ESTABLISHING BASELINE POLLUTION LOAD FROM PREEXISTING POLLUTIONAL DISCHARGES FOR REMINING IN PENNSYLVANIA[1]

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Abstract.--Recent changes to the Pennsylvania Surface Mining Conservation and Reclamation Act and the Federal Clean Water Act include provisions which limit liability for preexisting pollutional discharges to coal operators who reaffect previously mined areas, thereby encouraging the remining of abandoned mine lands. Both of these statutes require that baseline pollution load be established prior to commencing remining operations. The baseline pollution load is used to define premining water quality, determine effluent standards, and provide a "baseline" for evaluating the success of the remining operation in abating pollutional discharges. The baseline monitoring must be designed to accommodate the types of discharges present and must provide accurate measurement of flow rates. Observations of remining sites in Pennsylvania have shown that discharges typically exhibit one of three characteristic behaviors: 1) High flow - low concentration / low flow - high concentration response, where the flow rate varies inversely with the pollutant concentration and variability is very great; 2) Steady or damped response discharges which exhibit relatively minor or delayed response in flow rate and chemical characteristics; and 3) "Slugger" response, whereby dramatic increases in discharge are accompanied by little change in acidity concentrations, resulting in large increases in loading. Because discharges are affected by seasonal changes as well as individual recharge events, the baseline pollution load must be expressed as a statistical summary. The baseline data collection must be of sufficient duration and frequency to adequately characterize the range of conditions which are encountered.

INTRODUCTION

Recent changes to the Pennsylvania Surface Mine Conservation and Reclamation Act and the Federal Clean Water Act include provisions which limit liability for preexisting pollutional discharges when a surface mining operation reaffects previously mined areas. Both of these statutes were amended to encourage industry remining and reclamation of the thousands of acres of abandoned mine lands. Previously, under Pennsylvania's Clean Streams Law as well as the Clean Water Act, any preexisting pollutional discharge which was affected by a surface mining or coal refuse reprocessing operation became the perpetual responsibility of the mine operator, thus preventing release of the reclamation bonds.

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This created a strong deterrent to reaffecting previously mined areas which otherwise would have resulted in improved resource recovery, land reclamation, and in many cases, the reduction of acid mine drainage pollution, all without the expenditure of public monies.

BACKGROUND

The Pennsylvania Surface Mining Conservation and Reclamation Act was amended by Act 158 of 1984 of the Pennsylvania General Assembly to include provisions for remining. Regulations implementing Pennsylvania's remining law were approved by the Office of Surface Mining Reclamation and Enforcement (OSMRE) on February 19, 1986, and are set forth in 25 Pa. Code Chapter 87, Subchapter F for Bituminous Surface Mining and 25 Pa. Code Chapter 88, Subchapter G for anthracite. In January of 1987, the United States Congress similarly amended the Clean Water Act to establish modified permits for coal remining operations.

As of December 31, 1987, the Pennsylvania Department of Environmental Resources has issued 34 permits for remining under Subchapter F authorization (Fig. 1). These permits provide for the reclamation of over 1,100 acres of abandoned surface mines and daylighting of 500 acres of abandoned deep mines. A total of 112 preexisting pollutional discharges will be affected. While most permits affect only 1 or 2 discharges, up to 30 individual discharges have been affected within a single permit. Most of the permitting activity has been in the southwestern portion of the state, which is the most heavily impacted by acid mine drainage problems from abandoned mines.

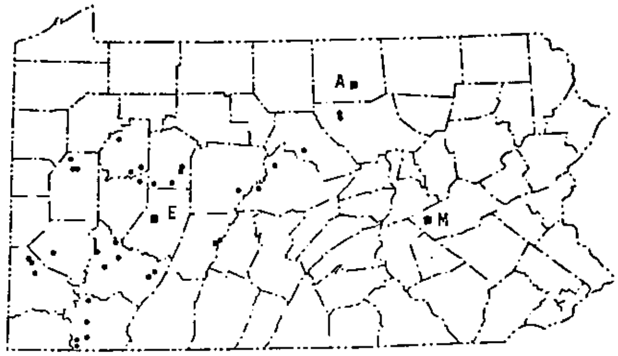

Figure 1.--Map showing location of surface mining permits issued under remining authorization in Pennsylvania and location of Arnot (A), Markson (M), and Ernest (E) Discharges.

BASELINE MONITORING

A key provision of both the Pennsylvania and Federal statutes is that the permit applicant is required to establish the baseline pollution load prior to commencing remining operations. Pollution load is the mass discharge (lb/day or kg/day) from the mine site of specific parameters such as acidity, iron, or manganese. It is found by multiplying the pollutant concentration by the discharge rate by a constant:

	English Units	Metric Units
Concentration	ppm	mg/L
Discharge Rate	gal/min	L/min
Constant	0.01202	0.00144
Loading Rate	lb/day	kg/day

The baseline pollution load is the pollution loading rate from the mine site prior to being reaffected by mining operations. A baseline is needed for two chief purposes: 1) to determine the effluent standards to be applied to the preexisting discharge(s), and 2) as a yardstick for evaluating the effect of the remining operation in abating or worsening the pollution load. In Pennsylvania, bond release is contingent upon there being no statistically significant degradation from the baseline pollution load. Accordingly, accurate determination of the pollution load during the baseline monitoring period is important to both the permittee and the regulatory authority.

Accurate flow measurement is essential for determination of pollution load. Accordingly, the baseline monitoring program must take two key factors into consideration: the behavior of the discharge and the physical nature of the discharge. Discharge behavior includes the variability of flow rates and water quality, which should be considered in planning the frequency of sampling, the length of the sampling period, and the design of flow measuring devices. The physical nature of discharges, which includes point versus non-point source discharges as well as their location in relation to the planned mining activities, can also influence flow measurement requirements. Flow from a single point-source discharge can usually be measured with a weir or other simple device. However, diffuse seepage areas, which are common on abandoned surface mines and refuse piles, usually require composite collection with conveyance to a single collection point. The most potentially difficult situation is encountered where discharges will be interrupted or relocated by mining. In this case, a thorough hydrogeologic investigation should be undertaken to plan for adequate post-mining monitoring.

Various flow-measuring devices and conveyances have been used for baseline monitoring on Pennsylvania remining sites. A catchment basin with a piped outflow is the most practical flow measuring device for low volume discharges. Discharge measurement is volumetric (e.g., using a bucket-and-stopwatch). Weirs or flumes are generally necessary for larger volume discharges. Flow measurement techniques using weirs or flumes are described in numerous sources including Eli et.al. (1980), Rantz et.al. (1982), and the U.S. Geological Survey (1977).

DISCHARGE BEHAVIOR

Observations of remining sites in Pennsylvania have shown that discharges typically exhibit one of three characteristic behaviors: 1) High flow - low concentration / low flow - high concentration response, where the flow rate varies ininversely with concentration and variability is generally very great; 2) Steady or damped response discharges which exhibit relatively minor or delayed response in flow rate with minor changes in chemical characteristics; and 3) "Slugger" response, whereby dramatic increases in discharge are accompanied by little change in acidity concentrations, resulting in large increases in loading. To examine discharge behavior in terms of baseline pollution load characterization, three mine discharges were studied (fig. 1.) The discharges were selected based on the availability of long-term water quality and flow records, and to represent the three characteristic response types as well as a wide range of hydrogeologic conditions.

Field Data

The Arnot No. 1 Discharge drains a relatively small deep mine complex in Tioga County, PA. Data were collected during the period from January 1980 through August 1983 by the Pennsylvania State University, Dept. of Geosciences under contract to the Pa. Dept. of Environmental Resources, Bureau of Abandoned Mine Reclamation (Duffield, 1985). The Markson Discharge is located in Schuylkill County, PA. and drains a large anthracite deep mine complex. Water quality data were collected from July 1981 through August 1986, and discharge measurements were obtained during portions of this period by the Pa. Bureau of Abandoned Mine Reclamation. The Ernest discharge emanates from a 110-acre coal refuse hollow fill in Indiana County, PA. Water quality and flow data were collected from March 1981 through January 1985 by the Pa. Bureau of Abandoned Mine Reclamation.

Arnot No. 1 Discharge

Figures 2a and 2b show the flow rate and acid load for the Arnot No. 1 Discharge throughout the measurement period. Both the flow rate and acid load are subject to large fluctuations with springtime peak flows in excess of 2,000 gal/min and summer and fall low flows of

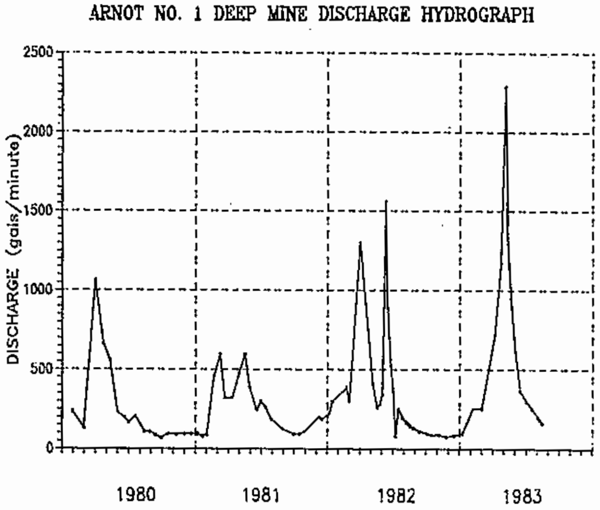

Figure 2a.--Discharge hydrograph for Arnot No. 1 Deep Mine Discharge.

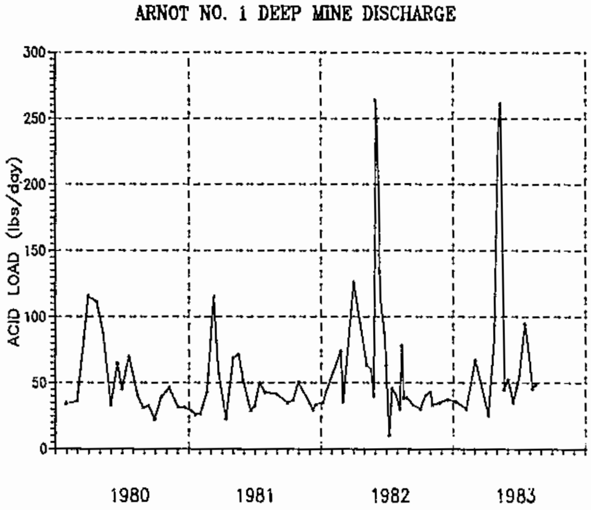

Figure 2b.--Acid load hydrograph for Arnot No. 1 Deep Mine Discharge.

less than 200 gal/min. This "flashy" hydrograph response typifies high flow - low concentration / low flow - high concentration discharges. Month-by-month comparisons of the discharge data (figs. 3a, 3b, and 3c) also show large variations in flow rate, particularly during the months of March through June. Acidity concentrations vary inversely with the discharge rate, with the highest median concentrations occurring during the low-flow months of September, October, and November. However, because acid loading rates represent a combination of discharge and concentration, the acid load is found to be greatest during the peak flow months. Therefore, flow rate dominates the loading

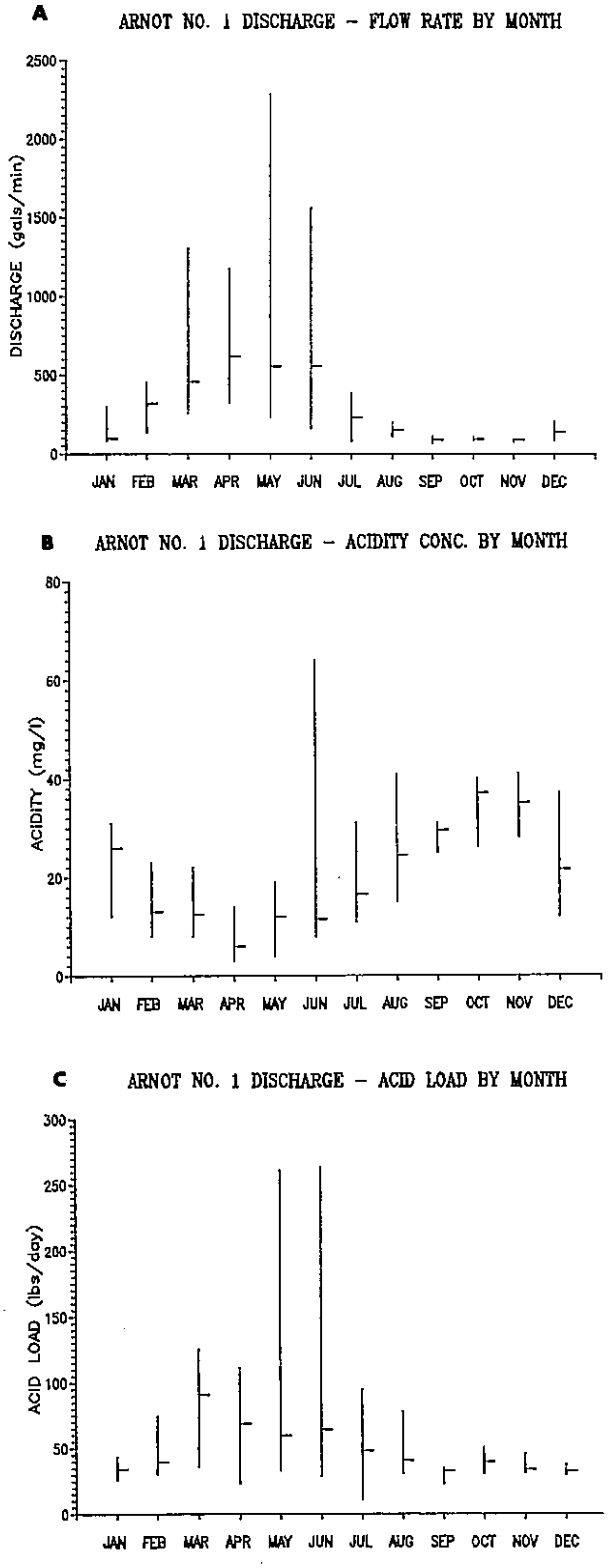

Figure 3.--Monthly median (horizontal line) and range (vertical line) values of (a) discharge, (b) acidity concentration, and (c) acid load for Arnot No.1 Deep Mine Discharge.

calculations. In Pennsylvania, the majority of preexisting discharges fall into this category. This usually occurs with non-point surface mine discharges where the capacity for ground water storage is relatively small and ground-water flow paths are short.

Markson Discharge

The Markson Discharge hydrograph (fig. 4a) shows comparatively little fluctuation in discharge rate throughout 1985, ranging from 790 to 1,900 gal/min. Similarly, acid loading rates are relatively stable (fig. 4b). Month-by-month comparisons of the entire Markson discharge data set (figs. 5a, 5b, and 5c) show some seasonal fluctuation in discharge rate, although far less than the Arnot discharge. Acidity concentrations, however, show little systematic variation throughout the year. Consequently, the distribution of acid loading rates mimics the distribution of discharge rates. Typically, steady or damped response discharges such as the Markson Discharge occur with deep mine complexes having large mine pools or surface mines with extensive ground water storage. Water quality and discharge rates remain relatively constant, owing to the large amount of ground water in storage acting as a reservoir which dampens fluctuations. Although not nearly as common, this type of discharge is the easiest to monitor since large fluctuations rarely occur. Fluctuations that do occur generally do so over longer time intervals rather than as short-term events.

Figures 6a and 6b compare discharge rates and acidity concentrations for the Arnot and Markson Discharges. As reflected in the monthly summary graphs, the Arnot Discharge shows a trend of decreasing acidity with an increasing discharge rate, apparently reflecting dilution of the mine drainage by recharge. The Markson Discharge, however, shows no systematic trend in acidity concentration with increasing discharge, presumably due to the large ground water storage reservoir and its ability to dampen changes in water quality.

Ernest Discharge

In terms of establishing a baseline, the most difficult monitoring situation is encountered with slugger discharges. This type of discharge exhibits large variations in discharge rate with relatively minor, if any, change in acidity concentrations. Consequently, rapid increases in flow result in similarly large increases in acid loading rates or acid "slugs". This appears to be the case with the Ernest Refuse Pile Discharge (figs. 7a and 7b). Flow rates vary dramatically in response to recharge events, from less than 3 to 470 gal/min. Concomitantly, acidity concentrations change very little, thereby resulting in large, rapid variations in acid loading. Presumably, the accumulation of water-soluble, acid-bearing salts in the refuse

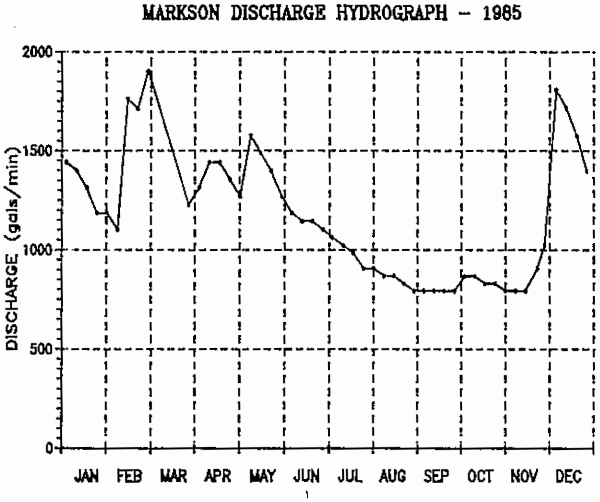

Figure 4a.--Discharge hydrograph for Markson Deep Mine Discharge.

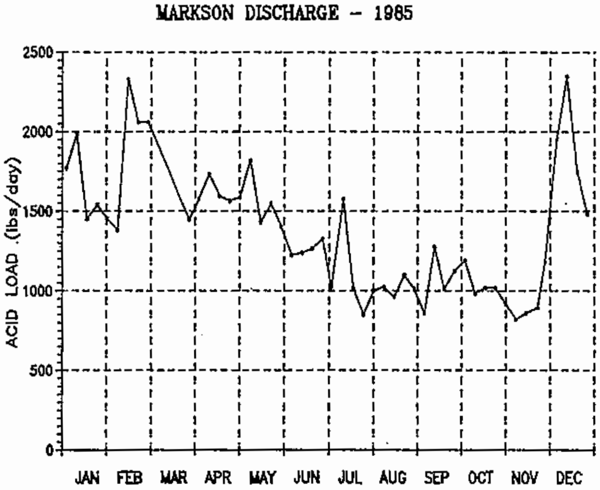

Figure 4b.--Acid load hydrograph for Markson Deep Mine Discharge.

pile allows rapid release of additional acidity following a recharge event. Figures 8a, 8b, and 8c. illustrate monthly differences in discharge and acid-loading rates. Although median loading rates are highest during the spring months, they exhibit large variations throughout the entire year.

BASELINE STATISTICAL SUMMARY

As shown by the Arnot, Markson, and Ernest examples, mine discharges are subject to large variations in pollution load, resulting from fluctuations in water chemistry and discharge rates. These variations may occur seasonally, because of changes in flow rates caused by fluctuating ground water levels, or they may occur with individual recharge events. Accordingly,

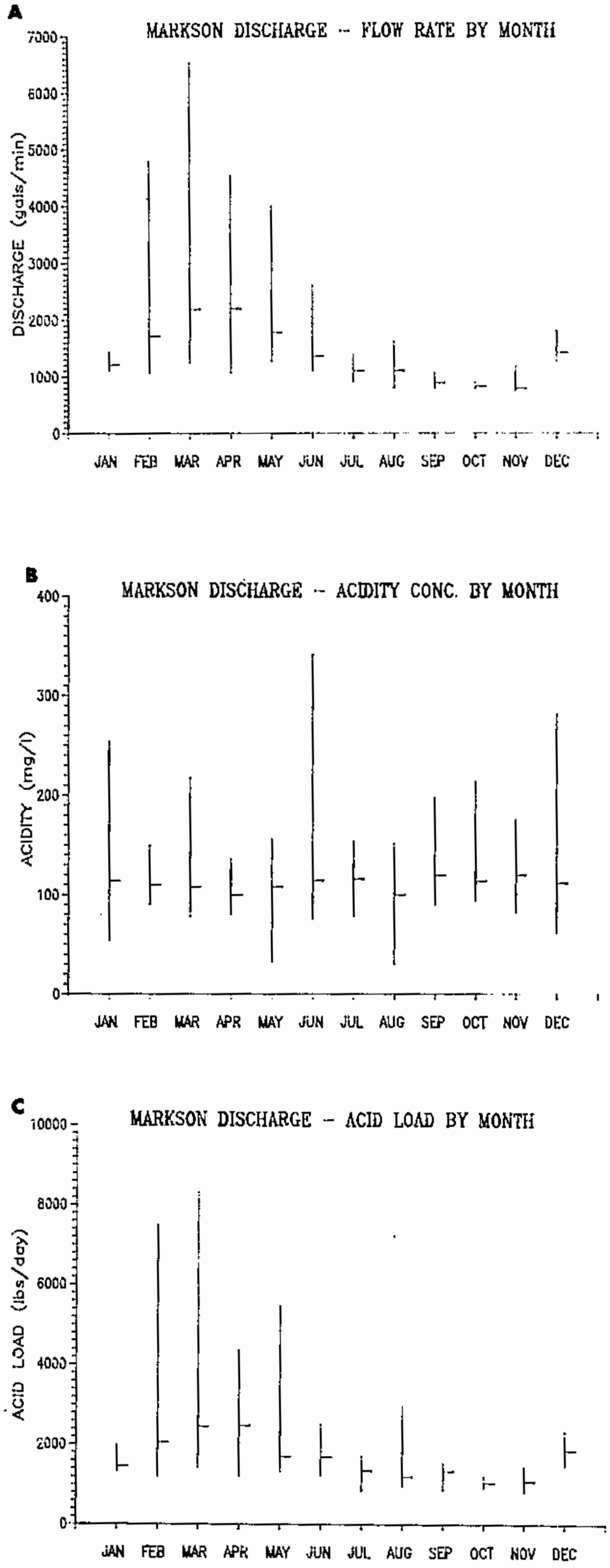

Figure 5.--Monthly median (horizontal line) and range (vertical line) values of (a) discharge, (b) acidity concentration, and (c) acid load for Markson Deep Mine Discharge. Graphs include all data from June, 1981 through August, 1986.

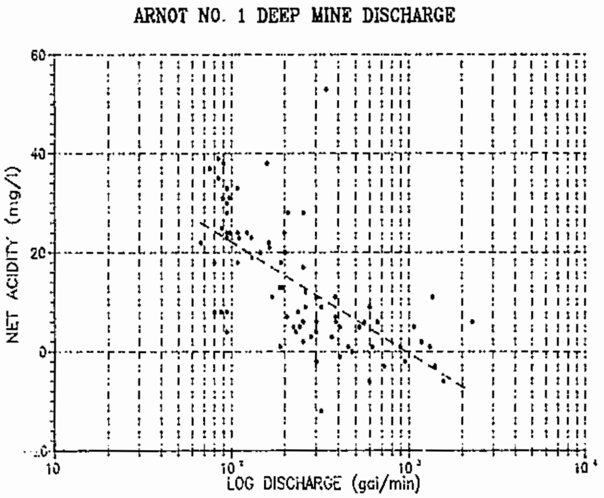

Figure 6a.--Plot of discharge versus net acidity for Arnot No.1 Discharge showing trend of decreasing net acidity with increasing discharge rate.

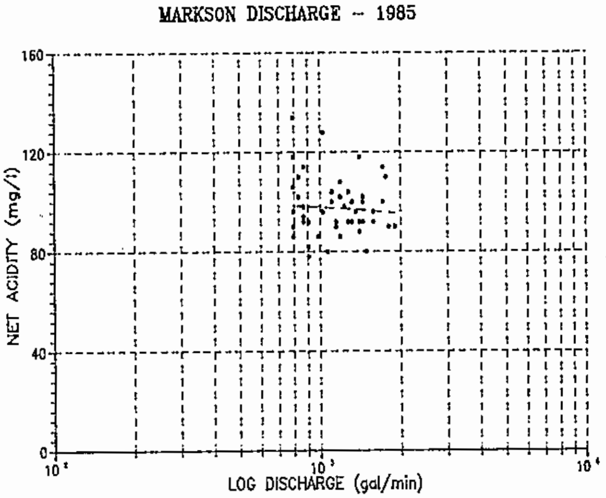

Figure 6b.--Plot of discharge versus net acidity for Markson Discharge showing lack of correlation and relatively small degree of variability in discharge and acidity values.

baseline pollution load must be represented as a statistical summary. In general, the longer the baseline period and the greater the number of samples, the more accurate the baseline summary will be. Since the baseline will be used to judge the success of the remining operation, the baseline becomes an "insurance policy" and must be accurate and statistically valid.

Various statistical parameters can be used to characterize baseline data. In Pennsylvania, baseline pollution load has been analyzed using the exploratory data analysis (EDA) techniques developed by Tukey (Tukey 1977, McGill et.al. 1978, Velleman and Hoaglin 1981). Table 1 presents a typical baseline summary includcluded in a permit for remining authorization. The baseline is summarized by five parameters: the range, median, hinge points or quartiles, the C values or approximate 95% confidence intervals, and the 95% confidence intervals about the median.

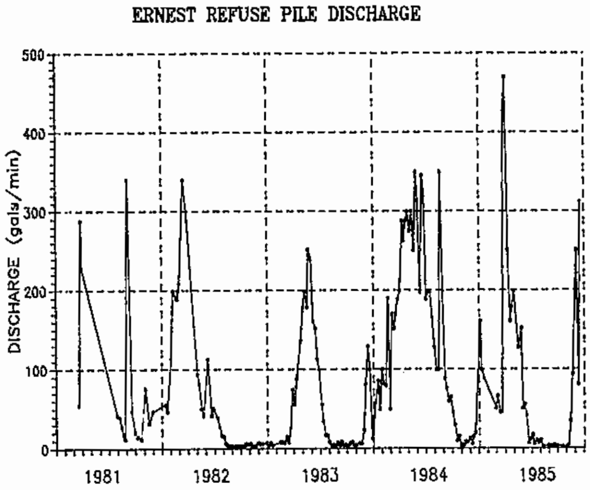

Figure 7a.--Discharge hydrograph for Ernest Refuse Pile Discharge.

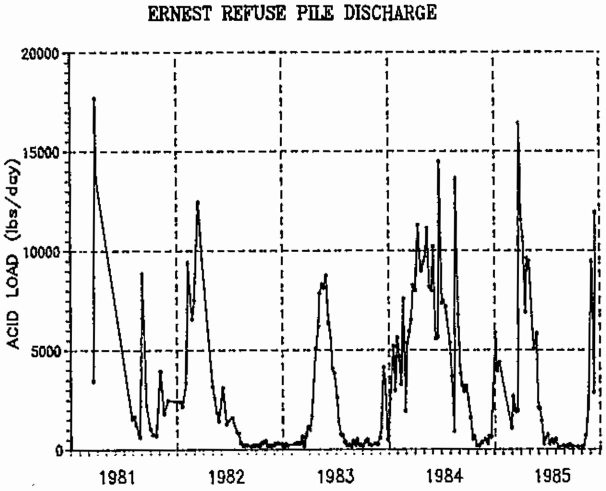

Figure 7b.--Acid load hydrograph for Ernest Refuse Pile Discharge.

CONCLUSIONS

The Arnot, Markson, and Ernest discharges were examined to study discharge behavior under a wide range of hydrogeologic conditions. Several conclusions can be drawn from these studies which have implications for baseline monitoring:

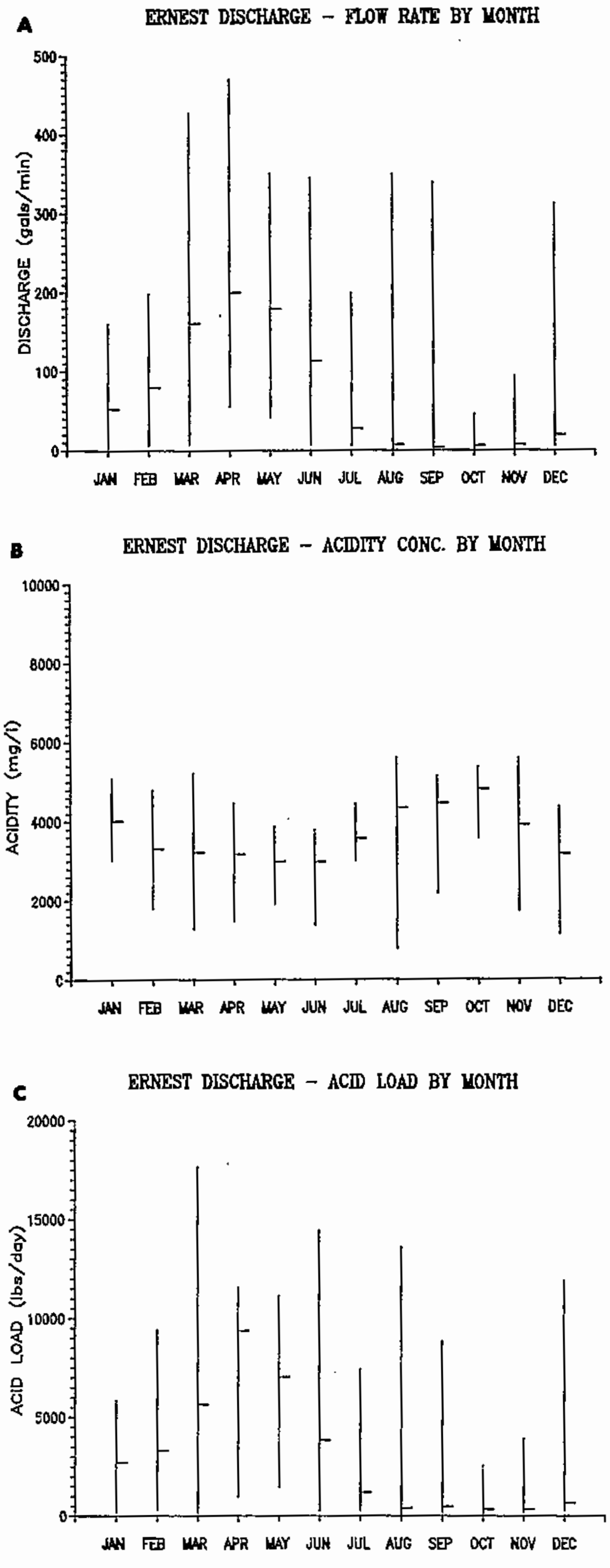

Figure 8.--Monthly median (horizontal line) and range (vertical line) values of (a) discharge, (b) acidity concentration, and (c) acid load for Ernest Refuse Pile Discharge.

Table 1.

Example of Pre-Mining Baseline Pollution Load Summary

BASELINE POLLUTION LOAD SUMMARY

PERMIT ID: EXAMPLE MONITORING POINT: SAMPLE LAT: 00-00-00 LONG: 00-00-00

		LOADING IN POUNDS PER DAY			
PARAMETER NUMBER OF SAMPLES (N)		ACIDITY 32	Fe 32	Mn 32	SULFATES 32
1. RANGE	LOW HIGH	1.10 188.55	0.01 8.22	0.04 4.89	3.76 421.77
2. MEDIAN		44.65	1.18	1.10	82.30
3. QUARTILES	LOW HIGH	19.00 73.26	0.17 2.91	0.47 2.23	37.02 167.73
4. APPROXIMATE 95% CONFIDENCE LIMITS	LOW HIGH	3.39 185.06	0.02 6.69	0.07 4.71	7.51 366.80
5. 95% CONF. INT. ABOUT MEDIAN*	LOW HIGH	27.24 62.06	0.29 2.05	0.53 1.68	40.36 124.33

*CONFIDENCE INTERVALS ABOUT MEDIAN = M +/- 1.96[1.25R/(1.35(SQR(N))]. WHERE M=MEDIAN, R=RANGE BETWEEN QUANTILES, SQR(N)=SQUARE ROOTS OF THE NUMBER OF SAMPLES. FROM R. McGILL, J.W. TUKEY, AND W.A. LARSEN, 1978, THE AMERICAN STATISTICIAN, VOL.32, NO.1, P.16.

1. Baseline monitoring must be of sufficient duration to represent the entire range of variability. This generally implies at least a year of monitoring; however, in Pennsylvania the highest and lowest loading rates usually occur in the period from February through October. Since variations can also occur between successive years, one year of background monitoring does not necessarily guarantee that sufficient monitoring has been conducted to adequately characterize the discharge for future years.

2. Since individual high flow or high loading events can occur over relatively short periods of time and fluctuations can take place rapidly, the monitoring interval must be sufficiently narrow to capture these events. For a steady-response discharge, a monthly interval may be adequate. Other discharge types, however, should be monitored more frequently and the monitoring interval should be consistent throughout the baseline period to avoid biasing the baseline by collecting more samples during selected (high flow or low flow) periods.

3. The statistical summary used to characterize the baseline and to evaluate post-mining performance must not give excessive weight to a single extreme, but infrequent event.

4. Proper flow measurement is of overriding importance in monitoring pollution load, as the flow measurement affects all load calculations and appears to dominate the baseline load variation.

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