Significance of Increased Precipitation and Drought Conditions from 2020 through 2024

EPCAMR reviewed precipitation data from the National Oceanic and Atmospheric Administration (NOAA) and the National Integrated Drought Information System (NIDIS) website for Luzerne County, PA. By looking back at historical data, EPCAMR was able to get a better understanding of the drought and extreme weather conditions from 2020 through 2024. The resources below help document and quantify historical drought conditions to help inform planning. Two historical drought datasets were explored side by side: the U.S. Drought Monitor (weekly, 2000–present) and the Standardized Precipitation Index (SPI) (monthly, 1895–present). The sources of the data are from the NOAA, USDA, and National Drought Mitigation Center, with the latest available data from July 2nd, 2024.

Luzerne County, including the Wyoming Valley, experienced a spike in abnormally dry conditions beginning in July 2020 and an abnormally dry period from September through December 2020. The period of April 2021 through July 2021 also experienced abnormally dry conditions as well as the period from January through March 2022. July through September 2022 did as well. April and May of 2023 saw some abnormally dry conditions as did July and August 2023 along with a period of moderate drought conditions. July 2024 is just starting to see abnormally dry conditions. 51.3% of Luzerne County during the period of January 2020 through July 2nd, 2024, experienced abnormally dry conditions. 3.8% of Luzerne County during the same period experienced moderately dry conditions.

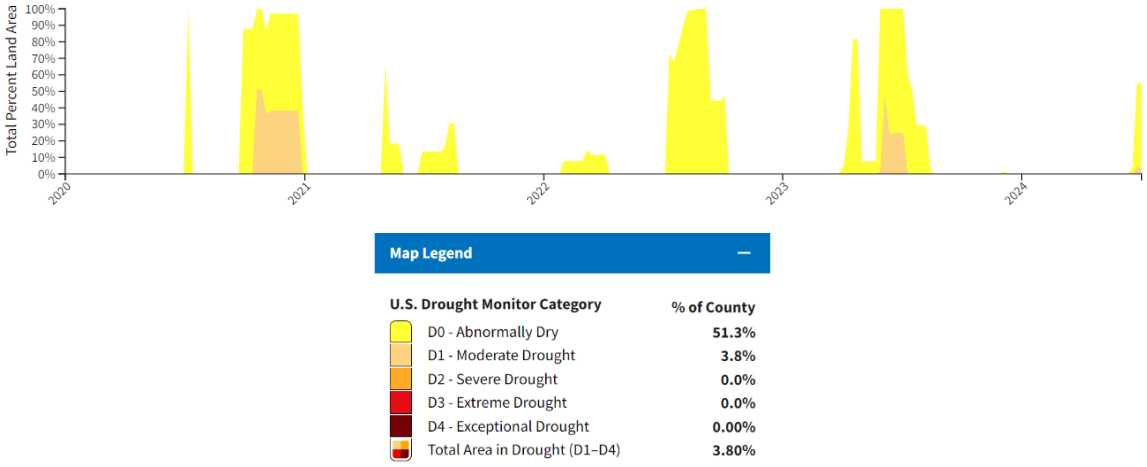

Figure 1. Chart of Luzerne County Drought Conditions from 2020-2024

Luzerne County, including the Wyoming Valley, experienced a moderately wet and abnormally wet period of precipitation beginning in January 2020 through April 2020 and an abnormally wet period in May 2020. The period of June 2021 through July 2022 saw an exceptionally wet and extremely wet period of precipitation. October through December 2022 was moderately and abnormally wet. April through June of 2023 saw some abnormally wet periods of precipitation. July 2023 through July 2nd, 2024, saw periods of moderately wet, extremely wet, and exceptionally wet conditions. 90.3% of Luzerne County during the period of January 2020 through July 2nd, 2024, experienced exceptionally wet precipitation. 9.2 % of Luzerne County during the same period experienced extremely wet precipitation and 0.2% of Luzerne County experienced severely wet precipitation.

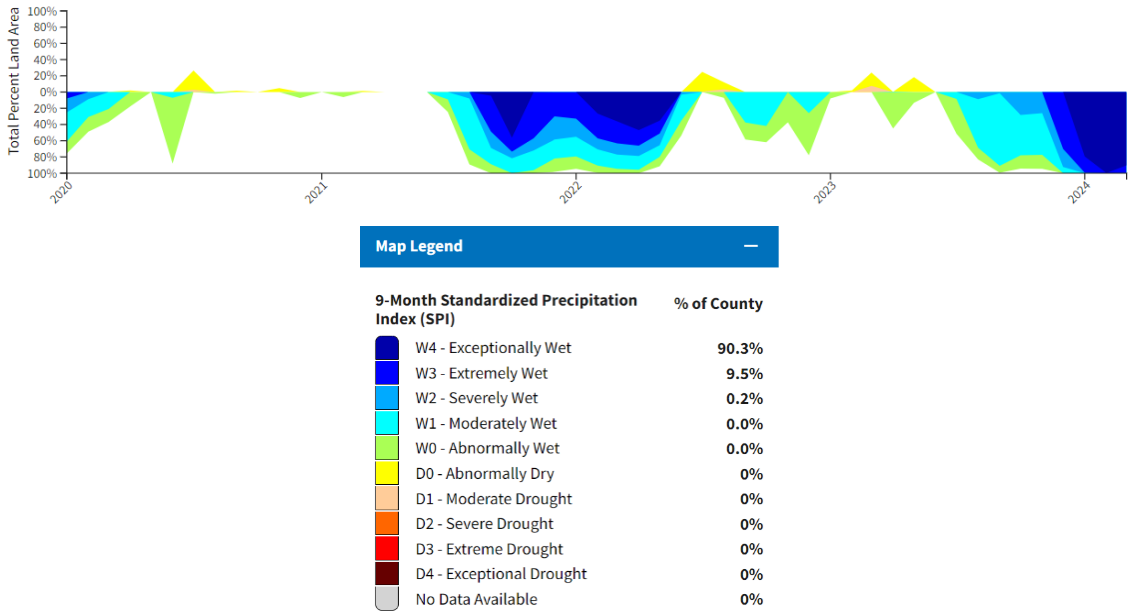

Figure 2. 9-Month Standard Precipitation Index (SPI) Conditions, Luzerne County, PA 2020-2024

The seasonal fluctuations in the precipitation events affect the headwater tributaries and streams within the Southern Wyoming Valley influence whether some of the streams were flowing or not. Because of the previous disturbances to the land from the extraction of Anthracite coal and the relocation and/or complete excavation and destruction of the original stream channels, surface waters, and precipitation events can often be dry or ephemeral throughout the year. While during storm events, the streams experience a spike in the flow and velocity of the water moving downstream, it is often short-lived, and episodic. The water during those events continues to be lost and infiltrates into the already fractured bedrock or stream channels allowing

the precipitation to percolate and migrate down into the subsurface mine spoils or permeable bedrock geology that serves as a conduit of dendritic fractures planes to the underground mine pools. Impacts to all aquatic systems are present in water courses, wetlands, ponds and lakes when surface hydrology is lost frequently from those systems.

Local Wyoming Valley meteorologist Mark Margavage, who runs a Weather Discussion Page on Facebook, provided EPCAMR with the Total Monthly Precipitation Data from (ThreadEx) for the Avoca Area that he was able to generate from a subscription he has with the Applied Climate Information System (ACIS). Figure 3 shows that in September of 2021, the highest amount of precipitation, 10.49" rained down over the area. The Table shows the actual monthly precipitation totals. Figure 4 shows the Total Annual Precipitation from October 2020 through September 2023 indicating a downward trend in rainfall over the area during this period.

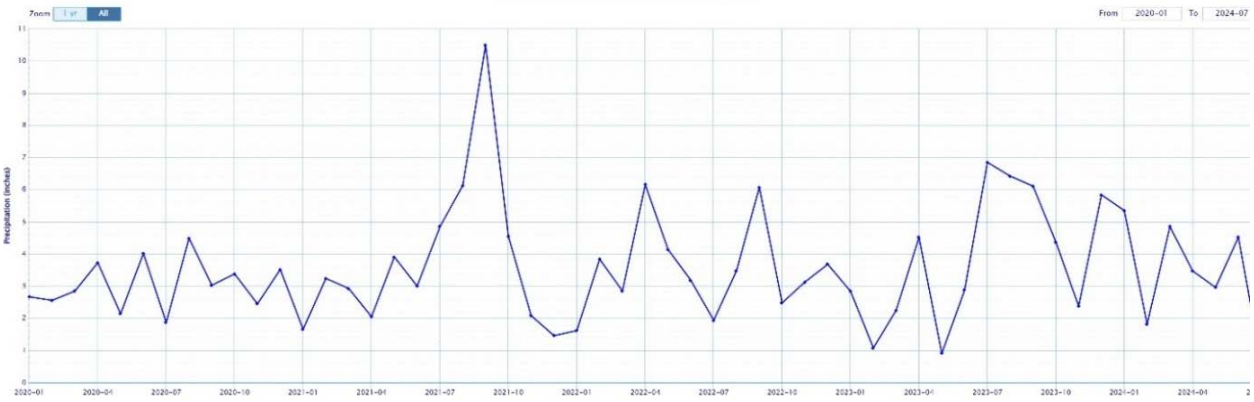

Figure 3. Total Monthly Precipitation from the Avoca Area, Luzerne County, PA from 01-2020 to 07-2024 (ThreadEx). Precipitation on y-axis ranges from 0 to 11 inches.

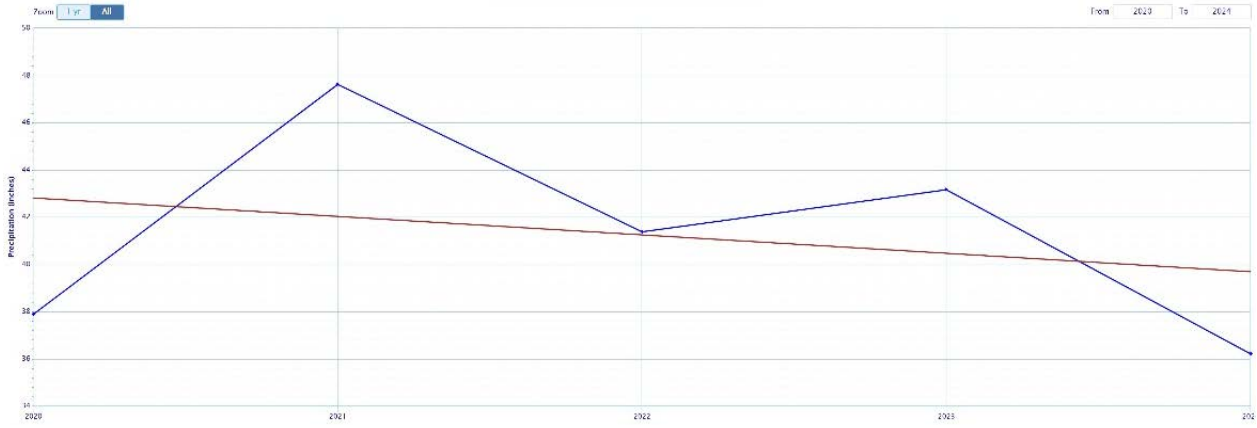

Figure 4. Total Annual Precipitation in the Avoca Area, Luzerne County from 2020-2024 (ThreadEx)

Table 1. Monthly Precipitation in the Avoca Area, Luzerne County from 2020-2024 (ThreadEx)

Year-Month	Total Precipitation
2020-01	2.67
2020-02	2.56
2020-03	2.85
2020-04	3.73
2020-05	2.14
2020-06	4.02
2020-07	1.87
2020-08	4.49
2020-09	3.03
2020-10	3.38
2020-11	2.45
2020-12	3.52
2021-01	1.66
2021-02	3.24
2021-03	2.93
2021-04	2.05
2021-05	3.91
2021-06	3.00
2021-07	4.85
2021-08	6.13
2021-09	10.49
2021-10	4.55
2021-11	2.08
2021-12	1.46
2022-01	1.62
2022-02	3.84
2022-03	2.85
2022-04	6.16
2022-05	4.14
2022-06	3.18
2022-07	1.94
2022-08	3.48
2022-09	6.07
2022-10	2.48
2022-11	3.13
2022-12	3.66
2023-01	2.84
2023-02	1.08
2023-03	2.25
2023-04	4.52
2023-05	0.91
2023-06	2.88
2023-07	6.85
2023-08	6.42
2023-09	6.11
2023-10	4.37
2023-11	2.38
2023-12	5.84
2024-01	5.35
2024-02	1.82
2024-03	4.85
2024-04	3.47
2024-05	2.96
2024-06	4.52

These periodic changes in the temperature conditions and rainfall precipitation events also have an impact on the fishery and macroinvertebrate communities. Temperature graphs of our HOBO data sensors will show the temporal changes throughout the periods that was able to be collected with continuous temperature data from the units throughout several monitoring points in the watersheds within the project area. Macroinvertebrate communities are depleted, less diverse, less in quantity and taxa and kinds, and marginal, at best. The data collected showed that for many of our in-stream water quality monitoring points.

The study also took into consideration that many of the streams that were monitored were being impacted by abandoned mine drainage (AMD) discharges with metals and acidity that could have affected the macroinvertebrate, EBT, and other species viability, resiliency, and ability to thrive in the patches that were identified by the NFWF. The inconsistency in the temperatures and the flow of water are factors that were considered and observed through data collection that has led to not finding an EBT stronghold in the watersheds assessed. The PA Fish & Boat Commission survey from 2012 showed that many of the locations they sampled were dry. The temperature readings charted in the Appendix as hydrographs also indicate the maximum temperature of 70 degrees that EBT can tolerate before experiencing extreme stress during Summer climate. A red line on each of the charts indicates the upper threshold for the EBT species. Since the study is on EBT habitat, it is required to reflect the temperatures that fulfill the species needs.

In reviewing the NOAA National Centers for Environmental Information (NCEIS) Storm Events Database for Luzerne County from January 1, 2020 through July 1, 2024 (1644 days), it was found 111 storm events were reported. Of those, 33 occurred within the NFWF Project Area and contain a detailed event type, event, flood cause, and episode narrative, and general location within the database attached in the Appendix. High winds, flash floods, floods, thunderstorm winds, heavy snow, Winter weather, Winter storms were the most common event types. Aside from the heavy wind periods, most of the other events correlate to temperature fluctuations and temporal changes that we saw in the HOBO Temperature probe data collected and to the snapshot data temperatures and periods of rainfall throughout the course of the entire project period. To further review this data, see the water temperatures measured by HOBO probes with maximum daily air temperature charts in the Appendix.

The year 2020 did bring some abnormal weather to Northeastern PA. Floods, tornadoes, torrential rains, high winds, and some heavy snowfalls all occurred throughout the year. According to the US Environmental Protection Agency, climate change impacts are associated with more frequent and more intense severe weather events. 2020's storms, especially the devastating summer floods, have spurred increased funding in many parts of PA for better storm management systems, flood and wastewater control, and other climate resilience projects. Tropical Storm Isaias hit on August 4th, 2020, with torrential rains.

On December 16th, 2020, a Nor'easter moved slowly up the US Eastern coastline from the afternoon of the 16th through the 17th. The storm system produced very heavy snowfall across parts of Central New York and Northeast Pennsylvania, particularly during the very early morning hours of the 17th. Extreme snowfall rates of 5-6 inches per hour were reported at times in the heaviest parts of the band with 10-20" of snow accumulating over Northeastern PA.

From January 31st, 2021 through February 1st, 2021, another complex long-duration Winter storm system affected Northeast Pennsylvania from around midday January 31st through the early morning of February 3rd. A strong surface low-pressure system developed off the Mid-Atlantic coast during this time and brought moderate to heavy snow to portions of Northeast Pennsylvania. As the storm pulled away, wrap-around moisture brought additional snow to portions of the area with accumulations of 17-24".

Hurricane Ida made landfall in September 2021 as a Category 4 Atlantic hurricane. On March 12th, 2022, the area was hit with 5-9" of snowfall by a low-pressure system that passed through Northeastern PA. The Summer of 2023 saw some strong thunderstorms on June 27th, 2023, and again on September 7th, 2023. To close out the year, on December 18th, 2023, heavy rainfall and snowmelt caused portions of Solomon Creek to flood in areas when a low pressure moved north along the Atlantic Seaboard spreading steady and heavy rain into Northeastern Pennsylvania during the overnight hours. Rainfall amounts of 2-4" were observed along with a considerable amount of melting snow into area rivers and streams. Widespread flash flooding and Susquehanna River flooding occurred during this event. Finally, on January 6th, 2024 and again on February 13th, 2024, the area saw heavy snowfall with accumulations between 4-14" with the first storm and between 4-13" with the second storm.

Significance of ABD & EBT Relationship of the Hydrogeologic Connection from Surface Waters to the Underground Mine Pools in the Wyoming and Southern Wyoming Valley

The EPCAMR Program Manager, Michael Hewitt, was able to provide an example of the significance of the relationship of the hydrogeologic connection from surface waters to the underground mine pools in the Southern Wyoming Valley in the Nanticoke Creek watershed. He highlighted a map from the PA Mine Map Atlas of " Glen Alden & State and Federal Mine Drainage Projects Completed-In Process-Proposed for North Branch Susquehanna River" from 1940. There were several different names for the creeks and tributaries at that time, however, they did show them on the surface. These areas were eventually deep-mined and then surface mined leading not only to the disconnection of many of the tributary streams and their headwaters from the downstream areas, but also to water loss of clean streams into the stripping pits or other abandoned mine features on the landscape within the watersheds that eventually lead to other outlet points where abandoned mine drainage (AMD) would surface and cause mine water pollution to the lower reaches of the majority of the streams in the Wyoming and Southern Wyoming Valley.

Figure 5. PA Mine Map Atlas Map of Glen Alden & State and Federal Mine Drainage Projects Completed-In Process-Proposed for North Branch Susquehanna River in 1940

The evaluation matched up some of the Abatement Plans in the Operation Scarlift Reports for the Wyoming Valley and it looked like some of the "State-Federal" projects on this map made it into the recommendations, specifically, the Newport Creek Abatement Plan (Skelly and Loy, 1974) and Nanticoke, Warrior, and Solomon Creeks Scarlift Report Proposed Abatement Plan (Geo-technical Services, 1975) portions.

Hewitt indicated that the section outlined on the map above for Wadhams Creek in Plymouth on the West Side of the Wyoming Valley was turned into a concrete flume with a collection basin at the bottom of the hill. EPCAMR staff and volunteers cleaned illegally dumped trash from the Boston Creek concrete flume in Larksville Borough many years ago and found the creek only makes it so far down the mountain and is lost to the underground mine workings. The stream channels tend to degrade, pick up sediment and waste culm from abandoned mine sites, and deposit the sediment loads in the flatter, more gently sloping areas along the historic floodplains of the Wyoming Valley.

The concrete flumes in the Nanticoke Creek headwaters and its tributaries are in the *Section 206-Ecosystem Restoration: Nanticoke Creek Watershed, Luzerne County, PA*- A Plan for Restoration of the watershed by the US Army Corps of Engineering Baltimore District and were reported as being in disrepair and lose flow to the underground mine workings. Areas with concrete flumes in disrepair are locations where recommended stream restoration projects can occur to prevent further loss of clean headwater streams into the mine workings and beneath the concrete flume structures. With the freeze/thaw cycles common to Northeastern PA, it may be difficult to prevent future degradation of the flumes if they were just to be rebuilt with concrete as a hard-engineered structure retrofit. When the headwater streams are restored to the surface, it helps to reestablish baseflows in the streams and prevents additional water from being added into the underground mine pool where it becomes a part of the larger mine pool complexes in the area, contributing to the formation of AMD (ACOE, 2005).

As of the Summer of 2024, the Earth Conservancy is beginning to focus on an initiative called the Nanticoke Creek Watershed Restoration. In June of 2023, they were notified that the organization had received a $1.96 Million Brownfields Cleanup grant from the US EPA for Phase I & II of the project. In June of 2024, they completed an Analysis of Brownfield Cleanup

Alternatives with the funding from the US EPA Brownfields Cleanup Program. In October of 2023, they were awarded a PA DEP AMD/AML grant for $17.5 Million to tackle the entire stream length from the headwaters in Watinksi Villa, the upper reach (headwaters of Nanticoke Creek) to the lost reaches of the Leuder's Creek.

Initial planning began back in 2020, with the Earth Conservancy self-funding the design and permitting work of nearly 15,000 linear feet of stream channel improvements and restoration for $380,000. Channel lining, bank stabilization, reconstruction using natural stream channel design principles, and the planting of riparian buffers will be a part of the overall project scope. They have broken up the project in to 3 phases, including the Nanticoke Creek-Main Stem, Leuder Creek, and the Nanticoke Creek-Upper Reach. The majority of these stream channels are dry and are lost to the underground mine workings.

Figure 6. Headwaters of Nanticoke Creek upon entering the Concrete Flume

Figure 7. Photo Collage of the Nanticoke Creek Headwaters being lost into the mine workings beneath the deteriorating and abandoned Concrete Flume

Finding the underground mine stop lines and putting the streams back on top of them may be a much better option. Stop lines on mine maps were supposed to be the locations that indicated that streams or waterbodies were located above and that mining of the coal and or pillars should be left intact and remain unmined, however, in the majority of cases, and from our review of thousands of mine maps, most miners and their companies, would "rob the pillars" and remove the coal as they retreated out of the areas of the mines regardless if there was a stream or waterbody above them or not. Hence, the Knox Mine Disaster that was discussed earlier in the report.

EPCAMR completed a natural stream channel design and construction project utilizing rock veins and the reestablishment of a floodplain along Solomon Creek in Ashley Borough within the study area. The project has kept the water in Solomon Creek on the surface and flowing enough to support a trout stocked fishery by redirecting flow towards the middle of the channel and away from the coal vein outcrops on the banks. The maps on the Mine Map Atlas from the 1950's show the surface areas, original stream channels and their morphology help determine where the original channels were located prior to the construction of Interstate 81. The mining industry and developers in general moved many watercourses prior to Federal and State regulations. EPCAMR is part of a team that scans, georeferences, and digitizes old paper mine maps to make them publicly available. With these maps, EPCAMR can create overlays in GIS to line up what coal veins are beneath the areas of impacts to surface waters. This mapping can determine where the stop lines were located and outcrops of coal to the surface, as well as abandoned mine features such as slopes, shafts, entries, air shafts, or boreholes. The mapping can be reviewed to locate surface water losses into the underground mine workings.

The *United States Geologic Survey Scientific Investigations Report 2007-5061-Effects of Historical Coal Mining and Drainage from Abandoned Mines on Streamflow and Water Quality in Newport and Nanticoke Creeks, Luzerne County, Pennsylvania, (1999–2000)* (Chaplin, Cravotta III, Weitzel, and Klemow, 2007) characterizes and evaluates potential strategies for AMD abatement in the 14-square-mile Newport Creek and 7.6-square-mile Nanticoke Creek watersheds. Both watersheds are mostly within the Northern Anthracite Coal Field and drain to the Susquehanna River.

The U.S. Geological Survey (USGS), in cooperation with the Earth Conservancy, conducted an assessment from April 1999 to September 2000 that included (1) continuous stage measurement at 7 sites; (2) water-quality and flow sampling at 21 sites on June 2-4, 1999, and at 24 sites on October 7-8, 1999; and (3) periodic measurement of flow and water quality at 26 additional sites not included in the sampling effort.

Stream water and surface runoff from the unmined uplands drain northward to the Wyoming Valley, where most of the water is intercepted and lost into abandoned underground mines. Water that infiltrates into the mine workings becomes loaded with acidity, metals, and sulfate and later discharges as AMD at topographic low points along lower reaches of Newport Creek, Nanticoke Creek, and their tributaries. Differences among streamflows in unmined and mined areas of the watersheds indicated that (1) intermediate stream reaches within the mined area upgradient of AMD sites were generally either dry or losing reaches, (2) groundwater flowing to AMD sites via underground mines could cross beneath surface-drainage divides, and (3) AMD discharging to the lower stream reaches restored water volumes lost in the upstream reaches.

The synoptic data for June and October 1999, along with continuous stage data during the study period, indicated flows during synoptic surveys were comparable to average values. The headwaters upstream of the mined area generally were oxygenated (dissolved oxygen range was 4.7 to 11.0 mg/L [milligrams per liter]), near-neutral (pH range was 5.8 to 7.6), and net alkaline (net alkalinity range was 2.0 to 25.0 mg/L CaCO3), with relatively low concentrations of sulfate (6.40 to 24.0 mg/L) and dissolved metals (less than 500 µg/L [micrograms per liter] of iron, manganese, and aluminum). In contrast, the AMD discharges and downstream waters were characterized by elevated concentrations of sulfate and dissolved metals that exceeded Federal and State regulatory limits.

The largest AMD sources were the Susquehanna Number 7 Mine discharge entering Newport Creek near its mouth (flow range was 2,109 gpm to 8,528 gpm), the Truesdale Mine Discharge (Dundee Outfall) entering Nanticoke Creek about 0.5 miles upstream of Loomis Park (flow range was 0.00 to 17,056 gpm), and a mine-pit overflow entering near the midpoint of Newport Creek (flow range was 1,795 gpm to 3,097 gpm). The three large discharges were poorly

oxygenated (dissolved oxygen concentration range was <0.05 to 6.4 mg/L) and had elevated concentrations of sulfate (range was 710 to 890 mg/L) and low concentrations of dissolved aluminum (less than 25 µg/L), but they had distinctive concentrations of net alkalinity and dissolved iron and manganese.

Effluent from the Susquehanna Number 7 Mine was near-neutral (pH range was 5.9 to 6.6) and net alkaline (net alkalinity range was 12.0 to 42.0 mg/L CaCO3) with elevated concentrations of sulfate (718 to 1,170 mg/L), dissolved iron (52,500 to 77,400 µg/L), and manganese (5,200 to 5,300 µg/L). Effluent from the Truesdale Mine also was near-neutral (pH range was 5.9 to 6.3) but had variable net alkalinity (-19.0 to 57.0 mg/L CaCO3) with elevated concentrations of sulfate (571 to 740 mg/L), dissolved iron (30,500 to 43,000 µg/L), and manganese (3,600 to 5,200 µg/L). Effluent from the mine-pit overflow in Newport Creek Basin was acidic (pH range was 4.3 to 5.0; net alkalinity range was -42 to -38 mg/L CaCO3) with elevated concentrations of sulfate (800 to 840 mg/L), iron (13,000 to 16,000 µg/L), and manganese (6,800 to 7,000 µg/L). Although the three large AMD sources did not contain detectable concentrations of dissolved aluminum, a small AMD source in the Nanticoke Creek Basin (flow less than 0.01 ft3/s to 0.06 ft3/s), along with other small AMD sources entering the South Branch of Newport Creek between Wanamie and Sheatown (flows less than 0.89 ft3/s), had elevated concentrations of dissolved aluminum (3,100 to 38,600 µg/L) that exceeded criteria for protection of aquatic organisms.

The chemistry of stream water after mixing with AMD inputs was variable, depending on the relative quantities of AMD and other water sources. For example, decreased flow rates and net alkalinities of AMD from the Truesdale Mine coupled with increased acid production from more extensive iron hydrolysis within Nanticoke Creek could explain the acidic quality about 0.5 miles downstream of the mine during drought (minimum pH was 3.2) compared to the near-neutral quality during normal flows (median pH was 6.8). Other co-occurring influences such as alkalinity from intermittent sewage inflows could explain the bimodal pH distribution near the mouth of South Branch; water had near-neutral pH (pH greater than 6.0) when sewage was abundant but acidic pH (less than 4.5) when it was not.

AMD in other mined areas with chemistry and flow similar to the discharges sampled for this study, has been treated with passive strategies that may include amendment of influent chemistry and almost always include retention in aerobic wetlands. For water similar in quality and quantity to the Truesdale Mine Discharge, with iron loading rates approaching 326 kilograms per day, aerobic wetlands of 4 to 16 acres combined with an alkalinity source have been used for passive treatment. For large, consistent net alkaline flows, such as the AMD discharge from the Susquehanna Number 7 Mine, wetlands of 12 to 49 acres have been used to remove dissolved iron, without supplemental alkalinity, provided that pH is maintained near neutrality. AMD sources with large flow rates, low pH, and elevated concentrations of dissolved metals, such as the mine-pit overflow, commonly warrant active treatment. For example, efficient alkalinity-producing systems, such as lime dosing, followed by ponds or wetlands of approximately 3 to 13 acres have been used to neutralize AMD and remove dissolved iron for similar situations.

Abandoned Mine Lands (AML) & Abandoned Mine Drainage (AMD) Impacts on ABD and EBT in the Wyoming and Southern Wyoming Valley in EPCAMR's Reclaimed Abandoned Mine Land Inventory System (RAMLIS)

EPCAMR has developed Summary Reports from PA DEP BAMR Mine Inspectors and Field Staff related to Abandoned Mine Land features contained within defined Problem Areas that describe the areas and individual features and AMD discharges from the early 1980s to the late 1990s that serve as a reliable source of historical background on the landscape post-mining after 1977. Warrior Creek, Nanticoke Creek, and Newport Creek Problem Areas are described. The summaries and narratives identify health and safety priority areas for the PA DEP BAMR, known as Priority 1 and 2 features. The summaries also have reclamation recommendations contained within the narratives and sometimes there might be an estimated cost to reclaim the features, however, most of them have not been updated for inflation and are the original comments when the field investigations took place back in the early 80s into the late 90s. EPCAMR has a RAMLIS GIS Tool that is available on our website to share information with our community partners, watershed organizations, Conservation Districts, and private sector partners.

EPCAMR's RAMLIS Investigations for Warrior Creek, Nanticoke Creek, and Newport Creek Problem Areas are in the Appendix.