THE STUDY

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The study was conducted in a series of six phases or steps:

STEP I - USE EXISTING DATA TO ESTABLISH RECONNAISSANCE PROGRAM

The initial step in the pilot study was the assembly of all known and available information on geology, hydrology, mining and water quality that might help reduce the scope of the stream reconnaissance program and augment the data base. The Appalachian Regional Commission's volumes on acid mine drainage and the Army Corps of Engineers' "Susquehanna River Basin Study" provided background and specific information for the study.

The Pennsylvania Department of Environmental Resources supplied mining information and water quality data. Former FWPCA (Environmental Protection Agency) stream and mine discharge water quality and flow data, obtained in a reconnaissance of Clearfield and Moshannon Creeks between 1966 and 1968, was very useful. This EPA data was contained in the computerized STORET system, and was accompanied by written field descriptions of all sampled pollution sources.

The office of the State Climatologist provided important climatic information, dating back to 1931, for both watersheds as well as recent water resources information for the entire state. The data was utilized in determining annual rainfall flow rates, predicting runoff and infiltration values for certain areas, and for checking existing sample data.

Penelec's Shawville generating station, which has been monitoring flow and analyzing water quality daily since 1954 on the West Branch, 9 miles northeast of Clearfield, Pennsylvania, between the mouths of Clearfield and Moshannon Creeks, supplied yearly conductivity duration curves, pH vs. consecutive workdays graphs, yearly pH - duration curves and flow data. This data was correlated with the State Climatologists information and was useful in assessing rainfall-stream flow relationships on the West Branch. The daily flow constants obtained from this data were used to adjust Skelly and Loy's sample data to represent average yearly flows.

The location and extent of mineable Allegheny Group coal, particularly the acid-producing Brookville-Clarion and Lower Kittanning coals, were obtained from geologic maps of the watershed areas. This geology was useful in narrowing down the reconnaissance program, since areas in which the Allegheny Group coals, particularly the acid producers, were absent could be eliminated from further consideration as acid sources. Streams eliminated from the study or sampled only to a minor extent on this basis were Black Bear Run, Sixmile Run and the central and upper reaches of Black Moshannon Creek.

Topographic data sheets supplied by the EPA were reduced to 1/2 size and assembled into a mosaic for each watershed. EPA sample station locations and some of the EPA data were superimposed on the mosaics of each watershed to reveal the extent of acid mine drainage pollution at the time of EPA sampling.

All pertinent data for both watersheds was accumulated and digested before the sampling program was established. Upon completion of this data examination, an initial reconnaissance program, consisting of roughly 125 sample stations, was established; and the water quality sampling began as discussed next in Step II.

STEP II - SUBDIVIDE BASINS INTO MODULES, PERFORM RECONNAISSANCE

The study area for this original pilot program encompassed more than 684 square miles of land surface area. To systematically organize a study, particularly one with extensive sampling that could cover such a large area in a short time, required a unique approach. Before any actual field work began, a study plan and a sampling and measuring method were devised to make the most efficient use of the time allotted for the program.

Based on the information obtained in Step I, modules or sub-watershed units were defined for all parts of both watersheds and shown on the watershed maps. These units or modules often consisted of the watersheds of the major tributaries to Moshannon and Clearfield Creeks, Modules were large in lesser mined regions where geology and water quality data indicated that acid mine drainage would probably be minimal. In heavily mined regions, the modules were small to more accurately define the acid mine drainage problem.

Once the modules had been defined, proposed sampling and measuring points were established. Initial sampling on Moshannon Creek generally covered the entire watershed, but on Clearfield Creek was limited to the main stream and the nine tributaries cited in the proposal for the pilot program: Trapp, Brubaker, Powell, Japling, Lost, Upper Morgan, Potts, Long and Roaring Runs. Sample locations were shown on pin board maps of the watersheds and later transferred to 7 1/2' topographic quads for field use. This initial modular sample design consisted of 65 stations in the Clearfield Creek Watershed and 60 stations in the Moshannon Creek Watershed.

The water sampling in Moshannon and Clearfield Creeks was of three basic types - modular, grab and monthly - each with a specific purpose and scope in relation to the nature of the overall study. The first two sampling runs were based on the modular system discussed above. They were designed to evaluate and categorize sub-watersheds or modules within each of the major watersheds. Three categories of modules were defined as follows:

1. Unpolluted - modules within which water quality is not severely degraded.

2. Polluted - significant sources of acid mine drainage where intensified study will definitely be required.

3. Weakly polluted - modules within which additional sampling will be required before a ' polluted or nonpolluted classification can be made.

The first sample run in each watershed generally delineated polluted, unpolluted and weakly polluted modules, while the second sample run was used to divide the "polluted" areas into smaller workable units and to reclassify marginal modules as either "polluted" or "unpolluted".

The same basic method of stream sampling and flow measuring was used on Moshannon and Clearfield Creeks. This method was designed to give the best possible results for a large number of samples taken over generally wide areas, in a relatively short time period. Surveyed cross sections and weirs or other time-consuming and expensive flow measuring devices were not used. Instead, average stream widths, stream depths, and flow velocities (using the floating chip and stopwatch method) were measured as accurately as possible; field pH's were measured; and 16 ounce water samples were taken for laboratory analysis. On larger streams, composite samples (samples were not taken at one spot but were gathered at various locations within the specific stream cross section) were taken to minimize the effects of poor mixing of waters in the main stream at the sample stations. Regular sample "splitting" (dividing one water sample into two separately identified bottles) was conducted to check the precision of the water quality analysis. Comparisons of mine drainage parameters analyzed indicated that the laboratory maintained an acceptable level of consistency and precision throughout the sampling program. Analysis of acidity was kept within 4 to 6 percent for most split samples.

Water sample analyses were performed by Microbac Laboratories, Inc., in Pittsburgh, for the usual mine drainage constituent concentrations--pH, acidity, alkalinity, total iron, ferrous iron, sulfate. Acidity analysis were performed according to procedures set forth on pages 46 and 47 of Standard Methods, 12th Edition, until September 30, 1972. After this date, all mine drainage water samples were analyzed by hot titration as set forth on page 438 of Standard Methods, 12th Edition.

Since the water samples were analyzed by different methods before and after September 30, the questions arose as to what relationships, if any, existed between the hot and cold analyses with regard to acid concentrations. A 1972 mine drainage study of the Tioga River Basin conducted by the Baltimore District Corps of Engineers listed the acid concentrations ranging from a few to several thousand mg/l for a large number of samples which were analyzed by both hot and cold titration methods. Construction of a graph of hot acid concentrations vs. cold acid concentrations revealed that the hot acid results were generally 5-7% lower than the results obtained by cold titration. This indicates that both hot and cold titration yield reasonably equivalent values, and the coal acidity values obtained in the first half of the pilot program were not misleadingly high or low, and would not alter early module classifications based on cold acidity values. During the sampling program period, 493 cold and 351 hot titrations were made to determine acidity for Clearfield Creek water quality samples. During this same period, 540 cold and 387 hot titrations were performed on Moshannon Creek samples.

A method for the close approximation of stream cross sectional areas using the mentioned parameters measured at each sample location was devised as follows:

> The shapes and cross sections of many known streams were analyzed and found to closely approximate a flattened ellipse of area Wd(Pi)/4, where W is the width and d is the mean depth of the stream. This calculation was also reduced to a graphical solution using two vertical 2 cycle log axes for Wand d and a 4 cycle axis between the W and d log axes for area. This middle axis was suppressed Lg Pi/4 units, allowing a straight line between Wand d to intersect the correct cross sectional area, which can be rapidly and fairly accurately read from the graph.

Measured stream velocities were then reduced by 20% to account for the higher than average velocity that occurs in the surface water layer of the stream. The adjusted velocities and cross sectional areas were then utilized to compute stream flows.

The initial modular sampling run was begun by three field crews of two men each. This run had to be canceled after only one-half day due to flood warnings, and was postponed further due to flooding and high flow conditions caused by tropical storm Agnes. The incomplete data collected in this first sampling attempt was analyzed and later used on a very limited basis to compare pre- and post-flood water conditions.

A post-flood reconnaissance of the Moshannon and Clearfield Creek Watersheds was made prior to further sampling to ascertain the extent of change of stream flows and water quality during the high flow conditions. Access routes were also checked to determine whether any changes in the design of the sample run #1 would be necessitated by the flooding .

When water conditions again permitted safe sampling and measuring, the first Modular Sample Run was resumed. Stream flows were abnormally high; streams and tributaries that were normally dry at this time of year still had considerable flow; and some flows that had never before existed were produced as a result of the heavy rainfall and buildup of hydraulic head within deep mines which altered deep mine flow paths and caused blow-outs. All accessible stations were sampled, but sampling crews were hampered by the high flows, washed out roads and bridges, and a few outdated topographic maps. All stream stations along the northern 20 miles of Moshannon Creek were inaccessible by road. A raft trip was made through this area under extremely hazardous high flow, white water conditions; and only flows, pH's and accurate locations of the tributary stream mouths were obtained.

Use of a computer account at the Pennsylvania State University was obtained and a program was developed to compute stream flows and loadings from the field and chemical analysis data for each station sampled. The results of the first modular sample run were computerized and used to establish some preliminary criteria for module classification:

1) Polluted category - pH less than 4.0

2) Unpolluted category - pH greater than 5.0 except where sulfate exceeds 75 ppm. High sulfate indicates neutralization of acid, therefore, these modules were temporarily classified as intermediate, pending further study.

3) Intermediate category - all other modules; further study will reclassify these modules as either hot or cold.

These initial module classifications enabled a more comprehensive second modular run to be designed, with the purpose of confirming existing polluted and unpolluted module classifications, dividing polluted modules into more workable sub-modules, and reclassifying intermediate modules as either polluted or unpolluted; thereby further narrowing the search for major mine drainage pollution source area. A monthly sampling scheme was also designed to provide periodic monitoring of important sample locations throughout the period of study. This consisted of 20 stations in the Clearfield Creek Watershed and 45 stations in the Moshannon Creek Watershed.

The second modular sample run on the two watersheds was completed in mid-July. The high flow conditions caused by tropical storm Agnes were no longer evident, but flows were still high for mid-summer, with many tributaries still flowing that are generally dry during the summer months.

The modular sampling program indicated that Moshannon Creek and all tributaries except Black Bear Run, Sixmile Run, and the tributaries northeast of Black Moshannon Creek were receiving substantial amounts of acid mine drainage at some point along their length.

The second modular run also revealed that the nine tributaries of Clearfield Creek designated for study in the pilot program were polluted. Later in the study period, modular sampling in this watershed was greatly expanded to include many other polluted tributaries not originally designated for study. Polluted modules of varying sizes were isolated in several portions of the watershed.

All polluted modules in both watersheds were subjected to intense study and sampling, as discussed next in Step III.

STEP III - INTENSIFY STUDY ON REDUCED SCOPE AREAS

This step was initiated during the second modular sampling run to further isolate large pollution sources within previously classified polluted modules. These watershed or sub-watershed units were then subjected to intense field investigations.

Sample crews walked streams collecting water samples and measuring stream flows. Each sampled pollution source or tributary was flagged, numbered, mapped and described in field notebooks. Strip mines and the outcrops of potentially polluting coal seams were walked out, and abandoned drifts, shafts, airways, inclines, caved areas, seeps, kills, and bony areas were located and mapped. Since this was not a full-scale, long-term sampling program, most pollution sources were grab sampled only once or twice. However, combined modular and grab sampling results were sufficient to identify the major pollution sources within both watersheds. EPA data for both watersheds was renumbered to fit Skelly and Loy's sampling and numbering scheme, and closely examined to supplement, where possible, Skelly and Loy's findings.

The intensive sampling program began upon completion of the second modular sample run, in mid-July, on the Centre County side of Moshannon Creek. All polluted Centre County modules south of Black Bear

Run had been intensively sampled by mid-September and work began immediately on the nine original polluted tributaries to Clearfield Creek. The sampling program was later expanded to include all other polluted modules in the Clearfield Creek Watershed, and was nearly complete by mid-December. Sample crews then began intensive work on Moshannon Creek's remaining polluted modules. Hawk Run, Grassflat Run, Knox Run, Sulphur Run, Browns Run and several other highly acid tributaries to Moshannon Creek in the northwest portion of the watershed were not intensively sampled. Nearly all acid mine drainage sources to these streams are downdip deep mine discharges from a single, large, interconnected "B" seam deep mining complex that underlies a large area bounded by Alder Run, Hawk Run, Weber Run and Moshannon Creek. The coal within this complex dips down several hundred feet from east to west practically eliminating deep mine sealing because of the large potential hydraulic head at down-dip discharge points. It is not feasible with present technology to abate even a small portion of the acid produced within the complex; therefore, only major pollution sources located by the EPA sampling program were resampled here.

Sample station mapping was updated daily as intensive sampling continued, and updated mapping and computerized sample data were periodically submitted to the Department.

STEP IV - PRELIMINARY EVALUATION

Preliminary evaluations of the feasibility of abating each of the pollution sources defined in step III were generally completed in the field office, after all obtainable data and pertinent information had been collected, plotted and studied.

Specific and regional geology and hydrology at pollution sources were studied and mapped, where possible. Local residents involved in or having knowledge of the local coal industry were interviewed for information pertaining to old mining sites, methods, drainage, and other important facts. Tax maps, mine permit information, aerial photographs, weather bureau records, mining records and soils information were obtained and studied.

United States Geologic Survey 7 1/2' topographic quads were enlarged to 1 inch = 1000 ft. scale for each polluted module or potential abatement area. These enlargements served as the base for "Mini -Mine Development Drawings", which were used extensively in later work.

Field work in this step was limited to that required to supplement, correlate, or confirm water quality data or other previously obtained information.

Water quality data combined with all other accumulated information provided the basis for preliminary evaluation of polluted modules. This preliminary evaluation made it possible to determine potential abatement areas and to establish some general priorities among them based on such factors as general hydrology and geology" present mining status, sources of pollution and feasible abatement methods. Several high priority areas were chosen as possible Quick Start projects and more intensive field work was immediately initiated in these areas, as discussed in Step V following.

STEP V - FINAL FEASIBILITY DETERMINATION

This step involved the final determination of abatement areas and the techniques to be used to abate acid mine drainage in those areas. Initially, a comprehensive study of the water quality data yielded a list of all polluted modules or sub-modules that were potential abatement areas. From this list a schedule was established and intensive field reconnaissance by a geologist began in each potential abatement area. The Mini-Mine Development Drawings (Scale 1" = 1000') were used extensively in this field reconnaissance. Draftsmen plotted Skelly and Loy and EPA sample station locations, coal contours and outcrops, faults, deep mine workings, drifts, air shafts, strippings and active mining permits. They also labeled roads and towns and listed property owners for each area. This mapping was periodically updated with additional new information on existing topography, seeps, kill areas, bony or refuse areas, additional strip areas, drifts and air shafts. Analysis of field reconnaissance information, Mine Development Drawings, and water quality data determined whether abatement work of some type was feasible and practical in each area. The latest abatement techniques were considered and plans were finalized for each area with emphasis on the greatest amount of abatement for the lowest cost. The abatement techniques considered for recommendation included the following:

1) diversion of surface water around strip cuts and deep mine fractures;

2) stream rechanneling to retain good quality water in stream beds;

3) backfilling;

4) soil treatment and planting of strip pits;

5) surface treatment or removal of refuse piles, storage areas, roadbeds;

6) deep mine and surface sealing;

7) grouting, slurry trenching, daylighting;

8) use of limestone waste products to increase PH of surface water percolating through strip mines;

9) treatment.

Construction costs and benefits were estimated for each recommended abatement project based on the costs and benefits of abatement accomplished in comparable projects in other areas. Preliminary report drafts were written for each abatement area as feasibility determinations and cost calculations were completed. The drafts contained all basic information that appears in this final report on abatement area location, geology, mining history, mine drainage, hydrology, water quality, recommended abatement, estimated costs and cost effectiveness.

Priorities for the recommendation of abatement work were then developed based on the following parameters:

1) amount of acid;

2) cost per lb/day acid abated;

3) amount of abatement anticipated;

4) location within watershed;

5) legal complications with property owners;

6) active mine permits;

7) accessibility.

Actual work on the final feasibility determination portion of the project began rather early, in mid-July, with the search for potential Quick Start areas - areas where abatement work could be immediately recommended. The four areas having the highest abatement potential were discussed in detail, and abatement recommendations were made for each area in the two previously submitted Interim Reports. The first Interim Report involved a single, large strip and deep mined hill in the Moshannon Creek Watershed which was contributing 1/3 of the creek's total acid load. Interim Report II dealt with three areas along Clearfield Creek near Madera - two strip mined areas and a deep mine. These reports were completed and submitted on August 28, 1972, and December 12, 1972 respectively.

In mid-December, intensive field reconnaissance began, according to an established schedule, in the remaining potential abatement areas. This field work continued into March during which time the "Mini-Mine Development Drawings" were being revised and preliminary report drafts were being written for each area in which abatement work seemed feasible. All report drafts were re-evaluated and, if necessary, revised prior to insertion into the abatement section of the final report.

Late in the project, Skelly and Loy discovered that State sponsored deep mine sealing feasibility and strip mine reclamation design projects were already in progress on State Game Lands No. 108 and 184 by Gwin, Dobson & Foreman, Inc. As a result, all deep mine related abatement work already under consideration by Skelly and Loy in these areas was discontinued and further field reconnaissance was halted.

STEP VI - FINAL REPORT

The preceding study methods and results of the pilot project were incorporated into this final report. Data is organized and presented in an easily readable and understandable fashion. Location maps, regional maps, Mine Development Drawings for all abatement areas, graphs, charts and other appropriate visual aids are included for ease in digesting narrative portions of the report. Mapping outside of the abatement areas and sample data of any kind are not presented in this report. All mapping completed during the pilot project and six copies of the complete computerized sampling results will be submitted to the Department separately as background information for the final report. Reproducible originals of all of the mapping will be kept available for future reproductions if required. A deck of computer cards containing all of the water quality, flow and loading data will be made available for future generation of additional water quality printouts.