PURPOSE

This report was prepared using funds from the Commonwealth of Pennsylvania's Growing Greener Program. The report is the result of a study to determine the extent and severity of mine drainage from abandoned surface and underground mining in the Upper Tioga River Watershed. Conceptual restoration plans to eliminate or treat these sources of mine drainage are recommended as a means to restore water quality to public use in the Tioga River and its tributaries. Cost estimates and priority rankings for abatement alternatives are provided.

GENERAL INFORMATION

Location

The Tioga River Watershed is located in Tioga and Bradford Counties about 35 miles north of Williamsport, Pennsylvania (Figure 1). The river originates in Armenia Township, Bradford County and travels southwest towards the town of Blossburg, flowing through the Northcentral Bituminous Coalfield. In Blossburg, the Tioga changes direction, flowing north through Mansfield and into Tioga Lake at the Tioga/Hammond Dam Complex. After exiting the Tioga/Hammond Dam Complex, the Tioga River flows into New York to its confluence with the Cohocton River to form the Chemung River.

Physical Characterization

The portion of the Upper Tioga River Watershed under investigation in this study encompasses an area of 402 square miles; including all the watershed area of the Tioga River and Crooked Creek upstream of the outlet of the Tioga/Hammond Dam Complex[1]. From its headwaters in Bradford County, the Tioga River flows southwest a distance of about 14 miles to Blossburg. In Blossburg, the Tioga River changes direction and flows north for a distance of about 17 miles to the outlet of Tioga Lake.

The Upper Tioga River Watershed can be divided into two distinct regions based on physiographic province, underlying geology, and land use. The upper region (from Marvin Creek upstream to the headwaters) lies in the glaciated high plateau section of the Northcentral Appalachian physiographic province (Figures 2 and 3). The topography of the section consists of forested hilltops with steep, narrow valleys. Its underlying geology is dominated by Mississippian and Devonian sandstones, along with deposits of Pennsylvanian Age coals. Forested land, mostly northern hardwoods, makes up a large percentage of the watershed in this region. Much of the land is managed by the Pa. DCNR as part of the Tioga State Forest.

[1] The total area of the Tioga River Watershed to its confluence with the Cohocton River to form the Chemung River near Corning, New York, is 1,391 square miles; it is 58 miles in length.

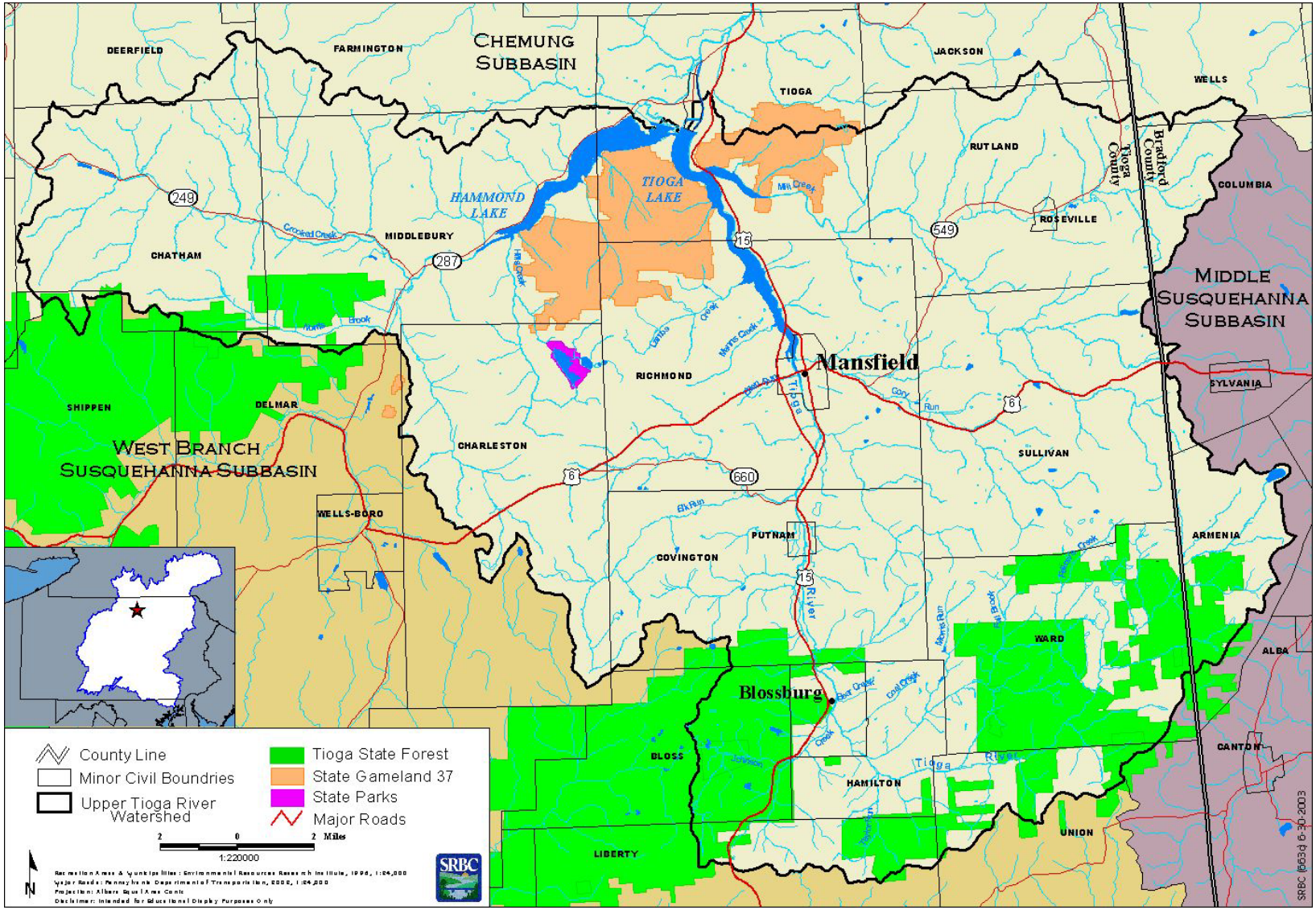

Figure 1. Upper Tioga River Watershed Location

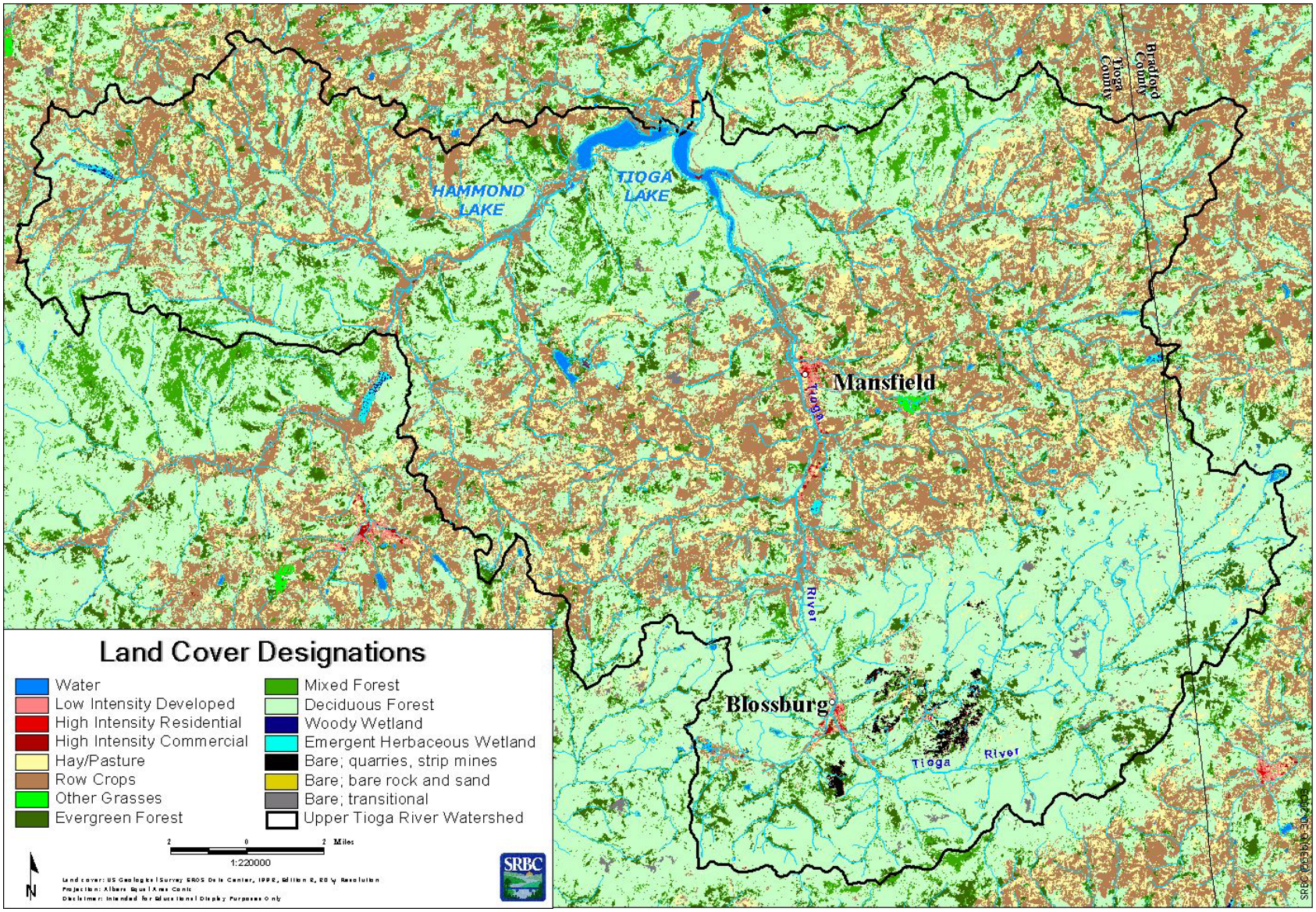

Figure 2. Land Use in the Upper Tioga River Watershed

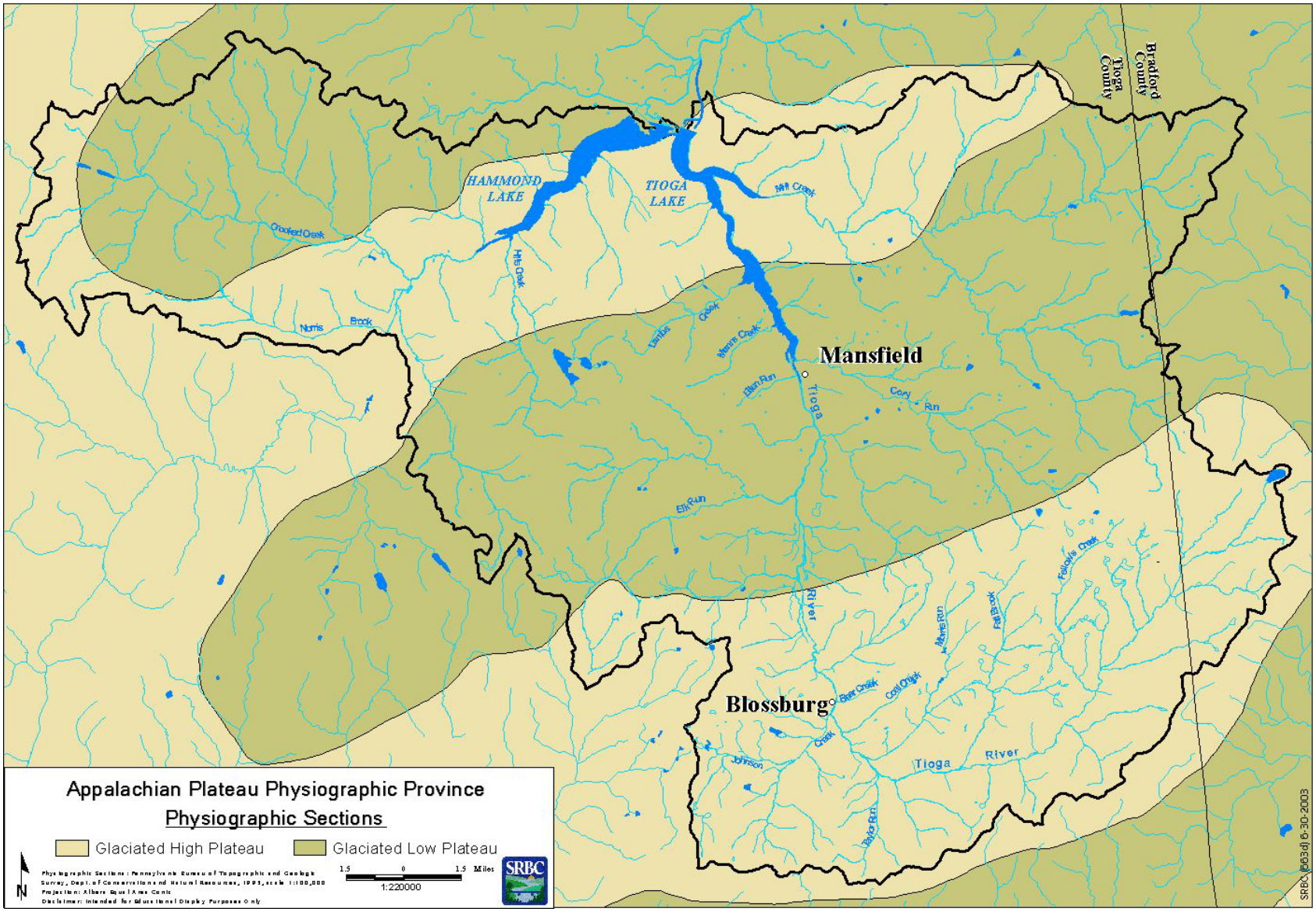

Figure 3. Appalachian Plateau Physiographic Province Designations in the Upper Tioga River Watershed

Reclaimed and abandoned surface mines and small population centers such as Blossburg, Arnot and Morris Run make up most of the remaining uses in the region. Many of the dwellings in this region of the watershed are used as seasonal or recreational dwellings.

The lower region (from Marvin Creek downstream to the Tioga/Hammond Complex) lies in the glaciated low plateau section of the Northern Appalachian Plateau physiographic province. In contrast to the topography of the upper region, the lower region consists of low, rolling hills with gentle slopes. The underlying geology is dominated by sandstones, siltstones, claystones, shales, and conglomerates of the Devonian Age. The lower region is a mosaic of pasturelands, croplands, and fields, with forested ridge tops. No mining uses occur in this region. The major population center of the watershed, Mansfield, is located in this region, along with other smaller population centers.

Demographic Characterization

According to the U.S. Census Bureau, Tioga County had a population of 41,373 in 2000, 0.34 percent of the population of the Commonwealth of Pennsylvania (U.S. Census Bureau, 2000). Although there are urban centers in the county (Mansfield, Blossburg, Wellsboro), only 16 percent of the population is considered urban, with the remaining 84 percent considered rural. Thus, it is considered a rural county by the U.S. Census designation, with a population density of 36.5 persons per square mile. The county is predominantly Caucasian (98 percent). Retired or disabled individuals constitute a large portion of the populace with 41 percent of the population aged 16 or older not included in the workforce. Industrial occupations consist of manufacturing (24 percent); education, health, and social services (22 percent); and retail trade (12 percent). Median household income is $32,020, lower than the state average household income of $40,106; per capita income is $15,549, also lower than the state average of $20,880. Poverty status is slightly higher in Tioga County with 9 percent of families, 28 percent of female households with no male present, and 13.5 percent of individuals living below the poverty line. This can be compared to the state average of 8 percent of families, 25 percent of female households with no male present, and 11 percent of individuals. Median property values are lower than the state average, $72,000 for the county compared to $97,000 for the state. However, a much larger percentage of housing units in Tioga County are for seasonal, recreational, or occasional use (15 percent compared to 3 percent). Ward Township in particular, with a total population of 128, contains 72 percent of housing units for seasonal, recreational, or occasional use.

Mineral Resources History and Characterization

Coal was discovered in the Tioga River Watershed near Blossburg in 1792, with the first deep mine opening in the Bear Creek Watershed between 1812 and 1815.[2] Settlement of the area was strongly driven by coal mining. The towns of Arnot, Morris Run, Blossburg, and Fall Brook (no longer existent) were all settled as coal mining communities; these towns were large enough to have their own amateur sports teams and have other characteristics of a large community. Coal mining was the primary industry in the upper section of the Tioga River

[2] More information on the history of coal mining in the watershed is available in Swisick 1994, Wellsboro Gazette 1932, and at www.Blossburg.com.

Watershed throughout the 18- and 1900s. Deep mining began in the Morris Run Watershed in 1853, in the Fall Brook Watershed in 1859, and in the Johnson Creek Watershed in 1865. Fall Brook, which exists as a few seasonal camps today, once supported a population of 2,300 (Swinsick, 1994). Morris Run once had a population of 2,500 and was so crowded that houses were built on stilts across Morris Run (Wellsboro Gazette, 1932). Arnot had a population of 3,500-4,000, the largest in Tioga County at the time (Boyer Kantz & Associates, 1976). Deep mining was the predominant form of mining in the watershed with its peak in 1886 with 1.4 million tons of coal produced from Tioga County deep mines (U.S. Army Corps of Engineers, 1977). At the turn of the century, production from deep mines in Tioga County began to decline as a result of increased production in other parts of Pennsylvania where coal was more economically mined. Starting around WWII, surface mining increased coal production until the early 1980s, when it began to again decline. Mining eventually ceased in 1990.

Six coal seams are present in the Upper Tioga River Watershed, four of which were mined. Table 1 lists the coal seams in stratigraphic order and gives their positions relative to the Bloss Coal, the major seam mined in the area. The coal seams occur as partially eroded layers overlying the ridge-forming Pottsville sandstone on the relatively flat mountaintops of a steeply-sided plateau. The coal seams are found in the Blossburg Syncline, which extends northeastward from Johnson Creek to Fellows Creek. All coal seams in the study area are close to the surface; the Bloss seam is only 250 feet below surface at its maximum depth (Gannett Fleming Corddry & Carpenter, Inc., 1968). Most of the coal seams are equivalent to coal seams of the Allegheny Group of the Pennsylvania System (Edmunds and others, 1979). It is possible that the lowest coal seam, Bear Creek, may be correlated with the Mercer Coal of the Pottsville Group; however, most studies identify it as the Brookville coal seam. All coal seams in the area have associated acid-producing materials (Gannett Fleming Corddry & Carpenter, Inc., 1968). Precise correlations between the coals of Tioga County and the standard named coals of western Pennsylvania have not been made due to disconformities, local dynamics, and faults; this has caused numerous inconsistencies in detailed stratigraphy and nomenclature.

Table 1. Stratigraphic Order of Coals in the Upper Tioga River Watershed

Coal Seam	Other Designation	Correlates With	Interval Above or Below Bloss Coal, Feet	
			Average	*Range*
Rock	E	Upper Freeport	+170	150-180
Seymour	D	Lower Freeport	+120	110-160
Morgan	C', Cannel – lower split only	Upper Kittanning	+80	70-100 indicated
Cushing	C, Foot	Middle Kittanning	+40	20-60
Bloss	B, Bear Creek – lower split only	Lower Kittanning	0	0
Bear Creek		Brookville (Mercer?)	-30	20-45

The bituminous coal region is generally characterized by mining of coal seams that lie in horizontal layers. When deep mining began in the watershed, entries (usually drifts) into the mines were dug from below the then-existing groundwater table. To keep the mines from filling with water, drifts were planned and dug to allow water to drain by gravity out of the mine using the naturally occurring geological dip in the Blossburg syncline. Barrier pillars used to separate

different mines were used minimally. Thus, water entering one mine could travel for many miles downhill collecting drainage from many other mine areas along the drainage path before discharging in large volumes from a common opening as AMD. This type of deep mine drainage can be particularly difficult to treat with current passive treatment technologies. The problem is amplified due to extensive fracturing of overburden materials and subsidence into underground voids, creating a conduit for surface run-off and groundwater to enter mine workings.

In addition to water entering mine workings through methods mentioned previously, unreclaimed surface mines and infiltrating stream reaches create additional problems. Often these surface mines have open pits and other features that retain precipitation, groundwater, and surface run-off. Due to fractures in the bottom of the pits or through a direct connection to deep mine workings, much of this retained water infiltrates into the underlying deep mine workings. If the surface mines are not connected to the deep mine workings, mine drainage may discharge as surface overflows or seepage directly into surface streams. Many of the surface mined areas in the watershed have been reclaimed since the 1970s, but some pre-Act[3] areas have not. Four undermined stream reaches throughout the watershed lose flow by infiltration into deep mine workings through fractures in their channels.

Water Resource Characterization

The upper region of the Tioga River Watershed (from Blossburg upstream to Fall Brook) is severely impacted by both AMD and non-AMD acidity (impaired streams are shown in red in Figure 4). Historical studies identified the source of much of the AMD as originating from gravity discharge of abandoned deep mines in the Morris Run, Coal Creek, and Bear Creek Watersheds. Johnson Creek was identified as being moderately impacted by mining activities and AMD in earlier studies. However, Johnson Creek was cited as a major source of oil and coal fines to the Tioga River, neither of which were observed in the course of this study. Fall Brook was mentioned in reports in the early 1970s as being mildly impacted by AMD; however, the AMD in Fall Brook produced little to no documented effect on the Tioga River. In the late 1970s, a co-operative fish hatchery operated by the Hillside Rod and Gun Club using water from the Tioga River experienced a severe fish kill. Investigations found that the AMD in Fall Brook had worsened significantly, impacting both Fall Brook and the Tioga River between their confluence and Morris Run. The Pa. DEP Statewide Surface Water Assessment Program (formerly the Unassessed Waters Program) identified additional watersheds as being impaired by AMD, including the Fellows Creek Watershed. However, the current study determined that some of these watersheds are not impacted by AMD, but rather organic acids and/or atmospheric deposition.

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[3] The Surface Mining Control and Reclamation Act of 1977 (SMCRA, Public Law 95-87) and its subsequent revisions were enacted to establish a nationwide program to protect the beneficial uses of land or water resources, and pubic health and safety from the adverse effects of current surface coal mining operations, as well as promote the reclamation of mined areas left without adequate reclamation prior to August 3, 1977. Unreclaimed mines that ceased operating by the effective date of SMCRA (pre-Act or pre-Law) are considered abandoned and, in Pennsylvania, become the responsibility of the Commonwealth.

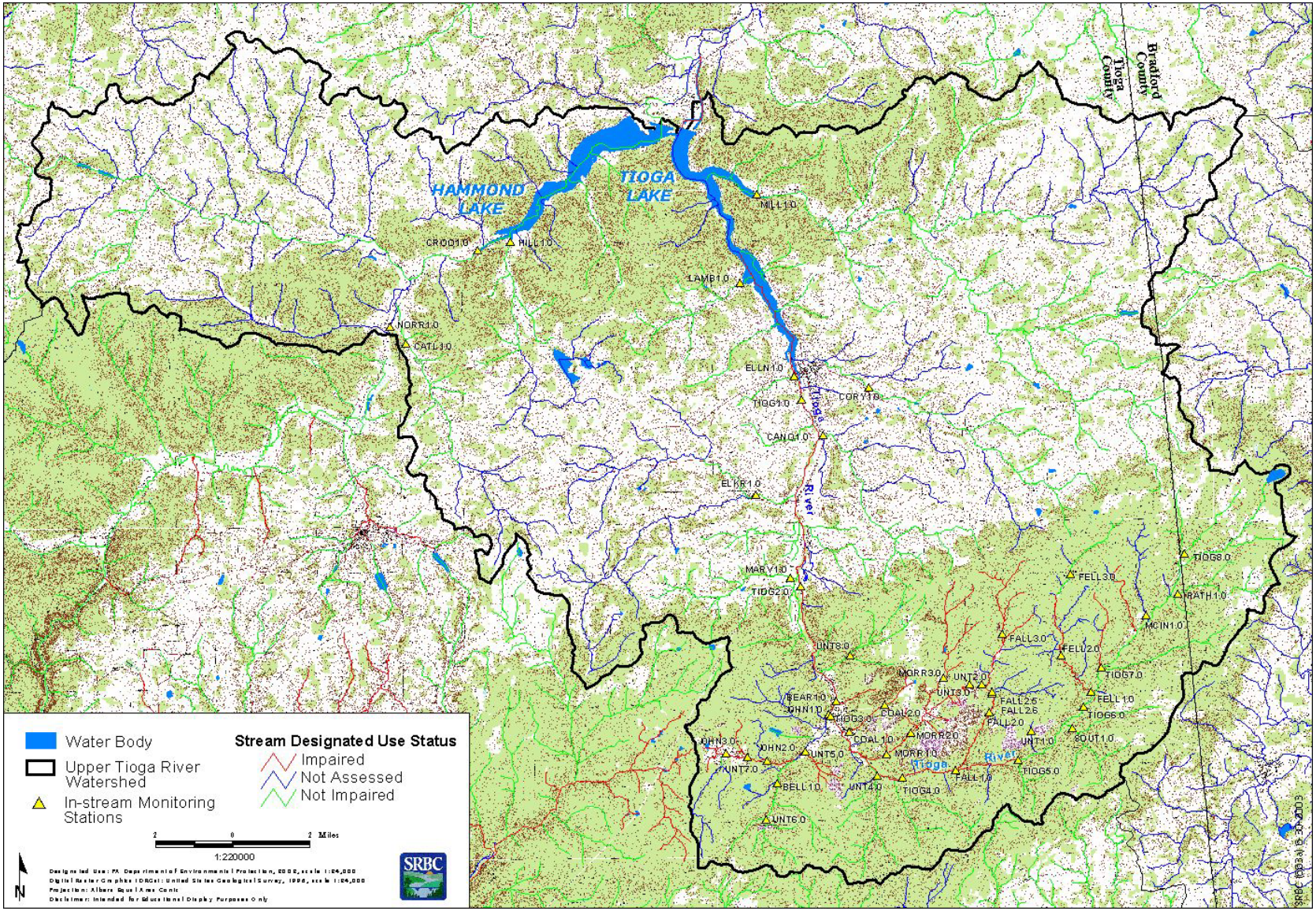

Figure 4. Use Attainment Status for Stream Reaches in the Upper Tioga River Watershed

Many of the tributaries in the headwaters of the watershed are small and intermittent; some originate in wetland areas. The headwaters of Fall Brook, Morris Run, and Fellows Creek, in addition to other tributaries that flow into the Tioga River from the north, are impacted by low pH due to tannic (organic) acids produced by extensive wetland areas in these watersheds, and by atmospheric deposition. Often, tannic acid causes the stream water to take on a deep orange hue that, without close inspection, can easily be mistaken for iron precipitates. Reaches impacted by non-AMD acidity possess low concentrations of metals and sulfates, and low conductivity (the combination of which are generally elevated in cases where impairments are due to AMD) but high concentrations of total organic carbon (TOC). Although TOC was not measured in this study, previous researchers have documented its elevation in the watershed (Hughey, 1993; Moase and others, 1999). Poorly buffered soils and cation leaching from soils due to the extremely low pH of precipitation in northern Pennsylvania provide little buffering capacity (alkalinity and acid neutralizing capacity) to streams (U.S. Environmental Protection Agency, 1999; Sharpe and Drohan, 1999). In addition to acidity, soils impacted by acid deposition also frequently leach toxic aluminum into streams. The combination of low pH and elevated aluminum concentrations, even episodically, precludes fish from inhabiting these streams. Gannett Fleming, Inc. determined that 25 percent of all the acidity in the watershed was not attributable to AMD but to these other sources (Rightnour and Hoover, 2003).

Many studies have been conducted to assess biological communities present in the Tioga River Watershed. As early as 1939, a Pennsylvania Fish and Boat Commission (PFBC) study noted that Morris Run contributed AMD to the Tioga River (Moase and others, 1999). In a U.S. Geological Survey (USGS) investigation previous to the construction of the Tioga/Hammond Dam Complex, the Tioga River was devoid of life from Morris Run to Crooked Creek, and was a recovering, but impaired, system all the way to the confluence with the Canisteo River in New York (Barker, 1971). In a 1993 aquatic biological investigation of the Tioga River headwaters, the macroinvertebrate community of the Tioga River was found to be severely impaired downstream of Fall Brook due to AMD (Hughey, 1993). The PFBC conducted an examination of the Upper Tioga River Watershed in 1999 and found no fish in Fall Brook, Morris Run, Coal Creek, Bear Creek, Fellows Creek, and McIntosh Hollow (Moase and others, 1999). In Pennsylvania, the entire Tioga River Watershed and all of its tributaries are classified as cold water fisheries (Commonwealth of Pennsylvania, 1999). Rathbone Creek and South Creek in the Tioga River headwaters were found to support Class A[4] wild brook trout populations. Rathbone Creek, South Creek, Coon Creek, Taylor Run, Dibble Run, Bellman Run, Long Run, and Frost Hollow were all recommended by the PFBC to be upgraded to high quality cold water fisheries based on excellent water quality, naturally reproducing fisheries, and/or use as a public water supply (Moase and others, 1999).

The mine drainage in the Tioga Watershed occurs in the upper one half of its length above the Tioga/Hammond Dam Complex; however, AMD impairs the Tioga River downstream to Tioga Lake, causing problems with both pH and metals (Figure 5a). The U.S. Army Corps of Engineers (USACE) operates the Tioga/Hammond Dam Complex, constructed in 1978 and filled

[4] Class A Wild Brook Trout fisheries are those that have: (1) total brook trout biomass of at least 30 kg/ha (26.7 lbs/acre); (2) total biomass of brook trout less than 15 cm (5.9 inches) in total length of at least 0.1 kg/ha (0.089 lb/acre); and (3) brook trout biomass must compromise at least 75 percent of the total trout biomass. Class A Wild Trout Fisheries represent the best naturally reproducing trout fisheries and are managed with no stocking.

in 1981, as a flood control and recreational project (Kulp and Pisarski, 1994). Tioga Lake impounds the Tioga River and controls a drainage area of 280 square miles; Hammond Lake impounds Crooked Creek and controls a drainage area of 122 square miles. Due to the degraded state of the water entering Tioga Lake, water from Hammond Lake, which is alkaline, must be mixed with the Tioga Lake water through a 2,700-foot connecting channel and released through multiple-elevation outlet gates before being discharged downstream as the Tioga River (Figure 5b). Studies completed in 1974, before construction, determined that the best abatement alternative would be to implement a suite of preventative measures throughout the watershed to reduce the volume of AMD produced and then build two chemical treatment plants to treat the remaining AMD (U.S. Army Corps of Engineers, 1977). However, this initiative was not funded and implementation was not initiated. To manage the degraded water entering Tioga Lake, a detailed operations plan was created by staff at the complex to ensure that water quality standards were being met downstream of the dam (U.S. Army Corps of Engineers, 1986). However, this plan took many years to develop and multiple fish kills occurred in both the Tioga River and Tioga Lake (U.S. Army Corps of Engineers, 1986). The USACE states that remediation of the mine drainage at its source would produce positive economic benefits for the operation of the Tioga/Hammond Complex by removing the source of impairment to Tioga Lake, while also restoring portions of the Tioga River and its tributaries (U.S. Army Corps of Engineers, 1986).

WATERSHED INVESTIGATION

Methods of Investigation

Initial investigation of the watershed included collection of all preexisting data, identification of mining-related problem areas, and establishment of a stream monitoring network. All pertinent USGS topographic maps, aerial photographs, mine maps, mining permits, and historical reports and records were reviewed. The watershed boundary was outlined and the study area divided into subwatersheds for separate investigation. Areas identified as impaired on Pennsylvania's Section 303(d) list (Pa. DEP, 2003) were delineated and targeted for field sampling. SRBC staff developed a volunteer-oriented problem area identification protocol and training manual for identifying mining-related problem areas for use by local stakeholders. Volunteers from the Tioga River Watershed Reclamation Projects, Inc. were trained in problem area identification. During spring through fall 2001, all AMD-impacted streams and the Tioga River mainstem from Bear Creek to the County Bridge Picnic Area (TIOG6) were walked to define sources of AMD and other mining-related problem areas. Discharge waters were identified and roughly characterized in the field. The field characterization included a test of pH and conductivity using portable meters, flow measurement (using portable flumes or buckets) or estimation, and completion of a problem area inventory checklist. Global Positioning System (GPS) measurements were taken at each problem area identified for entry into a GIS for mapping and analysis. During spring 2001 through fall 2002, field examination and verification of previously documented mining features was conducted.