SECTION 7: Hydrologic Balance

7.A – Overview

This section describes the concept of hydrologic balance and explores the evaluation of hydrologic balance in PADEP's permitting and enforcement process. Several aspects are examined: 1) The water quality monitoring suite and the ability to evaluate the implications of subsidence and repair on water quality; 2) The completeness of flow monitoring used in stream recovery evaluations; and 3) The range of flow test for the recovery of streams following subsidence impacts.

7.A.1 - Hydrologic Balance and the Act 54 Regulatory Framework

The Act 54 amendments to the Bituminous Mine Subsidence and Land Conservation Act (BMSLCA) state that the legislation does not supersede the standards designed to maintain the hydrologic balance as delineated by the Surface Mining Control and Reclamation Act of 1977 (SMCRA). SMCRA is the federal law regulating the environmental impacts of coal mining in the United States. Section 1266 of this law requires underground coal mining operations to minimize the disturbance to the hydrologic balance both at the mine site and at associated offsite areas. Hydrologic balance is defined as follows:

> Hydrologic balance means the relationship between the quality and quantity of water inflow to, water outflow from, and water storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake, or reservoir. It encompasses the dynamic relationships among precipitation, runoff, evaporation, and changes in ground and surface water storage. (30 CFR § 701.5)

Underground longwall coal mining affects the hydrologic balance through several fundamental mechanisms: impeded flow due to differential subsidence at the edge of the gate roads (pooling), rerouted surface water to subsurface flow paths (flow loss, wetland impacts), and altered aquifer systems that change groundwater dynamics.

However, comparison of defined protections of hydrologic balance with policy to protect structures, water supplies, and land damage, reveals very limited guidance in the Act 54 amendments about the hydrologic balance and the steps necessary to restore the hydrologic balance. The PADEP has provided technical guidance ("Surface Water Protection – Underground Bituminous Coal Mining Operations" Technical Guidance Document 563-2000-655) (referred to as the "TGD" in this chapter) that defines measures to protect the hydrologic balance during mining and to repair imbalances following mining impacts. While this technical guidance applies to all underground bituminous mining, much of the guidance is provided for activities that cause subsidence, particularly full extraction mining. For example, as long as room and pillar mines do not undermine wetlands with overburdens of less than 100 feet, wetlands are not required to be inventoried for room and pillar permits.

Fundamental questions remain about mining related subsidence and the hydrologic balance. Groundwater systems are undoubtedly impacted by subsidence given the attention to water supply impacts in the Act 54 amendments and the observations of spring relocation, wetland changes, and diminished stream flow common over mining. Yet, changes in groundwater are not well constrained (Section 8). For example, as part of the permitting process, subsidence models are prepared and compared with stream gradient to identify locations of likely pooling. There is no equivalent methodology for assessing groundwater changes. Further, there is not a consistent body of data the PADEP appears to use to evaluate regional changes to groundwater conditions. Groundwater impacts are not tracked in BUMIS and groundwater hydrologic monitoring and water supply loss data are not formally included in examination of stream recovery.

Protection of the hydrologic balance is fundamental to the Act 54 legislation. Evaluation of the current criteria and monitoring schedules can improve protections for both the environment and citizens.

7.B – Act 54 Hydrological Monitoring and Water Quality Dimensions of Hydrologic Balance

7.B.1 – Physical and Chemical Parameters for Hydrologic Monitoring

A substantial set of water quality parameters are monitored on a regular basis as a permit requirement (Permit Application 5600-PM-BMP0324, section 8.15). The vast majority, if not the entirety, of this monitoring is reported on a quarterly basis in hydrologic monitoring reports (HMR). This tendency arises from the flexibility in the permit requirements (Permit Application 5600-PM-BMP0324, section 8.15.g) which allow the operator to propose a monitoring schedule and the minimum requirements of PA Code Title 25 Chapter 89.59.a.2 of quarterly sampling. The University notes for this section and others that this regulation requires a minimum frequency, but also states, “The Department [PADEP] may also require the operator to conduct monitoring and reporting more frequently than every 3 months and to monitor additional parameters beyond the minimum specified in this section.” in PA Code Title 25 Chapter 89.59.b.

All underground mines are required to monitor these parameters. However, given the distribution of hydrological impacts documented elsewhere in this report and in prior reports (Iannacchione et al. 2011, Tonsor et al. 2014), the University will focus almost exclusively on HMR from longwall operations in our evaluation of the sufficiency of hydrological water quality data.

7.B.2 – Applicability of Monitored Water Quality Parameters to Subsidence Impacts

The water quality parameter suite specified by Permit Application 5600-PM-BMP0324 is very effective at assessing contributions from mine drainage. Permit Application 5600-PM-BMP0324 governs not only longwall mining, but also room and pillar and pillar recovery mining, in addition to preparation plant and coal refuse disposal permits.

However, these parameters are generally of limited utility for assessment of subsidence impacts. In this assessment period the overwhelming majority of hydrologic subsidence effects occurred over longwall operations (see Section 9). Most longwall mining occurs at depths well below local shallow water cycling (Section 3). That is, the depth of overburden over most longwall mines is far deeper than the bottom of the stream valley and the riparian aquifers that interact with the streams in these valleys. Therefore, interaction of surface waters and shallow ground waters with mine drainage from longwall mines is rare.

This limited utility is reflected in the use of the monitoring data. The water chemistry monitoring is not presented as part of stream recovery evaluations. There is no documentation of formal evaluation of water quality monitoring during renewals of longwall permits included in the permit files. Apparent data entry errors included in the HMR (see Appendix G) are not clarified and corrected. These data are expensive for the operators and not necessarily integral to PADEP's impact evaluation process for subsidence impacts. Monitoring effectiveness can be enhanced by clarifying water chemistry data use and need.

7.B.3 – Emerging Potential Water Quality Impacts Associated with Subsidence

If underground mining activities do release mine waters to the environment, then these data provide a record of background water quality conditions. However, the data are not sufficient to evaluate specific emerging water quality concerns. The 4th assessment report identified a persistent increase in conductivity in recovered streams (Tonsor et al. 2014). Conductivity is a function of the dissolved solids in the stream solution. In particular, there are two processes that may contribute dissolved material to streams in and around undermined areas: grouting and disruptions to human infrastructure.

The widespread use of grouting as a remediation technique (Section 9) introduces a substantial amount of new materials (predominantly cement.) to areas directly connected to streams and riparian aquifers. Grout materials, particularly easily dissolved grout materials, may contribute dissolved solids directly to local water bodies. Given the current suite of water quality indicators, it is not possible to unambiguously assess the downstream water quality implications of widespread grouting (alkalinity provides one potential means to evaluate grout inputs, however, there are many sources of alkalinity in these environments). The addition of calcium to the parameter suite would allow assessment of the role of cement inputs to local water chemistry.

In addition, as longwall activity has moved north toward the more suburban areas around Washington, PA there have been an increasing number of on-lot wastewater systems that are undermined (Figure 7-2). This is particularly problematic as subsidence impacts (i.e., cracks) can create large preferential flow paths that can compromise systems engineered to treat wastewaters. That is, a subsidence crack in the drain field will create flow paths that bypass the soil treatment on which the septic systems rely. These cracks are hard to detect if they do not create surface water discharge or system backups. These flow paths have the potential to introduce substantial loads of nutrients to local ground and surface waters. Addition of nitrate measurements to the chemical parameter suite would allow evaluation of these impacts on surface and groundwaters.

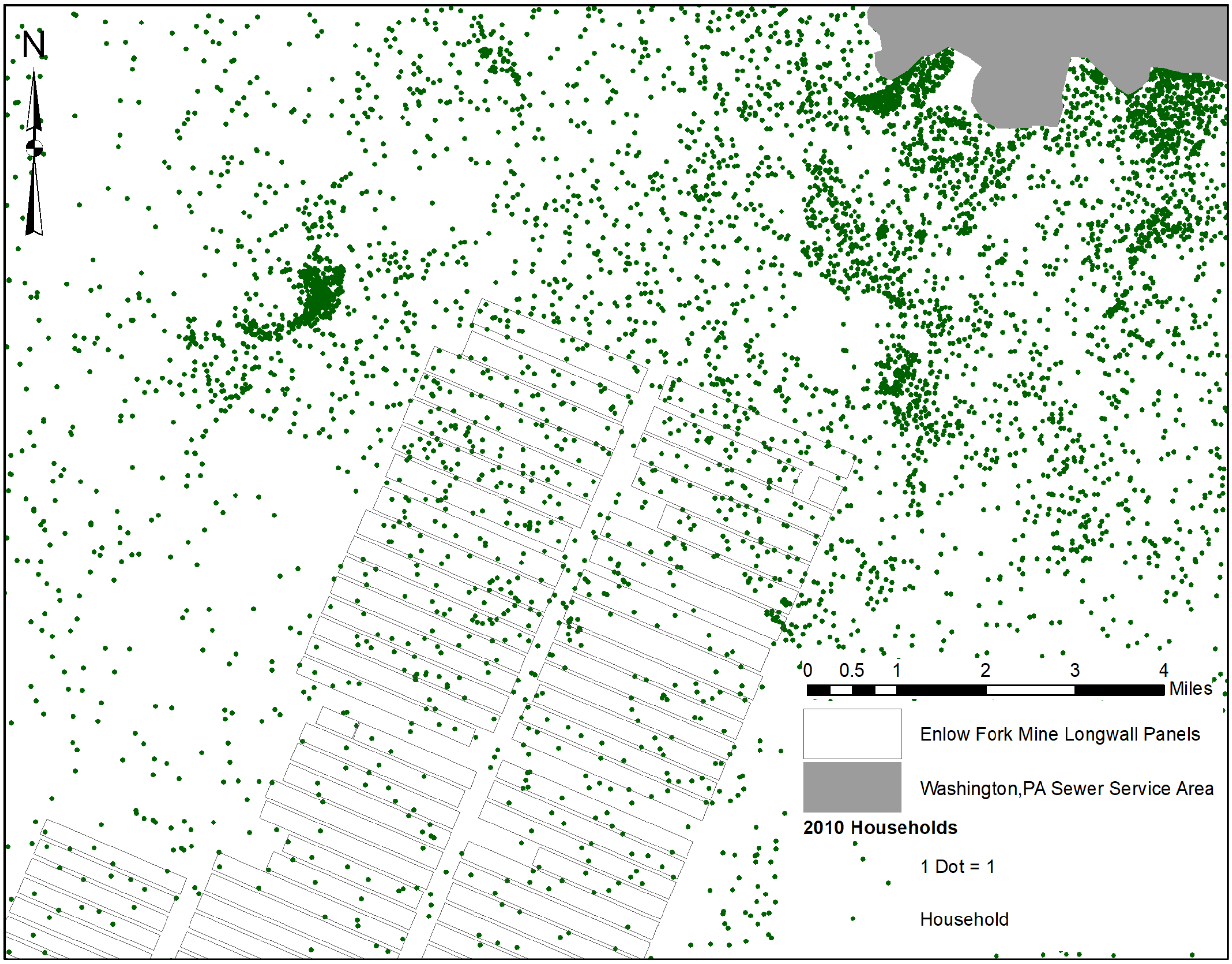

Figure 7-2. 2010 Decennial US Census household counts are show according to census block counts. One dot equals one household. Panels shown are for the Enlow Fork Mine and have been proceeding northward during the 5th assessment period. Grey areas are the Washington, PA sewer service area. Dots represent a household and are randomly placed within the appropriate census block. The vast majority of households not in a sewer district are assumed to rely on on-lot wastewater systems ("septic systems"). This northward movement has undermined areas with, on average, more septic systems than previous periods.

7.C –Flow Data in Stream Recovery Evaluation

PADEP requested the University evaluate whether the hydrologic data collected as part of the permitting and enforcement processes are adequate and complete. The two primary sources of hydrological data the University evaluated were the stream recovery evaluations and the hydrologic monitoring reports.

This section documents a systematic evaluation of the hydrologic data in stream recovery evaluations. The recent USGS study on estimation of baseflow in southwestern Pennsylvania (Hittle and Risser, 2019) evaluates multiple monitoring schedules designed to maximize information gained from a similar monitoring effort (i.e., ~60 sampling dates prior to undermining). Many of these schedules are more complicated than current schedules. Therefore, evaluation of submitted data can inform consideration of any potential changes in data collection guidance.

Evaluation of the completeness of stream monitoring, as specified in technical guidance documents, reveals substantial deviations from the schedule. In addition, several important biases in the distributions of flow data that occur in the current data are identified so they can be incorporated to improve evaluation of pre- and post-mining flow

7.C.1 – Evaluation of Stream Sampling Schedule in Stream Recovery Documentation

The University analyzed all received stream recovery evaluation (SRE) reports to evaluate if the hydrologic monitoring schedules outlined in the TGD were met. This process involved the optical character recognition of data in paper documents submitted to PADEP. As recommended in the 4th assessment report (Tonsor et al. 2014), this is a case where electronic submission of data would simplify and improve PADEP's ability to assess hydrologic change. A total of 82 SRE reports that included flow data were submitted during the 5th assessment period, and documented conditions in a total of 126 stream reaches.

Based on the SRE reports, PADEP either releases the stream from company responsibility because the post-mining range of flows were equivalent to the pre-mining range of flows and biological criteria are met or does not release the stream because the post-mining monitoring did not demonstrate flow or biological recovery. If streams are damaged, the TGD outlines criteria used by PADEP to evaluate the recovery of a stream, and therefore the release of company responsibility for further mitigation in the stream. The TGD defines the hydrologic criteria for streams as follows: "observations and measurements documenting the range of flows and seasonal variations in flow that constitute the normal range of conditions. This information should be based on measurements and observations over a 24-month period, at a minimum, and be sufficient to show the normal range of conditions". As mining approaches a stream a set schedule is dictated: "weekly measurements commencing six months prior to undermining the area of concern. Daily measurements commencing two weeks prior to undermining the area of concern and continuing until the potential for mining induced flow loss becomes negligible. If flow loss occurs, daily observations or measurements commencing from the date of the observed loss and continuing until flow fully recovers or is fully restored or until underground mining operations are determined not to be the cause of the problem. Weekly measurements continuing six months after the conclusion of daily monitoring".

Twenty-three of the 126 stream segments had monitoring periods that began less than two years prior to undermining (Table F-1). Of these 23 stream segments, seven of the SRE reports provided a reason in the SRE report for the shortened pre-mining monitoring period. The other 16 stream reaches that had less than two years of hydrologic pre-mining monitoring did not explain the shortened pre-monitoring time period.

One of the primary reasons supplied in the SRE reports for the shortened pre-mining observation period was that streams were undermined less than two years after new criteria outlined in the TGD became effective. For example, Stream UT-41282 in Cumberland Mine was monitored for less than two years "due to the timing of PADEP TGD implementation and associated longwall mining activities" (SRE 1627).

In many cases, for streams undermined during this period prior to this policy, if a compliance monitoring point was not in place, then evaluation of an adequate flow period was not possible. These cases include:

- Enlow Fork, stream CrC-6L was monitored for 14 months because "a compliance monitoring point is not identified for CrC-6L within coal mining activity permit (CMAP) No. 30841317. Hydrologic response to subsidence is evaluated for data collected at TGD observation point CrC-6L-01" (SRE 1621).
- Enlow Fork stream TemF-25L,1L was monitored for 10 months because "a compliance monitoring point is not identified for TemF-25L, 1L within CMAP No. 30841317. Hydrologic response to subsidence is evaluated for data collected at TGD observation point TemF-25L,1L" (SRE 1611).
- Enlow Fork stream TemF-33R was monitored for 20 months because "a compliance monitoring point is not identified for TemF-33R within CMAP No. 30841317. Hydrologic response to subsidence is evaluated for data collected at TGD observation point TemF-33R-01" (SRE 1614).
- Bailey stream 32539-SoF-5L-01 was monitored for 19 months because "a compliance monitoring point is not identified for SoF-5L, within CMAP No. 30841316; therefore, hydrologic response to subsidence is evaluated for data collected at TGD observation points SoF-5L-01, SoF-5L-02, SoF-5L-03. Monitoring of SoF-5L-01 began January 2006 and SoF-5L-03 began February 2005, following the TGD monitoring frequency recommendations of section IV.1.d(v)." (SRE 1733).

Over Enlow Fork there were two streams with less than two years of pre-mining data where monitoring points were close in proximity. To adequately understand pre-conditions in the stream, more than one monitoring point data set was used in recovery evaluation. In these cases, the hydrologic monitoring point is used instead of the stream monitoring point because a full 24-month time period of data was not collected prior to mining. Stream 32783-TemF-21L-01 and Templeton Fork-08 in Enlow Fork had pre-mining data only 19 months and 22 months prior to undermining (respectively). In stream 32783-TemF-21L-01, "CMAP No. 30841317 monitoring point SW25 is located near TGD observation point TemF-21L-01. SW25 is monitored quarterly. Due to the proximity to SW25 and increased monitoring frequency, hydrologic response to subsidence is evaluated for data collected at TGD observation points TemF-21L-01. In addition, in order to ensure adequate representation of the stream, the hydrologic response at station TemF-21L-06 was also evaluated" (SRE 1615). As another example, "due to the proximity to SW23, SW40, and SW24 and increased monitoring frequency, hydrologic response to subsidence is evaluated for data collected at TGD observation points TemF-08, TemF-14, and TemF-17, respectively. In addition, in order to ensure adequate representation of the stream, the hydrologic response at station TemF-11 was also evaluated" (SRE 1612).

In addition, the University examined the length of more frequent monitoring closer to undermining (weekly monitoring 6 months prior and daily monitoring 2 weeks prior). In this case, instead of evaluating based on the calendar time period, the number of samples within the calendar period were counted. This solved the problems of how to count gaps (if 3 weeks of measurement were missed in the middle of the six-month period, a calendar length evaluation would not capture that) and of irregular sampling (e.g., if a week was missed, sometimes 3 samples, all spaced 5 days apart were collected to make up). For the weekly sampling, only one sample was counted for each of the last two weeks when tallying the monthly numbers. These results are presented in Table F-1. In cases where the count is higher than the required count, but an "N" is indicated, these samples were not distributed across the weeks and therefore do not meet the specified schedules.

Of all 126 stream segments evaluated for recovery 117 were evaluated on range of flows. The other SRE reports presented biological data or described non-flow loss cases. Only two of those 117 evaluated for flow completely followed the defined schedule for flow monitoring (Table 7-1). The other 115 stream segments are either missing weekly data six months prior to mining, missing daily data two weeks prior to mining, or in many cases both. In some cases, the amount and timing of monitoring events were very close to those specified. However, in this analysis a hard criterion is used (i.e., close does not count).

Table 7-1 Completeness of pre-monitoring flow data as reported in SRE reports submitted during the 5th assessment period.

Stream Monitoring Compliance Summary	released	not released
Met none of the guidelines	9	9
Met all of the guidelines	1	1
Met 2 years of monthly monitoring guideline only	31	50
Met 6 months of weekly monitoring guideline only	2	2
Met 2 years of monthly monitoring guideline and 6 months of weekly monitoring guideline	1	6
Met 2 years of monthly monitoring guideline and 2 weeks of daily monitoring guideline	1	3
Met 6 months of weekly monitoring guideline and 2 weeks of daily monitoring guideline	1	0
Other cases: SREs not based on flows, only biological data reported, etc.	4	5

The monitoring schedules proposed in the USGS report (Hittle and Risser, 2019) are more complicated than the current monitoring guidelines. For example, some specify a series of sampling events that are triggered following precipitation. The underlying assumptions of the more sophisticated methods rely on a sufficient sample size. Current stream monitoring is not gathering flow data that are consistent with TGD recommended monitoring. Identification of the reasons for the consistent gaps in monitoring data is beyond the University's scope of work. However, the data are not complete as reported. Use of more sophisticated monitoring schedules assume complete data. To encourage data completeness, the University recommends compilation of these pre-monitoring data as mining progresses, to ensure complete pre-mining baseline data are available.

7.C.2 – Potential Biases Flow Monitoring Data

In current practice, a stream is considered "recovered" when the flows in the stream have a range that is "consistent" with the range of flows that occurred prior to mining. Taken literally, this criterion is not hard to meet, as the range of flows is generally dictated by large, but less common, storm flows. These storm flows are generally less impacted by subsidence.

Comparison of ranges is problematic for statistical reasons. The equivalence of means can be evaluated with a t-test. There is no such established statistical test for equivalency of ranges. Equivalence tests have been used to compare ranges and identify extreme ranges (Hauck & Anderson 1984). However, extremes in stream flow are typically driven by extremes in precipitation. Therefore, when using a range of flows comparison, the equivalence of flow ranges cannot be rigorously evaluated with statistical tests. This strongly contrasts the methods used in biological evaluations where total biological scoring is based on underlying assumptions about sample statistics (e.g., total biological score).

New regional methods to evaluate base flows have been proposed (Hittle and Risser, 2019). These methods were developed to maximize the information that can be inferred given a set sample size. The metrics used to evaluate the information are all based on modern probabilistic and statistical methods (e.g., the Maintenance of Variance Extension, Type 1 method). Further, only low flow data were evaluated during development of these methods. Similarly, a recent publication on subsidence impacts using mine operator data (Silvis et al. 2019) recognizes the need to treat flow records as a distribution and utilize rigorous statistical approaches in flow evaluation. Both approaches assume specific things about data distributions, not data ranges.

In the short term, comparison of flow ranges is policy. If new methods are adopted, they will require more attention to data distributions to ensure statistical assumptions are met. In either case there are several biases in sampling distributions that occur in the existing SRE report data. These biases need to be identified and explained whether evaluating the range of flows or using other emerging methods. Flow distribution visualizations were completed for each of the SRE reports made available to the University and are included in Appendix F.

7.C.2.a – Log--normal distributions obscure low flow data

Broad portions of the range of stream flows are driven by high flows that occur in response to storms. For example, the monitoring in UT 40410 in Greene County measured flow on 2/15/2013 that is roughly twenty-five times higher than flows measured throughout the remainder of the six-year period (Figure 7-3b). This extremely high flow suppresses the flows observed in the post-mining period and makes the two periods hard to contrast (Figure 7-3a&b). Changes to axis ranges improve comparability (Figure 7-3a&c). However, the low flow ranges remain a challenge to compare.

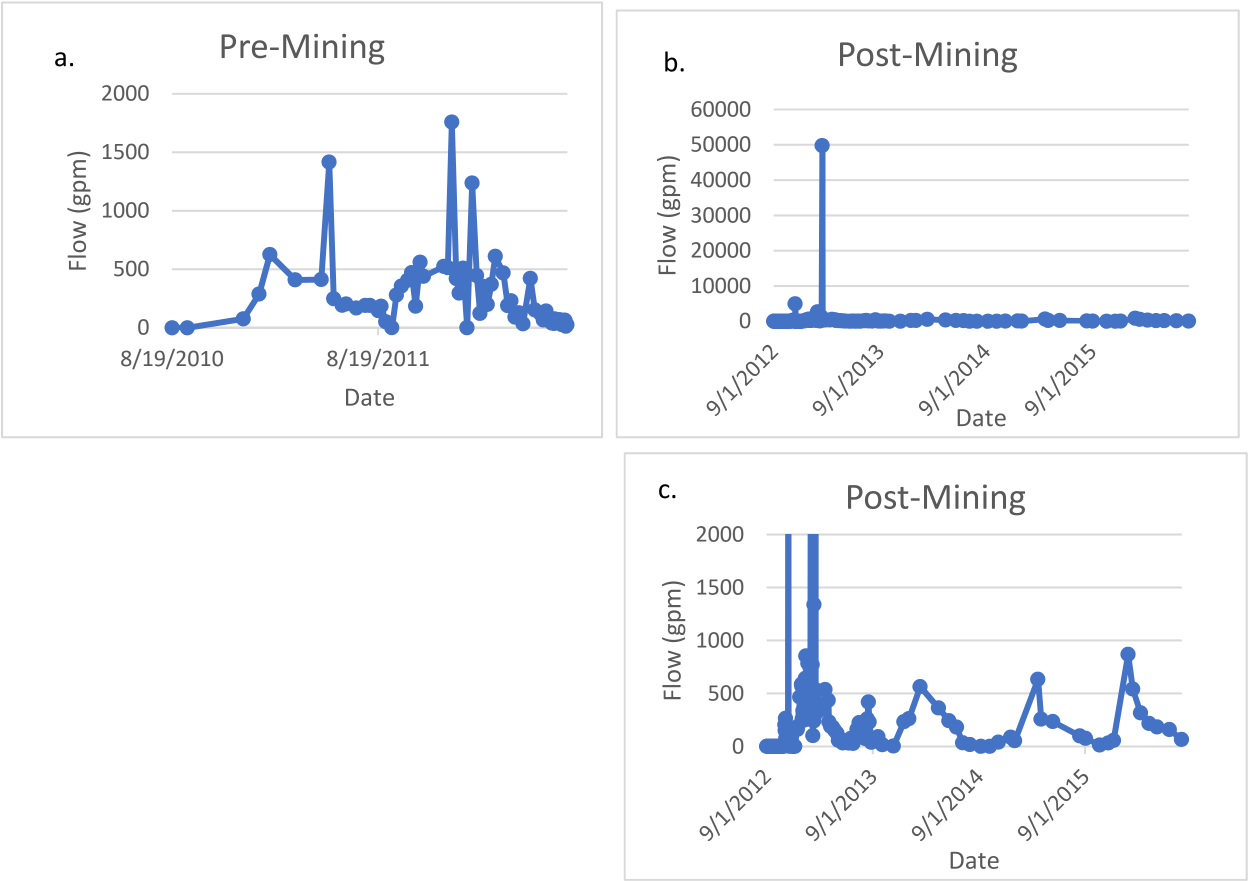

Figure 7-3. Plots of flow data from SRE report 1632. Data were scanned and text optically recognized using the Omnipage OCR software. Panel a) is pre-mining data, panel b) post mining data and panel c) the same post-mining data shown in panel b), but the axis is forced to meet values used in panel a).

SRE report 1632 visualized flow in the pre- and post- mining periods as box and whisker ranges (Figure 7-4). This visualization remains dominated by the storm flows as "whiskers" extend beyond the plotted range given the extreme flow on 2/15/2013. This extreme flow influences the entire post-mining record ("Post-Mining" in Figure 7-4).

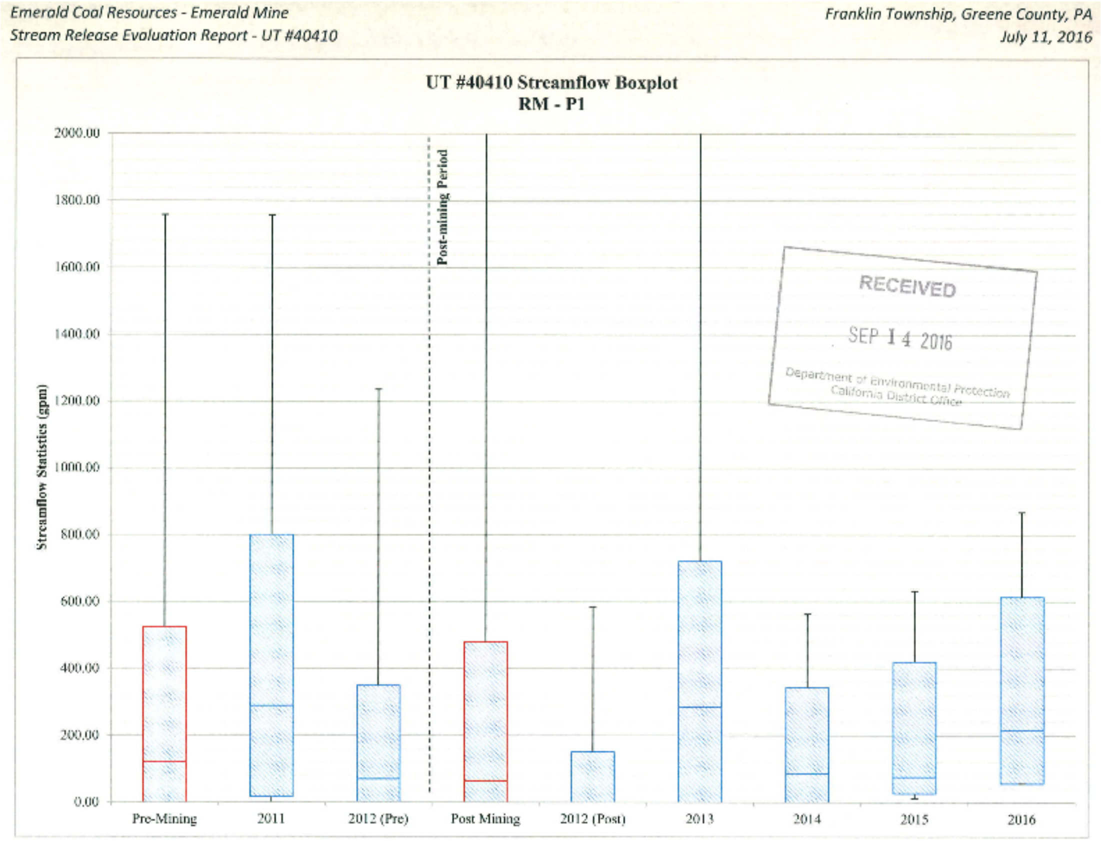

Figure 7-4. Example of presentation of pre- and post- mining ranges in flows. This plot is from SRE report 1632, the SRE report for UT 40410 in Greene County over Emerald.

Plotting log transformed flows in conjunction with the normal flow plots clarifies low flow ranges and distributions (Figure 7-5). In these log transformed plots, no-flow values are assigned a small value (0.1-gpm) and therefore values of negative one (-1) are no-flow samples. The period of flow loss immediately after mining is clear (Figure 7-5). Outside of the post-mining period, there are a similar number of pre- and post-mining, no-flow measurements (roughly two each). A paired flow and log transformed flow time series pair improves and clarifies flow range evaluation.

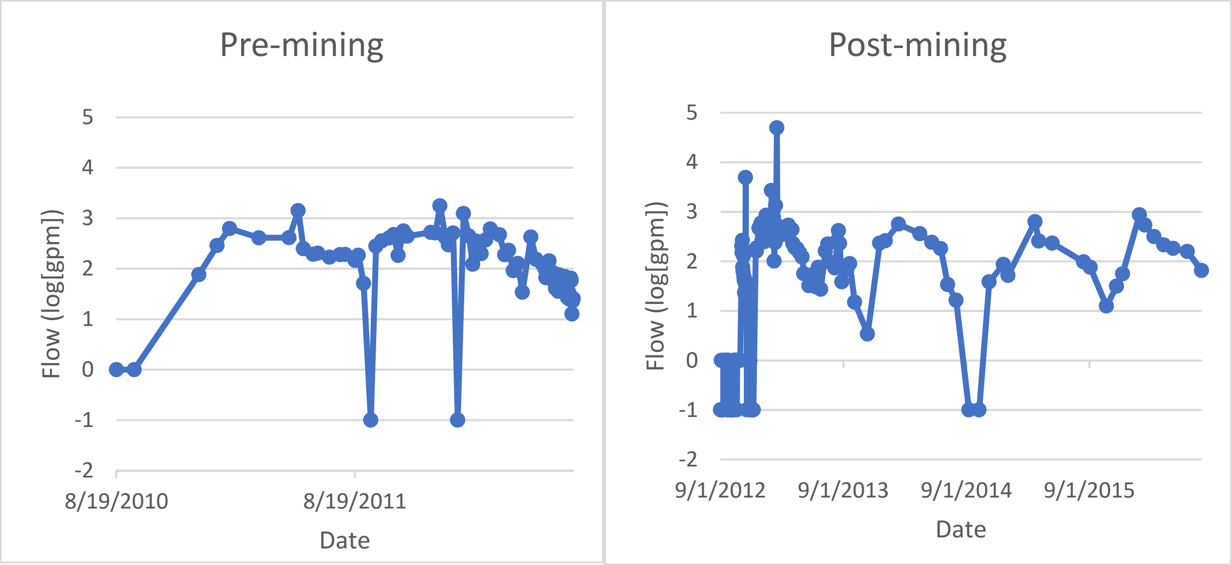

Figure 7-5. Log transformed flow data from SRE report 1632 for UT 40410. These data are the same data shown in Figure 7-4, after log transformation in the y-values. In general, no-flow conditions are noted with a 0.1-gpm flow, so appear here as negative one.

7. C.2.b – Evaluation of Sampling Bias in Flow Data

Biases can emerge as an artifact of any defined sampling schedule. The TGD sampling specifications include a set schedule that does not account for precipitation. If the undermining of a stream is preceded by several weeks of frequent precipitation, then this approach has the potential to bias the pre-mining data to storm flows relative to low flows. Likewise, if undermining occurs during the late summer/early fall, the concentration of sampling frequency prior to undermining would bias the pre-mining data to relatively lower flow periods. Two distribution comparisons can allow visual screening for potential biases: 1) the distribution of flows; and 2) the distribution of flow measurements across the year.

In general, surface flow is “log normal”, that is, the number of flows measurements is expected to be skewed toward low flow values. Low flow is common in a stream (even if there is one storm per week, that is still six times more low flows than storm flows if flows are measured on a daily basis). In the case of UT 40410, both pre- and post-mining flow records are log normal (Figure 7-6). This plot can reveal important contrasts in the size of the flow data sets (the pre-mining histogram is much smaller, reflecting a shorter sampling period). Both records have secondary peaks in flow frequency (pre-mining for flows between 352 and 440-gpm, post-mining in flows between 264 and 352-gpm), so there does not appear to be bias in this record. However, if one sampling period is distinct in shape (e.g., SoF-2R-01 in Appendix F) bias in one of the records must be evaluated before the ranges are compared.

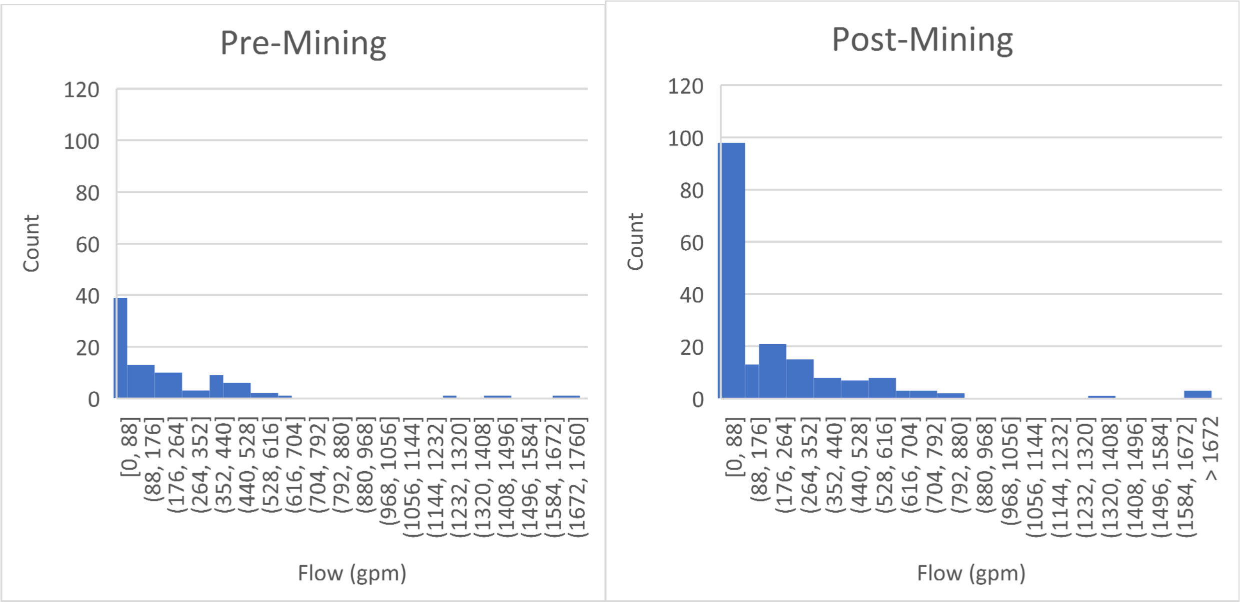

Figure 7-6. Distribution of flows UT 40410 as reported in SRE 1632.

The other potential bias is an oversampling of a characteristically wet or dry season. In western Pennsylvania, the peak water deficit occurs during late summer/early fall (Figure 7-7). This is the period where regional water tables are lowest due to cumulative evapotranspiration during the summer and growing season. This seasonal deficit can lower water tables in aquifers that feed stream flow, therefore low flows are typically lowest during this period. Likewise, during late winter and early spring, regional moisture has been replenished by precipitation, and low flows are higher relative to the rest of the year. This means, if one of these periods is sampled more heavily relative to the other portions of the year, then there will be a seasonality bias in the estimated range of flows. If late summer/early fall is over sampled, then the range of flows will be artificially low. If late winter/early spring is over sampled, then the range of flows will be artificially high.

To assess seasonal bias in sampling, the distribution of sampling days over the course of a year can be compared. For this analysis the Julian day (i.e., day of year) is determined for each sampling date in the record and the distribution of sampling days over the course of the year examined (Figure 7-8). Specification of 12 bars in the histogram divides the samples records into approximations of the months of the year. This method is slightly imprecise (for example February is overrepresented) but this imprecision doesn’t typically shift distribution shapes dramatically (sampling in March is not that much different than February in terms of water balance).

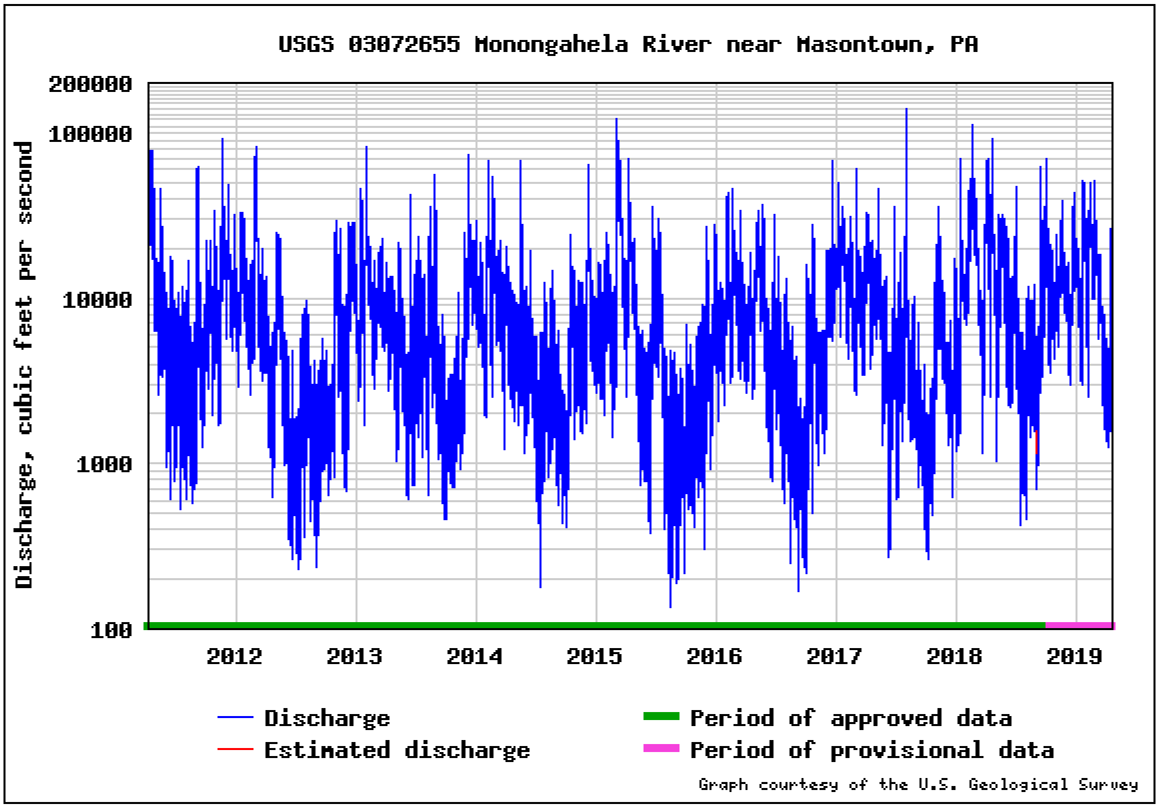

Figure 7-7. Plot of daily discharge from the Masontown USGS gage on the Monongahela River. Note the annual pattern in flows, where lowest flows are typically in late summer/early fall, coincident with moisture deficit maximums in western Pennsylvania.

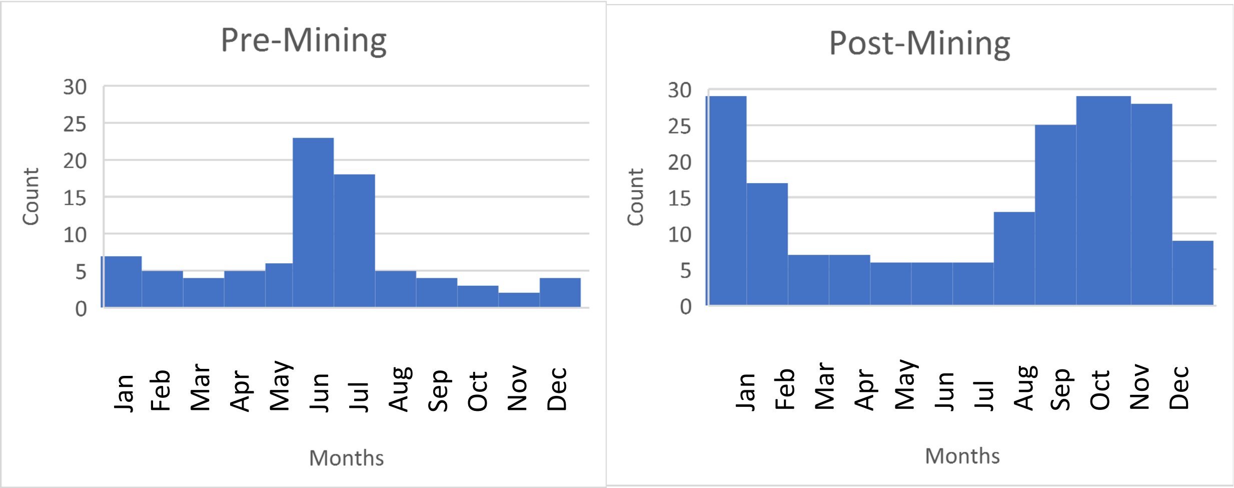

Figure 7-8. Distribution of sampling dates in UT 40410 (SRE 1632) for both pre- and post-mining sampling periods.

In the case of UT 40410, sampling prior to mining seems to be biased toward the summer months and sampling post mining is biased away from this summer period (Figure 7-8). This bias could unintentionally result in more similarity between the range of flow than is warranted by the actual flow conditions (more drier days in pre-mining and more wetter days in post-mining periods). Elimination of these biases improves the evaluation of the ranges of flow. Further, as base flow evaluation continues to evolve (Hittle and Risser, 2019; Silvis et al, 2019), identification of these biases will remain important to accurate comparisons of flow.

7.C.3 – Stream Release Documentation

Documentation of decisions regarding stream recovery improved during the 5th assessment period. All SRE reports are filed with a "STREAM RECOVERY EVALUATION REQUEST FORM" that documents recovery based on the biology and the range of flows. However, these forms do not completely justify decisions. The widespread deviations from stipulated monitoring periods are very rarely mentioned. In cases where pre-mining data do not exist, documentation of the argument and rationale for release was often cursory. Most important, the forms document disagreement among PADEP staff that is left unaddressed. In particular, subsidence agent input appeared to be less valued relative to hydrological and biological criteria. Certification does not trump frequent observation. Objections to release based on field observations can be addressed with clear technical rationale. Continued use and expansion of this documentation will improve protection of hydrological resources and minimize the disturbance to the hydrologic balance.

7.D – Summary

The hydrologic balance is a complicated concept, a technical test developed in a political context. Other sections of this report have extensive tabular content that details the reported effects and liability of impacts to structures, water supplies, and land. Much of this content grows out of specific language in the Act 54 amendments. Such guidance for protection of the hydrologic balance simply does not exist.

To increase the use and therefore effectiveness of HMR data, the University recommends PADEP 1) examine the water quality parameters required as part of hydrologic monitoring, and 2) add parameters to evaluate potential emerging threats to water quality. Development of simple QA checks that can be specified as part of SRE reporting will facilitate more efficient evaluation of stream flow.

The incomplete reported hydrologic data in the SRE reports can undermine the accuracy of flow comparisons and will cause problems in potential new flow monitoring schedules based on statistical methods (Hittle and Risser, 2019). At present, determination of recovery based on incomplete data sets occurs too often, and when it occurs the circumstances are often not documented. The data gaps are not small or infrequent (i.e., this is not a case where one week is missed during the six-month period or the longwall moves a little faster than anticipated during daily sampling). Fundamentally, assuring data completeness is vital to assessment of hydrologic recovery and therefore protection of the hydrologic balance.

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