UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
HARRISBURG, PENNSYLVANIA

ACIDITY CONTROL IN BALD EAGLE CREEK AND WEST BRANCH SUSQUEHANNA RIVER, CLINTON COUNTY, PENNSYLVANIA

By

Herbert N. Flippo, Jr.

Prepared in cooperation with the
U.S. Army Corps of Engineers
Baltimore District

OPEN-FILE REPORT 71-108

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ABSTRACT

Regression analysis of chemical and physical data collected on Beech Creek resulted in two curves that relate the concentration of free hydrogen ion to the electrical specific conductance of the water. These curves provide a means of estimating, through use of data telemetered from a water-quality monitor on Beech Creek, the acid load in the stream at any time. These estimates of acid loads in Beech Creek will enable the operators of Foster Joseph Sayers Dam on Bald Eagle Creek to release sufficient alkaline water from the reservoir to prevent fish kills in lower Bald Eagle Creek that could be caused by the acid from Beech Creek.

The acid content of the West Branch Susquehanna River upstream from the city of Lock Haven usually exceeds the amount that can be neutralized by Bald Eagle Creek. However, inasmuch as the alkaline content of Bald Eagle Creek exceeds the amount required to effectively neutralize the acidity of Beech Creek, some water may be conserved in the reservoir for the purpose of improving the quality of the West Branch when the river is unusually acid.

INTRODUCTION

Figure 1 is a map showing the principal hydrographic and cultural features of the study area. Appropriate criteria for controlling the release of the alkaline water impounded in Foster Joseph Sayers Reservoir on Bald Eagle Creek to neutralize acid from Beech Creek and in the West Branch Susquehanna River are being developed. The evaluation of many variables makes selection of the most practical release criteria a complex task. Desirable criteria will simultaneously maintain pH levels that are suitable to fish life in Bald Eagle Creek downstream from the confluence with Beech Creek, prevent fish kills caused by acid in the West Branch Susquehanna River downstream from Lock Haven, reduce flooding downstream from Blanchard and Lock Haven, and maintain reservoir levels that are suitable for recreational uses.

The principal difficulty encountered in the development of release criteria is the derivation of methods for making reliable estimates of instantaneous acid loads in Beech Creek and the West Branch. This problem was discussed in some detail by J. R. George (written commun., 1963), who also described the physical conditions in the study area and the chemical characteristics of Bald Eagle and Beech Creeks. Dr. John Lentz (written commun., 1964) made further analyses of the data collected by J. R. George. Additional data, which consist primarily of pH, temperature, and specific conductance readings collected at monitoring stations established in late 1968 at the town of Monument on Beech Creek and on the West Branch at the city of Renovo were available for the current investigations.

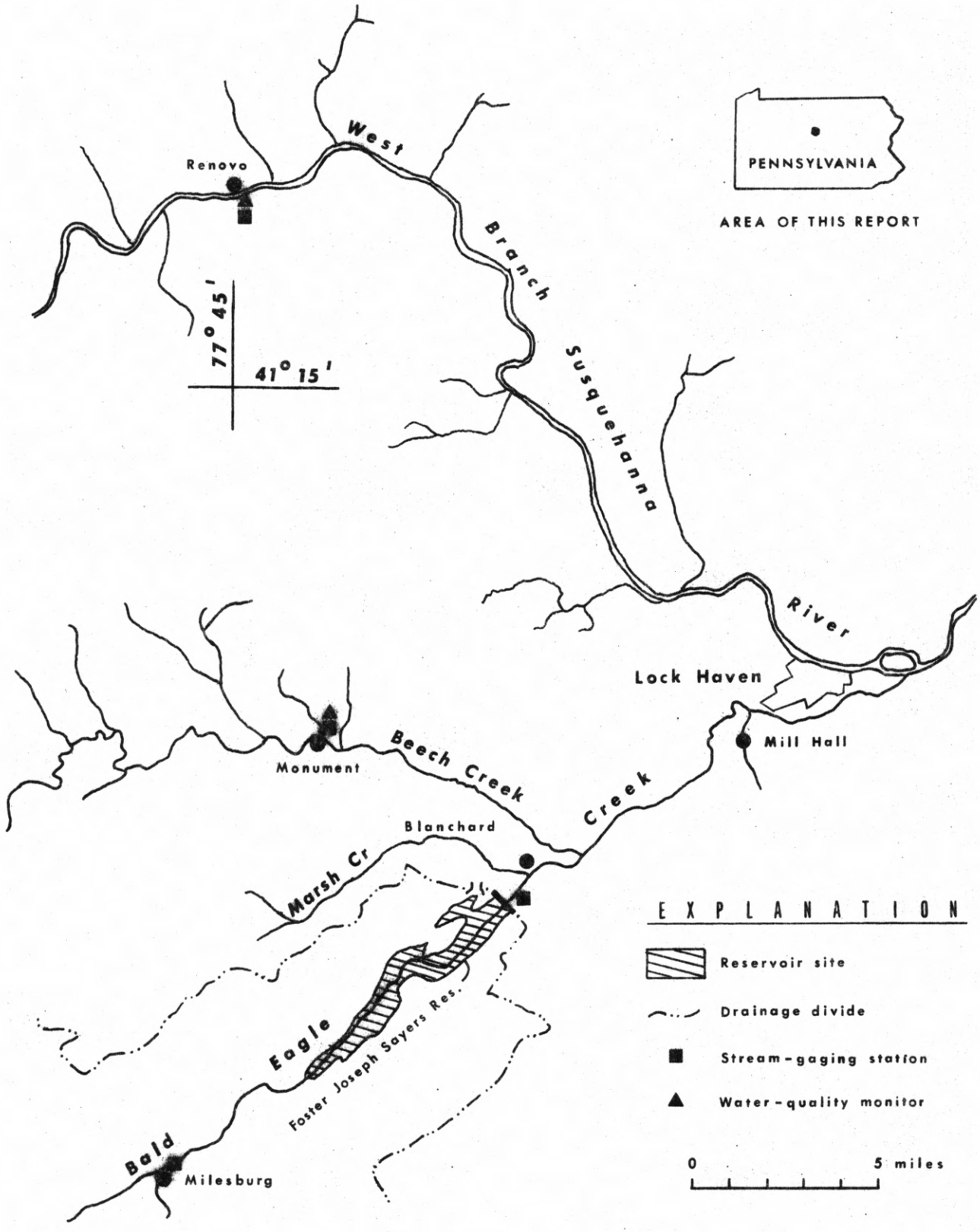

Figure 1.--Map showing location of the study area.

This report summarizes the results of investigations into the relationships of acidity and alkalinity to other chemical parameters, streamflow, and seasonal conditions. The information contained herein may be used to select provisional dam-operation criteria that will provide the desired control of water quality in Bald Eagle Creek and reduce the probability of fish kills in the West Branch. Release criteria that will permit more efficient use of alkaline reservoir water in the neutralization of acid waters may be developed when more data on the magnitude and variability of acid loads in Beech Creek and the West Branch are available.

These studies have been conducted in cooperation witn the U.S. Army Corps of Engineers, Baltimore District.

BALD EAGLE CREEK

Approximately 60 percent of the alkalinity derived from the Bald Eagle Creek basin originates in the 339-square mile part of the basin that drains into Foster Joseph Sayers Reservoir. In the past, the unregulated flow of Bald Eagle Creek has always adequately diluted and neutralized the acid entering the stream from Beech Creek. Thus, the commingled alkaline and acid waters always maintained pH levels and other quality characteristics that were tolerable to fish life.

The extremes and median monthly flows measured at the gaging station on Bald Eagle Creek at Blanchard, just downstream from Foster Joseph Sayers Reservoir, are presented in figure 2. The minimum monthly flows of record are slightly less than the 20-year, 30-day minimum flow of about 105 cfs (cubic feet per second) at this site.

Floods are expected (U.S. Army Corps of Engineers, written commun., 1963) to fill the reservoir to spillway levels only once in about 150 years. Thus, virtually all the runoff entering the reservoir, which averages 418 cfs, less seepage and evaporation losses, will be released through the conduit in the dam. For the normal range of pool elevations (610 to 632 feet), the release capacity of the conduit ranges from 3,050 to 6,700 cfs; thus, water may be rapidly released to neutralize unusually large loads of acid in the West Branch Susquehanna River. Under natural conditions of flow, a discharge of 3,300 cfs is exceeded only about 0.1 percent of the time.

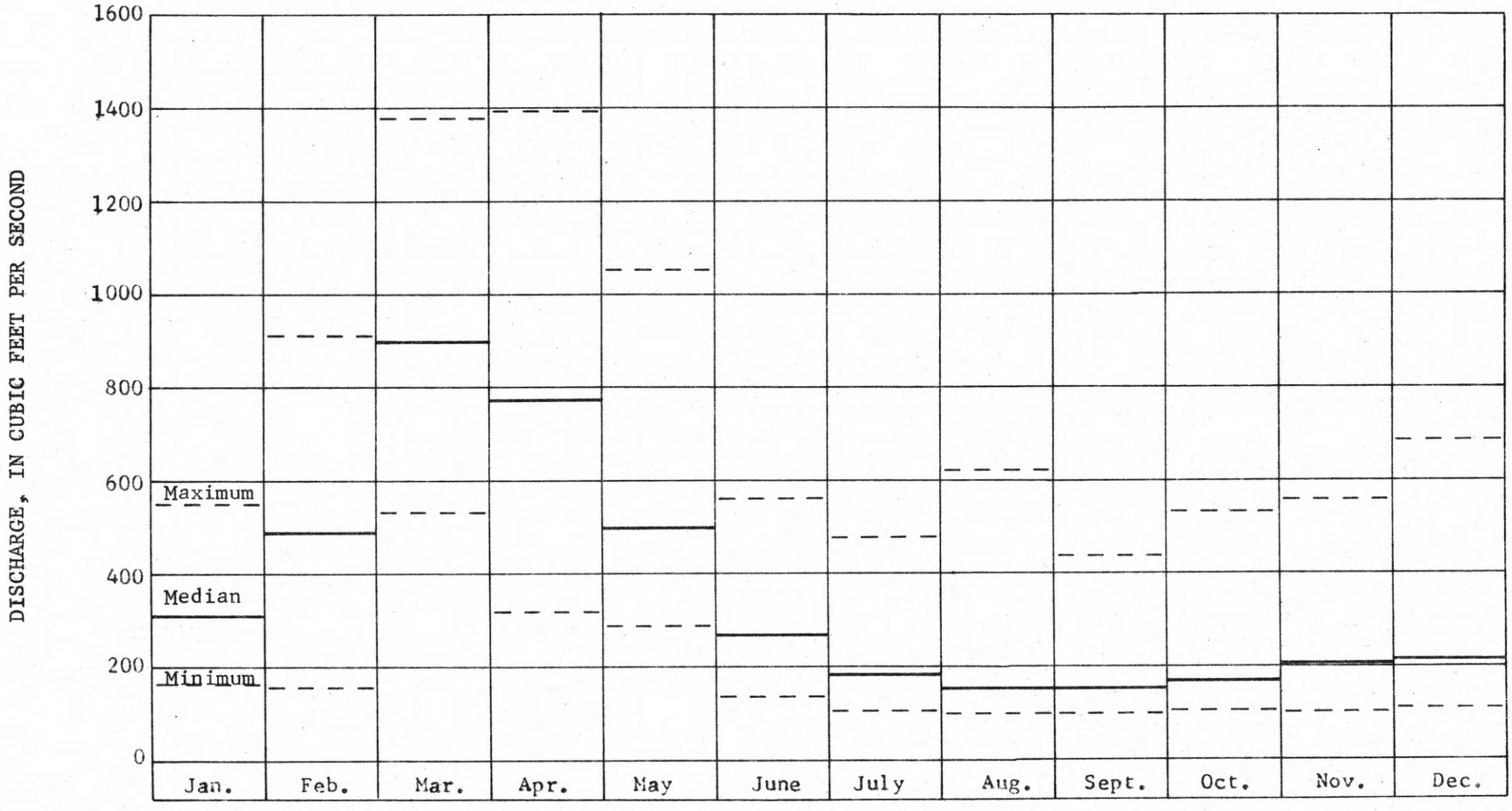

Figure 2.--Maximum, median, and minimum monthly discharges of Bald Eagle Creek at Blanchard, 1955-68.

The high alkalinity and pH of Bald Eagle Creek, together with generally low concentrations of iron, manganese, and sulfate (J. R. George, written commun., 1963), make this stream well suited for the neutralization and dilution of acidic Beech Creek and West Branch Susquehanna River. For the period from 1956 to 1969, 100 chemical analyses are available for Bald Eagle Creek at Blanchard. The observed range of bicarbonate concentrations is 50 to 195 mg/1 (milligrams per liter), and the discharge-weighted average concentration at this station is 110 mg/1. The values of 100 pH measurements of Bald Eagle Creek at Blanchard ranged from 6.6 to 8.6, and the median value was 7.7.

In the absence of flow regulation, an estimate of the bicarbonate content at Blanchard may be obtained from the general relation between discharge and concentration of bicarbonate, which is shown in figure 3. The reservoir will cause some moderation of bicarbonate concentrations at Blanchard; however, the average concentration is expected to remain about 110 mg/1. A better estimate of the bicarbonate concentration in the release water can be made from the specific-conductance and concentration-of-bicarbonate relation shown in figure 3.

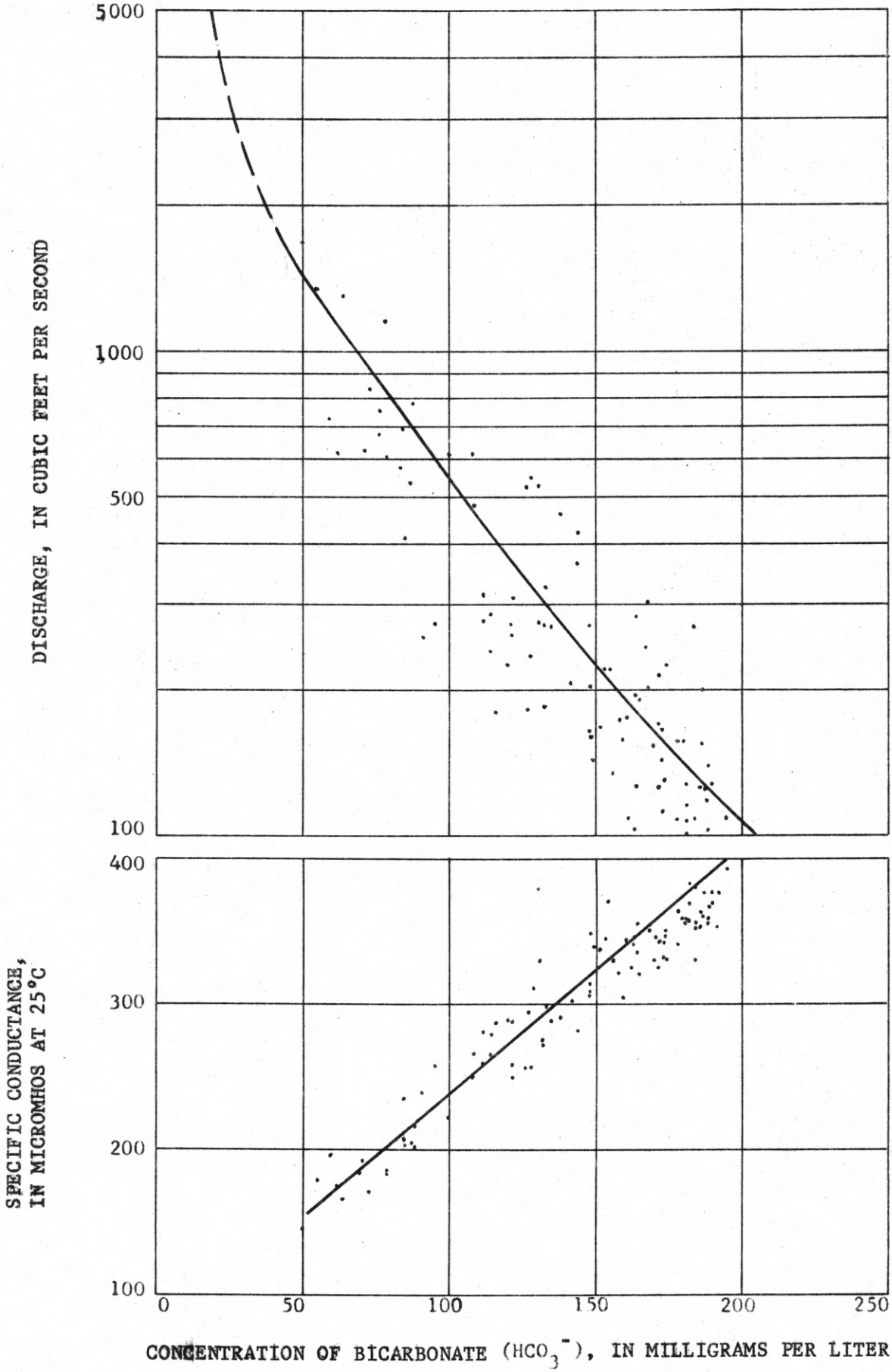

Figure 3.--Relation of discharge and specific conductance to bicarbonate content of Bald Eagle Creek at Blanchard.

Although Beech Creek does not immediately mix with Bald Eagle Creek at the point of confluence, pH data collected at near-median flows along a 5-mile reach of Bald Eagle Creek below the mouth of Beech Creek (J. R. George, written commun., 1963) indicate that the two streams become partially mixed in the first half a mile below the confluence. Presumably, the two streams intermix best when streamflow is high and turbulent. Thus, from about half of a mile below the confluence to Lock Haven, a reach of 8-1/2 miles, the chemical quality of Bald Eagle Creek will probably remain suitable for fish life if controlled releases of impounded water are provided.

BEECH CREEK

Most of the acidity in Beech Creek is derived from the upper third of its 172-square mile basin. In December 1968, an automatic water-quality monitor was placed in operation at Monument (drainage area = 152 square miles) for the purpose of collecting chemical and physical data that could readily be used to estimate the acid content of Beech Creek. J. R. George (written commun., 1963) has noted that at least two types of variations in acid concentrations occur when streamflow consists primarily of direct runoff; however, an increase in acid load always coincides with an increase in streamflow. J. R. George also showed that during most of the year a fair estimate of acidity could be made from a single regression curve relating specific conductance to acidity. However, reliance upon this relation will often result in errors of estimate of as much as 50 percent during the autumn and winter.

The data collected by the water-quality monitor during the period from December 1968 to December 1970 were studied and analyzed to derive a rapid and reliable method of estimating the acid concentration in the stream. The monitor records pH, specific conductance, and water temperature at 15-minute intervals. Continuous discharge records are also collected at this station. The monitor was checked and re-calibrated weekly, to insure that reliable data were collected. Also, the acid concentration in the stream was determined weekly. The data collected by J. R. George were incorporated into these analyses.

Through regression analyses it was determined that acidity (as concentration of the hydrogen ion) could be most reliably estimated from temperature and specific conductance data. Acidity values were plotted versus corresponding specific conductance values, as shown in figure 4.

The plotted data points show considerable scatter; however, the points that correspond to water temperatures equal to or below 15°C form a group that is largely separate from the group of points for water temperatures greater than 15°C. The curves developed from these two groups of data points for the estimation of acid concentration also are shown in figure 4. These curves tend to give slightly above-average estimates of hydrogen-ion concentrations; however, for the purpose of controlling the quality of lower Bald Eagle Creek, an overestimate of acidity is more desirable than an underestimate. Each curve was drafted so that about 95 percent of the time the estimated concentration of total hydrogen ion (H^+) would be greater than 80 percent of the average concentration in the creek at the time of the conductance measurement. Underestimated hydrogen-ion concentrations probably will never be less than 60 percent of the prevailing concentration in the stream.

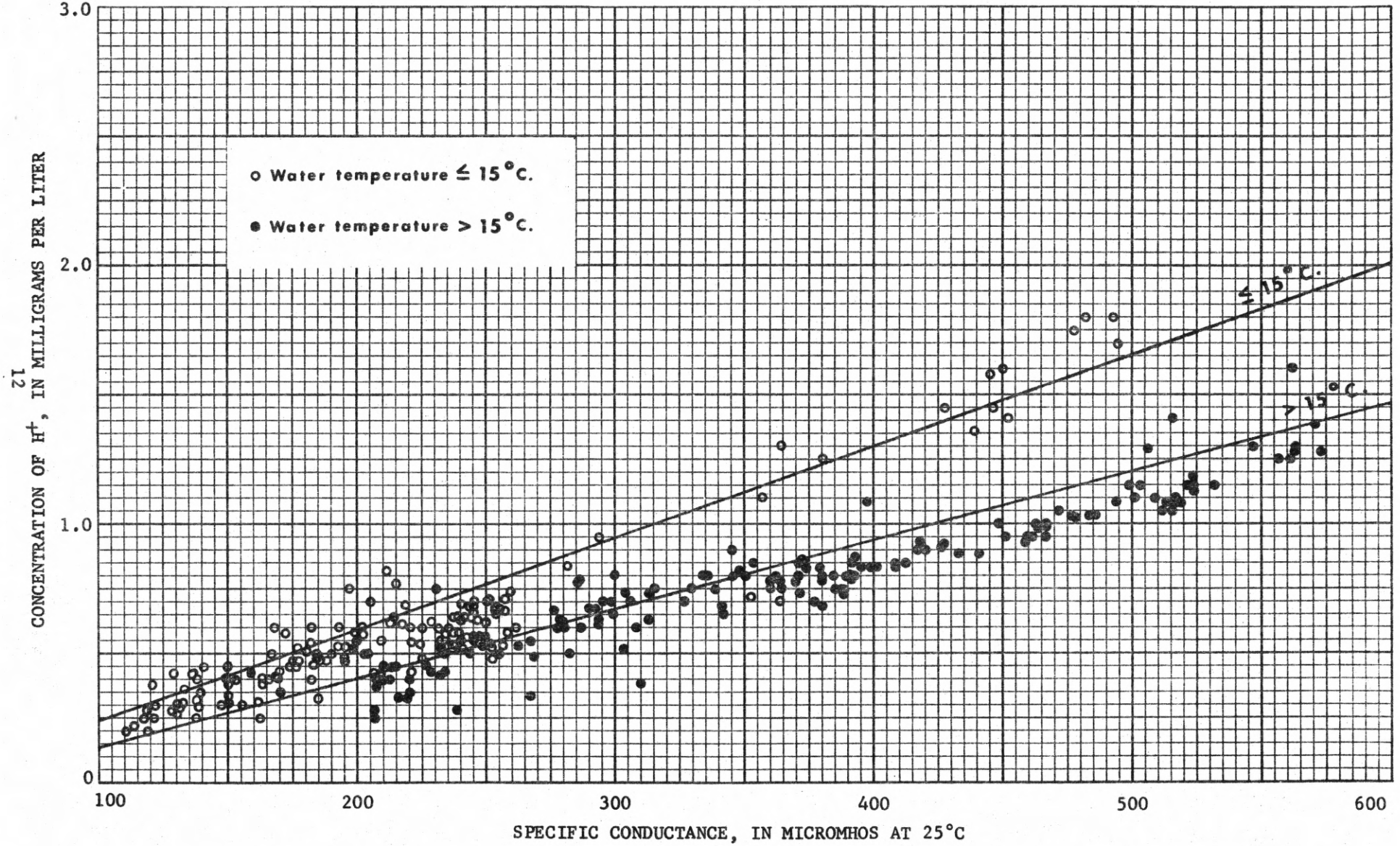

Figure 4.--Relations between acid concentration and specific conductance--Beech Creek at Monument

Some of the variations in the specific conductance-acidity relation apparently were related to specific seasonal and climatic conditions. Specific conductance-acidity relations were more variable in the period from mid-September to mid-November than during the remainder of the year. Also, for given specific conductance and water temperature values, acid concentrations were generally highest in autumn. However, the acidity record available is insufficient to determine if these acidity phenomena are typical autumnal characteristics. Other anomalously high acidities were observed to occur in conjunction with some winter storms and periods of snowmelt.

No consistent improvement in the estimate of the hydrogen ion concentration could be gained by relating this variable to pH, discharge, or antecedent water temperatures. Particularly, no method could be devised that would allow a reliable prediction of the occurrence, solely on the basis of monitor data, of periods when radical changes take place in specific conductance-acidity relations.

Estimation of instantaneous acid loads, for regulation of the release from the reservoir, are possible with the data telemetered by the monitor station and the relationships presented in figure 4. Mean daily specific conductances, discharges, and water temperatures were used in conjunction with the relations in figure 4 to prepare the acid-load hydrograph shown in figure 5. For brief periods in spring and autumn when water temperatures fluctuated from a few degrees above to a few degrees below 15°C the upper curve in figure 4 was used. Acid loads calculated from the acid content of water samples collected on random days provide a visual measure of the reliability of the estimated daily loads.

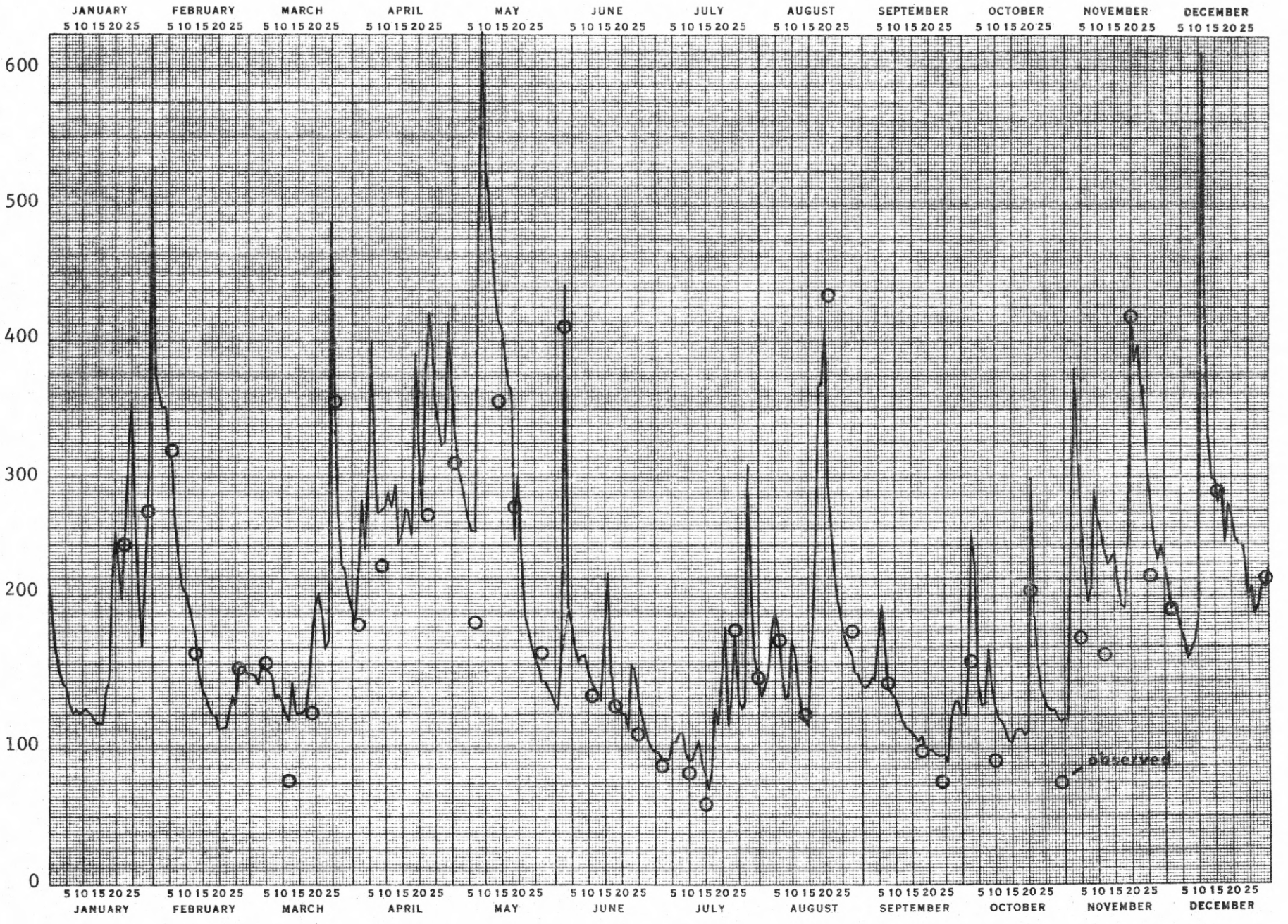

Figure 5.--Hydrograph of daily acid loads in Beech Creek at Monument

Neutralization of acidity from Beech Creek

Once the acid load of Beech Creek at Monument has been estimated, the volume of reservoir water that must be released to stoichiometrically neutralize this acid is readily calculable from the determined bicarbonate content of the released water. This estimate of the minimum release necessary for acid neutralization is practicable because: (1) the acid load of Beech Creek remains almost constant between Monument and the mouth, (2) the bicarbonate content of the release water will remain relatively stable over a wide range in discharge, and (3) water passing by Monument will reach the confluence several hours later than water passing through the outlet in the dam. In figure 6, the discharge of Bald Eagle Creek is compared to the release (at average bicarbonate content) necessary to stoichiometrically neutralize the acid in Beech Creek during the year 1969. It is noteworthy that the total discharge of Bald Eagle Creek at Blanchard is 6.2 times the total hypothetical release required to neutralize the acid load of Beech Creek. If the dam had been in operation during this year, so that the bicarbonate content of the release could have been obtained, the necessary release for neutralization would have shown more variability than is indicated in figure 6; however, the total release for the year would have been about 10 percent less than that shown, owing to conditions of above-average alkalinity in Bald Eagle Creek.

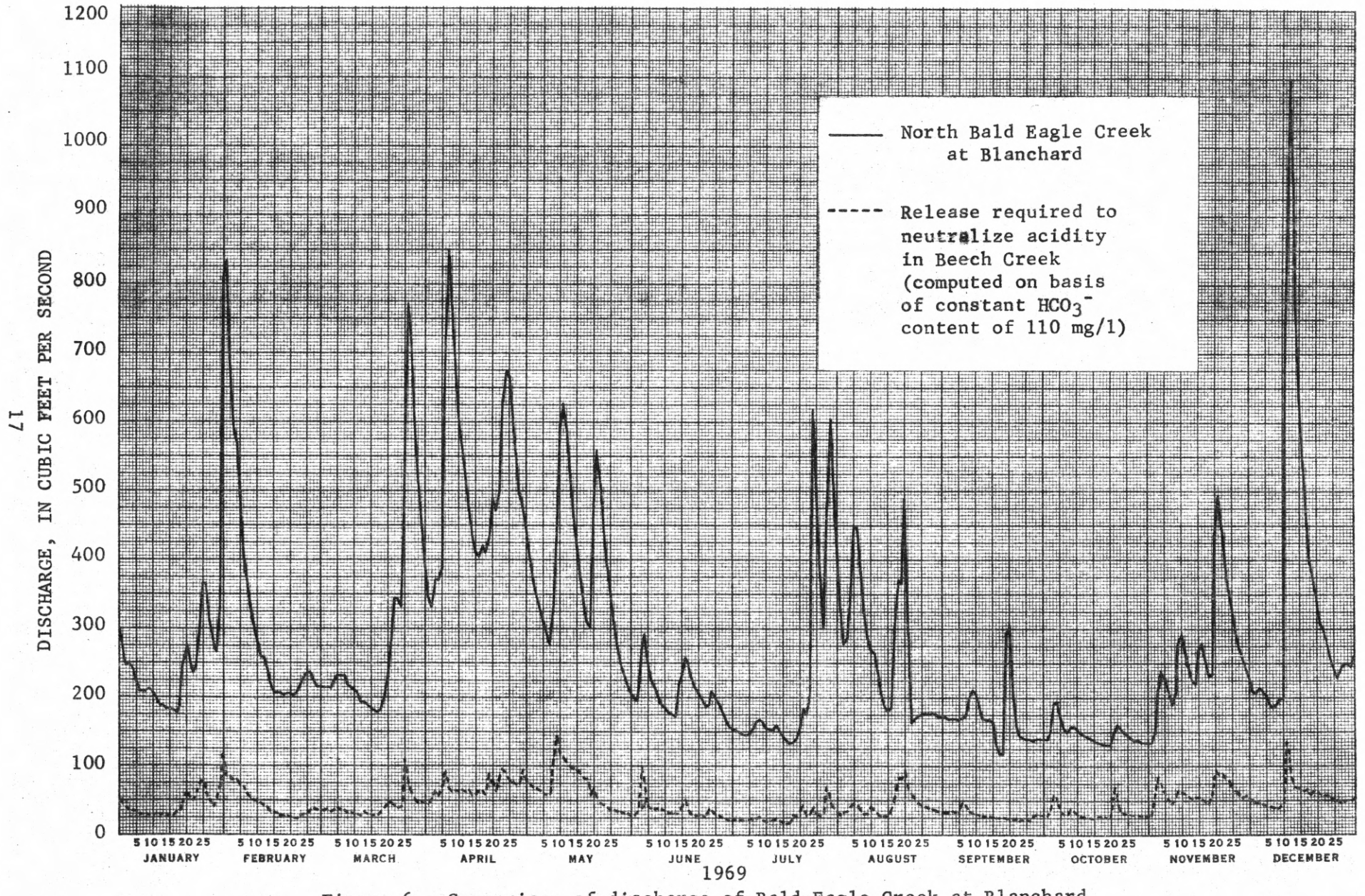

Figure 6.--Comparison of discharge of Bald Eagle Creek at Blanchard with hypothetical release from Foster Joseph Sayers Reservoir required to neutralize Beech Creek.

In order to maintain the chemical quality of the confluent water so that fish life will survive, it is necessary to release considerably more water than the amount required for stoichiometric neutralization. Results of titrations of water from Beech Creek with water from Bald Eagle Creek indicate that the resultant pH of stoichiometrically neutralized Beech Creek water generally is in the range of 5.5 to 5.7. Only eight samples of Beech Creek water were titrated with Bald Eagle water, but these samples were taken under a variety of flow conditions. Data for the eight titrations are given in table 1. These data suggest that the equivalents of bicarbonate in the released water should generally be from 2 to 6 times the equivalents of free hydrogen ion in Beech Creek if a pH of at least 6.7[1/] is to be maintained in lower Bald Eagle Creek. Thus, the equivalents of bicarbonate ion in the release water should be 1 to 5 times greater than the equivalents of free hydrogen ion in the combining water from Beech Creek. However, no method could be devised, on the basis of the data available, for making reliable day-to-day estimates of the required surcharge release. In general, a release rate equal to five times the rate necessary to stoichiometrically balance the acidity in Beech Creek, as computed from the curves in figure 4 and the bicarbonate content of the release, will probably maintain pH levels above 6.5 in lower Bald Eagle Creek.

1/ Pennsylvania Fish Commission's water-quality criteria for the propagation of fish and other aquatic life include a pH range of 6.7 to 8.6.

The information presented in figure 6 indicates that inflow to the reservoir will be more than adequate to provide the overload releases necessary to insure that pH levels in lower Bald Eagle Creek remain suitable to fish and other aquatic life. In the event of mechanical failure in either the water-quality monitor at Monument or the telemetering equipment, a release equal to the natural discharge of Bald Eagle Creek at Blanchard under the prevailing climatic conditions (which may be determined by correlation of streamflows) will provide adequate neutralization and dilution of the water from Beech Creek.

Table 1.--Results of titrations of Beech Creek water with Bald Eagle Water

Date of collection	Beech Creek at mouth		Bald Eagle Creek at confluence[1/]		Ratios: Bald Eagle to Beech Creek		pH at stoichiometric end point	Ratio of equivalents HCO_3^- to equivalents H^+ at indicated pH			pH of Bald Eagle Creek at Mill Hall	
	Discharge (cfs)	Concentration of H^+ (milliequivalents per liter)	Discharge (cfs)	Concentration of H^+ (milliequivalents per liter)	Discharge (cfs)	$\frac{HCO_3^- \text{ conc.}}{H^+ \text{ conc.}}$		6.0	6.7	7.0	Predicted with titration curves	Measured
8- 1-62	a/28	0.7	a/100	3.15	3.57	4.5	5.5	1.23	2.09	2.54	8.0	7.9
10-31-62	a/132	1.1	176	2.64	1.33	2.4	5.7	1.60	5.72	b/7.7	6.3	6.8
3- 7-63	a/390	.5	1,350	.90	3.45	1.8	5.6	1.66	b/3.8	b/5.2	6.9	6.7
4-12-63	260	.4	310	2.00	1.19	5.0	5.7	1.50	4.25	5.60	7.1	7.5
6- 4-63	a/270	.4	260	2.00	.96	5.0	5.6	2.35	6.00	9.0	6.5	6.9
1-27-70	a/160	.56	250	2.02	1.56	3.6	5.5	2.00	5.60	8.75	6.8	---
2-24-70	a/310	.53	610	1.35	1.97	2.5	5.5	1.79	3.65	6.28	6.9	---
3-25-70	a/390	.43	960	1.43	2.46	3.3	5.8	1.20	4.10	5.60	7.2	---

1/ Contribution from Marsh Creek excluded.

a/ Approximate.

b/ Estimated from titration curve.

Data that would permit an assessment of the effects of the impoundment on temperature, dissolved oxygen, and coliform in the reach below the dam are presently unavailable; however, the quality data available indicate that, with appropriate control of the released water, water quality in all but about half of a mile of this reach will generally meet the criteria for pH, iron, and dissolved solids set forth by the Sanitary Water Board (1967).

WEST BRANCH SUSQUEHANNA RIVER

The flow of the West Branch Susquehanna River at Renovo averages nearly 12 times the average flow of Bald Eagle Creek at Blanchard. Although the flows of the two streams exhibit a similar seasonal distribution, the relative magnitudes of daily and seasonal loads of acidity and alkalinity vary considerably.

The flow and the acid load of the West Branch change only slightly along the reach from the quality monitor at Renovo to Lock Haven. The data collected at Renovo since 1963, including the monitor data collected from September 1968 to December 1969, have been manually analyzed for the purpose of deriving methods for estimating the acid content of the West Branch. These studies showed that a crude estimate of the hydrogen ion concentration could be made from a curve relating this variable to discharge. This curve is shown in figure 7. Estimates based on this relation will rarely result in an overestimate of as much as 100 percent of actual acid concentration in the river; however, the concentration will exceed the estimated value by 100 percent, or more, about 15 percent of the time. The greatest underestimates can be expected to occur during periods of high flows in winter. This curve should not be used to estimate the acid concentration in the West Branch during periods when the river is known to be unusually acid.

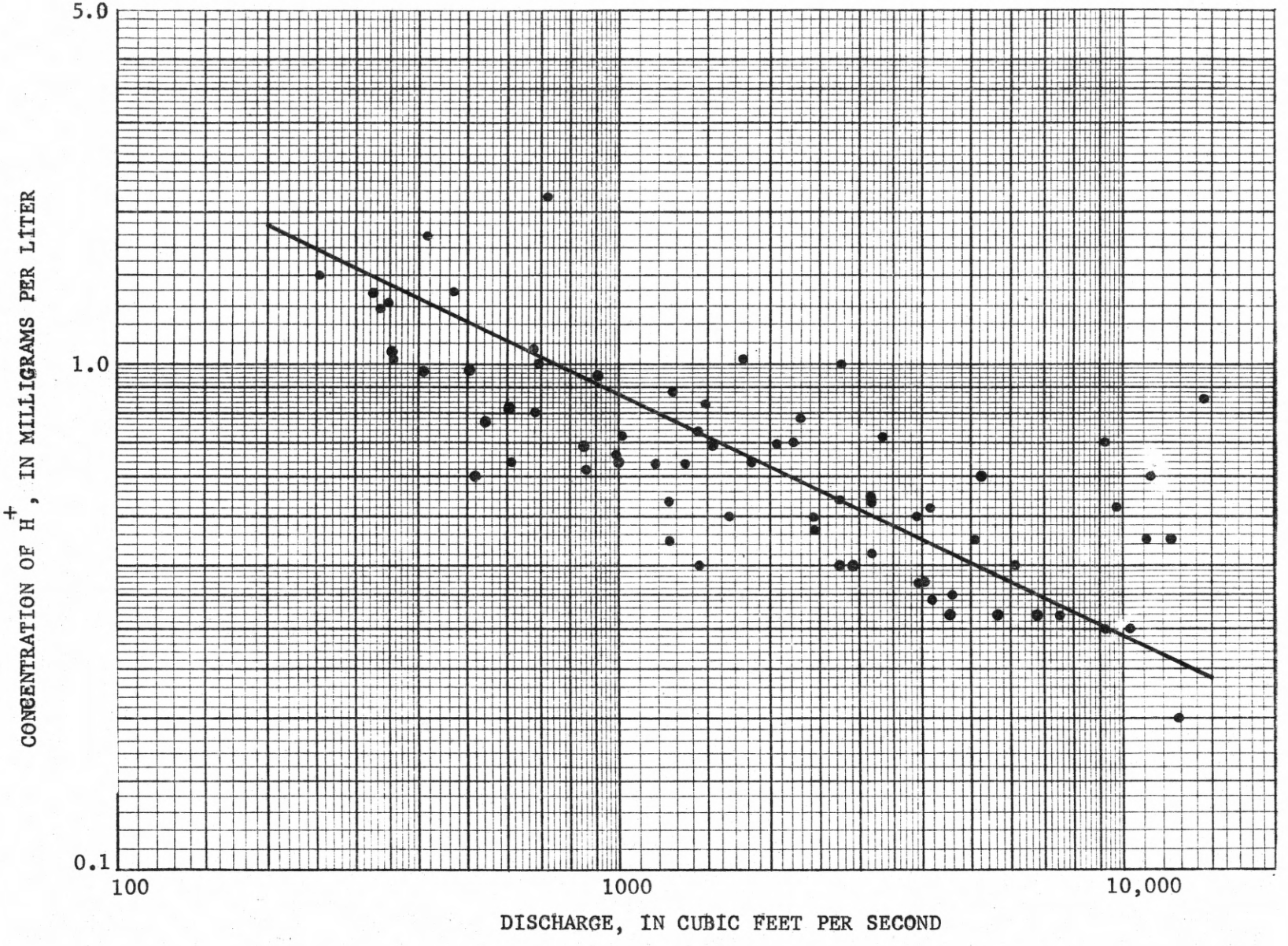

Figure 7.--Relation of acid concentration to discharge--West Branch Susquehanna River at Renovo.

Correlations between the deviations of the concentrations of H^+ from the mean curve and the corresponding values of pH, discharge, and water temperature were low. However, abnormally high (and low) acid concentrations were often, but not always, accompanied by above (and below) normal specific conductances--as determined from an average curve of relation between discharge and specific conductance. Occasionally, under conditions of relatively stable flow, below-normal specific conductances occurred in conjunction with above-normal acidities. The results of the weekly to biweekly samples collected in 1968 and 1969 suggest that unusually high concentrations of acidity may persist for several weeks at a time during the winter. There is no relation, however, between the abnormalities in acid concentrations and the daily variations in the specific conductances record by the monitor. No method could be devised that would, through the use of monitor data, produce a consistent or worthwhile improvement in the estimates of acid concentration made on the basis of the general relation shown in figure 7. After monitor record has been collected for several years, further analysis of the data may disclose a mechanism for improving the estimate of the hydrogen ion concentration.

Thirty-three analyses for acidity at Renovo were used to estimate the mean monthly acid loads of the West Branch Susquehanna River for the year 1969. For this same period, the monthly bicarbonate discharge of the Bald Eagle basin was estimated from the discharge at Blanchard, the bicarbonate-discharge relationship for this station (fig. 3), and the ratio of the drainage area above Blanchard to the total bicarbonate-producing area in the basin. Monthly bicarbonate loads were reduced by the amount of bicarbonate necessary to stoichiometrically neutralize the flow of Beech Creek. The results of these computations, which represent the monthly loads of hydrogen ion and bicarbonate ion mixing in the West Branch downstream from Lock Haven, are graphed in figure 8. These data suggest that during the winter months the acid load of the West Branch Susquehanna River usually far exceeds the neutralization capacity of Bald Eagle Creek. The alkalinity of Bald Eagle Creek was adequate to neutralize the acidity in the West Branch Susquehanna River only during July, September, and October in 1969.

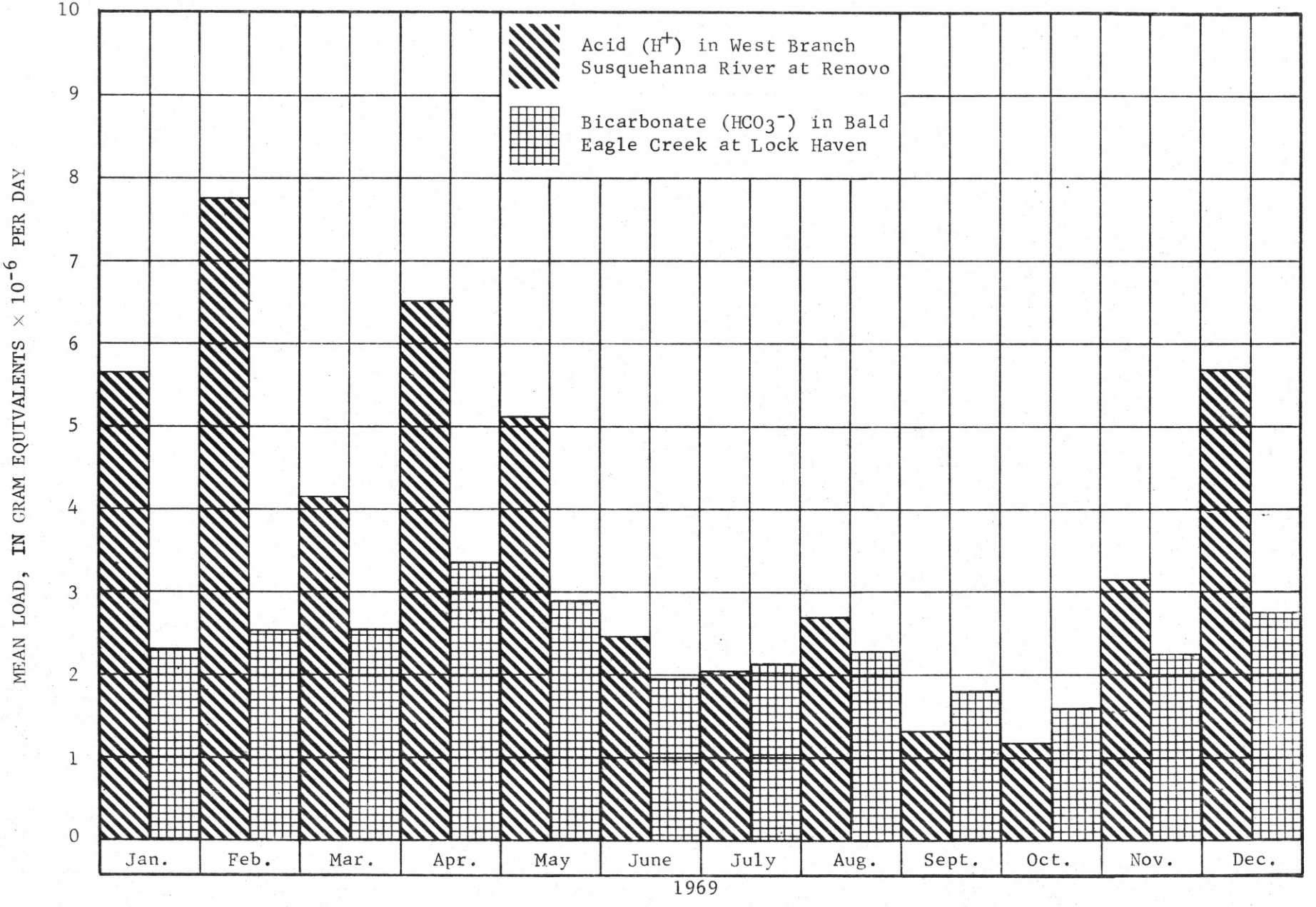

Figure 8.--Acid load of West Branch Susquehanna River at Renovo compared with bicarbonate load of Bald Eagle Creek at Lock Haven.

If water is released from the reservoir at an average rate of five times the quantity necessary to stoichiometrically neutralize the flow of Beech Creek, about 20 percent of the impounded flow of Bald Eagle Creek could be used to abate abnormally high acidity in the West Branch downstream from Lock Haven. Thus, surcharge releases from the reservoir may be timed to coincide with unusually acidic conditions in the West Branch provided that existing streamflow conditions are not such as to preclude the practicability of such releases.

REFERENCES CITED

Commonwealth of Pennsylvania, Sanitary Water Board, 1967, Article 301 -- Water Quality Criteria, 24 p.

U. S. Army Engineer District, Baltimore, 1963, Blanchard Reservoir Design Memorandum No. 1 (revised), 22 p., 37 plates, 1 appendix.