SECTION II --

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The findings, conclusions, and recommendations resulting from investigations of the Shamokin Creek watershed are summarized below:

1. The watershed covers approximately 137 square miles in Northumberland, Columbia, and Montour Counties. Apparently mine drainage pollution has been occurring in the watershed for approximately 135 years.

2. The watershed's population is estimated at 60,000. Anthracite coal mining, food processing, the manufacturing of textiles, wearing apparel, furniture, and fixtures, as well as the production of chickens, eggs, and hogs in its downstream portion are the watershed's principal industries.

3. Anthracite coal mining, once the mainstay of watershed economy, has severely declined from a peak production of 6,200,000 tons of coal, principally from deep mines, in 1917 to an estimated 1970 production of 840,000 tons, principally from strip mines and banks.

4. Significant coal reserves remain under extensive underground mine water pools in the watershed. Mining of these reserves will be difficult and costly even though new mining techniques may be developed, .and the demand for coal may increase. Watershed coal production is expected to continue during the foreseeable future at a reduced rate comparable to 1970 coal production.

5. Past intensive coal mining in the watershed headwaters area has resulted in severe pollution of watershed streams by acid mine drainage. Nearly all tributary streams in the headwaters area as well as the entire main stem of Shamokin Creek have been so affected.

6. Watershed streams have also been grossly polluted by raw sewage discharges from Mount Carmel and Kulpmont Boroughs,. Shamokin City, as well as Mount Carmel and Coal Townships.

7. All tributaries of Shamokin Creek in its middle and lower reaches appear to retain desirable stream quality as well as normal aquatic life.

8. Considerable portions of the watershed are used for hunting large and small game. No other significant recreational use is made of the watershed and its streams.

9. Acid mine drainage in the watershed is caused by numerous natural and man-made subsurface and surface conditions.

10. Coal mining has been confined to approximately 50.5 square miles, or 37 percent of the watershed, in its headwaters area within which coal measures exist. No coal measures are known to exist in the watershed north of the crest of Big Mountain.

11. Through past severe folding of the coal-bearing measures, watershed coal veins extend as much as 2,600 feet beneath the ground surface. As the result of subsequent major deep mining beneath the then existing ground water table and later breaching of barrier pillars between mines, and still later abandonment of major deep mines, large underground mine water pools were formed in the voids created within these mines. Surface and ground waters that enter deep mine workings flow for considerable distances through acid-producing materials and mine water pools, then through established overflow points to watershed streams as acid mine drainage. Eighteen mine drainage discharge points exist as overflows from11 separate underground mine water pools.

12. An estimated 25.3 percent, or 12.8 square miles, of the watershed headwaters area has been disturbed by active and inactive strip mines. Twenty-two active strip mines, situated principally within areas previously stripped, had operated during 1971.

13. Several types of interconnection between the ground surface and deep mine workings allow surface water to enter the workings. These include deep mine entries, subsidence areas, stream interception and infiltration areas, as well as strip mines. In addition, surface and ground waters gain access to deep mine workings through an extensively fissured overburden caused by deep mining close to the ground surface.

14. Most surface and ground waters apparently enter abandoned deep mine workings through strip mines and the fissured overburden.

15. An insignificant amount of acid mine drainage is caused by surface and ground waters coming in contact with extensive piles of refuse scattered throughout the watershed headwaters area.

16. Strip mining, the pulling of pillars, and roof falls may block, restrict, or alter apparent water flow routes through watershed deep mine workings.

17. Deep mine workings extend under the watershed divide, allowing surface and ground waters becoming part of mine drainage discharges to be conveyed into and out of the watershed.

18. Fifty-four mine drainage discharge points were identified during the investigations described in this report. The majority were associated with underground mine water pool overflows followed by refuse areas, deep mine entries, and strip mines.

19. All 54 mine drainage discharge points are located in the watershed head waters area at, and upstream from, the Glen Burn Colliery.

20. Mine drainage discharge points in addition to those identified during the field investigations probably exist under certain weather conditions not encountered during the investigations. The conclusions and recommendations set forth in this report are based solely upon the mine drainage discharge points observed during the investigations.

21. Of the 54 mine drainage discharge points located during the field investigations, 35 appear to continuously discharge mine drainage. Nineteen appear to intermittently discharge mine drainage.

22. Under average conditions, individual watershed mine drainage discharges are estimated to range from 0 to 7.76 mgd, iron concentrations from 0.1 to 115 mg/l, and acid concentrations from 0 to 1,140 mg/l.

23. Combined mine drainage volumes as well as major constituents and characteristics used for design purposes are summarized in the following:

	Design Average	**Design Wet Weather**	**Design Maximum**
Volume - mgd	44.2	65.8	1,500.0
pH Range	2.5-7.6	2.5-8.2	2.5-8.2
Total Iron			
mg/l	52.0	50.5	56.9
tons per day	9.58	13.9	356.0
Acid (as CaCO3)			
mg/l	218.0	210.0	225.0
tons per day	40.1	57.7	1,410.0

24. All mine drainage from 12 mine drainage discharge points and an estimated 50 percent of the flow from another mine drainage discharge point are lost to underlying deep mine workings via permeable stream beds or interconnected strip mines. This volume of mine drainage then becomes part of major mine water pool overflows. The mine drainage pollution load to watershed streams is shown in the following:

	Design Average	Design Wet Weather	Design Maximum
Volume - mgd	40.1	60.0	1,410.0
pH Range	2.5-7.6	2.5-8.2	2.5-8.2
Total Iron			
mg/l 53.5 52.6 59.1			
tons per day	8.95	13.2	346.0
Acid (as CaCO3)			
mg/l 213.0 209.0 227.0			
tons per day	35.5	52.4	1,330.0

25. Present Department of Environmental Resources mine drainage discharge limitations are as follows:

    pH not less than six or greater than nine
    Iron concentration not greater than seven mg/l
    No acid

26. Discharges from about half of watershed mine drainage discharge points meet Department of Environmental Resources iron discharge limitations. Few meet the pH and acid limitations.

27. Surface diversion works constructed in the past by major coal companies as well as from federal-state funds to prevent surface water from entering the deep mines have been rendered almost totally ineffective by subsequent strip mining in the watershed.

28. Discharges from 18 mine drainage discharge points account for most watershed pollution loads. On the average, these 18 discharge points contribute 95 percent of its flow, 98 percent of its iron loads, and 97 percent of its acid loads.

29. The Department of Environmental Resources has adopted general and specific quality criteria for the Susquehanna River Basin, of which Shamokin Creek is a part. These criteria are based upon the anticipated use of Susquehanna River Basin surface streams for (a) the maintenance and propagation of cold- and warm-water fish; (b) water supply for domestic, industrial, livestock, wildlife, and irrigation purposes; (c) boating, fishing, and water contact sports; (d) power; and (e) treated waste assimilation. None of these uses are presently made of watershed headwaters area streams, except for a few private water supplies. Trout Run, which is a source of public water supply, is the only other watershed stream used for any of these purposes. The basic intent of the Department appears to be to remove mine drainage pollutants from abandoned mines by abatement measures to initially protect major watershed streams.

30. The following specific Department of Environmental Resources quality criteria were used to evaluate the condition of watershed streams and to determine the effectiveness of alternative abatement plans:

a. pH not less than 6.0 or greater than 8.5

b. Total iron concentration not exceeding 1.5 mg/l

The acid content of watershed streams was used as a third criterion, although the Department has not yet adopted a specific stream acid criterion.

31. The average quality of waters observed at various locations along Shamokin Creek from December 1969 through November 1970 is summarized in the following:

	Headwaters Area Tributaries	Downstream Tributaries	Shamokin Creek Near Mount Carmel	Remainder of Shamokin Creek
pH	3.1 to 6.9	6.4 to 6.8	6.9	3.1 to 4.1
Total Iron mg/l	1.8 to 43.8	0.3 to 1.1	2.7	8.0 to 42.4
Acid (as CaCO3) mg/l	(1) -54 to 203	(1)-11 to 16	(1)-38	86 to 178

(1) Represents a negative acidity, or alkalinity.

As these data indicate, much of Shamokin Creek waters did not meet the Department of Environmental Resources' pH and iron criteria, and are acidic. Most tributary sampling stations were located at their mouths.

32. For this report, all abatement measures considered applicable to watershed problems and conditions were used singly or in com bination in developing abatement plans for the watershed. These abatement measures are listed in the following:

Preventive Measures
- Reconstruct stream channels
- Construct surface-water diversion ditches
- Restore strip mines
- Move refuse into strip mines
- Excavate and restore subsidence areas
- Regrade, cover, and plant refuse areas

Treatment Measures
- Chemically neutralize, oxidize, and settle mine drainage in treatment facilities

33. Preliminary consideration was given to developing abatement plans in each of three categories:

    a. Abatement plans based solely on the construction of preventive measures

    b. Abatement plans based solely on the construction of treatment measures

    c. Abatement plans based on the construction of combinations of preventive and treatment measures

34. Based on the investigations described in this report, it would be prohibitively expensive and totally impractical to develop for the watershed an abatement plan comprised solely of preventive measures.

35. For abatement plans comprised of preventive measures supplemented by treatment measures, estimates of acid mine drainage reductions attributable to the preventive measures were made on the basis of estimated increases in runoff coefficients, volumes of surface water kept from deep mine workings, and similar factors. In the preliminary design of treatment measures, due allowance was made for acid mine drainage reductions attributable to preventive measures. Treatment measures were designed to meet present Department of Environmental Resources mine drainage discharge limitations.

36. In developing abatement plans, consideration was given in certain cases to a bating all mine drainage discharges and in others only some discharges. Plans were studied that would reduce watershed mine drainage pollution by 90 to 100 percent. In developing abatement plans in which somewhat less than a 100 percent reduction was to be attained, every effort was made to concentrate on those discharges contributing 90 percent of the watershed mine drainage iron and acid loads. Preventive measures designed toward this end eliminated some additional mine drainage discharges.

37. Five abatement plans were studied in detail. Three of these plans consisted solely of treatment measures. The balance included combinations of preventive and treatment measures.

38. The abatement plan recommended for construction includes preventive and treatment measures. The recommended preventive measures would first be constructed. At some future date treatment measures would be constructed. Preventive measures comprising the recommended abatement plan would be located in several tri butary streams throughout the watershed headwaters area. Treatment measures consisting of four treatment plants would also be located in the watershed headwaters area.

39. The abatement plan recommended for construction will eliminate mine drainage at seven discharge points and reduce mine drainage at nine points. In addition, mine drainage at 18 discharge points would be collected and treated in the four treatment plants.

40. Recommended preventive measures will reduce watershed mine drainage acid and iron loads by approximately nine percent. Watershed coal measures are concentrated under a limited surface area. These measures have been extensively deep and strip mined, intercepting approximately half of the watershed headwaters area precipitation, which then becomes mine drainage discharges. A prohibitive amount of money would therefore have to be spent to achieve a significant watershed pollution load reduction through the construction of preventive measures. Recommended treatment measures will reduce loads by approximately 86 percent. Total reductions attributable to the entire recommended plan will approximate 95 percent.

41. Costs associated with the recommended plan are summarized in the following:

		Average Annual Costs					
		Initial 30 Years		Next 270 Years		300 Years	
	Project Cost	Total	Per Ton Acid Removed	Total	Per Ton Acid Removed	Total	Per Ton Acid Removed
Preventive Measures	$ 2,970,000	273,000	$219	$ 55,000	$ 44	$ 77,000	$ 62
Treatment Measures and Collection Systems	10,450,000	1,770,000	153	1,680,000	145	1,690,000	146
Total	$13,420,000	$2,043,000	$159	$1,735.000	$135	$1.764,000	$138

42. The estimated average quality of waters at various locations along Shamokin Creek after implementation of the recommended abatement plan is summarized in the following:

	Headwaters Downstream Area Portion	
	(8-5 thru 8-14)	(8-1 thru 8-4)
pH	6.7-7.3	6.7-7.0
Total Iron - mg/l	1.5-3.4	0.8-1.5
Alkalinity (as CaCO3) - mg/l	17 - 32	16- 30

If the recommended abatement plan is implemented, the downstream portion of Shamokin Creek on the average will meet the Department of Environmental Resources' iron criterion, whereas the entire length of Shamokin Creek will on the average meet the Department's pH criterion and be alkaline.

43. Active coal mining continues at a reduced rate in the watershed. At the end of 1971 there remained 38 active deep mine, strip mine, and bank processing operations that produced a total of 452,500 tons during 1971. Each of these operations has a short remaining life, in most instances less than five years, limited by the amount of coal remaining after earlier deep mining operations were completed, its accessibility, extent of underground mine water pools, extent and condition of past strip mining operations, percentage of coal remaining and its distribution in banks, and similar factors.

44. The remaining active deep and strip mines do not collect and pump mine water to the surface for discharge to watershed streams. Water developed by these active operations follows established flow routes into abandoned deep mine workings from which discharges occur.

45. It would be more practical to allow water attributable to active deep and strip mines to flow into abandoned underground mine workings for collection and treatment. Mine drainage attributable to active deep and strip mines is an insignificant portion of watershed mine drainage pollution.

46. A reasonable way by which active operators could assist in abating watershed mine drainage would be to pay money based on coal production to the Department of Environmental Resources to help defray costs of implementing abatement measures designed to eliminate watershed mine drainage. The amount of money paid per ton of coal mined should be consistent with that to be paid by active operators in other portions of the anthracite field.

47. The estimated average quality of waters in Shamokin Creek headwaters area tributaries after implementation of the recommended abatement plan is summarized in the following:

	North Branch and Locust Creek	**Quaker, Coal, Carbon, and Furnace Runs**
pH	4.0-5.0	6.9-7.8
Total Iron - mg/l	1.2-3.2	1.0-7.5
Acid (as $CaCO_3$) - mg/l	20- 50	
Alkalinity (as $CaCO_3$) - mg/l		18- 70

The North Branch of Shamokin Creek and Locust Creek on the average will be acidic, will not meet the Department of Environmental Resources' pH criterion, and will not in all stream stretches meet the Department's iron criterion. Other headwaters tributaries - namely, Quaker, Coal, Carbon, and Furnace Runs - will on the average meet the Department's pH criterion, will be alkaline, but will not all meet the Department's iron criterion.

48. Although all Shamokin Creek headwaters streams will not on the average meet the Department of Environmental Resources' pH and iron criteria, their improvement will be substantive after the recommended abatement plan is implemented.

49. Factors considered significant in selecting the abatement plan recommended for construction are summarized in the following:

a. An abatement plan comprised solely of preventive measures would be prohibitively expensive and totally impractical in the watershed.

b. An abatement plan comprised solely of treatment measures would be less costly initially and would give more positive control and more predictable results than a plan comprised solely of preventive measures.

c. Collection and treatment of acid mine drainage from all discharge points located during the field investigations would not guarantee complete elimination of mine drainage pollution. This is because of the general scattering of acid-producing materials throughout the watershed and the mine drainage discharges that would occur during severe precipitation.

d. The Department of Environmental Resources' current philosophy appears to be that of considering the construction of preventive measures, wherever practical and feasible, before considering the construction of treatment measures.

e. A plan comprised of both preventive and treatment measures, although having a higher initial cost than a plan comprised solely of treatment measures, is therefore recommended for construction. Long-term costs of these two plans are virtually the same.

f. The construction of preventive measures, which represents the first step of the recommended abatement plan, has the maximum cost benefit over extended periods.

g. The stage construction of preventive measures included in the recommended plan can be undertaken separately and the effectiveness of each measure evaluated.

h. After the construction and -evaluation of all recommended and any necessary additional preventive measures, the recommended treatment measures could be designed and constructed. The design of treatment measures could be based on a review of the latest data on existing and desired stream quality. The stage construction of each treatment measure could be separately undertaken and its effectiveness evaluated.

i. Based on available information and data, the recommended abatement plan will accomplish the Department of Environmental Resources' objective: to provide enhanced stream quality throughout the length of Shamokin Creek. .

j. The recommended abatement plan will eliminate 95 percent of current watershed mine drainage pollution loads. In addition, it will significantly improve the quality of tributaries receiving the most pollution. Watershed stream quality will be acceptable for existing uses and for foreseeable future uses.