GEOMORPHOLOGICAL AND PHASE I ARCHAEOLOGICAL SURVEY

MINARD MINE

ATHENS TOWNSHIP

BRADFORD COUNTY, PENNSYLVANIA

ER # 2020-PR-03544

REPORT APRIL 2024

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by

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REPORT
APRIL 2024

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MANAGMENT SUMMARY

In March 2024, Quemahoning LLC (Quemahoning) completed a geomorphological study and Phase I archaeological survey for the Minard Mine, a proposed non-coal surface mine permit (SMP 08230301) located in Athens Township, Bradford County, Pennsylvania. The geomorphological and archaeological survey area was confined to a limits-of-disturbance (LOD) defined by the U.S. Army Corps of Engineers as the "USCOE Limits for PHMC Evaluation," containing approximately 53 acres of steep mountain slopes located south of the Chemung River and Tutelow Creek. The proposed mine site access road requires two stream crossings, one for Tutelow Creek and a second for an intermittent tributary stream to Tutelow Creek. Quemahoning was retained by Tract Engineering, PLLC, and Bishop Brothers Construction Co., Inc. to complete the geomorphological study and Phase I archaeological survey.

The geomorphological study identified three alluvial landforms within the Minard Mine limits of disturbance (LOD), a delta-shaped alluvial fan issuing from an intermittent stream hollow, a T0 floodplain adjacent to the northeast side of Tutelow Creek, and a T1 terrace adjacent to the southwest side of Tutelow Creek. The remainder of the LOD consists of very steep mountainous terrain that exceeds 15% slope. The emphasis of the geomorphological study was on these alluvial deposits. Test trenches and shovel test pits revealed shallow gravel-laden soils along the southwest side of Tutelow Creek. Soils examined on the northeast side of Tutelow Creek were determined to have a potential for archaeological deposits to a depth of 85 cm. Deep archaeological testing was not needed for any of the landforms found within the Minard Mine LOD.

The geomorphological findings permitted the use of standard shovel test pits (STPs) for archaeological testing. Fourteen STPs were excavated across the alluvial fan and stream deposits along Tutelow Creek. No cultural artifacts or features were found. An examination of sandstone cliffs overlooking Tutelow Creek found no evidence of rockshelter sites. No archaeological sites were found within the Minard Mine LOD. No further archaeological work is recommended.

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1.0 INTRODUCTION

1.1 Location and Description

In March 2024, Quemahoning LLC (Quemahoning) completed a geomorphological study and Phase I archaeological survey for the Minard Mine, a proposed non-coal surface mine permit (SMP 08230301) located in Athens Township, Bradford County, Pennsylvania. The geomorphological and archaeological survey area was confined to a limits-of-disturbance (LOD) defined by the U.S. Army Corps of Engineers as the "USCOE Limits for PHMC Evaluation," containing approximately 53 acres of steep mountain slopes located south of the Chemung River and Tutelow Creek (Figure 1). The proposed mine site access road requires two stream crossings, one for Tutelow Creek and a second for an intermittent tributary stream to Tutelow Creek (Figure 2). Quemahoning was retained by Tract Engineering, PLLC, and Bishop Brothers Construction Co., Inc. to complete the geomorphological study and Phase I Archaeological Survey.

The study area is best accessed from the southern terminus of Minard Drive and southward across a wide flat of agricultural fields that extend to Tutelow Creek and the foot of the mountain slopes that overlook the Chemung River Valley (Figure 3). The proposed mine site access road extends from the northeast bank of Tutelow Creek to the footslope of the mountain along the southwest bank of the creek (Figure 4). This footslope is a delta-shaped alluvial fan deposit that issues from an intermittent stream hollow (Figure 5). The emphasis of the geomorphological study was on the alluvial fan deposits and the stream deposits adjacent to Tutelow Creek.

The remainder of the LOD consists of very steep mountainous terrain that exceeds 15% slope. The slopes are forested with a relatively open understory (Figure 6). Hemlock is the dominant tree species, but deciduous hardwoods are scattered throughout. Old logging roads crisscross the steep slopes. No mountain summits, saddles, or benches occur within the upper portions of the LOD, only backslopes. A broken line of sandstone cliffs rises from the hillside approximately 120 feet above the valley floor. The terrain leading up to the cliffs exceeds 40% slope. The rock ledges appear to be unstable, and lack overhangs, or potential habitation floors (Figure 7). Above the rock ledges is a small, abandoned stone quarry (Figure 8). The quarry face shows no evidence of drilling and blasting methods used to extract the rock. The quarry floor is accessed from an old haul road that extends north from the quarry toward the stream hollow.

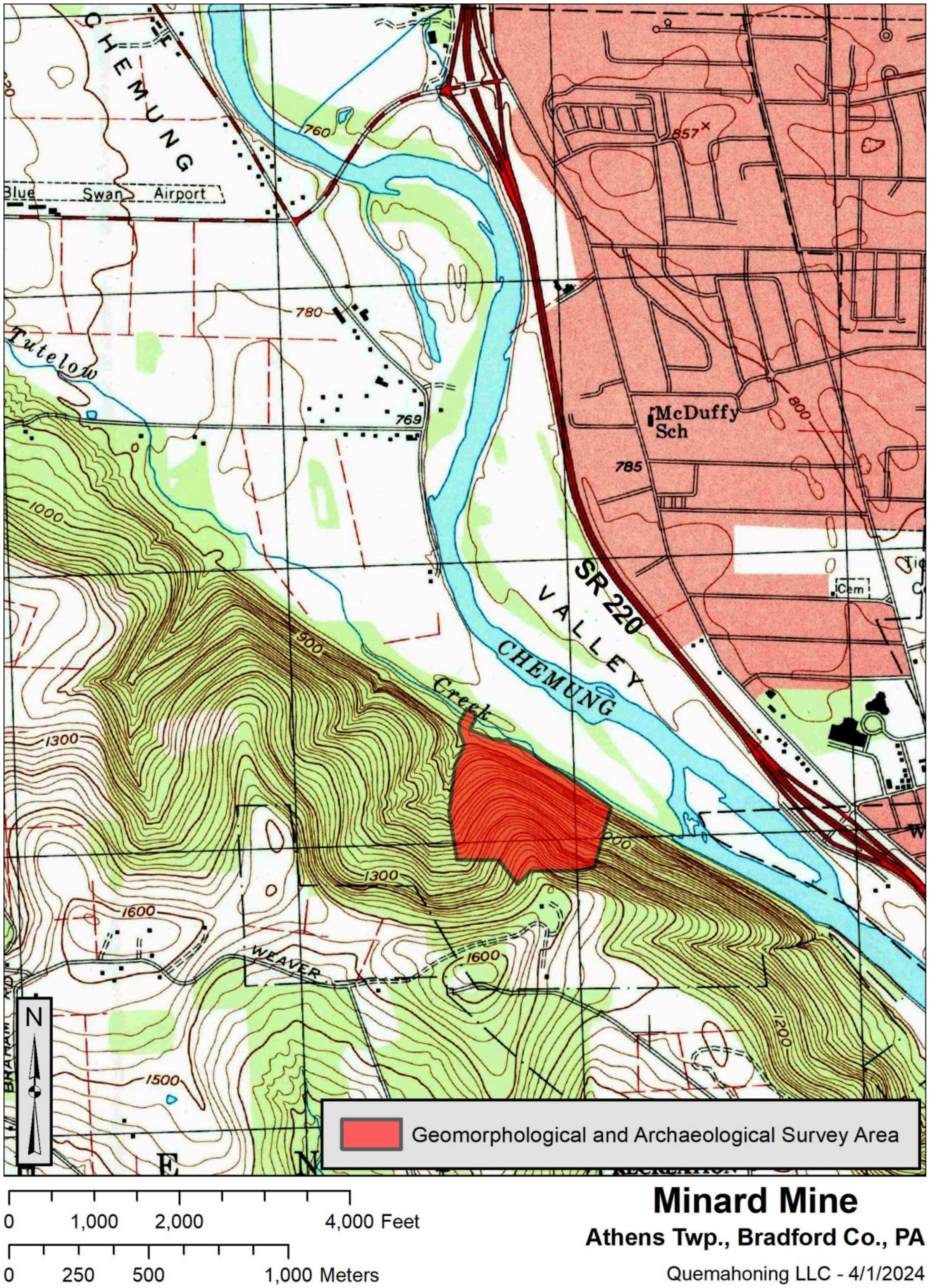

Figure 1. Section of the Sayre, PA-NY USGS 7.5' topographical map showing the geomorphological and archaeological survey area within the Chemung Valley. USGS (1995).

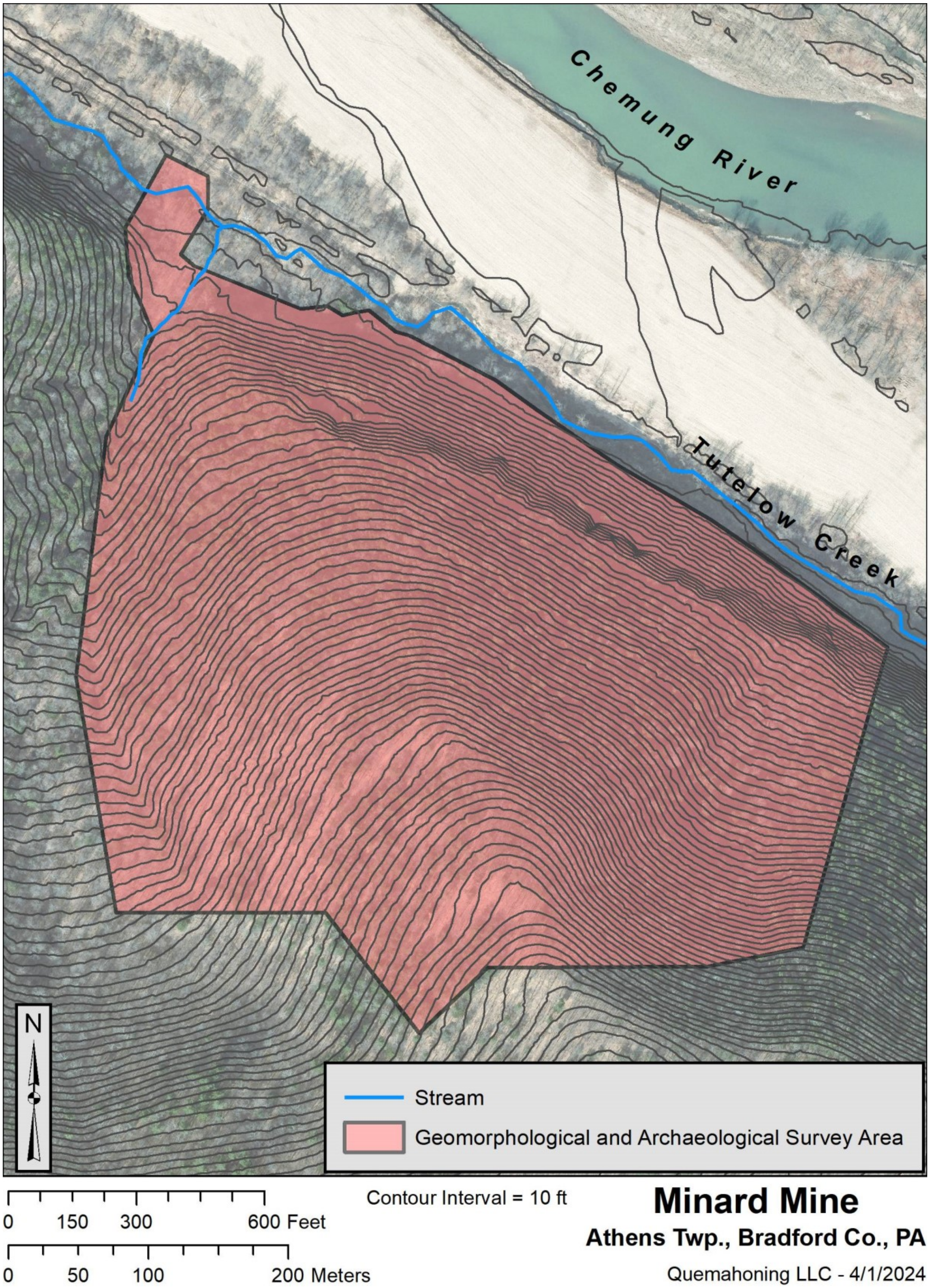

Figure 2. Map showing the locations of streams within the geomorphological and archaeological survey area. PEMA (2018).

Figure 3. View looking south toward the foot of the mountain from the end of Minard Drive.

Figure 4. Looking southeast down Tutelow Creek.

Figure 5. Looking northeast down the alluvial fan toward Tutelow Creek from the mouth of the stream hollow.

Figure 6. Looking north down the steep forested mountain slope and across the stream hollow.


Figure 7. Sandstone cliffs overlooking Tutelow Creek, looking south.


Figure 8. An abandoned sandstone quarry pit along the mountain slope, looking southeast.

2.0 ENVIRONMENTAL BACKGROUND

2.1 Physiography and Hydrology

The project area is situated within the Glaciated Lowland Section of the Appalachian Plateaus Physiographic Province (Figure 9). North of the Pennsylvania-New York border–less than 5 km (3 mi) from the Minard Mine–this same physiographic region is called the Allegheny Plateau region of the Appalachian Plateaus (Isachsen et al. 2004:4). This entire region was overridden by glacial ice during the late Wisconsinan glaciation, or last glacial maximum (LGM) (Sevon 2000; Briggs 1999). The Chemung River Valley with its wide valley bottom and mountainous valley walls is the dominant landscape feature. The river channel averages approximately 82 m (270 ft) wide, and portions of the outwash plain stretch 3.5 km (2 mi) across the valley. The Chemung River passes the Minard Mine LOD at an elevation of 746 feet above mean sea level while the mountain summit to the south climbs to 1,634 ft in elevation, resulting in a local relief of 888 ft.

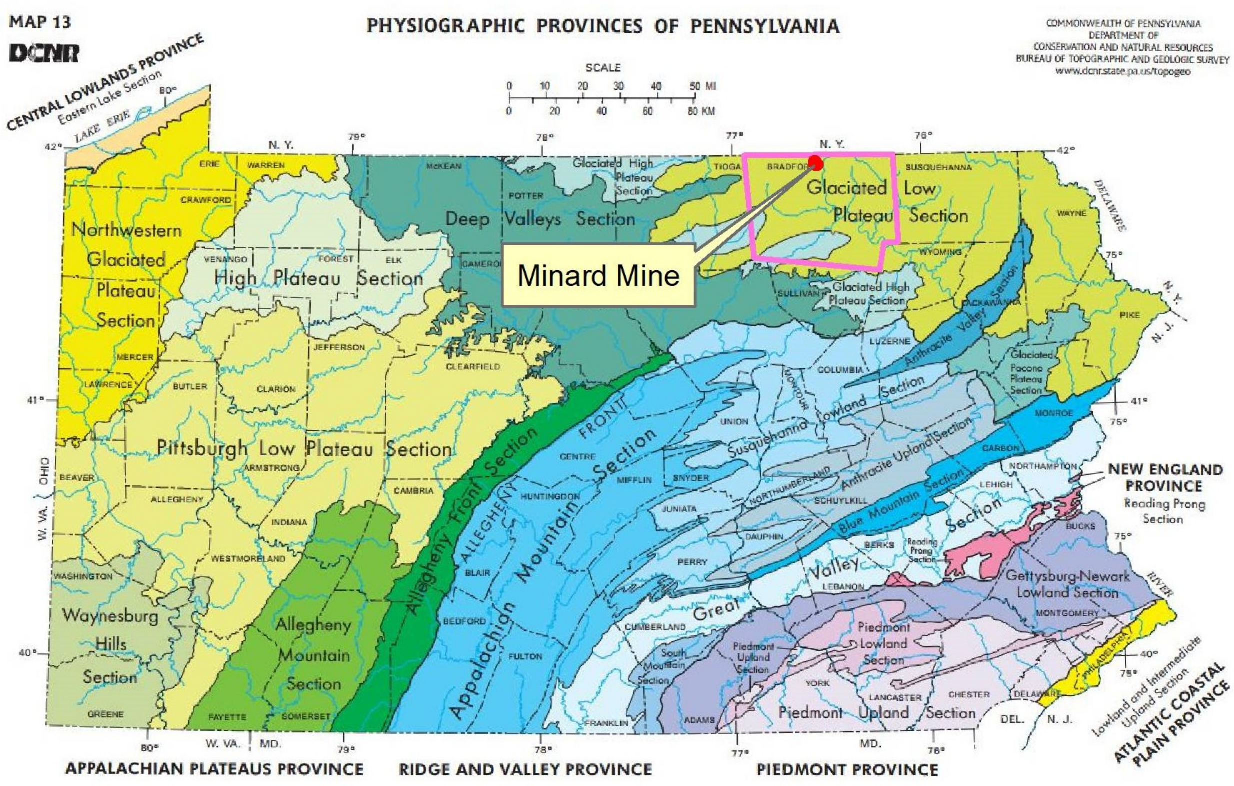

Figure 9. Physiographic map showing Bradford County and the project location. Sevon (2000).

The entire APE discharges into Tutelow Creek, a second-order stream and tributary to the Chemung River. The creek enters the river 850 m (2,800 ft) southeast of where the LOD crosses the creek. The Chemung River discharges as a third-order stream into the Susquehanna River only 6.7 km (4.2 mi) downstream from the study area. The alluvial fan deposit along the southwest bank of Tutelow Creek was formed by an intermittent stream that empties into Tutelow Creek. The intermittent stream dewaters a northeast-facing hollow that encompasses 0.57 km^2 (0.22 mi^2).

2.2 Geology and Soils

The bedrock underlying the Chemung and Susquehanna River Valleys and the surrounding Mountainous terrain belongs to the Upper Devonian Lock Haven formation. At its type locality near Williamsport, the formation is over 3,540 feet in thickness (Behr and Hand 2013). Due to this thickness, beds of the Lock Port formation dominate the surface geology across an area of 100 km east to west and more than 30 km north to south. Claystone, siltstone, and sandstone are the dominant lithologies. Shale and limestone occur as minor beds. Very fine-grained sandstone occurs in thin to three-foot-thick beds. Fossils are predominately marine in origin. The beds tend to be well-jointed (Behr and Hand 2013). Beds of hard fine-grained Lock Port sandstone, known locally as the bluestone, occur along the mountain slopes surrounding Sayre. Individual members and beds within the Lock Port formation have not been extensively studied, subdivided, or mapped (Harper 1999:126).

Soils across the Minard Mine LOD were mapped and classified by the Soil Survey (2024) as the Ochrepts-rock outcrop complex on slopes along and above Tutelow Creek, and the Dystrudepts, deep-Wellsboro-Oquaga association along steep, rubbly slopes within the intermittent stream hollow. Ochrepts and Dystrudepts are not named soil series, but rather taxonomic soil classifications. Ochrepts within the study area are well-drained, extremely stoney silt loam, and very channery loam derived from upland glacial till containing sandstone and siltstone. Dystrudepts are well-drained, very boulder and channery sandy loam formed in residuum from sandstone and shale along rubbly mountain slopes.

The resolution of the Soil Survey maps was not fine enough to accurately delineate areas of alluvium along Tutelow Creek. However, these soils are likely similar to the Holly, Pope, and Chenango series soils mapped across the adjacent alluvial plains (Figure 10). Holly soils are very deep, very poorly drained soils that form in loamy alluvium on flood plains, particularly in the back swamp areas of floodplains. Shallow gleyed B horizons are a defining characteristic that distinguishes Holly soils from the other soil types. Very deep, well-drained Chenango gravelly silt loam soils occur along higher portions of glacial outwash and kame terraces. Very deep, well-drained Pope loam soils form in acid coarse-loamy alluvium derived from sandstone and shale. Alluvial terraces containing Pope soils are occasionally flooded.

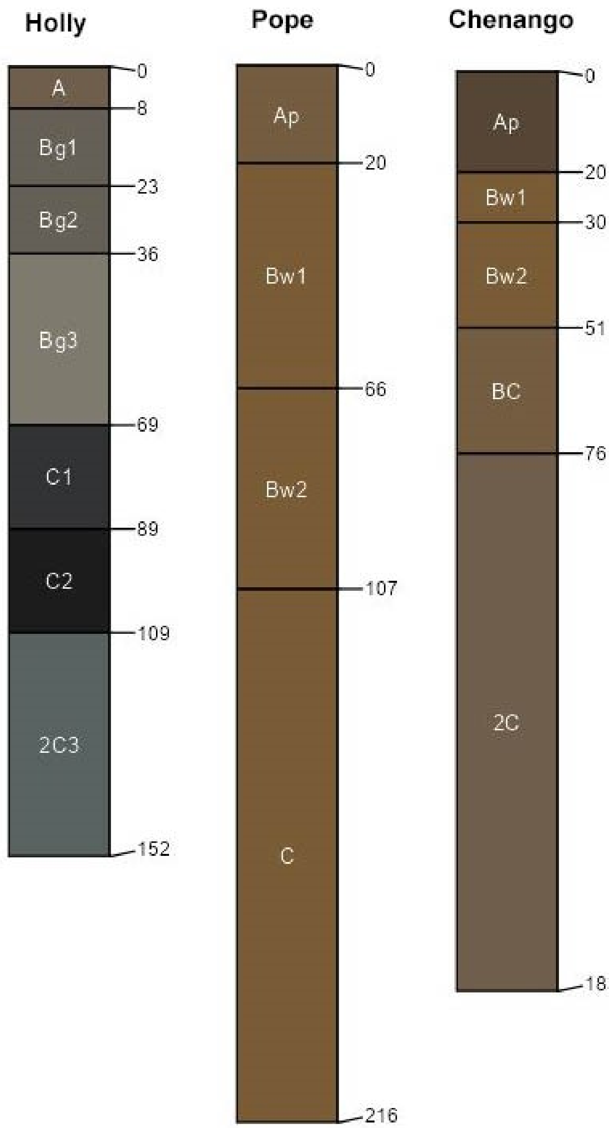

Figure 10. Typical soil profiles. California Soil Resource Lab (2024).

2.3 Geologic and Climate History

The landscape across western Pennsylvania is the result of over a billion years of geologic evolution. Pre-Cambrian basement rocks are overlain by more than 3,000 m (9,800 ft) of Paleozoic sedimentary rocks that represent near-continuous deposition with simultaneous subsidence (Shultz 1999; Saylor 1999). Deposition ended with the climax of the Allegheny Orogeny from which the uplifted and folded Appalachian Mountains and Plateaus were formed. The Allegheny Orogeny marks the suturing of the supercontinent Pangea after which erosion dominated the landscape of western Pennsylvania (Faill 1999). No Mesozoic- and Cenozoic-aged rocks were formed.

From an examination of the post-Triassic sediment record along the Atlantic margin, Poag and Sevon (1989) concluded that the Appalachian region experienced three tectonic uplifts, each followed by tectonic quiescence and high rates of erosion. The removal of large volumes of rock combined with the denuding of structural elements from earlier orogenies resulted in the erosional surfaces that characterize Pennsylvania today. A dominant characteristic of many stream valleys in the Appalachian region is the deep entrenchment of broadly looping meanders, which represent a mature, low-gradient river pattern that was locked into place by regional uplift and rapid river channel downcutting. Smaller streams in the headwaters formed dendritic, or tree-like patterns.

Drainage patterns in the Ridge and Valley Province differ from those on the Appalachian Plateau. The long linear ridgelines that characterize the Ridge and Valley Province are the headwaters for numerous small streams. Their stream valleys generally cut perpendicular to the trend of the ridge as they descend steeply into the valley below. Within the valley floor, the smaller tributaries converge into larger streams that generally traverse parallel to the valleys and ridges. This trellis stream pattern is typical of regions like central Pennsylvania where sharply tilled bedrock exhibits strong structural controls on patterns of erosion and stream formation. The landscapes of both the Plateau region and the Ridge and Valley region owe their origins to the regional uplift that exposed the bedrock to the forces of erosion. The principal difference in the resulting landscapes is in how erosion responded to the flat-lying bedrock underlying the Plateau region and the strongly folded, faulted, and tilted bedrock underlying the Ridge and Valley region.

Dating the geological events that formed the landscapes across Pennsylvania has been difficult and not without disagreement. Anthony and Granger (2007) used radiometric dating of cave sediments to measure episodes of river entrenchment within the Cumberland River Basin located in the southern portion of the Appalachian Plateau. The age of cave sediments combined with evidence of new vertical cave formation due to regional uplift suggests three periods of river entrenchment. Initial entrenchment occurred during the Pliocene between 3.2 and 3.1 Ma (million years), followed by the formation of a regionally recognized strath terrace known as the Parker Strath. Incision of the Parker Strath occurred between 2.5 and 2.4 Ma. Both episodes of incision are attributed to eustacy during periods of major marine regression. The last period of river entrenchment is attributed to the glacial reorientation of the Ohio Basin during the Pleistocene around 1.5 Ma. Region-wide aggregation of sediment at 0.85 Ma marked the beginning of intense glacial-interglacial cycling and shorter cycles of river incision, which resulted in the modern position of the river channel. These three periods of river entrenchment correlate with Poag and Sevon's (1989) last period of Atlantic margin sedimentation, which they attribute to great volumes of sediment removed as a result of continental glaciation.

The ancestral Allegheny and Monongahela Rivers originally drained northward through the St. Lawrence outlet but were reversed to their present southern outlet during the pre- or early Pleistocene by advancing ice sheets (Kaktins and Delano 1999). Anthony and Granger's (2007) 1.5 Ma age for the reorientation of the Ohio basin drainage system differs from previously accepted chronologies. Kaktins and Delano (1999) place the reversal of the northern flowing Allegheny and Monongahela Rivers to the southern flow of the Ohio River at sometime between 772 ka (thousand years) and the Illinoian advance (302 to 132 ka) based on flow direction in alluvial terraces and lack of magnetic polarity reversals within those sediments. Remnants of the north-flowing ancestral Allegheny and Monongahela Rivers are preserved in a series of abandoned channels and cutoff meanders known as the Parker Strath (Kaktins and Delano 1999). Kaktins and Delano (1999) attribute deep incision of the Parker Strath to the change in base level that resulted from the post 772 ka drainage reversal. Anthony and Granger's (2007) chronology places incision of the Parker Strath at 1.5 Ma, which directly conflicts with Kaktins and Delano's (1999) chronology.

The Susquehanna River dominates the central portion of Pennsylvania and dewaters the largest portion of the Ridge and Valley Province in the state (Figure 11). At about 27,500 square miles, the Susquehanna River Basin is the largest along the Atlantic coast of the United States (Kaktins and Delano 1999:379). Small to medium-sized tributaries exhibit the trellis pattern described above, however, the main stem of the Susquehanna and the North and West Branches traverse perpendicular to the pronounced parallelism of the region. The traverse nature of the river with its crosscuts through major water gaps has been subject to much speculation, all of which points to an origin that predates the present-day landscape. Most hypotheses posit that the origins of the river's modern course began by the Cretaceous period and as early as the Early Triassic period (Kaktins and Delano 1999:382-383). This older origin stands in contrast to the Allegheny and Ohio River systems which were strongly influenced by Late Pleistocene glaciations and reversal of their flow due to the blocking action of continental glaciers.

River entrenchment across Pennsylvania appears to have reached its greatest extent during the Sangamonian interglacial. Across glaciated regions, the Sangamon soil or paleosol formed in Illinoian tills and is the most well-developed and widely recognized paleosol across much of the mid-western U.S. (Hall and Anderson 1999; Jacobs et al. 2009). Climatic conditions that favored Sangamon soil development for 100,000 years also advanced the continued entrenchment of the region's streams. After examining evidence of Sangamon soils in northeastern Ohio, Szabo (1997) suggested that " . . . the post-Illinoian streams were wider and more deeply incised into the landscape than their post-Wisconsinan counterparts . . ." and that "a low-elevation base level may be one of the driving forces in controlling geologic processes during the Sangamonian through middle Wisconsinan substages." This deep entrenchment of stream channels likely enhanced landscape development through processes of hillslope erosion and colluviation as the Late Wisconsinan glaciation approached the northern Appalachian Plateau.

Four major periods of glaciation are recognized in Pennsylvania; two pre-Illinoian, one Illinoian, and one Late Wisconsinan (Crowl and Sevon 1999; Shepps et al. 1959). Each new episode of glaciation tends to erode or bury evidence of the previous glaciations; therefore, Late Wisconsinan tills and outwash dominate the glaciated landscapes of eastern and western Pennsylvania. Landscapes and the regional climate across Pennsylvania were strongly influenced by the Late Wisconsinan glaciers. Landscapes within the Wisconsinan limit were completely reworked by the advancing ice. Areas south of the maximum glacial advance were also strongly influenced by the presence of glaciers and their influence over the local climate. The cold periglacial climatic conditions controlled geological processes and the kinds of flora and fauna that could survive in the harsh conditions.

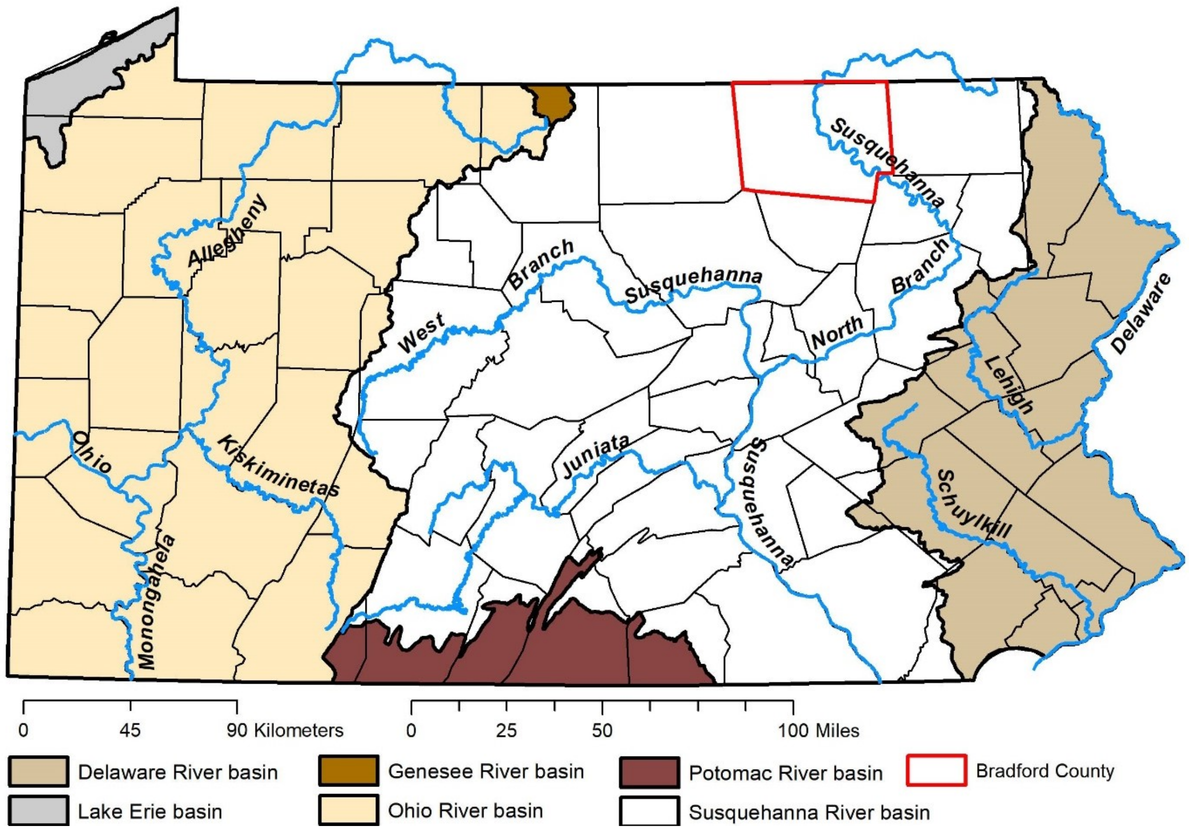

Figure 11. The major river basins of Pennsylvania. Penn State (1998, 1996), PennDOT (2022).

In northeastern Ohio, increasing slope erosion and colluviation after 24,000 radio-carbon years before present (RCY BP) suggests a colder climate and increasing periglacial conditions ahead of the advancing Late Wisconsinan ice (Szabo 1997; Amba et al. 1990). The arrival of the ice front was uneven throughout the northeast. In western Ohio, radiocarbon dates place the maximum advance between 23,000 and 19,000 RCY BP (Szabo et al. 2011). In eastern Ohio and northwestern Pennsylvania, the timing of the advance is less well constrained, but most reports place the LGM near 18,000 RCY BP, followed by a significant retreat of the ice front by 13,000 RCY BP (Szabo et al. 2011; Watts 1979; Schuldenrein and Vento 2010). Clark and Ciolkosz (1988) bracket the cold-phase maximum between 23,000 and 16,500 RCY BP for the Appalachian Highlands. Watts (1980) places the Late Wisconsinan between 22,000 and 13,500 RCY BP but includes words of caution over the arbitrariness of assigning precise dates. More recent studies of the Late Pleistocene chronology in southern New England and eastern New York combine multiple lines of evidence that include correlations with proglacial lake varves, paleomagnetics, and AMS radiocarbon dates (Ridge 2003). In this study, the Late Wisconsinan Maximum is placed between 28,200 and 23,700 Cal yr BP followed by a period of early ice retreat between 23,700 and 18,300 Cal yr BP, and three phases of deglaciation between 18,300 and 13,000 Cal yr BP. Ridge (2003) also noted that the arrival of the ice sheet at its maximum extent may have varied as much as a few thousand years across the Northeast.

Watts (1979) determined that the cold-climate vegetation zones extending away from the glacial limit were relatively stable between 23,000 and 13,500 RCY BP. During this time the region was cold, dry, and windy. Average temperatures during July were 5 to 15°C (41° to 59° F) colder than today, and annual precipitation was as much as 10 to 30% less (Clark and Ciolkosz 1988). Macrofossil and pollen evidence indicate the presence of sage-dominated tundra across the Appalachian Plateaus and tundra that may have extended south of the ice front as far as 450 km (280 mi) within the higher elevations of Pennsylvania, western Maryland, and West Virginia. Watts (1979) raised two possible causes for the presence of tundra. The presence of sage tundra may have been due to permafrost conditions with maximum annual mean temperatures between -2° and -8°C (28.4 to 17.6°F). Alternatively, tundra conditions could have resulted from an absence of trees due to wind and related environmental factors, but without permafrost. However, Park Nelson et al. (2007) used data collected from block fields found across the Appalachian region as evidence to support the presence of permafrost soils lying above the timberline during the last glacial maximum (LGM). Despite his earlier uncertainty, Watts (1979) also suggested that a band of treeless tundra with permafrost paralleled the ice front and extended south along the higher elevations of Pennsylvania and West Virginia.

Ciolkosz et al. (1986) cite abundant evidence that cold-climate environments once dominated the Pennsylvanian landscape as far as 160 km (100 mi) south of the ice front. Such periglacial environments can exist with or without the presence of permafrost. Relic periglacial features include patterned ground, involutions, ice-wedge casts, pingo scars, grezes litees, boulder fields, block streams, rock cities, hillslope colluvium, and gelifluction (solifluction) lobes with larger-scale hillslope colluvium deposits being the most extensive type of periglacial feature in Pennsylvania (Ciolkosz et al. 1986; Clark and Ciolkosz 1988). Present-day hillslopes in Pennsylvania with low angles of repose may be "super stable," and represent relic landscapes from more active periglacial times (Ciolkosz et al. 1986). Based on a study of late Pleistocene soils within the northernmost portion of the Salamanca Reentrant, Millar and Nelson (2001) attribute periglacial colluviation to solifluction. Solifluction (aka gelifluction) is the active low-gradient downslope movement of meltwater-saturated soil and regolith due to the combination of gravity flow and seasonal freeze-thaw creep but differs from mudflow with slower, more continuous movement that is not confined to channels (Bloom 1991; Thornbury 1969). Snyder and Bryant (2009) concluded that widespread periglacial colluviation within the Salamanca Reentrant was most active between 20,500 and 16,500 RCY BP.

In a study of hillslope deposits in central Pennsylvanian, Gardner et al. (1991) found evidence of two episodes of Late Wisconsinan colluviation. A period of colluviation began with cooling temperatures and the southern advance of ice sheets. The first pulse of colluvial deposition preceded the glacial maximum (26,000 to 22,000 RCY BP). Slope processes included gelifluction, debris flow, sheet wash, and channelized flow. During the height of glaciation (22,000 to 18,000 RCY BP) colder temperatures and permafrost conditions reduced sediment supply as evidenced by an erosional disconformity at the top of the pre-glacial maximum colluvium and the presence of relic frost cracks and ice-wedge casts within that same surface. This locking of the landscape was followed by a brief episode of mass wasting. The second impulse of periglacial colluviation buried the permafrost surface (18,000 to 13,000 RCY BP). Colluviation ended with the deglaciation of the Wisconsinan ice front and the end of periglacial conditions. Soil formation began on the surface of the colluvial deposits as the Late Pleistocene climate warmed and soil surfaces stabilized during the early Holocene.

Watts (1980) describes the climate trend from 13,500 to 10,000 years ago as transitional with the ice front retreating north of the Great Lakes basin. This period includes the Bolling through Allerod warming trend and the 1,600-year-long return of cold periglacial conditions during the Younger Dryas (Figure 10). Pioneer tree species began to migrate north with spruce tundra parklands while more closed boreal forests were located to the south. Haynes (2008) compiled stratigraphic data and associated radiocarbon dates from more than 90 archaeological sites across North America where Allerod through Younger Dryas-Holocene-aged strata was present. He tightly constrains the Younger Dryas between 10,900 ±50 RCY BP and 9,800 ±50 RCY BP (12,800 and 11,200 Cal yr BP). At many sites, a black organic mat marks the beginning of the Younger Dryas and a catastrophic event that ends the presence of North American ice age megafauna. The onset of the Younger Dryas is also significant to archaeology and first American studies in that the cooling event marks the end of the Clovis culture within the Paleoindian cultural period.

The Holocene began with the return of warmer and wetter climates (Figure 12). Retreating glaciers exerted less influence over the climate, which allowed floral zones to migrate northward. Some of the first migrant tree species included white pine, alder, fir, tamarack, and eastern hemlock (Watts 1979). After 8,500 RCY BP, the climate became more like our modern continental climate with greater seasonal differences in temperature and precipitation (Custer 1996). Oak and hemlock forests covered much of Pennsylvania by 6,000 yr BP. Hickory, chestnut, and other species that characterize the region's modern deciduous forests followed soon after. These migrations were not even across Pennsylvania and varied according to elevation and local environmental factors. The pollen record within Holocene-aged deposits indicates climatic conditions that alternated between warm moist and warm dry, and cool moist and cool dry during the Late Holocene. In the Blytt-Sernander chronostratigraphic model (Figure 10), the Atlantic, Sub-Atlantic, and Neo-Atlantic episodes correspond to warm and moist climate periods; the Boreal and Sub-Boreal were warm and dry; and the Scandic, Pacific, Neo-Boreal, and Modern episodes represent relatively cooler climate periods.

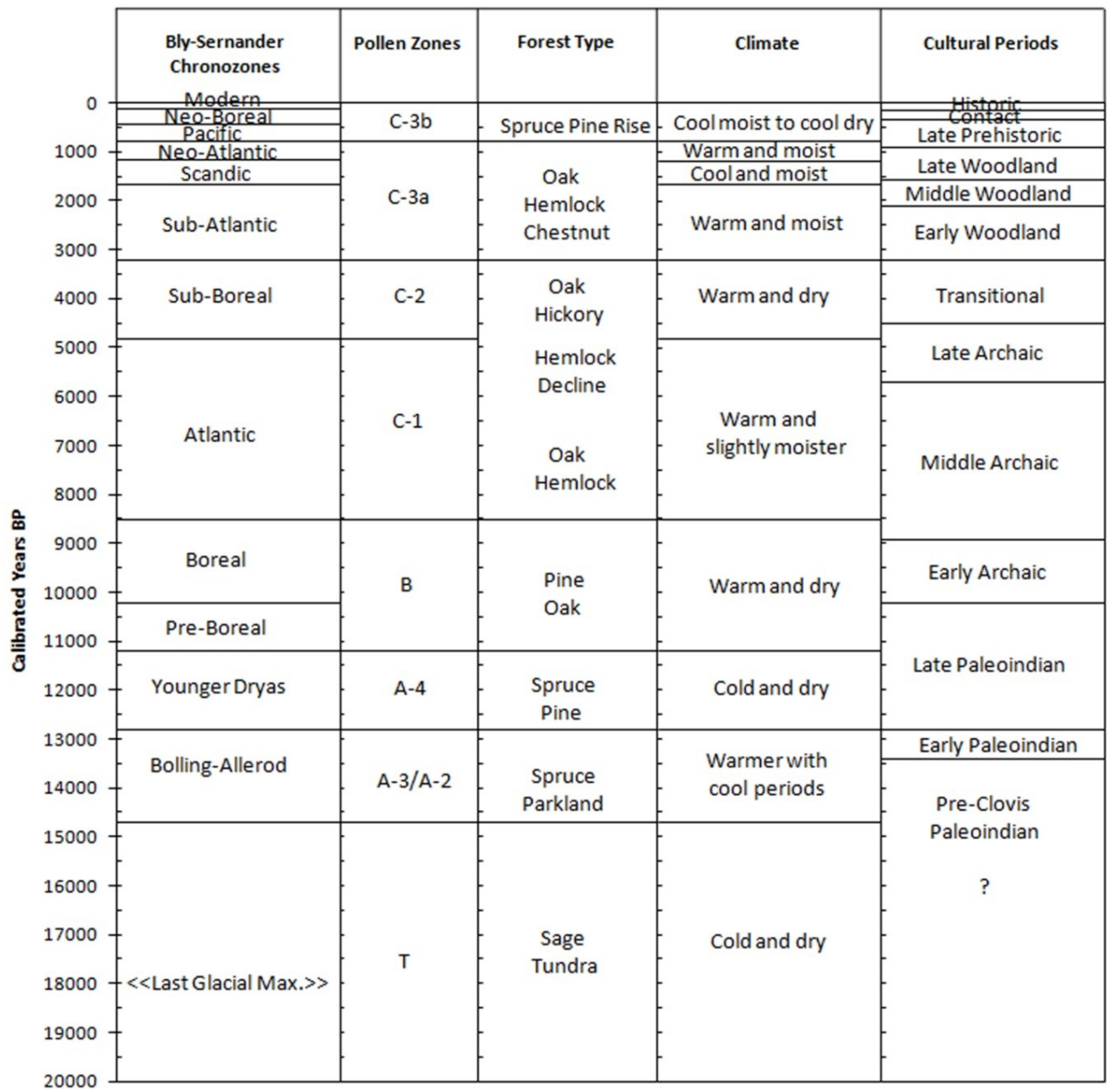

Figure 12. Time plot showing paleoenvironmental trends and cultural periods, after Vento et al. 2008 and Stitler et al. (2010). Ages in Cal yr BP compiled from Haynes (2008); Ellis et al. (2004); Wood (1976); and Schledermann (1976).

2.4 Trajectories of Buried Soils

Changes in climate and vegetation influence the geologic processes that govern the accumulation of sediment and the formation of soil. Over the past 20,000 years, alluvial terraces and colluvial footslope deposits have generally aggraded over time, but not without episodes of instability and degradation. Periods of instability are characterized by increased rates of erosion and deposition, while periods of stability are marked by soil formation due to decreased erosion and deposition. Vento et al. (2008) posit that sequences of buried soil A horizons found within river terraces across the mid-Atlantic region can, with caution, be used as allostratigraphic units that chronostratigraphically correlate to other buried A horizons across a river basin and possibly between river basins. Case studies for the Ohio, Susquehanna, and Delaware River basins provide examples in which paleosols and lithostratigraphic discontinuities have been radiometrically dated and correlated to specific climatic episodes and cultural periods (Vento et al. 2008; Schuldenrein and Vento 2010; Schuldenrein 2003; Stitler et al. 2010; Foss 1991). Within thick sequences of Holocene alluvial sediment, buried soil A horizons are often associated with strata dating to the late Boreal, mid and late Atlantic, sub-Atlantic, and neo-Atlantic climatic episodes. During these climactic episodes, floodplain stability and soil formation are attributed to reduced rates of overbank discharge and less aggressive slope erosion.

In mid-continent North America, Bettis (2003) found similar region-wide patterns in sedimentation and soil formation within colluvial slopes and alluvial fans. Cycles of aggregation and stability produced a pattern of soil stratigraphy. Major episodes of deposition occurred from 8500 to 6500 yr BP, 6000 to 4000 yr BP, and 3000 to 2000 yr BP. Bracketing these periods of increased erosion and deposition are episodes of landform stability and soil formation dating to about 10,000, 8500, 6500, 4100, and 2500 yr BP. Soil formation was strongest around 6500 and 2500 yr BP with corresponding soils that exhibit A-Bw or A-Bt horizons. Weaker soil-forming cycles typically produced A-C soil profiles. The soil formation patterns described by Bettis (2003) are similar to those described for Pennsylvania, but vary somewhat in chronology, possibly due to geographic variations in paleoclimates between the mid-continental and mid-Atlantic regions.

Many alluvial soils lack buried A horizons. Former surfaces within the soil profile most certainly contained A horizons, but these A horizons were not preserved after burial. Holliday (2004) recognizes sets of geologic processes that can lead to three differing trajectories of soil burial.

1. Rapid burial that leaves a complete soil profile preserved under younger sediment.
2. Erosion before burial, resulting in a truncated soil profile preserved under younger sediments.
3. Slow burial that allows pedogenesis to keep pace with sedimentation.

Under the first scenario, younger sediment encapsulates the buried A horizon (Figure 13). The thicker the overlying new sediment, the more isolated the buried A horizon is from continued soil weathering processes. Rapid and deep burial favor buried A horizon preservation. However, soil organic matter (SOM) is one of the least stable soil constituents, and in time, it can be leached from the profile by post-burial processes (Schaetzl and Anderson 2005; Birkeland 1999).

Holliday's (2004) second trajectory accounts for processes that can remove the surface horizons and place new sediment directly onto the eroded surface of the B horizon. A and E horizons tend to be more friable and less well consolidated than underlying B horizons, thus making them more susceptible to removal during episodes of surface erosion. This is especially true for well-consolidated Bt horizons that resist erosion. Very abrupt horizon boundaries and lithologic discontinuities may be the best indicators of truncated and buried soils.

The third possibility results in cumulative soil horizons in which the A and B horizons become over-thickened as the horizon boundaries move proportionally with the accumulation of new sediment (Figure 11). If the accumulation of new sediment outpaces the leaching of the organic matter, then the A horizon may become overthickened. However, in strongly acidic soils, leaching of organic matter and pedologic weathering at the bottom of the A horizon may offset the accumulation of sediment and new organic matter at the top of the A horizon. In this case, the underlying B horizon upbuilds and becomes over-thickened. As SOM at the bottom of the A horizon leaches away, the residual sediment succumbs to soil weathering processes and becomes welded into the upper portion of the underlying B horizon. Meanwhile, as fresh sediment accumulates on the surface, new SOM is incorporated into the top of the A horizon. The A horizon essentially moves upward, maintaining its thickness with the slow accumulation of sediment, while the underlying B horizon becomes thicker.

2.5 Classification of Landforms

T00 Scour Zone

Scour zones are low areas within the active floodplain that are usually inundated annually but are generally higher than the active stream channel. Scour zones are typically narrow, discontinuous stretches found along the insides of meanders. These areas are relatively low in height above the stream and often support only fast-growing herbaceous vegetation and shrubs. Scour zone surfaces usually slope toward the stream channel or, in areas where they are the widest, exhibit low bars and swales formed in sand and gravel. Sediments within scour zones are composed of lateral alluvial deposits of sand and gravel with minor accumulations of vertical deposits within swales. These lateral deposits often represent areas where new or incipient floodplains are forming. Sediments within scour zones represent recent deposition and have no potential for containing intact cultural deposits.

T0 Floodplain

T-0 surfaces represent active floodplains. Floodplains are defined as alluvial landforms that are usually inundated by overbank flooding every few years on average (Wolman and Leopold 1957). These surfaces are composed of vertically accreted alluvial sediments that were deposited by reoccurring overbank flood events. Floodplains are often longitudinally intermittent landforms along Pennsylvania's streams and are typically best developed along the inside of meanders. T0 floodplains are usually higher above the stream than adjacent scour zones. Levee bars along the proximal portions of floodplains typically delineate the floodplain along adjacent, lower T00 surfaces. Floodplain wetlands or back swamps are common in distal portions of the floodplain and may show evidence of former back channels or sloughs that have become infilled with fine overbank flood deposits.

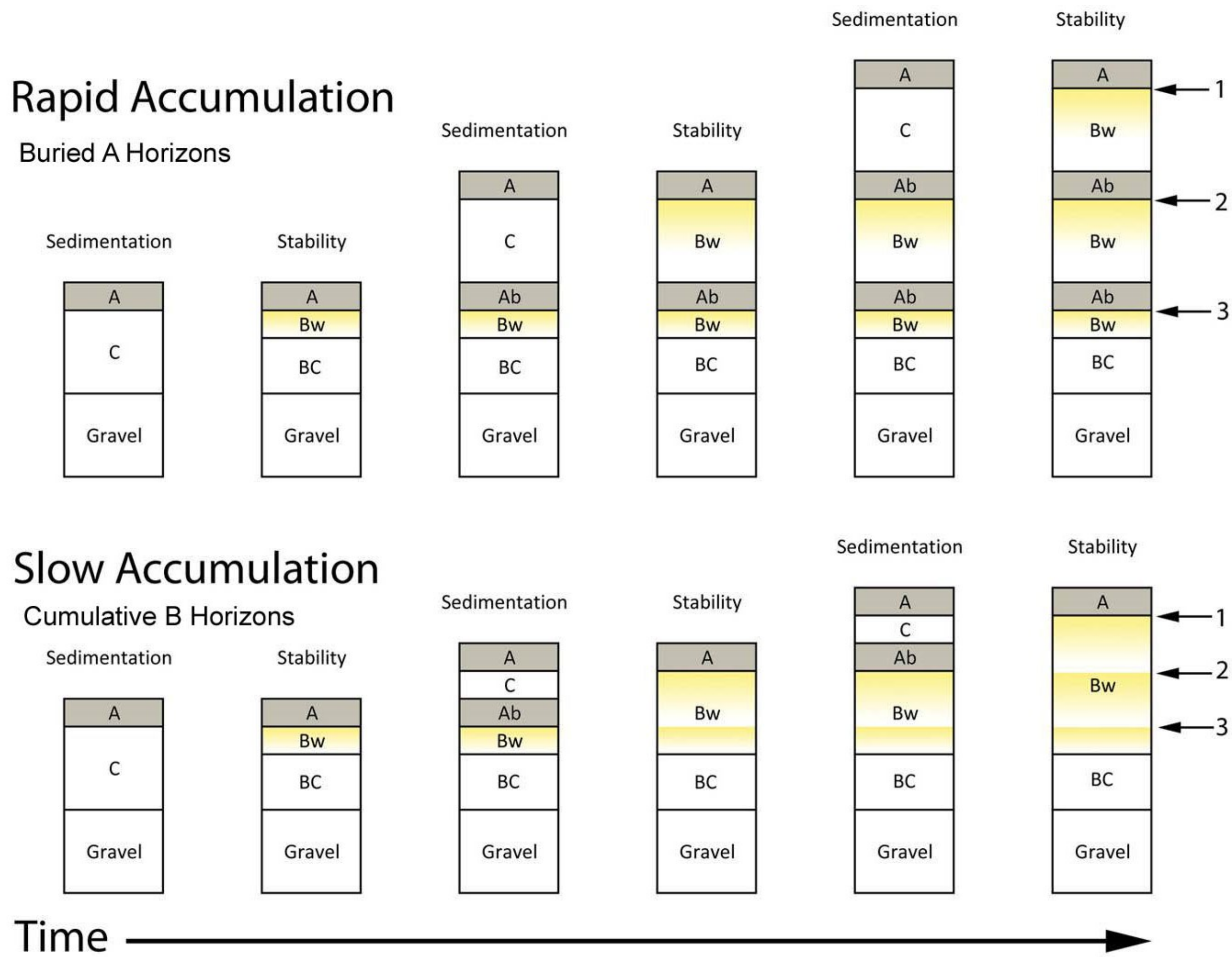

Figure 13. Chart showing two idealized trajectories of soil profile development in alluvial settings.

T0 floodplains are complex landforms that are still under construction. Along many of Pennsylvania's streams, they are often unpaired terraces that form through the combined processes of channel entrenchment and lateral channel migration. Their construction is time-transgressive, and their surfaces exhibit a downstream gradient that exceeds the gradient of the stream channel. Higher portions of the floodplain tend to be in upstream positions and represent more mature surfaces that experience longer flood recurrence intervals. Downstream portions tend to be lower and often exhibit sequences of more recent point bar formation.

T1 Terrace

T1 terraces are represented by alluvial surfaces that are notably higher than the active floodplain. They are old floodplains that have been partially or wholly removed from new overbank flooding as a result of stream channel incision. Structurally, T1 terraces may differ significantly from the lower floodplain, as they were formed during times when drainage-wide vegetation, climate, and rates of erosion may have differed from today. The underlying channel lag deposit within a T1 terrace is often higher in elevation than the basal gravels within the lower

T0 floodplain. Older terraces in Pennsylvania often exhibit more condensed soil profiles as compared to younger floodplains along the same stream segment.

T2 Terrace

T2 Terraces are essentially old floodplains that are higher and older than adjacent T1 terraces. Older terraces are sequentially numbered in order of height above the stream, T1, T2, T3, etc. Along streams that received influxes of glacial melt water, the highest and oldest recognizable terrace is often composed of glacial outwash gravel. Less common, older terraces with highly eroded surfaces can be identified along valley walls. Described as "old alluvium" in older county soil survey books, many of these older terraces pre-date the Wisconsinan glaciation. Soils in pre-Wisconsinan terraces usually contain argillic (Bt) and fragic (Bx) horizons.

Alluvial Fan

Alluvial fans form along smaller tributary streams where the higher gradient of the tributary stream rapidly transitions into the lower gradient setting of the larger river valley. As the gradient decreases, the stream is no longer competent enough to carry its load of sediment and gravel. Over time, the accumulation of sediment forces the stream to break out into areas that are less obstructed, and the channel alters its course. This shifting of the stream channel combined with the buildup of coarser materials at the fan axis creates the characteristic form of the alluvial fan. In Pennsylvania, alluvial fans are not uncommon, but they may be difficult to recognize without the aid of high-resolution elevation maps. Few exhibit the classic delta shape associated with fans found in drier climates and most are simply classified as alluvial terraces.

Little is known about the timing of alluvial fan development in Pennsylvania. In a detailed study of alluvial fans in the mid-continental United States, Bettis (2003) found that there were two major episodes of fan and slope building, occurring at 8500-6500 and 6000-2000 yr B.P. Late Holocene shifts in feeder stream channels removed earlier deposited sediments within the fan apex and mid-section, which created a complex series of cut-and-fill, fan-trench sequences. The climate conditions that controlled fan development in the mid-west may not be directly analogous to the conditions within western Pennsylvania.

Colluvium

Colluvium is sediment and rock fragments that accumulate along the base of gentle slopes and hillsides by rain wash, sheetwash, downslope creep, and other processes of downslope movement under the influence of gravity (Jackson1997:127; Schaetzl and Anderson 2005:212). In Pennsylvania, colluvium is commonly found as a depositional wedge or apron along foot slopes and toe slopes. Sediments that accumulate at the foot of exposed rock cliffs and within rockshelters are also colluvial, including sediments formed from grain-by-grain attrition of the rock face or overhang. Accumulation rates are typically slow and conducive to the formation of cumulative B horizons. Cumulative A horizons can form where recent deposition has been more rapid, often as a result of sheetwash erosion in cultivated fields or forest slopes denuded of vegetation. Although less common, rapid and thick accumulations of material carried downslope by slumps and debris flows can result in buried A horizons. Colluvial sediments may have a potential for stratified cultural deposits if episodes of deposition persisted during the Late Pleistocene through the Holocene.

Outwash Terrace

Outwash terraces are alluvial surfaces formed in association with glaciers (glaciofluvial). Glaciers discharge large and highly variable pulses of glacial meltwater. Accompanying the meltwater are large volumes of poorly sorted glacially transported materials. The fluvial action of the water tends to winnow out finer clay and silts leaving behind the coarser sand and gravel called outwash. The injection of outwash into a river valley can produce long valley-filling gravel trains that extend tens of miles downstream from the glacial front (Bloom 1998:387). Gravel trains can fill a valley with hundreds of feet of coarse material, often with pockets of fine-grained glaciolacustrine deposits trapped by temporary pro-glacial lakes. Remnants of glacial outwash and gravel trains are found in all of the major river valleys in Pennsylvania that received glacial meltwater during the Pleistocene. Many of these outwash terraces form the underlying structural core of alluvial terraces that form the modern valley floor.

Kame Terrace

Kame Terraces are glaciaofluvial landforms that form in direct association with a glacial ice mass. A kame is a conical mound hill composed of stratified glacial drift that was deposited through an opening in an ice block. Stratified glacial drift is created by the movement of water over, under, and between blocks of ice. Although stratified by the action of moving water, these deposits are usually less well sorted than outwash, but better sorted than glacial till. Kame terraces form between the ice mass and the valley wall (Bloom 1998:386), often as complex arrays of kames and stratified drift along the sides of valleys. Locally, the surfaces of kame terraces undulate, but at larger scales, they may exhibit concordant elevations above the valley floor. Kame terraces form in direct contact with the glacier and do not exist within valleys downstream of the glacial maximum.

2.6 Terraces along the Susquehanna River

Peltier (1949) studied the alluvial and glaciofluvial landforms found within the Susquehanna River Valley. Eight or more terraces were identified, four of which are Wisconsinan age, the Olean terrace, the Binghamton terrace, the Valley Heads terrace, and the Mankato terrace. Outwash deposits underlying the Olean, Binghamton, and Valley Heads terraces have been correlated to their respective glacial sub-stages. Binghamton till has been mapped across western New York and northwestern Pennsylvania. The Olean till is prominent across northeastern Pennsylvania. Till and moraine deposits associated with the Valley Heads substage occur across New York but are absent in Pennsylvania, representing a late stage of the retreating Wisconsinan glacier. The glacial ice front during the Mankato substage was too far north to contribute outwash gravel into the Susquehanna River Valley. Peltier (1949:80) proposed that the formation of the Mankato terrace is related to the river's response to periglacial climatic conditions during the Mankato substage.

Miller et al. (2004) identified four Susquehanna River terraces in their report on archaeological excavations along SR 11 in Juniata and Perry Counties, Pennsylvania. The lowest terrace (T0) represents recent alluvial deposits with no potential for archeological resources. The Port Huron/Valley Heads (T1/T1A) terrace rests 3.0 m (10 ft) above the river and contains Holocene-age sediments with a high potential for buried pre-contact cultural deposits. At a height of 9 m (30 ft) above the river, the Binghamton (T2) terrace received low rates of Holocene overbank sediments. Pre-contact artifacts occur in the plow zone and to a depth of approximately 40 cm (14 in) below the plow zone. The Olean (T3) terrace is the oldest and highest at 12 m (40 ft) above the river channel. Artifacts found on the Olean terrace are in the plow zone or immediately under the plow zone.

Stacked sequences of A and B horizons are found in Holocene-age sediments along the larger rivers in Pennsylvania. The underlying gravels were likely deposited in the Late Pleistocene. Vento et al. (2008) attribute these buried A horizons to prolonged reduced flood intensity and floodplain stability that correlate to specific climatic episodes. These buried A horizons are best expressed in the Port Huron/Valley Heads terrace near the bank edge or where over-bank deposits are thickest. Correlations occur in the Neo-Atlantic (1100 – 750 BP), Sub-Atlantic (3000 – 1700 BP), Atlantic (4500 BP), and Boreal (8000 BP) climatic episodes. (Vento et al. 2008) propose that these correlations between buried A horizons and climatic episodes can be traced across the major river basins and between the Ohio, Susquehanna, and Delaware basins.

The Memorial Park Site (36CN164) along the West Branch of the Susquehanna River near Lock Haven resides on the Port Huron terrace, 4 m above the river. Seven buried soils were identified in excavation blocks. Mean resident time (MRT) dates ranged from 1470 BP in the surface soil to 7090 BP in the deepest buried A. Excavations were completed to a depth of 300 cm and artifacts were recovered to a depth of 250 cm (Hart 1993:25,111-112).

The Wallis Site (36PE16) along the Susquehanna River near Liverpool rests on a Port Huron terrace 2.5-3.5 m above the river. Soils extended to a depth of at least 2 m. Artifacts contained in the Bw horizons of the surface sola dated to the Middle and Early Archaic periods. The deepest sola contained a sequence of 2AB-C2-C2g-2C3 horizons resting upon gravel. Paleoindian period artifacts were recovered from the C horizon sediments resting immediately above basal gravel (Miller et al. 2007).

A geomorphological assessment was completed along the North Branch of the Susquehanna River in the City of West Pittston. The study area was on an alluvial terrace that rests 5.5 to 6.4 m above the river. Hand auger borings recorded a soil profile with three sola extending to a depth of 410 cm. A 2BA horizon at 110 cm to 130 cm represents a former stable surface. The absence of a buried A horizon at the top of the third solum (3Bw1) indicated a scour and redeposition event. Lateral deposits of loose loamy sand (3C) occurred from 340 to 410 cm (Sams 2021).

3.0 METHODOLOGY

3.1 Field Methods for the Geomorphological Study

Background research included a review of pertinent geological literature, soil survey maps, and historic USGS topographical maps. Environmental spatial data was collected and assembled into a geodatabase. Geospatial data sets included recent and historic aerial imagery, LiDAR derived digital elevation models, and soil survey data. Landform maps were prepared to help guide the field investigation.

A hydraulic excavator provided by Bishop Brothers Construction Co. was used to excavate two trenches into alluvial deposits on the southwest side of Tutelow Creek. In addition, 14 shovel test pits (STPs) were excavated at 15-meter intervals across the alluvial deposits. On the northeast side of Tutelow Creek, one hand excavated shovel test pit (STP) was excavated to a depth of one meter in alluvial deposits. Below one meter, a 3-1/4-inch hand auger was used to sample soils to the depth of basal gravel. Wall profiles were measured, and field descriptions of soils and sediments were recorded. Photographs of selected STPs and each trench were taken with a Canon EOS Rebel XS digital camera and a Motorola One 5G UW Ace phone camera. GPS coordinates for each sample were captured using MapIt GIS software 7.8.0 and a Juniper Systems Geode GNS3 submeter GNSS receiver. Maps showing the results of the investigation were prepared using ESRI ArcGIS 10.6 software.

3.2 Field Methods for the Archaeological Survey

Field methods follow PHMC (2021) Guidelines for Archaeological Investigations in Pennsylvania. The portion of the Minard Mine LOD with slopes less than 15% encompasses approximately one acre. Within this one-acre area, STPs were excavated at 15-m intervals. All excavated soil was screened through ¼" hardware cloth. All STP results and soil profiles were recorded on STP forms. Pedestrian renaissance was conducted along the steep slopes in the forested areas designated as low potential for pre-contact archaeological sites.

Photographs were taken to document the project area and ground conditions. Photographs were captured using a Canon Rebel XS digital SLR camera and a Motorola One 5G UW Ace phone camera. Artifacts and collected samples received a unique Field Specimen number (FS#) that represents the provenience from which the material was removed. A field inventory of the collected materials was maintained. GPS locations were captured with a Juniper Systems Geode GNS3 submeter GNSS receiver and logged using MapIt GIS software 7.8.0. Fieldwork began on March 27, 2024, and was concluded on March 28, 2024. Maps showing the results of the investigation were prepared using ESRI ArcGIS 10.6 software.

4.0 RESULTS

4.1 GIS Analysis

A pre-field landform analysis was generated using high-resolution LiDAR elevation data collected by the US Geological Survey in 2019. A slope analysis found that 98% of the 53-acre LOD contains slopes greater than 15% (Figure 14). More than half of the LOD contains slopes greater than 40%. Linear areas with slopes greater than 80% were interpreted as potential rock ledges. A one-acre area located along Tutelow Creek in the northernmost portion of the LOD was the only terrain containing slopes less than 15%. This area encompasses a delta-shaped alluvial fan deposit that issues from an intermittent stream hollow and spreads across the footslopes and stream terraces along the southwest side of Tutelow Creek (Figure 15). On the northeast side of Tutelow Creek, a small portion of T0 floodplain resides within the LOD. This floodplain rests 4.7 to 5.0 m above the Chemung River, but only 1.0 to 1.3 m above Tutelow Creek. Subsurface testing for both the geomorphological study and the archaeological survey was focused on the alluvial fan and the T0 floodplain.

An examination of historic aerial photographs found that the entire LOD remained forested for more than 100 years (USDA 1939a, 1939b). The area was never cultivated due to the steep slopes and rubbly soils. The landscape patterns show no evidence of clearing or fencing for pastures and no indications of buildings or farmsteads. No previously recorded archaeological sites were found within the PA-SHARE database. The remnants of an early nineteenth-century canal basin are visible in the elevation maps, but the canal structure rests on the alluvial plain outside of the Minard Mine LOD.

4.2 Geomorphology Results

Two trenches were excavated within the alluvial fan deposit (Figure 16). Trench 1 (TR-1) was placed along the edge of the LOD near the center of the fan, approximately 20 m from Tutelow Creek and 18 m from the intermittent stream. Cobbles and pebbles were present on the surface. The trench was excavated to a depth of 120 cm. Dense gravel was encountered in all levels, but the cobbles became large below 90 cm (Figure 17).

Trench 1 (TR-1)

OA - 0 to 5 cm; very gravelly silt loam, black (10YR2/1), loose
AC - 5 to 45 cm; very gravelly silt loam, brown (10YR4/3), loose
BC - 45 to 90 cm; very gravelly loam, dark yellowish brown (10YR4/4), loose
C – 90 to 120 cm; very gravelly loam, dark yellowish brown (10YR4/4), loose

Trench 2 (TR-2) was placed 18 m northwest of Trench 1 and lower on the alluvial fan. Similar to Trench 1, cobbles, pebbles, and channers comprised more than 50% of the soil profile with loose silt loam filling the voids between individual stones (Figure 18). Excavation was discontinued at 95 cm below the ground surface where a coarser gravel was found in gleyed clay loam.

Trench 2 (TR-2)

AC - 0 to 41 cm; very gravelly silt loam, dark brown (10YR3/3), loose
BC - 41 to 95 cm; very gravelly silt loam, dark yellowish brown (10YR4/4), loose
BCg - 95+ cm; very gravelly/channery clay loam, mottled gray (2.5Y5/1) and strong brown (7.5YR4/6), weak subangular blocky

Fifteen STPs were plotted across the alluvial fan. STP 1 exposed 24 cm of alluvial silt loam resting over a gravelly C horizon containing loose pebbles, granules, and silt. Dense coarse gravel was absent from the A horizon. This soil profile may represent a transition from the alluvial fan to the overbank deposits of Tutelow Creek. The height of this surface above Tutelow Creek suggests the presence of a T1 terrace at 1.8 m above the creek.

Shovel Test Pit 1 (STP 1)

AC - 0 to 24 cm; silt loam, dark brown (10YR3/3), loose
BC - 24 to 40 cm; very gravelly silt loam, dark yellowish brown (10YR4/4), loose

STP 4 was not excavated because it landed on the slope of the stream channel. STP 15 was not excavated because it landed on a logging road that was cut from the adjacent footslope. A tree throw along the footslope near STP 15 revealed the underlying accumulation of sandstone channers (Figure 19). A similar surface accumulation of sandstone channers was noted along the footslope near STP 3. The remaining STPs were placed across the alluvial fan. Excavation revealed accumulations of dense gravel from the surface to the depth at which the excavation was ended (Figure 20). Cobbles, pebbles, and channers were found on the surface across most of the fan deposits. The area of the alluvial fan holds no potential for deeply buried cultural deposits. Only the surface soil horizon has the potential to contain cultural deposits.

STP 16 was placed on the T0 floodplain on the northeast side of Tutelow Creek. The upper 56 cm of soil represents a relatively recent accumulation of overbank sediment. The underlying Bw horizon exhibits some degree of stability, but its age is uncertain. The Bg horizon represents the accumulation of sediment within the context of a wet stream bottom. Soils on the T0 floodplain have a low potential for cultural deposits to a depth of 85 cm.

Shovel Test Pit 16 (STP 16)

OA - 0 to 5 cm; silt loam, dark brown (10YR3/3), very friable
BC - 5 to 56 cm; silt loam, dark brown (10YR3/3), very friable, massive
Bw - 56 to 85 cm; loam, dark yellowish brown (10YR4/4), very friable, massive
Bg – 85 to 132 cm; loam, gray (2.5YR2/1), very friable, weak subangular blocky
Auger refused by gravel at 132 cm, stream channel lag

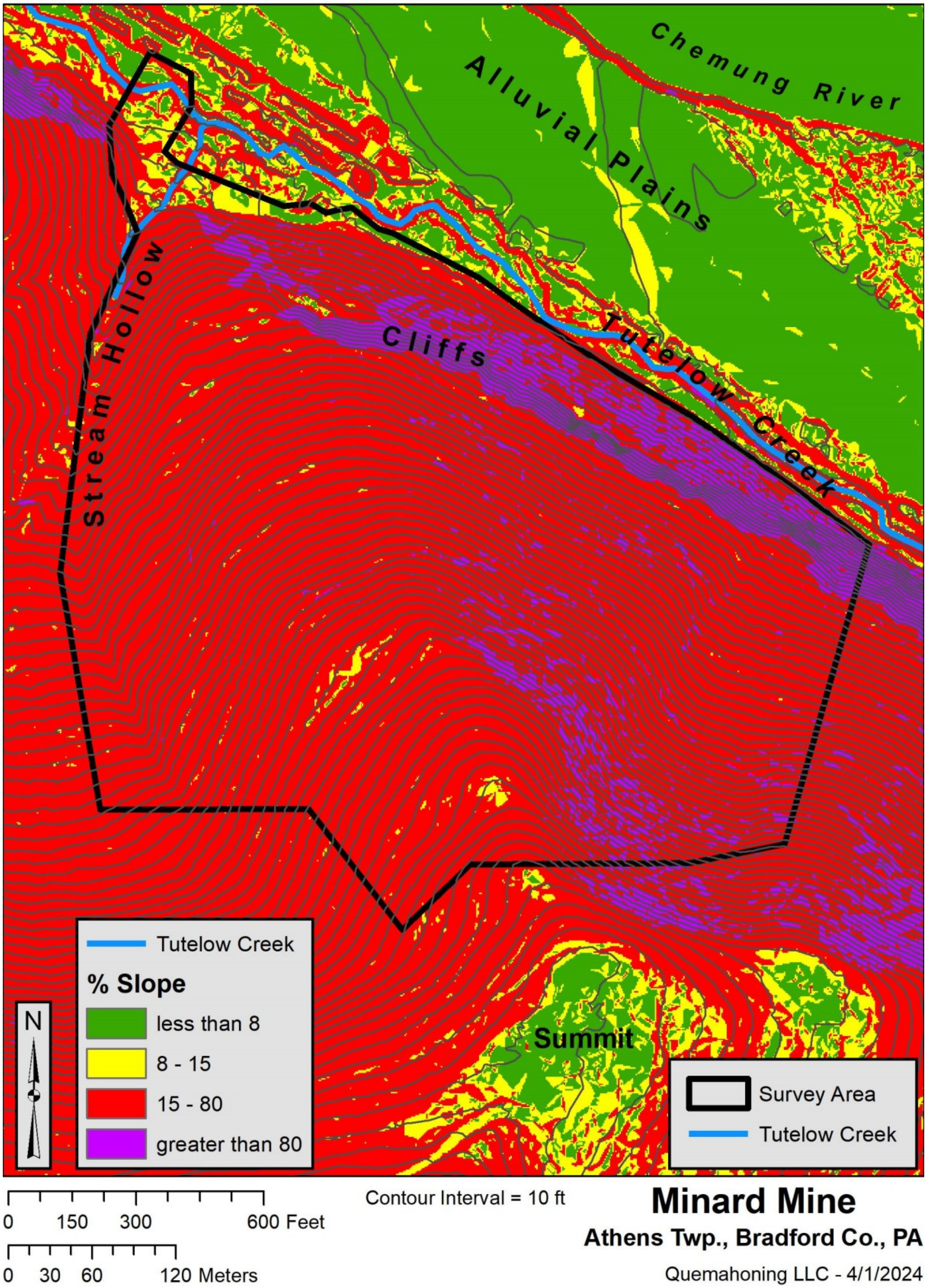

Figure 14. Map showing important landforms and landscape features revealed by elevation contours and the slope model. USGS (2019).

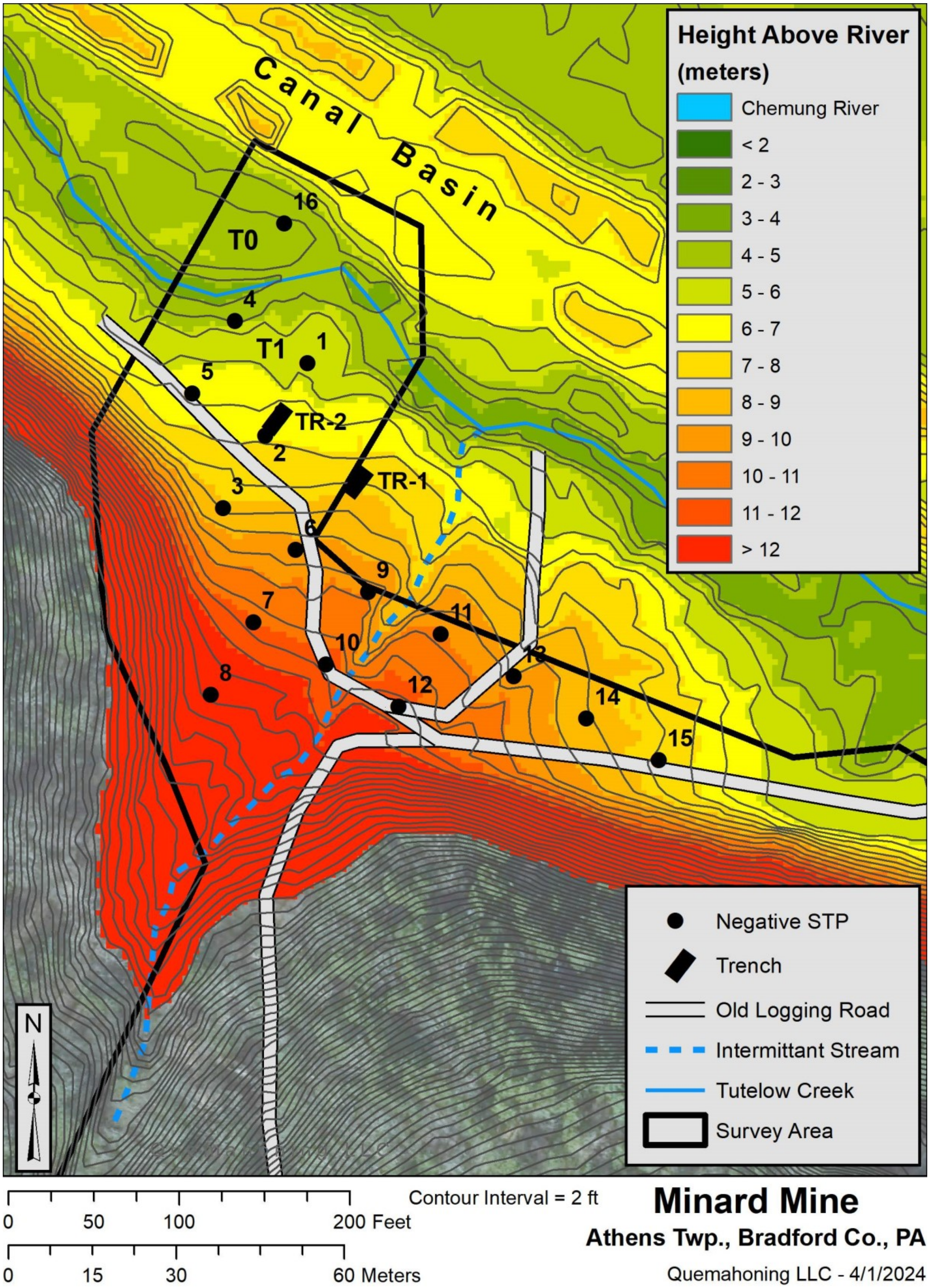

Figure 15. Map showing the ground height above the Chemung River, trench locations, and STP locations. PEMA (2018), USGS (2019).

Figure 16. The hydraulic excavator at Trench 1.


Figure 17. The southwest wall profile of Trench 1.

Figure 18. The southeast wall profile of Trench 2.

Figure 19. An accumulation of sandstone channers along the foot slope near STP 15, looking south.

Figure 20. Gravel excavated from the upper 15 cm of STP 9.

4.2 Phase I Archaeological Results

Fourteen STPs were excavated at 15-meter intervals across the alluvial fan and along Tutelow Creek. All fourteen STPs tested negative for cultural artifacts and deposits. Thirteen of the STPs were placed across the alluvial fan along the southwest side of Tutelow Creek. Coarse gravel was found in all thirteen STPs at a depth of 24 cm or less. One STP was excavated on the T0 floodplain along the northeast side of Tutelow Creek to a depth of 100 cm. Cliffs along the steep backslopes were examined for potential rockshelters. No rockshelters were found. A pedestrian reconnaissance survey was conducted across the remaining mountain slopes as much as the terrain permitted. Many of the slopes were too steep and scree-laden to safely traverse. Even segments of old logging roads were difficult to climb. No archaeological sites were found within the Minard Mine LOD.

Although located outside of the LOD, it should be noted that the floor of the canal basin has been graded for use as an electric power line right-of-way and portions of the basin walls lying adjacent to the Minard Min LOD have been removed to facilitate surface drainage (Figure 21).

Figure 21. View looking northwest down the center of the canal basin and electric power line.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The geomorphological study identified three alluvial landforms within the Minard Mine limits of disturbance (LOD), a delta-shaped alluvial fan issuing from an intermittent stream hollow, a T0 floodplain adjacent to the northeast side of Tutelow Creek, and a T1 terrace adjacent to the southwest side of Tutelow Creek. The alluvial fan is comprised of coarse gravel that represents high-energy deposition. The fan deposit built up over time as the stream swept back and forth across the surface while depositing fresh gravel bars and scouring new channels. There is no potential for deeply buried archaeological sites. Only the present-day surface has the potential for preserved archaeological deposits. Any artifacts or features that may have been present on buried surfaces would have been scoured and scattered by the high-energy current before the deposition of the overlying gravel. These findings permitted the use of standard STPs for archaeological testing across the alluvial fan.

Soil found within the T0 floodplain along the northeast side of Tutelow Creek continued to a depth of 132 cm. However, a gleyed B horizon was encountered at a depth of 85 cm which indicates a wet bottom land depositional setting that would not have been suitable for habitation sites. Archaeological testing on the T0 floodplain required excavation to a minimum depth of 85 cm, however, the STP was completed to a depth of 100 cm. Within the T1 terrace on the southwest side of Tutelow Creek, gravel-free silt loam alluvium was found to a depth of 24 cm and overlying a gravelly C horizon. Archaeological testing on the T1 terrace required excavation to a minimum of 24 cm, however, STP-1 was completed to a depth of 40 cm.

The geomorphological findings permitted the use of standard STPs for archaeological testing. Deep archaeological testing was not needed for any of the landforms found within the Minard Mine LOD. Fourteen STPs were excavated across the alluvial fan and stream deposits along Tutelow Creek. No cultural artifacts or features were found. An examination of rockledges overlooking Tutelow Creek found no evidence of rockshelters. No archaeological sites were found within the Minard Mine LOD. No further archaeological work is recommended.

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