# INVESTIGATION OF ENVIRONMENTAL INDICES FROM THE EARTH RESOURCES TECHNOLOGY SATELLITE, PR 568/MMC 200



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**16. Abstract**

Land use, water quality and air quality trends are being deduced from both ERTS-1 MSS imagery and computer compatible tapes (CCT's). The data analysis plan (Phase I) and the preliminary data analysis phase (Phase II) were concluded in January 1973. Results from these two phases are as follows:

(a) Method of analysis has been selected and checked out
(b) land use for two dates have been generated for one test site.
(c) water quality for one date has been produced partially.
(d) air quality for three has been produced and compared with ground truth.
(e) One of the two DCP Stations is in operation; the second station will be installed by March 1973

Land use classification exceeds pre-launch expectations. Water quality (turbidity) is not progressing as expected. Finally mesoscale air quality results have shown correlation with NOAA/EPA turbidity network. If air quality correlations continue to show favorable results, a rapid means of global turbidity may be avail- from ERTS MSS observations.



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## PREFACE

There are two objectives of this contract. The first is to develop land use, water quality, and air quality indices which reveal the trends most useful to the environmental resources manager whether at the Federal, state or local level. The second objective is to define the system (software and hardware) which can produce these indices in an automatic way i.e., man-out-of-the-loop.

This interim report covers the first two phases of contract - the Data Analysis Preparation and the Preliminary Data Analysis phases. These two phases were concluded 31 January 1973. Results to date shows promise in the development of all three indices using digital processing of the MSS CCT's with assistance from aircraft IR imagery in signature development. In order to achieve our second objective means must be found to remove this necessity for assistance from aircraft imagery and the removal of such MSS errors as banding. Results from these two phases are as follows:

(a) Method of analysis has been selected and checked out

(b) Land use for two dates have been generated for one test site.

(c) Water quality for one date has been produced partially.

(d) Air quality for three dates have been produced and compared with ground truth.

(e) One of the two DCP Stations is in operation; the second station will be installed by March 1973.

## 1.0 INTRODUCTION

This Type II Report describes the progress made by The MITRE Corporation during the first six months of effort on Contract NAS 5-21482, Investigation to Determine Environmental Indices from ERTS-1 Data. The specific objectives of the MITRE investigation include the following:

- Land use trends for two test areas in Pennsylvania over the August 1972 - October 1973 time period.
- Air quality/turbidity mesoscale trends over all of Pennsylvania for the August 1972 - October 1973 time period.
- Water quality along the Susquehanna River for one overflight date, October 11, 1972.
- Specifications for an operational system using an ERTS-type system, and selected analysis software for water, land and air environmental indices calculation and display.
- Special report on the possibility of automatic digital signature determination, i.e., the elimination of signature re-determinations for each imagery.

The investigation is comprised of three distinct phases. These are: (1) Phase I: Data Analysis Preparation; (2) Phase II: Preliminary Data Analysis; and (3) Phase III: Continuing Data Analysis.

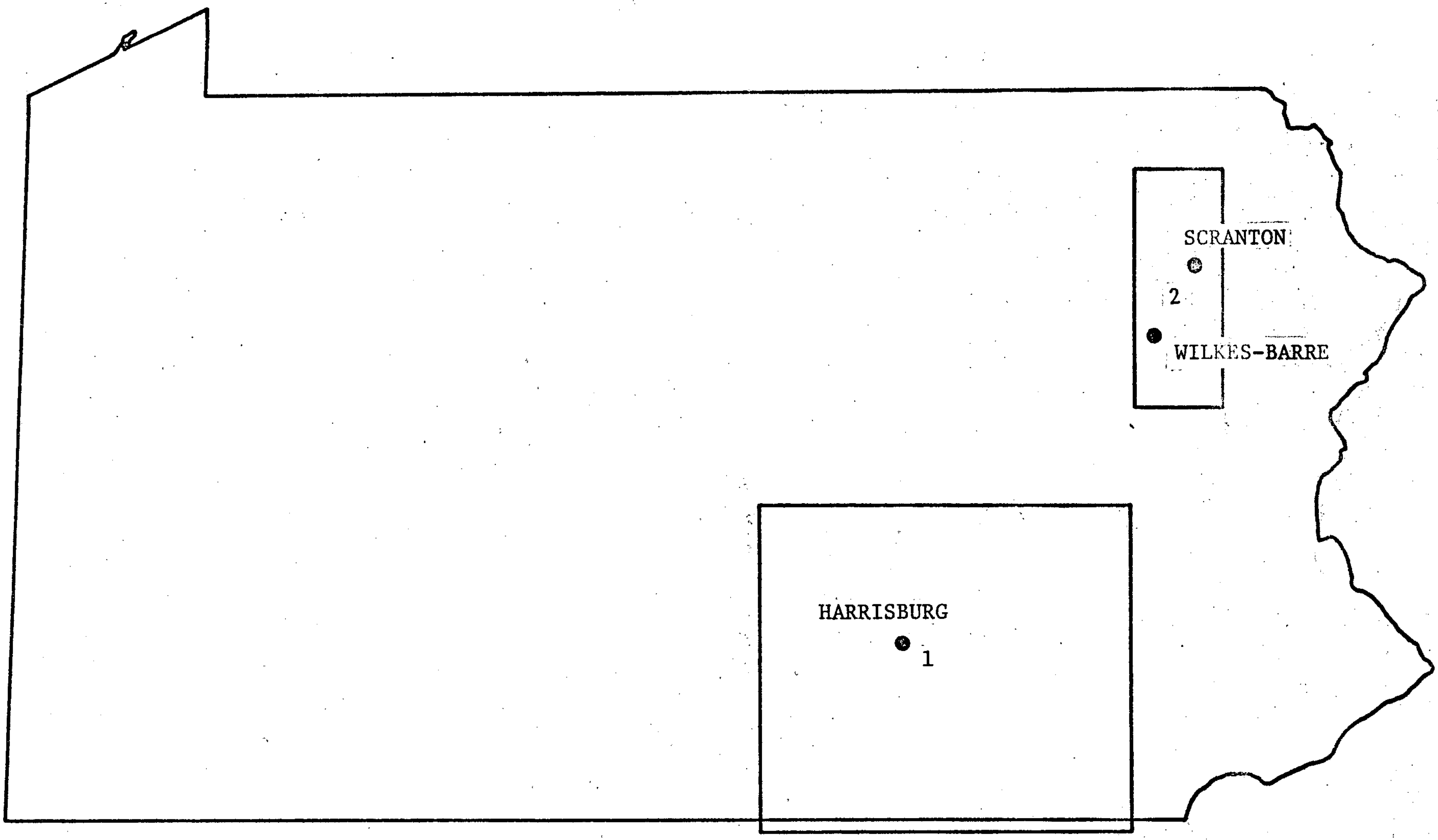
This report describes all tasks completed or still underway through the end of Phase II. The work involved in each of the first two phases is described according to the following outline:

- Phase I: Data Analysis Preparation
  - MSS Experiment Planning
  - DCP Experiment Planning
  - MSS Implementation
  - DCP Implementation
- Phase II: Preliminary Data Analysis
  - First ERTS-1 Data Analysis
  - Data Analysis Plan Development
  - Data Requirements Revision

Phase I was essentially the resource review, planning, and testing out stage for the investigation. Optimum use of the Data Collection Package (DCP) was made; software and techniques for processing MSS data were developed and tested; appropriate environmental parameters in the areas of land use, water quality, and air quality were selected; and the two test sites in Pennsylvania were reviewed with Federal and Commonwealth personnel (see Figure 1 for test site boundaries).

Phase II has been the stage wherein preliminary analysis of ERTS data was performed and the Data Analysis Plan for the remainder of the investigation was refined and formalized. The analysis of the following dates have been performed or are currently underway.

| Environmental Area | ERTS-1 Date |
|---|---|
| Land Use | 1 August 1972,<br>11 October 1972 |
| Water Quality | 11 October 1972 |
| Air Quality | 1 August 1972,<br>1 October 1972,<br>16 November 1972 |




PENNSYLVANIA

FIGURE 1
MITRE ERTS-1 TEST SITES

Land use analysis has incorporated ground truth for validation in the form of USGS maps and U-2 and C130 aircraft visible and IR photography. Recently acquired land use maps and quantitative data on trasportation and land use will be analyzed as well. To date this portion of the investigation has concentrated on the Harrisburg area test site, where 17 distinct land use parameters have been identified through combined digital and photointerpretive analysis.

Because of difficulties in using the Harrisburg test site as a water quality training area, a frame of the Washington, D.C. area showing turbid plume on the Potomac River was chosen for preliminary analysis to perfect methods. Six gradations of water turbidity have been identified for one section of the river, but to date analysis of other sections has been less successful. Banding in the MSS data is inhibiting completion of this water quality index development activity.

Air quality analysis has also centered on the Harrisburg test site. Preliminary results are showing a correlation between the average intensity of three available ERTS frames analyzed and ground truth turbidity measurements reported by the NOAA/EPA turbidity network for the same dates.

The Phase I and Phase II progress is reported in detail in the body of this report in sections 2.0 and 3.0 respectively.

## 2.0 PHASE I - DATA ANALYSIS PREPARATION

The first phase of MITRE's effort, covering approximately the first two months of the contract (before any actual ERTS-1 data were received) was a comprehensive examination of all potentially useful resources for achieving the objectives of MITRE's investigation, and, through initial analysis of ERTS and non-ERTS resource availability, planning the broad framework for optimum use of MSS and DCP data. This preliminary effort of data analysis preparation will be reported in four sections: MSS experiment planning, DCP experiment planning, MSS implementation, and DCP implementation.

### 2.1 MSS Experiment Planning

#### 2.1.1 Environmental Parameter Analysis

A number of tasks were undertaken simultaneously in Phase I in general and MSS experiment planning in particular. One main task in the MSS experiment planning was environmental parameter analysis. In this analysis, MITRE reviewed all available information on state-of-the art development, procedures, and techniques for using MSS in environmental applications. The purpose of this task was two-fold. First, determine which environmental parameters of interest to the MITRE investigation are potentially amenable to detection and analysis using the MSS data that the present ERTS-1 configuration can provide. Second, by accumulating a store of information on the already demonstrated applicability of MSS data analysis in the area of the environment, avoid the necessity to "re-invent the wheel" as the MITRE investigation continues. (e.g., if Willow Run, the state of California, or the USGS has already developed a reliable procedure for identifying an environmental parameter signature from MSS data, then it is logical in terms of time and effort for MITRE to make use of that information as the data analysis effort proceeds).

Table 1 breaks out in detail the land use, water, and air parameters that are of interest to MITRE's investigation. The table at this point is not meant to be exclusive or all-encompassing. Many more parameters in the media of land use, water and air may be amenable to ERTS-1 sensing, and some of these may be added to the table as the investigation proceeds. By the same token, some of the categories listed (e.g., gaseous pollutant concentrations in air, specific pH in water) may be found impossible to monitor based on data from the present ERTS configuration.

Some of the preliminary results of the environmental parameter analysis to date are shown on the charts that follow (Table 2 ). It must be noted that the charts reflect a very preliminary review of almost entirely pre-ERTS-1 experimentation. The resource availability task of environmental parameter analysis will continue through the duration of the investigation and the charts will be continually updated and augmented. As more information becomes available-- especially more information based on actual ERTS-1 MSS data investigations such as will be forthcoming with publication of proceedings of the recent NASA-sponsored ERTS-1 Symposium-- the charts will contain much more useful signature derivation information.

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TABLE 1

SELECTED ENVIRONMENTAL PARAMETERS OF INTEREST

MEDIUM 1. LAND USE

| ENVIRONMENTAL CATEGORY | MSS SIGNATURE INFORMATION | POTENTIAL USEFULNESS | OTHER COMMENTS | REFERENCE |
|---|---|---|---|---|
| 1.0 (Land Use Generally) | All ERTS channels are complementary and useful in land characteristics identification. | Monitoring land use changes. | | Short and MacLeod (Goddard). Fourth Annual Earth Resources Program Review, Vol. I, p. 7-7. (NASA, 1972) |
| 1.1 Agriculture (Primarily Corn Blight) | Various bands from 0.47μ to 0.92μ have been useful in monitoring plant stress | May permit monitoring of pollution effects on vegetation. | Thermal, reflective IR and visible channels have all been used in conjunction. No single channel seems best. | T. Phillips (LARS, Purdue U.), ibid., Vol. V, p. 128-8. |
| 1.1 Agriculture (Primarily Corn Blight) | The band from 1.0μ to 1.4μ seems best for crop discrimination. | May permit monitoring of pollution effects on specific plant types | Also useful in crop yield estimates. | Nalepka, et.al. (WRL Ann Arbor), ibid, p. 130-1. |
| 1.2 Forest and Woodland | The band from 0.52μ to 0.58μ appears best for identifying forests and discriminating between hardwoods and softwoods. | (Same as above) | Also useful in forest inventory. | S. Whitley (Mississippi Test Facility), ibid., Vol. I, p. 15-1. |
| 1.3 Waterways<br>1.4 Erosion Areas<br>(Also: 2.2 Water-Silt) | NIMBUS 3 HRIR data shows progress of run-off down Niger and Indus observed in 0.7-1.3μ region | May be useful in silt and turbidity monitoring. | Also useful in overall hydrological studies of river basins. | Solomonson and MacLeod (Goddard) Fourth Annual Earth Resources Program Review, Vol. I, p. 5-1 (NASA, 1972). |

TABLE 2

ENVIRONMRNTAL SIGNATURE INFORMATION

MEDIUM 2. WATER

| ENVIRONMENTAL CATEGORY | MSS SIGNATURE INFORMATION | POTENTIAL USEFULNESS | OTHER COMMENTS | REFERENCE |
|---|---|---|---|---|
| 2.0 (Water Generally) | Generally present MSS data can identify suspended particles, but not discriminate such parameters as DO, BOD, nitrates, etc. | At a minimum, MSS can monitor gross pollution and thereby alert ground team to monitor for specific pollutants | Thermal and laser sensors may be better for water monitoring. | Keefer and Sherz (U. of Wisconsin) from ASCE Meeting in Phoenix, Jan. 1971. p. 9 of reprint. |
| 2.1. Oil | Best detection appears to be in the 0.32μ to 0.38μ band. | Oil spills can be monitored during daylight. | Active sensors will permit day and night monitoring. U.V. and the 8μ to 14μ bands can determine thickness of spills. Florescence techniques are promising. | Wezernak and Polcyn (WRL Ann Arbor) <u>Technological Assessment of Remote Sensing Systems for Water Pollution Control</u> p. 4-36. |
| 2.2 Silt (See Land Use, 1.8 Wetlands and Estuaries) | -- | -- | -- | -- |
| 2.3 Industrial Chemicals | The 0.58μ to 0.62μ band appears best for detecting chemical effluents. | Daylight monitoring of industrial water pollution is possible. | I.R. Monitoring may be better in detecting discharges day or night by difference in water temperature. | Wezernak and Polcyn, ibid., p. 1-23. |
| 2.4 Eutrophication | -- | -- | -- | -- |
| 2.5 Turbidity | Measurement appears best in the 0.4μ to 0.65μ range. | Total suspended particles can be monitored for water pollution control. | Present passive sensing is not adequate for any great depth, but active systems are promising. | Wezernak and Polcyn, ibid., p. 1-23. |

TABLE 2 (Continued)

MEDIUM 2. WATER

| ENVIRONMENTAL CATEGORY | MSS SIGNATURE INFORMATION | POTENTIAL USEFULNESS | OTHER COMMENTS | REFERENCE |
|---|---|---|---|---|
| 2.6 Chlorophyll (Phytoplankton) | Detectable subsurface reflectance rise at 0.56μ, fixed at 0.53μ, diminish at 0.45μ. (At 0.56μ alone, cannot discriminate between chlorophyll and sediment. At 0.45μ alone, cannot discriminate between chlorophyll and other blue absorbing substances. | Indirect measure of pollution effect on aquatic life. Ground observation required. | Useful in understanding aquatic food change, migrations, and worldwide $CO_2/O_2$ exchange. | S. Duntley (Scripps) Fourth Annual Earth Resources Program Review, Vol. IV, p. 102-6, (NASA, 1972). |
| 2.6 Chlorophyll | Subtracting sample reflectance intensity at 0.443μ from reference reflectence intensity at 0.525μ, corrected by gain control, yields a measure of chlorophyll content. | Indirect measure of pollutant effect on aquatic life. Ground observation required. | Useful also in understanding aquatic food chain, migrations, and world $CO_2/O_2$ exchange. | J. Averson (NASA Ames) Fourth Annual Earth Resources Program Review, Vol. IV, p. 104-1 (NASA, 1972). |
| 2.7 Specific Characteristics | | | | |
| 2.7.2 B.O.D. | Waste treatment outfall is detectable at 0.72μ to 0.80μ. | Gross monitoring of sewage; ground observation required for B.O.D. analysis. | As with other water parameters, active sensing should enhance remote capabilities. | Wezernak and Polcyn, op.cit., p. 1-23. |

TABLE 2 (Continued)

MEDIUM 3. AIR

| ENVIRONMENTAL CATEGORY | MSS SIGNATURE INFORMATION | POTENTIAL USEFULNESS | OTHER COMMENTS | REFERENCE |
|---|---|---|---|---|
| 3.9.1 - $SO_2$ and 3.10 Vegetation Damage | Visible and IR shows plant damage (pines) near coke ovens. | Source monitoring (reveals where and when to look). | At present, other than remote sensing is required to tell composition and concentration of air pollutants. | Harney, et.al., BuMines Fourth Annual Earth Resources Program Review, Vol. III, p. 65-1 (NASA, 1972). |

TABLE 2 (Continued)

The major conclusions of the initial environmental parameter analysis were as follows:

1. Land use classification has been very successful using MSS data, and the list of parameters under the land use category in Table I can probably be expanded.
2. The water parameter list may be ambitious in the absence of a thermal band on ERTS-1. Consequently, early analysis will concentrate on identification of gross levels of total turbidity, silt, oil, and industrial chemical outfalls.
3. The air parameter listing also appears very optimistic at present. A mesoscale analysis (20-600 km), is first undertaken (Section 2.1.1) to determine the ability of ERTS-1 to characterize total turbidity and total background pollution burden trends over large areas. If successful, a microscale analysis (<20 km) will be attempted with the objective of defining haze levels, identifying point sources, and detecting pollution related vegetation stress.

As reported in MITRE's Bi-monthly Progress Report of 31 October 1972, the initial effort of environmental parameter analysis was completed during October 1972. However, as noted above, parameter information analysis will continue at a lower level of effort throughout the investigation as information becomes available.

### 2.1.2 Experiment Site Selection

The MITRE ERTS-1 proposal, as amended, states that the general investigation test areas will be the Harrisburg and Wilkes-Barre - Scranton regions of Pennsylvania. Included in reasons for selecting these investigation areas were the following:

- Availability of an extensive in-house environmental data base on the areas from MITRE's work for the U.S. Bureau of Mines in the northeastern Pennsylvania region.
- Availability of environmental data from EPA and the Commonwealth which could be used for correlation with ERTS-1 overflights.
- Availability of photogrammetric equipment and image analysis software which is compatible with the MITRE computer system from the Pennsylvania State University.
- Availability of recent aircraft overflight data covering the Susquehanna River in the Harrisburg vicinity for comparison with ERTS-1 MSS data (U-2, C-130).
- Engineering and scientific personnel available for consultation from the Commonwealth of Pennsylvania.
- The high suitability of the areas for the analysis of the potential of remote sensing of environmental parameters, because of the broad range of land use (urban/industrial, suburban, rural, forest), and existing problems of water and air pollution.

Once the overall investigation areas had been decided upon, MITRE, with the concurrence of the NASA Chief Scientific Monitor, opened dialogues with other ERTS-1 investigators and local, regional, state and federal environmental officials to solicit suggestions for specific targets. Figure 2 shows a summary of the many responses received. (Site 1 refers to the Harrisburg area, and Site 2, to the Wilkes-Barre - Scranton vicinity). As many of these targets as feasible are being incorporated into the MITRE investigation.

As reported in MITRE's Bi-Monthly Progress Report of 31 October 1972 the primary effort of experiment site selection culminated during October, although flexibility will be maintained to add critical areas or delete ones of limited usefulness as necessary.

| SITE | TARGET AREA | TARGET QUANTITIES | LAND AIR, OR WATER | SUGGESTED BY |
|---|---|---|---|---|
| 1 | HOLTWOOD DAM LAKE | ALGAE, THERMAL, SILT | W | EPA REGION III; PA. W.Q. |
| 1 | CONOWINGO DAM LAKE | " , " , " | W | " " "; " " " |
| 1 | SAFE HARBOR LAKE | " , " , " | W | " " "; " " " |
| 1 | CODORUS CREEK LAKE (INDIAN ROCK) | " , SILT | W | " " ". |
| 1 | BRUNNER ISLAND EFFLUENT | THERMAL, CHEMICALS, SILT | W | " " ". |
| 1 | CONEWAGO CREEK MOUTH | THERMAL, SILT | W | " " ". |
| 1 | LIME KILN AT ANNVILLE | PLUME DYNAMICS & LONG TERM EFFECT ON VEG. | A | " " ". |
| 1 | HARRISBURG | HAZE, ALL AIR & WATER QUALITY PARAMETERS | A,W | - |
| 1 | SUSQUEHANNA RIVER-SUNBURY TO MD. | WATER QUALITY | W | - |
| 1 | LANCASTER | HAZE, ALL AIR QUALITY PARAMETERS | A | STATE OF PA. |
| 1 | YORK | " , " " " " | A | " " " |
| 1 | SWATARA CREEK MOUTH | SILT | W | USGS/HARRISBURG |
| 1 | CONESTOGA CREEK MOUTH | SILT, OIL | W | " / " |
| 1 | JUNIATA RIVER MOUTH | SILT | W | " / " |
| 1 | THREE MILE ISLAND | ALL AIR & WATER QUALITY PARAMETERS | A,W | PSU |
| 1 | ALL OF SITE 1 | LAND USE | W,L | - |
| 1 | ALL OF SITE 1 | ANY DENUDED AREAS | L | STATE OF PA. |
| 2 | ALL OPEN PIT MINES | LINEAR DIM., AREA, & VOLUME; PH, THERMAL | L,W | EPA REG.III; PA. W.Q.O. |
| 2 | " REFUSE BANKS | " " , " , & " ; " " | L,W | " " "; " " |
| 2 | SUSQUEHANNA RIVER | ALL WATER QUALITY PARAMETERS | W | - |
| 2 | " " AT DANVILLE | " " " " | W | - |
| 2 | " " AT HUNLOCK CREEK | " " " " | W | - |
| 2 | SCRANTON | HAZE, ALL AIR QUALITY PARAMETERS | A | STATE OF PA. |
| 2 | WILKES-BARRE | " , " " " " | A | " " " |
| 2 | ALL OF SITE 2 | LAND USE | W,L | - |
| 2 | " " " 2 | ANY DENUDED AREAS | L | STATE OF PA. |

FIGURE 2

ERTS PRELIMINARY TARGETS

### 2.1.3 Procurement of Software and Services

In order to make use of available software and to avoid duplicate investigations, MITRE subcontracted with The Pennsylvania State University (PSU) Office of Remote Sensing of Earth Resources (ORSER) to provide support of our development of an ERTS Environmental Indices Program software. On 1 September 1972 a Statement of Work for PSU was developed by MITRE (Appendix A). This outlined the test sites to be used, the land use, water and air categories for investigation, the computer support and photointerpreter's support to be given, and possible support given by PSU for a Data Collection Platform.

PSU responded with their Preliminary Statement of Work (Appendix B) which described the tasks they would perform. The PSU Statement of Work outlined a two-phased effort, with the Phase I (1 October 1972 - 31 December 1972) objective to determine the best procedure for MITRE to follow using ERTS data. In Phase II (1 January 1973 - 30 September 1973) PSU would assist MITRE with the necessary computations of input data to MITRE's indices calculations.

A problem developed when ERTS imagery and CCT failed to supply data before the end of October 1972. This caused a shift in dates for Phase I and II activities with PSU; Phase I from 6 November 1972 through 2 February 1973 and Phase II from 4 February 1973 through 31 December 1973 were mutually agreed on.

With Phase I underway a procurement problem concerning the work done at PSU arose. Data would be obtained by MITRE more than one to two weeks after they were processed by PSU, and also the length of communication made the training of MITRE personnel in the use of the software difficult. Therefore, a decision was made to install a remote job entry terminal in MITRE's McLean Office. The requisition for the terminal (IBM 2741 or equivalent) was made at the beginning of November 1972 with the actual delivery date of the terminal on 19 January 1973. The hookup checkout was performed via telephone to PSU's IBM 370-165 computer on 26 January 1973.

On 8 March 1973 a revised Phase II Statement of Work for Phase II subcontract to PSU was reviewed (Appendix C). This subcontract redefined MITRE's purposes and the support expected from PSU. Included was the request that PSU supply MITRE with copies (tape and hardcopy) of present and future PSU MSS software for use at MITRE's McLean facility. It also includes a reaffirmation of tasks proposed in Phase I.

In general there is now a shift in software use and modification to MITRE's McLean facility. This is to allow specific computer problems to be solved with the least amount of difficulty and delay, and will aid in the development of our prime final product-- an operational software and hardware system specification for producing environmental indices from ERTS imagery and CCT with the least amount of man in the loop intervention possible.

## 2.2 DCP Experiment Planning

MITRE's proposal[1] outlined the use for two Data Collection Packages (DCP's)-one DCP dedicated to obtaining air quality and one DCP dedicated to obtaining water quality in the Harrisburg area. Such in-situ sensors were intended to act as ground truth data in test site 1 experiment area. In the sub-sections presented below, several modifications have been made to this original concept and, as will be explained, the optimum use of these DCP's is being made by applying both to water quantity (stage) stations in the Susquehanna River basin.

### 2.2.1 DCP Siting Efforts

MITRE's DCP siting efforts followed along three lines (1) looking for existing water and air quality stations in which the DCP would speed the reporting process, (2) looking for new sites of interest to Federal, state and/or local organizations, and (3) ground truth valuable to the MITRE experiments.

Many existing air and water sites were analyzed. For water, all Federal, state water quality stations were examined for possible utility to our siting efforts. The Commonwealth of Pennsylvania has water quality data recorded from 192 sites, however, examination of these found many stations discontinued, operated in a manual mode (grab sample, etc.) and many stations reported under a different name

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[1] MITRE Corporation M71-16, Revision 1, "Investigation of Environmental Indices from the Earth Resource Technology Satellite" February 1972.

in the Federal water data bases.[2,3,4] In addition, daily average data of the more common water quality parameters useful to MITRE's effort (turbidity, pH, DO, conductivity, temperature) are rarely recorded on a continuous basis.

Similarly, for air quality, we found that the State of Pennsylvania was operating four surveillance systems. These systems are:

(1) The Philadelphia County Aerometric Monitoring System (PCAMS)

(2) The Allegheny County Air Monitoring System (ACAMS)

(3) The Commonwealth of Pennsylvania Air Monitoring System (COPAMS)

(4) The Pennsylvania Air Quality Surveillance System (PAQSS)

The two (Philadelphia and Allegheny) county systems are comprised of primary real time stations and secondary sampling stations to monitor air quality in the respective counties. PCAMS, ACAMS, and COPAMS are real time systems. PAQSS is a comprehensive surveillance system designed primarily to document air quality in the air basin areas of the State.

Only COPAMS and PAQSS cover portions of the two MITRE test sites selected for study. Excerpted below are several paragraphs from the Commonwealth of Pennsylvania's Air Quality Implementation Plan[5] to emphasize the present status and near future plans for air quality monitoring.

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[2] "Catalog of Information on Water Data - Index to Surface Water Section", Office of Water Data Coordination, U. S. Department of Interior, Edition 1970.

[3] "Catalog of Information of Water Data - Index to Water Quality Section," Office of Water Data Coordination, U. S. Department of Interior, Edition 1970.

[4] EPA STORET Water Quality Information Systems.

[5] "Commonwealth of Pennsylvania's Air Quality Implementation Plan". Pennsyl- Department of Environmental Resources, December 10, 1971.

In general, the remaining surveillance systems are tailored to the growth and population density patterns of the State. Particular emphasis is placed upon the most heavily polluted areas. Outside of the heavily polluted and densely populated areas, monitoring will be done to examine transition and growth areas and to determine background levels. A few monitoring stations are used to maintain surveillance of specific major sources.

The PAQSS system will be comprised of approximately 100 stations, 50 of which are currently in operation throughout the State. Each station is, or will be, sampling total suspended particulate on a uniform schedule of one sample every sixth day by means of a high volume sampler. All filters are analyzed in the State Laboratories for quantitative determinations of fluorides, sulfates, beryllium, cadium, lead and iron. Randomly selected filters are analyzed for 14 other metals and benzene soluble organics. Settleable particulates and total sulfation are determined at each station on a monthly basis with dustfall jars and sulfation plates.

At approximately one-fourth of the PAQSS sites a sampling package continuous monitoring of sulfur dioxide, carbon monoxide and soiling (COHS) will be installed. At a similar number of other sites a second package for sampling nitrogen oxides, oxidants and total hydrocarbons will be installed. These sampling packages will be moved to different PAQSS sites on a random schedule so that an annual cycle of data for each pollutant will be obtained at each site in a four year period.

Monthly and quarterly mean values will be calculated for each site. Annual summaries will be prepared indicating the mean, standard deviation, minimum and maximum values. The number of times any air quality standard is exceeded at any site will also be determined.

COPAMS will be comprised of at least 17 continuously operating stations providing real time information by telemetry into a central control computer located in Harrisburg. Each station will be equipped to monitor sulfur dioxide, carbon monoxide, soiling, hydrogen sulfide, oxidants, methane and non-methane hydrocarbons, nitrogen oxides, wind speed, wind direction, temperature difference between 4 and 16 meters, ambient temperature and dew point temperature. All parameters will be monitored continuously with instantaneous values being recorded once per minute. Only the COPAMS stations are sufficiently automated to consider the installation of a DCP.

Several meetings with the State officials on this uncovered two interesting constraints - (1) the Commonwealth felt we could obtain all the air quality data MITRE would need via COPAM without installing a DCP link on any of its stations and (2) the State would not permit a DCP link to be installed as a back-up mode of communication for the State and the COPAM contractor felt nothing would be gained and that progress on COPAM would be reduced by such an effort.

It was therefore logical that MITRE look into the placement of two DCP stations at desirable sites where no stations existed. Suggested sites were obtained from the Commonwealth of Pennsylvania, Office of Water Quality, Region III of EPA, Pennsylvania State University, and the USGS/Harrisburg Office.

EPA Region III was most interested in the water quality including siltation and eutrophication behind the three major dam systems on the Susquehanna River (Holtwood, Safe Harbor, Conowingo), the Codorus Creek Lake for siltation and eutrophication, the water effluents from an existing steam-elective power plant on Brunner Island, the water quality from Conewago Creek which drains a heavily industrialized area near Harrisburg, the air pollutants emitted by a lime kiln plant in Annville, and the drainage from all open pit mines and refuse banks in and around Wilkes-Barre - Scranton area of Pennsylvania. No order of priority was arrived at for these possible DCP sitings.

The State Water Quality Office personnel were more specific. They would prefer water quality in the three Dam areas, the acidity dynamics of



C

the West Branch of the Susquehanna around Renovo, and the appearance of any denuded areas which may cause runoff siltation in either test site.

The Pennsylvania State University was interested in the air and water quality around a new nuclear power plant site at Three Mile Island just south of Harrisburg. Finally USGS/Harrisburg was interested in water quantity and quality at three of four tributaries to the Susquehanna (Swatara Creek, Conestoga Creek and Juniata River).

Figure 2, section 2.1.2, shows this array of possible experiments in which DCP's might be applied.

The DCP station design and hardware procurement tasks (section 2.2.2 and 2.2.3) were then performed to aid in the selection of two final DCP sites.

2.2.2 <u>DCP Station Configurations Analyzed</u>

Of the many siting/experiment possibilities covered it appeared that the following 9 had the most potential of being operative within 90 days of receipt of the DCP's as required by our contract.

(a) Refurbish and upgrade one of the two installed but unused Commonwealth water quality stations - Hunlock Creek and Danville.

(b) Use DCP as an alternate communication link on one of the seventeen COPAM air quality stations - Harrisburg being installed first.

(c) Install an automatic water quality station with DCP link at Harrisburg to replace present manual system.

(d) Install an automatic water quality station at Philadelphia

Electric Company's new nuclear powerplant at Peach Bottom in the Conowingo Dam Reservoir.

(e) Use DCP at alternate communication link on the existing USGS/USA-COE water quality stations at Renovo or Beech Creek. This was a high priority for the Commonwealth.

(f) Link the MITRE air quality station at McLean, Virginia via DCP.

(g) Construct a mobile air and/or water quality station by continuing existing MITRE air quality sensors and run to new equipment for multiple site use.

(h) Use DCP as strap down data link for the EPA Region III mobile van now under construction, available June 1973.

(i) Water quality/quantity station operated by USGS in Susquehanna and its tributaries.

The attributes and constraints of these various configurations are summarized in Table 3 . Capital, installation, and operating costs were obtained from various sources, hardware manufacturers, the USGS and MITRE instrumentation personnel. Such cost documentation will be retained unless NASA wishes such data forwarded at a later date.

| | Site | Experiment | Existing Sensor Capability | Additional Capital Costs | Installation and Operation Costs (11 Months) | Housing Available? | Power Available? | Protection Available? |
|---|---|---|---|---|---|---|---|---|
| a) | Hunlock Creek | water quality | Proteck SM 625 water monitor -4 parameters. | $8,000[1] | $25,000 | Yes | Yes (United Gas and Illuminating Co. owned) | Yes |
| | Danville | water quality | Same as Hunlock Creek | $8,000[1] | $25,000 | Yes | Yes (On private property, must subcontract for) | Yes |
| b) | Harrisburg | air quality | COPAM Station - 10 parameters | (Must be installed by COPAM prime contractor - GE; State of Pennsylvania would not fund.) | | Yes | Yes | Yes |
| | Harrisburg | air quality | COPAM Central Control for 17 stations | Same as above | | Yes | Yes | Yes |
| c) | Harrisburg | water quality | None | $8,000 | $25,000 | Yes | Yes | Yes |
| d) | Peach Bottom | water quality | Six parameters - some are manual operations | $5,000[2] | $11,000[2] | Yes | Yes | Yes |
| e) | Beech Creek or Renovo | water quality | Three parameters - Data Master Controllers. | Initially quoted verbally at $10K per station, later reduced to zero if USGS installs DCP and uses also. | | Yes | Yes | Yes |

[1] Proteck station was inspected by EPA personnel and recommended that the station not be utilized and replaced by Schneider Robot Monitor RM 25 with robot backflush cleaner system.

[2] Philadelphia Electric Company would provide some help installation and maintenance but would rather take data we need at time of satellite passage and thus not install DCP.

TABLE 3

Several Possible DCP Station Configurations

| | Site | Experiment | Existing Sensor Capability | Additional Capital Costs | Installation and Operation Costs (11 Months) | Housing Available? | Power Available? | Protection Available? |
|---|---|---|---|---|---|---|---|---|
| f) | McLean | air quality | Existing Station – 5 parameters | $9,700 | $19,500 | Yes | Yes | Yes |
| | McLean | air quality | Existing Station plus 2 parameters – 7 parameters | $12,275 | $20,510 | Yes | Yes | Yes |
| g) | Mobile | air and/or water | Seven air parameters plus six water parameters | $20,000 | $25,000 | Yes | Yes (Using Existing Surplus Van) | Yes |
| h) | Mobile | air and/or water | EPA Region III Van under construction ready in June 1973. | $0 | $0 | Yes | Yes | Yes |
| i) | Various Sites in Susquehanna Basin | water quantity and/or quality | varying from site to site through Data Master Controllers | $0 | $0 | Yes | Yes | Yes |

TABLE 3 (Continued)

2.2.3 DCP Hardware Procurement/Disposition

The two DCP's and the platform tester were received at MITRE (McLean, Virginia) on October 5, 1972. These items carried the following information.

| | |
|---|---|
| Serial No. 0069 | Data Collection Platform Assembly Model No. 63A 104 100G-3, Rev. B; DCP Electronics S/N EAB-OM-156; DCP Antenna S/N 154. |
| Serial No. 0145 | Data Collection Platform Assembly Model No. 63A 104 100G-3, Rev. B; DCP Electronics S/N EAB-OM-175; DCP Antenna S/N 133. |
| Serial No. 022 | Platform Tester, Model 47E225158G1 Rev. A. |

After review of the value of data obtained from the possibilities discussed in section 2.2.2 versus the cost to the program, it was decided that the two DCP's we dedicated to the water quality station at Renovo (option e-2), the water quantity station at Newport, Pennsylvania on the Juniata River and to accept the Philadelphia Electric Company data at Peach Bottom as our test of one of these dam basins on the Susquehanna as well as the COPAM data from the Commonwealth of Pennsylvania for air quality over MITRE Test Sites 1 and 2.

Accordingly, after coversation with Dr. Richard W. Paulson of the USGS/Harrisburg and Mr. Arthur Fihelly of NASA/ERTS Project Office, MITRE shipped the three items listed above to Dr. Paulson. See Appendix D for the MITRE Shipping Order and letter from Dr. Paulson to Mr. Earle J. Painter of NASA/GSFC substantiating this transfer of the two DCP's and tester. Dr. Paulson is to confirm directly to MITRE this transaction in writing in the near future.

## 2.3 MSS Implementation

Once preliminary MSS experiment planning was completed, the next step was implementation of the plans by testing out the procured resources on ERTS-1 MSS imagery and data tapes. Unfortunately, delay in the receipt of the first MSS tapes (received 6 November 1972) and corresponding imagery (received 25 November 1972) from NASA for the investigation areas caused delays in MSS implementation by approximately one month. An additional problem was that the first MSS data tapes and imagery received and used for MSS test runs covered different overflight dates, viz., 1 August 1972 and 6 September 1972 respectively. As will be addressed in a later section, simultaneous receipt of both imagery and data tapes for a given date would greatly expedite future analysis.

MITRE's approach to MSS implementation was to proceed in three distinct steps:

1. MSS imagery analysis test run
2. MSS digital analysis test run
3. MSS complementary imagery/digital test run

### 2.3.1 MSS Imagery Analysis Test Run

The first step in MSS implementation was the imagery analysis test run: an attempt to use photointerpretive techniques alone as a means of defining separable categories at least for land use and water quality. This portion of the MSS implementation was carried out at Penn State's Space and Engineering Laboratory under subcontract to MITRE.

A portion of Site 1, consisting of 144 square miles surrounding Harrisburg, Pennsylvania, was studied. The imagery used was that of

6 September 1972, namely image number 1045-15243 in the four channels of the MSS.

The photointerpretation was carried out independent of outside aid. There was no special study of the test area, no coordination with other researchers using computer programs, and no previous study of maps or aerial photos at larger scales. The intent was to determine what could be read directly from ERTS imagery alone. Although interpreters had a traveler's acquaintance with the Harrisburg area, care was taken not to identify items by their geographic location. Graytone variations were recorded, but interpreted only where their shape provided interpretive clues.

The imagery was studied under the following conditions.

1. Direct inspection of the image on a light table under magnifications of 4.5X and 7X, using a direct viewing lens or one lens of an Old Delft stereoscope.

2. Projection of the image by means of a Visucom overhead projector, from 10 feet, onto a flat screen at a magnification of 4X.

3. Projection of the image onto a table by means of a single Kelsh Plotter projector, at a magnification of 4.5X.

4. Projection of a glossy positive 4X enlargement using a Saltzman projector, resulting in a further enlarged scale of 7.5X (or 2 miles to the inch).

The above systems were, as far as is known, the only ones available at Penn State. A search of mapping equipment literature indicated that the Bausch & Lomb Zoom Transfer Scope or the Artograph Model 55C Mapograph would permit direct enlargement of the image transparancies to a scale permitting delineation of the detail desired. (Subsequently, a Bausch and Lomb Zoom Transfer Scope has been made available for use by MITRE at no cost by the USGS.)

Working at contact scale proved useless for documentation, although considerable detail could be observed with the hand lens. The overhead projector also could not be used, as the projected image could be viewed clearly only from a position of several feet from the screen.

The Kelsh Plotter was second only to the Saltzman in usefulness. It permitted direct projection of the image onto a table, where features could be mapped as observed. However, only a very small portion of the image could be viewed at one time, making it difficult to determine significant graytone signatures and to maintain consistency in delineating them. Mapping by this method is, in addition, a very slow process compared to the Saltzman.

The Saltzman projector appeared to give the best overall image definition combined with rapid tracing of observed features. It's chief drawback is the necessity of using photographic prints rather than the images themselves, resulting in some loss of graytone resolution.

Figures 3 through 6 are a demonstration of the results of photointerpretation of the four ERTS images, using the Saltzman projector. The outline on each overlay is a strict recording of what was viewed. No touchup work or editing was done and there was no "second guessing" as a result of support documentation.

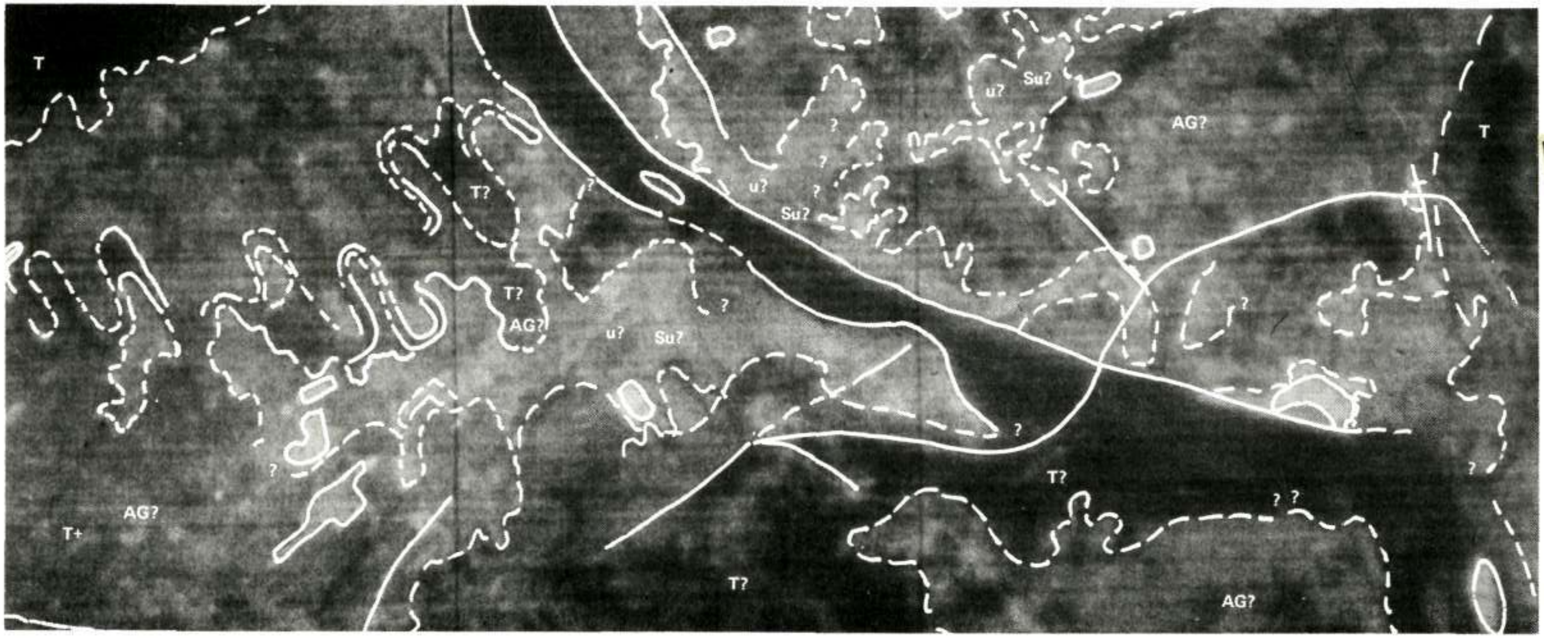



FIGURE 3

LAND USE CHANNEL 4


FIGURE 4

LAND USE CHANNEL 5


FIGURE 5

LAND USE CHANNEL 6

FIGURE 6

LAND USE CHANNEL 7

The following remarks pertain to the work shown in Figures 3 through 6 .

1. The four images used, representing the four MSS channels of scene number 1045-15243 taken 6 September 1972, were chosen because they were the best representation available for the scene for which data tapes also became available, facilitating later comparison. Better quality images for Test Site I are now available.

2. Positive glossy prints of the portion of these images covering Test Site I were made, enlarging the image 4 times. These were projected to a total enlargement of 7.5 times.

3. The overlays were made from the enlargements. Subsequent to this, a second set of photo enlargements at a scale of 7.5X were made, to facilitate interpretation of the overlays. The photo prints to which the overlays are attached, therefore, were not used to obtain the data on these overlays.

4. Only a small portion of Site I was chosen for study. This portion was considered to be sufficient to illustrate the problems involved and the results obtainable by photointerpretive techniques alone.

5. The time involved in producing the overlays was as follows:

| | |
|---|---|
| Channel 4 | 1¼ hours |
| Channel 5 | 2½ hours |
| Channel 6 | 1 hour |
| Channel 7 | 1 hour |

The results were of such quality that it was not considered worthwhile to attempt to planimeter the areas for quantification of the land use categories.

6. The following color key was used for the overlays:

| | |
|---|---|
| W | Water bodies and drainage |
| Solid Line (when not category boundary) | Roads |
| U/SU | Urban/suburban |
| T | Forest and woodland |
| Ag | Agriculture |
| C | Construction or mining |
| E | Erosion or siltation |

It should be noted that for each overlay the above designations are best estimates (determined from shape and/or relative positions) of what the particular graytone outlined most probably represented.

7. No attempt was made to evaluate air quality parameters at this time.

The results of the work done with the Saltzman projector are shown on the overlays of Figure 3 and on Table 4 . It can readily be seen from both the overlays and the Table that in only a few cases could a feature be uniquely determined by this technique, and in virtually no case could it be completely deliniated.

On no channel was it possible to determine unambiguously areas of suburban development and agriculture. A comparison of results from the four channels reveals widely differing assignments of areas to these two categories, as well as to the category of "forest."

In several areas, on all channels, it was not possible to determine accurately the shoreline of the Susquehanna River. It was discovered later that this difficulty was largely due to the loss of graytone definition on the paper print. For example, restudy of the original transparency

| Land Use Category | Channel 4 | Channel 5 | Channel 6 | Channel 7 | Preferred Channel |
|---|---|---|---|---|---|
| Drainage | Incomplete. Islands obscured. Shorelines grade into forest. | Incomplete. Shorelines grade into forest. | Confused with urban. | Some confusion with urban. | Channel 7 |
| Roads | Very incomplete. | Clearly defined where white. Unreliable when parallel to scan lines. Many dark lines could be roads or drainage. | Rarely seen and poorly defined. | Rarely seen. | Channel 5 |
| Urban | Grades into suburban. | Confused with probable bare fields. Otherwise fairly distinct. | Minor confusion with suburban and drainage. | Confused with drainage. | Channels 5 & 6 |
| Suburban | Not differentiable from urban. Confused with agriculture. | Not differentiable from agriculture. | Confused with agriculture. | Fair to poor distinction from both agriculture and urban. | All poor, due to confusion with agriculture. |
| Forest | Not differentiable from drainage and often confused with agriculture. | Some confusion with drainage. | Confused with agriculture. | Confused with agriculture. | Channel 5 |
| Agriculture | Confused with forest and often with suburban. | Not differentiable from suburban. | Confused with both forest and suburban. | Confused with forest and with portions of suburban. | All poor, due to confusion with forest and suburban. |

TABLE 4

RESULTS OF PHOTOINTERPRETATION OF ERTS IMAGERY USING THE SALTZMAN PROJECTOR

| Land Use Category | Channel 4 | Channel 5 | Channel 6 | Channel 7 | Preferred Channel |
|---|---|---|---|---|---|
| Construction | Confused with established concrete areas (e.g., airport) and areas of erosion. | Confused with established areas of concrete and with urban. | Indistinct. | Not visible. | Channel 4 |
| Erosion and Siltation | Confused with construction. | Not visible. | Not visible. | Not visible. | Channel 4 |

TABLE 4 (Continued)

RESULTS OF PHOTOINTERPRETATION OF ERTS IMAGERY USING THE SALTZMAN PROJECTOR for channel 7 revealed a much clearer shoreline in these areas, as well as several islands which had been "lost" on the paper print. (Corrections for these features were not made on the overlays.) Some of these "lost" islands are shown on the overlays as violet shadings in the Susquehanna, where these slight tonal changes in the river were originally thought to represent differences in water quality. Other than for these islands, differences in graytones of water areas were not observed, although they were looked for, especially where tributaries entered the main stream.

Only two orders of streams could be seen on ERTS imagery using the Saltzman projector and photointerpretive methods: the Susquehanna River and major streams entering it. A few lesser streams were seen on the original imagery by inspection with the hand lens.

This study has shown that photointerpretive techniques alone, when applied to ERTS imagery, are unsatisfactory as a single means of determining indices for land use categories, for the following reasons.

1. It is not possible, by the means attempted here, to unambiguously delineate areas of land use categories or water quality.

2. Establishment of indices for land use categories requires planimetry of areas. Where areas cannot be clearly outlined they cannot be accurately determined.

3. Up to 2½ hours were spent in mapping a small portion of Test Site I in a single channel. Clearly, mapping the entire Test Site in all four channels would take a large amount of time with very limited useful results.

4. A brief inspection of U-2 imagery (flown at 60,000 feet) of the same area indicates that some improvement of photointerpretive techniques could be realized by using U-2 photography to train the photointerpreter to recognize ERTS signatures. This would, however, increase the time requirements for a given area of investigation, and perhaps require additional U-2 flights.

5. Computer assisted photointerpretation is strongly recommended. This approach makes area delineation unnecessary, and therefore makes study of ERTS imagery free from delineation restrictions.

6. Previous work done at Penn State indicates that computer differentiation of areas from scanner data is far superior to that done by the human eye. The role of the photointerpreter, then, is in the identification, by shape comparison, of the features exhibited on computer output.

2.3.2 MSS Digital Analysis Test Run

The next step in MSS implementation was the MSS digital analysis test run. For this task, an attempt was made to classify and map the Test Site 1 area as well as possible within a limited time period and without the assistance of photo interpretation and without photographic and imagery materials other than ERTS-1 satellite imagery. The time period was set as two work weeks (10 days). ERTS-1 imagery and USGS 7-½ minute quadrangles of the area were used as support materials. ERTS-1 MSS digital data were used. The processing system described in Section 2.1.2 (Software Procurement) and Appendix E were employed. This project was actually the first time the processing system was used for the production of classification and map products where the emphasis was on production and not on development and testing. In the use of the system, all of the work was done via a remote typewriter terminal (IBM 2741) connected by phone lines to The Pennsylvania State University Computation Center. All output (except for the infrequent high-volume printer output) was directed back to the terminal. High-volume printer outputs were directed to The Computation Center and those outputs were collected once or twice a day when they were produced. Most of the analysis work was done by short computer runs to insure rapid turn around time. The tapes were identified as 1009-15244 and correspond to scene 15244 collected on August 1, 1972. The scene covered the southeastern quadrant of the state of Pennsylvania. (Test Site 1). Cloud cover was inconsequential over the area of interest. All four MSS channels were used in data processing; however, channel 7 was rated as poor.

Using the imagery for reference, two subsets of the full scene of data were defined. Each subset was put on a separate tape. The first subset was defined as scan lines 937 through 1150 and elements 2790 through 3010. The second subset consisted of lines 1051 through 1200 and elements 3010 through 3228. Both of the subsets came from the third tape of the four for the scene.

Printer map output is nearly in the same scale as the USGS 7-½' maps so that cross-reference to these maps is quite simple. After the initial use of the ERTS-1 imagery to locate and define the subsets, the imagery was not used further. The reason was that cross-reference to the 7-½' maps was more helpful and simple, whereas cross-reference to the imagery was comparatively difficult and not helpful because of the large scale.

The first step in the analysis was the production of an intensity map for the purpose of assisting in locating patterns and targets in the area of interest. The map was produced for the first subset since target identification was to be centered mainly in the area it represented. A small part of the overall map is presented in Figure 7, in which the pattern of Conodoguinet Creek is clearly shown. The creek flows into the Susquehanna River which is shown in the upper right corner of the figure.

```
  2825|2830|2835|2840|2845|2850|2855|2860|2865|2870|2875|
      |    |    |    |    |    |    |    |    |    |    |
1005 | ------------XXXX----------        ------          |
1006 |---X-XXXX----XXXXX----------           ------      |
1007 |--XXXXXXXX---XXXXX-------------        -------     |
1008 |--XXXXXXXX-XXXXXXXX--------------      --------    |
1009 |XXXXXXXXXXXXXXXXXX-----------------    ---------   |
1010 |-XXXXXXXXXXXXXXXXXX---------------   --   ------   |
1011 |XXXXXXXXXXXXXXXXXXXXX-----XX------   --    ------- |
1012 |XXXXXXXXXXXXXXXXXXXXX-----XX----           --------|
1013 |XXXXXXXXXXXXXXXXXXXXXXXX---XX--           ---------|
1014 |XXXXXXXXXXXXXXXXXXXXXXXXX-----  XXXXXXX    ----    |
1015 |      --XXXXXXXXXXXXXXX------  XXXXXXXXX     --    |
1016 |       --XXXXXXXXXXXXX----XX   XXXXXXXXXX     -    |
1017 |        -XXXXXXXXXXXXX---XX   XXXXXXXXXXXX         |
1018 |---      -XXXXXXXXXXXX----X   XXXXXXXXXXXXX        |
1019 |XXXXX     -XXXXXXXXXX----XX   XXXXXXXXXX---X--     |
1020 |XXXXXXX     XXXX---XX-----     XXXXXXXX---------   |
1021 | XXXXXXX       --X-------      XXXXXXXX---------XXX|
1022 | XXXXXXXX       XXXXX--XX-     XXXXXXX------X-XXXXX|
1023 | XXXXXXXXX       XXXXXXXXX--    --XXXXX----XXXXXXXX|
1024 |  XXXXXXXXX       XXXXXXX---    --XXXXXX---XXXXXXXX|
1025 |  XXXXXXXXXX       --XXXXX---    -XXXXXXX-XXXXXXXXX|
1026 |   XXXXXXXXXX       --XXXXXX--    -XXXXXXXXXXXXXXXX|
1027 |    XXXXXXXXXXX      --XXXXXXXX    -XXXXXXXXXXXXXXX|
1028 |     XXXXXXXXXXX      --XXXXXXXX    -XXXXXXXXXXXXXX|
1029 |     -XXXXXXXXXX-      --XXXXXXXX    -XXXXXXXXXXXXX|
1030 |X    ---XXXXXXXXXX      XXXXXXXXXXX   -XXXXXXXXXXXX|
1031 |X--  ----XXXXXXXXXXX     XXXXXXXXXXX   --X-XXXXXXXX|
1032 |X--   ---XXXXXXXXXXXX     XXXXXXXXXXX   ----XXXXXXX|
1033 |XXXXX   ----XXXXXXXXX---   XXXXXXXXXXXX   --XXXXXXX|
1034 |XXXXXX   ----XXXXXX-----    XXXXXXXXXXXX     XXXXXX|
1035 |XXXXXXXX    ----XX-- ----   -XXXXXXXXXXXXX    XXXXX|
1036 |XXXXXXXXXX   ----     --XXXXXXXXXXXXXXXXXXX   XXXXX|
1037 |XXXXXXXXXXX    -      -XXXXXXXXXXXXXXXXXXXXX   XXXX|
1038 |XXXXXXXXXXXX         --XXXXXXXXXXXXXXXXXXXXX    XXX|
1039 |XXXXXXXXX--XX         --XXXXXXXXXXXXXXXXXXXX    -XX|
1040 |XXXXXXXXX----          XXXXXXXXXXXXXXXXXXXXX    ---|
1041 |XXXXXXXX-----          XXXXXXXXXXXXXXXXXXXX     -- |
      |    |    |    |    |    |    |    |    |    |    |
  2825|2830|2835|2840|2845|2850|2855|2860|2865|2870|2875|
```

Low brightness — blank

Medium brightness — -

High brightness — X

FIGURE 7

BRIGHTNESS MAP OF CONODOGUINET CREEK AREA

The second step was the production of a uniformity map. A small portion of the map is shown in Figure 8. The U symbols show areas of local uniformity based on all four channels of spectral data. Clusters of these show broad areas of spectral uniformity which can be used as training areas to obtain spectral signatures of the associated targets. In Figure 8, the area labeled W was used for a river water training area and the area labeled H was used for a central urban training area. The asterisks were the symbols used to indicate local high contrast and some obvious boundaries can be seen as expressed by that symbol. By using the uniformity map, five training areas were initially defined. These were river water, forest, railway yard, central urban, and an unknown target which was found to be similar to the forest target and was therefore named as forest.

Statistics for the training areas were defined and the mean vectors (spectral signatures) and covariance matrices were computed. In Table 5, the pertinent statistical output for the river water target is presented and, in Figure 9, the histograms for the four channels are shown. The histograms for each channel show the number of observations in each percentile versus the reflectance percentile.

Uniform training areas could not be found for many targets; for example, clusters of uniform elements were either nonexistent or too small for reliable statistical estimates of creek water. Cluster analysis was used for the identification of targets and their signatures where training areas could not be defined. In Figure 10, the output for this program is shown where it was used to estimate the signature for

```
     2875|2880|2885|2890|2895|2900|2905|2910|2915|2920|2925|
         |    |    |    |    |    |    |    |    |    |    |
1005 |UUUUUUUUUUUUUUUUUUU * -  ---UU----    U-UU   U- ***|
1006 |UUUUUUUUU-UUUUUUUUU **--U----     *- - -    -   **|
1007 |U---UUUUUUUUU  * U-U **  -UU--UU--U-- -U--U      *|
1008 |UUU-UUWHUUUUU   **UU- **   U--UUU-U----U U  U -U  |
1009 |UUUUUUWUUUUU- * ** UU **    UUUU  -U      ----    -|
1010 |-UUUUUUUUUUUUUU *** -UUU **  -UUUU-UU   ---UU  U U|
1011 |*UUUUUUUUUUUUUUUU-   UUUU- * -UU - U- UU--U --     |
1012 |**UUUUUUUUUUUUUUUUUUUUUUUUU-** -UUU- U-- UU  -  * -|
1013 |** U--UUUUUU-UUUUUUUUUUUUUU- * UUUHU- ---- * U- - |
1014 | * UUUUUUUUU-UUUUU-UUUUUUUUU-U * UUU-U-U -*     * |
1015 |- *-UUUUUUUUUUUUUUUUUUUUUUUUUUU *  UUUUU-U-   *   |
1016 |- * UU-UUUUUUUUUUUUUUUUUUUUUUUUU**- U-UUUU-- UU   *|
1017 |  **UUUUUUUU--UUUUUUUUUUUU-UUUUU**  -UUUU-U-    ** |
1018 |      U  ---   --UUUUUUUUUUU-- UUUUU*** --U-UU   *** |
1019 |*******-- -      UUUU     ---  * UUUU ** -UUUU-  ** |
1020 |*    *   UU     UUUU           * *UUUU **-     - U |
1021 |      ***** U-- UUU       U U * *U -U- ***    - UU |
1022 |         -** -UUUUUU     U           UUUU-  **-- -U-U-|
1023 |   * U     ** UUUUUU-- UU     U     *U  U - *    -U - |
1024 |-            *** UUUUUUU    U     UU***-U -UUU ***U-U- |
1025 |      -      - - ***-U- UU     UUUUU   --UUUUUUUU  * U -|
1026 | -     -          **-UUUUU   *U-U-U- UUUUUUUUUUUU- ** |
1027 |-    --       -    *** --UUU-UU --UUUUUUU-UUUUUUUU-  |
1028 |-- U UU- -U---   - **  -UUU- U   U--UUUUUUUUUUUUUUUUU|
1029 |  U--U-- -   **   --- ** --U -UU-U-UUUUU   *** UUUUUU|
1030 |      U-       -    U--U ** --UUUUUU-UUUUU       ** UUUU|
1031 |-U-  UU--UU **           **   -UUUUUUUUUU **      *** U|
1032 |-     ---UU-- --U--   *   - ** -UUUUUUUUUU *      - ***|
1033 |        --U--U      U          *****-U-UUUUUU ***    - *|
1034 |U - *-UUU -U-U-      -U-       --  * -UUUUUUUU **      |
1035 |** - U- -UU            U-UU   -   -   ***UUUUUUUUU ***** |
1036 | *  *  --         ** UUUU--U        - ** -UUUUUUUU  ***|
1037 |- *    * -             -UU-U-U U-U-UU    ** -UUUUUUUU--|
1038 | * * U    ---      --U-UU-UU    -    - -     ** UUUUUUU -|
1039 |       *          --U-  ---U     -    ***  U- ******U U |
1040 | -   --  ---    U--    --          - -  *       * ***  |
1041 |  -                UUU     -  U       -U- --      ***  * |
         |    |    |    |    |    |    |    |    |    |    |
     2875|2880|2885|2890|2895|2900|2905|2910|2915|2920|2925|
```

| | |
|---|---|
| High local uniformity | U |
| Medium local uniformity | - |
| Medium local contrast | blank |
| High local contrast | * |
| River water training area | W |
| Central urban training area | H |

FIGURE 8

UNIFORMITY MAP OF A PART OF THE SUSQUEHANNA RIVER

## MEANS AND STANDARD DEVIATIONS FOR GIVEN CHANNELS

| Ch.4 | Ch.5 | Ch.6 | Ch.7 |
|---|---|---|---|
| 33.19 | 22.48 | 17.76 | 4.78 |
| 1.01 | 1.13 | 0.67 | 0.60 |

## VARIANCE-COVARIANCE MATRIX

| | | | | |
|---|---|---|---|---|
| Ch.4 | 1.02 | | | |
| Ch.5 | -0.17 | 1.27 | | |
| Ch.6 | 0.18 | 0.14 | 0.45 | |
| Ch.7 | -0.01 | -0.12 | -0.05 | 0.36 |
| | Ch.4 | Ch.5 | Ch.6 | Ch.7 |

## CORRELATION MATRIX FOR GIVEN CHANNELS

| | | | | |
|---|---|---|---|---|
| Ch.4 | 1.0000 | | | |
| Ch.5 | -0.1458 | 1.0000 | | |
| Ch.6 | 0.2617 | 0.1809 | 1.0000 | |
| Ch.7 | -0.0240 | -0.1723 | -0.1345 | 1.0000 |
| | Ch.4 | Ch.5 | Ch.6 | Ch.7 |

TABLE 5

STATISTICS FOR THE RIVER WATER TRAINING AREA

```
HISTOGRAM FOR CHANNEL  1      0.50 -  0.60  MICRONS
----------------------------------------------------
        EACH * REPRESENTS  1  OBSERVATION(S).

32 |*****************
33 |****************
34 |***************
35 |******
```

```
HISTOGRAM FOR CHANNEL  2      0.60 -  0.70  MICRONS
----------------------------------------------------
        EACH * REPRESENTS  1  OBSERVATION(S).

21 |***************
22 |**********
23 |*****************
24 |************
```

```
HISTOGRAM FOR CHANNEL  3      0.70 -  0.80  MICRONS
----------------------------------------------------
        EACH * REPRESENTS  1  OBSERVATION(S).

16 |*
17 |*****************
18 |******************************
19 |******
```

```
HISTOGRAM FOR CHANNEL  4      0.80 -  1.10  MICRONS
----------------------------------------------------
        EACH * REPRESENTS  1  OBSERVATION(S).

 4 |*****************
 5 |********************************
 6 |*****
```

FIGURE 9

HISTOGRAMS FOR THE RIVER TRAINING AREA

classification and mapping large areas, it was found that suburban areas were very well mapped with the highway signature and it was thusly renamed.

After an initial set of signatures was obtained, trial maps of blocks of data in the subsets were made. A second stage of target and signature determination was begun on the basis of these maps. The areas which were unclassified were investigated and, by the use of the methods applied before, additional signatures and targets were identified. At this stage, training areas were not limited to just clusters of U symbols but were allowed to include the next level of uniformity (symbolized by - Figure 10 ). The number of observations and the number of subsamples (subareas) within the training area for each target were substantially increased to overcome the effect of the decreased uniformity. The 7-½' maps were used in target identification to make sure that all subareas included in a training area were of the same target.

Having obtained these additional signatures, the whole area from both subsets was mapped. Ten to 15 percent of the whole area remained unclassified but the patterns of unclassified elements appeared to be related to some kind of nonurban land use, possibly agriculture. One of the areas by chance fell within the boundaries of the cluster analysis area used for the determination of the creek signature. The cluster analysis had classified the area homogeneously and the pattern matched the pattern of the unclassified area on the large map. The

```
  2820|2825|2830|2835|2840|2845|2850|2855|2860|2865|2870|
      |    |    |    |    |    |    |    |    |    |    |
1005 |                   ++     +00 0000XX0XX0        XX*|
1006 |                  -+=++     0+   00XX0X00         0|
1007 |-        -   +      +++       + +   0XX0000        |
1008 |        --    +    -+++       ++     00X0X0  ++    |
1009 |  -    ------         ++ -    0 0+0+    0X0X   0+0+|
1010 |   ++    ------       -           +++  000000X0 +00|
1011 | ++++  ++++ ++- -   ++         -+       0  000XX000|
1012 |       +++                     -+    XXXXXX0 000000|
1013 |          +++++    +  ++----       0X      0X0   0 |
1014 |    ---   ++     ---+   --   -   - 0 ++++++ 0XX  ++|
1015 | --              ---- -  --- -    00++++++++  X0 ++|
1016 |  -    00         ------- -      0X +++++++++ 0X000|
1017 |    XXXX**X0      - ------      0X0++++++++++  0X00|
1018 |   X0     0XX      --------     0X ++++++-- +  + 0X|
1019 |+-X0  ---- 0X0  -++-------      0X ++++-+ -- +++++ |
1020 |- X0----- - 0*0  +           0  00    +-    +0 0   |
1021 |- - X0------  0XX0                00++++++   +     |
1022 |-- 0X0------   0X0   ------ ---  000 +++           |
1023 |--  XX--------  0*0 0 ---------   00       +  +    |
1024 |    XX0-------   0X0   -------     00   ----    ---|
1025 |    XX0 --------  XX0     -------  0X  ------     +|
1026 |0   0X  -- ------- XX0     ------   X0  -- ---  +++|
1027 |-    XX0 --------    XX     -------- 0X0  ----  +++|
1028 |     0X0     ------   XX     ------   0X0 --  + +++|
1029 |-   - 0X0     -- -    0XX      --   -- 0X0  +++++ +|
1030 |---  - 0X        ---   0XX0  -----  --- 000  ++ ++ |
1031 |--  --  XX      -------  XX0  ---------- 0X0  + +  |
1032 |    --  0XX       ----++++0XX0  ---- ---- 0X0      |
1033 | --- +    0X0      -----++   0X  -----------0X0   -|
1034 |-          0XX     ----       0X0 -----------0X0   |
1035 |    -++       XX     --  0     0X0  ---------- X0  |
1036 |- -  ----  -- - XX -    XX0      00  ---------- XX0|
1037 |    ---      -   0X0  00X00    ++++0 ----------- X0|
1038 |--  --            0**XXXX00 ++  +==+X0 - ------- 0X|
1039 | ------ -  --      0X**XX00     +===+0X    ------ X|
1040 |--------           0000*XXX0+++=====+ 0X0    --- 0X|
1041 |- ------          000  XXX00+=======++  0X0  + 0XX0|
      |    |    |    |    |    |    |    |    |    |    |
  2820|2825|2830|2835|2840|2845|2850|2855|2860|2865|2870|
```

| | |
|---|---|
| Creek | X |
| River | * |
| Creek shore | O |
| Urbanized land | + |
| Open land | – |
| Unclassified | blank |

FIGURE 10

CLUSTER ANALYSIS MAP FOR CONODOGUINET CREEK AREA signature for the target named "open land" was taken from that run. It appears as the - symbol in Figure 10.

It was believed that heavy construction of a power plant was taking place on Three Mile Island. Three Mile Island is mapped on the 1963 Middletown 7-½' quadrangle as open land, but initial processing indicated that the area is now somthing other than open land. A cluster analysis was run on the whole island and surrounding water area which resulted in a signature for a target named "building." This signature, in addition to yielding a classification for Three Mile Island, filled in substantial areas in the Harrisburg metropolitan district which had been previously unclassified. From the 7-½' maps, the area appeared to be a heavy industrial and warehouse area.

The final maps produced in the project were based on the set of eleven signatures and have only three to four percent of the total area unclassified. The full set of signatures, names, and symbols are given in Table 6.

The euclidean distances of separation of categories are given in Table 7. See Section 3.2 of Appendix E for the description of the meaning of euclidean distance separations. In general, the separation between pairs of categories is large. A number of notable exceptions exist however, and these are discussed later. A critical distance of 10 was used for every class except for river water which had a value of 15 assisned to it. In the classification scheme an element was assigned to the class for which the euclidean distance from it to the class signature was smallest if the distance was smaller than the critical distance for the



E

| CATEGORY NAME | NUMBER | SYMBOL | LIMIT |
|---|---|---|---|
| FOREST1 | 1 | | 10.0 |
| RAIL1 | 2 | | 10.0 |
| RIVER1 | 3 | W | 15.0 |
| GRASS1 | 4 | | 10.0 |
| URBAN1 | 5 | * | 10.0 |
| GRASS2 | 6 | - | 10.0 |
| FOREST2 | 7 | | 10.0 |
| ROOF | 8 | V | 10.0 |
| SUBURB1 | 9 | # | 10.0 |
| HIGHWAY | 10 | @ | 10.0 |
| CREEK | 11 | | 10.0 |
| OPEN LAND | 12 | | 10.0 |
| BUILDING | 13 | + | 10.0 |

UN-NORMALIZED CATEGORY SPECIFICATIONS

| CHANNELS- | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 1 | | 29.28 | 18.76 | 46.68 | 27.60 |
| 2 | | 37.00 | 29.45 | 29.09 | 10.91 |
| 3 | W | 33.18 | 22.48 | 17.76 | 4.78 |
| 4 | | 31.78 | 21.61 | 41.06 | 22.00 |
| 5 | * | 36.13 | 28.25 | 29.71 | 12.58 |
| 6 | - | 32.83 | 22.83 | 43.79 | 22.50 |
| 7 | | 28.25 | 18.21 | 49.54 | 29.82 |
| 8 | V | 52.50 | 55.00 | 56.00 | 22.00 |
| 9 | # | 38.74 | 31.88 | 48.01 | 23.88 |
| 10 | @ | 40.59 | 36.50 | 51.95 | 25.59 |
| 11 | | 33.30 | 23.52 | 31.04 | 13.48 |
| 12 | | 33.40 | 22.74 | 61.00 | 35.23 |
| 13 | + | 42.42 | 37.58 | 39.20 | 15.90 |

TABLE 6

CATEGORY SPECIFICATIONS FOR MAPPING CATEGORIES

DISTANCES OF SEPARATION FOR CATEGORIES

| | | 1 | 2 | 3 W | 4 | 5 * | 6 - | 7 | 8 V | 9 # | 10 @ | 11 | 12 | 13 + |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.0 | 27.6 | 37.2 | 8.8 | 25.5 | 8.0 | 3.8 | 44.4 | 16.7 | 21.8 | 22.0 | 17.2 | 26.8 |
| 2 | | 27.6 | 0.0 | 15.1 | 18.8 | 2.3 | 20.3 | 31.3 | 41.7 | 23.1 | 28.3 | 7.7 | 40.8 | 14.9 |
| 3 | W | 37.2 | 15.1 | 0.0 | 29.0 | 15.7 | 31.5 | 41.0 | 56.5 | 37.4 | 43.1 | 15.9 | 52.9 | 29.9 |
| 4 | | 8.8 | 18.8 | 29.0 | 0.0 | 16.7 | 3.2 | 12.5 | 42.0 | 14.3 | 20.8 | 13.4 | 24.0 | 20.2 |
| 5 | * | 25.5 | 2.3 | 15.7 | 16.7 | 0.0 | 18.4 | 29.2 | 42.0 | 22.0 | 27.4 | 5.7 | 39.1 | 15.1 |
| 6 | - | 8.0 | 20.3 | 31.5 | 3.2 | 18.4 | 0.0 | 11.4 | 39.6 | 11.7 | 18.0 | 15.6 | 21.4 | 19.3 |
| 7 | | 3.8 | 31.3 | 41.0 | 12.5 | 29.2 | 11.4 | 0.0 | 45.2 | 18.3 | 22.6 | 25.7 | 14.4 | 29.6 |
| 8 | V | 44.4 | 41.7 | 56.5 | 42.0 | 42.0 | 39.6 | 45.2 | 0.0 | 28.1 | 22.7 | 45.3 | 40.1 | 26.9 |
| 9 | # | 16.7 | 23.1 | 37.4 | 14.3 | 22.0 | 11.7 | 18.3 | 28.1 | 0.0 | 6.6 | 22.3 | 20.2 | 13.7 |
| 10 | @ | 21.8 | 28.3 | 43.1 | 20.8 | 27.4 | 18.0 | 22.6 | 22.7 | 6.6 | 0.0 | 28.4 | 20.4 | 16.2 |
| 11 | | 22.0 | 7.7 | 15.9 | 13.4 | 5.7 | 15.6 | 25.7 | 45.3 | 22.3 | 28.4 | 0.0 | 37.0 | 18.8 |
| 12 | | 17.2 | 40.8 | 52.9 | 24.0 | 39.1 | 21.4 | 14.4 | 40.1 | 20.2 | 20.4 | 37.0 | 0.0 | 33.9 |
| 13 | + | 26.8 | 14.9 | 29.9 | 20.2 | 15.1 | 19.3 | 29.6 | 26.9 | 13.7 | 16.2 | 18.8 | 33.9 | 0.0 |

TABLE 7

SEPARATION DISTANCES FOR MAPPING CATEGORIES class. If the distance was greater than the critical distance, the classification would be attempted for the next nearest class and so on. If the element could not be assigned to any class under these rules, it was assigned to the "other" category which is used in this report synonymously with "unclassified." Consider the river water, for example. The distance of separation from each of the other categories is, in every case, greater than 15. Therefore, there is no chance of confusion between river water and any other category according to the rules of classification. There are a few other categories for which the same is true based on a critical value of 10. For most of the classes, there exist a few distances which indicate potential confusion. Consider classes 2 and 5 of Table 7, rail and urban 1 respectively. The distance of separation between these two classes is only 2.3; therefore, there is a potential for confusion between the two classes. The rest of Table 7 can be interpreted in the way of the above discussion. Three other pairs of classes have small distances of separation which should be mentioned. In addition to the aforementioned problem with the railway signature, it also has a relatively small distance of separation from the creek signature. Whether confusion actually exists or not in classifying rail and creek targets can only be resolved by ground truth. However, there appears to be some confusion of these two targets in the various railway yards, but it is possible that there might be enough sediment, low vegetation, and water in the yards to give a true response for the creek classification.

The two other pairs of categories with small separation distances are creek with urban 1 and highway with suburb 1. The reason for the similarity of creek and urban 1 signatures is not known at this time. The similarity of highway and suburb 1 signatures was not unexpected because the initial highway signature was renamed suburb 1 when it gave very good mapping results for suburban areas. The new highway signature was obtained later on and may indeed have been based on very similar targets to the suburb 1 signature. It seems though that the new highway signature is more related to parking lots and similar paved and unpaved areas than it is to the suburb 1 signature. Actual highways are mapped by both symbols.

A number of the vegetation classes are close but, for the present purposes, confusion among these classes is not of particular importance.

With regard to naming the categories, some serious problems exist. Some of the categories are easily named correctly, such as river water and the forest categories. The investigators do not put a great deal of emphasis on the names of other categories because they were named only inferentially with no direct means of being sure of the targets. It is not a simple matter to pick out vegetation signatures in ERTS data simply by looking at the signatures. It is even more difficult to identify other signatures. The 7-½' maps are of limited utility since they do not generally give the kind of information needed to identify a category except on an inferential basis. Ground truth or areal photographs would likely have been very helpful in specifically identifying and naming the targets.

Four maps resulting from this effort are shown in Figures 11 through 14. All four have resulted from the classification scheme described previously. A small part of a typical map is shown in Figure 15. The river and islands in the river are readily apparent. The central metropolitan area of Harrisburg, mapped with *'s, can be seen in the upper right portion of the figure. Heavy industrial and warehouse areas, mapped with +'s, can be seen adjoining the downtown area of Harrisburg. Across the river, the Camp Hill urban area can be seen mapped with #'s. The @'s in Camp Hill possibly indicate parking lots or bare ground, whereas the -'s indicate parks, cemeteries, and other such green areas. Interpretation of the large maps would be an extension of this brief interpretation of the map in Figure 16. The differences in the maps resulted from different assignment of symbols to categories, elimination of stray symbols, and smoothing of mapping boundaries.

The first map Figure 11 shows all of the nonvegetation classes with different symbols. The vegetation classes are all shown with the - symbol except for the one vegetation or open area class which is substantially different from the other vegetation classes. This atypical class was mapped with the = symbol. A comprehensive interpretation of the map will not be presented in this report. However, it should be pointed out that the trace of interstate highways and some secondary roads can be seen as well as a number of the bridges across the Susquehanna River. In the second map, Figure 12 only vegetation classes are mapped except for river water which was mapped as a reference. In this map, stray symbols were removed and boundaries were smoothed.

In the third map, Figure 13 , only water categories and the railway category were mapped. Stray symbols were not removed and boundaries

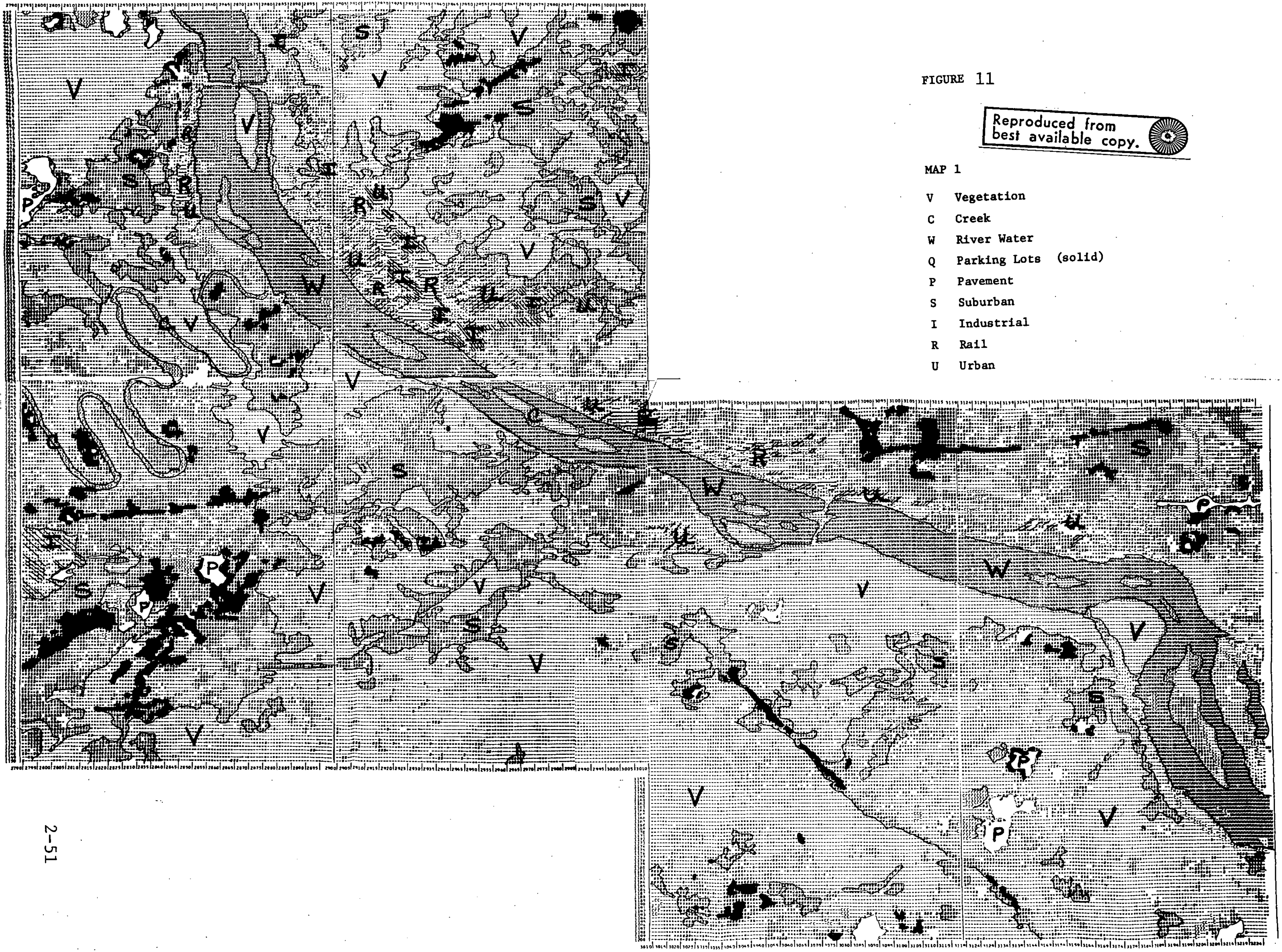


FIGURE 11



MAP 1

V Vegetation
C Creek
W River Water
Q Parking Lots (solid)
P Pavement
S Suburban
I Industrial
R Rail
U Urban

FIGURE 12

MAP 2

T Trees
F Forest (solid)
L Lawn
G Grass
O Open
W Water

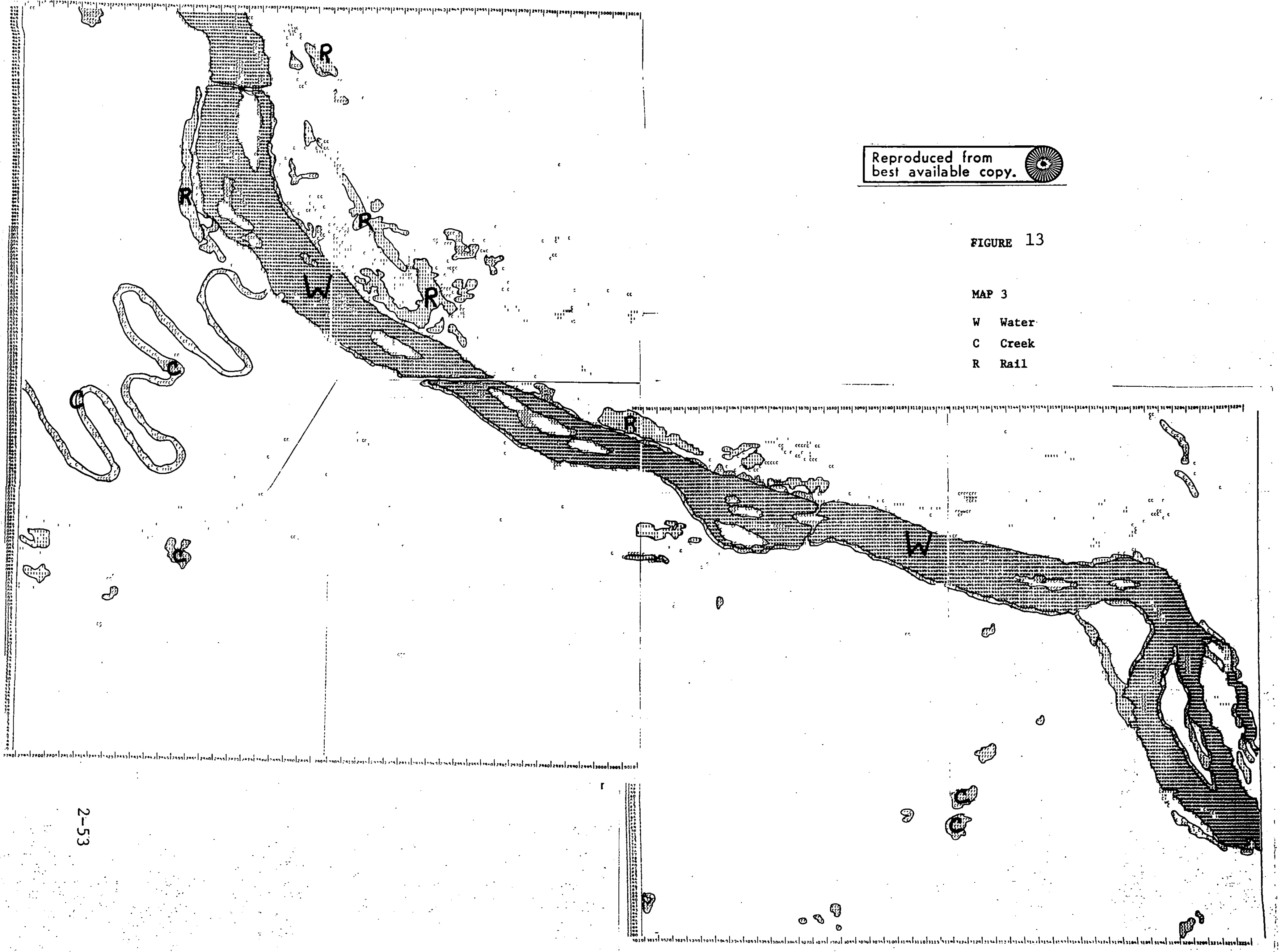





FIGURE 13

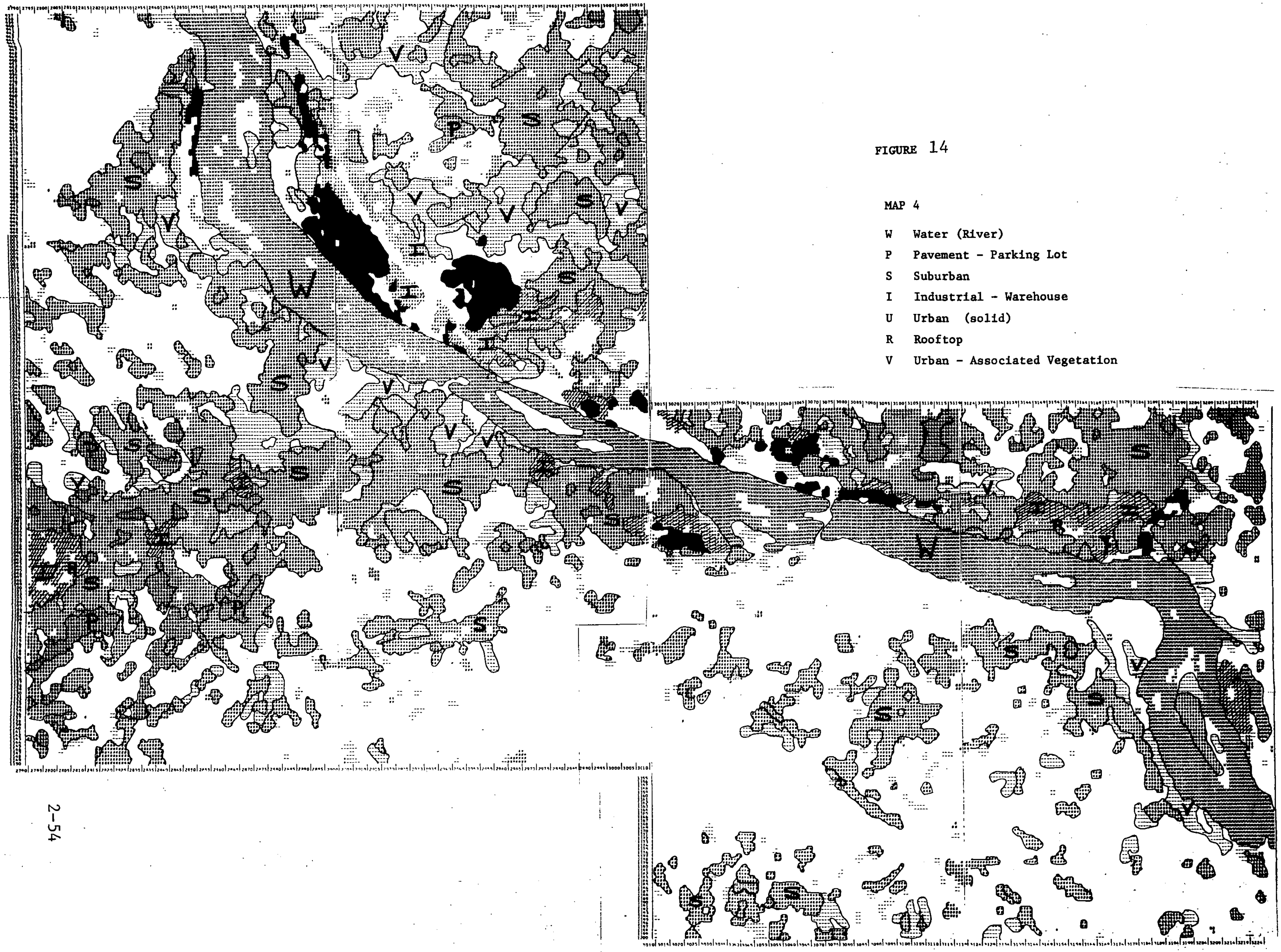
MAP 3

W Water

C Creek

R Rail

FIGURE 14



MAP 4

W Water (River)

P Pavement - Parking Lot

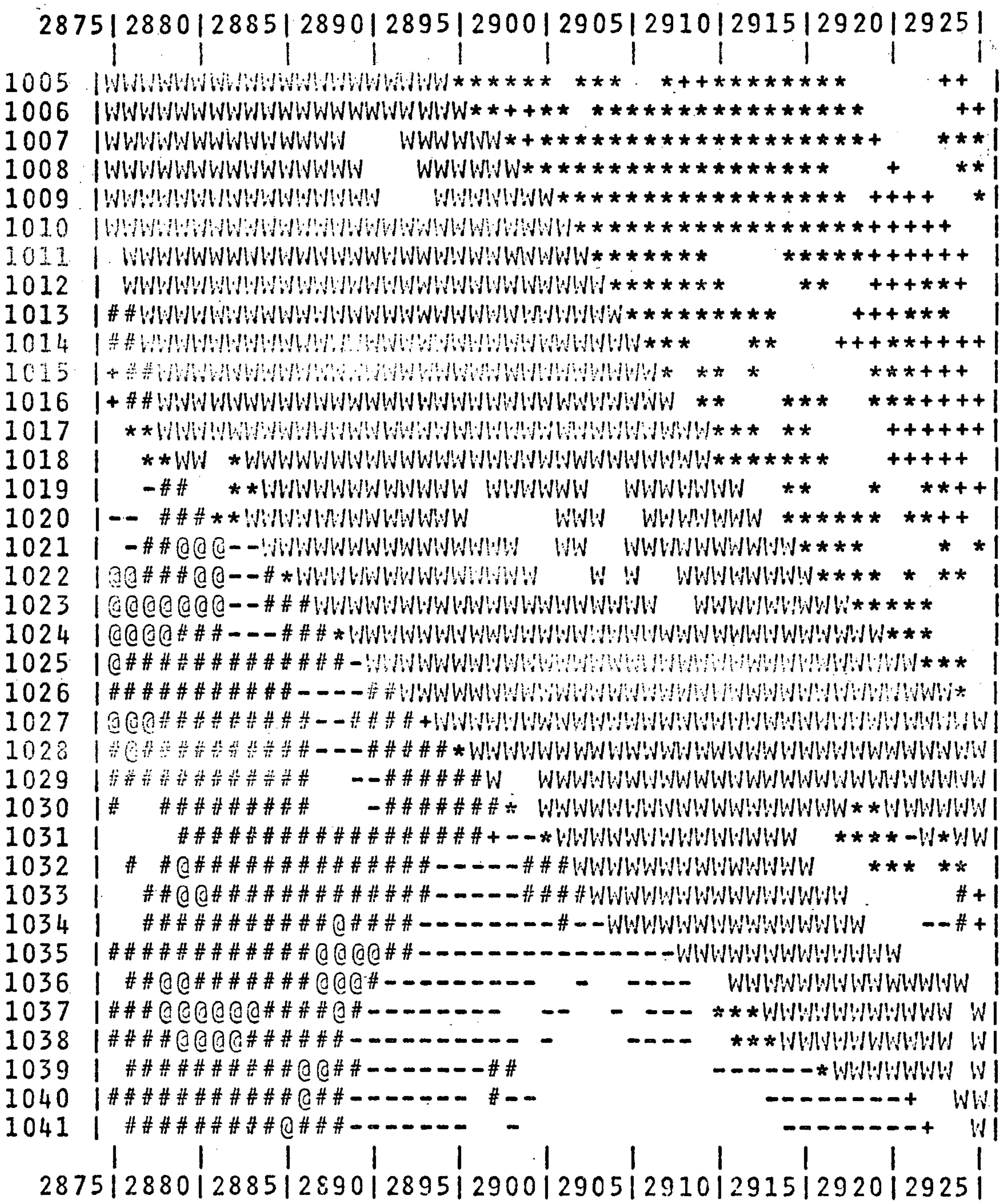
S Suburban

I Industrial - Warehouse

U Urban (solid)

R Rooftop

V Urban - Associated Vegetation



| Category | Symbol |
| --- | --- |
| Central urban areas | * |
| Suburban areas | # |
| Paved areas | @ |
| Industrial and warehouse areas | + |
| River water | W |
| Herbaceous vegetation | - |



FIGURE 15

MAP OF SIX CATEGORIES IN THE HARRISBURG VICINITY were not smoothed. The railway category was left in because its signature was so close to that of the creek. Many of the apparently stray symbols are indeed true according to the 7-½' maps.

The last map, Figure 14 , consists of only symbols for developed nonagricultural land. Railway symbols have been suppressed and river water was mapped as a reference.

The summary of the mapping results for each subset is given in Table 8 . The percentage in each category is the relative acreage in the category. The count for each category is the actual number of elements classified in the category. The conversion factor to acreage is approximately 1.12 acres/element based on the distance of separation between elements in a line and between lines.

The results of this MSS digital analysis test run ERTS-1 data can be translated to maps using only USGS maps for reference. Such maps agree quite well in general with the USGS maps except that the fine detail of the USGS maps cannot be achieved with ERTS-1 data. The ERTS-data-based maps indicate more meaningful land use categories can be mapped than that which has been done with USGS maps. In addition, the obvious, serious deficiency of the USGS maps is very strongly demonstrated. The USGS maps are obsolete in many areas even over the short period of time from the 1969 publication dates. The 1963 dated maps are of exceedingly limited utility in areas where rapid transitions in land use are in evidence. Because of the obsolescence and the absence of sufficient land use classification categories, the use of USGS maps alone to support ERTS - data-based mapping is inadvisable. Under-flight

Subset One

SUMMARY

| CATEGORY NAME | NUMBER | SYMBOL | LIMIT | COUNT | PER CENT |
|---|---|---|---|---|---|
| FOREST1 | 1 | | 10.0 | 3655. | 8. |
| RAIL1 | 2 | | 10.0 | 887. | 2. |
| RIVER1 | 3 | W | 15.0 | 2956. | 6. |
| GRASS1 | 4 | | 10.0 | 1249. | 3. |
| URBAN1 | 5 | * | 10.0 | 1622. | 3. |
| GRASS2 | 6 | - | 10.0 | 6844. | 14. |
| FOREST2 | 7 | | 10.0 | 5329. | 11. |
| ROOF | 8 | V | 10.0 | 130. | 0. |
| SUBURB1 | 9 | # | 10.0 | 11796. | 25. |
| HIGHWAY | 10 | @ | 10.0 | 2738. | 6. |
| CREEK | 11 | | 10.0 | 1119. | 2. |
| OPEN LAND | 12 | | 10.0 | 5303. | 11. |
| BUILDING | 13 | + | 10.0 | 2241. | 5. |
| OTHER | 14 | | 0.0 | 1425. | 3. |

Subset Two

SUMMARY

| CATEGORY NAME | NUMBER | SYMBOL | LIMIT | COUNT | PER CENT |
|---|---|---|---|---|---|
| FOREST1 | 1 | | 10.0 | 3335. | 10. |
| RAIL1 | 2 | | 10.0 | 554. | 2. |
| RIVER1 | 3 | W | 15.0 | 3735. | 11. |
| GRASS1 | 4 | | 10.0 | 659. | 2. |
| URBAN1 | 5 | * | 10.0 | 631. | 2. |
| GRASS2 | 6 | - | 10.0 | 3279. | 10. |
| FOREST2 | 7 | | 10.0 | 5494. | 17. |
| ROOF | 8 | V | 10.0 | 117. | 0. |
| SUBURB1 | 9 | # | 10.0 | 16076. | 18. |
| HIGHWAY | 10 | @ | 10.0 | 1086. | 3. |
| CREEK | 11 | | 10.0 | 817. | 2. |
| OPEN LAND | 12 | | 10.0 | 4795. | 15. |
| BUILDING | 13 | + | 10.0 | 847. | 3. |
| OTHER | 14 | | 0.0 | 1425. | 4. |

TABLE 8

SUMMARY OF CLASSIFICATION RESULTS FOR SUBSET ONE AND TWO photography or imagery is one needed basis of support for interpretation and mapping of ERTS data. In addition to this support, the necessity for timely ground truth to resolve anomalies should be anticipated.

2.3.3 MSS Complementary Imagery/Digital Analysis Test Run

Having attempted to demonstrate the possibilities of ERTS MSS data analysis first by photointerpretation alone, and then by digital analysis alone, MITRE then implemented the final logical step which was to combine the two techniques. The MSS complementary imagery/digital analysis test run was the final step in MSS implementation. Since complementary analysis has become generally the standard operating procedure now for land use and water quality, the results achieved during the MSS implementation stage of Phase I should be considered preliminary. The Penn State report of the combined photointerpreter and the digital mapper effort was submitted to MITRE on January 24, 1973. Throughout Phase II a number of refinements and improvements have been made with more MSS data becoming available, as noted in later sections.

For the MSS implementation stage, the 1 August MSS data tapes were once again employed. The first joint efforts involved a comparative analysis of land use classifications prepared by the separate photointerpretation and digital mapping teams. Initial joint studies involved the use of a Bausch & Lomb Zoom 70 Stereoscope to study infrared color film transparencies taken from U-2 aircraft flying at 65,000 feet in conjunction with computer generated maps. The camera had a 1.75 inch focal length, producing 70 mm format at a contact scale of 1:445,000 (approximately 1 in. = 7 miles).

The time-consuming nature of comparing the separate photographic image with the computer produced thematic maps quickly forced an attempt



F

to project the photograph directly onto a computer map. This was successfully accomplished with reasonable scale comparison, using an American Optical Company slide projector, Model D (Delineascope with 8 inch focal length lens and 500 watt illumination).

Because of the distorted nature of the computer map, caused by line and character per inch constraints, only small portions of the projected image could be brought into registry at one time. Clearly identifiable images of a unique nature were used to make these scale adjustments. The projector was mounted on a platform so that the image could be rotated about the projection axis and small adjustments in x and y translation of the photo image could easily be made. Overall scale was adjusted by the projector-to-screen distance.

Obvious targets, such as the Susquehanna River, its islands, and entering major streams were successfully identified. Small ponds, which registered only by single symbols, were properly classified. Some large cultural features, such as parking lots and rail yards, were identified in correct geographic location, but the exact limits of their boundaries were not fully satisfactory. Some vegetative classes were well identified, while others needed improvement. Several agricultural signatures were properly positioned, while others were confused with the signature generated for suburban areas.

A system of directly marking on the computer generated thematic map was used to outline areas for further study for signature improvement. These areas were defined by scan line and element numbers.

Further statistical analysis was performed on signatures in these areas. The results were, however, not satisfactory.

It was recognized that the signatures used to create this first series of maps were the result of computer mapping with only USGS 1:24,000 maps as a guide. Some of the signatures were "backed into," rather than determined by the direct approach of benchmark targets selected by photo interpretation. Moreover, concurrent studies in another area seemed to be producing separations of comparable signatures with much greater success. This was verifiable by a review of the statistics which indicated class separability. There seemed to be a case for a general attenuation of the quality of information recorded in channels 4, 5, and 6 for this scene, and records showed that channel 7 was distinctly of poor quality. Therefore, when the second run computer processing of signatures was unsatisfactory, it was decided to realign the approach.

The attached flow diagram (Figure 17 ) was generated as a means of coordinating the efforts of the computer mapping and the photointerpretation. It is on the basis of this method, and the image and computer tapes of 11 October 1972, of the Harrisburg Test Area (Image number: 1080-15185) that Phase II (preliminary data analysis) has proceeded, with improved complementary MSS imagery/digital analysis apparently emerging as the optimum approach.

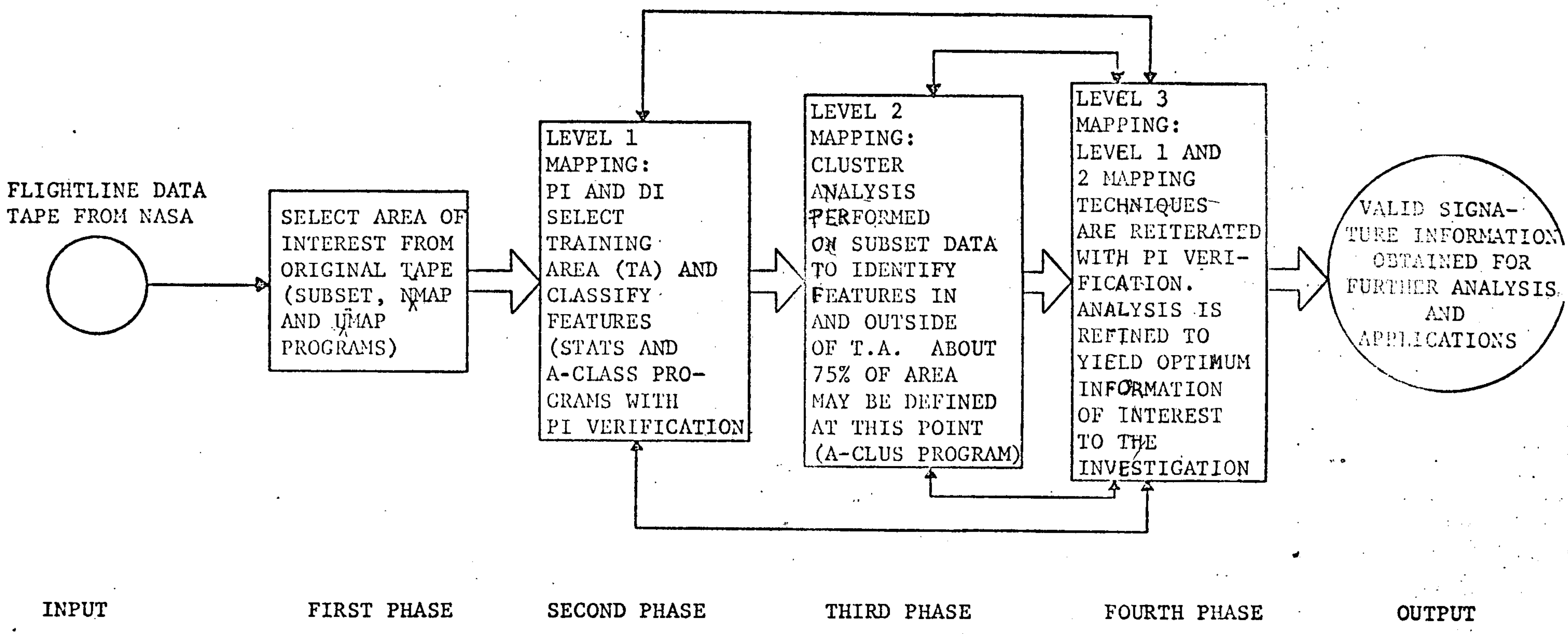



FIGURE 16

ERTS MSS DATA ANALYSIS SYSTEM

Note: PI = Photo Interpreter

DI = Digital Interpreter

## 2.4 DCP Station Implementation

Following the delivery of the two DCP's to USGS/Harrisburg on November 20, 1972, the water quantity station (ID 6073) has been put into operation at Newport, Pennsylvania since February 15, 1972. The second station is earmarked for the Renovo water quality station but delay in delivery of the sensors to transmitter harness has prevented this station from being placed into operation as of the end date for this report (February 28, 1973). These two DCP's paired with two DCP's obtained by Dr. Paulson are being used to obtain Susquehanna River Basin water quality and quantity dynamics. Four stations are insufficient to completely define this basin dynamics but is a start toward doing so. Both the USGS, EPA Region III and the U. S. Susquehanna River Basin Authority are interested in these DCP station data results as well as information useful to MITRE in our interpretation of ERTS-1 MSS data for test sites 1 and 2.

## 3.0 PHASE II - PRELIMINARY DATA ANALYSIS

Once initial planning had been completed and test runs had been made to determine the optimum approach to the analysis of the ERTS-1 MSS data, correlated with available ground truth data, the investigation shifted from a test and evaluation mode to one of preliminary operational analysis. As Phase II proceeded, the two other tasks of Phase II naturally complemented the preliminary data analysis. These were (1) development of the Data Analysis Plan which will serve as the basic guideline for the remainder of the investigation; and (2) a revision of previously stated data requirements which resulted from Phase I evaluation and the first two tasks of Phase II.

### 3.1 Analysis of Available ERTS-1 MSS Data

To date, 42 potential images of ERTS-1 coverage have been obtained over Test Site 1 and 29 for Test Site 2. The following statistics of good images have occurred.

| | Test Site I | Test Site II |
|---|---|---|
| No. of Images as of January 28, 1973 overflight | 42 | 29 |
| No. of Images with 20% cloud cover or less | 10 | 8 |
| No. of Images with 4 Good Channels | 7 | 5 |
| Percent Acceptable<br>• Cloud Cover (CC)<br>• CC and 4 Good Channels | <br>24.8%<br>16.7% | <br>27.6%<br>17.3% |

TABLE 9

ERTS IMAGE STATISTICS

The acceptable coverage dates are 10 and 11 October 1972, and 16 November 1972, 9 and 10 January 1973 and 26 January 1973. Other coverage dates had to be rejected based on failure to meet the following criteria:

- Greater than 20 percent cloud cover in the frame
- Excessive cloud cover within the Test Sites
- One or more MSS channels rated less than good.

Table 10 provides specific details of ERTS data available, ordered, and received to date.

1 August 1972 was used primarily in the MSS test runs of Phase I though it had one bad channel because it was the first data received. Data from the 11 October coverage is currently being processed for land use analysis in the Harrisburg test site area and for the water portion of investigation. Data from 1 August, 11 October, and November 16 coverage dates are being processed for the analysis of air quality/turbidity in the Site 1 area. Progress in each environmental area will be discussed separately.

| I. D. NUMBER | | | | | CLOUD COVER (%) (CC) | ORBIT NO. | RBV | | | MSS | | | | DATE | SITE NO. | | REMARKS | DATE RECEIVED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SATEL-LITE NO. | DAYS SINCE LAUNCH | HR. | MIN. | TENS OF SECONDS | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 1 | 2 | | TAPE | IMAGES |
| 1 | 007 | 15 | 12 | 4 | 100 | 96 | G | G | G | G | G | G | G | Jul 30 | | X | - | - | - |
| 1 | 007 | 15 | 13 | 1 | 100 | 96 | F | F | F | G | G | G | G | Jul 30 | X | | - | - | - |
| 1 | 008 | 15 | 18 | 0 | 100 | 111 | G | G | G | G | F | G | G | Jul 31 | | X | - | - | - |
| 1 | 008 | 15 | 18 | 3 | 100 | 111 | P | P | P | G | F | G | G | Jul 31 | X | X | - | - | - |
| 1 | 008 | 15 | 18 | 5 | 100 | 111 | G | G | G | G | G | G | G | Jul 31 | X | | - | - | - |
| 1 | 009 | 15 | 24 | 1 | 40 | 124 | G | G | G | G | G | G | P | Aug 01 | X | | Special Ordered 9/28/72 | 11/6/72 | 11/25/72 |
| 1 | 009 | 15 | 24 | 4 | 20 | 124 | G | G | G | G | G | G | P | Aug 01 | X | | Special Ordered 9/28/72 | 11/6/72 | 12/29/72 |
| 1 | 025 | 15 | 12 | 4 | 100 | 347 | - | - | - | F | G | G | G | Aug 17 | | X | | - | - |
| 1 | 025 | 15 | 13 | 0 | 100 | 347 | - | - | - | G | G | G | G | Aug 17 | X | | | - | - |
| 1 | 026 | 15 | 18 | 0 | 90 | 361 | - | - | - | G | G | G | G | Aug 18 | | X | | - | - |
| 1 | 026 | 15 | 18 | 2 | 80 | 361 | - | - | - | G | G | G | G | Aug 18 | X | X | | - | - |
| 1 | 026 | 15 | 18 | 5 | 80 | 361 | - | - | - | G | G | G | G | Aug 18 | X | | | - | - |
| 1 | 027 | 15 | 24 | 2 | 60 | 375 | - | - | - | G | G | G | G | Aug 19 | X | | Reviewed at GSFC-No Good | - | - |
| 1 | 027 | 15 | 24 | 5 | 60 | 375 | - | - | - | G | G | G | G | Aug 19 | X | | Reviewed at GSFC-No Good | - | - |
| 1 | 043 | 15 | 13 | 0 | 70 | 598 | - | - | - | G | G | P | G | Sep 04 | X | X | Reviewed at GSFC-No Good | - | - |
| 1 | 044 | 15 | 18 | 2 | 50 | 612 | - | - | - | G | G | P | G | Sep 05 | X | X | | - | - |
| 1 | 044 | 15 | 18 | 5 | 90 | 612 | - | - | - | F | F | P | G | Sep 05 | X | | | - | - |
| 1 | 045 | 15 | 24 | 3 | 10 | 626 | - | - | - | G | G | P | G | Sep 06 | X | | Tape Ordered 10/27/72 | - | 10/26/72 |
| 1 | 061 | 15 | 12 | 5 | 30 | 849 | - | - | - | G | G | G | G | Sep 22 | | X | | - | - |
| 1 | 062 | 15 | 18 | 1 | 20 | 863 | - | - | - | G | G | P | G | Sep 23 | | X | CC 100% over Site 2 | - | 10/30/72 |
| 1 | 062 | 15 | 18 | 4 | 40 | 863 | - | - | - | G | G | P | G | Sep 23 | X | X | CC 100% in ctr Site 1 | - | - |
| 1 | 063 | 15 | 24 | 2 | 90 | 877 | - | - | - | G | G | G | G | Sep 24 | X | | | - | - |
| 1 | 079 | 15 | 13 | 1 | 0 | 1100 | - | - | - | G | G | G | G | Oct 10 | | X | | 12/6/72 | 11/14/72 |
| 1 | 079 | 15 | 13 | 3 | 10 | 1100 | - | - | - | G | G | G | G | Oct 10 | X | | | 12/6/72 | 11/14/72 |
| 1 | 080 | 15 | 18 | 3 | 0 | 1114 | - | - | - | G | G | G | G | Oct 11 | | X | | 12/5/72 | 11/17/72 |
| 1 | 080 | 15 | 18 | 5 | 0 | 1114 | - | - | - | G | G | G | G | Oct 11 | X | X | | 12/5/72 | 11/17/72 |
| 1 | 080 | 15 | 19 | 2 | 0 | 1114 | - | - | - | G | G | G | G | Oct 11 | X | | | 12/5/72 | 11/17/72 |
| 1 | 081 | 15 | 24 | 4 | 100 | 1128 | - | - | - | G | G | G | G | Oct 12 | X | | | - | - |
| 1 | 081 | 15 | 25 | 0 | 80 | 1128 | - | - | - | G | G | G | G | Oct 12 | X | | | - | - |
| 1 | 097 | 15 | 13 | 3 | 100 | 1351 | - | - | - | G | G | G | G | Oct 28 | X | | | - | - |
| 1 | 098 | 15 | 18 | 5 | 100 | 1365 | - | - | - | G | G | G | G | Oct 29 | X | X | | - | - |
| 1 | 098 | 15 | 19 | 1 | 100 | 1365 | - | - | - | G | G | G | G | Oct 29 | X | | | - | - |
| 1 | 099 | 15 | 24 | 3 | 90 | 1379 | - | - | - | P | G | G | G | Oct 30 | X | | | - | - |
| 1 | 099 | 15 | 25 | 0 | 70 | 1379 | - | - | - | G | G | G | G | Oct 30 | X | | | - | - |
| 1 | 115 | 15 | 13 | 4 | 100 | 1602 | - | - | - | P | G | G | G | Nov 15 | X | X | | - | - |
| 1 | 116 | 15 | 19 | 0 | 50 | 1616 | - | - | - | G | G | G | G | Nov 16 | | X | | - | - |
| 1 | 116 | 15 | 19 | 2 | 10 | 1616 | - | - | - | G | G | G | G | Nov 16 | X | X | | - | 1/8/73 |

TABLE 10

ERTS-1 IMAGERY LOG FOR SITES I (HARRISBURG) & 2 (SCRANTON)

| I. D. NUMBER | | | | | CLOUD COVER (%) (CC) | ORBIT NO. | RBV | | | MSS | | | | DATE | SITE NO. | | REMARKS | DATE RECEIVED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SATEL-LITE NO. | DAYS SINCE LAUNCH | HR. | MIN. | TENS OF SECONDS | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 1 | 2 | | TAPE | IMAGES |
| 1 | 117 | 15 | 25 | 1 | 70 | 1630 | – | – | – | G | G | G | G | Nov 17 | X | | | – | – |
| 1 | 133 | 15 | 13 | 5 | 10 | 1853 | – | – | – | – | P | P | G | Dec 03 | X | X | | – | 1/17/73 (-4) |
| 1 | 134 | 15 | 19 | 0 | 100 | 1867 | – | – | – | – | P | P | G | Dec 04 | | X | | – | – |
| 1 | 134 | 15 | 19 | 3 | 100 | 1867 | – | – | – | – | P | P | G | Dec 04 | X | X | | – | – |
| 1 | 135 | 15 | 25 | 1 | 90 | 1881 | – | – | – | – | G | G | G | Dec 05 | X | | | – | – |
| 1 | 151 | 15 | 13 | 4 | 100 | 2104 | – | – | – | G | G | G | G | Dec 21 | X | X | | – | – |
| 1 | 152 | 15 | 19 | 0 | 90 | 2118 | – | – | – | G | G | G | P | Dec 22 | | X | | – | – |
| 1 | 152 | 15 | 19 | 2 | 90 | 2118 | – | – | – | G | P | P | G | Dec 22 | X | X | | – | – |
| 1 | 153 | 15 | 25 | 1 | 90 | 2132 | – | – | – | G | G | G | G | Dec 23 | X | | | – | – |
| 1 | 169 | 15 | 13 | 2 | 80 | 2355 | – | – | – | G | G | G | G | Jan 08 | | X | | – | – |
| 1 | 170 | 15 | 18 | 4 | 0 | 2369 | – | – | – | G | G | G | G | Jan 09 | | X | | – | 2/26/73 |
| 1 | 170 | 15 | 19 | 1 | 0 | 2369 | – | – | – | G | G | G | G | Jan 09 | X | | | – | 2/15/73 |
| 1 | 171 | 15 | 24 | 3 | 30 | 2383 | – | – | – | G | G | G | G | Jan 10 | X | | | – | – |
| 1 | 171 | 15 | 24 | 5 | 10 | 2383 | – | – | – | G | G | G | G | Jan 10 | X | | | – | 2/13/73 |
| 1 | 187 | 15 | 13 | 3 | 0 | 2606 | – | – | – | G | G | G | G | Jan 26 | | X | | – | 3/03/73 (-5) |
| 1 | 187 | 15 | 14 | 0 | 0 | 2606 | – | – | – | G | G | G | G | Jan 26 | X | | | – | 3/03/73 |
| 1 | 188 | 15 | 18 | 5 | 70 | 2620 | – | – | – | G | G | G | G | Jan 27 | | X | | – | – |
| 1 | 188 | 15 | 19 | 2 | 90 | 2620 | – | – | – | G | G | G | G | Jan 27 | | X | | – | – |
| 1 | 188 | 15 | 25 | 0 | 90 | 2620 | – | – | – | G | G | G | G | Jan 27 | X | | | – | – |
| 1 | 189 | 15 | 25 | 0 | 90 | 2634 | – | – | – | G | G | G | G | Jan 28 | X | | | – | – |
| 1 | 189 | 15 | 25 | 3 | 90 | 2634 | – | – | – | G | G | G | G | Jan 28 | X | | | – | – |

- (-4) means Channel 4 has not been received.
  The same applies to (-5) and (-6).

- G means Good, F means Fair, P means Poor.

TABLE 10 (Continued)

ERTS-1 IMAGERY LOG FOR SITES I (HARRISBURG) & 2 (SCRANTON)

### 3.1.1 Air Quality Index from ERTS-1 MSS Information

Over the last decade, the need to quantify the air quality of our nation has become apparent. New organizations, Federal, state and local, have been formed to manage this environmental resource. Though air quality monitoring has been carried on for decades, the sum total of these monitoring efforts at best has been sporadic, poorly planned, and very incomplete in depicting the areal and temporal features on scales larger than 20 kilometers. Major urban areas and industrial zones have been monitored by arrays of in-situ air quality sensors in which the intent was to understand the local or microscale (<20 km) distribution of the emissions and the corresponding variations of air quality; larger - mesoscale (20 - 600 km) distributions have been studied to a much lesser degree. Two or three fragments of mesoscale air quality information come to mind which bear review in order to set the stage for describing our work to date.

During the last ten years, many air quality display computer simulations have been attempted. A large number of these simulations follow a semi-deterministic approach where the pollution emissions of an urban area are mathematically modeled both areally and temporally. Transport and diffusion simulations of these emissions are performed taking into account local weather conditions and in some cases terrain. Displays of the air quality resulting from such simulations are then compared with measured in-situ air quality and the models are then fine tuned for more faithful representations of the quantitative value of air quality. Models for handling total particulates (settleable and suspended), oxides of sulfur, carbon monoxide, etc. exist and follow the general simulation procedure described above. Experience with total suspended particulates (TSP) has shown that there is a considerable difference between calculated and measured values in the urban area and that it is largely a constant offset which is called background TSP. This background TSP is found to vary across the United States but is generally on the order of one-half to two-thirds of the peak urban values monitored. Such a widely distributed TSP we have chosen to call the mesoscale air quality (MAQ). Too few non-urban air quality stations exist in this country to get a firm quantitative measure of this MAQ distribution. National Oceanic and Atmospheric Administration in conjunction with the Environmental Protection Agency and the World Meteorological Organization of the United Nations have a world array of air turbidity sensing stations (approximately 50 in the U.S.) obtaining data toward understanding this mesoscale and even the macroscale phenomena. will be said about this turbidity network data later in this report when MITRE's MAQ index efforts are described. A paper by Flowers, McCormick and Kurfis[6] related analysis of turbidity network data to mesoscale weather movements and rainfall showing the variability of turbidity over the United States.

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[6] E. G. Flowers, R. A. McCormick, and K. R. Kurfis, "Atmospheric Turbidity over the United States, 1961-1966", Journal of Applied Meteorology, Vol. 8, No. 6, pp. 955-962, December 1969.

A second insight into the MAQ has been described by Clodman and Taggart[7] where a correlation of APT pictures from the ESSA 2 satellite was compared with synoptic weather maps of the same time period. On numerous occasions when no major frontal areas were in the eastern United States and the atmospheric water vapor was negligible, large turbid areas of air were present. Clodman correlated these data with ground observations of ceiling and visibility and concluded that the ESSA 2 satellite pictures were showing a large multi-state air quality disturbance.

Thus both reported efforts[6,7] have pointed to the existence of a mesoscale air quality phenomena, and our experiences with the simulations have pointed to a need for quantitative temporal and areal measures of MAQ if we are to manage our air quality control efforts wisely. In the succeeding paragraphs we describe how we are attaining MAQ trends, non quantitative, areally and temporally. If continued correlations with the turbidity network and other Federal, state and local air quality assessments prove to be possible, then ERTS-1 will be a rapid means of mapping turbidity and/or MAQ. Care is required that we screen from our in-situ and turbidity network data all microscale effect. One crude measure has been to apply a population correction to the turbidity network data described below. Other corrections will be pursued in the next nine months of this contact.

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[7] J. Clodman and C. I. Taggart, "Tha Movement of Large-Scale Air Pollution Areas as Determined by Satellite Photography", Unpublished paper for the Director, Meteorological Services Research Branch, Atmospheric Environmental Service, Downsview, Ontario, Canada.

Our investigation in air quality has been in the development of an index of total air pollution burden variation (time and space), and, consequently, calculation of background air quality trends from ERTS-1 data, uses two inputs. The two inputs are (1) the measure of total grayness (reflectance intensity) of one specific test area from sequential ERTS-1 overflights; and, (2) the earth observations of atmospheric turbidity (NOAA/EPA turbidity network with Rayleigh scattering and ozone absorption compensated for) over the same area on dates of ERTS-1 coverage.

The first step is to select the dates of ERTS-1 coverage in which clouds are not present over the test area. Second, compile all the turbidity network data about the test area possible. Such data are gathered on a daily (3 times per day) basis; and therefore good ERTS-1 MSS, all channels, on a relatively cloud-free day becomes the controlling factor for correlation date selection. Days in which turbidity data are not available are days of high percentage of cloud cover; thus, our ERTS data would also be of no value. On the approximately one pass over test site every 18-days schedule, we have found that 1 August 1972, 11 October 1972, and 16 November 1972 had near zero cloud cover and good ERTS imagery.

The basic analytical tool used for the ERTS-1 MSS data has been the intensity map program. The intensity map program (see Appendix E for description of this program) not only prints a thematic map of the root-sum-square value of the reflectance of each channel pixel, but also computes the average grayness statistics for the selected test site for each MSS channel.

The average grayness is, of course, subject to interference by surface objects (heterogeneous nature of the test area) as well as by the total atmosphere. Thus, care must be taken in the test site selection for homogeneity. The Harrisburg training area boundaries are shown in Figure 17. The large, four block area shown is also being analyzed for turbidity variation on a given date.

Since the Turbidity Network [6,8,9] records turbidity using the Volz sunphotometer starting with a raw reflectance measure at 0.5 micrometers, we initially have used only ERTS-1 MSS Channel 4, which includes the 0.5 micrometers range data.

The second major input for analysis in addition to ERTS-1 intensity data, was turbidity network data. Originally operated for the National Air Pollution Control Administration (now part of E.P.A.) by NOAA, the Turbidity Network reports observed and calculated readings of turbidity from sites around the world and in most states on a daily basis. The standard instrument is a Volz sunphotometer. Turbidity network data from seventeen stations about our test area (see Figure 18) for the three optimal ERTS-1 dates (1 August 1972, 11 October 1972, and 16 November 1972), and the days before and after each optimal date, have been analyzed with corresponding daily weather maps to calibrate for rainfall and frontal movement (rainfall was found to have less than 24 hour effect,

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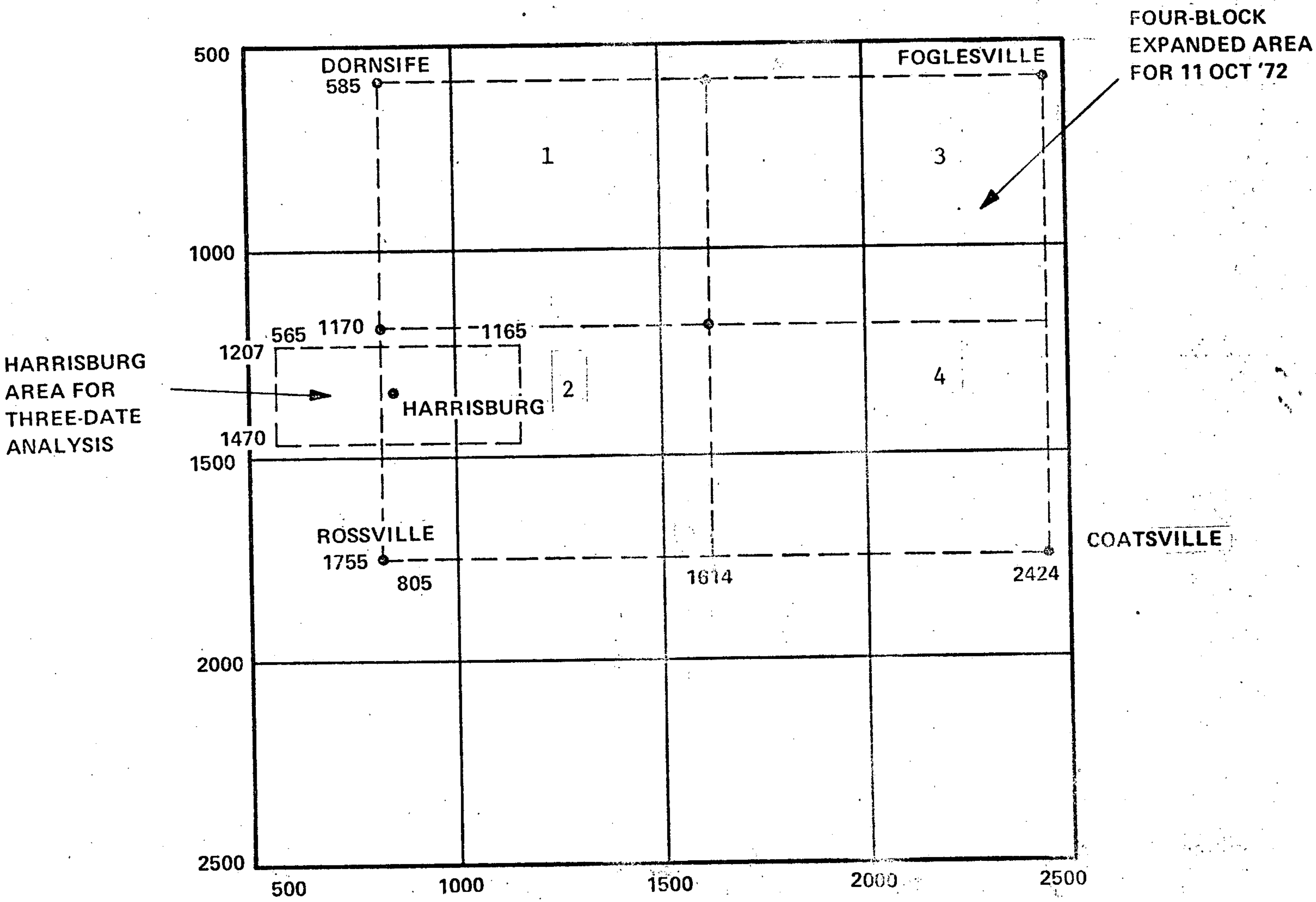
[8] R. A. McCormick, "Atmospheric Turbidity", Presented at 60th Annual Meeting of the Air Pollution Control Association, Paper 67-32, June 11-16, 1967.

[9] "Atmospheric Turbidity Data for the World", U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Vol. 1, July - December 1971.




*ELEMENT BOUNDARIES SHOWN ARE SPECIFICALLY FOR THE 11 OCTOBER 1972 MSS DATA. BOUNDARIES TEND TO CHANGE SLIGHTLY FOR DIFFERENT DATE'S COVERAGE OF THE "SAME" AREA.

FIGURE 17

AIR QUALITY TRAINING AREAS



6

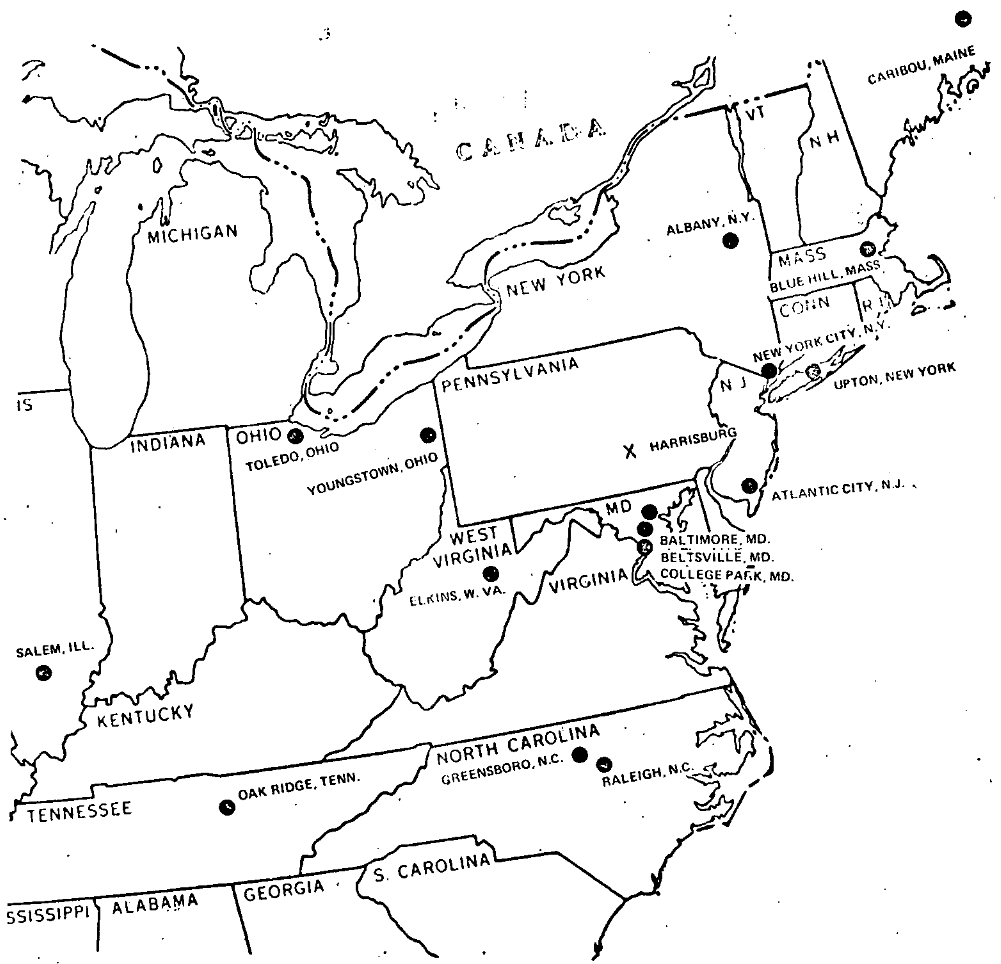



FIGURE 18
TURBIDITY NETWORK STATIONS
REPORTING DATA FOR THE MITRE ERTS-1 INVESTIGATION

mainly lowering turbidity at a given monitoring site, and frontal movement was found to have at least a 48 hour lowering effect.[8] When analysis and calculation was completed for each of about 17 monitoring sites selected from those closest and most relevant to MITRE's Test Site 1, a fundamental vector/gradiant analysis was performed to estimate ground-measurable turbidity at Test Site 1. The figures obtained from these calculations (which essentially reflect, at a given elevation, the extinction produced by the variable amount of dust, haze, and water vapor in the atmosphere-- viz., total turbidity), have been plotted as the available ground truth information that gives an indicator of total turbidity over Test Site 1. Figures 19 and Table 11 show this information in tabular and graphical form.

Because many of the turbidity network stations are located in major metropolitan areas, a second series of calculations were made in an attempt to reduce all reporting stations to a uniform "background" standard unrelated to local sources, based mainly on the work of Larsen[10] with regard to relating total suspended particulate (TSP) to population. Larsen has shown that urban TSP approximately doubles for every order of magnitude change in population of that urban area. In our analysis all turbidity network reporting stations were scaled to a 10,000 person population. Another choice would have been to scale to a rural population density more closely resembling a non-urban background. The

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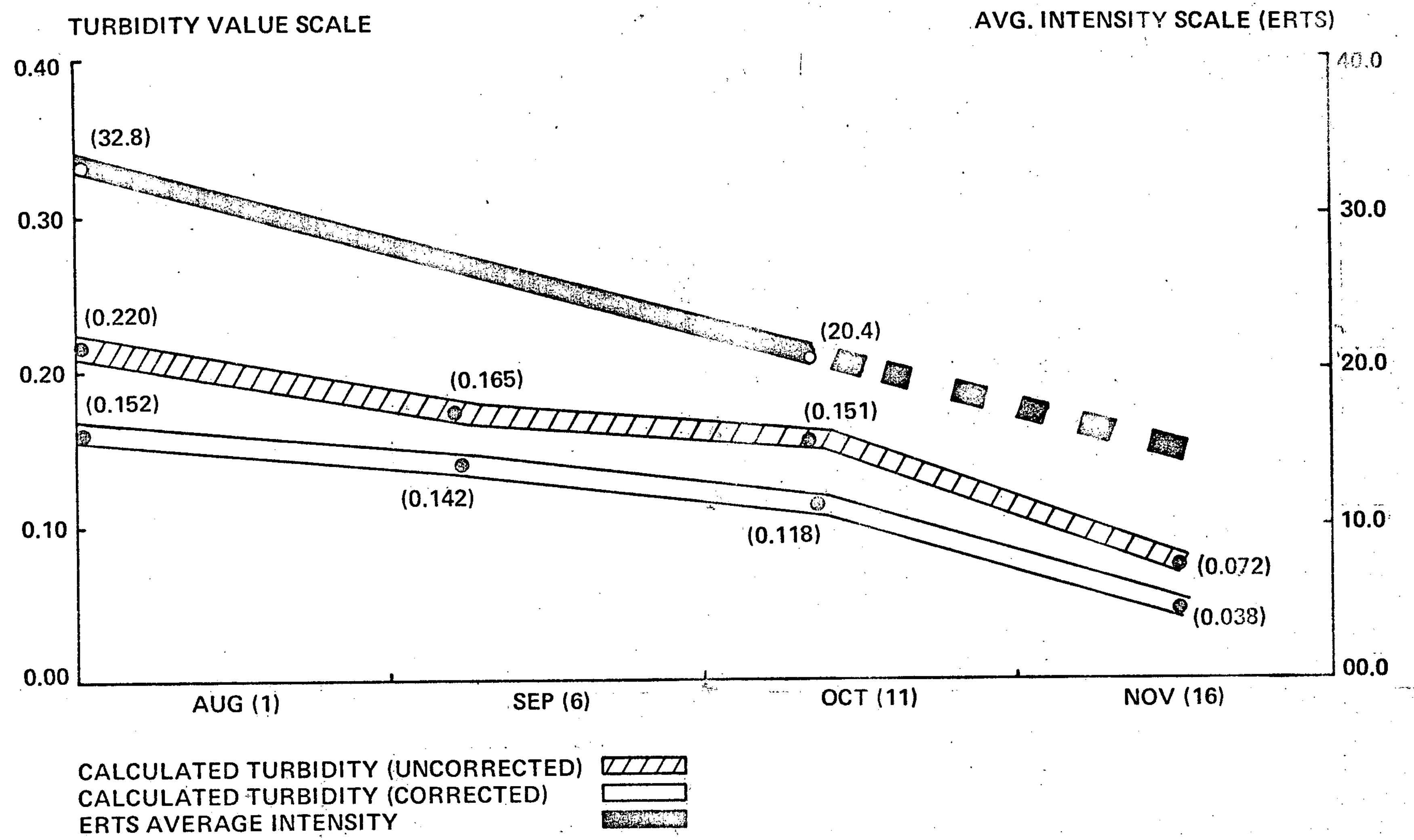
[10] R. I. Larsen, "United States Air Quality", Archives of Environmental Health, Vol. 8, pp. 325-333, February 1964.




COMPARISON OF ERTS-1 AVERAGE INTENSITY VARIATION WITH CALCULATED TURBIDITY VARIATION OVER THE HARRISBURG, PA. TEST SITE

FIGURE 19

ERTS -1 AVERAGE INTENSITY (CH. 4)

| | | | |
|---|---|---|---|
| 1 August 1972 | | 32.8 | |
| 11 October 1972 | | 20.4 | |
| 16 November 1972 | | 24.9 | (Corrected to 12.0) |
| 11 October 1972 | BLK 1 | 22.1 | |
| | BLK 2 | 24.4 | |
| | BLK 3 | 21.8 | |
| | BLK 4 | 26.4 | |
| | TOTAL (AVG) | 94.7 | (23.675) |

CALCULATED TURBIDITY FOR HARRISBURG TEST AREA

| | Uncorrected | Pop. Corrected |
|---|---|---|
| 1 August 1972 | 0.220 | 0.152 |
| 6 September 1972 | 0.165 | 0.142 |
| 11 October 1972 | 0.151 | 0.118 |
| 16 November 1972 | 0.072 | 0.038 |

TABLE 11

CALCULATED TURBIDITY DATA

many possibilities of introducing large specific error in this approach are well recognized, but it is nonetheless felt that, within an acceptable error range, useful correlations between in situ and satellite sensors will yield beneficial applications.

Our data presented in Figure 19 and Table 11 show such a trend. Comparison of ERTS-1 MSS Channel 4 data with ground truth Turbidity Network data for only three dates to this point in the MITRE investigation shows striking correlation, both in the scaled and raw data. As more data become available, and as analysis techniques are improved, ERTS-derived air indices and optimal ERTS air quality monitoring system specifications will be developed and presented.

### 3.1.2 Preliminary Data Analysis: Water Quality

Several attempts were made to identify water quality parameters through the complementary MSS imagery/digital analysis described in Section 2.3.3. ERTS-1 MSS data for both 1 August and 11 October were processed and analyzed for the Harrisburg test site. However, even with supplementary data from recent high-altitude aircraft overflights of the area, all efforts to classify gradations in water quality were unsuccessful. It was concluded by both MITRE and Penn State analysts that the Susquehanna River in the vicinity of Harrisburg presented too heterogeneous a target on the available dates to serve as a useful training area for ERTS-1 water quality investigation. The shallowness of the river at that point and the abundant presence of rock outcroppings, islands, and vegetation added to analysis difficulties. It was agreed that a more suitable training area would have to be located if this stage of the water quality investigation were to progress.

Imagery one frame removed from the test area on 11 October (1080-15192, showing the general Washington - Baltimore area) appeared to be suitable. A color composite of the scene clearly shows a large turbid plume on the Potomac River originating north of Washington and dissipating south of Quantico, Virginia, with several gradations of turbidity apparent in the imagery. While not actually in MITRE's test area, it was felt that analysis of this frame showing extreme turbidity would be very useful as a training device for later analysis of water quality in the Harrisburg training area. In addition, the Washington - Baltimore frame shows a less distinct plume at the mouth of the Susquehanna in Chesapeake Bay. Once parameter identification is successful in the training area, analysis can move to the Susquehanna mouth; and thence analysis can proceed upstream to water quality targets such as the Holtwood and Conowingo Dam Lakes, Safe Harbor Lake, and the Brunner Island effluent, all in MITRE's Test Site 1.

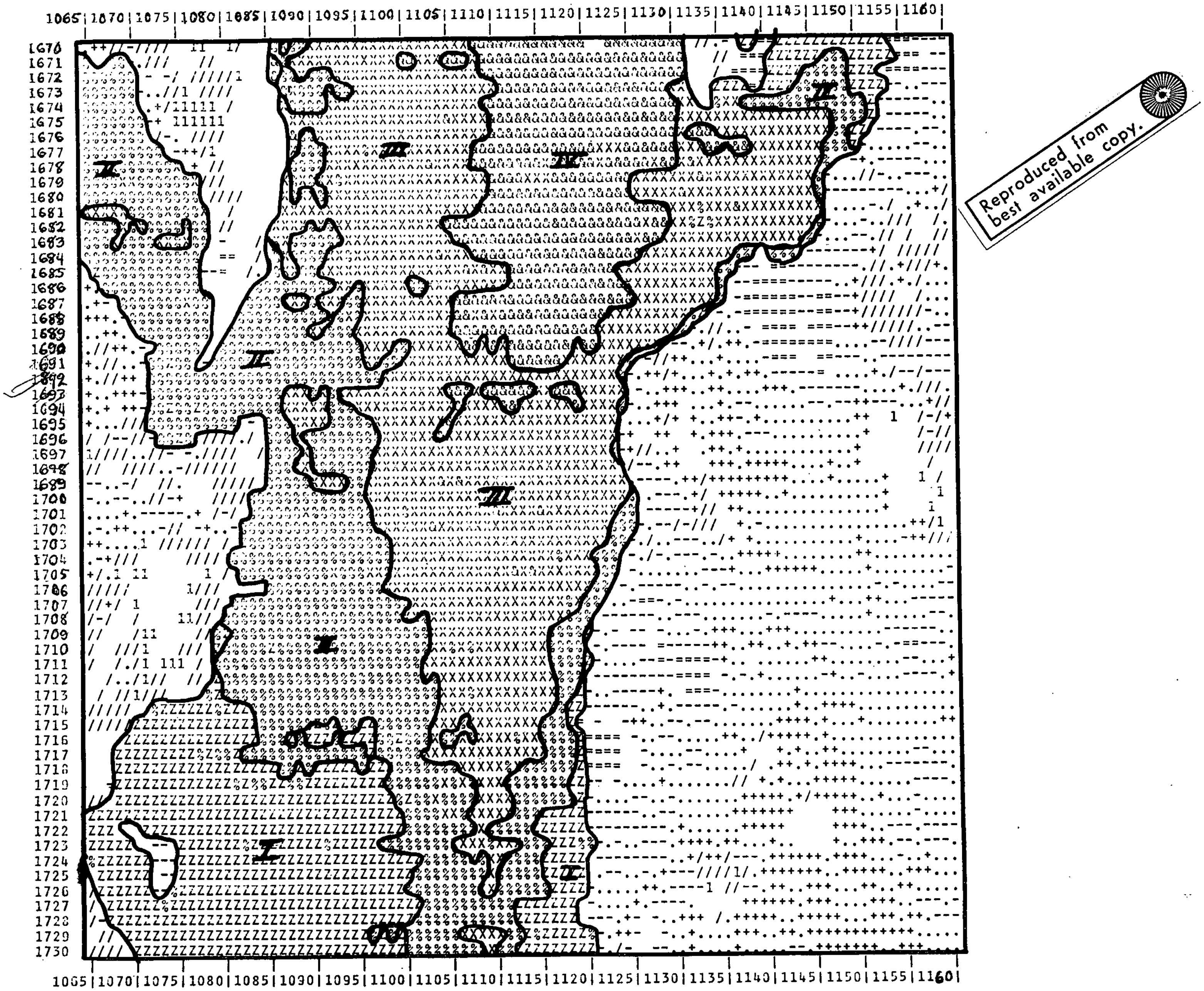
MITRE's first analysis was of a section of the Potomac near Quantico where the plume convergence with relatively clear river water appeared most obvious from the imagery. The first intensity map program run for the area revealed several gradations within the area clearly defined by USGS maps as being in the Potomac river. Subsequently a cluster analysis was performed on the area using a critical distance of 4.5, and four distinct signatures were plotted. Using maps and imagery, the signatures were assigned levels of turbidity I - IV, with I representing the clearest water and IV the most turbid. Figure 20 shows the Quantico training area with the Potomac running vertically down the center of the map. The turbid plume entering from the top of the map clearly shows as category IV. Water entering from Mattawoman Creek at the top right and Chopawomsic Creek at left center shows as a more clear category II. As the creek water and river water converges, a category III mixture appears. Further downstream where the plume has not yet reached, the relatively clear category I is shown.

Since almost no difficulties were encountered in classifying four turbidity categories, an attempt was made to increase the number of

ERTS WATER QUALITY CATEGORIES

I - Clear Water III - Moderate Turbidity

II - Low Turbidity IV - High Turbidity



signatures to six or more. Tightening the critical distance to 1.0 and other cluster analysis manipulations such as increasing the sample size from 150 pixels up to 900 has thus far produced up to six relatively distinct turbidity gradations.

Assuming for the time being that only four to six water quality categories could be readily classified with available techniques, it was decided to move to other points both upstream and downstream along the Potomac where the plume convergence was less clear than at Quantico, but still discernible, and attempt signature identification. The following points at the river miles indicated were selected for this next step in water quality analysis:

| | | River Mile |
|---|---|---|
| 1. | Popes Creek | 42.0 |
| 2. | Cedar Point | 49.0 |
| 3. | Maryland Point | 56.4 |
| 4. | Clifton Beach | 61.7 |
| 5. | Quantico | 67.5 |
| 6. | Mason Neck | 79.0 |
| 7. | Fort Hunt | 86.0 |
| 8. | Wilson Bridge | 90.8 |
| 9. | Hains Point | 94.7 |

For the first attempt at classification at the eight new points a supervised classification program was run using the signatures developed through cluster analysis at the Quantico training area. At all points other than Quantico, however, only a single water category was identified.

Intensity maps of the other points, as well as the imagery, nevertheless showed several gradations. As of this report, analysis is continuing along the following lines obtain signatures at the other eight points:

- Cluster analysis using all channels
- Cluster analysis using selected channels and combinations of channels (channels 4, 5, and 6; and channel 5 alone, may be the most suitable).
- Vary sample size from 150 to 900 pixels
- Tighten critical distance down to 1.0
- Attempt the several combinations of the above variations.

As soon as successful results are achieved on the Potomac training areas (i.e. as soon as digital output at least equals what can be discerned from the imagery) the water quality analysis will shift to the Susquehanna River.

While analysis of water quality on the Potomac has been in progress, a first attempt is also underway to structure an appropriate index of water quality as reflected by levels of turbidity. The following formula has been generated, and it is expected it will be refined and improved as the water quality investigation continues.

$R_{i,j,k}$ = Reflectance in (mw/cm$^2$ - ster) from Channel(k) of Water Type (i) in Test Area (j)

$A_{i,j}$ = Percent Area of Water Type (i) in Test Area (j)

$$A_j = \sum_{i=1}^{n} a_{i,j}$$ = Percent Area of All Water in Test Area (j)

$$\alpha_{i,j} = \frac{a_{i,j}}{A_j}$$ = Percent Area of Water Type (i) in All Water in Test Area (j)

$$\rho_j = \frac{1}{m} \sum_{k=1}^{m} (R_{i,j,k}) \cdot (\alpha_{i,j})$$ = Average Reflectance of Test Area (j) in ($mw/cm^2$ - ster)

### 3.1.3 Preliminary Analysis: Land Use

After successfully using 1 August MSS data for land use classification during the planning and implementation of Phase I, the preliminary land use analysis of Phase II chiefly has employed the 11 October data. Initial analysis involved generation of intensity and uniformity maps for the Harrisburg area test site. To achieve greater detail, 10 grade scales, or symbols, were used on the intensity map; and the intensity map was then projected onto a uniformity map to select good training areas.

Once training areas were selected, but before any further digital classification was attempted, the intensity/uniformity map training areas were compared to recent U-2 photography of the area for a first cut at land use category identification. By this elementary process, some success was achieved in detecting highways, creeks, and of course, the Susquehanna River. However, it appeared that only other areas adjacent to major geographic points could be readily identified.

The next step was to use the U-2 photography to select areas where land use signatures were desired. Cluster analysis programs were then run on these areas and training areas previously selected. This process was continued throughout the training area until over 70 categories were obtained. Since many of the more than 70 signatures were certain to be duplications, a classification program was next run to combine like signatures (i.e., from the tables of distances of the classification program, signatures with limit comparisons of less than 1.0 were merged to form a single signature). The rationale for designating the merged signature was as follows:

| Like Signatures | Merged Signature |
|---|---|
| all same designation | Same designation |
| all unknown | Remain unknown |
| some unknown; some known | Use known designation |
| different designations | "Confusion" designation |

As a result of these manipulations, 56 distinct land use categories remained. However, it was clear that many were still duplications of the same actual land use feature (for example, suburbs identified through supervised analysis of training areas still appeared classified separately from suburbs identified by cluster analysis). Consequently, artificially different categories were merged and assigned the same symbol. The final classification maps which were then run showed 17 distinct land use categories in the Harrisburg area. As this stage of analysis has just been completed prior to submission of this report, the press of time precluded outlining, reduction, and reproduction of the map for this report.

For validation of the digital map, according to the MITRE Data Analysis Plan, the final step was analysis and comparison of the digital map, aircraft photography, and "ground truth" (in this case, USGS maps). Generally very good agreement was found between the digital product and "ground truth". The one major exception was that some areas shown as fields on the USGS maps were digitally identified as suburbs. Temporarily these areas have been put in the "confusion" category; however, as noted in Section 2.3.2, the "ground truth" in this case is from four to ten years old. What was is fact field ten years ago may very well at this point in time have become suburb. Availability of more recent ground truth data, and possibly on-site inspection, is expected to clarify the discrepancy.

Most of the digital analysis for land use was performed by Penn State under MITRE's direction. Concurrently with Penn State's work, MITRE has been gathering the available land use ground truth data with the assistance of the Pennsylvania Department of Environmental Resources, the USGS-Harrisburg, and most especially the Tri-County Regional Planning Commission in Harrisburg. Mr. Oliver Fanning of the Planning Commission has provided MITRE with one of the few recent land use maps of the Harrisburg area to survive the flooding caused by Hurricane Agnes; and he was also most helpful in providing recent land use and transportation quantification for the area. These materials and documents will be most useful as the investigation proceeds to the analysis of land use trends as identified by ERTS-1 MSS data.



C2

## 3.2 Data Analysis Plan Development

As a natural outcome of the Phase I planning and implementation, reinforced and refined by the preliminary ERTS I data analysis performed in the first part of Phase II, the MITRE Data Analysis Plan evolved and was formalized in February 1973 in accordance with contract requirements. When approved by NASA (during March 1973), the Data Analysis Plan forms the data processing and analysis framework for the remainder of the MITRE investigation (March - December 1973).

The objectives that the Data Analysis Plan expects to yield are the following:

- Land use trends for Test Sites 1 and 2.
- Air Quality/turbidity mesoscale trends over Pennsylvania for the August 1972 - October 1973 time period.
- Water quality along the Susquehanna River for one overflight date - 11 October 1972.
- Specifications for an operational monitoring system using an ERTS-type system and selected analysis software for all three media
- Special report on the feasibility of automatic digital signature determination.

Rather than summarizing the 28 page document, it is felt useful to include it as Appendix E to this report.

3.3 Data Requirements Revision

The new or changed data requirements recognized during Phase I, and Phase II preliminary analysis, are found on pages E-31 and E-32 of the Data Analysis Plan in Appendix E.

## 4.0 NEW TECHNOLOGY

There are no new technology developments to be reported at this time.

## 5.0 PROGRAMS FOR NEXT REPORTING INTERVAL

With the approval of the MITRE Data Analysis Plan, expected during March 1973, the investigation will proceed to Phase III. Phase III is Continuing Data Analysis and will involve the following specific tasks:

1. Process available ERTS-1 data for the test sites through 31 October 1973.
2. Compare and correlate results of ERTS-1 MSS data analysis with analysis based on best available in-situ data.
3. Develop the investigation final report (Type III Report).
4. Return procured computer products.
5. Breakdown and return DCP equipment.
6. Achieve experiment results and publish significant findings.

The above tasks are to begin in March 1973 and continue through the termination date of 31 December 1973, at which time the major investigation objectives are expected to be achieved.

## 6.0 CONCLUSIONS

Since we have just completed the preliminary data analysis phase, any firm conclusions at this point would clearly be premature. Nevertheless, a brief discussion of potential conclusions may be useful here.

First, there is nothing that has been revealed in the analysis to date that would indicate that any of MITRE's stated objectives cannot be achieved. On the contrary, results in all three environmental areas - and in land use change particularly - the early results have been most encouraging. The gross level to which air quality has been analyzed thus far in the investigation has potential for much refinement and enhancement toward the objective of developing at least mesoscale air turbidity indices. Likewise, difficulties involved in obtaining repeatable signatures for water turbidity levels on different river sections should be overcome in the near term, so that that effort can proceed toward index development.

No formal work has yet been completed on the second major objective of the investigation - developing specifications for an optimum ERTS-type system for automatic environmental monitoring. Nonetheless, nearly all of the effort and learning taking place in Phase I, II, and III is directly related to development of that final product, and the last several months of the investigation will formally concentrate on indices and specifications development.

As a general statement regarding potential conclusions, it appears at this time that the objectives set for the MITRE investigation will be achieved.

## 7.0 RECOMMENDATIONS

The primary recommendation for improved operation during Phase III analysis is the following:

- Make both ERTS-1 imagery and MSS CCT for MITRE's test sites on a given "good" date available simultaneously to the Principal Investigator.

The recommendation is made in the interests of having more good ERTS-1 data more expediently available for analysis during the period of the investigation. Experience has shown that only approximately 28% of the once-every-18-days coverage of MITRE's test sites results in data products that are useful for further processing. These means only about four additional coverages can be expected for the rest of the investigation. If imagery must first be ordered, received, and reviewed before MSS CCT's can be made available, several weeks of what could be used in productive digital analysis is irretrievably lost. To get maximum use out of available ERTS-1 data, and to process the data expediently so that other aspects of the investigation can go forward, MITRE needs to receive imagery and MSS CCT simultaneously for any given date of coverage.

The second recommendation to be made at this time is the following:

- NASA should establish, at the Goddard Spaceflight Center or some other appropriate location, a central library containing documentation of the various computer programs and digital analysis techniques applied to MSS data. The documentation in the library should be made available free of cost (or at some nominal fee) to all legitimate investigators.

The two main benefits of this recommendation are obvious: (1) costly and time-consuming duplication of MSS software development efforts can be avoided; and (2) a large catalog of existing methods and approaches is available to investigators for planning their experimentation. A great many valuable analysis programs have been developed, for example, by the Jet Propulsion Laboratory, the Environmental Research Institute of Michigan, the Laboratory for the Application of Remote Sensing (Purdue), the Pennsylvania State University, and others. It seems in the common interest of NASA and all investigators to share this wealth of accummulated information on the analysis of ERTS-1 and similar MSS data.

## APPENDIX A

1 September 1972

### STATEMENT OF WORK FOR PENNSYLVANIA STATE UNIVERSITY IN SUPPORT OF MITRE ON ERTS ENVIRONMENTAL INDICES PROGRAM

1) Consultation with MITRE personnel on the data flow and analysis steps for generation of land use shifts, air pollution and water quality indices.

2) Assist in the selection of signatures to be used in MSS tape information in order to classify at least the following:

   (a) Seven land use categories -- agricultural; forest and woodlands; waterways; eroded or eroding areas and areas unproductive due to siltation; urban/suburban build-up areas; transportation facilities; areas involved in construction, mining, and other observable man-made earth moving activities.

   (b) Five water quality categories -- oil, silt, industrial chemicals, eutrophication, unpolluted water.

   (c) Four air quality categories -- clear, light haze, medium haze, heavy haze or turbidity.

3) Perform MITRE requested computer processing of ERTS 1 MSS tapes to define the following:

   (a) Land use in Sites 1 and 2 using the categories named in Task 2a.

| Site | Latitude | Longitude |
|---|---|---|
| 1 | 40° 45'N | 77° 30'W |
| 1 | 40° 45'N | 76° 00'W |
| 1 | 39° 40'N | 76° 00'W |
| 1 | 39° 40'N | 77° 30'W |
| 2 | 41° 40'N | 76° 00'W |
| 2 | 41° 40'N | 75° 35'W |
| 2 | 41° 00'N | 75° 35'W |
| 2 | 41° 00'N | 76° 00'W |

(b) Land use shift over one year of ERTS I data.

(c) Water quality in the major streams of Sites 1 and 2. This should include a mile by mile determination of the categories listed in Task 2b.

(d) Air quality at Sites 1 and 2 to the categories listed in Task 2c. Other categories may be added as the knowledge of ERTS imagery grows.

(e) Assist in the preparation of charts, maps, etc. on the non-imagery analyses.

Remote job entry and output transmission to MITRE/Washington may be requested using an IBM 2471 terminal.

4) Perform photo interpretation on all ERTS 1 MSS imagery received over one year necessary to:

(a) Analyze at least 20 specific targets to be defined later. As examples, plumes (air and water) from specific industrial sites will be watched and areas in which the soil has been removed monitored.

(b) Corroborate the non-imagery determinations outlined in Tasks 2 and 3, above.

(c) Assist in the preparation of photo-interpretation analysis results. The maximum area of the PI analysis will be no greater than 20,000 square miles, nautical. Some utilization of the General Electric special equipment is to be included if required.

5) Through the Institute of Research on Land and Water Resources of Pennsylvania State University, a subcontract to the USGS for services on the water quality station may be required. If MITRE determines that the station is compatible with their in-situ equipment, a contract between PSU and USGS appears to be the only practicable route at this time. If USGS so selects, some water quality station maintenance by PSU personnel may be required.

6) Perform maintenance on the Data Collection Platform to be placed within one 50 miles of PSU.

APPENDIX B

6 September 1972

Statement of Work for

The Pennsylvania State University

in support of

MITRE on ERTS Environmental Indices Program

The tasks to be performed by the Office of Remote Sensing of Earth Resources/Space Science and Engineering Laboratory at Pennsylvania State University for each phase are given below:

Phase I (1 October 1972 - 31 December 1972)

1) Consult with MITRE personnel on the data flow and analysis steps for generation of indices for land use shifts, air pollution, and water quality.

2) Using ERTS imagery, assist MITRE in the selection of several target areas identifiable by photointerpretive means. Target areas are areas which may lend themselves to classification within broad categories of major interest with the following being typical categories:

   (a) Seven land use categories -- agricultural; forest and woodlands; waterways; eroded or eroding areas and areas unproductive due to siltation; urban/suburban build-up areas; transportation facilities; areas involved in construction, mining, and other observable man-made earth moving activities.

   (b) Five water quality categories -- oil, silt, industrial chemicals, eutrophication, unpolluted water.

   (c) Four air quality categories -- clear, light haze, medium haze, heavy haze or turbidity.

3) Analyze the above target areas and evaluate the potential of developing signatures of ERTS-type data for automatic computer classification into separable categories.

4) Provide an evaluation report assessing the desirability (in terms of cost, manpower, time, etc.) of producing the separable categories by photointerpretation only.

5) Compare photointerpretation procedures with computer processing for purposes of producing maps indicating the various categories determined above.

The geographical areas within which the target areas are to be selected are Sites 1 and 2 as indicated below:

| Site | Latitude | Longitude |
|---|---|---|
| 1 | 40° 45'N | 77° 30'W |
| 1 | 40° 45'N | 76° 00'W |
| 1 | 39° 40'N | 76° 00'W |
| 1 | 39° 40'N | 77° 30'W |
| 2 | 41° 40'N | 76° 00'W |
| 2 | 41° 40'N | 75° 35'W |
| 2 | 41° 00'N | 75° 35'W |
| 2 | 41° 00'N | 76° 00'W |

6) MITRE desires to place a Data Collection Platform (DCP) in the Susquehanna River at a place to be chosen by MITRE. A subcontract between Penn State and USGS appears to be the most desirable route at this time from MITRE's viewpoint. ORSER/SSEL, with the cooperation of the Institute on Land and Water Resources at Penn State, will assist MITRE in establishing the contractual arrangements necessary for placement of such a DCP.

Phase II (1 January 1973 - 30 September 1973)

1. On the basis of items 4 and 5 under Phase I, advise MITRE on the selection of a primary method for production of suitable products.

2. Assist MITRE in the production of such products.

APPENDIX C

8 October 1973

PENNSYLVANIA STATE UNIVERSITY PHASE II STATEMENT OF WORK IN SUPPORT OF MITRE ON ERTS ENVIRONMENTAL INDICES PROGRAM

The prime purpose of MITRE's ERTS-1 efforts is to develop the specifications for an operational environmental quality reconnaissance system capable of showing the areal and temporal changes from ERTS-1 Multi-Spectral Scanner bulk digital data (CCT) and imagery. Such a system specification will cover in general and the spacecraft (S/C) sensor subsystem requirements, the handling and transmission subsystem, and the ground data handling and transmission subsystem. The software specifications will cover all computer (automatic) and manual techniques required to produce land use change, water quality change and air quality change to the limits of ERTS-1 MSS data.

The secondary purpose of MITRE is to determine various levels of environmental quality on two test sites in Pennsylvania. Boundaries of these two test sites were presented in the PSU Phase I statement of work. In order to accomplish this demonstration at least the following products will be produced: (1) four land use maps (four overflight dates) of the two test sites of like quality and granularity, (2) one water quality map (one overflight date) covering the Susquehanna River in the two test sites and (3) the air quality over both sites for every overflight date possible. Data to be analyzed will be selected from the August 1, 1972 - October 31, 1973 time period of ERTS-1 observations.

In order to accomplish these ends MITRE will need from the Office of Remote Sensing of PSU and PSU ERTS-1 experiment personnel over the February 4, 1973 to December 31, 1973 time period (Phase II) on the following specific tasks:

(1) Use of all PSU MSS data analysis software and manual processing techniques for digital and photo interpretation.

(2) Use of the PSU computer(s) to perform most of the primary and secondary purpose analyses outlined above.

(3) A copy (tape and hardcopy) of the present and future (through December 31, 1973 modifications) PSU MSS software for use at MITRE's McLean facility capable of handling up to twenty-four channel aircraft (A/C) and S/C CCT and imagery. MITRE will supply the blank tapes.

No modifications to the PSU software will be made by MITRE without consultation with PSU personnel and no copies of the PSU generated software will be given to any other organization without PSU approval.

(4) Use of PSU library of S/C and A/C digital tapes (CCT) and imagery covering Pennsylvania and neighboring states.

(5) Consulting from both photo-interpretation and digital-interpretation personnel in the accomplishment of both MITRE's prime and secondary purposes.

Some products must be generated by PSU personnel in the performance of this consulting personnel and forwarded to MITRE during Phase II. All computer printouts, image enlargements and enhancements produced at PSU during the course of Phase II requested by MITRE will be forwarded to MITRE by United Parcel Service and/or U. S. Mail within one week of their time of development. This will be standard operational procedure for Phase II.

(6) In order to keep records for scaling purposes and subcontract management, a monthly report by PSU to MITRE will be necessary covering the following. First report will cover February 1973 and last report December 1973.

(a) Technical progress performed during the reporting period.

(b) Each labor charge by PSU personnel - purpose, time expended, cost and time period covered.

(c) Each computer run performed by PSU personnel - purpose, running time, cost and date.

(d) Each computer run performed on PSU computer by MITRE personnel - running time, cost, date.



B

APPENDIX D

WATER RESOURCES DIVISION
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108

January 24, 1973

Mr. J. Earle Painter
Room S220, Building 6
Goddard Space Flight Center, NASA
Greenbelt, Maryland 20771

Dear Earle:

This letter is a request that four additional DCP ID's be included in the list of platform ID's we receive over the real-time teletype link from the NDPF. These DCP's are being field installed on USGS stations in the Susquehanna River basin. Two of the DCP's, ID 6373, and ID 6073, are being installed in cooperation with Ed Ward of the Mitre Corporation, and Professor George McMurtry of Penn State, who have an image-oriented ERTS investigation (GSFC UN 159). A third DCP, ID 6402, was supplied to N. H. Beamer by the EROS office for testing by the USGS Pennsylvania district. Mr. Beamer has worked closely with me and the Susquehanna River Basin Commission in chosing a location for the DCP. The fourth DCP, whose ID is as yet unknown to me, is presently in transit from Duane Preble's shop at MTF to my office. When the DCP arrives, I will inform Jim Williamson of the ID number. The four DCP's are being tested in the Susquehanna as prototype stations for the ERTS-B network we will be proposing. The impetus for DCP's in the Susquehanna was, of course, the flood of Hurricane Agnes. We want the data from the stations in real time because we plan to supply the National Weather Service's River Forecast Center (RFC) in Harrisburg with DCP stream gaging data from the Susquehanna and Delaware River basins.

Our plan to work more closely with the Harrisburg RFC is the basis for my recent request to transfer the NDPF teletype link from Philadelphia to Harrisburg.

In lieu of the impossibility of establishing a real time DCP link to Pete Ward's office in Menlo Park, I am willing to accept his data on my link and will work out a procedure with Pete to get some of his data to him. One pregnant possibility is for me to send his data over the commercial Western Union network. If the cost is not too bad Pete and I will probably go that route for the time being.

Finally, I am enclosing the DRBC's annual report of 1972, which contains some imagery of the Delaware River basin and a plug for the DCS. I thought you might be interested in receiving a copy.

Thanks for your help in keeping our DCS efforts on the right track.

Sincerely yours,

Richard W. Paulson
Hydrologist

Enclosure

cc: N. H. Beamer
Edward A. Ward

TURN DATE OF MATERIAL:

SHIPPING ORDER

APPENDIX D (Cont.'d) SHIPPING ORDER NO. 3475

# THE MITRE CORPORATION

BEDFORD, MASSACHUSETTS 01730

DATE 11/20/72

SHIP TO: U.S. Geological Survey
U. S. Federal Bldg.
4th Floor
Harrisburg, Pennsylvania 17108

PURCHASE ORDER N/A
ACCOUNT NO. 422-01
ORIGINATOR Wheaton/Ward
MAIL STOP W327

ATTN: Dr. Richard Paulson

| ITEM | QUANTITY | SERIAL No. | DESCRIPTION | PROPERTY No. | VALUE |
|---|---|---|---|---|---|
| 1 | 1 | 0069 | (ERTS DCP Signature) Data Collection Platform Assembly (DCP) Model #63A104 1 000-3 Rev B. DCP Electronics S/N EAB-ON-156, DCP Antenna Assembly S/N 154 | N/A | |
| 2 | 1 | 0145 | (ERTS DCP Signature) DATA Collection Platform Assembly (DCP) Model #63A1041000-3 Rev. B. DCP electronics S/N EAB -ON-175, DCP Antenna Assembly S/N 133. | N/A | |
| 3 | 1 | 022 | Platform Tester, Model 47822515861 Rev. 4. | N/A | |

REASON FOR SHIPMENT

Equipment to be used in field on Project 0710, NASA Contract #NAS-5-21842

LOCATION OF MATERIAL: [illegible] PURCHASING AGENT OR DESIGNEE:

ESTIMATE WEIGHT: DEPT. APPROVAL:

SHIP VIA: BEST WAY ☐ COLLECT ☐ AIR FREIGHT ☐ INSURED ☐

Do not write in this block

Checked by ______ Waybill No. ______ REMARKS ______

Date Shipped ______ Weight ______

Via ______ No. of Units ______ SHIPPING APPROVAL ______

CF 84-3



ORIGINATOR

APPENDIX E

# INVESTIGATION OF ENVIRONMENTAL INDICES FROM EARTH RESOURCES TECHNOLOGY SATELLITE

PR 568, MMC 200

DATA ANALYSIS PLAN

February 1, 1973

The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, Virginia

THE MITRE CORPORATION

WESTGATE RESEARCH PARK
McLEAN, VIRGINIA 22101
(703) 893-3500

14 February 1973 D20-718

ERTS Contracting Officer, Code 245
National Aeronautical and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Re: DATA ANALYSIS PLAN, PR-568/MMC# 200, Environmental Indices from ERTS-1 NAS 5-21482

Gentlemen:

The MITRE Corporation is pleased to submit the attached revised Data Analysis Plan. This Plan will be our method of handling ERTS MSS during Phase III - February 1, 1973 through December 31, 1973. Output of this endeavor will yield the following:

(1) Land use trends for two test areas in Pennsylvania over the August 1972 - October 1973 time period.

(2) Air quality/turbidity mesoscale trends over all of Pennsylvania over the August 1972 - October 1973 time period.

(3) Water quality along the Susquehanna River for one over-flight date, October 11, 1972.

(4) Specifications for an operational system using an ERTS-type system and selected analysis software for all three media.

(5) Special report on the possibility of automatic digital signature determination.

Questions concerning this report should be directed to the undersigned at (703) 893-3500, extension 2771, or to Mr. Edward A. Ward at (703) 893-3500, extension 2237.

Sincerely,

Richard S. Greeley
Principal Investigator
Associate Technical Director
Systems Development Division

RSG:EAW:eao

cc: Mr. Arthur Fihelly (1)
ERTS Technical Officer
Code 430
Goddard Space Flight Center
Greenbelt, Maryland 20771

Dr. William Nordberg (2)
ERTS Project Scientist
Code 650
Goddard Space Flight Center
Greenbelt, Maryland 20771

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LIST OF ILLUSTRATIONS

# DATA ANALYSIS PLAN

## 1.0 INTRODUCTION

This Data Analysis Plan (DAP) is the plan of work for MITRE's Phase III, Continuing Data Analysis Phase. This DAP is a replacement for the preliminary DAP submitted in the MITRE proposal, "Investigation of Environmental Indices from the Earth Resources Technology Satellite", M71-16 Revision 1, dated 14 February 1972.

The DAP plan calls for eleven months of analysis following the completion of Phase II Quick-Look Phase, with a completion date of 31 December 1973. No increase in funds is requested. Use of funds initially earmarked for ground truth hardware in our proposal have been redirected to cover techniques development support at Pennsylvania State University (PSU) and an end date extension of three months. This extension was due to late delivery of ERTS-1 products. The ground truth hardware and operational support is being supplied to this project without charge by the United States Geological Survey Harrisburg Office in conjunction with their ERTS-1 Susquehanna River experiments and their on-going water quantity or quality programs.

### 1.1 Objectives

The objectives of this investigation, as stated in our proposal, are to develop, demonstrate and verify the capability to calculate indices of specific environmental characteristics from ERTS space observations. All efforts are being made to devise a fully automatic approach for handling ERTS products to produce the following outputs.

- Environmental thematic maps of land use, water quality, and air quality.
- Environmental temporal and areal trends (indices) covering selected observation dates within the August 1, 1972 through December 31, 1973 time period.
- Specifications for the procedure(s) and system(s) developed to produce the indices and thematic maps.

The DAP plan presented here, however, requires several operations in which manual- man in the loop- processes are required. Success in the elimination of these "manual" operations is our ultimate goal and the specifications of the most realistic system will be the major product of this contract.

## 1.2 Environmental Indices

Three categories of environmental indices are being developed covering the following characteristics.

Shifts in land use with emphasis on:

- agricultural areas
- timber lands
- waterways
- urban/suburban areas
- eroded areas
- transportation
- construction, strip and open pit mining, other man-disturbed areas

Pollution of inland lakes and rivers with emphasis on:

- oil spills
- algae blooms
- other surface observables
- silting of dams and waterways

Pollution of urban and rural air with emphasis on:

- atmospheric turbidity
- damaged vegetated areas

More emphasis, however, is being placed on land use shift and air pollution. See section 2.0 for reasons for this change in emphasis.

Each index will be a combination of measurements of one or more parameters observed from space into a number or set of numbers which can serve a useful purpose in characterizing that portion of the environment.

The indices outlined above have been suggested from consideration of the responsibilities of the council on Environmental Quality, the Environmental Protection Agency- Headquarters and Region III, and various federal and state agencies responsible for protecting and improving the environment of the nation. Table I contains a list of specific point and area training areas within the two test sites (Harrisburg area and Wilkes-Barre, Scranton area) selected.

There are three major uses of these indices. First, the indices will provide an initial measurement of the status of the environment. There are many portions of the environment for which currently we do not have a comprehensive description. For instance, we do not have nationwide or even statewide compilation of land use. Also we do not have a complete picture of surface water pollution across the country. Second, these indices calculted from measurements taken over a period of time will indicate trends in the state of the various elements of the environment. For instance, we should know how much land area is being shifted from farmland to suburban housing and shopping areas, and how much estuary and coastal land area is being drained and built up. We should be able to measure how overall pollution is increasing or decreasing as major governmental programs get under way. Third, changes in the values of certain indices can in come instances alert us to take rapid action in case of a sudden deterioration of that portion of the environment.

| SITE | TARGET AREA | TARGET QUANTITIES | LAND AIR, OR WATER | SUGGESTED BY |
|---|---|---|---|---|
| 1 | HOLTWOOD DAM LAKE | ALGAE, THERMAL, SILT | W | EPA REGION III; PA. W.Q. |
| 1 | CONOWINGO DAM LAKE | " , " , " | W | " " " ; " " " |
| 1 | SAFE HARBOR LAKE | " , " , " | W | " " " ; " " " |
| 1 | CODORUS CREEK LAKE (INDIAN ROCK) | " , SILT | W | " " " . |
| 1 | BRUNNER ISLAND EFFLUENT | THERMAL, CHEMICALS, SILT | W | " " " . |
| 1 | CONEWAGO CREEK MOUTH | THERMAL, SILT | W | " " " ; |
| 1 | LIME KILN AT ANNVILLE | PLUME DYNAMICS & LONG TERM EFFECT ON VEG. | A | " " " . |
| 1 | HARRISBURG | HAZE, ALL AIR & WATER QUALITY PARAMETERS | A,W | - |
| 1 | SUSQUEHANNA RIVER-SUNBURY TO MD. | WATER QUALITY | W | - |
| 1 | LANCASTER | HAZE, ALL AIR QUALITY PARAMETERS | A | STATE OF PA. |
| 1 | YORK | " , " " " " | A | " " " |
| 1 | SWATARA CREEK MOUTH | SILT | W | USGS/HARRISBURG |
| 1 | CONESTOGA CREEK MOUTH | SILT, OIL | W | " / " |
| 1 | JUNIATA RIVER MOUTH | SILT | W | " / " |
| 1 | THREE MILE ISLAND | ALL AIR & WATER QUALITY PARAMETERS | A,W | PSU |
| 1 | ALL OF SITE 1 | LAND USE | W,L | - |
| 1 | ALL OF SITE 1 | ANY DENUDED AREAS | L | STATE OF PA. |
| 2 | ALL OPEN PIT MINES | LINEAR DIM., AREA, & VOLUME; PH, THERMAL | L,W | EPA REG.III; PA. W.Q.O. |
| 2 | " REFUSE BANKS | " " , " , & " ; " " | L,W | " " " ; " " |
| 2 | SUSQUEHANNA RIVER | ALL WATER QUALITY PARAMETERS | W | - |
| 2 | " " AT DANVILLE | " " " " | W | - |
| 2 | " " AT HUNLOCK CREEK | " " " " | W | - |
| 2 | SCRANTON | HAZE, ALL AIR QUALITY PARAMETERS | A | STATE OF PA. |
| 2 | WILKES-BARRE | " , " " " " | A | " " " |
| 2 | ALL OF SITE 2 | LAND USE | W,L | - |
| 2 | " " " 2 | ANY DENUDED AREAS | L | STATE OF PA. |

TABLE 1

Possible ERTS Point and Area Training Areas

## 2.0 DAP CHANGES

In our original DAP, three tasks were of a different design and complexity than being presented here-- (1) the use of data collection packages (DCP's) for ground truth, (2) the use of aircraft underflight data in the signature analysis procedure of the ERTS-1 satellite multispectral scanner (MSS) data, and (3) the depth in which each media (land, water, and air) are being analyzed.

The two DCP's supplied are being deployed along the major river of Harrisburg test site in cooperation with the U.S. Geological Survey--Harrisburg Office (USGS/H). Results from these stations and two stations being deployed by USGS/H in this river basin will give some insight into the dynamics of river water quality and quantity but are too few in number to give sufficient areal and temporal information to correlate with results derived from MSS tapes and imagery.

Many more in-situ sensor stations are needed to supply sufficient water quality ground truth. Federal and state in-situ stations have been examined and found to be too few in number and/or reports to give satisfactory water quality areal and temporal ground truth information.

The second major change is the use of aircraft (RB-57 and/or U-2) color and color infrared (IR) photography in the signature analysis process. Work performed in Phase II, the Quick-Look Phase, has uncovered the need for higher resolution imagery than ERTS-1 imagery and more recent land use information than obtainable from USGS 7.5 and 15 minute topographic maps presently available for our two test site areas. See Section 3 for a detail description of how computer derived land use maps are compared with U-2 and/or RB-57 photography for signature improvement development for digital data analysis. Such a comparison was found to be necessary in order to reach the levels of classification required to produce the list in Section 1.2.

The third change is in the depth in which each media (land, water, air) is to be covered in Phase III. Land use indices (trends) can be developed satisfactorily to levels shown in Section 1.2 with the use of recent aircraft color and color IR photography for selected test areas. The air pollution indices approach is being performed using the EPA/NOAA atmospheric turbidity data network (see Section 3 for description of this network and data). The water quality indices development, however, needs ground truth data in synchronization with the ERTS spacecraft and for aircraft overflights. All water quality data bases which might provide such ground truth data have been examined and found to be deficient from either area (granularity) point-of-view or the temporal point-of-view. Thus it has been decided to spend our remaining resources on the land use and air pollution indices and to perform a water quality index analysis for only one overflight date to prove out the acceptability of the approach presented in Section 3. Since the water quality approach is similar to the land use approach and thus exercise of the approach for land use over several observation dates will be sufficient to develop the systems specification for the final report presentation, it was felt that this de-emphasis was warranted at this time.

## 3.0 DETAILED DESCRIPTION OF THE DATA ANALYSIS APPROACHES

### 3.1 General Remarks

A step-by-step analysis system has been designed for machine and manual processing of ERTS data. Basically the software involved in the data analysis system is a combination of existing training area classification programs with a next-generation extension of cluster analysis techniques similar to those developed by the Laboratory for Applications of Remote Sensing at Purdue University.[1] Manual imagery interpretation is used to complement and verify computer analysis. The whole system comprises four main levels of data processing:

- Preliminary Reduction: MSS Scan line and element limits of CCT are set to determine the area to be examined; cloud cover is identified and blanked out; definable spectral boundaries are delineated.
- Level 1 Mapping: Ground truth data and MSS digital output are compared to select best training areas and classification of features within and near those areas are performed using supervised analysis software.
- Level 2 Mapping: Signatures within and near training areas are again determined independently by applying un-supervised analysis software (cluster analysis) and comparing to results from Level 1 supervised analysis.
- Level 3 Mapping: With approximately 75 percent of the area now generally defined, the final phase is a reiteration and refinement of Level 1 and Level 2 procedures so that the maximum possible amount of area can be classified.

Each of the four main data processing phases will be discussed in more detail.

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[1] H. Swain and Staff, LARS Purdue University "Advancements in Machine Processing of Multi-spectral Data." Fourth Annual Earth Resources Program Review (NASA, January 1972).

3.2 Signature Analysis Software Description

The preliminary reduction involves reviewing ERTS imagery to identify and define the boundaries of the selected test site or sites. Scan line and element limits are determined for an area of ERTS imagery which corresponds to the boundaries of the chosen test site. From these limits a tape is generated using the Pennsylvania State University Program (SUBSET[1]) which thus becomes our working tape. The main purpose of this phase is to reduce analysis of extraneous data and to avoid costly bypassing of unwarrented data if further analyses of the data are necessary.

The next step is the use of the PSU intensity map program, (N-MAP[2]). This program generates a vector representation to each observation and then develops an output map showing the RMS of the intensity pattern of reflected sunlight. That is, let $\bar{X}_{i,j,p,}$ represent the value of reflected energy sensed in channel (p) for a single element (j) in scan line (i). The geometric length of the vector is defined by

$$||\bar{X}_{i,j}|| = \sqrt{\sum_{k=1}^{p} \bar{X}^2_{i,j,k}}$$

This length is transformed into a percentage of the maximum possible length, M, which is then used for computer mapping of the test site.

$$M = \frac{||\bar{X}_{i,j}||}{\sqrt{128^2 p}}$$

128 = number of discrete levels (grey scales) in each channel (p) in the MSS data recorded on CCT.

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[1] A more complete documentation of this program may be found in Borden and Lackowski, ORSER-SSEL Technical Report 3-71: SUBSET Program Description, The Pennsylvania State University (October 1971).

[2] Borden, F. Y. ORSER-SSEL Technical Report 2-71: NMAP Program Description, The Pennsylvania State University (October 1971).

The digital N-MAP is compared with the U.S. Geological Survey (USGS) topographic maps and underflight imagery to determine if the correct section of ERTS imagery was selected.

In the next phase of the reduction the PSU program U-MAP[3] is used to compute the absolute Euclidean distance (d) to determine uniformity of each pixtel to its neighbor.

$$d^2 = \sum_{i=1}^{p} (\bar{X}_{1i} - \bar{X}_{2i})^2 .$$

Four distances are computed for each observation $\bar{X}_{i,j}$ using neighboring observations $\bar{X}_{i+1,j}$, $\bar{X}_{k,j+1}$ and $\bar{X}_{i+1,j+1}$. They are defined as follows:

$$D^2_{1,i,j} = \frac{1}{d_1} (\bar{X}_{i,j} - \bar{X}_{i,j+1})^2$$

$$D^2_{2,i,j} = \frac{1}{d_2} (\bar{X}_{i,j} - \bar{X}_{i+1,j})^2$$

$$D^2_{3,i,j} = \frac{1}{d_3} (\bar{X}_{i,j} - \bar{X}_{i+1,j+1})^2$$

$$D^2_{4,i,j} = \frac{1}{d_4} (\bar{X}_{i,j+1} - \bar{X}_{i+1,j})^2$$

The values of $\frac{1}{d_k}$, (k = 1, 2, 3, 4) represent the spatial increments separating two neighboring elements. $D'_{i,j}$ is assigned to the maximum distance computed from the above equations. This value is then translated to a 0-100 scale represented by $D_{i,j}$

$$D_{i,j} = \frac{100\ (D'_{i,j} - D_{min})}{D_{max} - D_{min}}$$

$$D_{min} = 0 \qquad D_{max} = \sqrt{128^2\ p}$$

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3Borden, F. Y. ORSER-SSEL Technical Report 2-71: UMAP Program Description, The Pennsylvania State University (October 1971).

Areas which have wide spread uniformity (i.e. small values of $D_{i,j}$) are chosen as possible training areas. These training areas are again cross-checked with USGS maps and underflight imagery to keep the area of interest pinpointed.

Level 1 Mapping will make optimum use of ERTS imagery, aircraft underflight imagery and U-MAP to determine optimum training areas. Once these are defined, a preliminary attempt is made at classification using the PSU STATS[4] program. The statistical analysis of the data includes the following signature information.

| | |
|---|---|
| mean | $\mu_1 = E\ (X) = XF(X)$ |
| variance | $\sigma^2 = E(X^2) - \mu^2$ |
| standard derivation | $\sigma = \sqrt{\sigma^2}$ |
| covariance | $C = E(XY) - \mu_1 \mu_2$ |
| correlation coefficient | $\rho_{12} = \dfrac{E\left[(X-\mu_1)\ (Y-\mu_1)\right]}{\sigma_1\ \sigma_2}$ |

For any category, a "good" signature on each ERTS channel will be defined as one with a low standard deviation and/or a bell-shaped histogram of pixtel D values.

While this may identify the training areas, there still will be adjacent non-uniform areas which need classification. A-CLASS[5] is the PSU program that attempts to classify these areas by using the signatures just determined in STATS. The classification is done according to the angle of separation, $\theta$, between vectors. In general, let $\bar{A}$ and $\bar{B}$ be vectors, (d) the distance between their end point, ($\theta$) the angle between $\bar{A}$ and $\bar{B}$,

$$\sin\ (\frac{\theta}{2}) = \frac{d}{2}$$

$$\theta = 2\ \sin^{-1}\ (\frac{d}{2}).$$

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[4]Borden and Lackowski, ORSER-SSEL Technical Report 5-71: STATS Program Description, The Pennsylvania State University (October 1971).

[5]Borden F. Y. Technical Report 6-71: A-CLASS Program Description, The Pennsylvania State University (October 1971).

For ERTS classifications the angles between a standard langth vector (I) and all known signatures (from STATS) are computed. $\theta_{min}$ is the minimum angle computed using signature category (A). $\theta_{min}$ is tested against a pre-determined critical angle, $\theta_c$. If $\theta_{min} < \theta_c$ the vector (I) will become classified as category A, otherwise it will be classified as "other". We proceed in this manner until the maximum possible number of vectors are classified into categories, that is, until the number of observations in "other" is one percent or less. As a final step photo interpretation of imagery is performed to verify results or correct misinterpretations.

Level 2 Mapping is the reduction of remaining unknowns in the data analysis effort using an unsupervised-automatic procedure. Here, cluster analysis (A-CLUS[6]) is combined with aircraft visible and infrared imagery to classify particularly small or non-uniform areas. A-CLUS uses unsupervised classification by developing its own set of signatures. Cluster analysis randomly selects the required number of sample points from the data. A trial group of centroids is determined from the first scan line of data using a critical angle, $\theta_c$. That is, for vectors $Z_1$ and $Z_2$, ($\theta$) the angle between, if $\theta < \theta_c$ vector $Z_1$ becomes the first centroid $C_1$. If, however, $\theta > \theta_c$ $C_1 = Z_1$, and $C_2 = Z_2$. Every other vector is checked against the initial centroids using the same criteria. The centroids coordinated are recomputed with each observation assigned to it, as is a value of standard deviation. Once all observations have been considered small unrepresentative clusters are dropped. Any clusters overlapping one another by one standard deviation are combined. This process continues till 10 clusters remain. This program is continued for all non-uniform areas until the maximum possible classifications are made.

The final phase in the ERTS data analysis system (Level 3) consists mainly of reiteration, refinement, and optimum use of all earlier

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[6] Turner, B. Cluster Analysis of Multi-Spectral Scanner Remote Sensor Data. The Pennsylvania State University Journal Paper 4147 (1 March 1972).

addressed techniques. In some cases it will be useful to redefine smaller areas or to repeat previous steps. These choices will be made in order to culminate with the most efficient distillation of data into useful reliable information.

## 3.3 Data Analysis Plan Details for Land Use, Water Quality, and Air Quality

From the general introduction explaining the analysis and validation techniques to be applied in the Data Analysis Plan, we now proceed to a description of how the Plan applies specifically to the three environmental categories of interest: land use, water quality, and air quality.

### 3.3.1 Land Use Analysis

The objectives of the analysis of land use data are (1) development, if feasible, of signature variation algorithms which will eventually permit purely digital analysis of land use trends; and (2) development of the specifications for the optimum ERTS-type system to provide the data required for signature algorithm generation and update. To build toward the achievement of these two main objectives, both photographic interpretation (PI) and digital interpretation (DI) are employed. The PI methods employed in land use analysis include ERTS and aircraft photointerpretation (color and color infrared), and comparison of these results and conventional topographic and land use maps with maps derived by analysis of digital ERTS data.

The interrelated PI/DI analysis proceeds through several phases. First, DI analysis is performed on ERTS data tapes of the first test area of interest (Harrisburgh, Pa. area) on a particular date for Preliminary Reduction and Level 1 Mapping. USGS topographic maps, ERTS photography, and aircraft photography if available are used to locate the test area on digital maps and define training areas. The STATS and A-CLASS programs described above are then run on the selected training areas to classify features and provide tables of statistics on signatures of interest. These signatures include, at this stage of investigation, agriculture, forest and woodland, waterways, erosion areas, urban/suburban, transportation, earth moving events, and wetlands/estuaries. Throughout Preliminary Reduction and Level 1 Mapping, there are continual inputs and feedback consisting of aircraft photography, conventional maps, and ground truth used to verify and enhance the digital analysis of ERTS-1 MSS data.

With the knowledge gained to this point, analysis proceeds to Level 2 Mapping. Here the A-CLUS program described above is run on the ERTS-1 MSS data covering sections of the selected training area where more specific identification and classification of land use parameters is desired. As an oversimplified summary, Level 1 Mapping generally outlines major features in an entire training area, and then Level 2 Mapping provides a more detailed identification and classification of land use features in specific areas of interest in the training area. Experience thus far indicates that after completion of Level 1 and Level 2 Mapping, approximately 75 percent of the training area may be defined in terms of the land use parameters.

Level 3 Mapping, the last mapping stage, is a reiteration, reevaluation, and refinement of the techniques employed in Levels 1 and 2, including the maximum available input of aircraft photography, conventional maps, and other ground truth data. The objective of this level of analysis is the maximum possible definition of land use parameters in the area of interest using state-of-the-art techniques and equipment. Reduction of over-classified areas is performed here.

In applying the Data Analysis Plan to land use parameters, as well as to those of water quality and air quality, interaction between the several levels of digital thematic mapping and aircraft color photography products is necessary for the verification and enhancement of signature information. The interaction is accomplished by use of the Bausch and Lomb Zoom Transfer Scope available for use at USGS, McLean, Virginia and

PSU cartographic devices. Aircraft photography (U-2, RB-57, C-130) will be superimposed on digital thematic maps developed by the techniques described above to improve our determinations of MSS data significance. Our digital maps have an approximate scale of one to 24,000 (7½ minutes USGS) and comment on pixtel areas of about 75 meters square. By superimposing the photographic products on the digital maps through successive reiterations, more accurate signature development is possible.

Once land use parameters in the training area are defined by the procedures described above, the next step for reaching investigation objectives is analysis of the signature information that has been derived. This is accomplished chiefly by comparison of signature information derived from ERTS-1 data with "known" information on the training area. The "known" information sources include land use studies; large scale topographic, geologic and land use maps; low-altitude aircraft photography; and other available ground truth information. The purpose of comparing digital signature information with ground truth land use information is two-fold. First, the accuracy and validity of the digital analysis approach is checked. The approach either is validated, or areas where improvement is needed are identified. In this way, any "weak spots" in the DI analysis techniques can be isolated and corrected. The second reason for comparison of digital and ground truth information at this stage is that it may be possible to detect land use trends using only one flightline date of ERTS-1 MSS data. This is possible because much of the ground truth data (maps, studies) will be at least several years old, and ERTS data may well reveal changes (e.g., urban/suburban development) since the time ground truth information was recorded.

While it may be possible to proceed directly from this point to develop signature algorithms and determine specifications, the total approach up to this point has dealt with a single training area and one date of ERTS-1 data. For more reliable validation, and for an opportunity to detect land use trends from one ERTS observation to another, the entire process is repeated on each available set of ERTS-1 data covering the training area, and sequential observations are available for analysis. Analysis of the signature information over several dates of observation is expected to reveal some changes which would be indicative of changing land use patterns in the training area over time. From this information, in turn, it is hoped that accomplishment of one of the main objectives of the investigation will be possible: namely, the derivation of signature change algorithms which will allow rapid automatic interpretation of land use trends from ERTS-1 MSS digital data. Additionally, analysis of signature information on the same area over sequential dates, and other areas as well for corroboration, will hopefully lead to accomplishment of the second main objective: namely, a delineation of specifications for an optimum ERTS-type system for land use trend monitoring.

Figure 1 shows the data analysis flow for the land use portion of the investigation.

### 3.3.2 Water Quality Analysis

The water quality parameter investigation will be applied after sufficient experience has been attained in analysis of the relatively less difficult land use parameters. The main procedures are essentially the same as in land use analysis, obviating the need for repeating the description of the entire process here. The ERTS CCT is processed by the same software through Levels 1, 2, and 3 Mapping of training areas containing rivers, lakes, reservoirs or other water bodies of interest for the date of interest. The signature verification inputs include the conventional maps and the aircraft photography employed for land use analysis. In addition, the water quality analysis will review and use data inputs from the Environmental Protection Agency's Region III STORET data bank (a data base of water quality measurements for the Region), daily in-situ water quality reports when available, state and USGS/H water quality information, and any available water quality or hydrological studies of the area of interest.

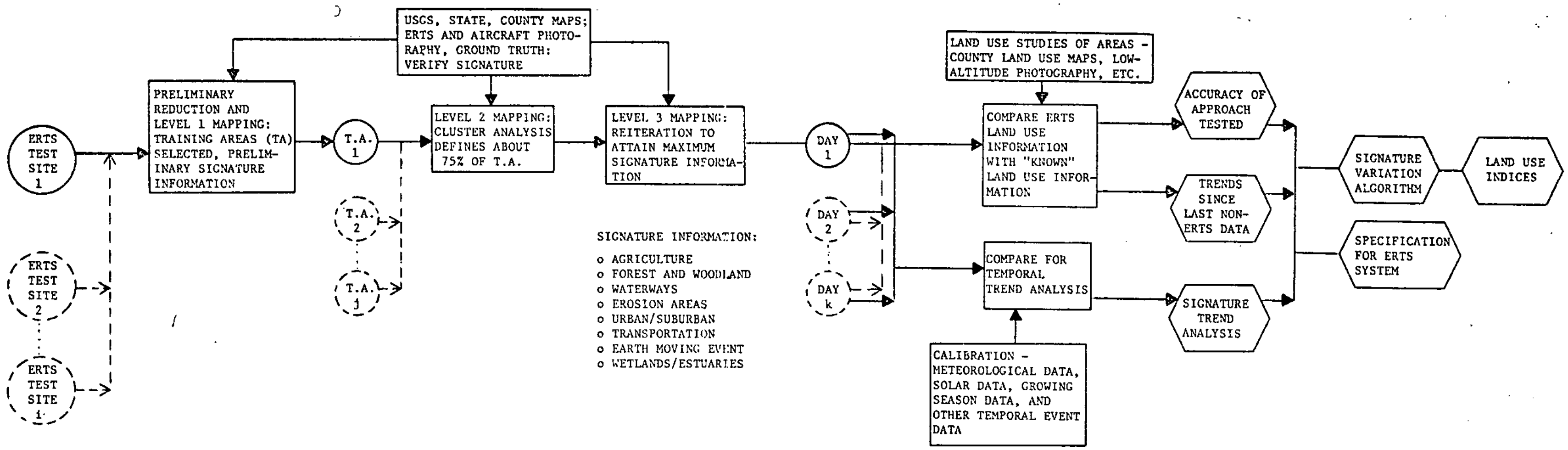


FIGURE 1

ERTS-1 DATA ANALYSIS PLAN: LAND USE

The product of the verified digital analysis is a set of signatures defining as many water quality parameters as possible. With the data currently available from ERTS-1, it appears that discriminant signatures may only be obtainable for turbidity, surface oil, and possibly siltation and chlorophyll. Nevertheless, an attempt will be made to classify signatures for all parameters on the investigation list. In addition to those cited, they include industrial chemicals, eutrophication, and at least five specific water quality characteristics (pH, D.O., B.O.D., temperature, and conductivity).

Once signatures are obtained for training areas by the process described above, the signature analysis of water quality parameters is compared with all available ground truth analysis at or near a given date. The comparison will result in a check on the accuracy of the signature analysis, and if the two analyses cover somewhat different time periods an indication of areal water quality trends may be observable.

From this point it may be possible to attempt directly to derive signature variation algorithms and develop optimum ERTS system specifications. The method for analysis for water quality is similar to that for land, and thus only one over-flight date will be analyzed for the two test sites. Proof of the DI and PI approaches will thus be obtained. Further dates are not warrented because of the inadequacy of good areal and temporal ground truth water quality data.

Figure 2 shows the data/information flow for the Data Analysis Plan applied to water quality parameters but only one date (day) will be produced in this contract effort. (See section 1.3 for details).

### 3.3.3 Air Quality Analysis

Experience thus far in the investigation of environmental categories indicates that air quality is the most difficult for obtaining specific signatures for all the parameters of interest. Initially the major effort is directed toward defining total atmospheric turbidity

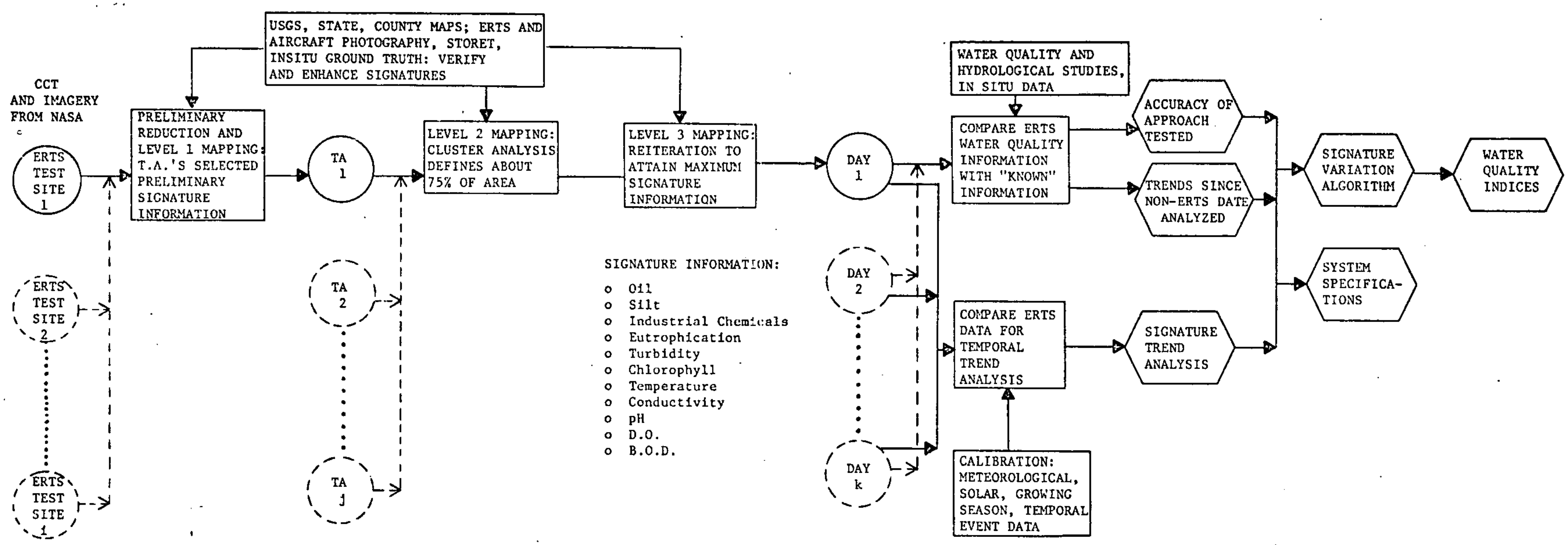


FIGURE 2

DATA ANALYSIS PLAN: WATER QUALITY

over the test area-- mesoscale* analysis. Once this is achieved, an attempt will be made to define the other air quality parameters of interest to the investigation-- microscale* analysis. These include black intensity (soot), brown intensity ($NO_x$), blue intensity (fine particulate), white intensity (moisture), air pollution effect on vegetation, and the specific pollutants $SO_2$, CO, and $O_3$.

The Data Analysis Plan for air differs somewhat from that applied to land use and water. In the first place, there are two approaches rather than one: an analysis of mesoscale air quality, and a separate analysis of microscale air quality. The mesoscale analysis has, as a preliminary objective, characterization of the atmosphere over the entire test area. Microscale analysis, on the other hand, involves specific examination in training areas in an attempt to identify air pollution sources and trends. Each approach will be described in more detail below.

Since the mesoscale analysis is concerned with general air quality trends over a large area, much of the detailed ERTS-1 data analysis previously described will not be required; however, more ground truth data are needed. The ERTS data analysis proceeds to Level 1 Mapping, at which point the general features in the test area are classified and tabulated for a given date. This information is then correlated with validated air quality data made available as ground (or in this case "air") truth. The ground truth primarily consists of measurements in and near the test area, provided by NOAA/EPA Turbidity Network. These turbidity data are supplemented by any air quality data available from Region III National Aerometric Data Information Service (NADIS), the state Commonwealth of Pennsylvania Air Monitoring System (COPAMS), and local agencies. Thematic maps and statistics derived from the ground truth data, when correlated with the ERTS-derived maps and

*The definitions of mesoscale and microscale areas, as used in this investigation, are generally consistent with meteorological definition: the former encompasses on the order of 100 miles square, and the latter, 10 miles square or smaller.

statistics, will provide the basis for developing air turbidity signature algorithms. When the mesoscale analysis is carried out on several different training areas and dates for the test area, it may be possible to observe broad air quality trends and develop indices.

A brief description of the Turbidity Network, primary source for ground truth data in the air quality investigation, may be helpful. The Turbidity Network is operated basically as an adjunct to selected U.S. meteorological measurement stations under the aegis of the National Oceanic and Atmospheric Administration and the Environmental Protection Agency. No station is located within MITRE's test area.

Stations around the test area whose data will be used include Atlantic City (NJ), Beltsville (Md.), Baltimore (Md.), College Park (Md.), Elkins (W. Va.), Toledo (O.), Upton (NY), Washington (D.C.), and Youngstown (O.)[5].

Measurements at each station are taken with Volz-type sunphotometers usually three times a day when line of sight to the sun is cloud free. The instrument measures meter deflection in microamperes at 0.38 $\mu$ and 0.50 $\mu$, which is directly proporational to the spectral irradiance received at the ground station through the atmosphere. At a given elevation, the measurement is related to the extinction produced by the variable amount of dust, haze, and water vapor in the atmosphere--in short, a measure of atmospheric turbidity[6].

In the mesoscale approach to MITRE's air quality investigation, measurements reported from the stations mentioned above are plotted for

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[5] A listing or worldwide stations and their data may be found in the Department of Commerce series Atmospheric Turbidity Data For the World available through the Superintendent of Documents, G.P.O., Washington, D.C. 20402.

[6] A more detailed discussion of turbidity measurement, turbidity coefficient, and related equations are found in McCormick et al "Atmospheric Turbidity Over the United States" in Journal of Applied Meteorology (Vol. 8, No. 6, Dec. 1969, pp. 955-962).

the dates that ERTS coverage of the test area is available. The Turbidity Network data will be analyzed and used in conjunction with meteorological data to develop isopleth maps of the test area at 0.5 $\mu$. These maps are then compared to ERTS-derived average greyness observed from N-MAP in Channel 4 (0.5 to 0.6 $\mu$) statistics to develop correlations. The objective of successful correlation analysis is the development of atmospheric turbidity signature algorithms and the consequent observation of air quality trends based on ERTS data.

The second approach in air quality analysis, microscale, makes use of the same ground truth data as mesoscale, with more specific application to training areas within the test area. Microscale analysis will be conducted only if time permits. The ERTS data analysis for microscale does not stop at Level 1: Digital analysis proceeds through all three levels to provide maximum definition in each training area, and to classify signatures for as many of the air quality parameters as possible. The objectives of the microscale analysis are to identify observable local air pollution trends, pinpoint local sources of air pollution, detect pollution damage to vegetation, and develop signature algorithms. As with land use and water, the final objective of both meso- and microscale analysis of air quality is to develop specifications for an optimum ERTS monitoring system.

Figure 3 shows the data/information flow for air quality data analysis.

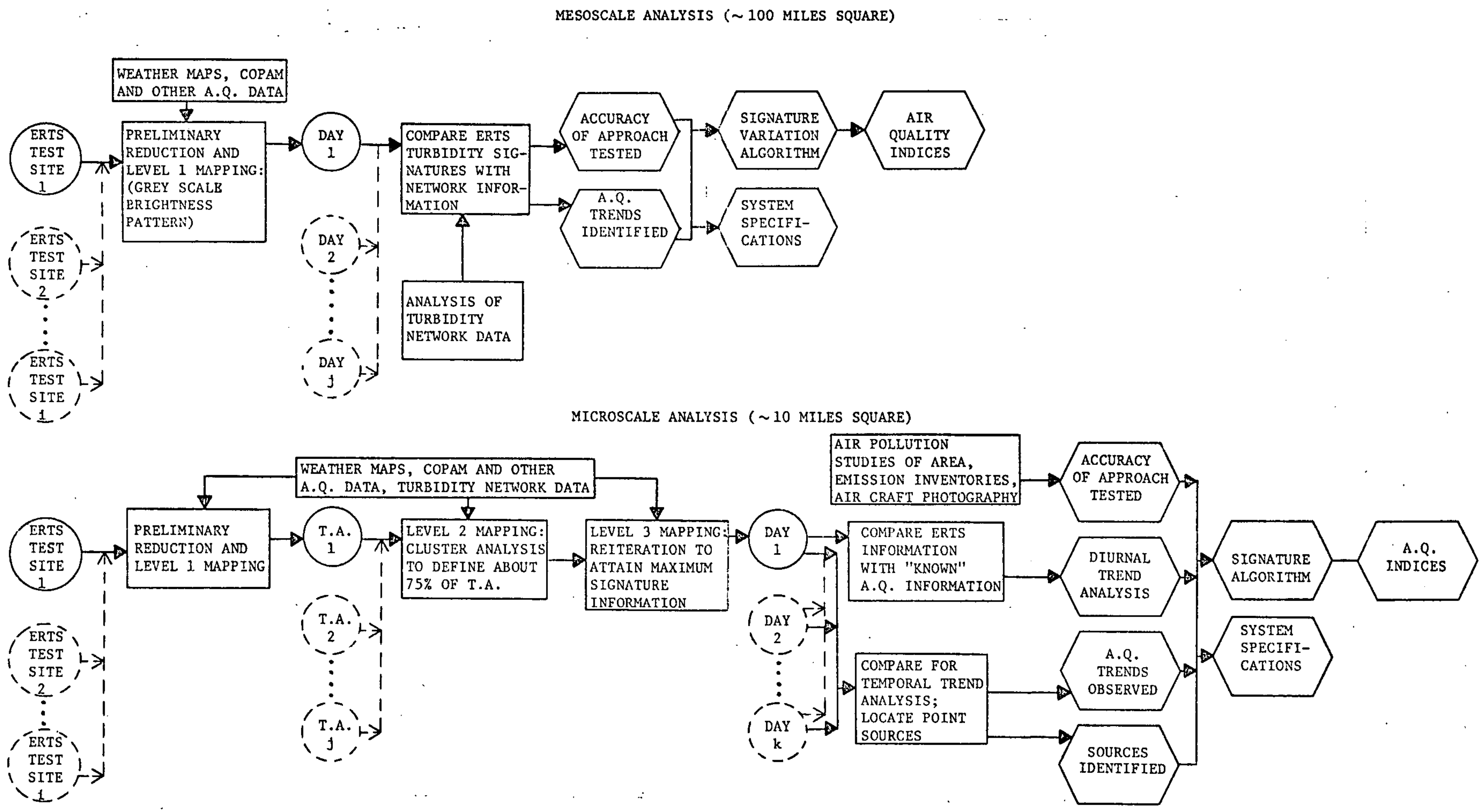


FIGURE 3

ERTS-1 DATA ANALYSIS PLAN: AIR QUALITY

## 4.0 SCHEDULE

The schedule for the completion of the data analysis tasks described in preceeding sections is shown in Figure 4. The schedule is tentative at this point because of the research nature of ERTS-1 investigations. For example, as Figure 5 shows, only eight of 29 possible opportunities for ERTS-1 data over the Harrisburg test site 1 have been acceptable, as of December 1972, according to the first criteria of no more than 20 percent cloud cover. Of these eight, only three thus far have had all four channels recording data adequate for comprehensive digital interpretation (DI) analysis, and all three were portions of the same test site or two consecutive days coverage. Moreover, technical problems involved with collecting and analyzing both ERTS and ground truth data cannot be predicted with accuracy as estimates are made of the time required in each stage of analysis. Because of these factors, we have attempted to allow adequate flexibility in the schedule to make possible the accomplishment of the objectives stated in Section 1.

The schedule essentially follows the development of the Data Analysis Plan as described in Section 3. The first environmental category analyzed, and the one which will involve the bulk of the total investigation effort, is land use. It is estimated that a minimum of three dates for each test site will receive three-level analysis, trend study, and signature algorithm derivation. The initial effort and the majority of total analysis time will be expended on land use. Successful development of the techniques in land use are expected to be applied as a model for the two remaining categories-- microscale air quality and water quality.

With land use analysis serving as the model for signature derivation, and in the expected absence of adequate supportive water quality ground truth data during the period of the ERTS-1 investigation only one date of ERTS coverage is scheduled for comprehensive analysis of water quality

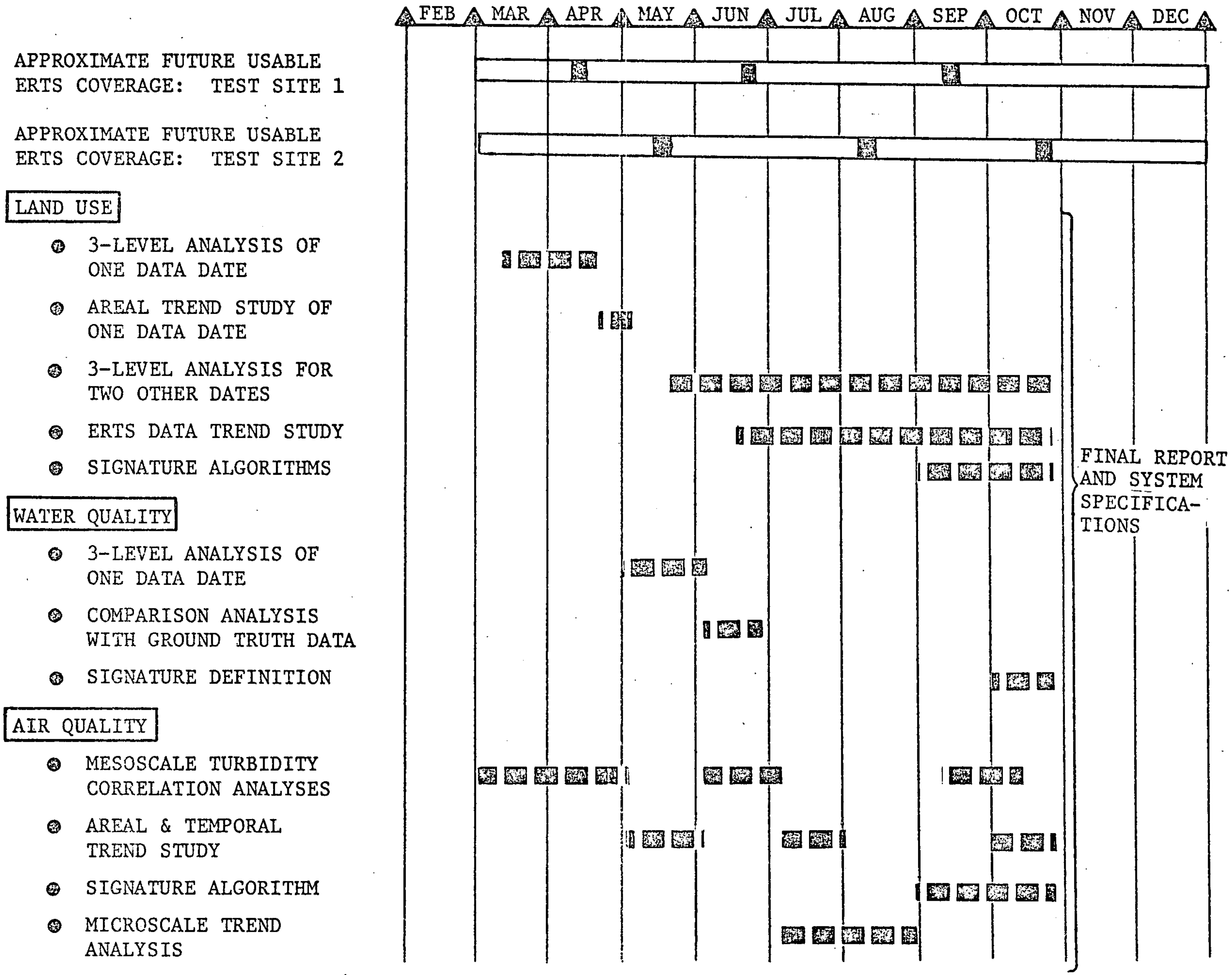


FIGURE 4

ERTS-1 DATA ANALYSIS PLAN SCHEDULE - CY 1973

| I. D. NUMBER | | | | | CLOUD COVER (%) | ORBIT NO. | RBV | | | MSS | | | | DATE | SITE NO. | | REMARKS | DATE RECEIVED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SATEL-LITE NO. | DAYS SINCE LAUNCH | HR. | MIN. | TENS OF SECONDS | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 1 | 2 | | TAPE | IMAGES |
| 1 | 007 | 15 | 12 | 4 | 100 | 96 | G | G | G | G | G | G | G | Jul 30 | | X | - | - | - |
| 1 | 007 | 15 | 13 | 1 | 100 | 96 | F | F | F | G | G | G | G | Jul 30 | X | | - | - | - |
| 1 | 008 | 15 | 18 | 0 | 100 | 111 | G | G | G | G | F | G | G | Jul 31 | | X | - | - | - |
| 1 | 008 | 15 | 18 | 3 | 100 | 111 | P | P | P | G | F | G | G | Jul 31 | X | X | - | - | - |
| 1 | 008 | 15 | 18 | 5 | 100 | 111 | G | G | G | G | G | G | G | Jul 31 | X | | - | - | - |
| 1 | 009 | 15 | 24 | 1 | 40 | 124 | G | G | G | G | G | G | P | Aug 01 | X | | Special Ordered 9/28/72 | 11/6/72 | 11/25/72 |
| 1 | 009 | 15 | 24 | 4 | 20 | 124 | G | G | G | G | G | G | P | Aug 01 | X | | Special Ordered 9/28/72 | 11/6/72 | 11/25/72 (-4) |
| 1 | 025 | 15 | 12 | 4 | 100 | 347 | - | - | - | F | G | G | G | Aug 17 | | X | | - | - |
| 1 | 025 | 15 | 13 | 0 | 100 | 347 | - | - | - | G | G | G | G | Aug 17 | X | | | - | - |
| 1 | 026 | 15 | 18 | 0 | 90 | 361 | - | - | - | G | G | G | G | Aug 18 | | X | | - | - |
| 1 | 026 | 15 | 18 | 2 | 80 | 361 | - | - | - | G | G | G | G | Aug 18 | X | X | | - | - |
| 1 | 026 | 15 | 18 | 5 | 80 | 361 | - | - | - | G | G | G | G | Aug 18 | X | | | - | - |
| 1 | 027 | 15 | 24 | 2 | 60 | 375 | - | - | - | G | G | G | G | Aug 19 | X | | Reviewed at GSFC (No Good) | - | - |
| 1 | 027 | 15 | 24 | 5 | 60 | 375 | - | - | - | G | G | G | G | Aug 19 | X | | Reviewed at GSFC (No Good) | - | - |
| 1 | 043 | 15 | 13 | 0 | 70 | 598 | - | - | - | G | G | P | G | Sep 04 | X | X | Reviewed at GSFC (No Good) | - | - |
| 1 | 044 | 15 | 18 | 2 | 50 | 612 | - | - | - | G | G | P | G | Sep 05 | X | X | | - | - |
| 1 | 044 | 15 | 18 | 5 | 90 | 612 | - | - | - | F | F | P | G | Sep 05 | X | | | - | - |
| 1 | 045 | 15 | 24 | 3 | 10 | 626 | - | - | - | G | G | P | G | Sep 06 | X | | Tape Ordered 10/27/72 | - | 10/26/72 |
| 1 | 061 | 15 | 12 | 5 | 30 | 849 | - | - | - | G | G | G | G | Sep 22 | | X | | - | |
| 1 | 062 | 15 | 18 | 1 | 20 | 863 | - | - | - | G | G | P | G | Sep 23 | | X | Cloud cover 100% over Site 2 | - | 10/30/72 |
| 1 | 062 | 15 | 18 | 4 | 40 | 863 | - | - | - | G | G | P | G | Sep 23 | X | X | Cloud cover 100% in ctr Site 1 | - | - |
| 1 | 063 | 15 | 24 | 2 | 90 | 877 | - | - | - | G | G | G | G | Sep 24 | X | | | - | - |
| 1 | 079 | 15 | 13 | 1 | 0 | 1100 | - | - | - | G | G | G | G | Oct 10 | | X | | 12/6/72 | 11/14/72 |
| 1 | 079 | 15 | 13 | 3 | 10 | 1100 | - | - | - | G | G | G | G | Oct 10 | X | | | 12/6/72 | 11/14/72 |
| 1 | 080 | 15 | 18 | 3 | 0 | 1114 | - | - | - | G | G | G | G | Oct 11 | | X | | 12/5/72 | 11/17/72 |
| 1 | 080 | 15 | 18 | 5 | 0 | 1114 | - | - | - | G | G | G | G | Oct 11 | X | X | | 12/5/72 | 11/17/72 |
| 1 | 080 | 15 | 19 | 2 | 0 | 1114 | - | - | - | G | G | G | G | Oct 11 | X | | | 12/5/72 | 11/17/72 |
| 1 | 081 | 15 | 24 | 4 | 100 | 1128 | - | - | - | G | G | G | G | Oct 12 | X | | | - | - |
| 1 | 081 | 15 | 25 | 0 | 80 | 1128 | - | - | - | G | G | G | G | Oct 12 | X | | | - | - |
| 1 | 097 | 15 | 13 | 3 | 100 | 1351 | - | - | - | G | G | G | G | Oct 28 | X | | | - | - |
| 1 | 098 | 15 | 18 | 5 | 100 | 1365 | - | - | - | G | G | G | G | Oct 29 | X | X | | - | - |
| 1 | 098 | 15 | 19 | 1 | 100 | 1365 | - | - | - | G | G | G | G | Oct 29 | X | | | - | - |
| 1 | 099 | 15 | 24 | 3 | 90 | 1379 | - | - | - | P | G | G | G | Oct 30 | X | | | - | - |
| 1 | 099 | 15 | 25 | 0 | 70 | 1379 | - | - | - | G | G | G | G | Oct 30 | X | | | - | - |
| 1 | 115 | 15 | 13 | 4 | 100 | 1602 | - | - | - | P | G | G | G | Nov 15 | X | X | | - | - |
| 1 | 116 | 15 | 19 | 0 | 50 | 1616 | - | - | - | G | G | G | G | Nov 16 | | X | | - | - |
| 1 | 116 | 15 | 19 | 2 | 10 | 1616 | - | - | - | G | G | G | G | Nov 16 | X | X | Prods. not rec'd as of 12/31/72 | | |
| 1 | 117 | 15 | 25 | 1 | 70 | 1630 | - | - | - | G | G | G | G | Nov 17 | X | | | - | - |

FIGURE 5

ERTS-1 IMAGERY LOG FOR SITES I (HARRISBURG) & 2 (SCRANTON)

signatures at this time. The effort allotted to water quality should be sufficient to define parameter signatures and develop system specifications for remote monitoring of some aspects of water quality.

The air quality analysis effort will concentrate on mesoscale turbidity analysis over a minimum of three dates of ERTS coverage for each test site. If high correlation with ground truth data is achieved, ground air quality trend analysis and signature algorithms will be developed over the period of the investigation. Microscale air quality analysis will proceed through the middle portion of the investigation at a lower level of effort. If successful, the microscale analysis will define localized pollution trends, identify point sources, and locate air pollution sources.

## 5.0 NEW SUPPORT REQUIRED

The DAP presented herein, requires the following support not presented previously in the MITRE original DAP.

- o Aircraft photography of the two test sites once per season. To be supplied by NASA ERTS Project Office.
- o Reduced and calibrated air turbidity data from approximately 18 stations. To be supplied at no cost to this project by NOAA/EPA at Environmental Data Service - Ashville/Division of Meteorology - Research Triangle Park.
- o Use of a Bausch and Lomb Zoom Transfer Scope. To be supplied at no cost to this project by USGS at McLean, Virginia.
- o Water quality and quantity sensors and operational maintenance for two DCP's on the Susquehanna River. To be supplied at no cost to this project by the USGS at Harrisburg, Pennsylvania.

All agencies except NASA have given verbal promise of support through the end date of this contract, 31 December 1973.

The required support from NASA listed above has the following specifications.

(1) Aircraft Data

(a) U-2 and/or RB-57 photography (of the order of one to sixty thousand scale) is required. These photography products should be both color and black and white 70 mm, positive transparencies covering the visible and near IR frequencies. These flights should have occurred once a season over at least one training area in each of the two test sites. U-2 flights (71-070, frame 0063) in December 1971 and (72-124, frame unknown) in July 1973 over Harrisburg, Pennsylvania are specifically requested.

(b) Data from any U-2, RB-57 or C-130 flight lines covering the Susquehanna River from the confluence at Sunbury to its mouth and the Wyoming Valley from Carbondale to Nanticoke are requested also.

(c) C-130 and C-54 color transparencies taken from low-altitudes (5,000 and 10,000 feet) taken in July 1972 and January 1973 are requested also as backup information.

(2) Data Interpretation Software

(a) Copies of the latest versions of MSS data analysis software and descriptive materials developed by Purdue University, Bendix and Pennsylvania State University suitable for ERTS-1 use are requested.

(3) ERTS CCT and Imagery

(a) Continued supply of 9½ inch bulk black and white positive transparencies for the two test sites for all occasions in which the cloud cover is less than 20% are requested.

(b) Automatic shipment of bulk CCT for areas passing (3a) constraints when all four channels are classified as Good (G) are requested.

(c) Automatic shipment of 9½ inch color composite positives passing (3a) constraints are desired.