NASA CR-132529

REMOTE SENSING OF
COAL MINE POLLUTION IN THE
UPPER POTOMAC RIVER BASIN

(NASA-CR-132529) REMOTE SENSING OF COAL MINE POLLUTION IN THE UPPER POTOMAC RIVER BASIN Final Report (Ambionics, Inc., Washington, D.C.) 70 p HC $6.50 CSCL 08H G3/13

N74-34817

Unclas 52141

Prepared Under Contract No. NAS1-12673 by
AMBIONICS, INCORPORATED
400 Woodward Building
Washington, DC 20005

TABLE OF CONTENTS

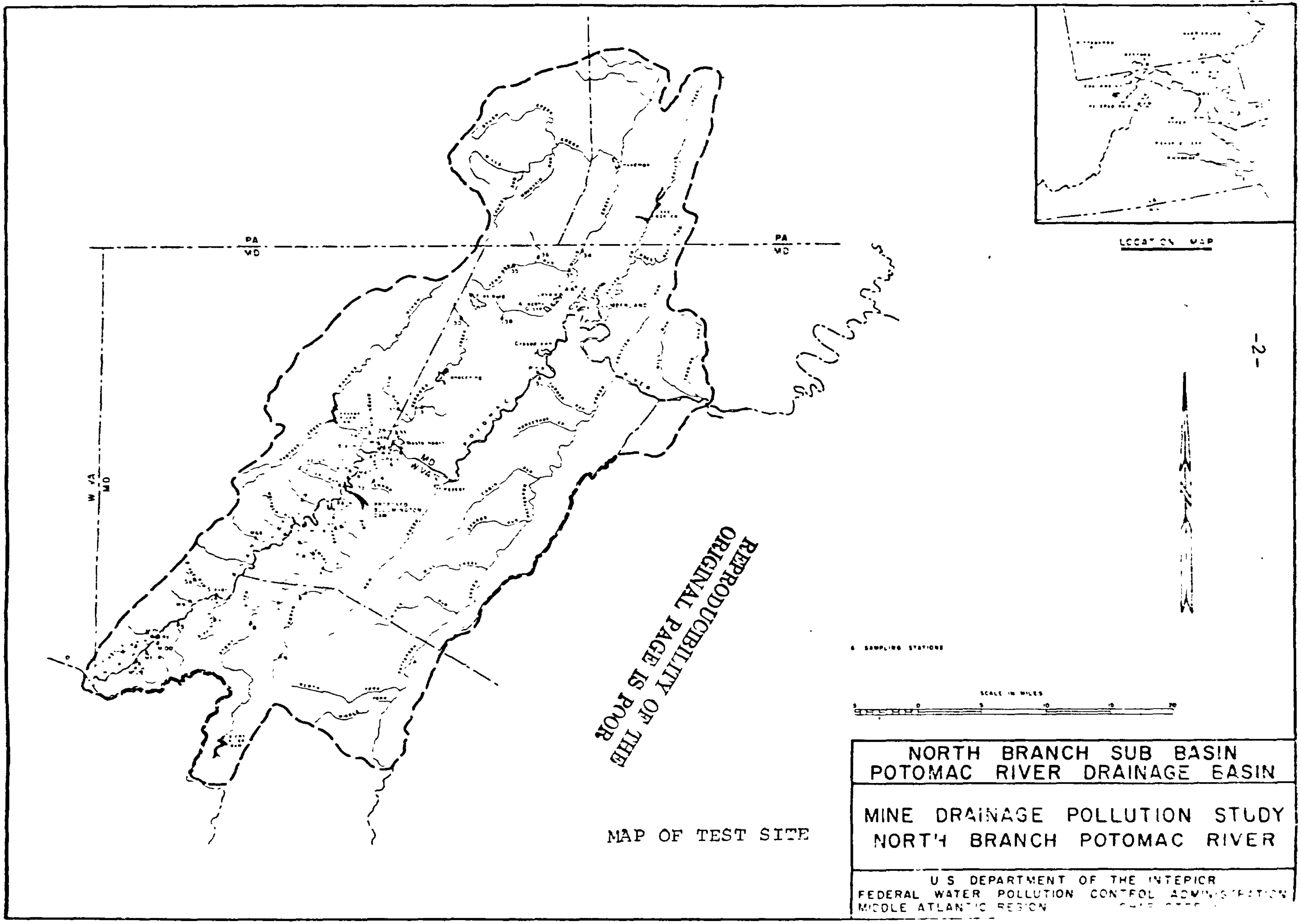
LIST OF ILLUSTRATIONS

1. INTRODUCTION

This constitutes the Final Report under NASA Langley Research Center Contract NAS-1-12673 "Application of Remote Sensing Technology to Monitoring Mine Drainage Pollution." The program was performed in cooperation with the Environmental Protection Agency (EPA) Offices of Water Programs and Research and Monitoring, EPA Region 3, EPA NERC Las Vegas and NASA Wallops Station, as well as various agencies of the states of West Virginia, Maryland and Pennsylvania.

The purpose of the program was to investigate the utility of combining data sensed remotely from satellites and aircraft with those obtained by traditional field methods of surface sampling, in a more effective approach to monitoring water pollution caused by mining activities, both active and abandoned.

The sparsely settled reaches of the upper Potomac River was selected as the test site (Figure 1). This area offered several advantages; it is almost devoid of industry except coal mining, lessening the confusing effects of other contributing



MAP OF TEST SITE

pollution sources. Active teams of scientists live and work in the area who have provided data on the history, land use practices, all polluting agencies, and the effects of pollution.

The scope of this program included:

1. A survey of remote sensing data pertinent to locating and monitoring sources of pollution resulting from surface and shaft mining operations.

2. The obtaining and analysis of representative samples of the raw and processed data obtained during the survey.

3. The formulation of plans and recommendations to demonstrate and optimize the data collection processes.

The purpose of this program was to determine methods by which ERTS and aircraft remote sensing could be used as a replacement for or supplement to traditional methods in monitoring coal mine pollution of the upper Potomac Basin.

We have done sufficient work to determine that while remote sensing in no way obviates the need for traditional grab sample monitoring, it can, indeed, provide a method for correlating, refining, and making more efficient a total monitoring program. Limitations we have found include the high probability that the test site will be obscured by clouds or haze during an

2. BACKGROUND

In August 1973, Ambionics undertook to determine the role that the remote sensing from the Earth Resources Technology Satellite (ERTS) and from aircraft could serve in monitoring pollution resulting from mining activities.

The test site selected was the Drainage Basin of the North Branch of the Potomac River, into which flow streams from West Virginia, Maryland and Pennsylvania. The area has estimated reserves of approximately two billion tons of coal and is subject to both surface and subsurface mining. The area is sparsely settled and almost entirely in forest. The physiography is described in greater detail in the following chapter.

The only major industry on the North Branch of the Potomac River is a paper mill in Luke, Maryland whose alkaline wastewater emptying into the Potomac is largely neutralized by the acidic mine waters coming downstream.

In Task I, data was gathered concerning land use, water sampling, mine locations and types, forest species and associations, as well as remote sensed data from ERTS and from an overflight of the test site by the NASA Wallops C-54 aircraft.

Task II consisted of organizing these data and associating the findings with remote sensing, both aircraft and satellite. Associative indications such as land use patterns and vegetative stress were sought in attempts to locate mine drainage. Efforts in this direction were unsuccessful. It was in the performance of Task II that various shades of "green" hues at the treatment plant for the North Branch mine at Bayard, West Virginia were noted by state personnel examining false color infrared aerial photography with Ambionics employees. Subsequent searching of the other aircraft images and noting the green color was done by the Ambionics team and compared with available sampling data. In <u>all</u> cases, the streams which appeared as green were influenced by waters emanating from mines, particularly underground coal mines. Attempts to employ spectral analysis with ERTS images and tapes in a similar manner to identify and monitor mine pollution were not successful. It should be noted that these streams were rarely more than two ERTS picture elements wide.

Ambionics found that usage of ERTS imagery in monitoring strip mining activities was much more rapid and accurate than methods presently employed. This technique is described in a following chapter.

Certain problems have occurred and are likely to prove troublesome for some time.

Ordering and receiving imagery from the EROS Data Center, Sioux Falls, South Dakota has proven overly time consuming and as response to recent magazine articles increases, this situation may worsen.

Computer compatible tapes (CCT's) are difficult to obtain at any time, yet contain more detailed information than imagery. Once CCT's were obtained, attempts were made with two firms, GE and IBM Federal Systems Division to process and enhance spectral differences between mine polluted water and unpolluted streams.

The GE Image-100 system was plagued with electrical problems and lack of machine availability at the time the tapes finally became available made this approach not feasible.

A contract was given by NASA-Langley Research to IBM. The results of the limited processing performed were indeterminate.

3. DESCRIPTION OF THE TEST SITE

A. Physiography

The area under study, the coal fields of the upper Potomac, includes several drainage basins in Pennsylvania, Maryland and West Virginia. In this report we shall concentrate primarily on the latter two states.

The physiographic province of primary concern is the Allegheny Ridges and Valleys. Folded strong and weak strata with even-crested ridges are predominant over valleys excepting the eastern edge of the Alleghenys which front on the Valley of Virginia. The folded nature of the rock strata is the result of an upheaval in which a land mass on the east was thrust westward against the Appalachian geosyncline.

The mountains thus formed were later eroded to a peneplain. This was followed by gentle unwarping which had a marked effect upon drainage. Ridges were produced by the resistance of sandstones and conglomerates against the reduction agencies while a more rapid reduction of the limestones and shales formed the valleys.

These mountains are a part of the Appalachian Plateau which includes most of West Virginia. On the western border the plateau reaches elevations near 2,000 feet in Tennessee . . Kentucky while in West Virginia it attains altitudes over 4,0 feet.

To the south a great range composed of Allegheny and Allegheny Front Mountains stretches along the eastern edge of the province. In the vicinity of Spruce Knob, standing at 4,860 feet as the highest point in the state, the range follows the western border of the province.

Both the main and tributary streams are forced north or south following the trend of the mountains. The Cacapon River, South Branch, and North Branch flow northward as major tributaries of the Potomac River.

The Allegheny Bituminous Coal Area is a part of the physiographic province, occurring around Grant. Tucker, Mineral and Preston counties in West Virginia, Garrett and Allegheny counties in Maryland and extending into Pennsylvania. Canaan Valley, one of the unique features of this area lies about six miles west of Allegheny Front Mountain in Tucker and Randolph counties in West Virginia. The coal region here lies primarily at two levels.

The dividing point is Allegheny Front Mountain running northeast to southwest through the region. The eastern sector of the coal producing series runs from 1500-2000 feet altitude while the western portion extends over 4000 feet in altitude. The soils in all cases are primarily erodable and acidic.

The coal bearing seams are all Carboniferous and from the Pennsylvanian Series. There are the Allegheny, the Monongahela and the Conemaugh series with the latter predominating. The Conemaugh is wholly confined to the valley and tributaries of the North Branch of the Potomac River. It outcrops in an extensive area having the shape of a crude isosceles triangle. The truncated apex is at Piedmont, West Virginia with a width of about two miles and the base is at the headwaters of the Potomac (Fr Knob, West Virginia) extending to the original Stony River Dam.

The natural vegetative associations vary at the two levels. East of the Allegheny Front, Oak and Oak Hickory forest predominates, while on the plateau, boreal species such as Spruce and Northern Hardwoods (Birch, Beech, Maple and Hemlock) are most common. Marsh, bog, swamp and beaver meadows extend over large areas here.

B. Vegetation

Mineral and Grant Counties, West Virginia, lie entirely within the North Potomac Drainage Basin, along with a small area of Tucker County. These areas contribute over seventy percent of the mine pollution as it occurs in the North Branch.

The principal types of vegetative cover within the upper Potomac drainage are Northern Hardwoods, Cove Hardwoods, Red Oak, Hard Pine-Oak, Chestnut Oak, Aspen-Pin Cherry, and Spruce (See map, Figure 2).

Under natural conditions altitude and soil moisture largely determine these types. Soil moisture in turn is affected by direction of slope and soil characteristics (porosity, hard pan, humus, etc.).

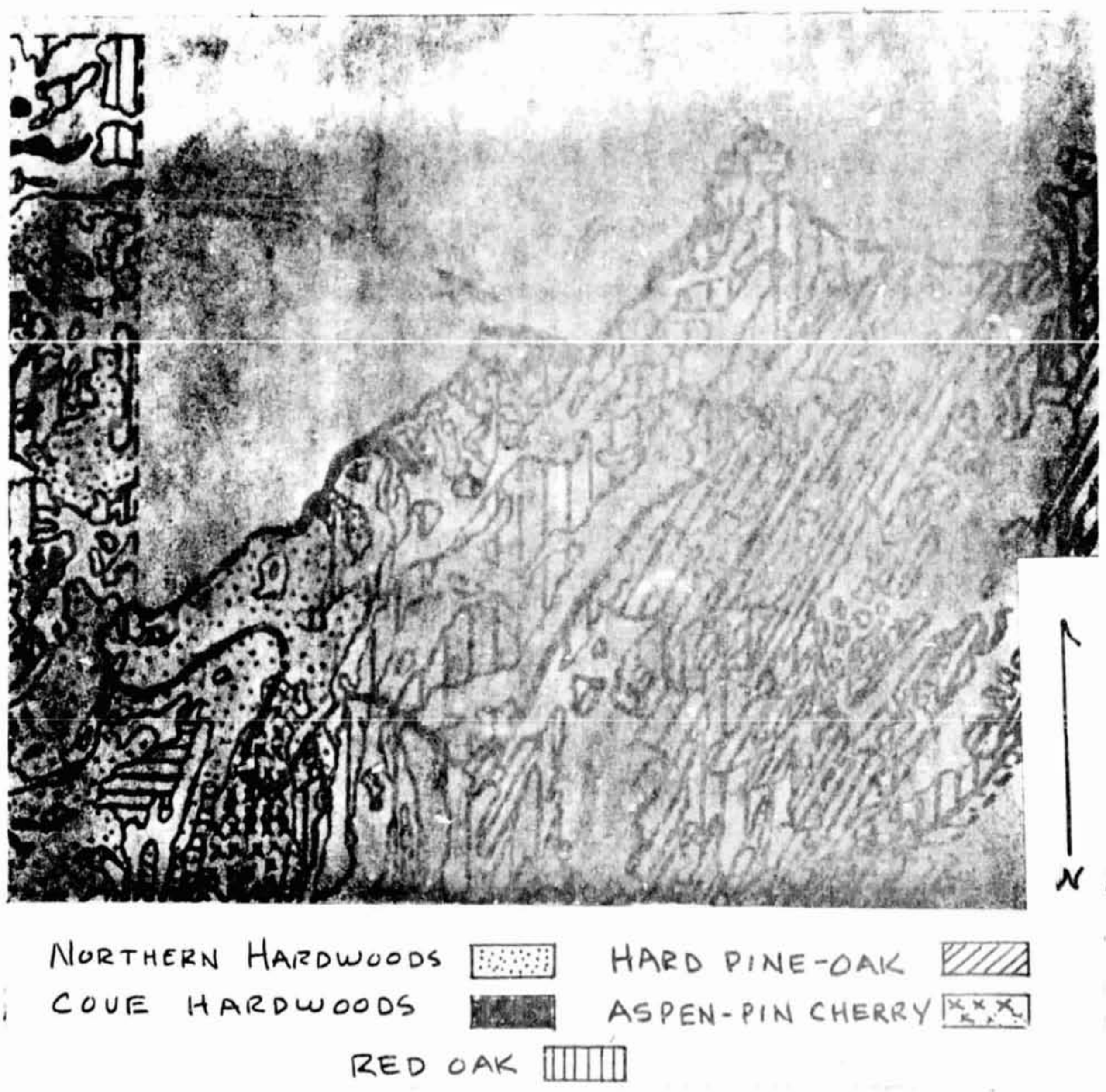
The headwaters of the Potomac is characterized by predominatly Northern Hardwoods at an altitude of 3,000 - 4,000 feet. This area which has undergone and is still subject to strip mining, fire, and logging is characterized as second growth with the largest trees under 18 inches DBH.

At the higher levels of the test site in West Virginia (particularly Grant County) the successional series for Northern Hardwoods on abandoned or cleared lands is:

FIGURE 2

FOREST TYPES IN WEST VIRGINIA

(TEST AREA IN BLUE)



Stage 1) Broom Sedge, bracken fern, shrubby St. John's Wort

Stage 2) Blackberry, Wild Raisen, Mountain Ash

Stage 3) Beech, Yellow Birch, Hemlock, Sugar Maple, Red Maple

The understory for stage three consists of reproduction of the dominant species above and shrubs and woody vines chiefly wild Grape, Greenbrier, Witch Hazel, Rhododendron and Blackberry. This forest type has a greater variety of understory species than most other forest associations with the possible exception of the Red Oak type. Other associated shrubs found here are Hobble Bush, Wild Raisen, Arrow-wood, Spice Bush, Mountain Ash and Hercules Club. Northern Hardwoods are not as productive of good stand density as other similar associations (ex: Cove Hardwoods). While mature Northern Hardwoods have a great many understory species, the number of stems is scant due to reduced light requirements of the upper story accompanied by the indirect effect of drainage and soils.

In terms of low light requirements, the crown cover species of Northern Hardwoods are relatively "tolerant" meaning relatively little sunlight is required for life and growth. As a result, there is little clustering of leaves at the ends of branches seeking sunlight. The even distribution of leaves results in greater darkness below. This is further compounded by the large expansion of the lower leaves in the shade as they compensate for less sunlight by creating more surface area. This shades out an above normal amount of understory.

The high well-drained area to which the Northern Hardwoods are confined is featured by Podzolic soils of marked acidity which also affects the understory to an undetermined degree.

As a point of interest, Podzolic soils are characterized by an upper layer which leaches out iron and aluminum compounds; precisely the type of compounds in the mine waters running through this area.

Remnants of spruce forests, decimated for the most part by fire and logging, occur between Cabin and Allegheny Front Mountains with often a heavy understory of Rhododendron. When this forest type has been burned, a fire sub-climax of Aspen-Pin Cherry comes in. This is the vegetative type around Mt. Storm Lake. The trunks are usually less than 6 inches DBH and the understory is sparse consisting almost entirely of tree reproduction including Aspen, Cherry, Birch, Maple and Hemlock. Broom Sedge provides the ground cover. Large areas of this forest have been cut down by beaver and extensive beaver meadows are characteristic with acres of spike-like Aspen stumps.

In rich soils in small pockets, particularly along the North Branch of the Potomac River itself, a Cove Hardwoods type, with Yellow Poplar predominating, is common. Black Birch, Cherry, and Hemlock are its associates. An understory of young trees, Dewberry, Blackberry, Sumac, and Hazelnut, exists in this area.

Apart from formal designations, throughout the entire West Virginia portion of the test site, Red Oak (Acer Rubra) will be found, also Hickory (Carya Spp). These two tree species become more prevalent in the eastern portion of the test site where altitudes are about 1,500 - 2,000 feet lower and the Red Oak forest type becomes dominant. This type is typified by Red Oaks, Hickories, Chestnut and Scarlet Oaks, and Yellow Pines. The understory is more crowded than that of Northern Hardwoods but also contains a plethora of species which include tree reproduction, Blueberry, Sumac, Sassafras, Crabapple, and Hawthorne.

Broom Sedge and ferns predominate the ground cover at these lower levels. Pasture land is much more common. Coal is not mined in this area. Cleared areas in the highlands west of the Allegheny Front are strip mines, seed and sedge wetlands, and sphagnum-lichens bog-like areas. In summation, the vegetation of the coal producing areas represents associations of more northern areas extending up into Canada and is unique in this respect. Of these, Northern Hardwoods, Spruce, Aspen-Pin Cherry and Cove Hardwoods are the most important. Agricultural areas tend to be of the row crop types with pasture restricted to the stream beds when it occurs.

C. Vegetative Stress

There has been no means devised as yet by which subsurface mining activities and their associated pollution (on land) can be detected and easily pinpointed by means of ERTS and aircraft imagery. Because it apparently makes sense that acid poisoned land and water should cause tangible harm to local vegetative growth, the idea that "vegetative stress" could be detected on near infra-red remote imagery and therefore constitute an indication of otherwise invisible mining activities is quite plausible. On paper it makes sense and some works on the subject, specifically recent investigations by Pennsylvania State University's George J. McMurtry have stated that under certain conditions it works.[1] It is, in essence, an interesting theory and if it worked everywhere, would be most convenient. In our test area in West Virginia we have not yet found any evidence to indicate that it applies.

---

[1]Telephone interview, Ned Berard/McMurtry 3/29/74; McMurtry's studies indicate that in tests in the Anthracite regions of Western Pennsylvania, he has detected isolated cases of areas up to two ERTS resolutions across containing detectable vegetative stress due to acid mine drainage. Such instances seemed to be the exception rather than the rule, however.

The reasons for this failure are manifold. Not the least of which is the fact that the test area is a highly atypical region ecologically, for its latitude. Briefly, the area has a climate, flaura and fauna more typical of Canada than of larger coal mining areas of West Virginia. Therefore, alterations of the "norm" here might not be easily transferable to studies of alteration of the vegetative "norm" elsewhere in the state.

Furthermore, the theory runs into some substantial functional difficulties aside from atypicality in our specific test area. First of all, the soils of the state are already naturally acid and consequently do not support typically non-acid tolerant vegetation. Under these conditions, with an acidic soil which leaches out acid compounds, any observable instances of "vegetative stress" due to mine drainage would be most remarkable. Secondly, most studies on the subject of "vegetative stress" resulting from acid mine pollution in this area indicate that vegetation is not affected beyond ten feet on either side of a polluted stream bank. Thirdly, our own investigations were unable to reveal any vegetative stress outside of the actual waters of the polluted streams, a fact which is testified to most eloquently by the photographs of Laurel Run.

D. Description of the Drainage System and Acid Pollution Within I'

Sources: The most striking feature about available accurate data on this subject is the lack of it. Certainly the importance of the headwaters of the Potomac River Basin deserves a large, detailed, accurate and continuously updated assessement of their physical condition and pollution levels, but such has not been the case. The only detailed summary of the area's topography and geological configurations was published in 1924. Secondary sources on the extent of acid mine drainage in the region are voluminous, but scant on specific details, poorly documented, and based on studies which are nearly ten years old.

Ambionics has bolstered its own knowledge of the subject by frequent interviews with members of the Maryland State Department of Water Resources, and the West Virginia Department of Natural Resources. Undoubtedly, Ambionics has as much current and detailed information on this subject as anyone, but it must be emphasized that comprehensive knowledge of existing data cannot surmount the problem of inadequate data available.

The information in this chapter should underline this problem. Sources will be provided for specific statements that are made, and when as is frequently the case, different sources disagree on the answer note will be made of this also.

In essence, a fairly detailed picture of the drainage basin and its topography can be presented, but an equally informative and reliable picture of the acid mine drainage problem in the area is impossible to provide.

The River: The test area (Figures 3, 4, 5) contains the entire North Branch of the Potomac River from its headwaters near Kempton, Maryland, following its erratic northeast/southeast zigzag pattern until it merges with the South Branch to form the Potomac River proper near Oldstown, Maryland. The North Branch is some 100 miles in length and is fed by over 300 miles of tributary streams.

Coal mining has been conducted in the area for over 150 years with the greatest level of activity being reached in 1907. The coal-bearing area of the North Branch basin lies in a continuous trough-shaped valley about 80 miles long, oriented in a northeast-southwest direction. The North Branch flows northeast through the center of the basin for almost two-thirds of its length. The northeast part of the valley is drained by Georges Creek, which flows southwest through the center of the valley to join the North Branch at Westernport. The coal-bearing region southwest of Westernport is known as the Upper Potomac Coal Field.

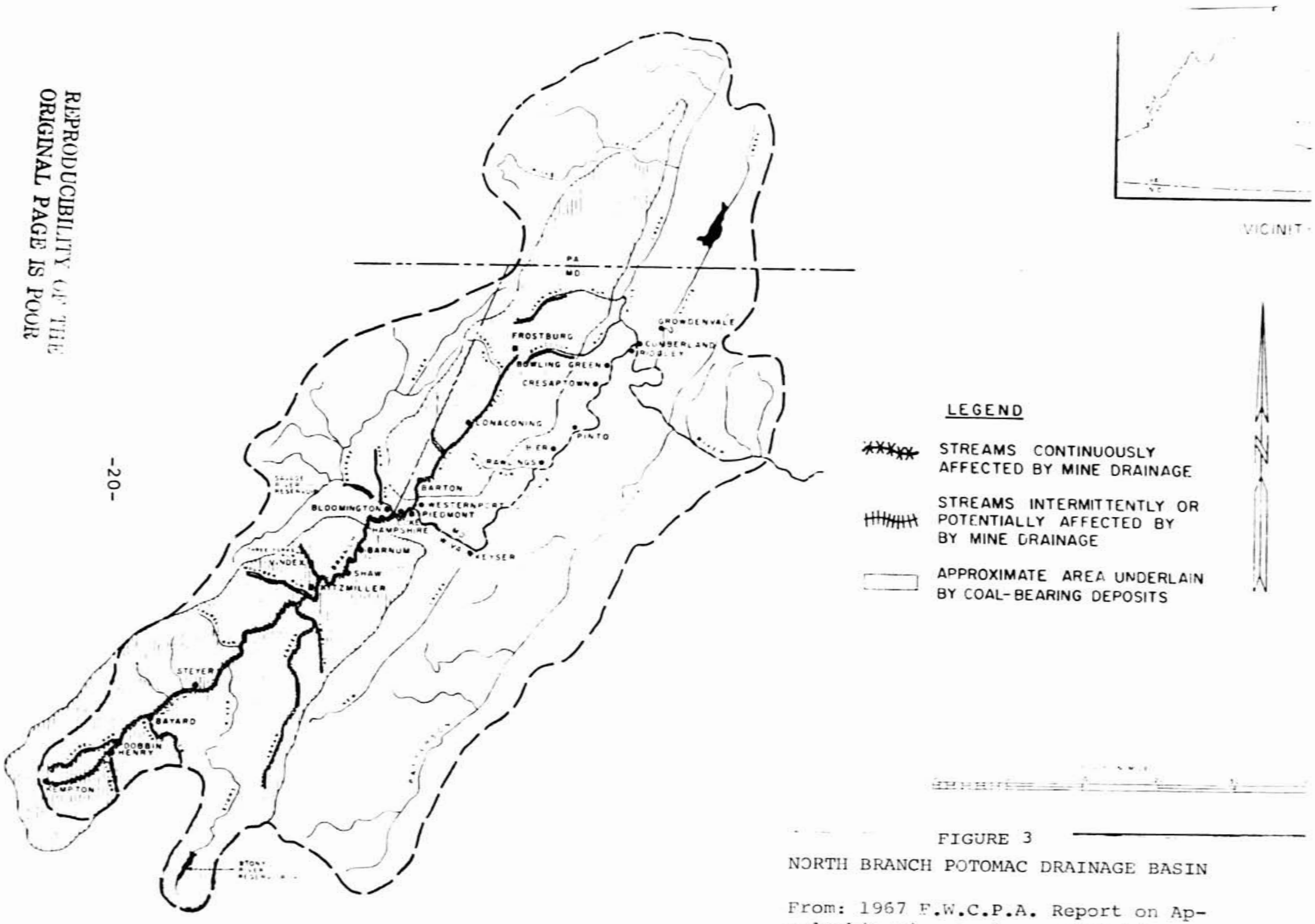


FIGURE 3

NORTH BRANCH POTOMAC DRAINAGE BASIN

From: 1967 F.W.C.P.A. Report on Appalachia Mine Drainage Pollution

FIGURE 4

DRAINAGE PATTERN

MINERAL COUNTY, W. VA.

ABRAM CREEK 1

NEW CREEK 2 PATTERSON CREEK 3

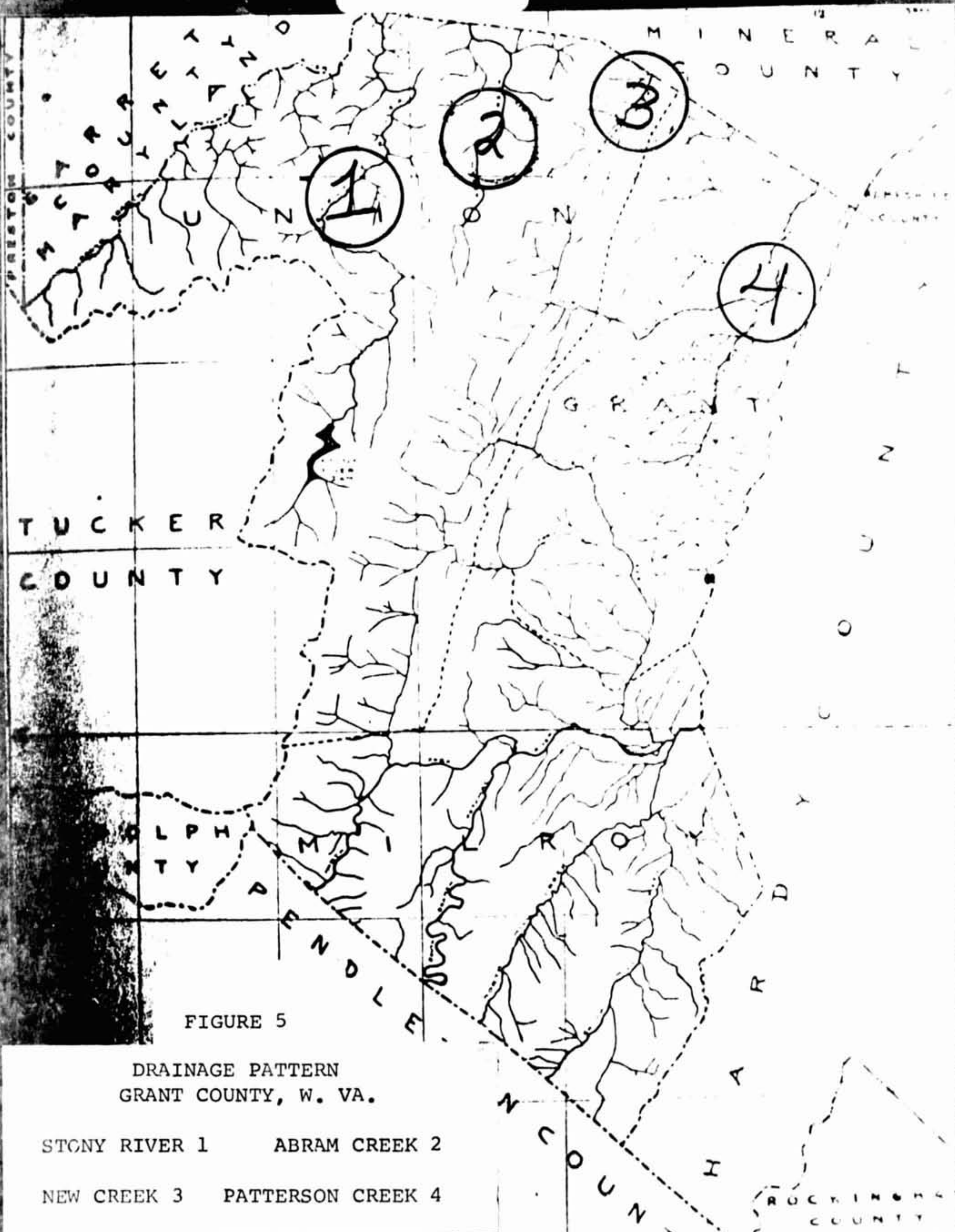


FIGURE 5

DRAINAGE PATTERN
GRANT COUNTY, W. VA.

STONY RIVER 1 ABRAM CREEK 2

NEW CREEK 3 PATTERSON CREEK 4

The coal region drained by Georges Creek, Savage River, and two small tributaries of Willis Creek is known as the Georges Creek Coal Field. Coal is mined from the Pittsburgh, Tyson, Bakerstown, Waynesburg, Freeport, and Kittanning coal seams. Both strip and shaft mining procedures are used and the number of acres affected is in the thousands. Not surprisingly, the greatest source of pollution in the North Branch is mine acid drainage. In 1966 virtually the entire North Branch was considered polluted by mine acid and over 170 miles of its tributaries were also. Eighty-one percent of the total net acidity measured in the stream originated in the Upper Potomac Coal Field, two percent in the Georges Creek Field, and seventeen percent was unaccounted for.

The amount of acid pollution is tremendous (Figure 6). In 1966 an estimated 89,695 pounds of acid <u>per day</u> was dumped into the North Branch through its tributaries. The problem of the acid drainage is compounded by the natural acidity of the water and the lack of natural alkalinity to neutralize it. Shales and sandstones containing coal and fire clays dominate the geology and there is only one limestone stratum in the Georges Creek watershed. The pH of the North Branch at its source is near 5.0 and

FIGURE 6

POTOMAC RIVER BASIN STREAM PARAMETERS

Stream	Total Length in Miles	Total Fall-ft.	Fall Rate ft./mi.	Drainage sq. mi.	pH	Acid Conc. tons/day	Acid Conc. lbs./day
orth Branch eadwaters (Kempton)					5.0	0.2	
obbin Ridge Run	2.9	400	137.9		3.2		
lk Run	2.79	530	189.96	3.80	3.4(2.8)	12	35,700
aurel Run (MD)	13.3	260	20	7.5	3.4	4.9	12,900
uffalo Creek	5.18	900	173.75	10.8	3.2	1.5	15,300(121,300
tony River	25.25	1655	65.54	59.29	3.2	0.8	4,500
ostland Run (MD)				9.2			1,000
bram Creek	18.79	1565	83.29	44.50	3.2	4.2	8,300
olfden Run (MD)	5.8	1280	226		3.2	0.1	
hree Forks Run (MD)	5.2	1340	257.6		3.3(1.8)	1.0	
eep Run	5.67	1420	250.44	9.7	3.2	trace	
lklick Run	3.85	555	144.6	9.74	3.2	0.3	340
iney Swamp	5.47	1560	285.9	5.03			3,200
avage River (MD) (Aaron Run pol. source)						0.8 alk.	
eorges Creek (MD)						0.6	
ew Creek	17.66	1200	67.95	53			
ennings Run (MD)	One time source of pollution to Willis Creek						
illis Creek (MD)	High Hardness and sulfate concentration - no acid load						
raddock Run (MD)	Intermittent source of pollution to Willis Creek						
atterson Creek	48.09	900	18.71	283.2	Normal	No acid	

with the addition of mine acids it become progressively more sour until it reaches a pH of around 3.0 at Kempton, Maryland. From that point the addition of alkaline industrial pollutants gradually raises the pH until it is near normal when the North and South Branches join at Oldstown.

The Tributaries:

Origin of the North Branch, near Kempton, Maryland: The streams which feed the swamp known as "Kempton-Laurel", which serves as the origin of the North Branch of the Potomac, flow down from the ridges of Tucker, Preston, and Grant Counties in West Virginia as well as Garret County, Maryland. At Kempton these combined tributaries were discharging an average of 0.2 tons of acid per day in 1966; this was less than one percent of the total average acid load dumped into the North Branch. Between this point and Steyer, Maryland, over two-thirds of the total mine acid dumped into the Potomac has already been added.

1. Dobbin Ridge Run - This is the first named tributary to the North Branch. It is located about four miles down river from Kempton. The stream falls a total of 400 feet as it winds its way down 2.9 miles of Grant County hillside. The stream has a rate of fall of 137.9 feet per mile and a drainage basin

of one square mile. Mine acid in the Dobbin Ridge Run is processed through an experimental neutralization station utilizing limestone drums. An average pH of 3.2 has been recorded for the stream* but no other data regarding acid load or the effectiveness of the neutralization station is provided by them or other sources.

2. <u>Elk Run</u> - Based on 1966 figures, this small stream is the single greatest polluter of the North Branch. The Maryland and West Virginia State authorities currently maintain that the situation has now changed and the title now belongs incontestably to Buffalo Creek, located five miles downstream. Nevertheless the case of Elk Run is an interesting one and warrants further detailing. Separated from Dobbin Ridge Run by a ridge that rises 1000 feet between them, Elk Run is located in Grant County, West Virginia. It is 2.79 miles long, falling a total of 530 feet at a rate of 189.96 feet per mile before converging with the Potomac. Within its 3.8 square mile drainage basin a coalyard and extensive mining is maintained by the Alpine Coal Company. In 1966 figures listed by the Interior Department gave the stream a pH of 2.8 at its confluence with the North Branch and a mean net acidity concentration of 1,900 mg/l despite the stream's

*Mitre Report

treatment station. Flows varied from 1.7 to 3.3 cfs, but the average net acidity was 12 tons/day. According to FWPCA's calculations this represented 38 percent of the daily acid load dumped into the North Branch. The 1973 MITRE report, using figures of unspecified origin, states that Elk Run's average pH is 3.4 and that its mean net acid load is 35,700 pounds per day.

According to the West Virginia Department of Natural Resources, the situation at Elk Run has changed drastically since MITRE's figures were calculated. Elk Run's stream bed was diverted around the sources of pollution and drainage of mine acid was diverted to Deacon Creek. New treatment facilities were installed and allegedly pollution has been drastically reduced until recently. At the time of this writing (March 1974) the situation at Elk Run has taken a turn for the worse. The treatment plant suffers from chronic breakdowns and currently sealed mines in the area have filled to near ground level with backed up acid water and are draining out of numerous bore holes. Currently there is no treatment of the mine waste in the area and the mine runoff is polluting both Deacon Creek and Elk Run.

3. Laurel Run - Laurel Run originates about 150 feet above an old abandoned strip mine. A quarter of a mile later it passes through the southern tip of the mine on its way to the Potomac. Thirteen miles later, after falling 260 feet (20 ft/mile) Laurel Run empties a sizeable acid load into the North Branch. the MITRE report states that the average daily load is 12,900 pounds and the average pH is 3.4. The FWPCA report states that Laurel Run empties 4.9 tons a day and records no pH level. The mystery concerns the original source of all this acid. The pollution appears to come from the abandoned strip mine the stream passes through, but Maryland State authorities believe that the actual source is a sealed shaft mine in West Virginia, which has backed up its acid waters until finding an outlet in the old strip mine. The FWPCA report gives a similar account, but no one seems to know for sure. Ambionics has pursued this question further but as yet we have been unable to locate any veteran mine inspectors from the area who might shed light on the problem.

The acid load has turned the stream into a "biological desert" but to the layman the stream would appear normal. Its reddish-brown stained stream bed is not unusual in an area abounding in iron ores, and the odd pools of greenish colored sediment do not look that out of place either. Large Hemlocks crowd the banks with their branches hanging over the water and the spaces between the Hemlocks are crowded with cottonwoods

4. Buffalo Creek - Buffalo Creek is not very big, only 5.18 miles long with a drainage area of 10.8 miles; but what it lacks in size it certainly makes up for in pollution. Near its source Buffalo Creek crosses several strip and auger mining projects known jointly as the North Branch Mine. Wastewater is pumped directly from the mine into settling pools which form the basis of a treatment station. Coming from pipes in the mine the water is a coal black, but after initial settling and treatment it turns a deep muddy orange. After treatment the water is drained into Buffalo Creek, supposedly in less polluted condition. As the water crosses under the main street of Bayard a few miles later it is still colored an unhealthy orange yellow.

MITRE states that the average pH is 3.2 and the net acid load is 15,300 pounds per day. The FWPCA report lists a net load of 1.5 tons a day. This is hardly a good situation, but current data obtained by Ambionics from the West Virginia Department of Natural Resources indicates that the problem is far worse in 1974 than when MITRE and FWPCA obtained their data.

when the treatment plant is "torqued out" or in a state of disrepair, which is appraently quite frequently, no readings can be taken. however, when the plant is fully operational thus supposedly purifying the water the readings obtained are quite startling. Fall acid loads seem to average around 121,300 pounds per day but they have been calculated as high as 172,600 pounds of acid per day, with a pH of 2.9. Maryland and West Virginia authorities believe that the Bayard Mine is now unquestionably the greatest single polluter of the North Branch, contributing as mueh as 50 percent of the total pollution in the area.

5. Stony River - The Stony River was, until about ten years ago, one of the finest trout streams in the state of West Virginia. It originates about twenty miles to the southeast of the North Branch's headwaters at Kempton and after meandering north through twenty-five and a quarter miles of West Virginia countryside it finally joins the North Branch below Steyer, Maryland, or about eight miles upstream from Buffalo Creek's confluence with the river. Stony River is a fairly large stream for this part of the country, over twenty-five miles long with

a total fall of 1,655 feet giving it an average fall of 65.54 feet per mile. It is a rather swift flowing river and once provided cool, highly oxygenated waters to support a thriving Appalachian stream eco-system.

When the 1967 FWPCA report was made their sources indicated that small mining operations had begun near the North Branch Stony River confluence and that some 0.8 tons of acid per day was entering the stream. The 1967 FWPCA report still maintained that trout could be found throughout much of the Stony River. In the mid-sixties a giant VEPCO power plant was built near the River's headwaters at Mt. Storm Lake by the Stony River Dam. When the MITRE report was made the VEPCO plant was in operation but no mention is made of it or its attendant pollution; however, mining pollution was listed at 4,500 pounds per day of acid and the river had an average pH of 3.2. According to ground observation by Ambionics' personnel, and verified by aircraft infra-red pictures, the Stony River appears quite polluted from the VEPCO plan on down to the North Branch. The River appeared to be another "biological desert" and assuming the MITRE figures of an average pH of 3.2 are correct, it is doubtful if anything is living in the Stony River.

6. Abram Creek - Abram Creek is a comparatively youthful stream with high banking cliffs and no significant bottom land. Its length traverses 18.79 miles in West Virginia before joining the North Branch above Kitzmiller, Maryland, and about a mile and a half downstream from where Stony River meets the North Branch. Its total fall of 1,565 feet and fall rate of 83.29 feet per mile make it a comparatively swift flowing major tributary.

The FWPCA report states that Abram Creek contributes 4.2 tons per day net acidity to the North Branch or roughly 13 percent of their total acid load figures for the river. The major source of mine drainage is located near the headwaters at Bismarck, West Virginia, but more is added by tributary streams. It is interesting to note that the FWPCA report accounts for only 3.9 tons of the daily acid load and states that this load is considerably diluted by alkalinity from an unidentified source before reaching the Potomac.

The MITRE report figures state that the average acid load is 8,300 pounds per day and that its pH is 3.2, making it the fourth greatest polluter of the North Branch by their standards.

Abram Creek is roughly similar in appearance to Stony River and is probably equally barren of life forms.

7. Three Forks Run - Three Forks Run is a relatively short stream (5.2 miles) running through Garret County, Maryland, and joining the Potomac a few miles downstream from Abram Creek. Its total fall is 1,340 feet and therefore considering its shortness it is quite swift (257.6 feet per mile average fall).

The 1967 FWPCA report describes Three Forks Run as "grossly polluted" by runoff from mines and possibly from spoil piles in the watershed. The report mentions that in August 1966 a pH of 1.8 was measured in the run. Net acid discharge is listed as 1.0 tons per day.

It is interesting to note that the MITRE report gives no more than a passing notice to Three Forks Run, mentioning that its average pH is 3.2. Considering that this "grossly polluted" tributary will be emptying its acid waste just upstream of the proposed Bloomington Dam the Report studied, this omission is most remarkable.

8. Deep Run - Little information is available about Deep Run, other than the fact that it has been rather polluted by acid drainage for over ten years. It is located eight miles downstream from Abram Creek on the West Virginia side, is 5.67 miles long, with a total fall of 1,420 feet and an average fall of 250.44 feet per mile. Its drainage basin is 9.7 square miles.

The FWPCA report states that the stream is mildly polluted and actually contains some living organisms, mostly microbes. Neither FWPCA nor MITRE gives any acid load data, but the MITRE report states that the average pH is 3.2, hardly indicative of "mild pollution."

9. Elklick Run - Elklick Run is a small Maryland stream (3.85 miles) which joins the North Branch about a mile downstream from Shaw, West Virginia, and adds a small load of acid to it. The FWPCA report states that the contribution is 0.3 tons a day net acidity and the MITRE report lists a load of 340 pounds a day and an average of 3.2.

10. Piney Swamp Run - Piney Swamp Run is currently considered one of the major polluters of the North Brancy by the regional authorities, but no current figures have yet been released to Ambionics. The stream is located in West Virginia near Hampshire. It is 5.47 miles long, with a total fall of 1,560 feet, and a fall rate of 285.19 feet per mile, making it rather swift.

Mining operations in the drainage basin are conducted by the Masteller Coal Company. MITRE lists the average acid load as 3,200 pounds per day and the FWPCA report gives a similar reading of 1.3 tons a day. No pH is registered.

11. Savage River - The Savage River is one of the major rivers of Western Maryland, and one of the few sources of alkalinity in the North Branch above the Upper Potomac River Commission Waste Treatment Facility. The source of alkalinity is industrial pollution along the tributary stream of Aaron Run, which discharges a net load of 0.8 tons a day of alkaline substances. The effect of this amount of alkali does not significantly raise the pH of the North Branch. Above the confluence of the Savage River with Aaron Run, the river's waters are relatively pure.

12. Georges Creek - Georges Creek drains some fifty square miles of the Maryland countryside before entering the North Branch at Westernport, Maryland. The FWPCA report states that it is a mild polluter, contributing a net load of 0.6 tons of acid a day, mostly from abandoned shaft mines along its banks. The MITRE report, perhaps because the stream enters the North Branch below the proposed dam site, makes no mention of its pH or acid load. The ICPRB report gives readings of between 1.5 - 3.5 for 1972. A report by Marks, Sloan, and Villa for FWPCA in 1968, however, states that the daily load varies from 2,500 to

to 37,000 pounds of acid per day. The median flow average is 20,000 pounds per day net acidity, making Georges Creek one of the major polluters of the North Branch.

13. Upper Potomac River Commission Waste Treatment Facility - According to the 1968 FWPCA report roughly 15,000 pounds net alkalinity is dumped into the North Branch from this facility downstream from Westernport, Maryland. Three miles downstream at Keyser, West Virginia, pH values of 6 and 7 have been recorded in comparison to the average of between 3.5 and 4.0 at Westernport according to the 1967 FWPCA report.

The source of the alkalinity is believed to be primarily waste material from the WESTVACO plant at Luke. At one time this plant emptied several tons a day of waste lime into the North Branch at the plant site but this practice has been discontinued and the lime is recycled by the plant.

While the River does not achieve a pH of 7.0 until it reaches Paw Paw, Maryland, the high acidity levels are not again reached after it passes the UPRCWTF.

14. Below Westernport to Oldstown - According to the 1966 FWPCA report, Willis Creek, which enters the Potomac above

Pinto, Maryland, is a source of slight acid drainage, but the 1968 FWPCA report says that this has ceased to be the case, and that only Braddock Run continues to contribute acid to the North Branch. Acidic conditions have been observed occasionally at Pinto, none have been recorded below Cumberland.

SOURCES

Barata, R.; Cardenas, J.; Golden, L. Thomas; An Assessment of the Impacts of Improved Water Quality In the North Branch Potomac River Basin, The Mitre Corporation, December 1973. Sponsor, Corps of Engineers, Baltimore District. Detailed Bibliography is given, but no footnotes; it is be..ieved that wate. quality information was derived from figures in a previously published report by the Maryland and West Virginia State agencies responsible for such work, perhaps in the mid-sixties.

Marks, Sloan and Villa, Mine Drainage Pollution of the North Branch of the Potomac River, 1966-68, Interim Report, FWPCA, Middle Atlantic Region, August 1968. Based on data from the Chesapeake Field Station, the Maryland Department of Water Resources, and the West Virginia Department of Natural Resources, Division of Water Resources.

Potomac River Water Quality Network, Water Year 1972, Interstate Commission on the Potomac River Basin. Based on figures from monitoring stations in the North Branch and selected tributaries, maintained by the Maryland Department of Water Resources and the West Virginia Department of Natural Resources, Division of Water Resources.

Reger, David B., Tucker, R. C.: West Virginia Geological Survey - Mineral and Grant Counties, 1924, Prepared by the State Geologists Office; Morgantown Printing and Binding Company, Morgantown W. Va. 1924.

Stream Pollution by Coal Mine Drainage in Appalachia, U. S. Department of the Interior, Federal Water Pollution Control Administration, Ohio Basin Region, Cincinnati, Ohio; Prepared 1967 - revised 1969. Sources of Information: FWPCA projects, and data from the Maryland Department of Water Resources (1965) plus other unlisted reports.

4. METHODS AND ANALYSIS

At the inception of this program, Ambionics, Inc. personnel researched all known sources of mining records and obtained data from the U.S. Bureau of Mine's Mapping Center at Pittsburgh, Pa. The Mapping Center is compiling a data base for all mines east of the Mississippi River. This process is still accumulative and, as yet, has not reached a stage where accuracy can be checked.

Another problem was that data for that part of Pennsylvania within the test site was unavailable.

In the company office, these data were plotted on 7°30" topographic quadrangles obtained from the U.S. Geological Survey. The corporation and mine name (or number) were placed with each location.

Recent land use maps were sought for the test site at Elkins, West Virginia (DNR) and College Park, Maryland (Md. Natural Resources Inventory). None have been prepared in many years.

However, the SCS was in the process of completing a land use study in West Virginia and in early 1974 copies were given to Ambionics. This was believed (at this writing) to have little detail.

More detailed maps were sought even though of earlier vintage. These were found at the West Virginia Geological Survey in Morgantown and at the DNR office in Elkins.

Water sampling data were obtained from the Interstate Commission on the Potomac River Basin, the Maryland Department of Water Resources and the West Virginia Division of Water Resources.

The ICPRB had annual summaries up through 1972, while the State Agencies possess data at gauging stations by dates up to the present. Special attempts to obtain data were made to correspond to ERTS passage days and NASA aircraft flights.

All available ERTS images of the test site showing ten percent cloud cover or less were obtained and analyzed. Computer compatible tapes of the May 16, 1973 ERTS pass were obtained and sent to IBM Federal Systems Division, Gaithersburg, Maryland for analysis under a separate NASA Langley contract.

Analysis

From data received in Task I the major pollution sources in the upper Potomac were located on false-color infra-red aerial photography supplied by NASA Langley. All occur in West Virginia. While conditions vary, the biggest offenders in terms of pounds of acid per day are:

North Branch Mine - Bayard, West Virginia

Alpine Mine - Henry, West Virginia

*Laurel Run - Kempton, Maryland - West Virginia

VEPCO Power Plant and associated mines - Mt. Storm Lake, West Virginia

**Abram Creek - Grant and Mineral Countys, West Virginia

Attempts to locate them on ERTS imagery were largely unsuccessful except for the VEPCO plant at Mt. Storm Lake and the North Branch Mine at Bayard. The source of Laurel Run is also visible on ERTS imagery.

Surface mining activities were examined in detail in Grant County, north of Stony River Dam using both ERTS and aircraft imagery. The aircraft imagery has been studied for

*Source unknown
**Many mines

not only direct evidenc' of pollution but supportive signals as well. The results will be discussed in the final section of this report.

Use of ERTS-1 Imagery and CCT's to Detect Strip Mining and its Attendant Ecological Effects

Recent significant work in strip mine analysis has been done by Robert H. Rogers and Larry E. Reed of Bendix Aerospace Systems Division, in Ann Arbor, and Wayne A. Pettyjohn of the Geology Department at Ohio State University in Columbus. Their paper "Automated Strip-Mine and Reclamation Mapping from ERTS" warrants a detailed synopsis.

In essence, Rogers, Reed and Pettyjohn maintain that their studies have proved that strip mining and its attendant environmental damage can be continuously monitored on a cost effective basis with an accuracy of around 97%. This is a marked improvement over present methods which employ ground observers who cover the areas sporadically with results of varying accuracy.

Their test site was a heavily strip-mined area in east-central Ohio. Their comments on previously existing data and impediments to securing it offer a valid comment on similar problems encountered by Ambionics staff members on this project.

> On site examination of individual mines, and particularly older mines, is hindered by (1) a lack of adequate mine map coverage; (2) deeply eroded, nonexistent, or blocked access roads; (3) lack of accurate or adequate records; (4) the great total size of the stripped area; (5) strip mine reclamation planting along roads that obscures adjacent barren land; and (6) dated aerial photographic coverage.
>
> Various agencies in the Ohio State Government collect certain types of coal mining data. There is, however, little or no coordination between agencies; automatic data processing is nonexistent and various filing systems approach the chaotic. Consequently, reports available to the public are severely dated, commonly inaccurate, and difficult to acquire.
>
> Examination of several water quality parameters in lakes, reservoirs, and streams throughout the region indicates a wide range of concentration, both in space and time. Furthermore, the quality cannot be readily predicted from one area to another or, for that matter, from one impoundment to the next in the same mine. Consequently, a detailed regional analysis of water quality cannot be adequately accomplished without a monumental budget.[1]

Their study was to evaluate the suitability of using ERTS computer compatible tapes (CCT) for automatic mapping. The procedure was to use "computer target 'spectral recognition' techniques as a basis for classification." Using numerous samples of the various categories of images the computer was to identify, a

---

[1]Robert H. Rogers, Larry E. Reed, Wayne A. Pettyjohn; "Automated Strip-Mine and Reclamation Mapping from ERTS." pp. 1-3.

numerical description or "cannonical analysis" program was devised whereby the characteristics to be monitored were assigned a set of "cannonical coefficients." After much trial, the system was refined to a point where it produced results with a consistent accuracy of 97%.

Among the items the computer could identify, were stripped earth, water with sedimentation, partially reclaimed earth, vegetation, and water without sedimentation. From the computer a false color image could also be obtained which would give a visual representation of the characteristics identified in a specific test site, and a percentage of each characteristic in the area was also rendered. The report concluded that the use of the ERTS CCT's was an accurate, rapid and comparatively inexpensive method of obtaining data on surface mining and that it was a marked improvement over techniques presently in use.

Using far less sophisticated and costly methods, Ambionics obtained similar results which would tend to substantiate many of the findings made by Rogers, Reed, and Pettyjohn. Our procedure was to select a specific area of our test site and have all known strip mines in it outlined on 7.5 minute topographic maps by the state authorities. We then took these maps to our office and placed them on a wall. Taking a 70mm negative of an ERTS image of the test site, we trimmed it to fit a 35mm slide frame and then projected this slide against the maps on the wall with a standard Kodak slide projector. When the images were aligned and correlated we place a sheet of clear acetate over the maps and proceeded to outline all shadows on the ERTS projection which prior study had led us to believe were strip mines. After this was completed, the results were verified by near infra-red aircraft photos taken of the area. We found that we were able to detect water, strip mined areas, and old strip mine sites in varying stages of regrowth. When our outline of strip mined areas was compared with that provided for us by the state authorities, it showed that they had failed to indicate over 75% of the strip mines in the area, and the strip mines they did identify, were frequently mislocated or incorrectly sized.

This method devised by Ambionics appears to be a simple, extremely inexpensive, and reasonably accurate method of monitoring strip mine activity and regrowth or reclamation efforts. It would be of use to any agency involved in monitoring strip mine progress and could be implemented with a minimum of funds and equipment, and administered by non-professional personnel.

5. DEMONSTRATION PROGRAM PLAN

Based upon the results of our efforts in this project, we present a plan for a program to demonstrate in a quasi operational mode the utilization of combined remote sensing and surface monitoring of coal mine pollution. A suggested demonstration site will include the Upper Potomac Basin herein described and, in addition, the Tygart River Basin in West Virginia.

Understanding the roles of satellites, aircraft, and the human interface at widely varied and reoccurring levels is of primary importance.

In defining these relationships as well as the role of each of the three major data gathering sources, Ambionics will demonstrate a more orderly and economical monitoring system than presently exists.

To demonstrate the role of the ERTS program in mine pollution abatement, investigators should recognize the principal functional steps in any abatement undertaking for comparisons in costs, accuracy, spacial and unit coverage.

These steps might be labeled:

1. Search
2. Monitor
3. Train (Select)
4. Treat (Reclamation)
5. Recheck

Remote sensing is involved in steps 1, 2 and 5. Planning and action are represented in steps 3 and 4. The tentative sequential procedure recommended is as follows:

1. SEARCH - Surface mining activities are most readily observed and measured on satellite imagery. An economical method was developed by Ambionics and described in Chapter 7 of the Six Month Report. Stripping operations, while offensive to the eye produce relatively little water pollution, but serve a major important function; numerous, and often extensive, surface mining operations are indicative of total (surface and subsurface) coal mining activities active and abandoned. The SEARCH state is primarily involved with areas of past and present mining activities.

The Preliminary Step is to establish in each area under investigation a "norm" on the ERTS imagery and, where possible, the CCT's. These "norms" should be established for each season and the following should be checked.

Water Color
Stream Size
Land Use Boundaries
Industrial Wastes
Evidence of Coal Mining Activities
(Tailings, Surface Operations,etc.)

Overlays are then prepared for these images (at a suggested scale of at least 1:250,000) representing each seasonal normal appearance. "Normal" is based on recently accumulated data compared to at least five years accumulated and averaged data collected by present methods. In most cases, the ERTS data should be correlated with aircraft and other sources of data.

These overlays will serve as the "base" maps for comparison purposes with maps derived from subsequent ERTS passages. Changes in size and shape of specific critical signatures may be quickly noted.

2. MONITORING - Slight changes in mine drainage volume or acidity cannot be observed on ERTS images, but their effects should be minimal. Any change noted on the space imagery is large enough to warrant investigation.

Aircraft photography represents the "fine tuning" in the search for mine drainage pollution and should be undertaken at least four times per year (once each season). The time of flight should be established to coincide with satellite passes. Should high cloud cover preclude analysis for ERTS imagery, it is still possible to relate aircraft coverage with field samples.

Instrumentation should include multispectral scanner and four-camera Hasselblad equipment as well as other sensors which may be available.

One of the major advantages of aircraft photography, particularly if color infrared imagery is employed, is that smaller streams (e.g.Braddock Creek outside of Cumberland, Maryland) can be observed and studied and evidence of strip mine pollution can be observed in season, which can be monitored for durability as well as intensity.

NOTE: Changes are the prime item of interest, when analyzing ERTS or aircraft images. These may be due to either extraction or reclamation efforts or breaking down of preventive measures.

3. TRAIN (Select) - Based on data obtained in steps 1 and 2, priority areas for reclamation work will be defined. Factors involved should include demographic, sociological, and economic influences. For example: In West Virginia, coal mine operations are recognized as a primary capital resource as well as a source of employment. This will influence that State's planning for reclamation.

Conversely, across the Potomac River, the Maryland Department of Water Resources not only must monitor mine pollution and evaluate the meaning of its findings (12 parameters - see Chart No. 1) but must make decisions as to whether new mining operations can be inaugurated and old ones may continue. The Maryland problem has been compounded by

WR-L-1
8/65 (Rev.)

TS

CHART NO. 1

STATE OF MARYLAND

NUMBER: J153

LABORATORY ANALYSIS REPORT

DEPARTMENT OF WATER RESOURCES

FILE TITLE	COUNTY OR CITY	COLLECTOR	SUBMITTER	DATE
NASA, WESTVACO to CUMBERLAND, POTOMAC RIVER	ALLEGANY	T. STEWART		8 10 73

ITEM	PLASTIC SAMPLE #	BOD #	GLASS ~~BOD BOTTLE~~	DO #		TIME	TEMP	pH	LAB CODE
1	T-565		F-14		PIEDMONT-WESTERNPORT BRIDGE POTOMAC R.		23.5	6.1	
2	K-299		F-19		WESTERNPORT R.R. BRIDGE GEORGES CK.		21.5	4.6	
3	K-132		F-46		POTOMAC RIVER PAST McCOOL		25.5	6.5	
4	T-937		E-31		POTOMAC RIVER AT RAWLINGS		27.5	6.9	
5	T-285		F-62		POTOMAC RIVER AT ABL.		27.5	7.0	

ANALYSES AND NOTATIONS: pH, T. ALK, T. H+ ACIDITY, MIN. ACIDITY, SS, DS, Fe++, T. Fe, T. AL, SO4, TURB.

ITEM	SUSPENDED SOLIDS P.P.M.	DISSOLVED SOLIDS P.P.M.	TOTAL SOLIDS P.P.M.	TURBIDITY P.P.M.	DISSOLVED OXYGEN P.P.M.	BIOCHEMICAL OXYGEN DEMAND 5 DAY/20°C P.P.M.	COLOR P.P.M.	LABORATORY pH	T. Alk Mg/L	Min. Acid Mg/L	T. H+ Acid Mg/L	SO4 Mg/L	T. Al Mg/l	T. Fe Mg/l	[illegible]	T. Mn Mg/l
1	240	250	490	240				6.8	6	0	18	150	17.7	5.3		6.9
2	46	766	812	80				5.0	2	0	56	472	5.3	3.6		3.8
3	44	657	701	85				6.8	40	0	8	293	3.8	1.5		1.9
4	46	723	769	72				7.2	48	0	0	340	3.0	1.9		1.8
5	42	714	756	76				7.1	48	0	0	318	3.6	1.8		1.8

ITEM	Fe+2 Mg/L
1	.80
2	.90
3	1.50
4	1.90
5	1.80

WP-L-1
8/65 (Rev.)

CHART NO. 1

STATE OF MARYLAND

NUMBER: J154

LABORATORY ANALYSIS REPORT

DEPARTMENT OF WATER RESOURCES

FILE TITLE: NASA WESTVACO TO CUMBERLAND

COUNTY OR CITY: Allegany | COLLECTOR: T. Stewart | SUBMITTER: | DATE: 8/10/72

ITEM	SAMPLE # (PLASTIC)	BOD #	GLASS	DO #	LOCATION	TIME	TEMP	pH	LAB CODE
1	T-765		E29		POTOMAC RIVER AT WILEY FORD BRIDGE		26.5	6.6	
2	T-412		F-39		WILL CREEK AT RR BRIDGE		24.5	8.6	
3									
4									
5									

ANALYSES AND NOTATIONS: pH, T. ALK, T.H ACIDITY, MIN. ACIDITY, SS, DS, Fe++, T. Fe, TAL, SO4, TURB

ITEM	SUSPENDED SOLIDS P.P.M.	DISSOLVED SOLIDS P.P.M.	TOTAL SOLIDS P.P.M.	TURBIDITY P.P.M.	DISSOLVED OXYGEN P.P.M.	BIOCHEMICAL OXYGEN DEMAND 5 DAY/20°C P.P.M.	COLOR P.P.M.	LABORATORY pH	T. Alk Mg/L	Min. Acid Mg/L	T.Hot Acid Mg/L	SO4 Mg/L	TAl Mg/L	T. Fe Mg/L	~~T.Fe++~~ ~~Mg/L~~	T. MN Mg/L
1	32	590	622	81				6.9	28	0	2	287	1.9	1.5		1.7
2	8	333	341	21				8.5	36	0	0	160	.8	.2		.2
3																
4																
5																

ITEM	Fe+2 Mg/L
1	1.05
2	.10
3	
4	
5	

the fact that under new regulations, sampling and analysis must be accomplished once per month.

West Virginia's sampling is irregular with a goal of once every 6 weeks.

4. TREAT (Reclamation) - The previous functional step represented the decision-making process. This includes grading, resodding and replanting stripped areas; sealing or resealing abandoned mines; and installation of treatment processing at active mines. The utilization of remote services (steps 1-3) enables a comprehensive approach to reclamation over entire drainage basins with the same personnel and time previously involved and provides assurance that the important targets are not being bypassed for lesser pollution sources.

5. RECHECK - Reclamation of surface mines can be quickly observed at minimal cost every few months by visual examination of ERTS imagery. Aircraft will probably be necessary to check abatement of pollution originating at subsurface coal mines. Actual surveillance costs will be monitored and estimates made for costs needed in an operational system.

Present cost figures were sparse from West Virginia, but it was interesting that the average field trip for sampling in that state consisted of a 100-mile round trip and covered 5 field stations. More complete figures were obtained for the State of Maryland within the Test Site.

To check the 12 parameters of each station (See Chart No. 1):

Professional salaries @ $20.00/hr		2 hrs 20 min	$47.00
Transportation (30 mi av) @ $3.60/hr		2 hrs	7.20
Clerical @ $4.30/hr		30 min	2.15
	Sub Total:	4 hrs 30 min	$56.35
Grab Sample @ $3.60/hr		10 min	.60
Read Guage @ $3.60/hr		10 min	.60
Study Rate of Flow @ $3.60/hr		40 min	2.40
	Sub Total:	60 min	$ 3.60
	TOTAL:	5 hrs 30 min	$60.35

The second sub-total may [illegible] a duplication within the hourly figures given in the first sub-total. Time is as much a factor as money. In Maryland, there are at present 45 checking stations in Garrett and Allegheny counties (Test Site), while in the West Virginia part of the Test Site a maximum of 18 checking stations exist, many of which are not visited regularly.

Average field time per sampling station is four and one-half hours (based on Maryland figures) under present conditions. With its present resources, on the occasions when all stations are to be checked, three to five 2-man crews spend an entire week in the field.

Only two men constitute the entire field team on the Upper Potomac in West Virginia.

The ERTS satellite has several unique characteristics including vast spatial coverage and a spectrum of sensing devices offering coverage from blue-green into the near-infrared, but it has one unique value which both the field work and the aerial photography should utilize -- regularity. Every 18 days, the satellite automatically records images over the same area. The satellite should serve as the "time clock" for all monitoring. Schedules of its passage should be submitted to all state and federal personnel responsible for sampling and analysis of water and other environmental studies in the affected areas, enabling field work to be scheduled ahead without inconvenience.

The importance of this, economically, cannot be overstated. If the Scientist or Field Technician has higher priorities on his time on the ERTS passage date, he can still stay within seasonal limits by recognizing a delay of only 18 days. Conversely, if only one sampling per season is desired, or deemed essential, a sampling coupled with imagery, as a corroborative source, presents weightier evidence than now exists on behalf of the professional (e.g., O.J. Lind, University of Vermont - Studies of Pollution Across the Lake Champlain Drainage Basin). Inclement weather is reduced as a factor both from the standpoint of cloud cover and transportation. Aircraft flights can be scheduled automatically under this system. Mechanical difficulties are not "catastrophic" since rescheduling can be set for 18 days hence.

Within the test site, mine pollution personnel have been notified by EPA of when ERTS is passing over. In West Virginia, stream sampling has already begun on the days of ERTS passage in May 1974. Discussions with these scientists have, for the present, disclosed two factors:

1. Periodic stream checks have largely broken down because of the press of other duties.

2. Conscientious state personnel have welcomed the satellite as the "time clock" and have begun sampling in May 1974 on the dates of ERTS-1 passage even in cloudy weather. In discussion with Ambionics, Inc., they feel that if weather is unsuitable to ground observers on the day field data is taken, they know they can do this again within three weeks.

In summation, Ambionics recommends the following:

1. The techniques developed in the work on the Upper Potomac be refined. Foremost among those are a clear understanding of land use for three major reasons.

(a) Comprehension of what is observed in terms of shape, size, tone or color texture and location on both ERTS and aircraft images and knowledge of what is actually present at that location. The coordinates have already been delineated on ERTS-1 imagery (1:100,000) over most of both the present test area and suggested demonstration site.

(b) The physical relationships or lack of them between management of the land and surface and subsurface coal mining past and present. Obvious land use categories will be mapped prior to going into the field employing satellite and aircraft imagery. *A priori* designations will be assigned to these areas on the map prior to going into the field.

(c) Recent land use maps of the area are either non-existent or unsatisfactorily definitive.

2. Areas of uncertain definition will be annotated for visiting in the field, and other areas, previously defined, will be marked for personal checks to validate office identification.

3. A large part of the program, of necessity, will be devoted to photo interpretation.

Photo interpreters will visually study, map, and isolate simultaneously with land use :

(a) known (or indicated) polluted mine waters and land areas from images.

(b) surface mines and resodding and planting operations.

(c) changes in the surface mines observed through sequential ERTS images. These changes will be recorded in two ways--the method described in Chapter VIII in the Six Month Report and a photo lab technique employing color comparisons where the difference between the old and new strip mine boundaries reveals itself as a new color readily observed. These areas will be measured and totaled to determine the direction rate and extent of operations.

4. Image processing and various interpretation techniques will be employed experimentally to analyze aquatic and suspected terrestrial environments to enhance chemical compounds associated with coal mine pollution. These methods will also be employed in pollution source location and pollution dispersal patterns.

5. For the purpose of checking interpretive results in conjunction with periodic field trips, state and federal personnel will be interviewed on the currency and type of existing records.

Ground photography will be employed in areas where records are current.

6. Various processes with aircraft and ERTS images will be tried and compared to water sample analyses made on the corresponding date. Attempts will be made to check colors (hue, intensity, and brightness) especially with:

Total acidity
pH
Iron compounds.

This will be done visually utilizing standard interpretation processes. On occasion it may be necessary to obtain computer analysis.

6. RESULTS AND CONCLUSIONS

Examination of both aircraft and satellite imagery indicated a number of factors and relationships. Before attempting to sort them out, they included:

1. Most of the surface mining observed was on the Maryland side of the Potomac, although it was prevalent on both banks.

2. All active subsurface mines are located on the West Virginia side.

3. Polluted water, untreated and treated was showing up around the North Branch Mine at Bayard, West Virginia in varying shades of green on the color infra-red aerial photography.

4. No vegetative stress, other than human clearing activities, is apparent for the season during which imagery had been obtained.

5. The entire area is sparsely settled.

6. Only one major industry is directly on the upper Potomac: (WESTVACO) at Luke, Maryland.

Obviously, the "green water" represents significance. Since "green" appears on aircraft imagery where water is known to contain mine pollution, by extrapolation, one might tentatively assume that any stream or impoundment showing greenish hues contains pollution.

Three members of the Ambionics staff went over all of the aerial photography (false color infra-red), scenes 1-70 of the August 10, 1974 flight and located and recorded all streams, impoundments, and other areas where these hues could be seen. An extensive cross reference between this information and field sampling records showed a very close correlation between the "green streak" and waters polluted by acid mine drainage. Aircraft data taken on March 15, 1974 showed the same indicator in all previously identified streams except the Stony River. Significantly, the Mount Storm power plant and coal mines had been shut down for several months at that time because of a fire in the conveyor.

Ambionics personnel went into the field to observe and photograph on the ground areas known and suspected to be polluted after examination of the aerial photography. We visited Laurel Run in Garrett County, Maryland. This stream flows through woods and farms at an altitude of between 2500-3000 feet and is subject to no influencing factors except mine wastes which apparently flow from a break-out of a sealed mine of unknown location.

While the stream is vermillion colored on the false-color infra-red, in the field there is hardly any color to the clear waters. Iron precipitate coating the bed of Laurel Run gives a yellow to faint pink tint. No vegetative stress is visible, nor was any stress readily visible elsewhere.

At the North Branch Mine at Bayard the green color in the holding pools and treatment tank in the infra-red transparencies is in reality bright orange to the observer on the ground.

Stony River, West Virginia appears as a brownish, rather turbid stream near Route 50.

All three areas are green on the infra-red film. All three contain acid pollution. Patterson Creek, used as a control in this program, flows through the test site and is known not to be subject to mine drainage. Examination of the aircraft imagery shows no trace of vermillion water and the stream sampling done for Ambionics at the time of flight indicates no evidence of mine degradation.

The reason for the green response is not known, although several theories have been advanced. Two of the theories maintain that the green color is a result of iron compounds in the water, whether carried actively by the stream or precipitated on its bottom. The first theory holds that the active ingredient is iron oxide, which is found in abundance in at least one of the streams (Laurel Run). The question here is that if the cause of the green response is iron oxide, then the green color on near infra-red would not necessarily be an indicator of acid mine drainage, for some streams in the area which are not polluted by mine drainage or other factors are reddish in color and have bottoms coated with iron oxide. The second theory holds that the color is a response to the presence of "yellow boy" on the stream bottoms. If this were to be the case, then the green color would most assuredly be an indicator of mine acid pollution alone.

A third theory has been extrapolated from work on the subject by Carl H. Strandberg. It maintains that the green color is an indication of an extremely low biological oxygen demand (B.O.D.) which results from the utilization of most of the water's available oxygen by the mine pollution to form sulfuric acid

(H_2SO_4). Under such conditions of low pH and low available oxygen, few organisms can survive. Among those that can are certain algae (of the genue Ulothrix) and specific forms of bacteria which are associated with the Ulothrix algaes and with deep mines. Obviously, if this theory were true, then it would show the green near infra-red response to be an indicator of mine acid pollution also. It is significant to note that this theory would account for the occurrence of the green color observed on the August 10, 1973 aerials of Stony River, a stream of some depth which might not register the color of its bottom on aerial photographs. Surely further study on the matter is warranted.

With respect to ERTS-1 images, Ambionics personnel have located both Laurel Run and the mine at Bayard, West Virginia through visual examination but have not found any constant indicators for pollution in the field.

ERTS-1 computer compatible tapes taken on May 1974 were examined at IBM under a NASA Langley Research Center contract. Earlier examination of 70mm "chips" were tried with the I^2S additive color equipment but with no success. The GE Image-100 system was experimented with using other tapes (not of the test site). This method shows promise for the future, but electronic breakdowns and lack of available time preclude its availability for this contract.

In conclusion, we have achieved this much. We have concluded that the combined approach of ERTS imagery, corresponding aircraft photography, and ground study are needed for an effective program of continuous mine acid pollution monitoring. We have developed a method of detecting mine acid polluted water (or streams with a high probability of such pollution) from aircraft imagery. We have developed an inexpensive and accurate means of monitoring strip mine activities which is markedly superior to present methods now in use by the West Virginia State authorities. While we expect further findings and refinements, we feel confident enough in our present analysis techniques to undertake an extended study in an enlarged test area.

Specifically, we feel that the next logical step would be to extend our study to the Ohio River Drainage Basin.

There are three data gathering methods used in this monitoring program -- ground-based sampling crews, aircraft, and the ERTS satellite. Each by itself has its advantages and disadvantages.

Optimum use of these complementing each other can minimize costs and increase the monitoring effectiveness.

The ground-based effort provides the greatest accuracy in determining what is actually present at a particular spot at the time of sampling and analysis. The problem is that ground data cannot be readily obtained over large areas within a short time and environmental relationships are difficult to observe for a particular time period without large expensive staffs.

Use of aircraft provides a remote sensing platform and usually sufficient detail so that ground-based findings can be extrapolated without difficulty. As scale gets smaller, the area sensed increases but detail is lost. Distortion increases from the center to the outer edge of aerial imagery which is a disadvantage where precision measurements are important.

The cost of aircraft monitoring is considered too high for regular coverage over extended areas.

ERTS has the advantage of regular coverage (every 18 days) over large areas (110 miles by 110 miles). The cost for this data is minimal. Resolution is much less than that of aircraft photography (approximately 50-75 meters) with accompanying loss of detail. Changes can be observed in shapes, sizes and/or colors, which can be related to surface phenomena. This information can be readily verified by aircraft and/or ground crews, thus, allowing more efficient and effective utilization of these resources. For example, changes in strip mine and reclamation activities show up readily on the ERTS image (Figure 7).

The techniques developed under this contract should be refined in the North Branch test site - specifically, a better understanding of the causal relationship between the "green streak" and mine pollution should be investigated. In addition, we recommend that a demonstration program be performed using the techniques herein developed in the Tygart Valley River in the Ohio drainage basin. This stream has extensive mine pollution and drains an area significantly different in physiography and ecology from the present test site.

FIGURE 7
Portion of ERTS Image 1405-15242-5 taken 1 Sept. '73 showing strip mine activities in test site