V. HYDROGEOLOGY

The Composite map, Plate No. 2, shows hypothetical water table contours of the Bernice Basin. These were prepared to illustrate the interpretation of the hydrology of the two drainage tunnels. The primary data used in the preparation of the contours include, measured elevations of water levels in wells, drill holes, abandoned strip mines, mine adits, and the drainage tunnels themselves, as well as elevations of similar features estimated from the 1:24,000 topographic maps. It is also assumed that the floor of the mined out areas of the B coal controls the water table in the areas drained by the two tunnels.

In the Gutten and Lewis areas, a number of points were obtained from measured elevations of water levels in open, recent drill holes and standing water in abandoned strip mines. These elevations clearly show that the water table here is not affected by underground mine drainage. The contours show a subdued replica of the topographic land surface, the normal situation in un-mined areas. The Gutten drift does have a small flow of water and probably drains a small part of the old workings in the western part of the Gutten area. The flow is so small that it seems likely that there is no direct connection with the Connell Deep Mine Complex.

In the Bliss area, there is almost no ground water level information available. From considerations of the water balance of the "C" drainage tunnel, it is evident that most or all of this area discharge to the "C" tunnel, and the contours are drawn on the assumption that the floor of the workings in the B coal represent maximum elevations of the water table. Note that the "C" tunnel penetrates both the B and C coals and hence drains both workings. This assumption necessitates a ground water divide just south of Bernice and again somewhere on the south side of the basin. These divides can be seen on the water table contours, Plate No. 2, where two 1900 contours and two 1880 contours parallel each other. It is believed that the postulated fault between the Bliss and Gutten areas completely separate the areas hydrologically.

The water table contours in the Connell and Northern Anthracite areas are based primarily on elevations of the B coal mine workings, the drainage tunnel, and surface water elevations in the strip mines at the eastern end of the basin. A ground water divide must exist between the B and C tunnel drainage areas. It is probably controlled by a minor reversal of dip in the coal beds not shown on the coal structure contours (which are based on limited drill hole data in this area). The ground water divide south of Bernice extends eastward along the northern side of the Connell Mine workings. South of the divide, the contours slope generally southward, controlled by the "B" tunnel. There are probably pools of standing water in the B mines in the areas of closed structure contours. Elsewhere it is assumed that the water table is at, or just below, the floor of the B mine, except in the immediate vicinity of the "B" drainage tunnel.

There are a number of areas of perched water above the mines, as indicated by the swamps and ponds shown on the topographic maps. These are probably controlled by impervious layers in the glacial till which covers much of the area. However, this perching is probably local and the water is eventually discharged downward to the mines below.

The water table contours in the Northern Anthracite area are based on estimated and measured elevations of water in the abandoned strip mines (before the recent operations), the swamp, and other considerations. Underground mine maps of this area clearly show it is connected with the Connell Mine. Some surface water from the swamp enters one of the old strippings and apparently percolates into the old workings, since the pool in the strip mine has no surface outlet. There is also some seepage from the swamp into the old workings. The mine maps indicate that some headings ended in "clay" and that they were wet. The ground water divide, therefore, is probably under the swamp.

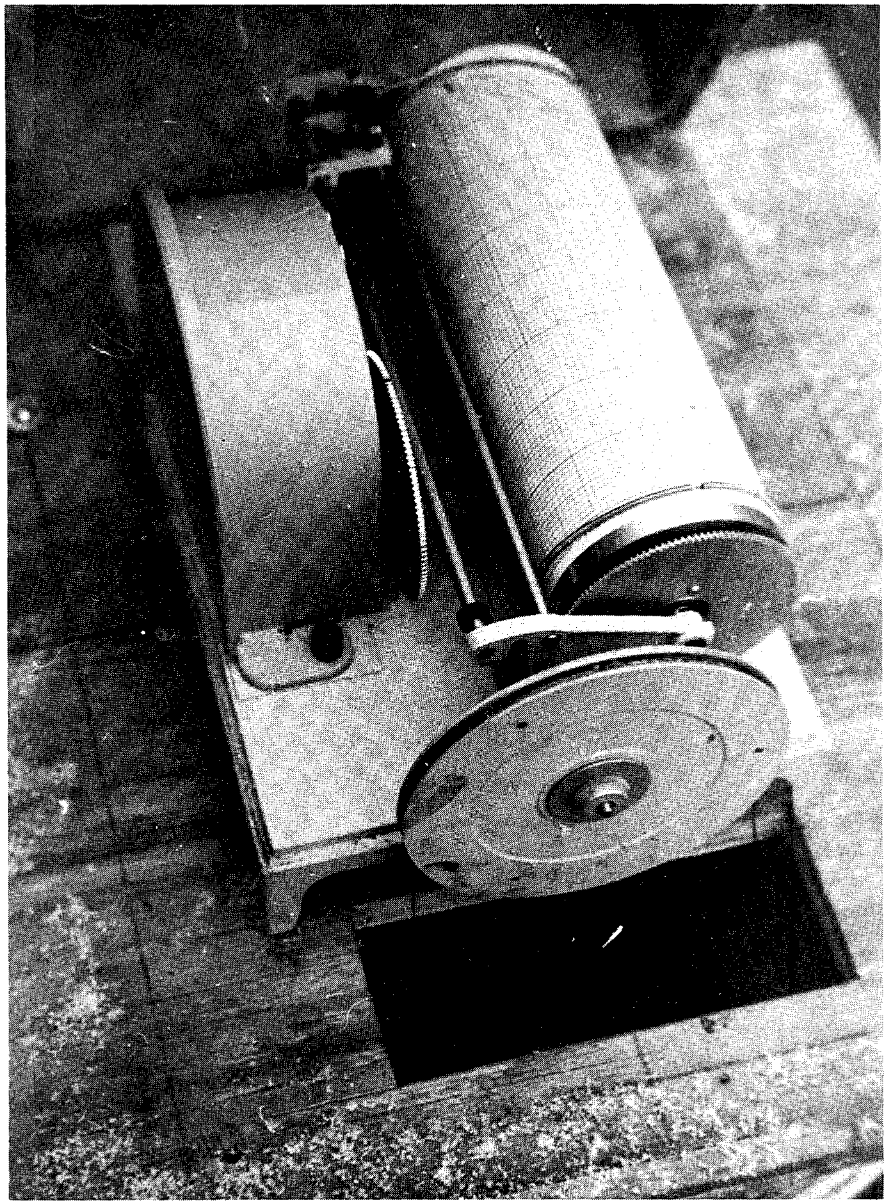
The areas drained by the tunnels have been estimated to be 700 acres for the "C" tunnel and 1800 acres for the "B" tunnel.

A. TUNNEL FLOWS AND WATER BALANCE

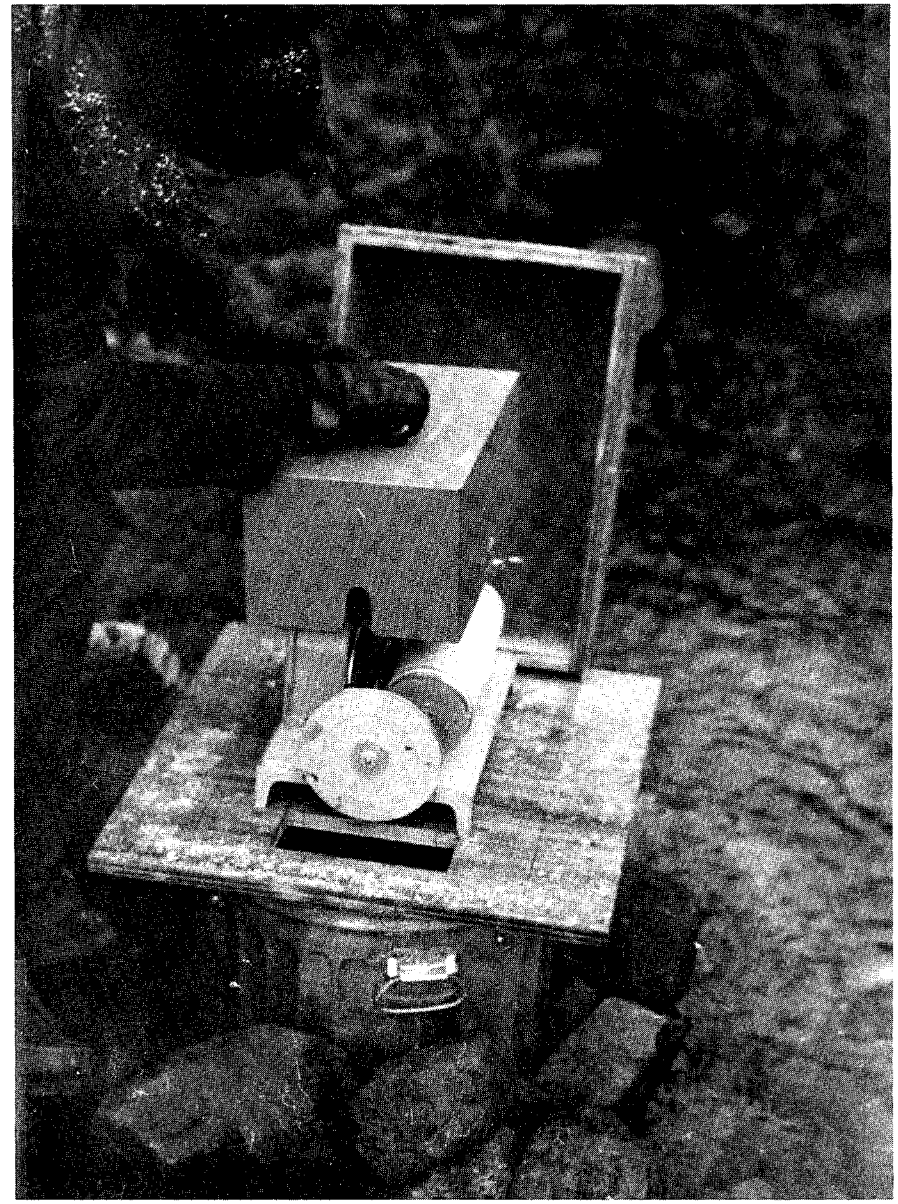
Monthly flow measurements were made on the B Vein and C Vein Drainage Tunnels for a period of one year. However, it was felt that these records were not sufficient to provide a clear picture of the dynamics of the hydrology of the deep mine complex. Therefore, in order to obtain a continuous daily flow record weirs and water level recorders were installed near the outlets of the tunnels in August 1975. Figure 6 shows the type of recorder being used in conjunction with a stilling well. Records were obtained for August 13-31 and September 1-25. On September 27, high flows caused by tropical storm Eloise washed out both weirs. On December 30, the recorders were once again installed on the repaired weirs. Although there was some malfunction of the recorders, due to extremely cold weather, the records of the flows obtained for January through April, 1976 were sufficiently complete to make it possible to draw accurate conclusions concerning flows.

Within close proximity to the study, a weather recording station is located at Dushore, which supplies climalogical data to the National Oceanic and Atmosphere Administration of the United States Department of Commerce. Precipitation data for the study was obtained from this source. Detailed precipitation records are shown in Appendix A.

Table I shows the monthly average flows for the period of record. Both weirs overflowed for several days in January and February. In calculating the average flows it was assumed that the flow of the "B" tunnel averaged twenty cfs and the "C" averaged five cfs during the overflow periods.



WATER LEVEL RECORDER



RECORDER AND STILLING WELL

"B" VEIN TUNNEL

FIGURE 6

Table I
Monthly Flows

	"B" TUNNEL CFS	MGD	AF	"C" TUNNEL CFS	MGD	AF
January 1976	3.00	1.94	184	1.50	0.97	92
February 1976	8.30	5.36	494	3.40	2.20	195
March 1976	4.70	3.04	290	1.90	1.20	117
April 1976	3.50	2.25	207	1.49	0.96	88

B weir - 4 winter months - average 294 AF/month
6 winter months - flow 1762.5 AF.
C weir - 4 winter months - average 123 AF/month
6 winter months - flow 738 AF.
Note: CFS - Cubic Feet per second
MGD - Million Gallons per day
AF - Acre Feet

Figure 7 is a hydrograph showing the flow records for the two tunnels during the months of January through April 1976.

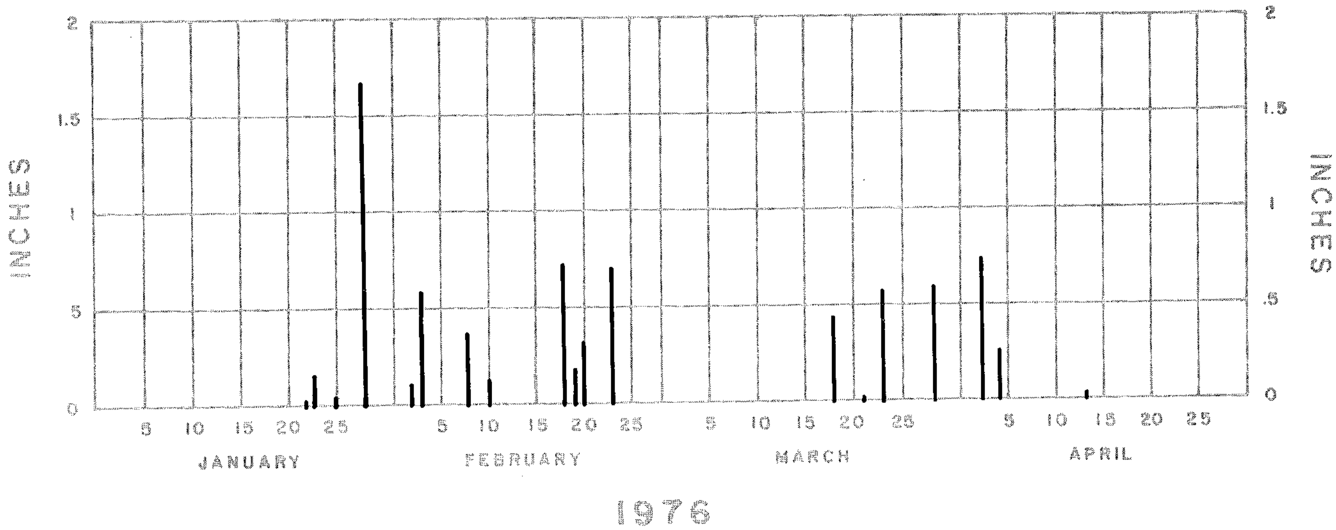
Examination of the hydrographs shows some interesting facts concerning the hydrology of the area. The "C" tunnel responds more quickly to periods of recharge than does the "B" tunnel. For example, on January 26, the "C" tunnel had begun to rise while the "B" tunnel began to rise one day later. During the week of March 16 to 23, the "C" tunnel shows several small fluctuations not observed in the "B" tunnel. Even more noticeable, the rainfall on March 27 produced a rise which began on March 31 in the "C" tunnel but did not begin rising until April 2 in the "B" tunnel. Generally, the monthly or weekly flow of the B tunnel appears to be 2.5 times that of the C tunnel.

The effect of recharge during the winter months was calculated with reference to the rainfalls of March 27 and April 2. The flow of both tunnels shows a steady recession from March 25 to March 30. This recession was projected to April 20 and the excess flow contributed by the total of 0.42" of precipitation was calculated. Table II is a summary of the results of this calculation. The figures represent a high rate of infiltration but it occurred at a time when the ground had thawed and evapotranspiration was at a minimum.

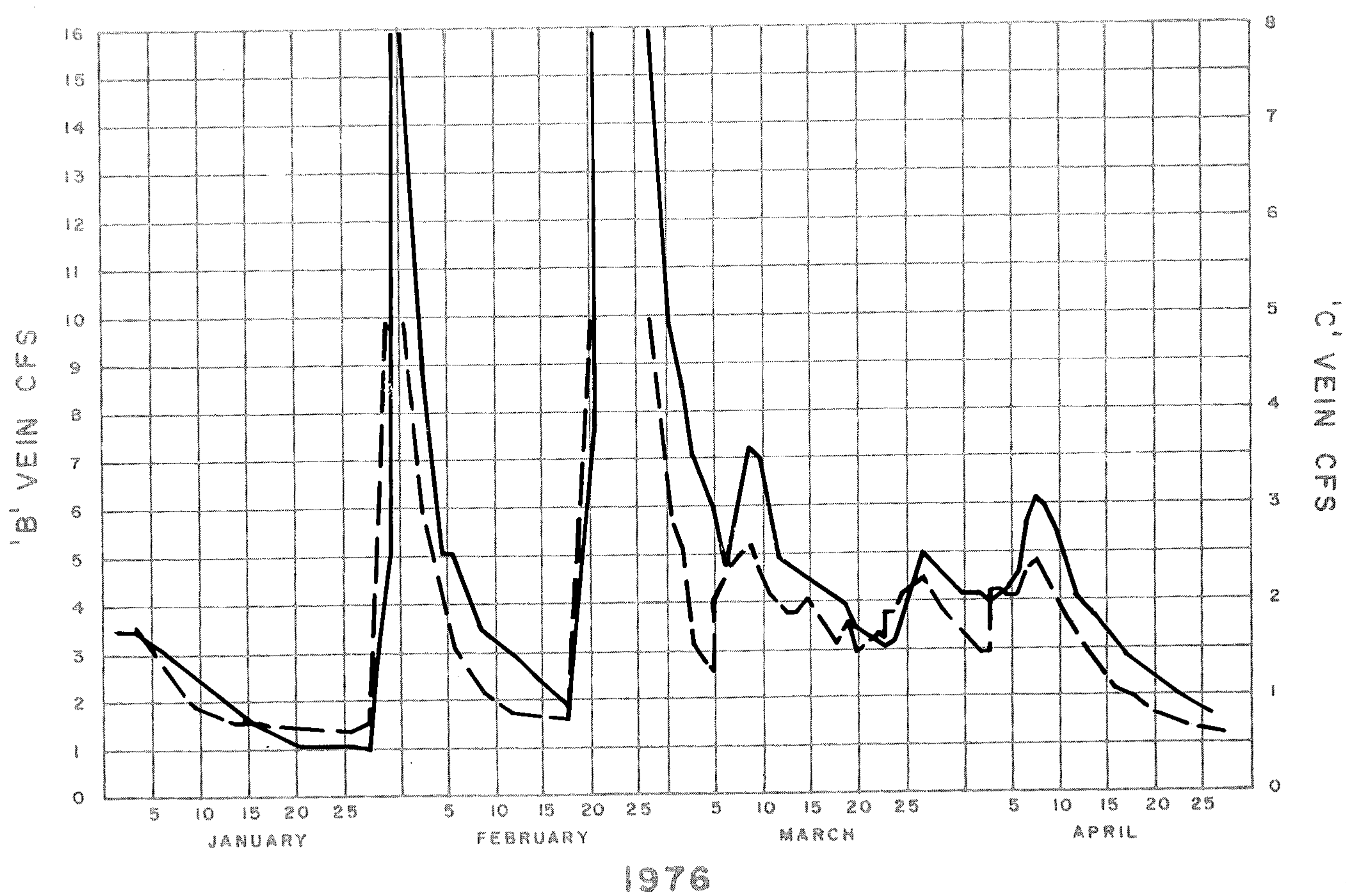
Table II
Infiltration

B Weir	Excess flow, March 31 – April 24 = 15,878,900 gals.	= 48 AF
	Rainfall – 0.42” over 1800 acres	= 63 AF
	Infiltration	= 76%
C Weir	Excess flow, March 31 – April 18 = 5,887,537 gals.	= 18 AF
	Rainfall 0.42” over 700 acres	= 24.5 AF
	Infiltration	= 73%

B WEIR – C WEIR HYDROGRAPH



PRECIPITATION



DISCHARGE

'B' VEIN ————

'C' VEIN — — — —

FIGURE 7

In order to calculate a water balance it was necessary to determine average rainfalls for the area. Table III shows the rainfall measured at Dushore in 1975. Because departures from the normal are not known for this station, departures were interpolated by comparison with records of other stations in the Upper Susquehanna Valley. The derived total of 40 inches of normal precipitation for the year agrees well with the published values.

Table III

Dushore Rainfall
1975

	Jan	Feb	Mar	Apr	May	Jun	
Measured	3.92	4.10	3.22	1.71	3.97	4.48	
Estimated Departure	+0.70	+1.60	+0.20	-1.75	--	+1.40	
Normal	3.22	2.50	3.02	3.46	3.97	3.08	
	Jul	Aug	Sept	Oct	Nov	Dec	Total
Measured	3.37	5.27	13.69	4.48	3.14	2.65	53.00
Estimated Departure	-0.60	+0.75	+10.00	+1.00	+0.15	-0.10	
Normal	3.97	3.52	3.69	3.48	2.99	2.75	39.65

November through April normals = 17.94"
May through October normals = 21.71"

The average tunnel flows were based on the measured flows and extrapolated in the following manner: the flows for January through April were calculated from the hydrographs and it was then assumed that these flows were typical for the winter months. The average was, therefore, extended for the total six winter months, November through April. From the appearance of the April recession and the C weir data for August through September 1975, it was estimated that the summer flows were one cfs for the "B" tunnel and o.5 cfs for the "C" tunnel.

Table IV is an abbreviated water balance for the Bernice Basin. For this purpose the flow of the tunnels is equated to ground water infiltration over the drainage area of each tunnel. Because of the quick response to recharge shown by the hydrographs, it is assumed that there is no change in ground water storage over the six month periods considered. The basic water balance formula, in its simplest form, is Precipitation = Runoff + Evapotranspiration. In this equation, Runoff, on a yearly basis, is surface or direct runoff plus the ground water contribution to stream flow. In preparing the state-wide water balance (Becher, 1970) the evapotranspiration is derived by subtracting measured stream runoff from measured precipitation. On a state-wide basis, P = 41", R = 21", ET = 20". It is also calculated that the ground water contribution to R is on the order of 12 to 15 inches.

Table IV
Partial Water Balance
P = I + ET + R

<u>B Weir - 1800 Acres</u>

<u>Winter</u>					
P	=	2700 AF	(1.50' =	18",	Table III)
I	=	1763 AF	(0.98' =	12",	Table I)
ET + R	=	937 AF	(0.52' =	6",	Difference)
<u>Summer</u>					
P	=	3294 AF	(1.83' =	22",	Table III)
I	=	362 AF	(0.20' =	2.5",	Table I)
ET + R	=	2932 AF	(1.62' =	19.5"	Difference)

<u>C Weir - 700 Acres</u>

<u>Winter</u>					
P	=	1050 AF	(1.50' =	18",	Table III)
I	=	738 AF	(1.05' =	13",	Table I)
ET + R	=	312 AF	(0.45' =	5",	Difference)
<u>Summer</u>					
P	=	1281 AF	(1.83' =	22",	Table III)
I	=	180 AF	(0.26' =	3",	Table I)
ET + R	=	1101 AF	(1.57' =	19",	Difference)

In Table IV, the measured quantities are tunnel flows which is ground water infiltration (I) and precipitation (P). Evapotranspiration (ET) and surface runoff (R) are obtained by difference. The table shows that within the drainage areas of the two tunnels the ground water infiltration is 14.5 inches (12 inches + 2.5 inches) for the B Weir and 16 inches (13 inches + 3 inches) for the C Weir, which is in close agreement with the state-wide figures. This agreement is considered to be a confirmation of the interpretation of the areas drained by the tunnels. Therefore, essentially all of the flow from the tunnels is from the mined-out areas. A small part of the tunnel flows may be contributed from a swamp at the eastern end of the basin. It is also clear that the C tunnel drains all of the Bliss area, west of the Bernice Fault, but gets little or no contribution from the Gutten mine.