interbedded sedimentary rock and shale.
The dominant soils in the headwaters of the tributaries that drain the southern ridges include those in the Ungers-Neshaminy-Watchung map unit. These soils formed in residuum or colluvium from conglomerate, sandstone, siltstone, diabase, and other dark basic rock. Unger and Neshaminy soils are deep, well drained fine loamy soils along ridges and convex slopes. They have slow to moderate runoff potential and low to moderate erosion hazard. Watchung soils are deep, poorly drained fine soils in depressions, on flats and foot slopes in uplands. They have moderate to rapid runoff potential and high to severe erosion hazard.

The dominant soils along the middle and upper reaches of Quittapahilla Creek as well as the middle and lower reaches of the southern tributaries include those in the Hagerstown-Duffield-Clarksburg map unit. They are deep, well drained to moderately well drained silt loam soils in limestone valleys. They formed in residuum and colluvium from limestone with some sandstone and shale. These soils have moderate to rapid runoff potential and moderate to high erosion hazard.

The dominant soils along the lower reaches of Quittapahilla Creek as well as the northern tributaries include those in the Berks-Weikert-Beddington map unit. They are shallow to deep, well drained loamy skeletal and fine loamy soils in uplands. They formed in residuum from acid shale, sandstone, and siltstone. Berks and Weikert soils have moderate to rapid runoff potential and low to moderate erosion hazard. Beddington soils have slow to moderate runoff potential and moderate erosion hazard.

The dominant soils in the Brandywine subwatershed include those in the Beddington-Berks-Holly map unit. These are deep and moderately deep, well drained and very poorly drained to poorly drained fine loamy soils on uplands and floodplains. They formed in residuum from acid shale and sandstone and in alluvium. Berks soils have moderate to rapid runoff potential and low to moderate erosion hazard. Beddington soils have slow to moderate runoff potential and moderate erosion hazard. Holly soils have rapid runoff potential and low to moderate erosion hazard.

2.6 – Land Use and Land Cover

Plate 8 and Table 2.6.1 show the land use and land cover in the Quittapahilla Creek watershed. The dominant land use along the southern ridges of the watershed is forest. State Game Lands, administered by the Pennsylvania Game Commission, account for the largest areas with additional forest in private ownership. The majority of the forests are deciduous. However, some coniferous and mixed species areas are scattered throughout the subwatersheds. Deciduous tree types include northern red oaks, black oak, pin oak, yellow poplar, white ash, sugar maple, and red maple. Virginia pine, white pine and shortleaf pine are the dominant conifers. Although land use in the southern subwatersheds generally changes to pasture and cropland on the slopes and along the valleys between the forested ridges and Route 322 and Route 419, each area has a relatively unique mix of land uses.

The upper Killinger Creek subwatershed is a mix of small – medium lot-size residential subdivisions and large farms with pasture and row crops. Large farms with pasture and row crops and scattered large lot homesteads are typical of the land use along Buckholder Run. Upper Gingrich Run includes the Thousands Trails Campground with its small lake, the lumber mill owned and operated by Walter H. Weaber & Sons, Inc., and large farms with pasture and row crops. Upper Bachman Run includes large lot-size residential subdivisions, Pennsy Supply's Fontana Quarry, Philhaven Hospital, and large farms with pasture and row crops. Land use in the upper Beck Creek subwatershed includes the Gretna Glen Camp with its small lake, and large farms with pasture and row crops. The upper Snitz Creek subwatershed is a mix of new and old small lot-size residential subdivision communities with supporting public facilities (e.g., fire, school, and athletic fields) and small commercial establishments. These communities include Quentin, Cornwall Center, Burd Coleman Village, Anthracite, and Miners Village. Cornwall Manor Retirement Community encompasses an extensive area between Cornwall Center and Anthracite. The area between Burd Coleman Village and Cornwall Furnace includes abandoned iron ore mining quarries, haul roads, and mine waste piles. Land use along the upper Unnamed Tributary draining South Lebanon includes the community of Rexmont.

The middle and lower reaches of each subwatershed are equally unique in their land use characteristics. In this part of the watershed Killinger Creek is predominately large farms with pasture and row crops. However, medium - large lot-size residential subdivisions in South and North Londonderry Townships, as well as small lot-size residential subdivisions and commercial properties in Palmyra drain to the creek. Before entering the mainstem Quittapahilla Creek, Killinger Creek passes beneath Route 422 and flows through the Pennsy Supply's Millard Quarry. Although Bachman Run is bordered predominately by large farms with pasture and row crops, several medium – large lot-size residential communities in South Annville Township drain to the creek. With the exception of the Royal Oaks Golf Course, Lebanon Valley Country Club, a small – medium lot-size residential subdivision, and scattered residences, land use in this part of the Beck Creek subwatershed is large farms with pasture and row crops.

The Snitz Creek subwatershed is the most developed of the free flowing southern tributaries. It drains land that includes numerous small – medium lot-size residential subdivisions in the Cornwall, West Cornwall, and North Cornwall Townships. It also drains the Fairview and North Cornwall Golf Courses, as well as the densely developed commercial properties along Route 72. In spite of all of this development, the majority of the land area draining to the creek is large farms with pasture and row crops.

The Unnamed Tributary draining South Lebanon is the most densely developed subwatershed. However, along most of its length it is in pipe or concrete flume. In this part of the subwatershed, land use along the Unnamed Tributary includes the Lebanon Valley Business Park, Veteran's Administration Medical Center, V.A. South Hills Golf Course, several public schools, numerous old and new small lot-size residential

neighborhoods, and densely developed residential/commercial properties and public facilities in the City of Lebanon.
In the northern part of the Quittapahilla Creek watershed, Brandywine Creek is the most densely developed subwatershed. Upstream of Stovers Dam, its headwaters are predominately large farms with pasture and row crops. The Yule Tree Farm occupies the land north of Kimmerling Road and west of N 8th Street. Development in this part of the watershed includes residences with small – large size lots along the roads, a church and private school with athletic fields, the Stovers Dam Recreation Area, and Lebanon Community Theater. Brandywine flows through the Mt. Lebanon Cemetery before joining an unnamed tributary that drains the Reinoehlsville and Sunset communities. Land use surrounding this tributary includes a few large farms with cropland, old and new small – medium lot-size residential areas, and a few small commercial properties.

The Brandywine is piped from 8th Street to 12th Street in the City of Lebanon.
A second unnamed tributary drains the Sand Hill community, which includes old and new small – medium lot-size residential areas. This unnamed tributary enters a pipe under a Municipal stockpile and waste area just west of 8th Street and joins with the Brandywine. From 12th Street to its confluence with the mainstem Quittapahilla Creek, the Brandywine flows through a series of flumes (grass-, gabion-, and concrete-lined) and pipes. In this part of the subwatershed the Brandywine drains areas that include the Tailings Pond north of Maple Street, Coleman Memorial Park Cemetery, and a densely developed area of residential, commercial, and industrial properties, as well as Penn DOT's District 8-8 Maintenance Facility.

A small unnamed tributary joins the main stem Quittapahilla Creek from the north in Annville near Weaver Street. For most of its length this drainage-way is piped. The area that it drains includes large farms with pasture and row crops, large lot-size residential areas, Grandview Memorial Park and Fairland Cemetery, as well as commercial and industrial properties near and along Route 422. The remaining unnamed tributaries that join the mainstem Quittapahilla Creek from the north drain subwatersheds in the North Annville Township, where large farms with pasture, row crops, orchards, and deciduous forests are the predominant land uses. Downstream of its confluence with Killinger Creek the mainstem Quittapahilla Creek is joined by several small, unnamed tributaries that drain land from the south in the North Londonderry Township. Land use in these subwatersheds is an equal mix of large farms with pasture and row crops, large lot-size residential communities, and forest.

Plate 2 – Subwatersheds Map

Plate 3 – Topography Map

Plate 4 – General Geology Map

Plate 5 – Detailed Geology Map

Plate 6 – General Soils Map

Plate 7 – Detailed Soils Map

Plate 8 – Land Use/Land Cover Map

Land Use/Land Cover	Land Use and Land Cover in Major Subwatersheds (Acres)								Entire Watershed
	Killinger	Buckholder	Gingrich	Bachman	Beck	Snitz	Brandywine	Mainstem	
Open Water	54.0279	0.2224	5.7823	12.4542	8.8959	94.0728	83.3980	80.1870	339.0405
Low Density Residential	274.0736	N/A	9.3405	21.0555	63.5833	377.5061	467.1953	2237.5283	3450.2826
High Density Residential	34.0271	N/A	N/A	0.3561	1.0738	83.6446	91.6223	1003.2637	1213.9876
Commercial/Industrial/Transportation	34.0271	N/A	N/A	19.1053	20.1975	61.2464	119.3740	1172.1642	1625.1694
Quarries	307.0510	N/A	N/A	N/A	N/A	196.6985	49.3716	113.7637	666.8848
Transitional	N/A	N/A	N/A	7.5015	1.1718	0.2224	N/A	N/A	8.8957
Deciduous Forest	416.7282	187.8776	757.2894	822.7896	741.2200	2237.3786	421.4519	1857.3545	7442.0898
Coniferous Forest	47.1262	4.1177	17.8630	40.6462	36.9465	150.2546	28.2711	232.4163	557.6416
Mixed Forest	44.2962	6.2887	32.9507	44.2304	43.9131	178.2018	45.8464	294.6508	690.3781
Pasture/Hay	2063.4568	192.2233	1302.4714	2752.6193	2697.0384	3032.7736	766.3171	8433.3407	21,240.2406
Row Crops	1846.4607	190.0605	1013.9287	1210.6059	1448.2217	1457.4171	109.9296	4028.3424	11,304.9666
Urban/Recreational Grasses	N/A	N/A	N/A	N/A	128.0990	N/A	N/A	N/A	128.0990
Forest/Scrub-Shrub Wetlands	N/A	N/A	N/A	N/A	0.2224	5.3375	N/A	50.9285	56.4884
Emergent Wetlands	1.5568	0.2224	0.2224	1.5568	3.5584	17.3471	15.7902	51.8182	92.0723
Total	5268.2894	581.0126	3193.4455	4932.9208	5194.1418	7892.1011	2198.5675	19,555.7583	48,816.2370

Table 2.6.1 General Land Use and Land Cover Characteristics of the Quittapahilla Creek Watershed

Quittapahilla Creek starts as a small spring on a dairy farm in the South Lebanon Township. The surrounding land that drains the headwaters to the south and east is still fairly rural and includes large farms with cropland and pasture. However, as the Quittapahilla flows north toward the City of Lebanon farmland quickly gives way to residential subdivisions, shopping centers, fast food restaurants, schools, hospitals, and the Lebanon County Prison. Flowing beneath Route 422 the creek turns west and flows through the center of the City. Storm drains carry runoff from densely developed neighborhoods to the north and south into a highly altered channel that was first modified in the 18th century. Although the Bethlehem Steel Plant and related industries that occupied much of the land along the creek shut down years ago, redevelopment has brought new industries. As a result of the flood mitigation projects that the City initiated in the late 1970's Quittapahilla Creek is conveyed in a concrete flume from 3rd Street to 19th Street. The land on either side of the channel includes typical urban uses (e.g., offices, banks, small businesses, car dealerships, gas stations, libraries, neighborhoods of row homes, small parks, etc.) characterized by high percent impervious surfaces all routed via storm drains to the creek.

After leaving the City of Lebanon the creek flows in a direction that roughly parallels the intensely developed corridor along Route 422 through West Lebanon, Cleona, and Annville. On its way west it meanders along its natural floodplain where a surprising amount of area has been maintained in forest cover in spite of the adjacent land use. These wooded areas are most often associated with steep, rocky slopes or wet seeps and springs, and other areas with saturated soil conditions. With the exception of the Lebanon Wastewater Treatment Plant, cropland is the predominant land use along the left (south) floodplain and adjacent slopes. In some areas crops have been planted to within a few feet of the bank. Land use along the right (north) floodplain and adjacent slopes is more variable and includes old and new residential subdivisions, parking lots of businesses that front on Route 422, schools and parks with athletic fields, as well as the Quittie Creek Nature Park in Annville.

At the western end of Annville the Quittapahilla Creek flows under Route 422 and heads in a northwest direction. Immediately downstream of the Annville Wastewater Treatment Plant the creek enters a concrete flume that conveys it through a land area pocked with abandoned quarries. The creek empties into a natural channel on a large farm upstream of Clear Spring Road. From this point to its confluence with Swatara Creek, farms and homesteads on large parcels border the Quittapahilla. Although riparian buffers are relatively narrow on most of the farms, a significant amount of area has been maintained in forest cover. These wooded areas are associated with land preserved by local sportsman's clubs, protected by conservation easements, or natural areas unsuitable for agriculture such as steep, rocky slopes or wet seeps and springs, and other areas with saturated soil conditions

2.7 – Hydrology

2.7.1 – U.S. Geological Survey Stream Gage Record Analysis

U.S. Geological Survey records indicate that the mean annual stream flow measured at the USGS stream gaging station on Quittapahilla Creek near Bellegrove is 106 cfs. Mean monthly streamflow is highest from March - April, ranging 146 – 150 cfs. Mean monthly streamflow is lowest from August - November, ranging 75.9 – 84.7 cfs. Annual peak discharges for the period 1975 - 1994 ranged 404 cfs – 4800 cfs.

A flood frequency analysis of the maximum annual peaks at the Bellegrove gage site indicates that peak discharges are 586 cfs, 725 cfs, 908 cfs, 2204 cfs, 3275 cfs, 4321 cfs, and 5626 cfs, for the 1.25-yr, 1.5-yr, 2-yr, 10-yr, 50-yr, and 100-yr recurrence interval (RI) flows, respectively.

The USGS also collected stream flow data on Beck Creek near Cleona from 1963 to 1981. However, there is some concern regarding the reliability of estimates for the less frequent, higher volume storms for this gage site.

2.7.2 – Field Calibration of Bankfull Discharge

As part of this study field calibration surveys were conducted at five USGS gaging stations in the Ridge and Valley region of Pennsylvania and Maryland including Beck Creek, Quittapahilla Creek, Swatara Creek, Monocacy Creek, and Marsh Run. The watersheds draining this gages range in size from 7.87 to 116 square miles.

In preparation for the field assessment effort the U.S. Fish and Wildlife Service (USFWS) conducted an in-office review/evaluation of nine USGS gage stations. The following gage sites met the criteria for possible inclusion in the study and were evaluated in the field:

Swatara Creek near Pine Grove, PA - 01572025 (Active)
Quittapahilla Creek near Bellegrove, PA - 01573160 (Discontinued)
Beck Creek near Cleona, PA - 01573086 (Discontinued)
Letort Spring Run near Carlisle, PA – 01569800 (Active)
Bixler Run near Loysville, PA – 01567500 (Active)
Monocacy Creek at Bethlehem, PA – 01452500 (Active)
Newburg Run at Newburg, PA- (Discontinued)
Clark Creek near Carsonville, PA (Active)
Marsh Run at Grimes, MD - 01617800 (Active)

Based on the field evaluations, four gages were found to be acceptable for the gage calibration work – Beck Creek, Quittapahilla Creek, Swatara Creek and Monocacy Creek. In order to provide additional data for developing the curve, USFWS included the Marsh Run gage site, which they had already surveyed. Since Beck Creek and

Quittapahilla Creek are both inactive gage sites, their historic rating tables had to be validated/updated.

The Quittapahilla Creek Watershed Association entered into a cooperative agreement with the USGS field office in New Cumberland, PA to validate and update the rating tables. The necessary field measurements and analytical work was completed and the rating tables updated. Utilizing the new rating tables, the USFWS conducted the gage calibration surveys at the four selected USGS gaging stations and developed the regional regressions for use in estimating bankfull discharge and verifying bankfull indicators during the morphologic stream assessment. Upon further consideration it was determined that the geology underlying the Swatara Creek watershed was sufficiently different from the other sites that the data from this gage was not included in the final development of the regressions. Because the limited number of gage sites surveyed significantly affected the reliability of these regional regressions it was determined that they should not be used to develop bankfull discharge estimates.

2.7.3 – U. S. Geological Survey Regional Regressions

The U.S. Geological Survey recently published regional regressions that were developed utilizing data from 66 gage sites in Pennsylvania and Maryland (J. Chaplin, 2005). The large data set provided curves with very reliable predictive capability. More importantly USGS also developed regressions specific to carbonate watersheds making them both reliable and directly applicable to Quittapahilla Creek.

These regressions were used as part of this study to calibrate the HEC-HMS hydrologic model and estimate bankfull discharge. The regional curve and regression equation relating drainage area to bankfull discharge is included in the Appendix to this report.

2.7.4 – 100 Year Floodplain

Plate 9 presents a map showing the 100-year floodplain along Quittapahilla Creek and its tributaries. As shown on the floodplain map, the 100-year flood inundates significant areas of the Quittapahilla Creek and tributary valleys. In some segments of the Quittapahilla Creek watershed the floodplain does not extend very far beyond the channel and its adjacent floodway. In other segments the floodplain covers significant areas of the valleys. The floodplain reaches its greatest extent in the middle and lower segments of the mainstem Quittapahilla Creek, as well as middle and lower Snitz Creek and the Unnamed Tributary that drains South Lebanon. In these areas it nearly covers the entire valley floor. Much of the floodplain area shown was inundated to depths of several feet during Hurricane Agnes in 1972. As a result, the City of Lebanon initiated flood mitigation projects along the mainstem Quittapahilla Creek and Unnamed Tributary that drains South Lebanon.

2.7.5 – Hydrologic Modeling and Analysis

The Quittapahilla watershed was modeled using the HEC-HMS computer program. Digital Elevation Models (DEM) for the USGS quadrangles of Lebanon and Palmyra, Pennsylvania were first imported into Arc-View, a computer model, which works with GIS databases. Also, a county-wide digitized stream coverage was imported into the model to compare with the flow paths determined by Geo-HMS, a sub-routine of Arc-View, which determines flow directions and paths. Comparison with the countywide stream coverage aided in locating the proper modeling points. With this information the project area was determined along with the pertinent sub-watersheds. After the data were prepared, it was then imported into the HEC-HMS program. The Geo-HMS sub-routine creates the basin model to be used in HEC-HMS. This supplies the areas of the sub-watersheds and a schematic of the watershed showing subwatersheds, routing reaches, and junctions as shown in Figure 2.7.2. Parameters other than subwatershed areas, such as reach lengths, must be entered into the model manually.

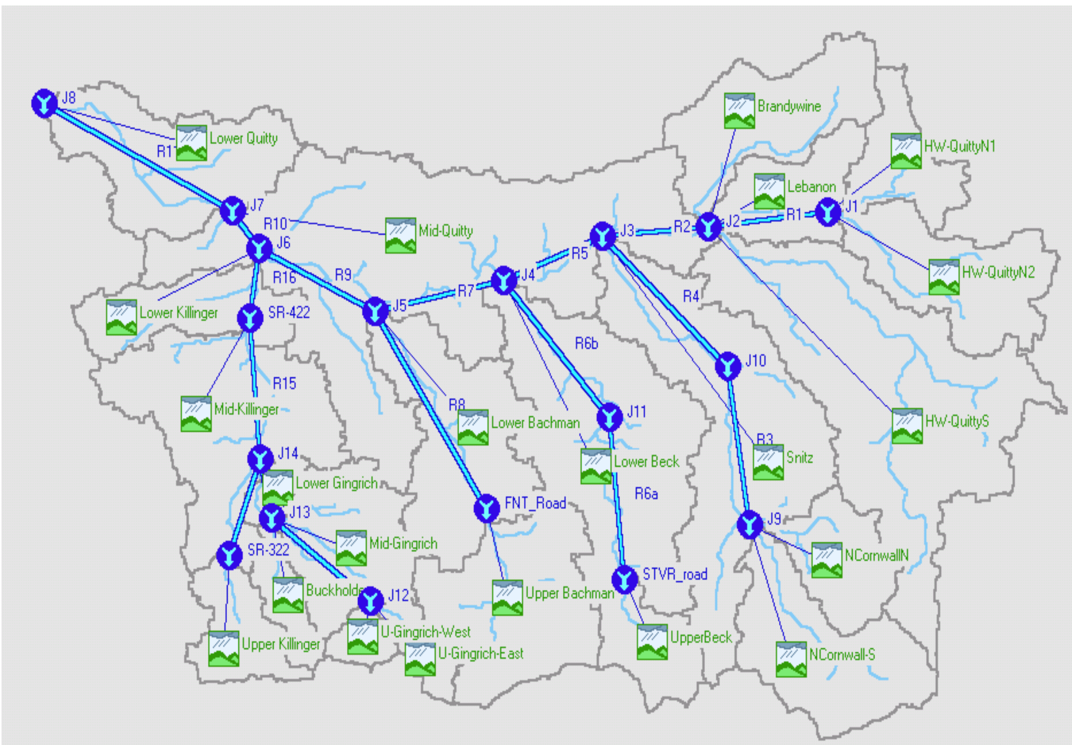

Figure 2.7.2 Modeling Schematic of the Quittapahilla Creek Watershed

- Modeling Points

All points of interest are designated as subwatersheds outlets so that a flow could be determined. The model is comprised of 22 subwatersheds. Three USGS gaging stations are located within the Quittapahilla watershed. They are located at the outlets of Bachman Run, Beck Creek and on the Quittapahilla Creek near North Annville. The information pertaining to the gages are summarized in Table 2.7.1.

Plate 9 – Floodplain Map

Due to the limited number of years of record and the age of the data, the information from the gages was not used to calibrate the model. This watershed undergoes a fair amount of land use change every year. Therefore calibrating the model with this out-dated gage information would result in model parameters which do not represent current conditions. However, they are listed for a possible later need.

USGS Stream Flow Data								
Number	**Name**	**Area (sq.mi.)**	**Latitude**	**Longitude**	**Location**	**Start**	**End**	**Data**
01573086	Beck Creek	7.87	40°19'24"	76°29'00"	near Cleona, Pa	8/1/63	3/31/81	peak, discharge, water quality
01573095	Bachman Run	7.30	40°18'58"	76°30'58"	Annville, Pa	4/1/93	9/30/95	peak, discharge, water quality
01573160	Quittapahilla Creek	74.20	40°20'34"	76°33'46"	near Bellegrove, Pa	9/26/75	4/11/93	peak, discharge

Table 2.7.1 Stream Gage Information

- Precipitation Inputs

Several meteorological models were developed within the HEC-HMS model. An SCS Type II distribution was used to develop the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year events. The corresponding 24-hour rainfall depths for these events were determined from the Penn-DOT IDF curves.

Also, several precipitation gages were located in or around the Quittapahilla watershed. The gages are shown in Table 2.7.2. Like the stream flow data, the precipitation gage information was not used in the calibration due to the fact that the stream gage information was not used.

NWS\NOAA Precipitation Data							
Number	**Name**	**Latitude**	**Longitude**	**County**	**Start**	**End**	**Data**
364778	Landisville 2NW	40°07'	76°26'	Lebanon	5/1/52	Present	Hourly
364896	Lebanon 2W	40°20'	76°28'	Lebanon	5/1/48	Present	Hourly
365703	Harrisburg Intl. Airport	40°12'	76°46'	Dauphin	10/1/91	Present	Hourly

Table 2.7.2 Precipitation Gage Information

- Procedures and Parameters

There were several hydrologic procedures used to represent the watershed. The SCS curve number (CN) method was used to determine rainfall excesses after a storm event. The SCS unit hydrograph method was then used to predict the runoff response to these rainfall excesses. Finally, the Muskingum routing method was used to route a storm hydrograph from one point of interest to another through a river reach. All of these methods are performed in the HEC-HMS computer program. A large number of watershed parameters were obtained. They included watershed areas, flow lengths, land uses, and soils information. SCS curve numbers (CN) were used to quantify land use and soil information. Flow lengths, slopes, and land uses were used to determine the time of concentration for each of the sub-watersheds. This time of concentration was then converted to a lag time due to the fact that the lag time is the parameter required by the HEC-HMS program. Finally, reach lengths and travel time estimates were determined for the Muskingum routing method. Table 2.7.3 summarizes the sub-watershed areas, land uses, and curve numbers used in the HEC-HMS basin model.

Subwatersheds	Area	%Forest	%Urban	CN
Brandywine	3.25	5	20	81
HW-QuittyN1(upper)	1.63	3	5	77
HW-QuittyN2(lower)	3.15	3	3	74
Lebanon	1.91	0	85	88
HWQuitty-S	9.45	8	10	71
NCornwall-S	2.55	30	5	70
NCornwall-N	1.81	30	5	70
Snitz	6.89	5	3	71
UpperBeck	1.44	50	0	68
LowerBeck	6.73	3	5	71
UpperBachman	4.12	25	3	71
LowerBachman	4.04	3	5	71
Mid-Quitty	12.81	5	20	71
Lower-Quitty	3.87	15	5	69
UGingrich-E	0.75	90	0	67
UGingrich-W	0.49	90	0	67
Mid-Gingrich	2.84	5	3	70
LowerGingrich	0.49	3	3	70
Buckholder	0.85	15	3	70
UpperKillinger	1.47	30	3	72
Mid-Killinger	5.25	3	10	71
Lower-Killinger	2.14	15	5	75

Table 2.7.3 Subwatershed Data

- Model Results

The HEC-HMS model was first run using the initial estimates of watershed parameters. These peak flows are summarized for the entire watershed and several of the sub-watersheds in Table 2.7.4. Next the estimates of peak flows for varying return periods were determined using the USGS regression equations for Pennsylvania and also are summarized in Table 2.7.4. These are then compared to the estimates obtained from the HEC-HMS model. The comparison of flows provides a means of determining if the estimates from the HEC-HMS model are reasonable. The estimates from the model should be approximately close to those obtained from the USGS regression equations.

Watershed	USGS Predictions				HEC-HMS Predictions	
	10-year	25-year	50-year	100-year	10-year	100-year
Brandywine	960	1380	1764	2223	1143	1846
HW-QuittyN1(upper)	499	755	1000	1303	504	872
HW-QuittyN2(lower)	817	1224	1611	2088	756	1339
Lebanon	1037	1350	1611	1901	1029	1562
HWQuitty-S	1959	2811	3590	4521	1886	3498
NCornwall-S	564	832	1083	1386	1026	1880
NCornwall-N	432	642	840	1080	529	983
Snitz	1473	2168	2819	3612	1729	3247
UpperBeck	299	449	590	762	451	905
LowerBeck	1503	2205	2860	3657	1660	3121
UpperBachman	834	1228	1594	2038	1257	2309
LowerBachman	1011	1499	1959	2523	1026	1926
Mid-Quitty	2787	3892	4877	6033	2288	4183
Lower-Quitty	878	1295	1684	2158	988	1896
UGingrich-E	143	215	282	363	238	488
UGingrich-W	103	156	205	266	159	488
Mid-Gingrich	740	1109	1461	1895	651	1225
LowerGingrich	192	300	405	539	143	279
Buckholder	265	406	541	710	246	451
UpperKillinger	360	541	712	921	469	839
Mid-Killinger	1299	1893	2444	3110	1253	2271
Lower-Killinger	554	827	1086	1402	609	1083
Combinations of Smaller Watersheds						
UpperQuitty	3714	5172	6468	7988	4903	8450
Snitz	1993	2880	3695	4673	2790	5147
BeckCreek	1595	2324	2999	3815	1958	3574
Bachman	1553	2260	2912	3699	1931	3525
Gingrich	998	1463	1893	2413	1263	2401
Killinger	2425	3469	4417	5547	2986	5427
Lebanon-Outlet	3746	5206	6500	8016	4903	8450
QuittyGage	9528	13082	16195	19814	10682	19009
Entire WS	9826	13469	16654	20352	10003	17788

Table 2.7.4 – Peak Flow Summary Table

- Comparison of Peak Flow Estimates

The peak flow estimates from the USGS regression equations and HEC-HMS model were compared for the return periods of 10 and 100 years. This was done to determine the differences for large and small flood events. The comparison revealed for the smaller 22 subwatersheds that the USGS estimates were higher for the 100-year return period. This was expected because many of the subwatershed areas were less or near the lower limit of watershed area (0.93 mi^2) for use of the equations. However when comparing the larger subwatersheds the differences between the USGS equations and HEC-HMS model estimates were much less. Percent differences between the estimates ranged from 1 to 13 percent. Therefore considering the limitations of the USGS equations for smaller watersheds, more significance was placed on comparing flows for the larger sub-watersheds. This implies that the HEC-HMS model is sufficient for predicting the flow for a 100-year event.

When comparing the estimates for the 10-year return period, larger variations were observed. Typically the HEC-HMS model predicted higher flows than the USGS equations. Ignoring the estimates for the 22 smaller subwatersheds and considering only the larger subwatersheds revealed percent difference in peak flow estimates ranging from 2 to 40%. These differences are considerably higher than were observed for the 100-year estimates indicating that the HEC-HMS model will likely over estimate the peak flow for the 10-year event.

3.0 – Morphologic Stream Assessment

3.1 – Introduction

This section summarizes the results of the morphologic stream assessment conducted along the mainstem Quittapahilla Creek. The geomorphic features of Quittapahilla Creek were mapped, the current conditions photographically documented, and the overall stability assessed along the mainstem from Lebanon to Swatara Creek. To facilitate the data collection effort and subsequent data analysis, the mainstem was divided into six segments. In most cases, the segment limits corresponded to natural features (e.g., confluences with major tributaries) or manmade features (e.g., upstream and downstream ends of concrete flumes). Mainstem segments have been divided into reaches on the basis of convenient lengths of channel to assess. Segments and reaches are numbered in a consecutive downstream order. Figure 4.1 presents a map of the Quittapahilla Creek mainstem segments and reaches.

Following the assessment procedures of Rosgen (1996) the Team mapped current geomorphic features, assessed current channel condition; identified factors influencing channel condition; identified the location and nature of channel stability problems; evaluated the direction, rate and nature of historic channel adjustments; evaluated the degree to which the existing channel conditions differ from an accepted range of morphological values for stable streams; and determined the sensitivity of the stream reaches assessed to alterations in hydrologic or sediment regime and/or direct disturbances. The supporting documentation for the morphologic stream assessment is presented in the photographs and summary tables included in this section. Field data sheets and plots of profiles, cross-sections, pebble counts, and sediment samples are included in the Appendix to the report.

3.2 – Field Calibration Surveys to Verify Bankfull Channel Field Indicators

Field calibration surveys were conducted at four USGS gage stations in the Quittapahilla Creek watershed, immediately adjacent watersheds and similar watersheds in the Ridge and Valley Physiographic Region of Pennsylvania and Maryland. This information was utilized to develop project specific regional curves relating drainage area to bankfull channel dimensions for use in the morphologic stream assessment. However, because the limited number of gage sites surveyed significantly affected the reliability of these regional regressions it was determined that they should not be used for this study.

3.3 – U. S. Geological Survey Regional Regressions

The U.S. Geological Survey recently published regional regressions that were developed utilizing data from 66 gage sites in Pennsylvania and Maryland (J. Chaplin, 2005). The large data set provided curves with very reliable predictive capability. More importantly USGS also developed regressions specific to carbonate watersheds making them both reliable and directly applicable to Quittapahilla Creek. These regressions were used as part of this study to calibrate the HEC-HMS hydrologic model, estimate bankfull discharge, and verify the data collected during the morphologic stream assessment. The regional curve and regression equations relating drainage area to bankfull channel dimensions are included in the Appendix of this report. Table 3.1 compares values for bankfull cross-sectional areas and bankfull discharge predicted with the USGS regional regressions by versus measured field data.

Reach	Drainage Area (Sq Mi)	Predicted from USGS Regional Regressions		Measured Field Data				
		Discharge (cfs)	XS Area (ft^2)	Rif -1 XS Area (ft^2)	Rif-2 XS Area (ft^2)	Pool 1 XS Area (ft^2)	Pool 2 XS Area (ft^2)	Discharge (cfs)
2	19.4	290.2	76.0	76.7	74.1	73.2	90.2	285
3	19.4	290.2	76.0	96.2	83.3	80.7	85.6	280
7	32.3	401.0	110.0	104.6	98.6	117.1	115.9	403
11	32.3	401.0	110.0	119.1	96.6	129.1	110.8	411.8
14	32.7	404.0	111.5	107.8	113.6	134.2	112.6	369.2
18	42.1	474.4	134.2	102.7	102.0	137	136.5	359
20	43.3	482.9	137.0	103.2	110.1	134.3	127.1	484.4
29	55.36	564.3	164	203.6	191.1	158.4	175.8	519
34	56.92	574.3	167.4	155.5	182.3	225.4	231.8	548
35	72.28	668.2	199.5	147.9	150.5	235.6	157.1	332
36	73.35	674.5	201.7	147.8	200.8	194.4	187.5	675.6
41	75.61	687.6	206.2	170.9	209.2	232.8	242.1	559.3

Table 3.1 – Comparison of Predicted Bankfull Cross-Sectional Areas and Bankfull Discharge versus Measured Field Data

3.4 – Geomorphic Features of Quittapahilla Creek

The geomorphic features of Quittapahilla Creek were mapped from the headwaters south of the City of Lebanon to the confluence with Swatara Creek.

The 1994 Quarter Quad aerial photographs were utilized for the geomorphic mapping in the field. The aerial photographs were developed at a scale of 1 inch = 100 feet and overlaid with mylar sheets onto which the left and right stream banks of Quittapahilla Creek had been digitized. Stream channel and adjacent floodplain features were then hand drawn on these mylar base maps. Landscape features shown on the aerial photographs could be seen through the mylar sheets, thereby providing points of reference for orientation in the field.

The geomorphic mapping effort focused on verifying existing land use activities and land cover including type and condition, identifying and documenting unstable conditions in upland and riparian areas, characterizing stream channel morphology and condition, and identifying point and non-point sources of pollution. Observations on riparian and stream bank vegetation, meander pattern, depositional features, debris and channel blockages, vertical stability, streambed materials, streambed features (e.g., riffles, pools, runs and glides), bank height, stream bank erosion were mapped and recorded. The location of significant points in the field (e.g., storm drain outfalls, wastewater discharge outfalls, and springs) were noted on the maps and recorded to facilitate relocation with a Garmin Hand-Held GPS Unit.

The Geomorphic and Habitat Maps submitted previously document the findings of the effort. Utilizing the information developed from the fieldwork, Stream Reach Data Sheets were completed to facilitate data entry for each of the reaches into the Quittapahilla Creek Watershed database.

This information was utilized to focus where the detailed morphologic stream assessment was conducted along Quittapahilla Creek. In addition, this information, in conjunction with other information (i.e., geomorphic, hydrologic, water quality, biological, etc.), provided a basis for identifying and prioritizing problem areas along Quittapahilla Creek.

The Geomorphic and Habitat Maps provide supporting documentation for the Findings Report. They were also utilized for identifying the location of recommended best management practices and restoration projects along Quittapahilla Creek.

3.5 – Morphological Description and Assessment of Stream Condition

This work included the detailed levels of geomorphic assessment and is critical to evaluating the overall condition and stability of Quittapahilla Creek and completion of the geomorphic component of the watershed assessment.

Representative reaches along Quittapahilla Creek were classified into specific categories of stream types (i.e., B4, C4, E4, etc.) utilizing the standard field procedures recommended by Rosgen (1996). The information developed from the representative reaches was then used to categorize the remaining reaches using the extrapolation field procedures recommended by Rosgen (1996). The profile, cross-section, pebble count, and sediment sample field data is included in the Appendix of this report. The Level II morphological data from the representative reaches is summarized in Table 3.2 below.

Reaches along Quittapahilla Creek were selected for assessment of stream channel condition and influencing factors including riparian vegetation, meander pattern, depositional pattern, debris and channel blockages, sediment supply, vertical stability, streambank erosion potential, and near bank stress. Level III Characterization of Stream Condition Forms were completed for each reach evaluated. This data is summarized in the Bank Erosion Hazard Index (BEHI) and Reach Stability Ranking tables included in the Appendix of this report.

Table 3.2 – Quittapahilla Creek Representative Reaches - Level II Survey Data Summary

Reach	Drainage Area (mi^2)	Bed Feature	Bankfull Width (ft.)	Bankfull Mean Depth (ft.)	Bankfull Cross-sectional Area (ft^2)	Width/Depth Ratio	Entrenchment. Ratio	Water Surface Slope (ft/ft)	Reach/Riffle Average Bed Material D50 (mm)	Manning's Estimated Bankfull Discharge (cfs)	Stream Type
2	19.4	Pool	27.9	2.6	73.2	NA	NA	0.0021	9.6/17.3		
2		Pool	31.2	2.9	90.7	NA	NA				
2		Riffle	32.1	2.4	76.7	13.4	10.0			286.0	C4
2		Riffle	31.6	2.3	74.1	13.5	10.0			284.3	
3	19.4	Riffle	39.3	2.4	96.2	16.0	7.4	0.001	2.7/9.0	279.6	C4
3		Pool	28.8	2.8	80.7	NA	NA				
3		Riffle	30.0	2.8	83.3	10.8	9.7				E4
3		Pool	27.5	3.1	85.6	NA	NA				
7	32.3	Riffle	33.4	3.1	104.6	10.7		0.0016	7.1/11.0	403.2	E4
7		Riffle	37.8	2.6	98.6	14.5	9.6			373.4	
7		Pool	36.1	3.2	117.1	NA	NA				
7		Pool	35.9	3.2	115.9	NA	NA				
11	32.3	Riffle	33.6	2.9	96.6	10.4	4.1	0.0012	6.1/11.0	336.0	E4
11		Pool	40.6	3.2	129.1	NA	NA				
11		Riffle	43.7	2.7	119.1	16.0	4.2			411.8	C4
11		Pool	35.3	3.1	110.8	NA	NA				
14	32.7	Pool	32.7	4.1	134.2	NA	NA	0.0087	9.4/40.2		
14		Riffle	37.2	2.9	107.8	12.8	8.6			329.2	C4
14		Pool	31.4	3.6	112.6	NA	NA				
14		Riffle	35.7	3.2	113.6	11.2	8.3			369.2	C4
18	42.1	Pool	46.0	3.0	137.0	NA	NA	0.0012	4.0/6.0		
18		Riffle	37.1	2.8	102.7	13.4	4.65			359.0	C4

Table 3.2 – Quittapahilla Creek Representative Reaches - Level II Survey Data Summary (Cont'd)

Reach	Drainage Area (mi^2)	Bed Feature	Bankfull Width (ft.)	Bankfull Mean Depth (ft.)	Bankfull Cross-sectional Area (ft^2)	Width/Depth Ratio	Entrenchment. Ratio	Water Surface Slope (ft/ft)	Reach/Riffle Average Bed Material D50 (mm)	Manning's Estimated Bankfull Discharge (cfs)	Stream Type
18	42.1	Riffle	42.5	2.4	102.0	17.7	4.65	0.0012	4.0/6.0	325.0	C4
18		Pool	40.3	3.4	136.5	NA	NA				
20	43.3	Riffle	40.6	2.7	110.1	15.0	6.2	0.009	14.0/19.8	520.5	C4
20		Pool	39.8	3.4	134.3	NA	NA				
20		Riffle	38.7	2.7	103.2	14.5	6.2			484.4	C4
20		Pool	40.3	3.2	127.1	NA	NA				
29	55.36	Riffle	63.8	3.2	203.6	20.0	2.6	0.0007	4.3/18.8	519.1	C4
29		Pool	103.4	1.5	158.4	NA	NA				
29		Riffle	54.2	3.5	191.1	15.4	2.6			512.7	C4
29		Pool	57.1	3.1	175.8	NA	NA				
34	56.92	Riffle	68.5	2.7	182.3	25.8	2.44	0.0012	10.3/22.6	548.0	C4
34		Riffle	55.0	2.8	155.5	19.5	2.67			522.2	C4
34		Pool	51.7	4.4	225.4	NA	NA				
34		Pool	49.7	4.7	231.8	NA	NA				
35	72.28	Riffle	63.9	3.4	215.5	18.9	4.6	0.0005	8.9/14.1	501.7	C4
35		Riffle	100.7	1.8	185.3	54.7	3.4			362.6	C4
35		Pool	51.9	4.5	235.6	NA	NA				
35		Pool	47.4	3.9	187.1	NA	NA				
36	73.35	Pool	45.4	4.3	194.4	NA	NA	0.0011	16.0/34.5		
36		Riffle	63.9	2.3	207.2	27.6	1.54			675.6	B4c
36		Riffle	63.5	3.2	200.8	20.1	1.54			686.5	B4c
36		Pool	53.6	3.5	187.5	NA	NA				

Table 3.2 – Quittapahilla Creek Representative Reaches - Level II Survey Data Summary (Cont'd)

Reach	Drainage Area (mi^2)	Bed Feature	Bankfull Width (ft.)	Bankfull Mean Depth (ft.)	Bankfull Cross-sectional Area (ft^2)	Width/Depth Ratio	Entrenchment. Ratio	Water Surface Slope (ft/ft)	Reach/Riffle Average Bed Material D50 (mm)	Manning's Estimated Bankfull Discharge (cfs)	Stream Type
41	**75.61**	**Riffle**	**61.7**	**3.5**	**213.1**	**17.9**	**2.35**	**0.0005**	**24.4/20.6**	**559.3**	**C4**
		Pool	**56.4**	**4.1**	**232.8**	**NA**	**NA**				
		Riffle	**62.4**	**3.4**	**209.2**	**18.6**	**2.16**			**532.6**	**B4c**
		Pool	**54.1**	**4.5**	**242.1**	**NA**	**NA**				
44	**75.61**	**Riffle**	**77.6**	**3.0**	**232.4**	**25.9**	**1.71**	**0.0019**	**10.7/34.0**	**719.5**	**B4c**
		Pool	**57.0**	**4.4**	**251.4**	**NA**	**NA**				
		Pool	**74.3**	**3.3**	**247.7**	**NA**	**NA**				
		Riffle	**51.3**	**3.7**	**190.7**	**13.8**	**2.79**			**714.2**	**C4**

3.6 – Level IV - Stream Stability Validation Monitoring

Verification of the assessment data through monitoring was considered an important component of the overall effort. In order to document channel erosion rates, twenty-five cross-sections along Quittapahilla Creek were monitored for channel stability over a period of twelve months. This involved the installation of permanent cross sections, surveying the cross sections, and resurveying the cross sections at the end of twelve months. The permanent cross sections were installed and surveyed in August 2001. Funding was not available to complete the assessment work until 2003. As a result the resurvey of the permanent cross-sections did not take place until 20 months after installation. The results of the survey are presented in Table 3.3 below.

Table 3.3 – Survey Results for Permanent Cross-Sections

X-Section	**Width (ft)**			**Depth (ft)**			**XS Area (ft2)**		
	2001	**2003**	**Diff**	**2001**	**2003**	**Diff**	**2001**	**2003**	**Diff**
1	40.5	42.4	**+1.9**	1.42	2.59	**+1.2**	57.65	109.83	**+52.2**
2	51.6	52.7	**+1.1**	2.09	1.89	**-0.2**	107.91	99.6	**-8.3**
3	29.9	29.2	**-0.7**	3.15	2.64	**-0.5**	94.22	76.99	**-17.2**
4	34.2	35.0	**+0.8**	2.71	2.43	**-0.3**	92.59	85.03	**-7.6**
5	35.7	36.4	**+0.7**	3.24	3.09	**-0.2**	115.7	112.3	**-3.4**
6	39.0	39.2	**+0.2**	2.60	2.56	**-0.1**	101.2	100.53	**-0.7**
7	31.5	32.2	**+0.7**	2.97	3.37	**-0.4**	93.54	108.66	**+15.1**
8	38.6	38.6	**0.0**	3.5	3.37	**-0.1**	135.27	129.98	**-5.3**
9	57.1	54.5	**-2.6**	3.35	3.04	**-0.3**	191.12	165.58	**-25.5**
10	43.1	43.4	**+0.3**	4.56	4.44	**-0.1**	196.36	192.84	**-3.5**
11	56.0	55.8	**-0.2**	2.87	2.85	**0.0**	160.64	158.86	**-1.8**
12	52.1	53.2	**+1.1**	3.15	2.87	**-0.3**	164.09	152.6	**-11.5**
13	47.1	48.6	**+1.5**	3.4	3.38	**0.0**	160.3	164.1	**+3.8**
14	51.0	52.5	**+1.5**	3.1	3.25	**+0.2**	158.0	170.73	**+12.7**
18	55.7	57.0	**+1.3**	2.83	3.05	**+0.2**	157.53	173.61	**+16.1**
19	62.7	63.5	**+0.8**	3.4	3.58	**-0.2**	212.99	227.44	**+14.5**
20	83.0	83.5	**+0.5**	3.06	2.77	**-0.3**	254.16	231.7	**-22.5**
21	75.0	71.3	**-3.7**	3.42	3.45	**0.0**	256.63	245.97	**-10.7**
22	70.1	76.0	**+4.9**	2.91	3.99	**+1.1**	204.17	303.56	**+99.4**
23	64.7	67.4	**+2.7**	2.69	2.87	**+0.2**	174.35	193.55	**+19.2**
24	80.84	81.65	**+0.8**	2.93	3.08	**+0.2**	236.77	251.89	**+15.1**
25	51.4	54.9	**+3.5**	3.02	3.13	**+0.1**	155.1	171.63	**+16.5**

The data shows a general trend of increasing channel width and decreasing depth consistent with the observed problems of lateral erosion and bed aggradation. The notable exceptions are Cross-sections 1 and 22 where overall channel size increased significantly due to lateral erosion and bed degradation. These changes are consistent with field observations.

3.7 - Findings of Channel Morphology and Stability Assessment

3.7.1 – General Overview of Stream Conditions

The condition of the mainstem Quittapahilla Creek is generally characterized by lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars, riffles embedded with fine sediments, and debris jams along many reaches. From the construction of the first mill dam in the early 1730's to the construction of the Hazel Dike in the early 1900's and the extension of the flood protection works following Hurricane Agnes in 1972, the creek has undergone significant alterations. These channel modifications in addition to the changes that occurred in land use as the watershed went from forest to agriculture, and more recently urbanization, have all contributed the current sedimentation and stability problems.

Notwithstanding the significant amount of impervious area in its headwaters and the concrete flumes rapidly conveying storm flows to the natural sections of the channel, the creek is holding its own. Several factors have contributed to the Quittapahilla's overall ability to withstand land use and channel alterations. The cohesive nature of the silt clay banks along most reaches of the creek provides resistance to the erosive forces of storm flows. As a consequence, annual erosion rates along most of the creek are measured in tenths of feet per year as opposed streams with banks composed of sands and gravels where erosion rates are often measured in feet per storm event.

The nature of the creek bed has prevented it from incising as many creeks do in response to a changing hydrologic regime associated with urbanization. Although not always evident, the creek bed along most of its length rests on bedrock. Along many reaches a layer of gravel, sand and silt covers the bedrock. Where these finer materials have been removed by storm flows the bedrock is exposed as ledges, drops and chutes. A number of the upper reaches have sections of composed of boulder and cobble riffles. Bank heights are limited by the depth the stream can down cut before encountering bedrock or some other grade control mechanism. Although the silt, sand and gravel layer is thickest in the downstream reaches, the relatively shallow depth to bedrock over much of the upper creek and along key sections throughout has kept bank heights relatively low. This has contributed to overall lower bank erosion rates.

Although riparian buffers are lacking along many reaches, the significant length of the mainstem that has a woody riparian buffer is remarkable for a creek with the type of land use activities present along the Quittapahilla Creek corridor. The presence of mature trees and shrubs along significant lengths of the creek also contributes to overall lower bank erosion rates.

3.7.2 – Detailed Descriptions of Main Stem Segments

The following sections provide detailed descriptions of the geomorphic conditions along each segment of the mainstem Quittapahilla Creek.

Segment 1

Segment 1 is 6315 linear feet in length and includes Reaches 1 – 6. The upstream limit is the downstream end of the concrete flume near 19th Street in Lebanon and downstream limit is the confluence with Snitz Creek. With the exception of Reaches 4 and 5, and the downstream end of Reach 3 the segment is a laterally and vertically unstable C4 stream type. Reach 4 is an F4 stream type and Reach 5 is a B4/B1 stream type. The overall channel plan form of the segment is characterized by relatively low sinuosity indicative of historic channel straightening.

Results of the stability assessment show bank height to bankfull ratios along most of the reach range from 1.0 – 2.0. The higher banks are susceptible to erosion and gravitational failure. In spite of increased flow depths and velocities associated with channel incision and increased runoff the reach is overwhelmed by the sediment load from upstream sources. Bed aggradation is a problem throughout as evidenced by development of mid-channel, lateral and point bars along much of the segment. There are significant constrictions at the 22nd Street and Chestnut Street bridges at the downstream end of Reach 1 and 2 respectively that creates backwater under bankfull and higher flows.

The condition of Reach 1 is characterized by lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars and debris jams. Lateral erosion has damaged the endwall of a storm drain outfall exposing the pipe and causing the endwall to jut into the channel. Due to its location immediately downstream of the concrete channel this reach has the highest percentage of unstable banks. Approximately 46% of the banks have high to very high bank erosion potential. Grade control is provided by the armored riffle at the downstream end of the reach. This reach had a Reach Stability Ranking of 18.7, which means that compared to all of the other reaches along Quittapahilla Creek it is extremely unstable.

The upper and middle sections of Reach 2 are relatively stable. However, the lower section is characterized by lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars and debris jams. The constriction at the Chestnut Street Bridge creates a significant backwater under bankfull and higher flows that appears to affecting sediment transport through this section of the reach. This reach had a Reach Stability Ranking of 2.8, which means that compared to all of the other reaches along Quittapahilla Creek it is relatively stable.

Reach 3 is characterized by lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral, mid-channel, and transverse bars. Although the bank and riparian vegetation along this reach includes some mature trees and shrubs, there is a general lack of lateral control to prevent continued bank erosion and channel migration. The potential for continued bank erosion, loss of trees and channel migration is high. Results of the stability assessment confirm that approximately 35% of banks along this reach have high bank erosion potential. This reach had a Reach Stability Ranking of 12.7, which means that compared to all of the other reaches along Quittapahilla Creek it is very unstable.

Although Reach 4 is deeply entrenched boulders and bedrock outcrops along the toe and lower slopes of the banks as well as heavy vegetation along the left terrace and concrete walls at the rear of the commercial properties fronting on Rte 422 provide considerable lateral control. Grade control is provided by the boulder riffle at the downstream end of the reach.

Reach 5 is a relatively stable B4/B1 channel with boulder riffles and bedrock step pools and chutes. Lateral control is provided by boulders and bedrock outcrops along the toe and lower slopes of the banks as well as heavy vegetation along the left and right terraces. This reaches had a Reach Stability Ranking of 5.6.

Reach 6 is also stable although water quality has been impacted by wastewater discharges from the Lebanon Wastewater Treatment Plant. During the field assessment it was observed that the stream water along the outfall was warmer than the section immediately upstream. In addition, an abundance of fish in the pool at the outfall suggests nutrient enrichment associated with the discharge. This reach had a Reach Stability Ranking of 8.6, which means that compared to all of the other reaches along Quittapahilla Creek it is unstable.

Figure 3.1 – Upstream end of Reach 1 looking toward concrete channel

Figures 3.2 and 3.3 – Bank erosion and undercut trees along Reach 1

Figures 3.4 and 3.5 – Bank erosion along Reach 1. Note silt clay material evident in upper photograph.

Figure 3.6 and 3.7 – Debris jams and mid-channel bars along Reach 1

Figure 3.8 – Storm drain endwall damaged by erosion along Reach 1

Figure 3.9 – Dirt bike trails in floodplain along Reach 1

Figure 3.8 – 22nd Street Bridge at downstream end of Reach 1/upstream end of Reach 2

Figure 3.9 – Spring in left floodplain immediately downstream of 22nd Street Bridge

Figure – 3.10 and 3.11 – View along upper Reach 2

Figure 3.12 – Eroding bank and debris jam along lower Reach 2

Figure 3.13 – Armored banks along lower Reach 2

Figures 3.14 and 3.15 – Floodplain along Reach 2

Figure 3.16 - Chestnut Street Bridge downstream end Reach 2/upstream end Reach 3

Figure 3.17 – Upstream end of Reach 3 looking downstream from Chestnut Street Bridge

Figures 3.18 and 3.19 – Bank erosion along upper Reach 3

Figure 3.20 – Bank erosion and bar formation along upper Reach 3

Figure 3.21 – Debris jam along lower Reach 3

Figures 3.22 and 3.23 – Bank revetment along rear of Dairy Queen at upstream end Reach 4

Figures 3.24 and 3.25 – Stable channel along Reach 5

Figures 3.26 and 3.27 – Bank revetment (upper photo) and localized erosion (lower photo) along Reach 6

Figure 3.28 – Wastewater discharge from Lebanon WTTP at downstream end Reach 6

Segment 2

Segment 2 is 10,985 linear feet in length and includes Reaches 7 – 15. The upstream limit is the confluence with Snitz Creek and downstream limit is the confluence with Beck Creek. Reaches 7, 9, 11, and 14 are C4 stream type channels that are laterally unstable throughout. Reaches 8, 10, 12, 13, and 15 are relatively stable C4 stream type channels with localized bank erosion. The overall channel plan form of the segment is characterized by moderate to low sinuosity indicative of historic channel straightening.

Results of the stability assessment show bank height to bankfull ratios along the reaches range from 1.05 – 4.0. The higher banks are susceptible to erosion and gravitational failure. Bed aggradation is a problem throughout Reaches 9, 11, 13, 14, and 15 as evidenced by development of mid-channel and lateral bars along significant portions of these reaches. Although debris jams were infrequent a significant blockage was observed along the lower section of Reach 7. Channel constrictions have been created by the bridges at Elizabeth Street, Garfield Street, and Mill Street at the downstream end of Reaches 8, 10, and 12 respectively, causing backwater conditions under bankfull and higher flows.

The overall conditions of Reaches 7, 9, 11, 13 B and 14 are characterized by lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars. Although the bank and riparian vegetation along these reaches includes mature trees and shrubs, there is a general lack of lateral control to prevent continued bank erosion and channel migration. Reaches 7, 9, 11, and 14 had the highest percentage of unstable banks with 46%, 30%, 21%, and 42% of the banks exhibiting high bank erosion potential. Reaches 7, 9, 11, 13B and 14 were the most unstable reaches in this segment with Reach Stability Rankings of 13.7, 11.0, 11.7, 13.1, and 11.7, respectively. Reaches 8 and 12 were unstable with Reach Stability Rankings of 6.1 and 10.17, respectively. Reaches 10 and 15 were relatively stable with Reach Stability Rankings of 3.8 and 5.1, respectively. Although grade control is provided by the armored riffles and bedrock steps along many of the reaches, Reaches 7, 8, and 9 have long sections with clay beds that are overlain with a cobble, gravel and sand. Long, deep pools have developed where the coarser layer has been washed away and the clay scoured. It was evident that some of these scour areas are actively eroding and migrating in an upstream direction. Although sedimentation was observed throughout the segment, there is a definite trending toward finer materials in a downstream direction. A significant portion of the streambed material along the lower section of Reach 15 was silt, sand and detritus.

Channel alterations along this segment include rip-rap armoring, wooden retaining walls, stone walls, and old mill races. Reaches 9, 13, and 15 are the most significantly altered reaches. A significant length of the left bank along upper Reach 9 has stone walls. A timber retaining wall has been installed along the right bank in the lower section of the reach. The historic mill at Mill Street diverted Reach 13 through two channels at the old mill site. A significant length of the right bank along lower Reach 15 has been armored with rip-rap. The lack of a riparian buffer is a common problem throughout much of the segment. In residential neighborhoods along the right floodplain mowed lawns with scattered trees are the typical vegetation. On agricultural land along the left floodplain row crops with scattered trees are the typical vegetation.

Figure 3.29 – View along upper Reach 7

Figure 3.30 – View along upper Reach 7

Figure 3.31 – Scour pool and clay ledge along middle Reach 7

Figure 3.32 – Bank erosion along middle Reach 7

Figure 3.33 – Debris jam along lower section of Reach 7

Figure 3.34 – Downstream end of Reach 7

Figure 3.35 – Upstream end of Reach 8

Figures 3.36 and 3.37 – Bank revetment lower middle section of Reach 8

Figures 3.38 and 3.39 – Bank erosion along lower section of Reach 8 upstream of the Elizabeth Street Bridge.

Figures 3.40 and 3.41 – Upper section of Reach 9

Figure 4.42 – Eroding right bank along middle section of Reach 9

Figure 3.43 – Timber retaining wall along right bank middle of Reach 9

Figures 3.44 and 3.45 – Eroding stream bank at rear of yards along middle of Reach 9

Figure 3.46 – Eroding stream bank at rear of yards along lower section of Reach 9

Figure 3.47 – Stable upper section of Reach 10, lacking riparian buffer along yards

Figure 3.48 – Stable upper section of Reach 10, lacking riparian buffer along yards

Figure 3.49 – Stable middle section of Reach 10, lacking riparian buffer along yards

Figure 3.50 – Stable lower section of Reach 10 upstream of Garfield Street Bridge.

Figure 3.51 – Looking downstream at upper Reach 11 from Garfield Street Bridge.

Figure 3.52 – Eroding right bank along ball fields downstream of Garfield Street Bridge.

Figure 3.53 – Looking downstream along middle section Reach 11.

Figure 3.54 – Eroding right bank along ball fields downstream middle of Reach 11.

Figure 3.55 – View looking downstream along lower Reach 11

Figure 3.55 – Corn planted to edge of eroding bank along upper Reach 12

Figure 3.56 – Stormwater management pond along floodplain in Reach 12

Figure 3.57 – Stable section of Reach 12

Figure 3.58 – Left branch of Reach 13 upstream of Mill Street

Figure 3.59 – Left branch of Reach 13 downstream of Mill Street

Figure 3.60 – Left branch of Reach 13 downstream of Mill Street

Figure 3.61 – Right branch of Reach 13 upstream of Mill Street

Figures 3.62 – Right branch of Reach 13 downstream of Mill Street

Figures 3.63 – Right branch of Reach 13 downstream of Mill Street

Figure 3.64 – Stone deflectors along upper Reach 14 near Cleona Boulevard Sewage Pumping Station

Figures 3.65 and 3.66 – Eroding bank along rear of yards in upper Reach 14

Figure 3.67 – Eroding bank along rear of yards in upper Reach 14

Figure 3.68 – No riparian buffer along rear of yards in upper Reach 14

Figure 3.69 – Eroding bank and footbridge at downstream end of Reach 14

Figure 3.70 – Scour pool and eroding banks at downstream end of Reach 14

Figures 3.71 and 3.72 – Eroding banks along rear of yards in upper Reach 15

Figures 3.73 and 3.74 – Looking downstream (upper photo) and upstream (lower photo) at bank revetment along rear of yards middle Reach 15

Figures 3.75 – Bank revetment along rear of yards in middle Reach 15

Figure 3.76 – Bank erosion on bank opposite bank revetment

Figure 3.77 – Bank erosion along lower Reach 15

Figure 3.78 – Stormwater management pond in floodplain along Reach 15

Figure 3.79 – Floodplain along lower Reach 15

Figure 3.80 – Looking upstream from bridge at downstream end of Reach 15

Figure 3.81 – Eroding left bank along cornfield at downstream end of Reach 15

Figure 3.82 – Looking upstream toward bridge at downstream end of Reach 15

Segment 3

Segment 3 is 14,885 linear feet in length and includes Reaches 16 – 25. The upstream limit is the confluence with Beck Creek and downstream limit is the confluence with Bachman Run. With the exception of Reach 17 and the downstream end of Reach 20 the reaches along this segment are C4 stream types. Reach 17 is currently functioning as a C5 stream type with a bed composed predominantly of sand, silt and organic muck. The lower section of Reach 20 is a C2/C1 stream type. Short sections of Reaches 18, 19, 20, and 21 have characteristics more typical of B2c/B1c stream types. However, due to their short length these sections were not broken out as separate reaches. Although there are several broad sweeping meanders in Reaches 17, 23 and 25, the overall channel plan form of the segment is characterized by relatively low sinuosity indicative of historic channel straightening. Channel constrictions have been created by the bridges at Spruce Street and Oak Street (Route 934) at the downstream end of Reaches 19 and 23 respectively, causing backwater conditions under bankfull and higher flows.

The overall conditions of Reaches 16, 17, 21, 23, and 25 are characterized by lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars. Results of the stability assessment show bank height to bankfull ratios along the reaches range from 1.0 – 2.4. The higher banks are susceptible to erosion and gravitational failure. Reaches 16, 17, 21, 23, and 25 have highest percentage of unstable banks with 29%, 30%, 30%, 23%, and 77% of the banks exhibiting high bank erosion potential. Reaches 18, 22 and 24 were considered relatively stable with Reach Stability Rankings of 1.3, 4.0, and 5.0, respectively. Reaches 16 and 23 were considered unstable with Reach Stability Rankings of 9.0 and 8.3, respectively. Reaches 17 and 21 were considered very unstable with Reach Stability Rankings of 11.3 and 14.5, respectively. Reach 25 is the most unstable reach along the entire main stem with a Reach Stability Ranking 28.5.

Bed aggradation is a problem throughout Reaches 17, upper 18, 22, 24, and upper 25 as evidenced by a high percent embeddedness of riffles and the development of mid-channel and lateral bars along significant portions of some of these reaches. Although debris jams were generally infrequent to moderately frequent partial blockages were observed along Reaches 16, 18, 22, and 24. Reach 17 had an unusually large number of debris jams and lateral bars throughout. With the exceptions of Reaches 16, lower 21, and 25, which have incising sections, grade control is provided throughout this segment by the boulder riffles and bedrock steps along many of the reaches. A number of reaches have long sections with bedrock overlain with cobble, gravel and sand.

Channel alterations along this segment include rip-rap armoring, concrete walls, in-stream habitat structures, and old mill dams. A significant length of the left bank along upper Reach 19 has a concrete wall and rip-rap armoring. Other alterations include the remains of an old mill on Reach 19 upstream of Spruce Street and numerous in-stream habitat structures along Reach 20 downstream of Spruce Street. The design and placement of these habitat structures makes them of questionable value. In fact they may actually result in unintended negative consequences as they alter channel hydraulics and sediment transport processes in this reach. Numerous in-stream habitat structures were installed along Reach 21 in Quittie Creek Nature Park. Although most of the structures appeared to be functioning as intended, a steep, constructed riffle near the middle of the reach was directing flow into the adjacent right bank causing considerable erosion. This section of stream was repaired. However, field observations indicate this spot may continue to be a problem. The old mill dam on Reach 21 in Quittie Creek Nature Park may function as a barrier to fish migration under extreme low flow conditions as occurred in 2001.

Much of this segment has considerable riparian buffer composed of mature woods. However, the lack of a riparian buffer is a common problem on the commercial properties along the right floodplain of Reach 18 where parking lots and scattered trees are the typical condition. In the residential neighborhoods along the right floodplain of Reaches 23, 24, and 25 mowed lawns with scattered trees are the typical condition.

Figure 3.83 – Looking upstream toward bridge at upstream end of Reach 16

Figure 3.84 – Looking downstream along middle section of Reach 16

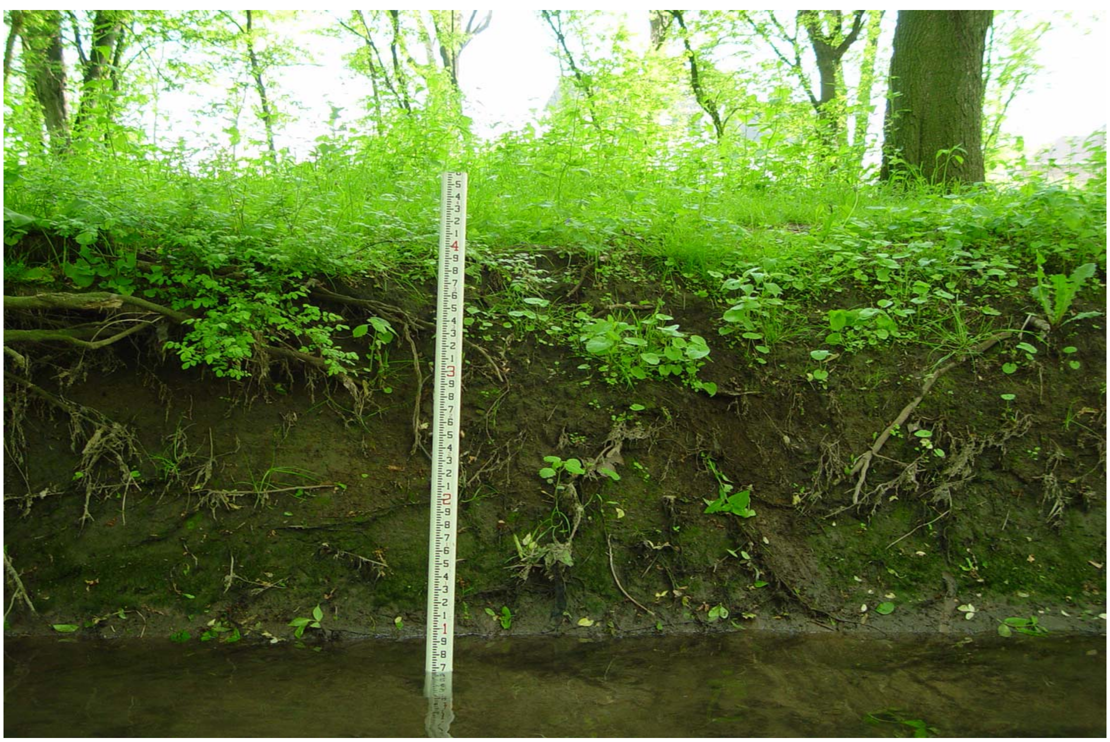

Figure 3.85 – Bank erosion along middle section of Reach 16

Figure 3.86 – Clay ledge along streambed middle section of Reach 16

Figure 3.87 – Looking downstream along lower section of Reach 16

Figure 3.88 – Bank erosion along lower section of Reach 16

Figure 3.89 – View along upper section of Reach 17

Figures 3.90 and 3.91 – Views along middle section of Reach 17

Figure 3.92 – View along lower section of Reach 17

Figure 3.93 – View along upper section of Reach 18

Figures 3.94 and 3.95 – Views along middle section of Reach 18

Figures 3.96 and 3.97 – Views along middle section of Reach 18

Figures 3.98 and 3.99 – Views along lower section of Reach 18

Figures 3.100 – Spring along lower section of Reach 18

Figures 3.101 – Storm drain outfall at end of Willow Drive along lower Reach 18

Figures 3.102 and 3.103 – Views along lower section of Reach 18

Figure 3.104 – Spring at upstream end of Reach 19

Figure 3.105 – Looking downstream along upper Reach 19

Figures 3.105 and 3.106 – Views along Reach 19

Figures 3.107 and 3.108 – Looking toward Spruce Street Bridge at downstream end of Reach 19 (upper photo) and upstream end of Reach 20 (lower photo)

Figures 3.109 and 3.110 – Looking downstream along upper Reach 20

Figure 3.111 – Left bank along upper Reach 20

Figure 3.112 – Looking upstream along upper Reach 20

Figure 3.113 – Log (foreground) and rock (background) habitat structures along Reach 20

Figure 3.114 – Bedrock section along lower Reach 20

Figure 3.115 – Looking upstream at steep riffle constructed to improve habitat along middle Reach 21 in Quittie Park.

Figure 3.116 – Looking downstream at repairs of right bank blown-out by flows directed into bank by constructed riffle.

Figure 3.117 – Bank erosion along left bank opposite blown-out bank.

Figure 3.118 – A lunker-structure installed to improve habitat along lower Reach 21 in Quittie Park

Figures 3.119 and 3.120 – Views along lower Reach 21 upstream of old mill dam

Figures 3.121 and 3.122 – Bank erosion along lower Reach 21 upstream of old mill dam

Figure 3.123 – Old mill dam at downstream end of Reach 21 in Quittie Park

Figure 3.124 – View along upper section of Reach 22

Figure 3.125 – View along upper section of Reach 22

Figure 3.126 – Bank erosion along upper section of Reach 22

Figure 3.127 – Spring along left floodplain in middle section of Reach 22

Figure 3.128 – View along middle section of Reach 22

Figure 3.129 – View along lower section of Reach 22

Figure 3.130 – Looking downstream along upper section of Reach 23

Figure 3.131 – View along upper section of Reach 23

Figure 3.132 – Looking upstream at spring along left floodplain in middle section of Reach 23

Figure 3.133 – Bedrock outcrops along lower middle section of Reach 23

Figure 3.134 – View along lower section of Reach 23

Figure 3.135 – Looking downstream toward Route 934 Bridge at downstream end of Reach 23

Figure 3.136 – Looking upstream toward Route 934 Bridge at upstream end of Reach 24

Figures 3.137 and 3.138 – Views along upper section of Reach 24

Figure 3.139 – Right bank along middle section of Reach 24

Figure 3.140 – Looking downstream along middle section of Reach 24

Figure 3.141 – Looking upstream along lower section of Reach 24

Figure 3.142 – Looking upstream at storm drain outfall end of King Street at downstream end of Reach 24

Figures 3.143 and 3.144 – Looking downstream along the upper section of Reach 25

Figure 3.145 – Looking downstream along the middle section of Reach 25

Figure 3.146 – Bank erosion along the middle section of Reach 25

Figure 3.147 – Bank erosion along the middle section of Reach 25

Figure 3.148 – Looking upstream along the lower section of Reach 25

Figures 3.149 and 3.150 – Bank erosion along the lower section of Reach 25

Figures 3.151 and 3.152 – Looking toward left floodplain along lower Reach 25 at the upper confluence with Bachman Run (to left of upper photograph) and the lower confluence with Bachman Run (to right of lower photograph)

Segment 4

Segment 4 is 11,375 linear feet in length and includes Reaches 26 – 33. The upstream limit is the confluence with Bachman Run and downstream limit is the confluence with Killinger Creek. Although reconnoitered and photographically documented, the 2550 linear feet of concrete flume that conveys the flow of Quittapahilla Creek between Reaches 28 and 29 was not included in the detailed evaluation of the main stem. A brief description of its condition is presented below.

With the exception of Reach 27, the reaches in this segment are laterally and vertically unstable C4 stream types. Although there are several broad sweeping meanders in Reaches 26 and 29, the overall channel plan form of the segment is characterized by relatively low sinuosity indicative of historic channel straightening. Channel constrictions have been created by the bridges at Route 422, Clear Springs Road and Syner Road at the downstream end of Reaches 27, 29, and 31 respectively, causing backwater conditions under bankfull and higher flows. The most significant backwater condition is created at the downstream end of Reach 28 where the creek enters the concrete flume.

With the exception of Reach 27, the overall conditions of the segment are characterized by moderate degree of lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars throughout. Results of the stability assessment show bank height to bankfull ratios along the reaches range from 1.0 – 1.43. The notable exception was a 75 foot length of bank in Reach 29 that had a bank height to bankfull ratio of 2.0. Reach 26 had the highest percentage of unstable banks with 70%, of the banks exhibiting high bank erosion potential. The other reaches ranged from 0% to 18.5%.

Aggradation is a problem throughout all reaches in the segment as evidenced by a high percent embeddedness of riffles and the development of mid-channel, lateral, and point bars along most of the reaches. Debris jams were frequent along Reaches 28, 29, 30, 31, 32, and 33. Reach 31 had an unusually large number of debris jams and lateral and mid-channel bars throughout. One debris jam completely blocked the channel and caused significant aggradation with localized scour pools where flow dropped over the obstruction. With the exceptions of Reaches 26, 28 and 32, which have an old mill dam, concrete flume, and bedrock at the downstream end of each reach respectively, the segment lacks grade control. Reaches 30 and 33 were considered relatively stable with Reach Stability Rankings of 1.0 and 5.5, respectively. Reaches 29, 31, and 32 were considered unstable with Reach Stability Rankings of 7.0, 6.0, and 9.1, respectively. Reach 16 was the most unstable reach in this segment and the second most unstable along the entire mainstem with a Reach Stability Ranking of 25.0.

Channel alterations along this segment include rip-rap armoring, an old mill dam, and a significant length of concrete flume. A significant length of the left bank along Reach 26 has rip-rap armoring. Other alterations include the remains of an old mill dam at the downstream end of Reach 26 upstream of Route 422. Given that much of the original dam structure had been removed it did not appear that the old dam would function as a barrier to fish migration even under extreme low flow conditions as occurred in 2001. With the exception of the Hazel Dike in the City of Lebanon, the concrete flume that conveys the flow of Quittapahilla Creek between Reaches 28 and 29 is the most dramatic channel alteration along the mainstem. There are actually two flumes. The main flume, which is approximately 2550 in length, conveys 100% of the baseflow. However, storm flows are split between this main flume and a secondary flume (approximately 3275 feet in length) that runs parallel to it. The main flume appeared to be in relatively good condition. However, the condition of the secondary flume is deteriorated with broken sections of concrete and gaps that allow storm flow to run beneath the flume eroding the supporting soil base and causing further collapse and damage. Moreover the flow running beneath the flume is also eroding the earthen berm that separates the two flumes. A section of berm along the middle portion of the flumes appeared to have been breached allowing flows from the secondary flume to drop into the main flume. Over time this condition will worsen and cause both flumes to fail. This situation needs immediate attention.

Much of this segment has considerable riparian buffer composed of mature woods. However, the lack of a wooded riparian buffer is a common problem on the agricultural properties along the right floodplain of Reaches 31, 32, and upper 33 where mowed lawns or old fields with scattered trees are the typical condition.

Figure 3.153 – Looking downstream along the upper section of Reach 26

Figure 3.154 – Looking downstream along the middle section of Reach 26

Figure 3.155 – Bank erosion along the middle section of Reach 26

Figure 3.156 – Looking downstream along the lower section of Reach 26

Figure 3.157 – Bank erosion along the lower section of Reach 26

Figure 3.158 – View of old mill dam at Brandt's Flour Mill at downstream end of Reach 26

Figure 3.159 – Looking upstream along split channel section of Reach 27 downstream of old mill dam at Brandt's Flour Mill

Figure 3.160 – Looking upstream along right side of split channel downstream of old mill dam at Brandt's Flour Mill

Figure 3.161 – Looking downstream toward Route 422 Bridge at downstream end of Reach 27

Figures 3.162 and 3.163 – Looking downstream along upper section of Reach 28

Figure 3.164 – Looking downstream along lower section of Reach 28 adjacent to Annville WWTP

Figure 3.165 – Debris jam and aggradation at downstream end of Reach 28

Figure 3.166 – Looking downstream toward end of Reach 28. Debris jam at left of photograph is blocking opening to secondary concrete. Opening to main flume is right of center.

Figure 3.167 – Opening to main concrete flume.

Figure 3.168 – View along main flume.

Figures 3.169 and 3.170 – Views along main flume

Figures 3.171 and 3.172 – Views along main flume

Figures 3.173 and 3.174 – Opening to secondary flume (upper photograph) and lower section of secondary flume (lower photograph) partially filled with sediment and overgrown with wetland vegetation

Figure 3.175 – Looking upstream along upper Reach 29 toward the old quarry road at the downstream end of the main concrete flume

Figure 3.176 – Looking downstream along upper Reach 29 below the old quarry road at the downstream end of the main concrete flume

Figures 3.177 and 3.178 – Left bank (upper photograph) and right bank (lower photograph) along upper Reach 29

Figure 3.179 – Looking upstream along the middle section of Reach 29. Secondary flume enters reach from the right of the photograph.

Figure 3.180 – Looking downstream toward meander bend, middle section Reach 29.

Figure 3.181 – Looking downstream from meander bend, middle section Reach 29.

Figure 3.182 – Eroding bank in meander bend, middle section Reach 29

Figure 3.183 – Right floodplain in meander bend, middle section Reach 29

Figure 3.184 – Right bank and terrace in second meander bend, middle section Reach 29

Figures 3.185 and 3.186 – Looking upstream (upper photograph) and downstream (lower photograph) along lower section Reach 29

Figure 3.187 – Looking upstream along lower section Reach 29 from Clear Springs Bridge

Figure 3.188 – Looking downstream along upper section Reach 30 from Clear Springs Bridge

Figure 3.189 – Looking upstream along lower section Reach 30 at debris jam

Figure 3.190 – Looking downstream along riffle in upper section Reach 31

Figure 3.190 – Looking downstream along pool in upper section Reach 31

Figure 3.191 – Looking downstream at debris jam and lateral bar along middle section Reach 31

Figure 3.192 – Looking upstream at large debris jam in lower section Reach 31

Figure 3.193 – Looking downstream at large mid-channel bar in lower section Reach 31

Figures 3.194 and 3.195 – Bank erosion along lower section Reach 31

Figure 3.196 – Looking downstream toward downstream end of Reach 31

Figure 3.197 – Syner Road Bridge at downstream end of Reach 31

Figure 3.198 – Syner Road Bridge at upstream end of Reach 32

Figure 3.199 – Looking downstream along upper Reach 32

Figure 3.200 – Looking downstream along Reach 32

Figure 3.201 – Evaluating bank erosion along middle section of Reach 32

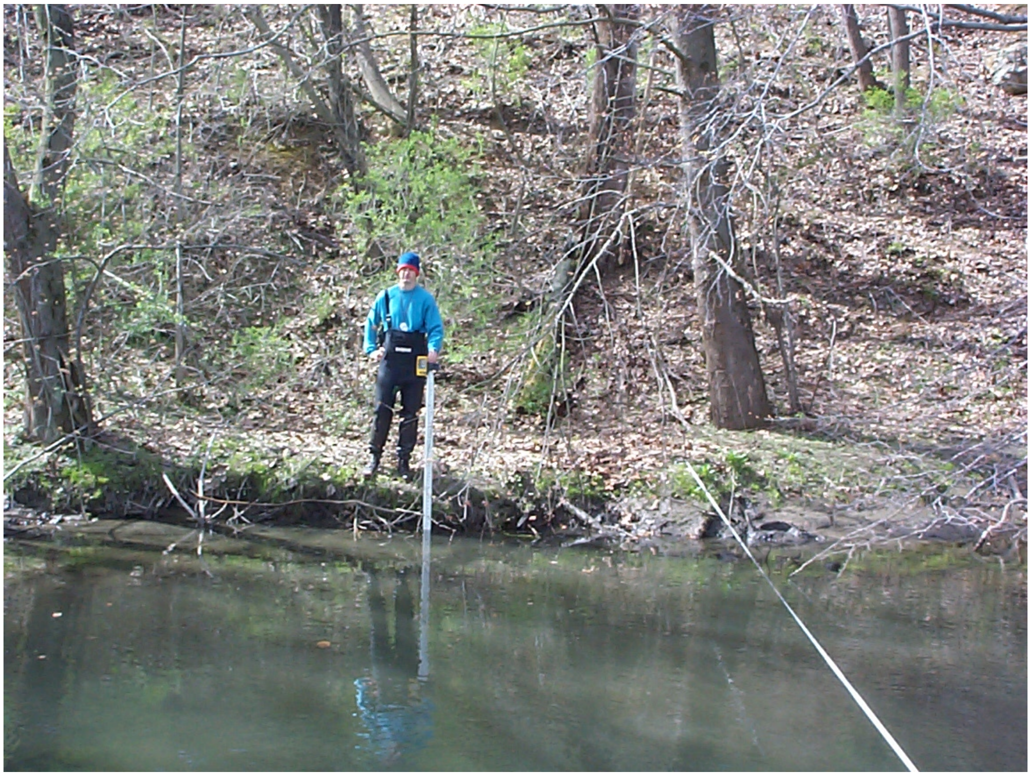

Figure 3.202 – High terrace along left side of Reach 32

Figure 3.203 – Evaluating bank erosion along lower section of Reach 32

Figure 3.204 – Looking downstream along upper Reach 33

Figure 3.205 – Looking downstream at large mid-channel bar along middle section of Reach 33

Figure 3.206 – Looking upstream along Reach 33 wetland seepage ditch enters reach from left of photograph. Heavy growth of submerged aquatic vegetation

Figure 3.207 – Looking downstream at large pool in middle section of Reach 33

Figure 3.208 – Evaluating bank erosion along lower section of Reach 33

Figure 3.209 – Looking upstream at confluence with Killinger Creek. Tributary enters reach from right of photograph

Segment 5

Segment 5 is 11,760 linear feet in length and includes Reaches 34 – 40. The upstream limit is the confluence with Killinger Creek and downstream limit is the confluence with the Unnamed Tributary that drains the Steelstown area of North Annville.

With the exception of Reach 36, the reaches in this segment are laterally and vertically unstable C4 stream types. Reach 36 is an unstable B4c stream type. The overall channel plan form of the segment is characterized by relatively low sinuosity indicative of historic channel straightening. Although the Palmyra-Bellegrove Bridge crosses the mainstem between Reaches 35 and 36 there are no significant man-made channel constrictions to create backwater conditions along this segment.

With the exception of Reach 35, the overall conditions of the segment are characterized by a moderate degree of lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars throughout. Results of the stability assessment show bank height to bankfull ratios along the reaches range from 1.0 – 1.39. Reaches 35 and 38 had the highest percentage of unstable banks with 30% and 24.5% respectively, of the banks exhibiting high bank erosion potential. The other reaches ranged from 2.7% to 18.2%.

Aggradation is a problem throughout all reaches in the segment as evidenced by a high percent embeddedness of riffles and the development of mid-channel and lateral bars along most of the reaches. Numerous mid-channel bars and islands have developed along the upper section of Reach 36 immediately downstream of the Palmyra-Bellegrove Bridge. Debris jams were frequent along Reaches 34, 35, 39, and 40. Reaches 34 and 40 had an unusually large number of debris jams and lateral and mid-channel bars throughout. One debris jam in Reach 34 blocked a significant portion of the channel cross-section and caused significant aggradation with localized scour pools where flow dropped over the obstruction. The segment lacks grade control throughout. Reaches 37, 39 and 40 were considered relatively stable with Reach Stability Rankings of 3.2, 4.2 and 1, respectively. Reaches 36 was considered unstable with a Reach Stability Ranking of 8.1. Reaches 34, 35, and 38 were considered very unstable with Reach Stability Rankings of 12.3, 10.9, and 10.3, respectively.

Channel alterations along this segment include in-stream habitat structures and an old mill race. In-stream habitat structures were installed along the upper section of Reach 34 at some time in the past. Remnants of the structures suggest that the design and placement of these habitat structures made them of questionable value. In fact, they appear have altered the local channel hydraulics and sediment transport processes causing unstable conditions to develop. Other alterations include the remains of an old mill race at the upstream end of Reach 39. Its location at the upstream end of a meander bend and the fact that storm flows are diverted away from the main channel into the mill race appears to have contributed to sediment transport problems and localized aggradation and scour.

Much of this segment has considerable riparian buffer composed of mature woods. However, the lack of a wooded riparian buffer is a common problem on the agricultural properties along the right floodplain of Reaches 34, 35, 37, and 39 and the left floodplain of Reaches 36 and 38 where mowed lawns or old fields with scattered trees are the typical condition.

Figure 3.210 – Looking downstream along upper Reach 34

Figure 3.211 – Evaluating bank erosion along upper Reach 34

Figure 3.212 – Looking upstream along upper Reach 34

Figure 3.213 – Left terrace along upper Reach 34

Figure 3.214 – Right bank along middle Reach 34 on Weaver Farm

Figure 3.215 – Looking downstream along middle Reach 34

Figure 3.216 – Evaluating bank erosion on Weaver Farm along middle Reach 34

Figure 3.217 – Left floodplain along lower Reach 34

Figure 3.218 – Looking upstream at debris jam along lower Reach 34 (April 2003)

Figure 3.219 – Looking upstream at debris jam along lower Reach 34 (July 2001)

Figure 3.220 – Looking downstream on Weaver Farm along upper Reach 35

Figure 3.221 – Right floodplain on Weaver Farm along upper Reach 35

Figure 3.222 – Looking downstream along middle Reach 35 (April 2003)

Figure 3.223 – Looking downstream along middle Reach 35 (July 2001)

Figure 3.224 – Looking upstream along fishing club lower Reach 35

Figure 3.225 – Looking downstream along fishing club lower Reach 35

Figure 3.226 – Looking upstream along fishing club lower Reach 35

Figure 3.227 – Right floodplain along fishing club lower Reach 35

Figure 3.228 – Looking downstream along upper Reach 36 at confluence with School Creek. School Creek enters reach from right of photograph

Figure 3.229 – Looking downstream along upper Reach 36 at Palmyra-Bellegrove Bridge

Figure 3.230 – Looking downstream along upper Reach 36 at Palmyra-Bellegrove Bridge

Figure 3.231 – Thick mats of submerged aquatic vegetation along Reach 36

Figures 3.232 and 3.233 – Looking upstream (upper photograph) and downstream (lower photograph) along Reach 36 from Palmyra-Bellegrove Road Bridge

Figure 3.234 – Looking upstream along middle section Reach 36

Figure 3.235 – Right top of bank and floodplain along middle section Reach 36

Figure 3.236 – Right top of bank and floodplain along middle section Reach 36

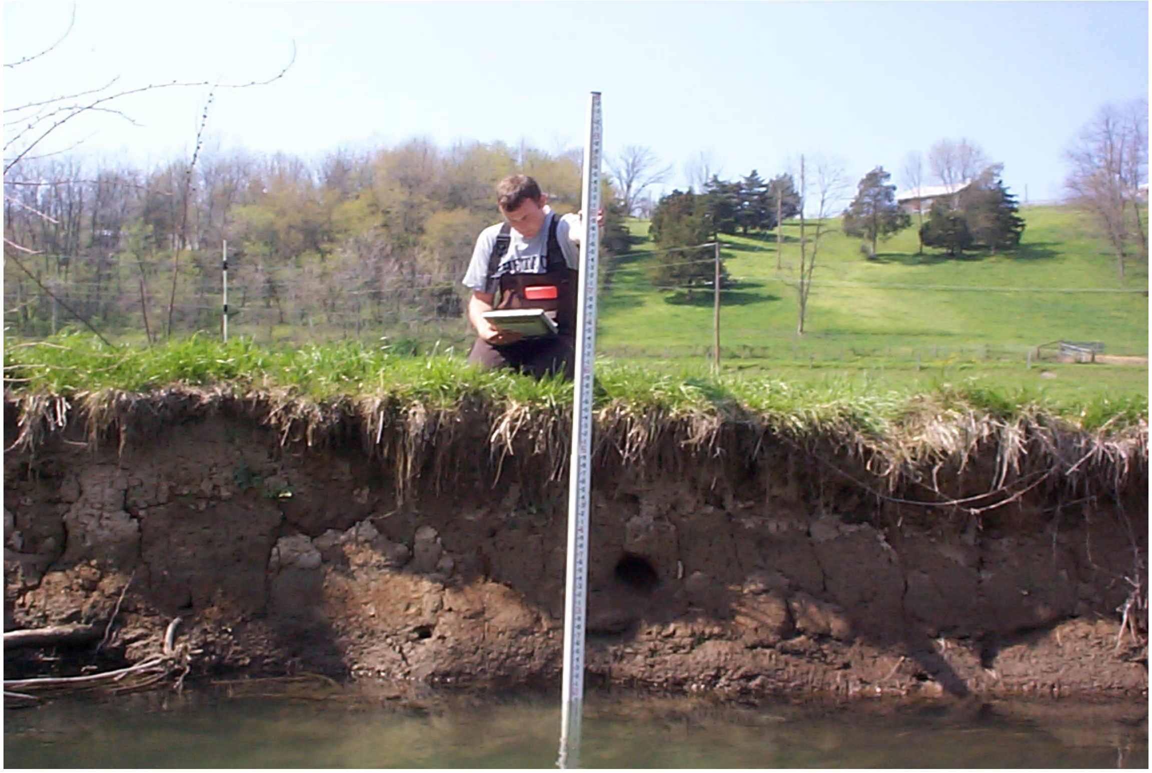

Figure 3.237 – Evaluating bank erosion along middle section Reach 37

Figure 3.238 – Evaluating bank erosion along middle section Reach 37

Figure 3.239 –Looking downstream along lower Reach 37

Figure 3.240 –Signs of beaver activity along lower Reach 37

Figure 3.241 –Looking downstream at large mid-channel bar at lower end of Reach 37

Figure 3.242 –Looking downstream along upper section Reach 38

Figure 3.243 –Left bank and floodplain along upper section Reach 38

Figure 3.244 –Looking downstream along lower middle Reach 38

Figure 3.245 –Right bank and high terrace along lower middle section Reach 38

Figure 3.246 –Looking downstream along lower Reach 38

Figure 3.247 –Looking upstream along upper Reach 39

Figure 3.248 –Right bank and floodplain along upper Reach 39

Figure 3.249 –Looking downstream along lower Reach 39

Segment 6

Segment 6 is 14,400 linear feet in length and includes Reaches 41 – 52. The upstream limit is the confluence with the Unnamed Tributary that drains the Steelstown area of North Annville and downstream limit is the confluence with Swatara Creek.

With the exception of Reaches 41 and 44, the reaches in this segment are laterally and vertically unstable C4 stream types. The lower section of Reach 41 and the upper section of Reach 44 are unstable B4c stream types. The overall channel plan form of the segment is characterized by relatively low sinuosity indicative of historic channel straightening. Channel constrictions have been created by the bridges at Syner Road, Valley Glen Road, and Gravel Hill Road at the downstream end of Reaches 42, 50, and 51 respectively, causing backwater conditions under bankfull and higher flows.

The overall conditions of the segment are characterized by a moderate degree of lateral erosion, high sediment supply, and vertical instability (i.e., aggradation) with lateral and mid-channel bars throughout. Results of the stability assessment show bank height to bankfull ratios along the reaches range from 1.0 – 2.92. Reaches 41 had the highest percentage of unstable banks with 39.8% of the banks exhibiting high bank erosion potential. The other reaches ranged from 0% to 16.3%.

Aggradation is a problem throughout all reaches in the segment as evidenced by a high percent embeddedness of riffles and the development of mid-channel and lateral bars along most of the reaches. Reaches 41, 43, 44, 46, 47, 48, and 49 had numerous large debris jams. Reaches 48 and 49 had an unusually large debris jams and lateral and mid-channel bars throughout. Several debris jams blocked a significant portion of the channel cross-section and caused significant aggradation with localized scour pools where flow dropped over the obstruction. The segment lacks grade control throughout. Other than the historic channel straightening there was no evidence of channel alterations along this segment. Reaches 42, 43, 45, 47, and 50 were considered relatively stable with Reach Stability Rankings of 4.1, 1.7, 2.5, 4.2 and 1.3, respectively. Reaches 44, 46, 48, 49, and 51 were considered unstable with Reach Stability Rankings of 5.7, 5.1, 5.1, 7.6, and 8.3, respectively. Reach 41 was considered very unstable with a Reach Stability Ranking of 13.5.

Much of this segment has considerable riparian buffer composed of mature woods. However, the lack of a wooded riparian buffer is a common problem on the agricultural properties along the right floodplain of Reaches 41, 42, 43, 44, 48, 49, and 50 and the left floodplain of Reaches 43 and 51 where mowed lawns or old fields with scattered trees are the typical condition.

Figure 3.250 –Looking upstream along lower Reach 40 and upper Reach 41. Unnamed Tributary enters reach at left of photograph

Figure 3.251 –Looking downstream along upper Reach 41

Figure 3.252 –Left bank and high terrace along upper Reach 41

Figure 3.253 –Looking upstream along middle Reach 41

Figure 3.254 –Looking downstream along middle Reach 41

Figure 3.255 –Tributary entering reach along left bank middle Reach 41

Figure 3.256 –Looking upstream at debris jam along lower Reach 41

Figure 3.257 –Looking downstream at debris jam along lower Reach 41

Figure 3.258 –Debris jam and eroding right bank along lower Reach 41

Figure 3.259 –Looking downstream at debris jam along Reach 42

Figures 3.260 and 3.261 –Views along Reach 42

Figure 3.262 –Looking downstream Reach 42

Figure 3.262 –Looking downstream at Lower Syner Road Bridge, end of Reach 42

Figures 3.263 and 3.264 –Looking downstream along Reach 43

Figure 3.265 –Looking upstream along Reach 43

Figure 3.266 –Looking upstream along upper Reach 44

Figure 3.267 –Looking downstream along upper Reach 44

Figure 3.268 –Right bank and floodplain along upper Reach 44

Figure 3.269 –Surveying along left bank and floodplain along upper Reach 44

Figure 3.270 –Looking downstream towards end of Reach 44

Figure 3.271 – Evaluating bank erosion along downstream end of Reach 44

Figure 3.272 – Evaluating bank erosion along middle of Reach 45

Figure 3.273 – Debris jam and mid-channel bars along upper section of Reach 46

Figures 3.274 and 3.275 – Looking downstream along Reach 46

Figure 3.276 – Debris jam and lateral bar along Reach 46

Figure 3.277 – Looking upstream along Reach 47

Figure 3.277 – Looking downstream along Reach 47

Figure 3.278 – Evaluating bank erosion along Reach 47

Figure 3.279 – Evaluating bank erosion along Reach 47

Figure 3.280 – Large debris jam along upper section Reach 48

Figure 3.281 Debris jam and lateral bars along middle section Reach 48

Figure 3.282 – View along lower middle section Reach 48

Figure 3.283 – Debris jams along middle section Reach 48

Figure 3.284 – Mid-channel bars along lower middle section Reach 48

Figure 3.285 – Swimming hole with beach and picnic area along upper section of Reach 49

Figure 3.286 – Large debris jam, mid-channel bars and islands along lower section of Reach 49

Figure 3.287 – Channel completely obstructed by large debris jam, mid-channel bars and islands along lower section of Reach 49

Figure 3.288 – Looking downstream along middle section of Reach 50

Figure 3.289 – Thick mats of submerged aquatic vegetation along middle section Reach 50

Figure 3.290 – Large debris jam upstream of Valley Glen Road Bridge at lower end of Reach 50

Figure 3.291 – Looking downstream along upper section of Reach 51

Figure 3.292 – Looking downstream along middle section of Reach 51

Figure 3.293 – Looking downstream toward Gravel Hill Road at lower end of Reach 51

Figure 3.294 – Looking upstream toward Gravel Hill Road along upper section Reach 52

Figure 3.295 – Looking downstream toward Swatara Creek along lower section Reach 52

Section 4 – Subwatershed Analyses

4.1 – Introduction

Included in this section is a detailed analysis of each of the major subwatersheds in the Quittapahilla Creek Watershed. The information utilized in that analysis was gathered from existing GIS databases, topographic maps, soil surveys and maps, geologic maps and reports, land use and land cover maps, as well as historic and recent aerial photography. Information gathered from a Level I - Geomorphic Characterization, and the field reconnaissance and photographic documentation of the subwatersheds conducted in Summer 2001 provided additional information.

The geomorphic characterization focused on classifying stream reaches in these subwatersheds into the generalized stream types (i.e., A, B, C, D, etc.) described in A Classification of Natural Rivers (Rosgen, 1994). The stream reaches were classified based on information gathered from USGS quadrangle maps, aerial photography, and field reconnaissance. This task provided information that was useful in focusing the field reconnaissance effort. Conversely the field reconnaissance provided verification of the initial reach classification.

The field reconnaissance and photographic documentation was conducted to assess and document existing conditions in the major subwatersheds. It focused on verifying existing land use activities and land cover including type and condition, identifying and documenting unstable conditions in upland and riparian areas, and characterizing stream channel morphology and condition. The preliminary findings presented below are based on information developed during the field reconnaissance and photographic documentation of the subwatersheds conducted in 2001

4.2 – Field Reconnaissance Findings

4.2.1 – General Comments

Although conditions vary among the subwatersheds, the effects of land use activities on channel stability, water quality and habitat are evident in all of the subwatersheds. Field observations indicate that agriculture, mining, timber harvesting, development, channel alterations, water diversions, and wastewater discharges have all contributed to the current problems. While impacts from these activities were anticipated, it appears that some of the well-intentioned habitat improvement projects completed in the past also have contributed to channel instability and poor habitat.

4.2.2 – Agriculture

The most significant impacts in the subwatersheds are associated with agricultural practices. In particular, unrestricted livestock grazing along the tributaries has directly impacted channel morphology by trampling of the banks, widening of the channel, and increasing sedimentation. Historic vegetation control practices such as spraying and mechanical removal of undesirable vegetation probably contributed to the loss of much of the woody vegetation from the banks and riparian zone along creeks. However, the current lack of woody vegetation and the subsequent loss of channel stability is a direct result of the unrestricted grazing activities.

Figures 4.1and 4.2 – Stream banks trampled by livestock (cattle) along Beck Creek (upper photo) and Snitz Creek (lower photo)

Figure 4.3 – Trampled streambed and banks and degraded water quality caused by livestock along Beck Creek

Figure 4.4 – Stream banks trampled by livestock (horses) along Snitz Creek.
Note fencing along left bank.

Figure 4.5 – Stream banks trampled by livestock (horses) along Snitz Creek.

Table 4.1 – Summary of the effects of unrestricted livestock grazing based on the length of stream channel impacted.

Watershed	Total Stream Length (Miles)	Length of Stream Impacted (Miles)	Percent of Total
Killinger Creek	6.8	1.85	27.0
Buckholder Creek	2.0	0.0	0.0
Gingrich Run	3.8	0.9	23.5
Bachman Run	6.4	1.4	21.0
Beck Creek	6.8	1.9	28.0
Snitz Creek	8.33	0.8	9.0
Brandywine Creek	5.3	0.0	0.0
Unnamed Tributary	4.28	1.03	24.0
Quittapahilla Creek	18.0	0.0	0.0

4.2.3 – Stream Bank Fencing Program

Interestingly, the efforts of the Watershed Association were evident. Reaches along the tributaries where landowners have agreed to fence their sections of the creeks show definite signs of recovery.

After fencing and livestock exclusion, vegetation encroaches, the stream channel narrows and deepens, sediment transport capacity increases, the substrate coarsens and overall habitat improves. The fencing program has also provided riparian buffers where native trees, shrubs, and grasses become established, stabilizing stream banks and providing wildlife habitat

Figure 4.6 – Section of Beck Creek recovered after fencing

As of November 2005, the stream bank fencing program included 18 farms with a total of 35, 566 feet (6.7 miles) of the main stem Quittapahilla Creek and its tributaries fenced. Beck Creek has been the biggest beneficiary of this program with 11,491 feet of stream fenced, followed by Bachman Run, Main Stem Quittapahilla Creek, Snitz Creek, and Gingrich Run with 7,716 feet, 6,350 feet, 5,639 feet and 4,390 feet, respectively. Livestock crossings are often installed as part of the fencing program. Thus far, 21 crossings have been installed.

Figure 4.7 – Stream bank fencing with a stable livestock crossing

Figure 4.8 – Stream bank fencing. Arrow shows location of channel.

Figure 4.9 – Recovering section of Beck Creek.

Figure 4.10 – Recovering section of Snitz Creek.

Observations suggest that the success of these fencing projects is strongly influenced by the landowner's level of commitment to maintain their project over the long-term. During the field reconnaissance it was observed that a number of the farms were not maintaining their stream bank fencing. Some fences were in poor condition or completely down. It was obvious that livestock still had relatively easy access to the stream on these properties.

Figure 4.11 – In the upper photograph the green arrow indicates the livestock crossing, the red arrow indicates a point where livestock can still access the stream. Poor fence layout and maintenance allows livestock easy access to the stream.

Figure 4.12 – Result - stream in poor condition in spite of fencing

The type of fence also appears to influence the success of the project. The high tensile strength wire fences, with sturdy wooden posts appear to function best. On farms where thin fiberglass-coated posts and double strands of lightweight wire were used, cattle were observed running back and forth through the fences. Even electric fences didn't fare much better.

4.24 – Other Streamside Agricultural Best Management Practices

A number of farms were observed to be utilizing some of the currently accepted best management practices for cultivated areas (e.g., grass filter strips, grass waterways, no till cultivation, cover crops, etc.).

Figure 4.13 – Vegetative buffer strip separates Killinger Creek from adjacent corn fields

Many of the creeks have been ditched and straightened to accommodate cultivation. This condition was particularly common on farms in headwater areas. In fact, significant portions of Buckholder Run and Gingrich Run have undergone these alterations. Although most of these stream reaches had minimal habitat, they were relatively stable because they were protected with vegetative buffer strips. These buffer strips also function to filter sediment that would otherwise runoff cultivated areas directly to the stream. The wider the buffer the more effective it is at trapping and removing sediments. Factors affecting the minimum buffer width required include the erosion potential of the soils, the slope of the adjacent fields, and the size of overall area draining to the buffer.

Figures 4.13 and 4.14 – Vegetative buffer strips along Buckholder Run

4.2.5 – Logging and Lumber Mills

Logging operations in riparian areas has impacted the headwaters of Killinger Creek and Buckholder Run. The failure to utilize any type of best management practices has contributed to especially unstable conditions in the logged areas of upper Buckholder Run.

Figure 4.15 – Stream impacts associated with poor logging practices. Arrows show direction of stream flow.

The photograph above documents stream impacts associated with poor logging practices observed during the field reconnaissance. The stream channel was completely obliterated by this haul road crossing. The logging company that conducted this harvest is not known.

In 1996 the headwaters of Gingrich Run were severely impacted by storm water runoff from the Walter H. Weaber & Sons, Inc lumber mill site, which carried wood fibers, saw dust, mulch, and leachate from wood by-products. Solids, organic enrichment, and low dissolved oxygen levels degraded approximately one mile of Gingrich Run.

Under a PADEP Consent Order issued in 1997, corrective actions were taken. Field observations made during the field reconnaissance of the Gingrich Run watershed indicate that these corrective actions were implemented and appear to be functioning and well maintained.

Figure 4.16 – Silt fence, stone check dam and straw bales across drainage swale trap sediments carried in runoff from roads at the Walter H. Weaber & Sons, Inc lumber mill site.

Figure 4.17 – Sediment basin with wetland vegetation effectively treats runoff from materials storage area prior to discharge to Gingrich Run

4.2.6 – Quarries

Millard Quarry

As part of the field reconnaissance of the Killinger Creek watershed, a tour was conducted of the Pennsy Supply's Millard Quarry and Processing Plant. Based on observations made during the tour it was apparent that the mining operations at this facility are contributing to increased turbidity and sedimentation along lower Killinger Creek and Quittapahilla Creek downstream of the confluence. Much of the very fine material that makes its way to the creek is a by-product of the operation and would probably be very difficult to completely eliminate from the wastewater stream discharging from the sedimentation ponds. However, runoff from the material processing areas and conveyors appears to be a contributing source as well.

It is important to note that at the time of the field reconnaissance, when these photos were taken, the Millard Quarry was owned by Carmeuse Chime Minerale. It is unknown whether these problems have been corrected since Pennsy Supply acquired the property.

Figure 4.18 – Runoff carrying fine sediments trapped in sump area for cleanup and removal.

Figure 4.19 – The fine material collects beneath the conveyors and on most surfaces throughout the plant

Figure 4.20 – Storm water runoff carries the fine material over the stream banks and into Killinger Creek.

Figure 4.21 – The wash ponds are an additional source of fine sediments. This photograph shows discharge from wash ponds.

Figure 4.22 – Wash pond discharge flowing downstream through culvert.

Figure 4.23 – Discoloration and increased turbidity are evident along Killinger Creek downsteam of discharge point.

During the geomorphic mapping of the main stem Quittapahilla Creek it was observed that the discoloration and increased turbidity caused by the quarry was still evident as far as the Blauch Farm, which is approximately 3.5 miles downsteam of the discharge point.

Fontana Quarry

As part of the field reconnaissance of the Bachman Run watershed, a tour was conducted of the Pennsy Supply's Fontana Quarry. Based on observations made during the tour it appears that the mining operations at this facility have little or no impact on the water quality of Bachman Run. However, it does appear that the quarry has had a significant effect on the baseflow of one of the headwater tributaries. Stream channels on and adjacent to the Fontana site have been relocated and channelized. One headwater tributary, the East Fork of Bachman Run carried baseflow until it reached the channelized section around the quarry. There was no baseflow until the East Fork joined the Middle Fork of Bachman Run just upstream of Route 241. Although the Middle Fork of Bachman Run has been channelized also, no impacts to water quality or baseflow were evident.

Figure 4.24 – View of Fontana Quarry

Figure 4.25 – Sedimentation ponds at quarry

Figure 4.26 – Discharge pipe from sedimentation pond.

4.2.7 – Development

For urbanizing watersheds, the degree of stream instability is directly related to the amount of impervious cover and storm drainage. Smooth, hard pavement and storm drain systems route storm water runoff rapidly to nearby streams. Impervious cover and storm drainage:

- Decrease the volume of water infiltrated into the soil;
- Decrease groundwater recharge;
- Decrease stream baseflow;
- Increase the volume of direct runoff;
- Decrease the time it takes to convey runoff from streets, sidewalks and parking lots to the nearest stream channel; and
- Increase the energy available to erode the stream channel.

Studies suggest that as little as 10% impervious cover within a watershed can cause significant channel stability problems. We know that urban channels adjust over time, eroding and enlarging in response to increased storm flow volume and velocity.

Riparian and streamside vegetation is routinely impacted by mechanical removal and spraying with herbicides for: preparation of riparian land for maintenance of power line, utility, and road right-of-ways; maintenance of public parks, recreation and open space areas; maintenance or expansion of residential recreation facilities and yard areas.

Filling of floodplains to accommodate new development, channelization and/or construction of flood dikes to protect existing properties in the floodplain, channel straightening to eliminate channel migration and overbank flows can result in a loss of flood storage capacity and channel instability.

Development and its effects on hydrologic and sediment regimes can have an effect on the physical habitat by causing streambed and bank erosion and sedimentation that alter channel characteristics (e.g., dimension, pattern, slope) and microhabitat features (e.g., depth, substrate, cover, and pool/riffle ratios).

Channel instability and sediment is a significant problem for urbanizing watersheds. During the development phase most sediment enters streams from construction sites in upland areas. Post development sources of sediment are primarily from within the channel as streambeds and stream banks are eroded by increased runoff from compacted soils and paved areas. Sedimentation causes substrate embeddedness and aggradation, which reduces the flow conveyance capacity of the channel. Stream bank erosion and flooding can significantly affect water quality by exposing or inundating private sewage disposal systems, public sanitary sewer lines, under ground and above ground fuel storage tanks, and landfills.

Sewage spills that occur when septic systems or sanitary sewer lines are exposed and damaged by channel erosion contribute oxygen consuming organic wastes, nutrients, and pathogens associated with human waste that have serious health consequences for aquatic life and humans.

Runoff from urban land contains a variety of pollutants from trash to toxic compounds. The ubiquitous shopping carts, bicycles, soda cans, and plastic containers somehow manage to find their way into most urban streams. Rain falling on streets, sidewalks and parking lots washes particulate material worn from automobile tires and brake linings, as well as waste oil, antifreeze, and road salts into storm drain inlets for conveyance to the nearest stream. Pesticides, fertilizers, and pet wastes washed from lawns, golf courses, and parkland are also common contributors to the degraded water quality typical of urban streams. During the hot days of summer, runoff from heated paved surfaces can significantly increase stream temperature. The biological availability of many toxic pollutants is enhanced as water temperature rises.

The land along the Quittapahilla Creek and its tributaries is rapidly developing. Development has already impacted reaches along Killinger Creek, Bachman Run, Beck Creek, Snitz Creek, the Unnamed Tributary draining South Lebanon, and Brandywine Creek.

Figure 4.27 – Paved surfaces and storm drainage are components of development such as the Creekside subdivision along Snitz Creek

Figure 4.28 – Multiple bridge and culvert stream crossings are a component of this development in Quentin.

Figure 4.29 – This section of Snitz Creek has no bank or riparian trees and the yards are mowed right to the top of the bank.

Figure 4.30 – This commercial property is encroaching on the floodplain and stream channel of Brandywine Creek

Figure 4.31 – Industrial development along a channelized section of Brandywine Creek

Standard construction and maintenance practices at golf courses include mechanical removal of bank and riparian trees and shrubs, establishing turf with non-native grasses, mowing turf areas to waters edge, and application of pesticides, herbicides and fertilizers.

Figures 4.32 and 4.33 – This section of Beck Creek has been impacted by the maintenance practices at the Royal Oaks Golf Course

Figure 4.34 – The construction practices often include floodplain fill and channel alterations to accommodate the layout of tees, greens and fairways.

Figure 4.35 – Grass clippings + fertilizers + sunlight = nutrient and organic enrichment, algal blooms, low dissolved oxygen levels, poor habitat conditions

4.2.8 – Channel Alterations

Some of the earliest alterations to Quittapahilla Creek and its tributaries occurred when as many as 50 grist mills and saw mills were constructed along the creeks during the 1700's and 1800's. Operating a mill required the construction of a dam on the creek to form a millpond with a dependable supply of water. A race or small stream was dug to divert stream flow to turn the water wheel which operated the millworks. Although the dams have been removed, some of these old mill sites still exist. These mill dams had a significant effect on sediment transport and sediment storage causing the channels and floodplains upstream of each dam to aggrade over time. In addition, they created barriers to fish movement.

Upper Quittapahilla Creek, the Unnamed Tributary draining South Lebanon, and Brandywine Creek have been most severely affected by channel alterations. The Hazel Dike constructed to protect the City of Lebanon from floods like the one that occurred in 1889 converted much of the upper Quittapahilla Creek to concrete flume during the early 1900's.

Figure 4.36 – Construction of the dike through the City of Lebanon (circa 1918)

Figures 4.37 and 4.38 – Construction of the dike through the City of Lebanon (circa 1918)

Figure 4.39 – Construction of the dike through the City of Lebanon (circa 1918)

The flooding that occurred during Hurricane Agnes in 1972 prompted the City of Lebanon to complete additional flood mitigation works. A significant portion of the Upper Quittapahilla Creek is now conveyed through the City in a concrete flume.

Figure 4.40 – View along upper Quittapahilla Creek in Lebanon

Figures 4.41 and 4.42 – Views along upper Quittapahilla Creek in Lebanon

Figure 4.43 – View along upper Quittapahilla Creek in Lebanon

Almost the entire length of the Unnamed Tributary is concrete flume or pipe. In fact, one of the few remaining open channel sections in its headwaters was being piped when the field reconnaissance was conducted. Significant portions of lower Brandywine Creek are concrete flume or pipe, as well.

Figure 4.44 – Unnamed Tributary draining South Lebanon

Figure 4.45 – Unnamed Tributary draining South Lebanon

Stream channel alterations associated with flood mitigation such as those that have been implemented along the Upper Quittapahilla Creek, Unnamed Tributary and Brandywine Creek create channels that are virtually devoid of habitat. These engineered channels are relatively straight, wide, trapezoidal channels, with uniform profiles. They are generally designed to convey all flows (baseflow, bankfull flow, and flood flow). As a consequence, baseflow is usually very shallow or may actually flow beneath the substrate because it is spread out over such a large surface area. The uniform profile replaces the typical riffle-pool sequence with a continuous riffle that provides no cover from predation or strong flushing currents. Vegetation on the banks is replaced with riprap or gabions or concrete revetment to maintain the engineered form, and grade control structures may be installed to maintain bed stability. Because the channel is oversized for bankfull flows as well, its sediment transport capacity is significantly reduced. This results in increased substrate embeddedness and ultimately aggradation, which reduces flow conveyance capacity.

These channel and floodplain "improvements":

- Eliminate access to the floodplain
- Convey passing floodwaters more rapidly to downstream areas
- Increase peak flood stage
- Increase the energy of the flood downstream
- Decrease sediment transport capacity under bankfull flow conditions
- Increase channel instability in downstream areas
- Lower water tables
- Increase loss of riparian wetlands
- Decrease recharge of groundwater aquifers
- Degrade in-stream habitat

Although not as dramatic, varying degrees of channel alterations have occurred along all of the major tributaries in the Quittapahilla Creek Watershed. Removal of stream bank vegetation, stabilization with riprap, and ditching are the most common alterations in the rural areas of the watershed.

Figure 4.46 – Bank stabilization along Beck Creek

Figure 4.47 – Bank stabilization along Bachman Run

Figure 4.48 – Bank stabilization along Snitz Creek

Figure 4.49 – Bank stabilization with cinder blocks along Snitz Creek

Figure 4.50 – A portion of lower Killinger Creek upstream and downstream of Route 422 is a concrete flume

Table 4.2 – Summary of the effects of channel alterations based on length of stream channel altered.

Watershed	Total Stream Length (Miles)	Length of Stream Impacted (Miles)	Percent of Total
Killinger Creek	6.8	1.2	17.5
Buckholder Creek	2.0	0.43	21.0
Gingrich Run	3.8	0.94	25.0
Bachman Run	6.4	2.0	31.0
Beck Creek	6.8	1.3	19.0
Snitz Creek	8.33	1.7	20.0
Brandywine Creek	5.3	3.5	66.0
Unnamed Tributary	4.28	0.0	0.0
Quittapahilla Creek	18.0	3.7	20.5

4.2.9 – Flow Diversions

A number of flow diverting structures were observed along the major tributaries. Generally these diversions were designed to maintain water levels in ponds in the adjacent floodplain. While most were for irrigation water for nurseries or livestock watering, some were purely for aesthetics.

Figures 4.51 and 4.52 – Diversion box (upper photograph) routes water from Snitz Creek to pond (lower photograph) for irrigating nursery stock.

Figures 4.53 and 4.54 – Diversion box (lower photograph) routes water from Beck Creek into pond (upper photograph) for irrigating the Royal Oaks Golf Course.

Figure 4.55 – Livestock watering and irrigation diversion. Note small gravel check dam constructed across the channel (left) to divert flow from Beck Creek into diversion inlet box (right).

Figure 4.56 – Photograph shows flow from Snitz Creek diverted to an ornamental pond. Note small rock and log check dam constructed across the channel to divert flow into diversion inlet box.

Figure 4.57 – Photograph shows diversion of Snitz Creek for an ornamental pond. Note the small cinder block check-dam constructed across the channel to divert flow into diversion inlet box

The volume of water carried by a stream under baseflow conditions directly influences its habitat features, including surface area, depth, velocity, cover, temperature, and concentrations of dissolved oxygen and carbon dioxide. The overall surface area available as habitat fluctuates with discharge. During periods of seasonal low flow and droughts, very little surface area may be available to stream organisms. As discharge increases during periods of higher baseflow, or during storms, side channels and isolated pools become available even in headwater areas. The timing of discharge has a very strong influence on biological activities, including feeding, spawning and migration of fish, the downstream drift of aquatic insects, and the growth and development of most aquatic organisms. Consequently, two streams with similar channel dimensions but different baseflow regimes will have different habitat characteristics.

While the majority of the diversion structures observed appeared to be designed to limit the volume flow of baseflow diverted to a small percentage of the total, a number of the diversions observed included channel manipulation that was diverting a considerable proportion of the baseflow out of the channel and into ponds. Given that Summer 2001 was a drought period, these baseflow diversions significantly impacted the reaches along the ponds. In addition, ponds can significantly raise the temperature of the diverted flow before it is returned to the stream, thereby affecting reaches downstream of the pond as well.

4.2.10 – Fish Barriers

Utilization of the various habitats within a stream varies diurnally and seasonally by species and life stage, and depends on the particular activity in which an organism is engaged. Many species of fish, such as Brown Trout, move from one part of a stream reach to another on a daily basis depending on whether they are feeding, resting, avoiding predation, or unfavorable water quality conditions. During spawning season these same fish may move a considerable distance to reproduce. These movements are critical to the survival of the individual fish as well as the population of fish within a given stream system.

Water depth and channel obstructions can limit upstream and downstream movement and access to important areas, such as spawning grounds. Low baseflow conditions and bedrock ledges are natural features that create impassible barriers to upstream movement of fish. Shallow flow through or significant drops at the downstream end of road culverts and channel obstructions, such as small dams or on-line ponds, can create impassible barriers to fish movement as well.

Although major channel obstructions were few, several small dams and on-line ponds are creating significant barriers to fish migration.

Figure 4.58 – Small dam constructed on Main Stem Lower Snitz Creek to divert flow to an off-line pond

Figure 4.59 – Small dam constructed on Middle Fork of Upper Snitz Creek

4.2.11 – Fish Habitat Structures

Impacts from the various land use activities and channel alterations were anticipated. However, it appears that some of the well-intentioned habitat improvement projects completed in the past also have contributed to channel instability and poor habitat.

Inappropriate selection and placement of habitat structures can lead to channel instability and failure of the structures. Typical channel instability caused by improperly selected/placed habitat structures include: 1) flattening of local channel slope, loss of sediment transport capacity, channel aggradation, lateral adjustments and channel widening; and 2) steeping of local channel slope, increased bed and bank scour, lateral adjustments and channel widening.

The effect of these structures depends on channel morphology (i.e., width/depth ratio, slope, bed material, entrenchment), where the structure is placed relative to its location in the channel plan form and profile, existing channel conditions, sediment supply, and the type of habitat structure. Most standard fish habitat structures were designed to enhance habitat conditions in stable streams. They were not intended to be channel-stabilizing structures. Their successful application requires a thorough understanding of stream dynamics, as well as fish and fish habitat.

Figure 4.60 – Failed fish habitat structure on lower Beck Creek. Note difference in channel width upstream and downstream of the structure.

Figure 4.61 – Poor placement of habitat structures has caused channel instability and failure of these structures in a stream that could provide excellent fish habitat without artificial structures.

5.0 – Ecological Assessment

5.1 – Introduction

Evaluating information and data from historic biological surveys can provide an understanding of how biological communities have changed with land use activities in a watershed. The available biological data was utilized to evaluate historic conditions and determine trends for the biological communities along Quittapahilla Creek and its tributaries.

As part of the current study, surveys were conducted to evaluate the existing habitat conditions and the biological communities in the Quittapahilla Creek watershed. Ten stations were identified along the Quittapahilla Creek and its major tributaries for macroinvertebrate and fish surveys. This component of the study provided information on existing conditions that was utilized in conjunction with water quality monitoring and geomorphic assessment data to identify and prioritize problems along the mainstem Quittapahilla Creek and its major tributaries. The biological surveys also established baseline conditions prior to the implementation of any restoration or management measures.

5.2 – Historic Biological Communities

The data compiled from biological surveys (macroinvertebrate and fish) conducted by various state agencies (e.g. PA Fish Commission, PA DER, etc.) from the mid-1960's through the late 1980's indicates that the historic biological surveys have been relatively limited in scope and often part of specific pollution investigations. For example, earlier benthic macroinvertebrates studies conducted at sampling sites along the mainstem were qualitative in nature. Samples were collected with a hand screen and by examining individual rocks. Although the state periodically conducted fish surveys, they were generally limited to site-specific pollution investigations at a few sites scattered throughout the watershed. Data compiled from other investigations are equally limited in scope. For example, a study conducted by Bethlehem Steel Corporation between 1975 and 1978 was part of the NPDES monitoring program at their Lebanon Plant.

The early studies paint a very bleak picture of Quittapahilla Creek, with high levels of contaminants and limited biological communities dominated by pollution tolerant organisms. A DER report from 1972 states "At no point sampled was found what could be described as a healthy aquatic community" (PA DER, 1972). A Fish Commission report from the same year (PA FC, 1972) states that the origin of the Quittapahilla is at a good quality spring but that "the stream's quality quickly deteriorates under the influence of numerous waste water inputs". This same report also states that "Under present conditions, the stream is little more than an open sewer".

More recent benthic macroinvertebrates studies have been quantitative. However, they have been limited to a few site-specific studies. For example, studies conducted by staff of the U. S. Department of Agriculture included macroinvertebrate sampling to evaluate the effects of the Watershed Association's stream bank fencing projects. As part of this effort Beck Creek, Bachman Run, Snitz Creek and locations along Quittapahilla Creek were sampled in 1999 and 2000. The most recent data available includes the results of macroinvertebrate sampling and habitat assessments conducted in Spring 2001 by Pennsylvania DEP.

These later studies show improving conditions along the mainstem Quittapahilla and in its tributaries. Benthic macroinvertebrate densities and diversity increase, with pollution intolerant taxa appearing. Limited available fish data show a similar trend. The several more intensive investigations along the main stem show similar trends of improving conditions and biological communities in a downstream direction. Exceptions are obvious downstream of the sewage treatment plants.

5.3 – Trout Stocking in the Quittapahilla Creek Watershed

The Pennsylvania Fish & Boat Commission administers a very active trout-stocking program throughout the state. Although Bachman Run and Snitz Creek have been stocked since the early 1960's, earlier trout stocking along the mainstem Quittapahilla Creek conducted by the Pennsylvania Fish Commission was halted in 1967 due to high pollution levels. Recognition of improving conditions led the Pennsylvania Fish & Boat Commission to begin stocking trout along the lower sections of Quittapahilla Creek (Swatara Creek – Clear Springs Road) in 1985. The Commission began stocking along Section 3 (Snitz Creek – Spruce Street) and Section 4 (Spruce Street – Quittie Park) in 1990 and 1992, respectively.

In 2002 the PADEP restricted the number of trout the Commission can produce in its hatcheries under its water quality authority. In spite of these restrictions the program still released as many as 4 million fish in 2003 (M. Schneck, 2003). The Quittapahilla Creek watershed annually receives its share of the stocked trout. The preseason stocking list breakdown for 2003 was: Bachman Run 390 brook, 390 brown and 520 rainbow; Snitz Creek 640 brook, 480 brown and 480 rainbow; Mainstem Quittapahilla Creek 3,200 brown and 3000 rainbow; and Stovers Dam 3,100 rainbow trout.

Preseason stocking occurs in March each year. During the geomorphic and habitat mapping conducted in August 2001, two adult brown trout (approx 15 - 18 inches) were observed resting in a spring channel just off the mainstem Quittapahilla Creek in the vicinity of 22nd Street. Adult brown trout were observed at several other points along the mainstem.

5.4 – Evaluation of Existing In-Stream Habitat

5.4.1 – Rationale

As pointed out previously, one objective of this project is establishing a naturally reproducing trout population through channel restoration and habitat enhancement. In conducting habitat evaluations, it is critical to determine the quality of the existing habitat and the need for improvements relative to a target species.

In the eastern United States, trout stocking efforts usually include Brook Trout (Salvelinus fontinalis), Rainbow Trout (Salmo gairdneri), and/or Brown Trout (Salmo trutta). Although Brook Trout (Salvelinus fontinalis) are native to the eastern United States, they are extremely sensitive to water quality conditions, particularly temperature. Therefore, they are not a good candidate for stocking in the Quittapahilla Creek watershed. Rainbow Trout (Salmo gairdneri) are native to the drainages of the western United States. Although they have been transplanted to many streams in the east, optimum habitat is characterized by cold, clear, rocky streams with slow, deep water, stable stream flow and temperature regimes. Brown Trout (Salmo trutta) are native to Europe but have been introduced in the eastern United States where self-sustaining populations have developed.

As noted, Quittapahilla Creek is stocked annually with brown and rainbow trout. Depending on the degree to which stream conditions improve in the watershed either species may develop reproducing populations. However, given that brown trout are the hardiest of the three trout species (i.e., more tolerant of less than optimum conditions) and that the success of the restoration effort is influenced by factors beyond the control of the Watershed Association it was assumed that brown trout are the species most likely to develop reproducing populations. Existing in-stream habitat along the mainstem Quittapahilla Creek was mapped and evaluated. Habitat value was determined utilizing a list of parameters developed from the Habitat Suitability Index Models and In-stream Suitability Curves: Brown Trout (USFWS, 1986) and the Rapid Bioassessment Protocols for Use in Rivers and Streams (USEPA, 1989).

Because this part of the assessment focused on habitat criteria for a naturally reproducing trout population, habitat parameters relevant to spawning and sustaining embryos, fry, juvenile and adult fish were emphasized in the evaluation process. The habitat parameters included: temperature; dissolved oxygen concentrations; pH; nitrate-nitrogen concentrations; depth of pools and riffles/runs; percent of the total stream area that provides adequate cover for adult trout during the low flow period; an evaluation of channel substrate relative to potential spawning areas, fry and juvenile escape cover and resting areas, macroinvertebrate habitat in riffles/runs, and the % fine sediment (embeddedness) in riffles/runs; percent of stream length that is pools; a rating of the quality (i.e., size, depth, structure) of the pools; dominant stream bank vegetation; percent of the stream bank covered by vegetation; and the percent of the stream area shaded.

Because the habitat evaluation was conducted in Summer 2001, which was a drought year, Quittapahilla Creek was experiencing extreme low flow conditions. As a consequence, the results of the evaluation presented in this report should be considered representative of worst case conditions. The habitat evaluation is documented in the Geomorphic and Habitat Maps and the Field Reconnaissance Maps previously submitted and in the figures and tables accompanying the detailed descriptions of the habitat conditions along each segment of the mainstem Quittapahilla Creek.

5.4.2 – Detailed Descriptions of Mainstem Segments

Segment 1

Segment 1 is 6315 linear feet in length and includes Reaches 1 – 6. The upstream limit is the downstream end of the concrete flume near 19th Street in Lebanon and downstream limit is the confluence with Snitz Creek. Figure 5.1 presents a graph of the temperatures recorded during the monitoring period relative to specific life stage requirements for brown trout and Table 5.1 below summarizes the habitat data for this segment relative to other habitat parameters.

The summer water temperatures measured in this segment during the 2003 water quality monitoring period ranged from 51.4 to 74.5º F. As Figure 5.1 shows, the daily maximum temperatures routinely exceeded the optimum for adult and juvenile Brown Trout. In fact, the maximum temperatures recorded during the period were only slightly lower than the upper tolerance limit (i.e., 80.6º F) for this species. These high temperatures are likely a result of the location of the segment immediately downstream of the concrete flume that conveys Quittapahilla Creek through the City of Lebanon. In fact, it is surprising that the maximum temperatures weren't higher given the percentage of impervious surfaces and extensive storm drainage system in the City.

Figure 5.1 shows that by early November, the time during which brown trout would normally begin spawning, water temperatures had fallen into the range at which spawning could occur. In mid-November a maximum daily water temperature peak was recorded that exceeded the upper tolerance limit for brown trout embryos. However, by late November and early December the maximum temperatures had dropped into the optimum range for embryo development. Because the temperature monitoring did not include the spring months there is no data to evaluate the effects temperature might have on fry that would normally be emerging in March. The recorded data suggest that overall the water temperature conditions along this segment would provide a stressful environment for all life stages of trout.

Interestingly, the measured dissolved oxygen and pH levels were consistently within the optimum range. However, measured nitrate-nitrogen levels were well above the optimum. Other water quality parameters of concern include: conductivity, suspended and dissolved solids, turbidity, total nitrogen, total Kjeldahl nitrogen, total phosphorus, ortho-phosphate, alkalinity, hardness, copper, and lead. The extremely high levels of these constituents are indicative of pollution caused by urban runoff from the City of Lebanon.

Along most reaches in this segment the range and average depths of pools and riffles are optimum. However, pools make up only 18 – 48% of the total bed features. Most of the pools that do exist are small with limited or no structure. With the exception of Reaches 2 and 3, there is a fair amount of in-stream cover (e.g., debris, logs, and boulders) for adult trout under low flow conditions. Although spawning habitat was limited, potential spawning substrate does exist and there is a minimal amount of substrate of adequate size to provide escape or resting cover for fry or juveniles. The riffles and runs included enough coarse substrate material along most reaches to support an abundant macroinvertebrate community. The dominant bed material in riffles and runs is medium gravel and the degree of embeddedness is less than 25% over most reaches.

With the exception of Reach 3, the dominant bank vegetation is mature trees and shrubs. The percentage of the banks covered with vegetation is relatively high (>80%). The segment is heavily shaded (i.e., 50 -75%) along most reaches. Along Reach 3 the dominant bank vegetation is mowed grass with a few scattered trees. The percentage of the banks covered with vegetation is relatively low (i.e., 25-49%) and the reach is not well shaded.

Segment 2

Segment 2 is 10,985 linear feet in length and includes Reaches 7 – 15. The upstream limit is the confluence with Snitz Creek and downstream limit is the confluence with Beck Creek. Figures 5.1 and 5.2 present graphs of the temperatures recorded during the monitoring period relative to specific life stage requirements for brown trout and Table 5.2 below summarizes the habitat data for this segment relative to other habitat parameters.

The summer water temperatures measured in this segment during the 2003 water quality monitoring period ranged from 51.4 to 74.5º F in the upper reaches and 52.3 to 72.5º F in the lower reaches. Figures 5.1 and 5.2 show that the range of daily temperature fluctuations is decreasing in a downstream direction. The daily maximum temperatures recorded in both the upper and lower reaches routinely exceeded the optimum for adult and juvenile Brown Trout. However, temperatures appeared to moderate by August along the lower reaches. These high temperatures are likely a result of several factors including stormwater runoff from the City of Lebanon and Town of Cleona, discharges from the Lebanon WTTP at the downstream end of Segment 1, and the low percentage of shading along most of the reaches in this segment.

Figures 5.1 and 5.2 show that by early November water temperatures had fallen into the range at which spawning could occur. Although lower in temperature, the mid-November water temperature peak observed in Segment 1 was observed in this segment as well. The maximum temperature exceeded the optimum for brown trout embryos, but not the upper tolerance limit as in Segment 1. By late November and early December the maximum temperatures were consistently in the optimum range for embryo development. Because the temperature monitoring did not include the spring months there is no data to evaluate the effects temperature might have on emerging fry. Water temperature conditions have improved along this segment. However, they still have the potential to provide a stressful environment for all life stages of trout.

The measured dissolved oxygen and pH levels were consistently within the optimum range. Measured nitrate-nitrogen levels were still well above the optimum. Other water quality parameters of concern include: conductivity, suspended and dissolved solids, turbidity, total nitrogen, total Kjeldahl nitrogen, total phosphorus, ortho-phosphate, alkalinity, hardness, copper, and lead. The extremely high levels of these constituents are indicative of pollution caused by urban runoff from the City of Lebanon and Town of

Cleona, discharges from the Lebanon WTTP, as well as agricultural runoff contributed by Snitz Creek.

Along most reaches in this segment the range and average depths of pools and riffles are optimum. With the exception of Reach 7, pools make up only 7 – 40% of the total bed features along this segment. Most of the pools that do exist are small with limited or no structure. With the exception of Reaches 7 and 11, there is a minimal amount of in-stream cover (e.g., logs, boulders and overhanging vegetation) for adult trout under low flow conditions. Spawning habitat was limited and potential spawning substrate does not exist. With the exception of Reach 14, there is a minimal amount of substrate of adequate size to provide escape or resting cover for fry or juveniles. The riffles and runs did not include sufficient coarse substrate material along most reaches to support an abundant macroinvertebrate community. The dominant bed material in riffles and runs is small gravel and the degree of embeddedness is 30 – 50% over most reaches.

With the exception of Reaches 7 and 8, the lack of a riparian buffer is a common problem throughout much of the segment. In residential neighborhoods along the right floodplain mowed lawns with scattered trees are the typical vegetation. On agricultural land along the left floodplain row crops with scattered trees are the typical vegetation. The percentage of the banks covered with vegetation is relatively low and these reaches are not well shaded.

<u>Segment 3</u>

Segment 3 is 14,885 linear feet in length and includes Reaches 16 – 25. The upstream limit is the confluence with Beck Creek and downstream limit is the confluence with Bachman Run. Figures 5.2 and 5.3 present graphs of the temperatures recorded during the monitoring period relative to specific life stage requirements for brown trout and Table 5.3 below summarizes the habitat data for this segment relative to other habitat parameters.

The summer water temperatures measured in this segment during the 2003 water quality monitoring period ranged from 52.3 to 72.5º F in the upper reaches and 51.8 to 72.2º F in the lower reaches. Although lower than the maximum temperatures measured in Segments 1 and 2, the maximum temperatures in both the upper and lower reaches still exceed the optimum for adult and juvenile Brown Trout. Temperatures along both the upper and lower reaches appeared to moderate by August. The high temperatures along this segment are likely a result of stormwater runoff from the Towns of Cleona and Annville.

By early November water temperatures had fallen into the range at which spawning could occur. The mid-November maximum water temperature peak observed in Segments 1 and 2 was observed in this segment as well. However, the peak was lower, exceeding the optimum for brown trout embryos, but not the upper tolerance limit as in Segment 1. By late November and early December the maximum temperatures were consistently in the optimum range for embryo development. Because the temperature monitoring did not include the spring months there is no data to evaluate the effects temperature might have on emerging fry. Although, water temperature conditions are continuing to improve along this segment, they still have the potential to provide a stressful environment for all life stages of trout.

The measured dissolved oxygen and pH levels were consistently within the optimum range. Measured nitrate-nitrogen levels were still well above the optimum. Other water quality parameters of concern include: conductivity, suspended and dissolved solids, turbidity, total nitrogen, total Kjeldahl nitrogen, total phosphorus, ortho-phosphate, alkalinity, hardness, copper, and lead. The extremely high levels of these constituents are indicative of pollution caused by urban runoff from the City of Lebanon, the Towns of Cleona and Annville, discharges from the Lebanon WTTP, as well as agricultural runoff contributed by Snitz and Beck Creeks.

Along most reaches in this segment the range and average depths of pools and riffles are optimum. Reaches 17 and 21 have ideal pool/riffle ratios. Pools make up 69% and 63% of each reach, respectively. Unfortunately, pools make up only 18 – 30% of the total bed features along the remainder of the segment. The majority of pools are large and deep with good structure. With the exception of Reaches 24 and 25, there is a fair amount of in-stream cover (e.g., logs, boulders, undercut trees, and overhanging vegetation) for adult trout under low flow conditions. Potential spawning sites exist along Reaches 19 - 23. However, the other reaches are by a high percentage of fine sediments. Reaches 18 – 23 have a high percentage of substrate of adequate size to provide escape or resting cover for fry or juveniles. Reaches 17, 24 and 25 lacked suitable fry/juvenile size material. Only the riffles and runs along Reaches 18 – 23 included enough coarse substrate material along most reaches to support an abundant macroinvertebrate community.

Numerous in-stream habitat structures along were installed along Reach 20 at some time in the past. The design and placement of these habitat structures makes them of questionable value. More recently, in-stream habitat structures were installed along Reach 21 in Quittie Creek Nature Park. Although most of the structures appeared to be functioning as intended, a steep, constructed riffle near the middle of the reach was directing flow into the adjacent right bank causing considerable erosion.

With the exception of Reaches 18, 24 and 25, the dominant bank vegetation is mature trees and shrubs. The percentage of the banks covered with vegetation is relatively high (50-80%). The segment is heavily shaded (i.e., 50 -75%) along most reaches. Along Reaches 18, 24 and 25 the dominant bank vegetation is mowed grass with a few scattered trees. The percentage of the banks covered with vegetation is relatively low (i.e., 25-49%) and the reach is not well shaded.

Segment 4

Segment 4 is 11,375 linear feet in length and includes Reaches 26 – 33. The upstream limit is the confluence with Bachman Run and downstream limit is the confluence with Killinger Creek. Figures 5.3, 5.4 and 5.5 present graphs of the temperatures recorded during the monitoring period relative to specific life stage requirements for brown trout and Table 5.4 below summarizes the habitat data for this segment relative to other habitat parameters.

The summer water temperatures measured in this segment during the 2003 water quality monitoring period ranged from 51.8 to 72.2º F in the upper reaches and 51.5 to 71.2º F in the lower reaches. Although the maximum daily temperatures measured along the main stem have been decreasing in a downstream direction, the maximum temperatures along all reaches still exceed the optimum for adult and juvenile Brown Trout. Temperatures along both the segment appeared to moderate by August. The high temperatures along this segment are likely a result of stormwater runoff from the Towns of Cleona and Annville and the low percentage of shading along many of the reaches in this segment.

By early November water temperatures had fallen into the range at which spawning could occur. The mid-November maximum water temperature peak observed in Segments 1, 2 and 3 was observed in this segment as well. The peak exceeded the optimum for brown trout embryos. By late November and early December the maximum temperatures were consistently in the optimum range for embryo development. Because the temperature monitoring did not include the spring months there is no data to evaluate the effects temperature might have on emerging fry. Water temperature conditions continue to improve in a downstream direction. However, water temperature along this segment still has the potential to provide a stressful environment for all life stages of trout.

Although the measured dissolved oxygen was consistently within the optimum range, the maximum and minimum concentrations were lower than measured along Segments 1 – 3. The measured pH level was consistently within the optimum range. Measured nitrate-nitrogen levels were still well above the optimum. Other water quality parameters of concern include: conductivity, suspended and dissolved solids, turbidity, total nitrogen, total Kjeldahl nitrogen, total phosphorus, ortho-phosphate, alkalinity, hardness, copper, and lead. The extremely high levels of these constituents are indicative of pollution caused by urban runoff from the City of Lebanon, the Towns of Cleona and Annville, discharges from the Lebanon and Annville Wastewater Treatment Plants, as well as agricultural runoff contributed by Snitz Creek, Beck Creek, and Bachman Run.

Along most reaches in this segment the range and average depths of pools and riffles are optimum. Reaches 26, 28, and 33 have ideal pool/riffle ratios. Pools make up 79%, 67% and 73% of each reach, respectively. Pools make up only 35 – 45% of the total bed features along the remainder of the segment. Unfortunately, the majority of pools are moderate size and with minimal structure. With the exception of Reaches 26, 28, and 29 there is a minimal amount of in-stream cover (e.g., logs, undercut trees, and overhanging vegetation) for adult trout under low flow conditions. Potential spawning sites were very limited due to a high percentage of fine sediments along all reaches except Reach 27 and 28. Most reaches lacked substrate of adequate size to provide escape or resting cover for fry or juveniles. Only the riffles and runs along Reach 28 included enough coarse substrate material along most reaches to support an abundant macroinvertebrate community. Along most reaches macroinvertebrates would be limited to colonizing woody debris or submerged aquatic vegetation.

With the exception of Reaches 26, 29 and 30, the lack of a riparian buffer is a common problem throughout much of the segment. On agricultural land along the floodplain pasture or old field with scattered trees is the typical vegetation. The percentage of the banks covered with vegetation is relatively low and these reaches are not well shaded.

Segment 5

Segment 5 is 11,760 linear feet in length and includes Reaches 34 – 40. The upstream limit is the confluence with Killinger Creek and downstream limit is the confluence with the Unnamed Tributary that drains the Steelstown area of North Annville. Figures 5.5 and 5.6 present graphs of the temperatures recorded during the monitoring period relative to specific life stage requirements for brown trout and Table 5.4 below summarizes the habitat data for this segment relative to other habitat parameters.

The summer water temperatures measured in this segment during the 2003 water quality monitoring period ranged from 51.5 to 71.2º F in the upper reaches and 51.4 to 69.0º F in the middle and lower reaches. Although the daily maximum temperatures have dropped more than 5.5º F from Segment 1 to lower Segment 5, the maximum temperatures still exceed the optimum for adult and juvenile Brown Trout. These high temperatures are likely a result of the low percentage of shading along many of the reaches in this segment.

By early November water temperatures had fallen into the range at which spawning could occur. The mid-November maximum water temperature peaks observed in the other segments appears to have all but dissipated by the time it reached the lower reaches of this segment. The daily maximum peak recorded in the upper reaches exceeded the optimum for brown trout embryos, while the peak recorded in the lower reaches was at the upper limit of the optimum. Figures 5.5 and 5.6 show that by late November and early December the maximum temperatures were consistently in the optimum range for embryo development. Because the temperature monitoring did not include the spring months there is no data to evaluate the effects temperature might have on emerging fry. Water temperature conditions have improved along the lower reaches of this segment to the point that stressful conditions would generally be associated with temporary fluctuations that all life stages of trout could weather.

The measured dissolved oxygen and pH levels were consistently within the optimum range. Measured nitrate-nitrogen levels were still well above the optimum. Other water quality parameters of concern include: conductivity, suspended and dissolved solids, turbidity, total nitrogen, total Kjeldahl nitrogen, total phosphorus, ortho-phosphate, alkalinity, hardness, copper, and lead. The extremely high levels of these constituents are indicative of pollution caused by urban runoff from the City of Lebanon, the Towns of Cleona and Annville, discharges from the various wastewater treatment plants along the main stem and tributaries, agricultural runoff contributed by the tributaries, as well as discharges from the Millard Quarry on Killinger Creek.

Along most reaches in this segment the range and average depths of pools and riffles are optimum. Reach 35 has almost all pools. However, pools make up only 18 – 45% of the total bed features along the remainder of the segment. Thee majority of pools are moderate size and with minimal structure. With the exception of Reach 35, there is a minimal amount of in-stream cover (e.g., logs, undercut trees, and overhanging vegetation) for adult trout under low flow conditions. Potential spawning sites were very limited due to a high percentage of fine sediments along all reaches except Reach 38. Most reaches lacked substrate of adequate size to provide escape or resting cover for fry or juveniles. Only the riffles and runs along Reaches 38 included enough coarse substrate material along most reaches to support an abundant macroinvertebrate community. Along most reaches macroinvertebrates would be limited to colonizing woody debris or submerged aquatic vegetation.

In-stream habitat structures were installed along the upper section of Reach 34 at some time in the past. Remnants of the structures suggest that the design and placement of these habitat structures made them of questionable value. In fact, they appear have altered the local channel hydraulics and sediment transport processes causing unstable conditions to develop.

With the exception of Reach 35, the lack of a riparian buffer is a common problem throughout much of the segment. On agricultural land along the floodplain pasture or old field with scattered trees is the typical vegetation. The percentage of the banks covered with vegetation is relatively low and these reaches are not well shaded.

Segment 6

Segment 6 is 14,400 linear feet in length and includes Reaches 41 – 52. The upstream limit is the confluence with the Unnamed Tributary that drains the Steelstown area of North Annville and downstream limit is the confluence with Swatara Creek. Table 5.6 below summarizes the habitat data for this segment relative to measured habitat parameters.

The most downstream station at which water quality monitoring was conducted was Station Q6 at the Palmyra-Bellegrove Bridge along Reach 36, which falls in the middle of Segment 5. As a consequence, there is no data available to evaluate temperature conditions along Segment 6. The temperature data could have been extended downstream along this segment. An argument could be made that contributions of cool water from springs and shaded tributaries may mitigate the increases in temperature associated with a general lack of shade along most of the reaches downstream of Station Q6. However, it was determined that this would not be an appropriate use of the temperature data. It was determined that extending the other water quality data beyond Segment 5 was inappropriate as well. Therefore, the habitat evaluation of Segment 6 was limited to the physical habitat parameters actually measured in the field.

Along most reaches in this segment the range and average depths of pools and riffles are optimum. Reaches 41, 43, and 48 have ideal pool/riffle ratios. Pools make up 52%, 53% and 60% of each reach, respectively. Pools make up only 0 – 42% of the total bed features along the remainder of the segment. The majority of pools along the upper reaches are large and deep with good structure. Most of the pools along the middle and lower reaches are small with minimal structure.

The upper reaches have a fair amount of in-stream cover (e.g., logs, undercut trees, and overhanging vegetation) for adult trout under low flow conditions. With the exception of Reach 48, the middle and lower reaches have very little in-stream cover for adult trout under low flow conditions. Although some potential spawning sites were observed, in general they are limited due to a high percentage of fine sediments along most reaches. Most reaches lacked substrate of adequate size to provide escape or resting cover for fry or juveniles. Only the riffles and runs along Reaches 41, 44, and 45 included enough coarse substrate material along most reaches to support an abundant macroinvertebrate community. Along most reaches macroinvertebrates would be limited to colonizing woody debris or submerged aquatic vegetation.

Reaches 45, 46, and 47 had a high percentage of bank cover (>80%) composed of mature trees and shrubs and were well shaded. However, the lack of a riparian buffer is a common problem throughout much of the segment. On agricultural land along the floodplain row crops with scattered trees are the typical vegetation. The percentage of the banks covered with vegetation is relatively low and these reaches are not well shaded.

5.5 – Existing Biological Communities

5.5.1 - Methodology

An assessment of the existing biological communities was devised as an integral component of the current study. This assessment was designed to provide insights into in-stream conditions at representative locations throughout the Quittapahilla watershed. Initially envisioned as a network of 20 sampling stations throughout the watershed, budgetary limitations pared this desired level of coverage down to 10 stations.

Although reduced in number, the selected sampling stations provide for the assessment of biological stream communities throughout the watershed. Six stations are located on the mainstem Quittapahilla Creek. These stations are labeled from Q1 to Q6 in a downstream direction. The four largest tributaries in the watershed were also sampled near their confluence with the Quittapahilla. These tributaries are Snitz Creek, Beck Creek, Bachman Run, and Killinger Creek, which are listed in order of their confluence with the Quittapahilla, from upstream to downstream. The locations and relationships of the biological assessment sampling stations are shown on Plate 11. Each sampling station consisted of a 300-foot representative reach at each location.

The selected biological communities for assessment were benthic macroinvertebrates and fish. These are the most commonly utilized indicators of in-stream conditions since they are readily sampled and have a wealth of taxonomic and ecological information available. Standardized methods based on the EPA Rapid Bioassessment Protocols for Wadeable Streams and Rivers (Barbour, et al., 1999) were utilized, and are described in each section below. Results for each station are discussed separately and combine macroinvertebrate

Plate 11 – Biological Survey Stations Map

and fish information to provide a comprehensive view of ecological conditions. The summary section discusses these findings in the context of the watershed as a whole.

The biological surveys were delayed due to the abnormally wet weather of 2003, a record year of precipitation in the region. Stream flows were much higher than anticipated, especially in the lower Quittapahilla Creek stations. These conditions are in stark contrast to the conditions of 2001 and 2002 when record drought conditions resulted in much reduced stream flows, with surface flow eliminated in several tributaries. Sampling was delayed as long as possible within the mandated schedule to allow for as much recovery and return to normalcy as possible. Further implications will be discussed under each section below, and in the summary.

5.5.2 – Benthic Macroinvertebrates Communities

Benthic macroinvertebrates are most commonly used to assess stream ecological conditions due to their relative immobility and habitat selection. These organisms are generally collected from the substrate or submerged vegetation or debris, are visible to the naked eye, and include immature stages of insects with terrestrial adults and some adult insects; or worms, molluscs, or crustaceans that are fully aquatic. Their long aquatic life cycles provide long-term indicators of in-stream conditions, and their benthic habitat is subjected to sediment deposition, which often includes attached pollutants.

Benthic macroinvertebrates were collected at each of the ten sampling stations on December 9, 2003. This is a fall collection and may differ from data collected in spring collections due to life cycle stages of various organisms. Although stream flows were higher than normal for fall, it was anticipated that spring samples would be more difficult to obtain. Spring samples are often preferred when one seasonal sample is collected since many immature aquatic insects are most developed prior to spring emergence. However, fall samples do provide an opportunity to collect fall-emerging aquatic insects that are often not collected in spring samples.

Samples were collected using the 20-jab method. A standard D-frame aquatic net was used to collect 20 separate samples from approximately one square foot of habitat throughout the sampling reach. These samples were divided proportionally among the various habitats present within the sampling reach. Riffle samples were collected with the aid of running water as with a kick seine, while pool and vegetation samples were taken with a sweeping or jabbing motion.

All 20 samples were combined into one composite sample for each sampling station. Due to the unpredictable weather patterns of 2003 and a preference for live sorting of macroinvertebrates from entrained debris, samples were deposited live into separate five-gallon buckets for each station. Fine mesh screening was secured over each bucket mouth with duct tape to retain organisms. Low but non-freezing temperatures and entrained submerged aquatic vegetation kept oxygen levels sufficient for organism survival.

Samples were fully picked of visible macroinvertebrates over the next several days. Sub-sampling is often employed in benthic macroinvertebrate studies, but full inventories of in-stream fauna were desired for this assessment. Many samples were extremely heavy with SAV and other debris, which was fully inspected before discarding. Obviously terrestrial organisms were also discarded.

Picked macroinvertebrates were placed into labeled Nalgene jars with 70% ethyl alcohol (ETOH) for preservation. Alcohol preservative was decanted and replaced with fresh ETOH after 24 hours to limit inadequate preservation due to introduced water and internal organism fluids. Macroinvertebrates were sorted and identified using a Bausch & Lomb zoom stereoscopic microscope and fiber-optic lighting. Final sorting of debris was also accomplished and all organisms returned to fresh ETOH in labeled Nalgene jars for long-term storage and retention.

Taxonomic determinations were made to the lowest practical taxonomic level, which for the purposes of this assessment are class for worms, family for molluscs, and genus for insects, excluding Diptera, which were generally identified to family level. While lower taxonomic determinations may provide additional ecological information, greater precision generally requires relatively mature organisms and more intensive specimen preparation and examination. The chosen level of detail provides for sufficient information while remaining within budgetary constraints.

A variety of taxonomic references were utilized in making identifications, with Freshwater Macroinvertebrates of the Northeastern United States (Peckarsky, et al. 1990) the primary reference. Additional references utilized include Thorp and Covich (1991), Merritt and Cummins (1996), Wiggins (1990), and Stewart and Stark (1993).

The general results of the benthic macroinvertebrate sampling are provided in Table 5.7. This is a concise single-page table showing general results at higher taxonomic levels of family and above. An expanded summary table is provided as Table 5.8, which shows greater taxonomic detail, where applicable. Generic breakdowns of family level numbers are provided for most insect and crustacean families, as well as breakdowns between larvae and adults of aquatic beetles (Coleoptera). As explained above, further taxonomic detail was not practical.

An ecological information table is also provided for the benthic macroinvertebrate taxa collected. Table 5.9 provides information on the tolerance value and functional feeding groups of each taxon, with relevant notes. Tolerance value pertains to the tolerance of a particular taxon to pollution, with higher numbers signifying greater tolerance on a scale of 1-10. Functional feeding groups refer to the method of obtaining food. This information was derived from the RBP Manual tables using the nearest geographic region. Additional information was derived from Merritt and Cummins (1996).

As noted in the note section of this table, many of the higher taxonomic groups have a wide variety of tolerance values and functional feeding groups associated with included taxa. This is especially true of the Chironomidae (midges) which are largely moderately tolerant and feed as gathering collectors, but include genera and species that exhibit a very broad range of characteristics.

A series of metrics were calculated for each sampling station using the benthic macroinvertebrate community data, and are presented in Table 5.10. These metrics are simple measures that can allow for comparison between sites and provide insight into community structure. EPT measures refer to members of the insect orders **E**phemeroptera, **P**lecoptera, and **T**richoptera, which are generally intolerant of pollution and indicative of good habitat and water quality. The biotic index is a weighted average of tolerance values for each station, corresponding to the range of tolerance values (0-10).

The tolerance value is a measure of the tolerance of each taxon to pollution with higher values signifying a greater tolerance to pollution. Therefore, a lower biotic index is indicative of a higher quality macroinvertebrate community comprised of a higher proportion of pollution intolerant organisms.

More detailed statistical analyses are possible using this data, but generally require much more rigorous sampling and taxonomic scrutiny for such approaches to be reliable. Care must also be utilized when interpreting data due to the limited taxonomic detail of many groups with great diversity (i.e. midges). All metrics presented in Table 5.10 are based on family level and higher taxonomic classifications to maintain consistency.

Another cautionary note pertains to the limestone creek nature of the Quittapahilla Creek watershed. Most of the standard measures and ranges for stream assessments are based on typical freestone streams, and natural systems that differ significantly (i.e. limestone creeks, coastal plain streams) may appear to be marginal when in fact they are functioning near their natural potential. A literature and internet search did not find any suitable indexes for analyzing limestone creek data. Establishment of a regional reference for limestone creeks would be necessary to further define the conditions of the Quittapahilla and its tributaries.

Scientific Name	Common Name	Q1	Q2	Q3	Q4	Q5	Q6	Snitz	Beck	Bach	Kill
Turbellaria	Flatworms								48		
Nematoda	Roundworms	5				1	1	1			
Oligochaeta	Segmented Worms	5	1	2	7	6	14	4	20	18	2
Hirudinia	Leeches					3	1		4		
Corbiculidae	Asiatic Clams		1	12	6	6		13	43		
Physidae	Physid Snails					1			2	6	
Hydrocarina	Water Mites								15	19	
Ostracoda	Seed Shrimps								72	4	
Amphipoda	Scuds	23	12	120	467	128	211	13	75	129	64
Isopoda	Sowbugs	23	3	3	7	5	5	9	274	53	1
Decapoda	Crayfish	1	2	1	5	4	2	2	4	2	1
Dytiscidae	Diving Beetles								1		
Elmidae	Riffle Beetles	5	2		22	3	17	4	10	13	4
Chironomidae	Midges	40	9	13	37	29	51	30	57	78	12
Empididae	Dance Flies					1		1			1
Simuliidae	Black Flies	14	28	6	134	28	25	38	32	1	
Tabanidae	Biting Flies	1					1		1		
Tipulidae	Crane Flies	1		4	4		14	4	1	1	6
Baetidae	Minnow Mayflies							2			
Ephemerellidae	Spiny Mayflies						2		1	3	
Heptageniidae	Flatheaded Mayflies							1			
Tricorythidae	Trico Mayflies							1	3	2	
Glossosomatidae	Saddlecase Caddisflies					1	9				2
Hydropsychidae	Netspinning Caddisflies	8	8	1	116	2	29	4	5	2	1
Limnephelidae	Casemaking Caddisflies					1					
Leptoceridae	Longhorned Caddisflies								3	1	
Psychomiidae	Nettube Caddisflies			1							
Capniidae	Winter Stoneflies						1				3
Taeniopterygidae	Broadback Stoneflies						3	1	1		1
Total Taxa		**11**	**9**	**10**	**10**	**15**	**16**	**16**	**21**	**15**	**12**
Total Organisms		**126**	**66**	**163**	**805**	**219**	**386**	**128**	**672**	**332**	**99**

Table 5.7 – Fall 2003 Macroinvertebrate Survey Results Summary

Scientific Name	Common Name	Q1	Q2	Q3	Q4	Q5	Q6	Snitz	Beck	Bach	Kill
Turbellaria	**Flatworms**								**48**		
Nematoda	**Roundworms**	**5**				**1**	**1**	**1**			
Oligochaeta	**Segmented Worms**	**5**	**1**	**2**	**7**	**6**	**14**	**4**	**20**	**18**	**2**
Hirudinia	**Leeches**					**3**	**1**		**4**		
Corbiculidae	**Asiatic Clams**		**1**	**12**	**6**	**6**		**13**	**43**		
Corbicula fluminea			1	12	6	6		13	43		
Physidae	**Physid Snails**					**1**			**2**	**6**	
Hydrocarina	**Water Mites**								**15**	**19**	
Ostracoda	Seed Shrimps								**72**	**4**	
Amphipoda	**Scuds**	**23**	**12**	**120**	**467**	**128**	**211**	**13**	**75**	**129**	**64**
Gammarus sp.		23	12	120	467	128	211	13	75	129	64
Isopoda	**Sowbugs**	**23**	**3**	**3**	**7**	**5**	**5**	**9**	**274**	**53**	**1**
Caecidotea sp.		23	3	3	7	5	5	9	274	53	1
Decapoda	**Crayfish**	**1**	**2**	**1**	**5**	**4**	**2**	**2**	**4**	**2**	**1**
Dytiscidae	**Diving Beetles**								**1**		
Agabus sp.									1		
Elmidae	**Riffle Beetles**	**5**	**2**		**22**	**3**	**17**	**4**	**10**	**13**	**4**
Dubiraphia sp. (A/L)								1/0			
Optioservus sp. (A/L)		0/1				0/3	1/9		2/6	3/10	0/4
Stenelmis sp. (A/L)		4/0	1/1		21/1		7/0	2/1	1/1		
Chironomidae	**Midges**	**40**	**9**	**13**	**37**	**29**	**51**	**30**	**57**	**78**	**12**
Empididae	**Dance Flies**					**1**		**1**			**1**
Simuliidae	**Black Flies**	**14**	**28**	**6**	**134**	**28**	**25**	**38**	**32**	**1**	
Tabanidae	**Biting Flies**	**1**					**1**		**1**		
Tipulidae	**Crane Flies**	**1**		**4**	**4**		**14**	**4**	**1**	**1**	**6**
Antocha sp.				4	4		13	4		1	3
Tipula sp.		1					1		1		3
Baetidae	**Minnow Mayflies**							**2**			
Acerpenna sp.								2			
Ephemerellidae	**Spiny Mayflies**						**2**		**1**	**3**	
Ephemerella sp.							2		1	3	
Heptageniidae	**Flatheaded Mayflies**							**1**			
Stenonema sp.								1			

Table 5.8 – Fall 2003 Macroinvertebrate Survey Results Expanded Summary

Scientific Name	Common Name	Q1	Q2	Q3	Q4	Q5	Q6	Snitz	Beck	Bach	Kill
Tricorythidae	**Trico Mayflies**							**1**	**3**	**2**	
Tricorythodes sp.								1	3	2	
Glossosomatidae	**Saddlecase Caddisflies**					**1**	**9**				**2**
Glossosoma sp.						1	9				2
Hydropsychidae	**Netspinning Caddisflies**	**8**	**8**	**1**	**116**	**2**	**29**	**4**	**5**	**2**	**1**
Cheumatopsyche sp.		6	8	1	18		7	1	4	1	1
Hydropsyche sp.		2			98	2	22	3	1	1	
Limnephelidae	**Casemaker Caddisflies**					**1**					
Hydatophylax sp.						1					
Leptoceridae	**Longhorn Caddisflies**								**3**	**1**	
Triaenodes sp.									3	1	
Psychomiidae	**Nettube Caddisflies**			**1**							
Lype sp.				1							
Capniidae	**Winter Stoneflies**						**1**				**3**
Allocapnia sp.							1				3
Taeniopterygidae	**Broadback Stoneflies**						**3**	**1**	**1**		**1**
Taeniopteryx sp.							3	1	1		1
Total Taxa		**13**	**9**	**10**	**11**	**15**	**18**	**18**	**23**	**16**	**12**
Total Organisms		**126**	**66**	**163**	**805**	**219**	**386**	**128**	**672**	**332**	**99**

Table 5.8 – Fall 2003 Macroinvertebrate Survey Results Expanded Summary (Cont'd)

Scientific Name	Common Name	Tolerance Value	Functional Feeding Group	Notes
Turbellaria	Flatworms	4	Predator	Diverse FFGs
Nematoda	Roundworms	5	Parasite	
Oligochaeta	Segmented Worms	10	Gathering Collector	
Hirudinia	Leeches	6	Predator	
Corbiculidae	Asiatic Clams	8	Filtering Collector	Exotic
Physidae	Physid Snails	8	Scraper	
Hydrocarina	Water Mites	8	Predator	Parasitic as larvae
Ostracoda	Seed Shrimps	6	Gathering Collector	Large macro type (>2mm)
Amphipoda	Scuds	8	Shredders	
Isopoda	Sowbugs	6	Gathering Collectors	
Decapoda	Crayfish	5	Shredders	Diverse FFGs
Dytiscidae	Diving Beetles	6	Predators	
Elmidae	Riffle Beetles	6	Scrapers	
Chironomidae	Midges	6	Gathering Collectors	Diverse FFGs and TVs
Empididae	Dance Flies	6	Predators	
Simuliidae	Black Flies	7	Filtering Collectors	
Tabanidae	Biting Flies	8	Predators	
Tipulidae	Crane Flies	4	Gathering Collectors	Diverse FFGs
Baetidae	Minnow Mayflies	4	Gathering Collectors	
Ephemerellidae	Spiny Mayflies	2	Gathering Collectors	
Heptageniidae	Flatheaded Mayflies	4	Scrapers	
Tricorythidae	Trico Mayflies	4	Gathering Collectors	
Glossosomatidae	Saddlecase Caddisflies	0	Scrapers	
Hydropsychidae	Netspinning Caddisflies	6	Filtering Collectors	
Limnephelidae	Casemaking Caddisflies	2	Shredders	
Leptoceridae	Longhorned Caddisflies	6	Shredders	
Psychomiidae	Nettube Caddisflies	2	Scrapers	
Capniidae	Winter Stoneflies	3	Shredders	
Taeniopterygidae	Broadback Stoneflies	2	Shredders	

Table 5.9 – Macroinvertebrate Ecological Information

Analytical Metric	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Snitz**	**Beck**	**Bach**	**Kill**
Total Organisms	126	66	163	805	219	386	128	672	332	99
Total Taxa	11	9	10	10	15	16	16	21	15	12
Percent Dominant Taxon	31.7	42.4	73.6	58.0	58.4	54.7	29.7	40.8	38.9	64.6
EPT Taxa	1	1	2	1	3	5	5	5	4	4
Percent EPT Individuals	6.3	12.1	1.2	14.4	1.8	11.4	7.0	1.9	2.4	7.1
Percent Collectors	90.5	93.9	98.8	96.6	93.2	90.9	92.2	86.8	87.7	87.8
Percent Shredders	0.8	3.0	0.6	0.6	2.3	1.6	2.3	1.2	0.9	5.1
Percent Scrapers	4.0	3.0	0.6	2.7	2.3	6.7	3.9	1.8	5.7	6.1
Percent Predators	4.8	0	0	0	2.3	0.8	1.6	10.3	5.7	1.0
Biotic Index	6.59	6.57	6.04	6.21	6.32	5.98	6.40	7.11	6.66	5.67

Table 5.10 – Fall 2003 Macroinvertebrate Survey Analyses

5.5.3 – Fish Communities

Fish are also commonly utilized for assessing the condition of stream ecosystems. Much information is available on the ecology, life histories, and physiology of most eastern fishes. General information is also available on the pollution tolerances of various fishes. Fish are often considered to be less reliable indicators of in-stream conditions since they are capable of rapid movement into and out of disturbed habitats. However, certain benthic fishes may be relatively less mobile than other fishes, and may be indicative of long-term benthic conditions.

Fish were collected in the summer of 2004 during two single day collecting trips and a two-day overnight collecting trip scheduled around weather. Snitz Creek and Beck Creek sampling was conducted on July 6, and Bachman Run and Quittapahilla Creek Station Q1 sampling was conducted on July 14. The remaining stations were sampled on longer consecutive field days, with Quittapahilla Creek Stations Q2, Q3, and Q4 sampled on July 29, and Quittapahilla Creek stations Q5, Q6, and Killinger Creek sampled on July 30. Two significant rainstorms occurred between the between the single-day and two-day sampling events.

Fish are generally not as seasonal in presence and distribution as benthic macroinvertebrates, although spring and fall spawning migrations do occur in certain species, and distributions may be affected by high or low stream flows. Sampling was initially scheduled for 2003, but was postponed due to continuing frequent rainfall and high stream flows.

Sampling was conducted using a Smith-Root Model VII backpack electrofisher and a three-man crew consisting of the senior electrofisher operator and two netters. The electrofisher also participated in netting with a small handnet. Electrofishing proceeded in an upstream direction from the lower end of the sampling reach, with stunned fish netted and placed into buckets. Fish were periodically transferred to larger holding tanks on shore.

All fish were collected when possible, although there were occasional escapes. Block nets were not used at any station since they were entirely impractical to employ at the larger mainstem stations due to heavy flows. Although multiple passes can improve thoroughness, single passes were conducted at each station to remain within budgetary constraints, and generally produced a wide range of fishes.

All fish were identified, tallied, and released alive into the sampled reach. Observable mortality was extremely minimal and was limited to several minnows. Voucher specimens were not retained. Fish were identified by observable characteristics, with utilization of Fishes of Pennsylvania (Cooper, 1980) and other guides when necessary. Other identification references consulted include Rhode, et al. (1990), Jenkins and Burkhead (2000), and Page and Burr (1991).

Most fish species collected were familiar regional species, and no abnormal colors and/or forms were encountered that would make identification problematic. The most significant taxonomic issue relates to sculpins (family Cottidae). The genus *Cottus* is the source of much past taxonomic confusion and current uncertainties (well explained in Jenkins and Burkhead, 1999).

Field examination of large numbers of sculpins in the Quittapahilla watershed compared most favorably with characters for the slimy sculpin (*Cottus cognatus*) although not all sculpins were examined in great detail in the field or microscopically. Further intensive study could reveal additional species, although the Slimy Sculpin is generally found alone (Jenkins and Burkhead, 1999). An earlier report noted the mottled sculpin (*Cottus bairdi*) as present in Quittapahilla Creek, but this may be due to earlier confusion over the status of various *Cottus* species.

Sampling was delayed as much as possible in 2004 to allow for flow recession to make sampling easier, safer, and more thorough. However, continued steady rains kept stream flows higher than normal. Tributaries were sampled with relatively no problems, but the middle (Q3, Q4) and especially lower (Q5, Q6) mainstem sampling stations were limited by high flows and discolored water.

These lower stations are near the limit for effective backpack electrofishing even during low flow conditions, which did not materialize in 2003 or 2004. Many of these reaches exhibit steep banks with deep pool and run type habitats. Electrofishing in these stations was largely confined to very limited shallower riffle areas and along streambanks. Therefore, data collected from these stations must be considered to be incomplete, but still provides useful data. Tributary data and data from the upper Quittapahilla Creek stations (Q1, Q2) should be considered fully valid.

Fish data from the sampling events are presented in Table 5.11 with tallies provided for species and total fish collected at each station. Table 5.12 presents general ecological information for each species collected, with tolerance value and trophic level information presented from two sources. The RBP Manual (Barbour, et al., 1999) data is from the fish information tables, with the nearest geographical area information provided. Also listed are the data from An Index of Biological Integrity for Northern Mid-Atlantic Slope Drainages (Daniels, et al. 2002), formulated for the larger watershed containing Quittapahilla Creek.

Other relevant notes are also provided in Table 5.12. Fish species stocked by the Pennsylvania Fish & Boat Commission are identified, as well as exotic and naturalized species. Most of the sunfishes (family Centrarchidae) found in eastern Pennsylvania are native west of the Appalachian Mountains and have either expanded their range via natural dispersal aided by anthropogenic activities, or were intentionally stocked and became established as naturally maintained populations. Benthic species are also noted since they share general habitat and sediment and contaminant exposure factors with benthic macroinvertebrates.

The aforementioned IBI (Index of Biological Integrity) for Northern Mid-Atlantic Slope Drainages (Daniels, et al. 2002) was developed for a relatively large area including the Susquehanna watershed, which includes Quittapahilla Creek. Application of the IBI requires the calculation of various metrics and determination of ranks, with a final IBI score resulting. Higher IBI scores reflect higher biological integrity, which is a manifestation of habitat and water quality (Karr, et al. 1986).

Table 5.13 presents the results of the IBI analysis of the fish data collected during this assessment. These results will be discussed in greater detail for each station and in the summary, but care must be utilized in comparing results due to the sampling difficulties discussed above.

5.5.4 – Station by Station Summary of Existing Biological Communities

Station Q1

Station Q1 is located downstream of the concrete flume section of Quittapahilla Creek immediately upstream from 22nd Street. The lower section of this reach where the samples were collected is relatively stable but receives a proportionally higher level of impervious surface runoff than the other main stem stations. The middle and upper sections of this reach, closer to the flume outfall, are very unstable. The adjacent stream banks and floodplain are forested.

The benthic macroinvertebrate community is not very diverse and is populated with generally pollution tolerant organisms. A total of 126 organisms from at least 11 taxa were collected. Generally pollution tolerant midge larvae (Chironomidae) were the dominant organism, comprising nearly 32 % of the sample, followed by two types of moderately sized crustaceans, scuds (Amphipoda, genus *Gammarus*) and sowbugs (Isopoda, genus *Caecidotea*). EPT taxa were limited to relatively small numbers of moderately tolerant Hydropsychidae caddisflies.

Collectors, both filtering and gathering, are by far the dominant functional feeding group at 90.5 % of the sampled organisms, suggesting high levels of fine particulate organic matter (FPOM). This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present. The biotic index is moderately high at 6.59, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant midges, scuds, and sowbugs contribute to this high score.

The fish community surprisingly produced the highest number of species of all Quittapahilla Creek stations. Ten species were collected, distributed among 157 total fish. The pollution tolerant blacknose dace (*Rhincthys atratulus*) was the most numerous fish with 44 individuals, with a nearly equal number (37) of small green sunfish (*Lepomis cyanellus*) also collected. Sunfish were the dominant group at this location, with 12 small bluegills (*Lepomis macrochirus*) and 4 small and moderate-sized pumpkinseeds (*Lepomis gibbosus*) also collected. One stocked rainbow trout (*Onchorhynchus mykiss*) was collected at this station.

Scientific Name	Common Name	Q1	Q2	Q3	Q4	Q5	Q6	Snitz	Beck	Bach	Kill
Onchorhynchus mykiss	Rainbow Trout	1								1	
Salmo trutta	Brown Trout		1	1				3		4	1
Cyprinus carpio	Carp							1			
Notropis hudsonius	Spottail Shiner		2								
Margariscus margarita	Pearl Dace	2	6		3			1		3	
Rhinichthys atratulus	Blacknose Dace	44	6		29	2	12	75	49	116	5
Rhinicthys cataractae	Longnose Dace		1				3	2			
Semotilus atromaculatus	Creek Chub	9	1	2	1		25	3			1
Catostomus commersoni	White Sucker	23	10	1	18	14	11	14	22	6	4
Noturus insignis	Margined Madtom								2		
Fundulus diaphanus	Banded Killifish							1	5		
Ambloplites rupestris	Rock Bass										1
Lepomis cyanellus	Green Sunfish	39	2					1	8		
Lepomis gibbosus	Pumpkinseed	4		2	1	1					
Lepomis macrochirus	Bluegill	12				2					5
Micropterus dolomieu	Smallmouth Bass						1				
Micropterus salmoides	Largemouth Bass				1		2	1			
Etheostoma olmstedi	Tessellated Darter	1			1	5	13	1	2	4	
Cottus cognatus	Slimy Sculpin	22	24	213	462	10	124	3	207	55	32
Total Species		**10**	**9**	**5**	**8**	**6**	**8**	**12**	**7**	**7**	**7**
Total Fish		**157**	**53**	**219**	**516**	**34**	**191**	**106**	**295**	**189**	**49**

Table 5.11 – 2004 Fish Survey Results Summary

Scientific Name	Common Name	Tolerance Value (1)	Tolerance Value (2)	Trophic Level (1)	Trophic Level (2)	General Notes
Onchorhynchus mykiss	Rainbow Trout	Moderate	Intolerant	Piscivore	Piscivore	Stocked
Salmo trutta	Brown Trout	Moderate	Intolerant	Piscivore	Piscivore	Stocked
Cyprinus carpio	Carp	Tolerant	Tolerant	Omnivore	Generalist	Exotic
Notropis hudsonius	Spottail Shiner	Moderate	Moderate	Insectivore	Insectivore	
Margariscus margarita	Pearl Dace	Moderate	Moderate	Insectivore	Insectivore	
Rhinichthys atratulus	Blacknose Dace	Tolerant	Tolerant	Generalist	Generalist	
Rhinicthys cataractae	Longnose Dace	Intolerant	Moderate	Insectivore	Insectivore	Benthic
Semotilus atromaculatus	Creek Chub	Tolerant	Tolerant	Generalist	Generalist	
Catostomus commersoni	White Sucker	Tolerant	Tolerant	Omnivore	Generalist	Benthic
Noturus insignis	Margined Madtom	Moderate	Moderate	Insectivore	Insectivore	Benthic
Fundulus diaphanus	Banded Killifish	Tolerant	Tolerant	Insectivore	Insectivore	
Ambloplites rupestris	Rock Bass	Moderate	Moderate	Piscivore	Piscivore	Naturalized
Lepomis cyanellus	Green Sunfish	Tolerant	Tolerant	Insectivore	Generalist	Naturalized
Lepomis gibbosus	Pumpkinseed	Moderate	Moderate	Insectivore	Generalist	Naturalized
Lepomis macrochirus	Bluegill	Moderate	Tolerant	Insectivore	Generalist	Naturalized
Micropterus dolomieu	Smallmouth Bass	Moderate	Moderate	Piscivore	Piscivore	Naturalized
Micropterus salmoides	Largemouth Bass	Moderate	Moderate	Piscivore	Piscivore	Naturalized
Etheostoma olmstedi	Tessellated Darter	Moderate	Moderate	Insectivore	Insectivore	Benthic
Cottus cognatus	Slimy Sculpin	Moderate	Intolerant	Insectivore	Insectivore	Benthic

Table 5.12 – Fish Ecological Information

Reference 1 EPA Rapid Bioassessment Protocols (Barbour, et al., 1999)
Reference 2 An Index of Biological Integrity for Northern Mid-Atlantic Slope Drainages (Daniels, et al., 2002)

Metric	Metric Description	Q1	Q2	Q3	Q4	Q5	Q6	Snit z	Beck	Bach	Kill
1*	***Total number of fish species****	9 (5)	8 (3)	4 (3)	7 (3)	6 (3)	8 (3)	10 (5)	7 (5)	5 (3)	6 (3)
2*	Number of benthic-insectivorous species	2 (3)	2 (3)	1 (1)	2 (3)	2 (3)	3 (5)	3 (5)	3 (5)	2 (3)	1 (1)
3*	Number of water column species	3 (3)	1 (1)	1 (1)	1 (1)	1 (1)	0 (1)	2 (3)	2 (3)	0 (1)	1 (1)
4*	Number of terete minnow species	2 (3)	3 (3)	1 (1)	2 (3)	0 (1)	1 (1)	2 (3)	0 (1)	1 (1)	1 (1)
5	Percentage of dominant species	28 (5)	45.2 (3)	97.2 (1)	89.5 (1)	41.1 (3)	64.9 (1)	70.7 (1)	70.1 (1)	61.3 (1)	65.3 (1)
6	Percentage of individuals that are white suckers	14.6 (3)	18.8 (1)	0.4 (5)	3.4 (3)	41.1 (1)	0.05 (5)	13.2 (3)	7.4 (3)	3.1 (3)	8.1 (3)
7	Percentage of individuals that are generalists	84.7 (1)	47.1 (1)	2.2 (5)	10.0 (5)	55.8 (1)	25.1 (3)	89.6 (1)	26.7 (3)	66.1 (1)	30.6 (3)
8	Percentage of individuals that are insectivores	14.6 (1)	50.9 (5)	97.2 (5)	89.7 (5)	44.1 (3)	73.2 (5)	6.6 (1)	73.2 (5)	31.2 (3)	65.3 (5)
9	Percentage of individuals that are top carnivores	0.6 (1)	1.8 (3)	0.4 (1)	0 (1)	0 (1)	0 (1)	3.7 (3)	0 (1)	2.6 (3)	2.0 (3)
10*	Fish per sample (fish/100 sq. meters)	18.7 (3)	6.3 (3)	19.6 (3)	46.3 (3)	2.4 (1)	13.7 (3)	31.0 (3)	88.0 (3)	56.0 (3)	14.6 (3)
11	Percentage of species with two age classes	20.0 (3)	22.2 (3)	20.0 (3)	37.5 (3)	16.6 (3)	50.0 (5)	25.0 (3)	42.8 (5)	42.8 (5)	28.5 (3)
12	Percentage of individuals with disease or anomalies	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
IBI Score		**37**	**32**	**34**	**37**	**27**	**38**	**36**	**40**	**32**	**32**

Table 5.13 – 2004 Fish Survey Index of Biotic Integrity (IBI)

* Values are based on maximum species richness line (MSRL) and maximum density line (MDL) graphs in Daniels, et al., 2002.
** Stocked species (trout) and species present only as young of year are not included.

This station exhibited the greatest evenness among species for all stations, with the dominant species accounting for 28 % of the total number of fish. The wide variety of fish species in terms of habitat, trophic level, and tolerance values suggests a balanced community, and the presence of multiple age classes suggests varied habitat conditions and relatively constant flows. This station produced an IBI score of 31. With extremely limited habitat available upstream due to the concrete flume, this area may function as a congregational area for fish attempting to migrate upstream. There may also be relatively high numbers of prey organisms available as export from the concrete channel.

Station Q2

Station Q2 is located on Quittapahilla Creek near Cleona Park, downstream of the confluence of Snitz Creek. The sampling reach is located immediately downstream of the Garfield Street bridge. Strong sewage-type odors were noticeable during both sampling events, possibly related to sewer line leakage or the discharge from the Lebanon Wastewater Treatment Plant which is located 0.75 miles upstream of the sampling site. However, trout were observed rising to surface prey in the pool upstream of the bridge and a fisherman conveyed his success in this reach.

The benthic macroinvertebrate community appeared to be depressed, with the lowest number of organisms of any station, at 66 organisms in at least 9 taxa. Pollution tolerant blackfly (Simuliidae) larvae were the dominant taxon at 42.4%, followed by the relatively tolerant scuds and midge larvae. EPT taxa were limited to the moderately tolerant hydropsychid caddisfly *Cheumatopsyche*.

Collectors are by far the dominant functional feeding group at 93.9 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present, and no predators were collected. The biotic index is moderately high at 6.57, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant blackflies, scuds, and midges contribute to this high score.

The fish community also appears to be depressed at this location, with only 53 fish of nine species collected. Slimy sculpins were the most dominant species at 45.2 % of all fish. White suckers (*Catostomus commersoni*) were the next most common species collected, with 10 fish of varying size classes.

In addition to trout observed outside of the sampling reach, one stocked brown trout (*Salmo trutta*) was collected in this reach. This station produced the only spottail shiners (*Notropis hudsonius*) collected during this assessment, although this water column schooling species likely exists in the lower mainstem stations but were not collected due to water depth and clarity limitations. One longnose dace (*Rhinicthys catarctae*) was also collected, which is generally considered to be intolerant of pollution and limited to low temperature streams. This station produced an IBI score of 29.

Station Q3

Station Q3 is located on Quittapahilla Creek in Quittie Creek Nature Park below the confluence of Beck Creek. The sampling reach is located immediately downstream of the old dam spillway. Septic odors were present during the fish sampling similar in intensity to station Q2, but were not noted during the benthic macroinvertebrate sampling. The old concrete dam spillway appears to be an impassable fish blockage during most flow conditions.

This station produced 163 benthic macroinvertebrates from at least 10 taxa. As is found in all middle and lower mainstem stations, the dominant taxon by far is the scud *Gammarus*, which accounts for 73.6% of all organisms collected. Scuds are typically dominant in most limestone creeks in the region. The next most numerous organisms were midge larvae and the exotic invasive Asiatic clam (*Corbicula fluminea*). This invasive hard-shell clam is often deleterious to native bivalve molluscs, none of which were found at any sampling location, and is very tolerant of most types of pollution.

Collectors are the strongly dominant functional feeding group at 98.8 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present, and no predators were collected. The biotic index is moderately high at 6.04, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant scuds, midges, and Asiatic clams contribute to the high score.

The fish community was less dense and diverse than expected, with the fewest species produced of any station at five. Although 219 fish were collected, 213 of these (97.2 %) were the dominant slimy sculpin. Only one or two individuals of the other species present were collected, with one stocked brown trout. More trout would be expected in this reach due to stocking patterns and excellent pool habitat. However, angling pressure is likely high in this public park reach, and high turbid flows with excellent root and debris cover certainly impeded collection efficiency. This station produced an IBI score of 29.

Station Q4

Station Q4 is located on Quittapahilla Creek below the confluence of Bachman Run and just below Brandt's Mill and immediately upstream of the Route 422 Bridge. This sampling reach was generally more shallow than station Q3, with less available cover for large game fish. A side small side channel associated with the mill was included in this survey. Extensive beds of SAV exist throughout the lower part of this reach, comprised primarily of elodea (*Elodea* sp.).

This station produced very dense numbers of benthic macroinvertebrates, with 805 organisms of at least 10 taxa. Scuds accounted for over half of the collected organisms, producing 58% of the total. The dense SAV beds provide ideal habitat for scuds, and also for sowbugs, which were surprisingly scarce (7 individuals). Other dominant taxa were blackflies (134 individuals) and hydropsychid caddisflies (116 individuals).

Collectors are the strongly dominant functional feeding group at 96.6 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present, and no predators were collected. The biotic index is moderately high at 6.21, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant scuds, blackflies, and hydropsychid caddisflies contribute to the high score.

The fish community collected at this station is also very dense and heavily dominated by one species. 516 total fish were collected of 8 species, but 462 of these (89.5%) were slimy sculpins. The next most numerous species were blacknose dace (29 individuals) and white suckers (18 individuals). No trout were collected at this location. A single immature largemouth bass (*Micropterus salmoides*) was collected from the SAV beds. This station produced an IBI score of 31.

Station Q5

Station Q5 is located on Quittapahilla Creek immediately downstream from the Syner Road Bridge, but above the confluence of Killinger Creek and the primary discharge from the Millard Quarry operation. This station is located 1.5 miles downstream of the Annville Wastewater Treatment Plant, and sewage odors were again noticeable. Channel gradient is much less than upstream mainstem stations. In addition to sampling constraints due to water depth and turbidity, sampling was affected by deep unconsolidated soft sediments throughout much of the reach.

The benthic macroinvertebrate community was comparatively diverse with several intolerant organisms present in small numbers. 219 organisms of 15 taxa were collected. Scuds were again dominant, accounting for 58.4 % of the organisms collected. Relatively tolerant fly larvae were then next most dominant taxa with similar numbers of midges (29) and blackflies (28).

Interesting intolerant taxa present in low numbers include the mayfly *Tricorythodes* (Tricorythidae), and the caddisflies *Glossosoma* (Glossosomatidae) and *Hydatophylax* (Limnephellidae). Tricorythid mayflies are usually the most common limestone creek mayfly with a moderate tolerance value of 4, while the listed caddisflies have tolerance values of 0 and 2, respectively.

Collectors are the strongly dominant functional feeding group at 93.2 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present. The biotic index is moderately high at 6.32, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant scuds, midges, and blackflies contribute to the high score.

The fish community was relatively depressed, with the lowest number of collected fish of any station. Only 34 fish of 6 species were collected in this reach. Very deep pools with significant woody debris combined with the high and turbid stream flows to certainly have a negative effect on collection efficiency. White suckers were the dominant species collected, with 14 individuals of varying sizes. One large white sucker (16”-18”) escaped after leaping between netters and disappearing into dense woody cover.

Slimy sculpins were the next most numerous fish, with 10 individuals collected, but this is much lower than adjacent stations. The apparent scarcity of fish did not appear to be entirely related to collecting constraints. Relatively easy to sample vegetated flats upstream of the Syner Road bridge were spot sampled after completion of the survey with relatively few sculpins and limited other species found. This station produced the lowest IBI score of all stations at 21, partially due to the low fish density.

Station Q6

Station Q6 is located on Quittapahilla Creek below the confluence of Killinger Creek. The sampling reach was initially located immediately upstream of the Palmyra-Bellegrove Road Bridge for the benthic macroinvertebrate sampling. At the time of the fish sampling, however, nearly all of this reach was unwadeable due to high flows, limited visibility, and steep banks with immediate drop-offs. Upon discovering these conditions the sampling reach was split with limited riffle and streambank sampling through the original reach, and more intensive collection in a shallower side channel and vegetated streamside areas immediately below the bridge.

The benthic macroinvertebrate community was relatively dense and diverse, with 386 organisms collected of at least 18 taxa. Scuds are again the dominant taxon, comprising 54.7 % of the sample, followed by midge larvae (51 individuals). The next most numerous organisms are hydropsychid caddisflies (29) and blackflies (25).

Surprising low numbers of intolerant organisms continue a trend first seen at the upstream station Q5. This station produced the highest number of EPT taxa (5 families, 6 genera) along with Snitz Creek. Tricorythid mayflies are again present, along with greater numbers of the very intolerant caddisfly *Glossosoma*. Perhaps most significantly, the only mainstem collections of the generally intolerant stoneflies were made at this station, albeit in very small numbers. One small recently molted *Allocapnia* (Capniidae) was collected along with three *Taeniopteryx* (Taeniopterygidae) stonefly nymphs.

Collectors are the strongly dominant functional feeding group at 90.9 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present. The biotic index is moderately high at 5.98, suggesting fair water quality conditions, but this is the second lowest biotic index score for all stations.

The fish community was relatively diverse and dense, although sampling was significantly limited by high and turbid stream flows. The sampling reach was split between the selected sampling reach and a more accessible downstream reach as explained earlier. A total of 191 fish were collected from 8 species present. Slimy sculpins were the dominant species collected, comprising 64.9 % of the sample. Creek chubs (*Semotilus atromaculatus*) were the next most numerous species collected.

Notable species included longnose dace, three of which were collected from the upper riffle in the sampling reach. Two juvenile Largemouth Bass and a juvenile smallmouth bass (*Micropterus dolomieu*) were collected among vegetation below the bridge. Larger predatory and other fishes are certainly present throughout this reach but were not able to be sampled. This station produced an IBI score of 33.

<u>Snitz Creek</u>

The Snitz Creek sampling station is located on the lower reach of the stream prior to its confluence with Quittapahilla Creek. This sampling location is located next to the Lebanon Wastewater Treatment Plant, but does not receive effluent. The sampling reach was located immediately below the Dairy Road box culvert.

The benthic macroinvertebrate community was moderately dense and comparatively diverse. A total of 128 organisms of at least 18 taxa were collected. The dominant taxon were blackflies, which exhibited the lowest relative taxon dominance of all stations at 29.7 %. Midge larvae were also relatively dominant (30 individuals), with the next most numerous taxa scuds and Asiatic clams (13 individuals each).

Although EPT taxa were limited in numbers, a wide variety were present. EPT taxa include the mayfly genera *Acerpenna* (Baetidae), *Stenonema* (Heptageniidae), and *Tricorythodes*, the stonefly *Taeniopteryx*, and the hydropsychid caddisflies *Cheumatopsyche* and *Hydropsyche*. This station produced the highest number of EPT taxa (5 families, 6 genera), along with Quittapahilla Creek station Q6.

Collectors are the strongly dominant functional feeding group at 92.2 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present, and no predators were collected. The biotic index is moderately high at 6.40, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant scuds and midges contribute to the high score.

The fish community of Snitz Creek produced the widest variety of fishes of any sampling station. A total of 106 fish of 12 species were collected in this reach. Blacknose dace were the dominant species collected, comprising 70.7 % of the sample. White suckers were then next most numerous species, with 14 suckers of varying age classes collected. Three stocked brown trout were collected, with at least one escape.

One small carp (*Cyprinus carpio*) was also collected, with an immature largemouth bass, suggesting migration into Snitz Creek from mainstem fishes. The banded killifish (*Fundulus diaphanus*) was also collected at this station, and was only collected again during this study in the adjacent Beck Creek. This species is usually found throughout Coastal Plain low-gradient streams and bays, but is also found in disjunct populations in spring creeks. The high dissolved mineral content of limestone creeks may provide a physiological benefit similar to low salinity coastal waters (Jenkins and Burkhead, 1999). The wide variety of taxa and ecological preferences suggest a well-balanced fish community. This station produced an IBI score of 31.

Beck Creek

The Beck Creek sampling station is located near the lower reaches of Beck Creek prior to its confluence with Quittapahilla Creek. The sampling reach is located immediately downstream of the Bricker Lane culvert. The sampling reach flows through an open meadow with little woody plant growth. Stream edges appear to be recovering from past livestock abuse, and are stabilizing with dense reed canary grass (*Phalaris arundinacea*) and entrapped sediments. SAV is also prevalent throughout the channel and is primarily comprised of thick beds of elodea (*Elodea* sp.).

The benthic macroinvertebrate community is very dense and is the most diverse among all stations. A total of 672 organisms from at least 21 taxa were collected. In contrast with all other stations, the dominant taxon is the aquatic sowbug *Caecidotea*, which comprised 40.8 % of the sample. Scuds were a distant second in numbers, with 75 scuds compared to 274 sowbugs.

An unusually large ostracod (order Ostracoda) was collected in large numbers in this reach. These are micro-crustaceans known as seed shrimp that are normally not visible to the naked eye; however, these were 2-3 mm in length and are a mottled greenish-blue in color. This organism was only found elsewhere in the watershed in limited numbers (4 individuals) in the adjacent Bachman Run. Midge larvae, flatworms (Turbellaria), and Asiatic clams were the next most numerous taxa, with 57, 48 and 43 individuals, respectively. It should be noted that flatworms were not collected at any other station.

Although not numerous, a variety of EPT taxa were collected. The mayflies *Ephemerella* and *Tricorythodes* were collected along with the stonefly *Taeniopteryx*. The two common hydropsychid caddisfly genera were collected along with *Triaenodes* (Leptoceridae), which was additionally collected only in the adjacent Bachman Run.

Collectors are the dominant functional feeding group at 86.8 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present, but a comparatively high proportion of predators (10.3 %) can be attributed to the classification of flatworms as predators. The collected flatworms may or may not be predaceous, and predatory forms are often scavengers. The biotic index is the highest of all stations at 7.11, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant sowbugs and other taxa contribute to the high score.

The fish community was very dense for such a small stream, but was not very diverse. A total of 295 fish of seven species were collected. The fish community was strongly dominated by slimy sculpins, which comprised 70.1 % of the sample. Blacknose dace were the next most numerous species, followed by white suckers, with 49 and 22 individuals, respectively.

Species of interest include the banded killifish discussed in the previous station description, and the only watershed collection of the margined madtom (*Noturus insignis*). Madtoms are small catfish that function as benthic insectivores, a role similar to the dominant sculpins, which may limit madtom distribution in the watershed. The narrowing of the channel due to vegetative growth has also exposed rock substrate in the center of the channel, providing ideal madtom habitat (also known as “stonecats”). Although not collected during the survey, a carp of approximately 14 inches was observed being caught by a young angler below the Bricker Lane culvert. This station produced the highest IBI score of all stations at 35.

<u>Bachman Run</u>

The Bachman Run sampling station is located on the lower reaches of Bachman Run. The sampling reach is located immediately upstream of the Reigerts Lane culvert. The stream in this reach is intermittently shaded with scattered trees, but is generally open. A secondary culvert exists approximately 150 feet upstream of the main roadway culvert that supports only a footpath. SAV is common, primarily *Elodea*, and areas of flooded reed canary grass are present along the stream edges.

The benthic macroinvertebrate community is dense and relatively diverse. A total of 332 organisms of at least 15 taxa were collected at this station. Scuds are again the dominant taxon, comprising 38.9 % of the sample, which is less skewed than many other samples. Midges are the next most numerous taxon, with 78 individuals, followed by sowbugs with 53 individuals.

Although present throughout the watershed, sowbugs are most numerous in Bachman Run and the adjacent Beck Creek. The EPT taxa are also nearly identical between these two streams, with only the stonefly *Taeniopteryx* missing from Bachman Run (only one found in Beck Run). Bachman Run and Beck Creek are the only stations to produce the leptocerid caddisfly *Triaenodes* and the large ostracod discussed above. Water mites (Hydrocarina) were also collected only in Bachman Run and Beck Creek.

Collectors are the dominant functional feeding group at 87.7 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment. Other functional feeding groups are minimally present. The biotic index is moderately high at 6.66, suggesting fair water quality conditions. The dominance of the relatively pollution tolerant scuds, midges, and sowbugs contribute to the high score.

The fish community is moderately dense with moderate diversity, with a total of 189 fish collected of seven species. Blacknose dace were the dominant fish species, comprising 61.3 % of the sample. Slimy sculpins were the next most numerous species, with 55 individuals collected.

This station produced the most trout of all stations, with four brown trout and one rainbow trout collected, all apparently stocked fish. Several other trout escaped near the upper end of the sampling reach. Three trout were collected in a short run upstream of the secondary bridge among heavy streamside reed canary grass growth. This station produced an IBI score of 27, partially due to low numbers of water column and terete minnow species (only one of each). However, the high numbers of trout (all in excellent condition) may contribute to the lower numbers of small fishes.

Killinger Creek

The Killinger Creek sampling station is located on Killinger Creek just upstream from its confluence with Quittapahilla Creek. The sampling reach is heavily wooded, and in-stream vegetation is non-existent. This station is located below the Millard Quarry and accepts large quantities of sediment-laden wash effluent. Turbidity was very high during sampling events, and the substrate is noticeably covered with bluish-gray fine sediment.

The benthic macroinvertebrate community is relatively depressed, but is surprisingly diverse with intolerant organisms present. A total of 99 organisms of at least 12 taxa were collected. Scuds are the dominant taxon, comprising 64.6 % of the sample. Midge larvae are the next most numerous taxon, with 12 individuals collected, and all other taxa were present in single digits.

EPT taxa are low in numbers, but are moderately diverse. No mayflies were collected, but both *Allocapnia* and *Taeniopteryx* stoneflies were collected in low numbers. Two caddisfly taxa were collected, with the intolerant *Glossosoma* present with the moderately tolerant *Cheumatopsyche*.

Collectors are the dominant functional feeding group at 87.8 % of the sampled organisms, suggesting high levels of FPOM. This may be due to increased levels of primary production, suggesting nutrient enrichment, which may be entrained with sediment particles. Other functional feeding groups are minimally present. The biotic index is the lowest of all stations at 5.67.

The fish community is moderately diverse but appears to be depressed in density. A total of 49 fish were collected from 7 species present. The dominant fish is the slimy sculpin, comprising 65.3 % of the sample. Other fishes were collected in single digits. A single stocked brown trout was collected from a small pool in this reach.

A moderately sized rock bass (*Ambloplites rupestris*) was collected from the deepest pool in the sampling reach. This pool was framed by large boulders and possessed a coarse substrate, providing the ideal habitat for this species. Such habitat is limited throughout the watershed, but it is likely that scattered clusters of rock bass occur in similar habitats in the mainstem or in other tributaries.

The ability of the sculpins to dominate in this high sediment load stream is impressive, especially given their benthic nature. This station produced an IBI score of 27. The presence of the rock bass and stocked trout may also have a negative effect on small fish numbers as with Bachman Run. Anecdotal evidence from local fishermen suggests relatively high numbers of larger fish are found in Killinger Creek compared to other Quittapahilla tributaries.

5.5.5 – Ecological Assessment Summary

The benthic macroinvertebrate and fish sampling programs were designed to provide general "snapshots" of biological conditions at representative locations throughout the Quittapahilla Creek watershed. Budgetary restraints limited the desired 20 stations to 10 stations and also limited the level of sampling intensity at each station and the level of detail possible in the lab. Limited available past studies were not standardized and differ in scope and location.

Therefore, declarative statements and rigorous statistical analyses in regard to temporal and geographic trends cannot be made. However, the information collected does provide insights into current conditions throughout the watershed and may provide a baseline for future studies.

Quittapahilla Creek appears to be in relatively good condition biologically given its past history and heavily impacted watershed. Past studies that have been reviewed depict severely impacted conditions throughout much of the main stem and in several tributaries. Has previously noted, Bachman Run and Snitz Creek have been stocked since the early 1960's. However, earlier trout stocking along the main stem Quittapahilla Creek conducted by the Pennsylvania Fish Commission was halted in 1967 due to high pollution levels. Recognition of improving conditions led the Pennsylvania Fish & Boat Commission to begin stocking trout along the lower sections of Quittapahilla Creek (Swatara Creek – Clear Springs Road) in 1985. The Commission began stocking along Section 3 (Snitz Creek – Spruce Street) and Section 4 (Spruce Street – Quittie Park) in 1990 and 1992, respectively.

Most of the previous studies reviewed for the Quittapahilla watershed were conducted by the Pennsylvania Department of Environmental Resources. These reports range from 1972 to 1987. More recent reports may exist but were not reviewed. Other reports reviewed were authored by the Pennsylvania Fish Commission or private consultants for industries, primarily for the former Bethlehem Steel plant in Lebanon.

The early studies paint a very bleak picture of Quittapahilla Creek, with high levels of contaminants and limited biological communities dominated by pollution tolerant organisms. These early investigations were conducted prior to the enactment and enforcement of the Clean Water Act and subsequent regulations. Later studies show improving conditions along the main stem Quittapahilla and in its tributaries. Benthic macroinvertebrate densities and diversity increase, with pollution intolerant taxa appearing. Limited available fish data show a similar trend. The several more intensive investigations along the main stem show similar trends of improving conditions and biological communities in a downstream direction. Exceptions are obvious downstream of the sewage treatment plants.

A DER report from 1978 (DER, 1978) states “Downstream from the Lebanon sewage treatment plant the Quittapahilla follows a definite trend of decreasing organic impact.” This report also states that “The entire stream could be characterized a recovery zone.” This trend is supported by DER data reviewed for their water quality monitoring network station WQN-238. This station was located upstream of the confluence with Swatara Creek. Data for this station from 1972 to 1987 has been reviewed.

In addition to all of the macroinvertebrate taxa found at upstream sampling locations, a number of generally intolerant taxa have been collected at station WQN-238. These additional taxa include snails (Lymnaeidae), true flies (Stratiomyidae and Rhagionidae), aquatic beetles (Psephenidae), fishflies and alderflies (Megaloptera, families Corydalidae and Sialidae), caddisflies (Hydroptilidae), mayflies (Heptageniidae and Oligoneuriidae), and stoneflies (Perlidae and Perlodidae).

The DER 1972 also included fish data for the main stem Quittapahilla, which were less diverse at similarly situated stations than those collected for this assessment. Species collected in 1972 were all tolerant fishes that were also collected in 2004, in varying assemblages. The only additional species collected in the vicinity of a current sampling station, was the cutlips minnow (*Exoglossum maxilingua*), which was collected near station Q6. A sampling site near the current station Q2 (just below the Lebanon WWTP) yielded no fish. Common shiner (*Luxilus cornutus*) was reported collected at a sampling site upstream from the current station Q1, but was not collected at lower stations in 1972, nor at any station in 2004.

A 1972 fish sampling station was located near the confluence of Quittapahilla Creek and Swatara Creek, well below current station Q6. Beyond the more common Quittapahilla Creek fishes and those additional species discussed above, five additional species were recorded. These fishes are the fallfish (*Semotilus corporalis*), bluntnose minnow (*Pimephales notatus*), swallowtail shiner (*Notropis procne*), yellow bullhead (*Ameiurus natalis*), and johnny darter (*Etheostoma nigrum*). The johnny darter record most likely refers to the tessellated darter (*Etheostoma olmstedi*) found throughout the watershed. The johnny darter is restricted to the western portion of Pennsylvania and the two species are very similar and were until recently synonomized (Cooper, 1980).

The current general downstream trend in Quittapahilla Creek appears to be one of recovery from urban impacts. These impacts include the general urban impacts of imperviousness and stream channel manipulation in addition to documented and undocumented point discharges. Notable exceptions to the general trends are stations Q2 and Q5, which are the first stations downstream from municipal sewage treatment plants, and have generally lower numbers and taxa.

Numbers of benthic macroinvertebrates and taxa generally increase in a downstream direction, with more sensitive taxa appearing only in the lowest reaches. Fish data does not show a readily discernable trend, but this is somewhat attributable to sampling limitation in the lower mainstem reaches.

The tributaries all appear to be in better overall condition than the receiving Quittapahilla Creek. Urban impacts and point discharges are much reduced in the tributary watersheds, but agricultural impacts increase. Notable exceptions include the several industrial plants on Snitz Creek and the quarry on lower Killinger Creek.

Snitz Creek stands out for producing the highest diversity of fishes of any site, along with the highest diversity of mayfly taxa. Beck Creek and Bachman Run are very similar in biological community structure. Similarities include large numbers of sowbugs and nearly identical EPT taxa, and these are the only stations to produce large ostracods, water mites, and the leptocerid caddisfly *Triaenodes*. They do possess distinctions, however, with the sowbugs and copepods much more numerous in Beck Creek versus Bachman Run, and an apparently warmer water fish fauna in Beck Creek. Killinger Creek stands out as the most inhospitable on first glance with the heavy sediment load and deposition, but actually exhibits the lowest biotic index score and produced a wide variety of intolerant organisms.

Section 6 – Water Quality Assessment

6.1 – Introduction

Evaluating information and data from historic water quality monitoring can provide an understanding of how water quality conditions have changed with land use activities in a watershed. The available water quality data was utilized to evaluate historic conditions and determine trends along Quittapahilla Creek and its tributaries.

The current study included water quality monitoring of storm flow events at ten sites along Quittapahilla Creek and its tributaries. The monitoring conducted by the consulting Team included installation of staff gauges at each site, installation of continuous-reading digital thermographs at each site; flow measurements and rating curve development for each site; sample collection and analysis for five storm events at each site. The storm water samples were analyzed for: temperature, pH, dissolved oxygen, specific conductance, total acidity, total alkalinity, biochemical oxygen demand, nitrate, orthophosphate phosphorus, total phosphorus, total dissolved solids, total Kjeldahl nitrogen, total nitrogen, total suspended solids, turbidity, hardness, copper, lead, zinc, and fecal coliform.

Funded under a separate grant, bedload and suspended sediment load samples were collected at one station on the lower main stem Quittapahilla Creek and two tributary stations. The data was collected across a range of stream flow conditions and was used to develop a sediment rating curve for determining sediment transport and sediment yield characteristics for the system. The detailed results of the sediment discharge evaluation are presented in a separate report (Skelly & Loy, Inc. and Clear Creeks Consulting, 2005) and summarized in this section of the report.

The additional monitoring effort allowed a baseline to be established for water quality conditions, comparison of baseflow and storm flow conditions, computation of pollutant loadings of key parameters, calibration of the water quality model to actual water quality conditions in the watershed, and establishment of a long-term monitoring program for tracking improvements in water quality as restoration and management measures are implemented.

6.2 – Historic Water Quality Conditions

The water quality data compiled and reviewed indicates that the historic water quality monitoring has been relatively limited in scope and often part of specific pollution investigations. The available data was utilized, to the extent practical, to evaluate historic conditions and determine trends for the water quality along Quittapahilla Creek and its tributaries. However, it appears that the information is either too dated and/or limited in scope to provide the characterization of existing conditions needed for this current assessment.

These early investigations were conducted prior to the enactment and enforcement of the Clean Water Act and subsequent regulations. In addition to typical urban area inputs, industrial point discharges were certainly at peak levels. Later reports focus more on the Bethlehem Steel plant and discharges from the Lebanon and Annville sewage treatment plants. An industrial plant site in North Cornwall on upper Snitz Creek also has been investigated for detrimental discharges.

Later studies show improving conditions along the mainstem Quittapahilla and in its tributaries. Benthic macroinvertebrate densities and diversity increase, with pollution intolerant taxa appearing. Limited available fish data show a similar trend. The several more intensive investigations along the mainstem show similar trends of improving conditions and biological communities in a downstream direction. Exceptions are obvious downstream of the sewage treatment plants.

A DER report from 1978 (DER, 1978) states “Downstream from the Lebanon sewage treatment plant the Quittapahilla follows a definite trend of decreasing organic impact.” This report also states that “The entire stream could be characterized a recovery zone.” This trend is supported by DER data reviewed for their water quality monitoring network station WQN-238. This station was located upstream of the confluence with Swatara Creek. Data for this station from 1972 to 1987 has been reviewed.

More recently, the Biology Department of Lebanon Valley College has been conducting water quality monitoring under baseflow conditions at a number of locations along Quittapahilla Creek and its tributaries.

The Biology Department’s water quality monitoring was conducted in 1999, 2000, and 2001 at one site on Snitz Creek (Dairy Road); four sites on Beck Creek (Bricker Lane, Royal Road, Reist Road, and Oak St); five sites on Bachman (two sites along Rte. 241 near headwaters, Fontana Rd., Bucher Lane, and Reigerts Lane), and one site on the Quittapahilla Creek (Glen Road). The parameters monitored included temperature, pH, turbidity, nitrate-nitrogen, orthophosphate, and alkalinity. This water quality data has been compiled for review and evaluation

6.3 – Total Maximum Daily Loads (TMDL) Study

Studies conducted by PADEP in the 1980’s and 1990’s indicated that the aquatic resources in the Quittapahilla Creek Watershed are impaired. The mainstem, as well as all of the major tributaries to Quittapahilla Creek are listed as impaired in the 303(d) listings. The 2000 305(b) Report prepared by PADEP indicates that there are 88.9 miles of stream in the Quittapahilla Creek Watershed. Only 1.82 miles of stream (2%) were found to support designated aquatic life uses.

The recently released Total Maximum Daily Loads (TMDLs) Report (PADEP, 2000) cites excessive sediment and nutrient levels as a major water quality problem in the Quittapahilla Creek Watershed. The report indicates that these pollutants are causing increased algae growth, large accumulations of fine sediments on the streambed, and degradation of in-stream habitat.

6.4 – Water Quality Modeling and Analysis

6.4.1 – General Overview Rationale and Methodology

An assessment of various pollutant loads generated within sub-areas of the Quittapahilla Creek watershed was completed using a GIS-based watershed modeling tool developed by Evans et al. (2006) at Penn State's Environmental Resources Research Institute. This tool (called AVGWLF) facilitates the use of the GWLF watershed model via a GIS software (ArcView) interface, and is currently being used by the Pennsylvania DEP to help support its ongoing TMDL projects within Pennsylvania. As explained later, this modeling application was further refined for use in this particular project.

The core watershed simulation model for this application is the GWLF (Generalized Watershed Loading Function) model developed by Haith and Shoemaker (1987). The GWLF model provides the ability to simulate runoff, sediment, and nutrient (N and P) loadings from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values.

GWLF is considered to be a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios, but each area is assumed to be homogenous in regard to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but simply aggregates the loads from each area into a watershed total; in other words there is no spatial routing. For sub-surface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated sub-surface zone, where infiltration is simply computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

With respect to the major processes simulated, GWLF models surface runoff using the SCS-CN approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the USLE algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are then applied to the calculated erosion to determine sediment yield for each source area. Within AVGWLF, streambank erosion is calculated using a "stream power" approach similar to that described by Dietrich et al. (1999) and Prosser et al. (2001). Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges can also contribute to dissolved losses and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Sub-surface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the sub-surface sub-model only considers a single, lumped-parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values.

For execution, the model requires three separate input files containing transport-, nutrient-, and weather-related data. The transport (TRANSPRT.DAT) file defines the necessary parameters for each source area to be considered (e.g., area size, curve number, etc.) as well as global parameters (e.g., initial storage, sediment delivery ratio, etc.) that apply to all source areas. The nutrient (NUTRIENT.DAT) file specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations, etc.). The weather (WEATHER.DAT) file contains daily average temperature and total precipitation values for each year simulated.

In utilizing the AVGWLF interface, the user is prompted to identify required GIS files and to provide other information related to "non-spatial" model parameters (e.g., beginning and end of the growing season; and the months during which manure is spread on agricultural land). This information is subsequently used to automatically derive values for required model input parameters which are then written to the TRANSPORT.DAT and NUTRIENT.DAT input files needed to execute the GWLF model. Also accessed through the interface is a statewide weather database that contains twenty-five years of temperature and precipitation data for seventy-eight weather stations around Pennsylvania. This database is used to create the necessary WEATHER.DAT input file for a given watershed simulation.

6.4.2 – Refinements to Modeling Approach

As stated above, AVGWLF is currently being used by DEP to support its TMDL assessments as mandated by the USEPA. This approach was refined, however, to allow for more detailed analysis of pollutant loads in the Quittapahilla Creek watershed. Specifically, more detailed data sets were used and a limited amount of calibration work was undertaken to more accurately reflect local landscape conditions. Additionally, information on the presence of existing agricultural best management practices (BMPs) and stream protection activities were accounted for in estimating loads in each sub-area.

6.4.3 – Substitution of More Detailed Data

With respect to enhanced GIS data sets, more detailed GIS data layers for soils, land use/cover, and topography were used for this project than are typically used with AVGWLF for statewide TMDL assessments. For example, Figure 6.1 shows the more detailed "SURGO" soils data set used in the Quittapahilla Creek watershed in comparison to the more generalized "STATSGO" soils data typically used with AVGWLF.

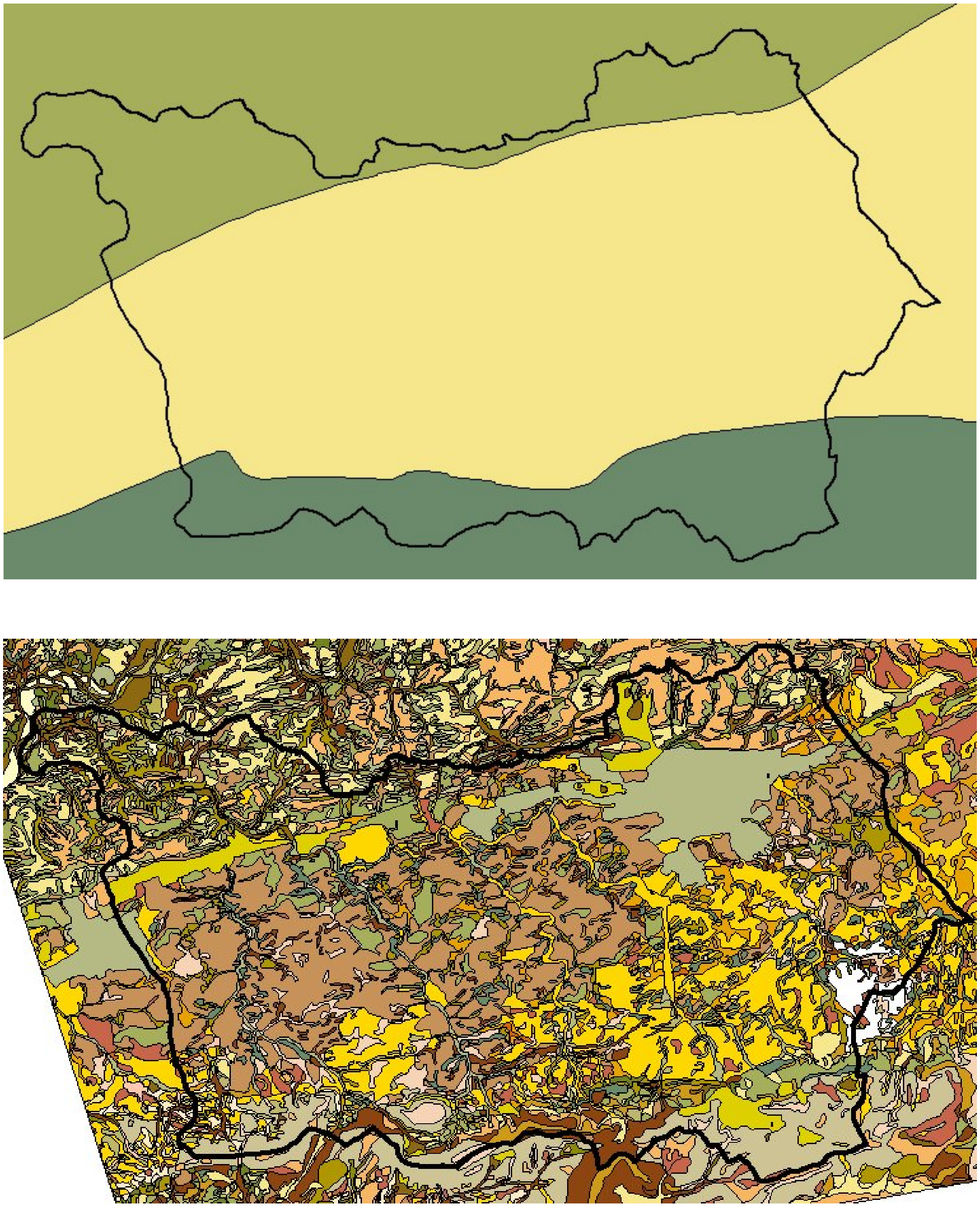

Figure 6.1 – Comparison of generalized STATSGO (upper) versus detailed SURGO (lower) soils data.

Similarly, digital elevation data with a spatial resolution of 30 meters was used instead of the 100-meter data normally used. Finally, the digital land use/cover data set normally used was updated utilizing recently available digital ortho-photos to better represent current land use/cover conditions in the area.

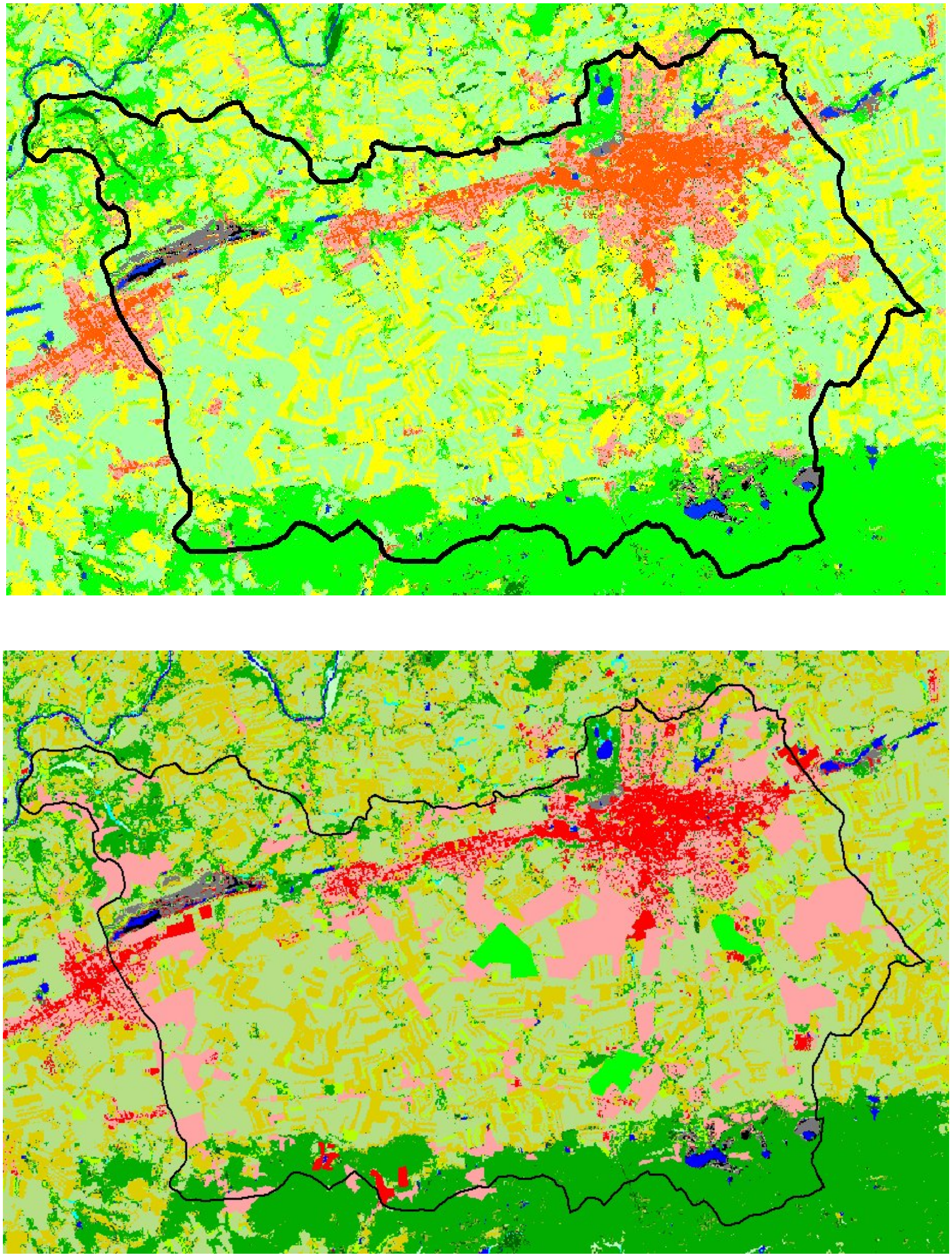

Figure 6.2 – Comparison of old (upper) and updated (lower) land use/cover data .

Additionally, instead of using information on farm animal density compiled at the zip code boundary level as typically used in AVGWLF when run for most other statewide applications, estimates of animal density in this case were actually based on more local information. Specifically, available digital ortho-photos for the area were used to identify the locations of dairy farms in each sub-watershed and to estimate typical herd sizes.

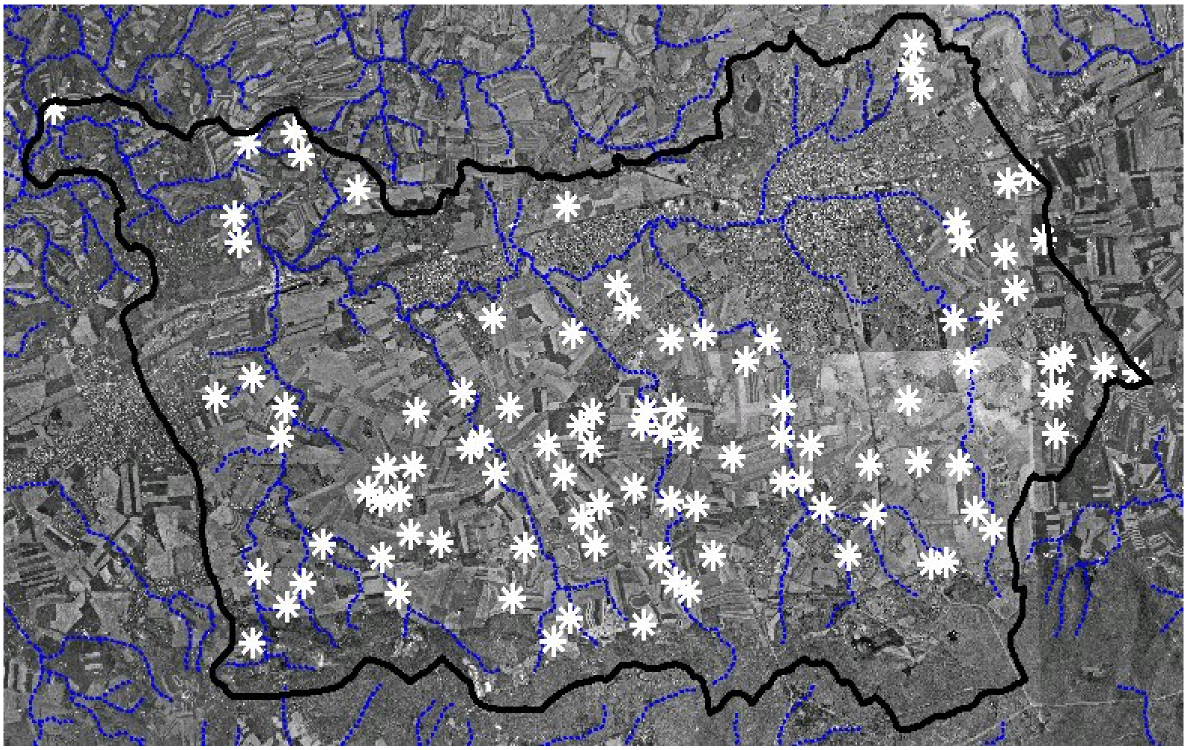

Figure 6.3 – Digital ortho-photos with dairy farms (in white) superimposed on them.

6.4.4 – Model Calibration

Over the last half-dozen years, a very limited number of stream samples have been collected by various project participants on nitrogen, phosphorus and sediment concentrations at or near the mouth of the Quittapahilla Creek watershed. Flow data were also available for a gaging station maintained by the U.S. Geological Survey near the mouth of the watershed up until September of 1994. For the purposes of this study, this information was used to derive nitrogen, phosphorus and sediment loads for the watershed during the period 3/90 to 9/94. The AVGWLF model was run to generate simulated loads for the same time period and adjustments were iteratively made to various model parameters until a reasonably good fit was obtained between observed and simulated loads. Plots of the load comparisons are shown in Figures 6.4 through 6.6. The results obtained, though less than perfect, were believed to be fairly good given the relatively sparse data used to generate the "observed" load estimates. In particular, it is felt that the simulated loading rates for nitrogen, phosphorus and sediment do, in fact, represent local loading rates fairly well.

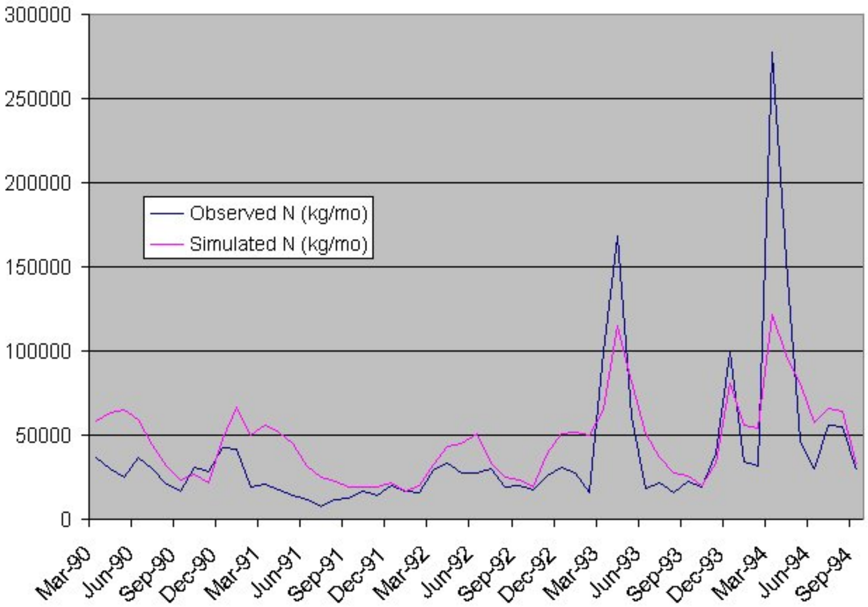

Figure 6.4 – Comparison of observed vs. simulated nitrogen loads.

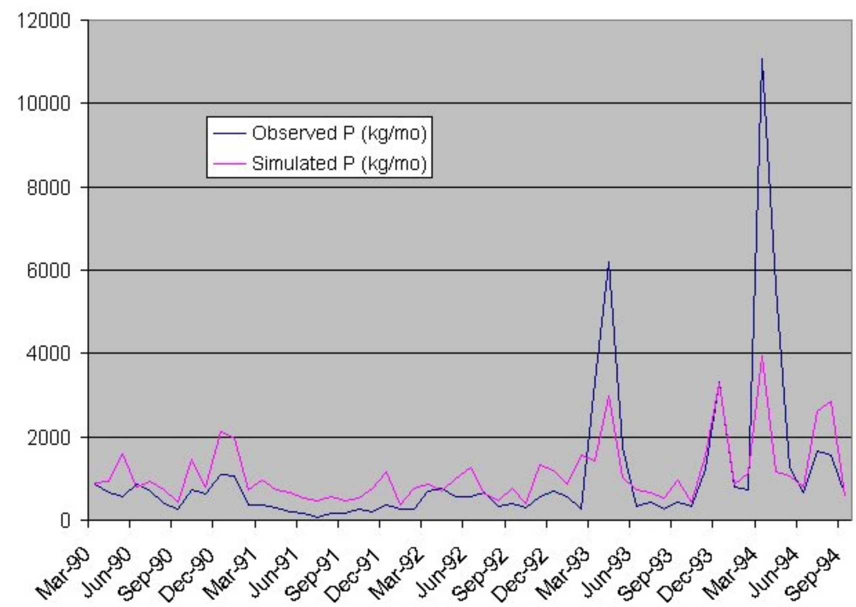

Figure 6.5 – Comparison of observed vs. simulated phosphorus loads.

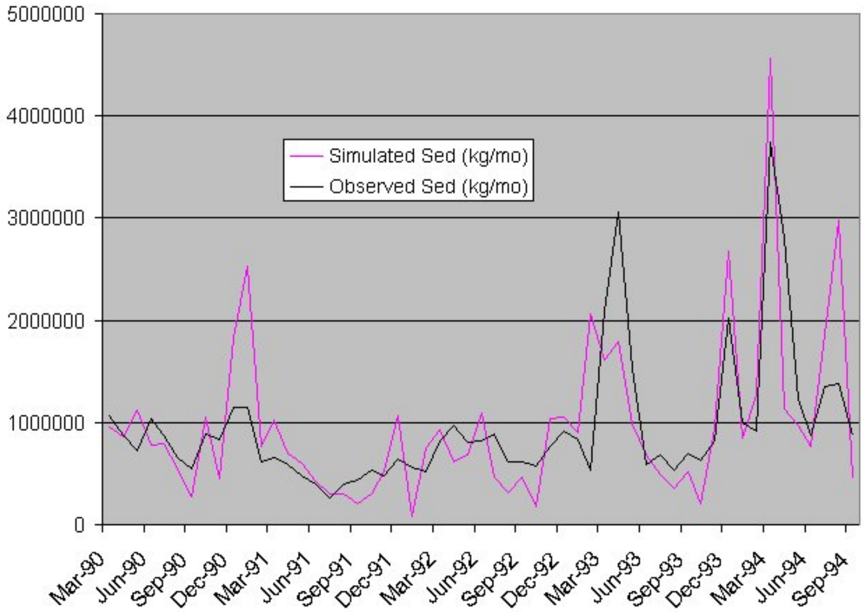

Figure 6.6 – Comparison of observed vs. simulated sediment loads.

6.4.5 – Model Application and Results

For this particular study, the AVGWLF modeling tool was run for each of twenty-one sub-watersheds comprising the larger Quittapahilla Creek watershed (see Figure 6.7 and Table 6.1). In each case, weather data for a period of ten years (1988-1998) was used to calculate mean annual sediment, total nitrogen and total phosphorus loads.

To properly account for the effect of existing agricultural BMPs and stream protection activities, information on the type and extent of these activities was compiled by the local watershed group and subsequently used within AVGWLF via the “scenario editor” function. The extent of such activities is summarized by sub-watershed in Figure 6.8.

The calculated mean annual loads for each sub-watershed (in both total and per unit area loads) are shown in Table 6.2. The stream names associated with each of the numbered sub-watershed are given in Table 6.3. For the entire Quittapahilla, the mean annual total nitrogen, total phosphorus, and sediment loads were approximately 1,201,064 lb/yr, 31,450 lb/yr, and 20,800,647 lb/yr, respectively. The corresponding mean annual loading rates for nitrogen, phosphorus, and sediment are approximately 24.4 lb/ac, 0.64 lb/ac, and 423 lb/ac, respectively.

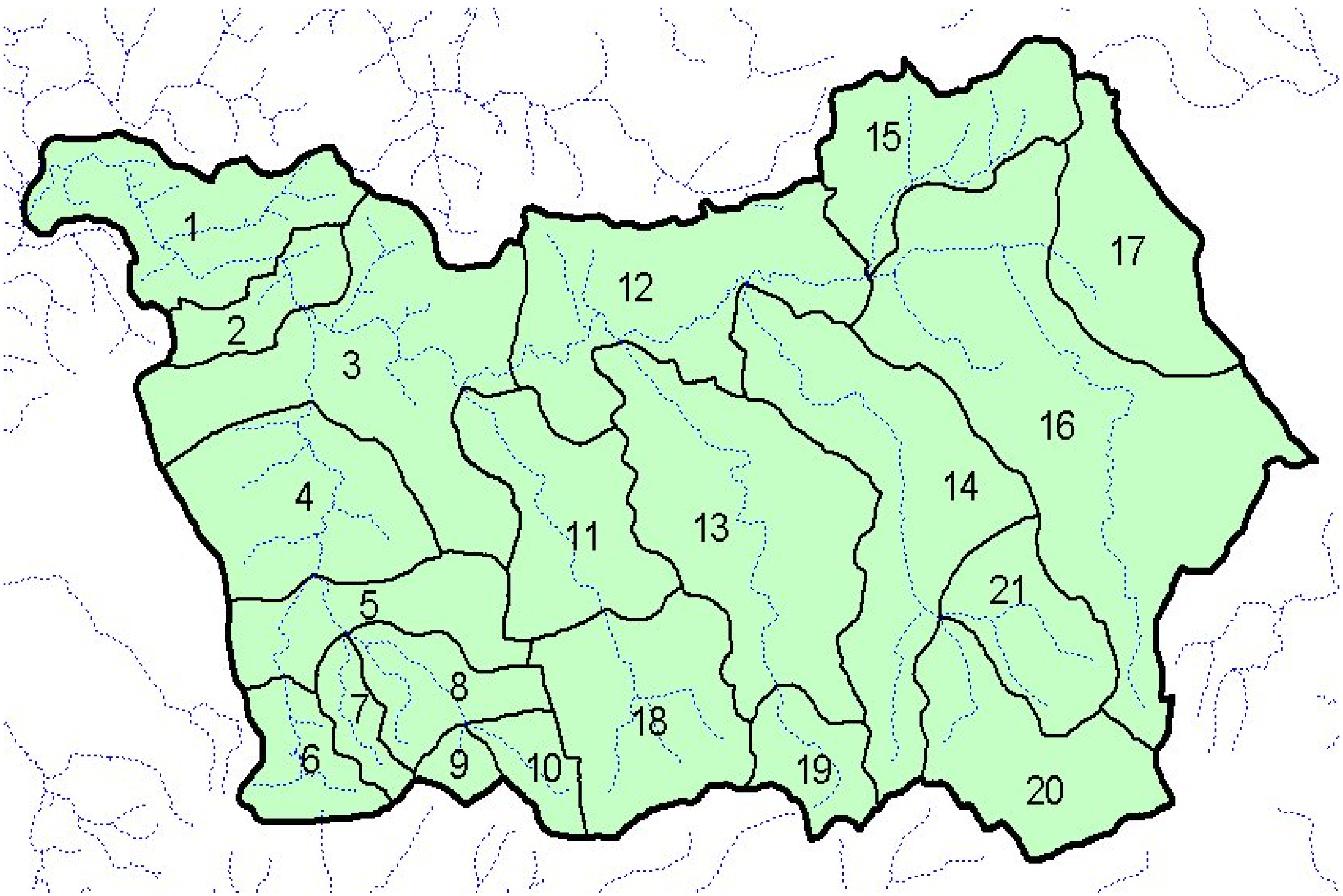

Figure 6.7 – Location of sub-watersheds.

Basin Number	Name Based on Principal Stream
1	Mouth of Quittapahilla Creek
2	Lower Quittapahilla Creek
3	Confluence of Killinger and Quittapahilla Creeks
4	Middle Killinger Creek
5	Upper Killinger Creek – Gingrich Run
6	Upper Killinger Creek
7	Buckholder Run
8	Middle Gingrich Run
9	Tributary to Gingrich Run
10	Upper Gingrich Run
11	Lower Bachman Run
12	Quittapahilla near confluence of Beck and Snitz Creeks
13	Lower Beck Creek
14	Lower Snitz Creek
15	Brandywine Creek
16	Middle Quittapahilla Creek
17	Upper Quittapahilla Creek
18	Upper Bachman Run
19	Upper Beck Creek
20	Upper Snitz Creek
21	Tributary to Snitz Creek

Table 6.1 – Subwatershed Basin Numbers and Names

BMP's FOR QUITTAPAHILLA WATERSHED

Sub-Watershed 1 — Quittapahilla Creek

BMP	Feet
Fencing	6330 ft
Rip.Buffer	6330 ft

Sub-Watershed 4 — Killinger Creek

BMP	Acres
nutrient mngt.	148.4
Fencing	4390 ft.
Rip.Buffer	4390 ft.

Sub-Watershed 11 — Bachman Run

BMP	Acres
nutrient mngt.	242.3
cons. Crop rotation	198.2
no-till	266.7
residue mngt./mulch till	111
cover crop	88.6
Fencing	7716 ft
Rip.Buffer	7716 ft

Sub-Watershed 13 — Beck Creek

BMP	Acres
Fencing	7945 ft
Rip Buffer	13,124.4 ft
Cons. Crop Rotation	469.5
strip cropping	151.5
cover crop	128.4
residue mngt.-mulch till	170.3
prescribed grazing	32.1

Sub-Watershed 14 — Snitz Creek

BMP	Feet
Fencing	5639 ft
Rip.Buffer	5639 ft

Sub-Watershed 16 — Un-named tributary

BMP	Acres
Cons. Crop rotation	92
residue mngt.	59
nutrient mngt.	92
no-till	59

Sub-Watershed 19 — Beck Creek

BMP	Feet
Fencing	3554 ft
Rip Buffer	3554 ft

NOTE: THE FENCING AND BUFFERS WEF
COMPLETED BY THE WATERSHED
ASSOCIATION FROM 2001 - 2003
THE REMAINING BMP's WERE FOR
THE LAST TWO YEARS

Figure 6.8 – Summary of existing BMP usage within the watershed.

Basin	Size (acres)	N-Total (lbs)	N-Rate (lbs/acre)	P-Total (lbs)	P-Rate (lbs/acre)	S-Total (lbs)	S-Rate (lbs/acre)
1	2495	23,333	9.35	900	0.36	843,413	338.1
2	857	12,458	14.54	452	0.53	465,255	542.8
3	4419	235,776	53.36	6787	1.54	3,143,889	711.5
4	2628	49,223	18.73	1292	0.49	1,274,490	485.0
5	1635	39,066	23.89	1100	0.67	1,187,613	726.3
6	968	41,064	42.41	481	0.50	332,735	343.6
7	529	5,746	10.87	223	0.42	211,680	400.5
8	1109	20,167	18.18	556	0.50	629,087	567.2
9	299	820	2.74	62	0.21	85,995	287.7
10	598	4,106	6.87	143	0.24	187,866	314.3
11	2285	45,994	20.13	981	0.43	74,188	325.7
12	3767	57,204	15.19	1762	0.47	1,844,483	489.7
13	4298	102,515	23.85	1960	0.46	1,122,786	261.2
14	4080	275,733	67.57	6681	1.64	1,613,840	395.5
15	2213	40,431	18.27	750	0.34	592,263	267.6
16	7291	120,660	16.55	3925	0.54	3,293,829	451.7
17	2225	33,381	15.00	878	0.39	714,641	321.1
18	2650	42,243	15.94	1067	0.40	1,113,084	420.0
19	906	4,284	4.73	146	0.16	91,287	100.7
20	2302	9,704	4.22	476	0.21	466,358	202.6
21	1526	37,143	24.33	829	0.54	841,869	551.5

Table 6.2 – Load results for Quittapahilla Creek by sub-watershed.

The values cited above indicate relatively high loading rates in comparison with other watersheds in Pennsylvania. This is not surprising given that the Quittapahilla Creek watershed is dominated by urban development and agricultural activities. Disturbed areas (i.e., mines and quarries) also appear to contribute substantial loads, particularly with respect to sediment.

For comparison purposes, data compiled previously by Evans, et al. (2002 and 2003) on the characteristics and pollutant loads for watersheds throughout Pennsylvania are shown in Tables 6.3 and 6.4. As can be seen from Table 6.4, the estimated nutrient and sediment loads for the Quittapahilla are similar to those calculated for watersheds such as the Codorus, Conestoga, Conewago, Neshaminy and Swatara which are somewhat similar in composition with respect to developed areas, agricultural activities, and point source pollution discharges.

Within the Quittapahilla Creek watershed as a whole, the predominant sources of nitrogen include agricultural activities (including livestock operations such as dairy farms), disturbed areas (e.g., mines and quarries), point source discharges, and septic systems. The principal sources of phosphorus include agricultural activities, disturbed areas, and point source discharges. The primary sources of sediment appear to be agricultural activities, disturbed areas, and streambank erosion. Table 6.5 summarizes the primary sources of nutrient and sediment pollution by subwatershed. As can be seen from this table, all areas of the Quittapahilla watershed are affected by pollutants generated via agricultural activities. To a lesser extent, and to varying degrees, subwatersheds are also affected by loads from disturbed areas, point source discharges, and streambank erosion.

Watershed Name	Size (acres)	Percent Developed	Percent Wooded	Percent Water	Percent Disturbed	Percent Agriculture
Beech Creek	109,181	0.6	90.4	0.1	5.0	3.9
Blacklick Creek	246,963	2.5	73.9	0.6	2.3	20.7
Brodhead Creek	183,553	4.4	87.3	0.1	0.0	8.2
Casselman Creek	204,804	1.6	61.2	0.2	2.2	34.8
Chartiers Creek	175,405	17.5	48.9	0.0	1.0	32.6
Clarion River	527,497	1.1	91.8	0.4	1.1	5.7
Clearfield Creek	241,353	1.0	80.6	0.6	3.9	13.9
Codorus Creek	174,273	9.0	27.2	0.1	0.5	63.2
Conestoga Creek	303,744	9.7	25.0	0.1	0.9	64.3
Conewago Creek	326,715	2.7	32.4	1.0	0.2	63.8
Conodoguinet Creek	324,367	5.0	32.8	0.8	0.1	61.3
Driftwood Branch	190,104	0.4	96.5	0.1	0.4	2.6
Fishing Creek	231,548	0.6	68.8	0.1	0.3	30.2
Juniata R./Raystown Br.	460,165	1.2	64.6	0.4	0.5	33.4
Kettle Creek	157,297	0.0	95.9	0.2	0.7	3.2
Loyalsock Creek	278,480	0.2	88.6	0.1	1.0	10.1
Lycoming Creek	137,300	0.5	85.6	0.1	0.4	13.4
Neshaminy Creek	131,792	20.2	37.6	0.0	1.1	41.1
Oil Creek	208,888	1.0	76.9	0.1	0.3	21.8
Penns Creek	198,556	0.3	70.3	0.5	0.2	28.7
Pine Creek	630,630	0.2	88.5	0.3	0.5	10.5
Redbank Creek	340,213	2.2	70.9	0.2	1.8	24.9
Schuylkill River	224,279	3.8	74.8	1.8	5.0	14.6
Sherman Creek	154,269	0.2	69.2	0.1	0.2	30.3
Slippery Rock Creek	260,127	1.5	57.2	1.1	1.4	38.7
Spring Creek	54,935	6.1	44.0	0.3	0.1	50.0
Swatara Creek	365,545	5.7	43.8	0.9	0.8	48.8
Tioga Creek	282,692	0.4	64.2	0.1	1.2	34.1
Towanda Creek	176,328	0.3	68.6	0.1	0.0	31.0
Tunkhannock Creek	264,777	1.5	68.0	1.9	0.0	28.6
Yellow Breeches Creek	137,490	6.1	56.2	0.1	0.4	37.2
Young Woman Creek	29,549	0.0	99.7	0.1	0.0	0.2

Table 6.3 – Land use/cover characteristics of selected Pennsylvania watersheds

Watershed Name	Total Nitrogen	Total Phosphorus	Sediment
Beech Creek	1.41	0.11	27.0
Blacklick Creek	3.02	0.12	-
Brodhead Creek	2.89	0.42	-
Casselman Creek	8.92	0.41	-
Chartiers Creek	5.49	0.52	-
Clarion River	2.44	0.17	-
Clearfield Creek	3.86	0.20	116.4
Codorus Creek	14.07	0.49	446.8
Conestoga Creek	30.69	1.01	854.4
Conewago Creek	16.71	0.38	416.1
Conodoguinet Creek	13.95	0.46	252.9
Driftwood Branch	2.61	0.13	63.5
Fishing Creek	5.49	0.19	31.2
Juniata R./Raystown Br.	7.72	0.30	230.5
Kettle Creek	2.89	0.12	24.7
Loyalsock Creek	3.35	0.14	29.3
Lycoming Creek	2.90	0.12	22.5
Neshaminy Creek	11.33	0.84	808.0
Oil Creek	2.92	0.20	-
Penns Creek	8.08	0.28	89.6
Pine Creek	2.83	0.17	25.3
Redbank Creek	3.57	0.20	-
Schuylkill River	8.62	0.28	-
Sherman Creek	5.10	0.18	35.1
Slippery Rock Creek	4.32	0.20	-
Spring Creek	14.87	0.68	63.8
Swatara Creek	14.80	0.48	772.5
Tioga Creek	3.73	0.19	106.4
Towanda Creek	2.67	0.15	19.0
Tunkhannock Creek	3.89	0.22	66.3
Yellow Breeches Creek	9.74	0.36	49.7
Young Woman Creek	2.72	0.09	-

Table 6.4 – Nutrient and sediment loading rates of selected Pennsylvania watersheds in (lb/ac)

Basin	Nitrogen			Phosphorus			Sediment		
	AA	DA	PS	AA	DA	PS	AA	DA	PS
1	X								
2	X			X			X		
3	X			X			X		
4	X	X	X	X	X	X	X	X	
5	X			X			X		X
6	X			X			X		
7	X		X	X		X	X		X
8	X			X			X		
9	X			X			X		
10	X			X			X		
11	X			X			X		
12	X			X			X		
13	X			X			X		X
14	X			X			X		X
15	X		X	X		X	X		X
16	X		X	X	X	X	X		X
17	X			X			X		
18	X			X			X		
19	X			X			X		
20	X		X	X			X		
21	X	X		X	X		X	X	

Table 6.5 – Summary of primary sources of nutrient and sediment loads by subwatershed

Note: AA = agricultural activities, DA = disturbed areas, PS = point sources, and SE = streambank erosion

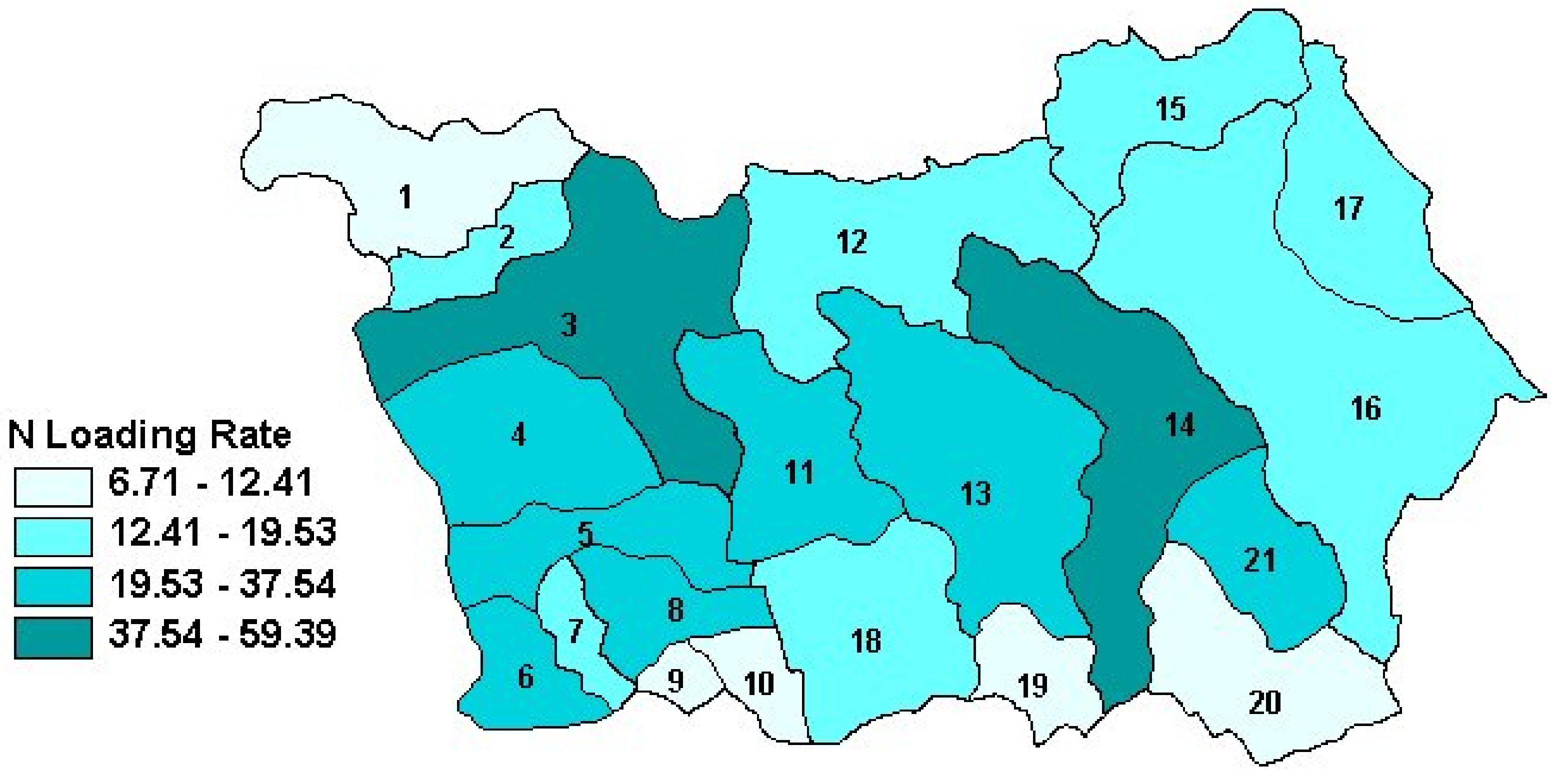

Figure 6.9 – Total nitrogen loading rates (in lbs/acre)

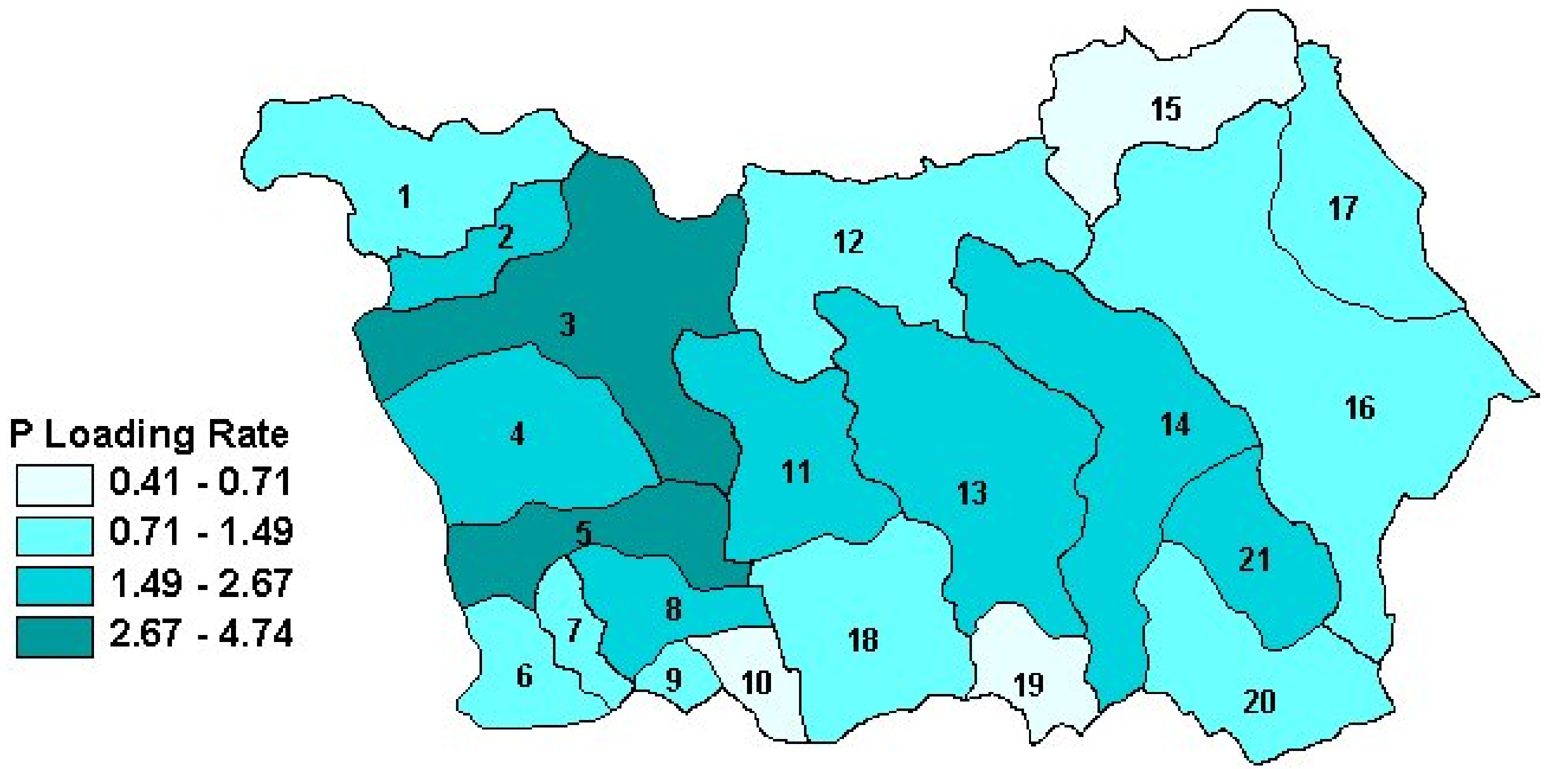

Figure 6.10 – Total phosphorus loading rates (in lbs/acre)

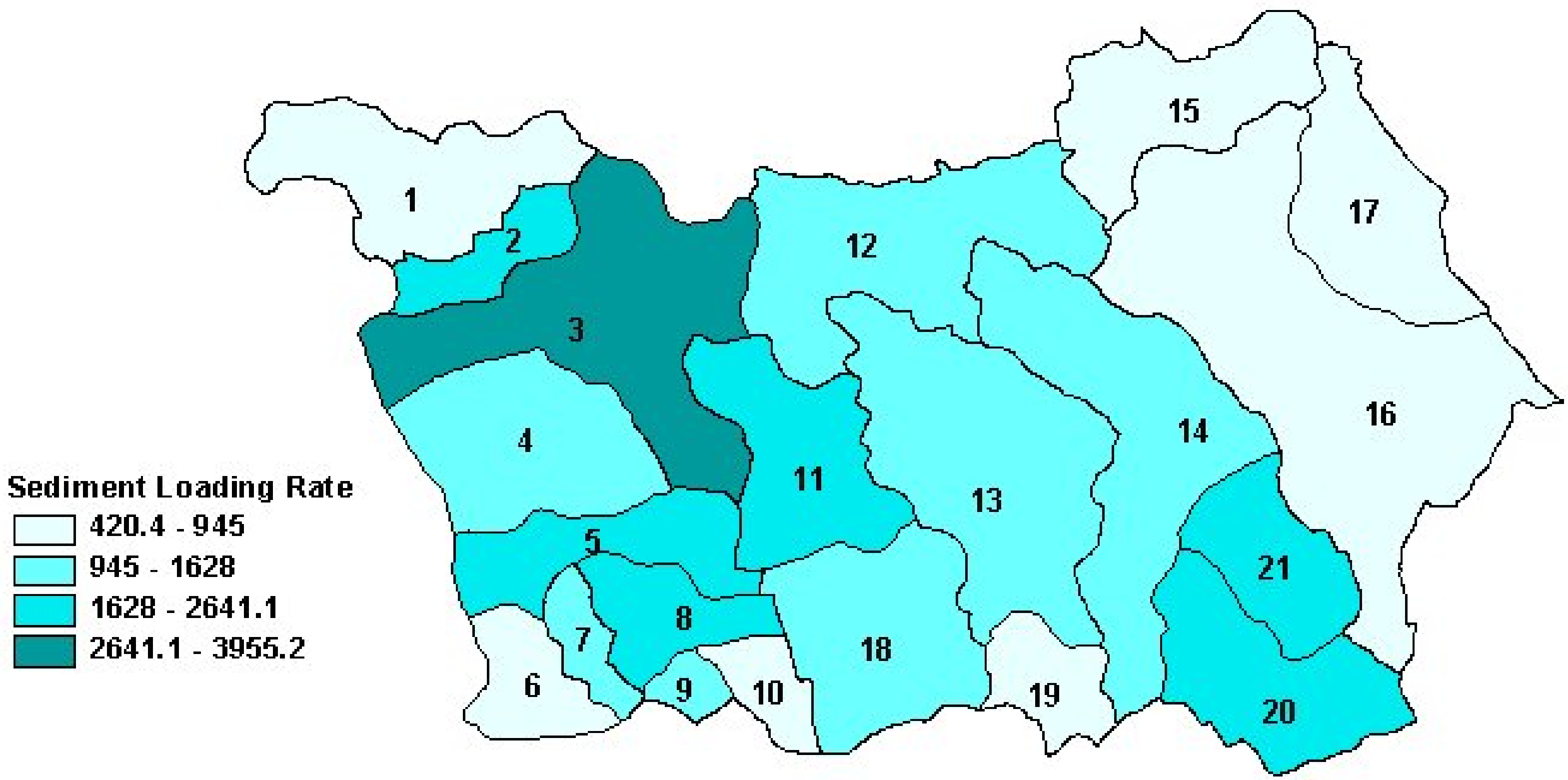

Figure 6.11 – Sediment loading rates (in lbs/acre)

6.5 – Point Source Discharges

There are ten wastewater treatment plants (WWTP) located in the Quittapahilla Creek Watershed. Four are municipal facilities serving townships and boroughs, and six are package plants that serve an individual residence, hospital, quarry, campgrounds and a small mobile home community. There are several other point source discharges in the Quittapahilla Creek Watershed. They include treatment of contaminated groundwater, non-contact cooling water, tank pressure testing water and quarry process wash water. Plate 10 and Table 6.6 show point source discharges in the Quittapahilla Creek watershed.

Pennsylvania Permit #	**Primary Facility**	**Type Discharge**	**Type Treatment**	**Receiving Stream**
PA0027316	City of Lebanon	Municipal Wastewater	Activated sludge	Quittapahilla Creek
PA0083267 and PA0087394	Butler Manufacturing	Ground water Cleanup & Cooling Water	Air Stripper & None	Quittapahilla Creek
PA0084867	Sun Oil Quentin	Ground water Cleanup	Air Stripper	Beck Creek
PA0081752	Philhaven Hospital	Domestic Wastewater	Extended Aeration and Filtration	Bachman Run
Mining Industrial Minerals Reg Program	Pennsy Supply Fontana Quarry	Groundwater and Wash Water	Sedimentation Basin	Bachman Run
PA0021806	Township of Annville	Municipal Wastewater	Two Stage Activated Sludge	Quittapahilla Creek
PA0083747	Walter H. Weaber & Sons	Domestic Wastewater	Extended Aeration	Gingrich Run
PA0081841	Thousand Trails Campground (Hershey)	Domestic Wastewater	Extended Aeration	Gingrich Run
PA0087700	South Londonderry Campbell East	Municipal Wastewater	Extended Aeration, Chlorination/ Dechlorination	Killinger Creek
PA0033065	Palm City	Domestic Wastewater	Extended Aeration Sand Filter	Killinger Creek
PA0024287	Borough of Palmyra	Municipal Wastewater	Trickling Filter, Activated Sludge, Phos. Removal	Killinger Creek
PA0081655	Philadelphia Mixers	Industrial Tank Testing water & Cooling Water	None	Killinger Creek
PA0080713	Pennsy Supply Millard Quarry	Domestic Wastewater	Extended Aeration	Killinger Creek
Mining Industrial Minerals Reg Program	Pennsy Supply Millard Quarry	Groundwater and Wash Water	Sedimentation Basin	Killinger Creek
PAG0043594	Dale Huffman	Domestic Wastewater	Single Family Residence STP	Unnamed Tributary

Table 6.6 – Point source discharges in the Quittapahilla Creek Watershed

Plate 10 – Point Source Discharges

6.6 – Existing Water Quality Conditions

Which aquatic organisms will inhabit a particular reach of stream is influenced by water quality conditions. Temperature, pH and the concentrations of dissolved gases and solids affect an individual organism's, as well as a population's survival, growth rate, spawning success, embryonic development, susceptibility to parasites and disease, ability to compete for resources and to avoid predation, and spatial distribution. Some species, such as Brown Trout, are particularly sensitive to poor water quality conditions. Evaluating existing water quality was an objective of the current study.

- Baseflow Water Quality Monitoring

As noted the Biology Department of Lebanon Valley College has been conducting water quality monitoring under baseflow conditions at a number of locations along Quittapahilla Creek and its tributaries since 1999. The water quality monitoring was conducted at one site on Snitz Creek (Dairy Road); four sites on Beck Creek (Bricker Lane, Royal Road, Reist Road, and Oak St); five sites on Bachman (two sites along Rte. 241 near headwaters, Fontana Rd., Bucher Lane, and Reigerts Lane), and two sites on Quittapahilla Creek (Palmyra-Bellegrove Road and Glen Road). The parameters monitored included temperature, pH, turbidity, nitrate-nitrogen, orthophosphate, and alkalinity. This water quality data was reviewed and evaluated.

- Storm Flow Water Quality Monitoring

The current study included water quality monitoring of storm flow events conducted by the consulting team at ten monitoring stations throughout the watershed (Plate 12). The storm flow water quality data in conjunction with the baseflow water quality data established a baseline for water quality conditions. It also allowed calibration of the water quality model to actual water quality conditions in the watershed and established a long-term monitoring program for tracking improvements in water quality as restoration and management measures are implemented. The information was utilized in conjunction with biological survey data and geomorphic assessment data to identify and prioritize problems along the mainstem Quittapahilla Creek and its major tributaries.

The monitoring effort included installation of staff gages at ten monitoring stations, installation of continuous reading temperature loggers at each site; flow measurements and rating curve development for each site; sample collection and analysis for five storm events at each site.

Staff gages were installed at the ten monitoring sites. Discharge was measured each time water samples were collected. Discharge was determined by the velocity-area method by: dividing the wetted channel cross-section at the site into intervals; measuring mean velocity, depth, and width for each interval; determining interval discharges; and summing the interval discharges to determine total discharge. A Marsh-McBirney electromagnetic current meter was used to measure velocity. Gage height was determined from the staff gauge and recorded along with velocity, depth, width, and discharge measurements.

In June 2003 continuous reading temperature data loggers were installed at the ten stations. StowAway® Tidbit™ Weatherproof and Waterproof Temperature Loggers were used to measure and record water temperature.

Sampling was conducted under storm flow conditions for five storm events per site at the ten monitoring stations from June through December 2003. During each sampling period, discharge was measured, field measurements were taken and grab samples collected, preserved and transported to the lab for analyses. Water samples were collected, handled, preserved, and analyzed utilizing standard procedures consistent with USEPA protocol. Measurements taken in the field included; temperature, pH, dissolved oxygen, and specific conductance. Laboratory analyses of the grab samples included; total acidity, total alkalinity, biochemical oxygen demand (BOD), total nitrogen, total Kjeldahl nitrogen (TKN), nitrate nitrogen, total phosphorus, orthophosphate phosphorus, dissolved solids, total suspended solids, turbitiy, hardness, copper, lead, zinc, and fecal coliform.

- Findings of the Water Quality Monitoring Program

Table 6.7 shows that along the mainstem Quittapahilla Creek the levels of nearly all parameters measured fall into the range of concentrations considered problematic for limestone streams. The most important parameters are discussed in this section.

Total acidity expresses the total quantity of various acids present in a stream. Acids may derive from natural sources such as the decay of plant material and groundwater flowing in contact with certain rock formations. Human sources include acid rain, coal mine drainage, industrial discharges, and the decomposition of organic wastes. Increasing acidity can mobilize toxic metals making them more readily available for uptake by aquatic organisms. The normal range for limestone streams is 0 – 2.6 mg/l. Although results were not consistent, during some storms the concentrations of total acidity along the mainstem Quittapahilla Creek and its tributaries ranged from 6 – 10 mg/l, falling well above the 3.4 mg/l value considered problematic for limestone streams.

Total alkalinity, the opposite of acidity, is an expression of a stream's buffering capacity or ability to minimize shifts in pH caused by the introduction of acids from natural or human sources. As such, it also controls the availability of toxic metals. The normal value for limestone streams is greater than 20.0 mg/l. The USEPA recommends that alkalinity not be reduced more than 25%. The concentrations of total alkalinity along the mainstem Quittapahilla Creek and its tributaries ranged from 71 – 196 mg/l. The maximum levels were consistent for all the mainstem and tributary stations. The lowest minimum values were measured at the upper mainstem stations with concentrations increasing in a downstream direction.

Organic wastes, such as sewage, manure, food processing wastes, entering streams are decomposed by bacteria. In the process, the bacteria use oxygen in the water to oxidize the wastes. The decomposition of large amounts of organic wastes can cause and oxygen deficits, significantly reducing the amount of oxygen available to fish and macroinvertebrates. Biochemical oxygen demand or BOD is a measure of the amount of oxygen consuming organic material. Normal concentrations for unpolluted streams range from 1 – 3 mg/l. Concentrations greater than 5.0 mg/l indicate a potential waste problem. The BOD concentrations along the mainstem Quittapahilla Creek and its tributaries ranged from 2.2 – 7.9 mg/l. The highest values measured along the mainstem were at Stations Q2 (immediately downstream of the Lebanon WWTP) and Q3. The tributaries all showed elevated levels with the highest concentrations measured at the Bachman Run and Killinger Creek stations. Bachman Run consistently exceeded the BOD levels for unpolluted streams.

Two gases (molecular nitrogen and nitrous oxide) and five forms of non-gaseous, combined nitrogen (amino and amide groups, ammonium, nitrate, and nitrite) are important in the nitrogen cycle. The amino and amide groups are found in soil organic matter and as constituent of plant and animal protein. The ammonium ion is released from the decomposition of proteinaceous organic matter and urea. It is also synthesized in industrial processes involving atmospheric nitrogen fixation. The nitrate ion is formed by the complete oxidation of ammonium ions by microorganisms in soil or water. Growing plants assimilate nitrate and ammonium and convert them to protein. Nitrate is the most readily available form of nitrogen for plant growth. Ammonium also serves as a nutrient for plant growth. However, it can be toxic to aquatic life, particularly in its un-ionized form as ammonia. The nitrite ion is formed from nitrate or the ammonium ion by certain microorganisms found in soil, water, sewage and the digestive tract. Nitrite can also be toxic to aquatic life. In oxygenated natural water systems nitrite is rapidly oxidized to nitrate. The major sources of nitrogen to streams are municipal and industrial wastewater; septic systems; run-off from fertilized farm fields, lawns, and golf courses, livestock wastes; leachate from solid waste disposal in dumps or landfills; atmospheric deposition; automobile exhausts and other combustion processes; and losses from natural sources such as mineralization of soil organic matter. Because these nutrients can have such a significant impact on aquatic systems it was important to measure the levels of key nitrogen forms as part of the monitoring program. Natural concentrations of total nitrogen range from 0 – 0.011 mg/l. Nitrate levels in unpolluted streams range from 0 – 2.35 mg/l. Total Kjeldahl nitrogen or organic nitrogen which is measure of complex organics from sewage, livestock waste, etc was included. Normal levels of these organic nitrogen range from 0 – 0.05 mg/l.

Concentrations of the nitrogen compounds measured under storm flow conditions along the mainstem Quittapahilla Creek and its tributaries consistently exceeded the values considered problematic for limestone streams. Concentrations of total nitrogen measured along the mainstem ranged from 2.66 – 6.94 mg/l and were consistently high at all stations. With the exception of Snitz Creek, maximum concentrations of total nitrogen were consistently higher along the tributaries than along the mainstem. Along the mainstem TKN concentrations ranged from 1.0 – 5.3 mg/l with the highest levels measured at Station Q1. TKN concentrations were elevated along the tributaries, with highest concentrations measured along Beck Creek and Bachman Run. Nitrate concentrations along the mainstem ranged from 0.96 – 6.03 mg/l with a general trend of decreasing minimum and maximum concentrations in a downstream direction. With the exception of Snitz Creek, maximum concentrations of nitrates were consistently higher along the tributaries than along the mainstem.

Phosphorus enters streams from natural sources, such as the decomposition of plant and animal matter and the dissolution of rock formations by groundwater, as well as human sources, such as wastewater discharges, run-off from fertilized farm fields, lawns and golf courses, as well as atmospheric deposition. Phosphorus is a nutrient for plant growth. Excessive levels can cause eutrophication and stimulate massive blooms of algae and submerged rooted weeds. As the plants die off, oxygen is used in the decomposition process causing oxygen deficits that can impact fish and macroinvertebrates. This is of particular concern for lakes, reservoirs, and estuaries such as the Chesapeake Bay. Normal concentrations of phosphorus for limestone streams range from 0 – 0.07 mg/l.

Concentrations of total phosphorus and orthophosphate measured under storm flow conditions along the mainstem Quittapahilla Creek and its tributaries consistently exceeded the values considered problematic for limestone streams. Concentrations of total phosphorus measured along the main stem ranged from 0.11 – 0.52 mg/l and were consistently high at all stations. With the exception of Snitz Creek, maximum concentrations of total phosphorus were consistently higher along the tributaries than along the mainstem. Bachman Run had the highest measured concentration (0.62 mg/l). Concentrations of orthophosphate measured along the mainstem ranged from 0.03 – 0.18 mg/l and were consistently high at all stations. The maximum concentrations of total phosphorus ranged from 0.08 – 0.44 mg/l and 0.04 – 0.22 mg/l for Bachman Run and Killinger Creek, respectively and were consistently higher than along the mainstem.

Suspended sediment is that portion of a stream’s sediment load that is fine enough to be carried in suspension in the water column. This includes all particles in water which will not pass through a filter of 0.45 microns (0.000018 inches). Particles that are smaller are considered part of the dissolved fraction of sediments. Suspended sediment enters waterways from a wide variety of natural sources including weathering of soils and bedrock, landslides and volcanic activity, and stream bank erosion. Human sources include run-off from cultivated land, livestock grazing in streams and riparian areas, urban land development and runoff from urban areas, mining, timber harvesting, and the accelerated stream channel erosion and sedimentation resulting from these land use activities. Suspended sediment in runoff from cropland and construction sites, and eroded from banks damaged by livestock grazing and urban runoff deposits on the streambed, smothering bottom dwelling insects and fish eggs buried in the gravel substrate. Sediments carried in suspension can irritate or clog the gills of adult fish. Sediment can have an effect on the physical habitat by causing streambed and bank erosion and sedimentation that alter channel characteristics (e.g., dimension, pattern, slope) and microhabitat features (e.g., depth, substrate, cover, and pool/riffle ratios). The USEPA recommends that suspended sediments not exceed 25 mg/l. Concentrations of suspended sediment in stable Piedmont and Ridge and Valley limestone streams range from 0 – 10 mg/l.

Concentrations of suspended sediments measured under storm flow conditions along the mainstem Quittapahilla Creek and its tributaries consistently exceeded the values considered problematic for limestone streams. Concentrations of suspended sediment measured along the mainstem ranged from 9.0 – 873 mg/l and were consistently high at all stations. Mainstem Station Q1 had the highest maximum concentration of suspended sediment for all stations. Concentrations of suspended sediment measured along the tributaries ranged from 7.0 – 820 mg/l and were consistently high at all stations. Killinger Creek had the highest maximum concentration of suspended sediment for all tributary stations.

Dissolved oxygen and pH are critical water quality parameters relative to maintaining viable populations of fish and macroinvertebrates. All aquatic organisms have an optimum range in which they function best. Outside this optimum range the organisms are stressed and their behavior and ability to function is impaired. They also have tolerance limits beyond which survival is unlikely. Normal dissolved oxygen concentrations for limestone streams range from 9.0 – 12.0 mg/l. Normal pH ranges from 6.8 – 8.1.

Dissolved oxygen concentrations measured along the mainstem Quittapahilla Creek ranged from 5.3 – 10.9 mg/l. The minimum concentrations fell in the range of values considered problematic for limestone streams. Q1, Q4, Q5, and Q6 had the lowest minimum concentrations. With the exception of Bachman Run all of the tributaries fell within the normal range of values for limestone streams. With the exception of Station Q6, the pH values measured along the mainstem fell within the normal range of values for this parameter. The pH values measured along Beck Creek and Bachman Run fell within the normal range. The pH values measured along Snitz Creek and Killinger Creek fell within the suspect range for limestone streams.

The water quality data confirm that Quittapahilla Creek and its tributaries have been impacted by nutrient and organic enrichment as well as sedimentation associated with urban runoff, mining, and agricultural operations including cultivation for crops and livestock grazing.

Plate 12 – Water Quality Monitoring Stations Map