REMOTE SENSING METHODOLOGY FOR BIOENVIRONMENTAL SURVEILLANCE IN THE VICINITY OF THE BOARDMAN COAL-FIRED POWER PLANT, OREGON

BY

D. SCOTT DENKERS

A RESEARCH PAPER

submitted to

THE DEPARTMENT OF GEOGRAPHY

in partial fulfillment of

the requirements for the

degree of

MASTER OF SCIENCE

December 1981

Directed by

Dr. A. Jon Kimerling

ACKNOWLEDGEMENTS

Dr. Lolita Carter of the Environmental Sciences Department, together with other personnel at the Portland General Electric Company have provided invaluable assistance to the Geographic Applications Laboratory during the formative years of this remote sensing program.

Gary Beach provided the original organization, interpretive groundwork and background files for the Geographic Applications Laboratory.

Special thanks are extended to these people and to all others who have helped in this study.

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REMOTE SENSING METHODOLOGY FOR BIOENVIRONMENTAL SURVEILLANCE IN THE VICINITY OF THE BOARDMAN COAL-FIRED POWER PLANT, OREGON

ABSTRACT: In 1979, the Geographic Applications Laboratory of the Department of Geography, Oregon State University, was retained by the Portland General Electric Company to form and supervise a program to monitor the bioenvironment in the vicinity of the Boardman Coal-Fired Power plant. This partially fulfills requirements of the Department of Energy in allowing the newly built power plant to become operational. This was achieved in August, 1980. Remote sensing was chosen as the tool to perform this task because of its ability to monitor large areas effectively at a minimal cost. Three imagery modes of varying scale were selected: (1) LANDSAT Multispectral Scanning; (2) High level color infrared imagery acquired by NASA U-2 operational aircraft, and; (3) Low level color and color infrared imagery, which was selected as the primary source of analysis. After establishing study area boundaries, study sites and primary imagery flight lines, the functions of this project included: imagery acquision; analyical interpretation; monthly and annual written evaluations of study area conditions and imagery quality; and establishment of a background file for future analytical reference.

INTRODUCTION

The purpose of this paper is to describe the methodology used in monitoring possible adverse bioenvironmental effects as a result of the operation of the Boardman Coal-Fired Power Plant. This new facility, located 19 kilometers southwest of the town of Boardman in northeastern Oregon, is located on Poverty Ridge and covers approximately 10,522 hectares of relatively flat terrain. Associated features of the power plant include a cooling reservoir covering 566 hectares south and adjacent to the plant, a coal handling facility to the east and adjacent to the plant, and an ash disposal site covering 200 hectares at the southeast corner of the cooling reservoir. The plant chimney is a 200 meter stack which carries the heated flue gas from an electrostatic precipitator into the atmosphere.[1]

Adjacent to the Boardman Power Plant is located the U.S. Naval Weapons Systems Training Facility; a bombing range encompassing 205 square km. of undeveloped rangeland. Circular, center pivot agriculture located directly west of the power plant and east of the bombing range is being practiced by Sim Tag Farms and Sabre Farms respectively. South and outside the bombing range perimeter, dryland farming is commonly practiced. Figure 1 illustrates the general area in the vicinity of the power plant.

The Geographic Applications Laboratory, a section of the Department of Geography at Oregon State University, was contracted by the Portland General Electric Company (P.G.E.) to perform a required general bioenvironmental monitoring program. Remote sensing, the tool chosen to accomplish this purpose, was selected because of its ability to detect possible bio-

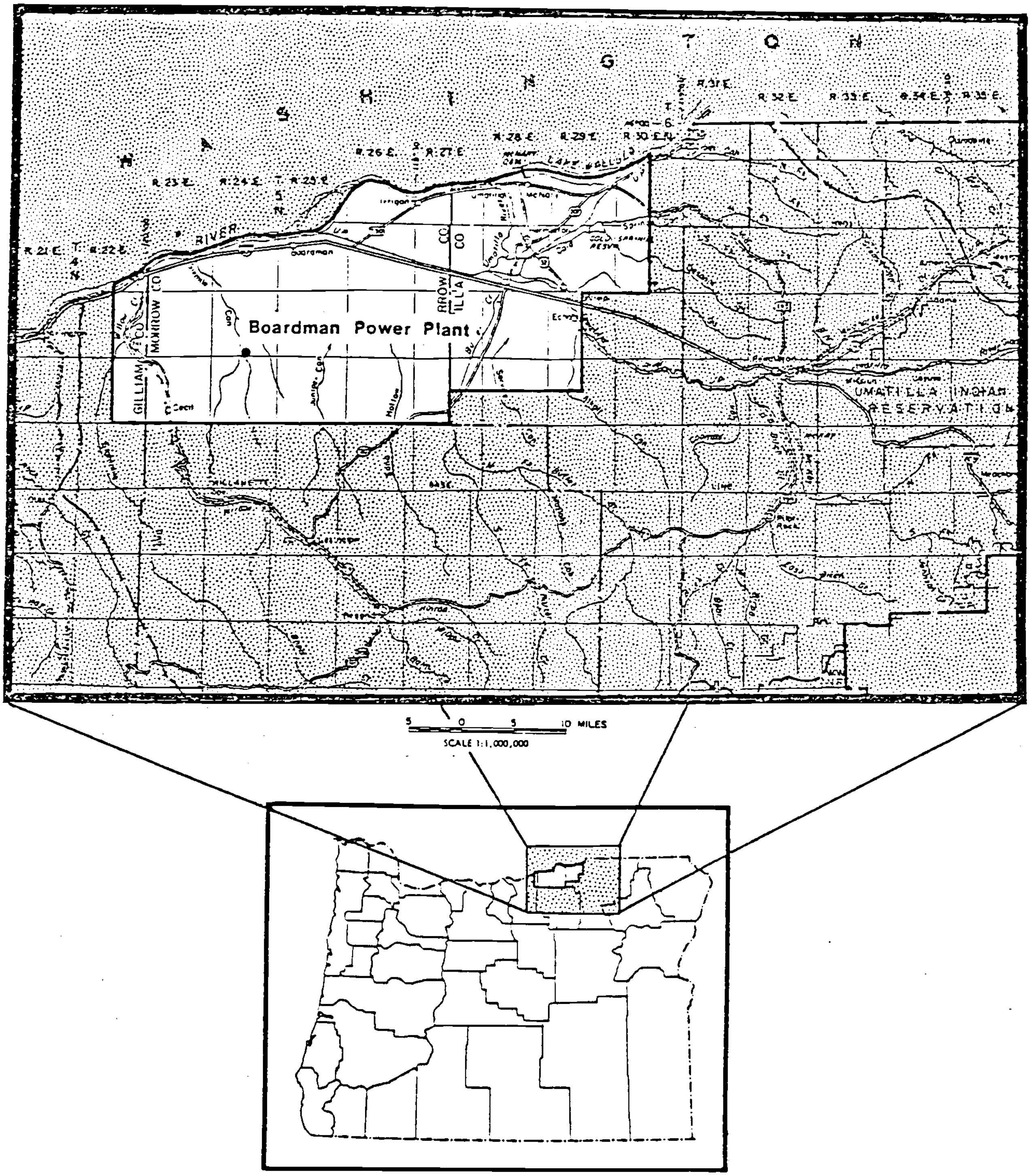

Figure 1. Location of the Boardman Study Area, Oregon.

environmental changes relatively cheaply over an extensive area. As defined by the American Society of Photogrammetery, remote sensing "encompasses the total observational process from remote platforms."[2] This therefore allows for speed in detection of general variations in the environment which can later be ground checked in detail if considered important.

Portland General Electric, a Pacific Northwest electric utility company, completed construction of the 550 megawatt Boardman Coal-Fired Power Plant in 1980. After testing, it became operational in August of the same year. As a part of state and federal regulations, a monitoring program is required to constantly watch for any adverse effects on the surrounding biological environment due to particulate emissions or other operationally related pollutants. Operation of the utility is contingent upon approval and application of a monitoring program by the Department of Environmental Quality (D.E.Q.), who in turn must report to the Department of Energy (D.O.E.). This latter federal agency is empowered to revoke the operational license of power plants if satisfactory monitoring programs are not carried out. State law provides for an environmental and effluent monitoring program for thermal power plants under Oregon Administrative Rule (O.A.R.) #345-26-060(12)(b).[3] This specifically calls for soil and vegetative monitoring in the vicinity of the power plant in question. It is for the partial completion of this objective that the Geographic Applications Laboratory has been contracted on a yearly basis since 1979.

PREVIOUS STUDIES

The applicability of the use of remote sensing techniques in monitoring the bioenvironmental effects of coal-fired power generating plants have been amply demonstrated in several past studies. The U.S. Environmental Protection Agency has provided major funding for these studies. One of the most comprehensive investigations has been achieved assessing the bioenvironmental impacts associated with the Colstrip Coal-Fired Power Plant in southeast Montana (Osberg, et al., 1976; Preston and O'Guinn, 1980; Preston and Lewis, 1978; U.S. Environmental Protection Agency, 1974a). These studies have provided an inventory of the major ecosystem components in the Colstrip area, and have recorded ecosystem changes that occurred before and during power plant operation. The basic remote sensing methodology utilized in these studies was duplicated for the Boardman study. This is because the Colstrip investigation found that,

> "...sufficient detail can be seen in this imagery to enable us to trace and describe pollution stress patterns that develop in grasses and other types of vegetation....Information from this source...should aid the overall program in assessing microclimatic and air pollution patterns and effects."[4]

Further investigations have been carried out in connection with sulfur dioxide emissions from coal-fired power plants and the effect on the surrounding biological environment. In a study sponsored by the Tennessee Valley Authority, estimates were made of sulfur dioxide emissions and related injuries to neighboring vegetation from a 2600 megawatt power plant (Sapp,1978), and the use of remote sensing in evaluating SO_2 damage to grasslands proximal to the Colstrip power plant was described in Preston and Gullett (1979). In an evaluation of the impact of a coal-fired generating plant in the Four Corners region of the southwest United States, estimates were made as to the effects of sulfate, floride, and trace elements on rangeland vegetation. Physical and chemical characteristics of precipitation downwind from the proposed power plant site were also studied (U.S. Department of the Interior, 1971).

General remote sensing studies on the effects of vegetation damage are numerous. Murtha, 1978; U.S. Environmental Protection Agency, 1974b; U.S. Department of the Interior, 1978; Tingey et al., 1971; and Brandt and Heck, 1968, are a few examples. Genderen (1974), though not limiting his attention to coal-fired power plants, describes a basic remote sensing program for the detection of vegetational stress in an industrial area. The author states that crop stress detection is most easily accomplished with the use of infrared imagery analysis, since it is this spectral wavelength reflectance that is generally most effected when vegetation is stressed. The usefulness of infrared imagery in bioenvironmental monitoring is described by Casalinuovo and Sawan (1976), and Pitney (1978). Carneggie and Reppert (1969) describe the use of large scale 70mm aerial color photography which, when used in conjunction with large scale infrared imagery, results in a very effective monitoring technique of spectral signature comparison. An overall perspective of the uses, techniques and modes of remote sensing may be obtained from the Manual of Remote Sensing (Reeves, 1979).

PROJECT DESCRIPTION

The function of this monitoring program is primarily to document possible changes on vegetation populations, both native and introduced, to search for areas of vegetational stress and to identify the probable causes of any variations that may occur. Since this area of Oregon has recently experienced a rapid growth in agriculture as a result of technologically advanced farming practices, dramatic changes in the biotic make up of this area should be expected. This, along with other environmentally influential factors, must be taken into account when evaluating observed variations.

The following sections describe the physical and biological parameters of the area in question, the types of imagery used in analysis, flight line and study site selection, instrumentation and techniques utilized in analysis, the applicability of the methodology used, and the important results and observations of the program during the 1979, 1980 and 1981 field seasons.

FLIGHT LINE AND STUDY AREA SELECTION AND DELINEATION

The Boardman study area was selected on the basis of flight line positioning and encompasses an area in northeastern Oregon east of Willow Creek, south of the Columbia River, west from Cold Springs Reservoir and north of the extended southern limit of the Boardman Bombing Range. This area is generally located within township and range coordinates R.23E. and R.30E., and T.2N. and T.5N. The towns of Hermiston, Boardman, Irrigon, and McNary are located within this area, all of which are to the north and northeast. Interstate 5 also passes through the northern and east central portions of the study area. The Boardman Coal-Fired Power Plant is located in the west central section. This asymmetrical orientation of the study area, in respect to the power plant, was chosen because the dominant lower level winds which are from the west southwest. With this prevailing wind pattern, the majority of airborne particulates from the power plant stack, coal pile, and ash disposal site, will end up most likely effecting the downwind bio-environment.

Flight lines for low level imagery acquisition were selected on the basis of covering major concentrations of circle pivot agricultural plots, transecting native rangeland vegetation surrounding the power plant site, and to have the primary flight line pass over the power plant in the direction of the prevailing wind.

STUDY SITE SELECTIONS

A total of fifty-one study sites were selected for interpretive analysis by the Geographic Applications Laboratory and were confirmed by P.G.E. personnel. The original study site selection was based on a constant radius interval of 2 km. from the Boardman Coal-Fired Power Plant. Further factors considered in the selection process included: (1) a wide representation of indigenous agricultural practices and crop types, (2) coverage of native rangeland within and around the Boardman Bombing Range, and (3) coverage of P.G.E. terrestrial plots and meteorological stations.

Use of the constant radius interval provided a systematic approach to the selection process. This system provided a roughly uniform spacing between sites along particular flight lines. Consequently, plant emissions, if detected, can be analyzed more effectively as a function of distance.

Original study site selection included thirty-eight center pivot agricultural plots, five conventionally irrigated plots (linear hand moved or motorized irrigation pipes, and flood irrigation), one dryland agricultural plot, and seven native rangeland sites. During the 1980 field season one of the flight lines was moved to provide greater bioenvironmental analysis coverage of center pivot agricultural plots northwest of of the power plant. This revision led to a slight change in agricultural types covered. The number of center pivot irrigated agricultural plots increased to thirty-nine and dryland farming plots were not represented. The remaining numbers of study plot agricultural types remained the same.

The study sites were numbered consecutively as to the sequence of flight coverage. Abandoned plots (16 and 17) were replaced by 16a and 17a. Each flight line was also numbered consecutively from one through eight. An agreement with Crop Protection Incorporated established particular flight directions in the correct order of numbering.

Refer to figure 2 for the numbering and location of the fifty-one study sites and flight line positioning.

PHYSICAL DESCRIPTION OF THE STUDY AREA

Topography, Geology and Soils

The Boardman Power Plant study site is situated on the north sloping Deschutes-Umatilla Plateau.[5] Basaltic bedrock is overlaid in this area with a thin mantle of windblown sand and loess. Numerous east northeast trending active and inactive sand dunes cross the study area. These

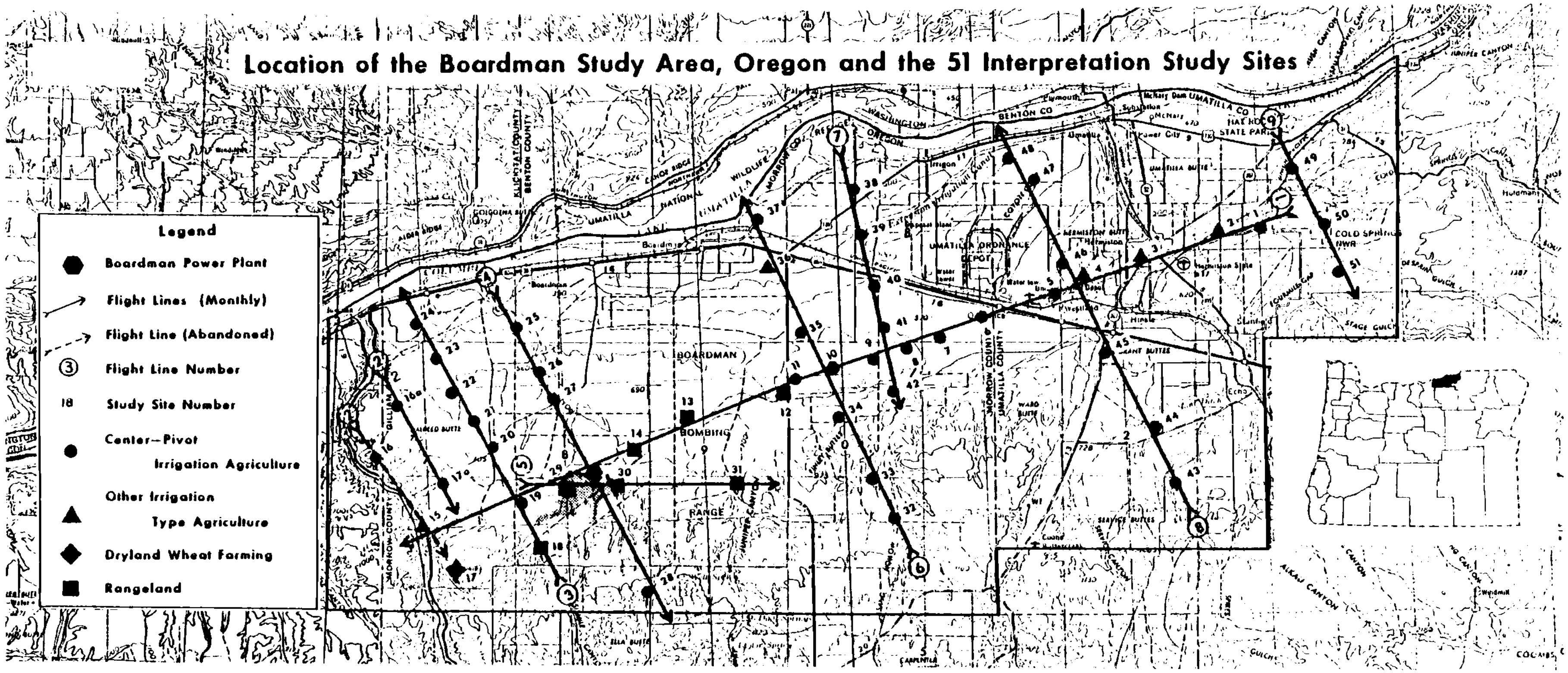

Figure 2. Location of the 51 Interpretation Study Sites and Flight Line Orientation

are oriented in the direction of the highest and most persistent wind velocities. Numerous sand blowouts occur in areas of natural or human induced disturbance. Eolian erosional processes are the dominant geomorphic modifier at this time.[6]

Soils in the Boardman area are composed of fine sands, loamy fine sands, and fine sandy loam. They are very shallow for a distance of 3 to 6.5 kilometers south of the Columbia River, with exposed bedrock not uncommon. An increase in soil depth is seen further south. These soil characteristics result in high erosional hazards, particularly where soils have been exposed as a result of recently constructed agricultural plots.

Many intermittent stream channels dissect the region. The only perennial water courses of the area are the Columbia River, Umatilla River, Willow Creek and Butter Creek. Most stream channels display a northerly direction of flow due to the topographic characteristics of this region.

Climate

This region of Oregon is classed as semi-arid. Maritime and continental air masses dominate the area, with the Columbia Gorge acting as a channel for both air masses. Cold continental air masses affect the winter climate; mild, maritime air masses influence the summer climate. Annual precipitation averages 230 mm. in the study area, 70% of which falls between October and April. Regional winds persist throughout the year, but as mentioned above, the prevalent winds from the west southwest generally have the highest velocities.

Natural Vegetation and Agricultural Land Use

Natural rangeland vegetation is composed of a mix of perennial bunch grasses, Idaho fescue, big sagebrush, and rabbit brush. With the advent of farming around the turn of the century, the previous climax vegetation was rapidly replaced by cheat grass (Bromus tectorum) and other alien species such as russian thistle (Salsola kali). Consequently, only a few areas remain where the native vegetation grows undisturbed.[7]

Agriculture in the Boardman region has expanded rapidly in recent years due to newer technological farming techniques, which make the cultivation of cash crops feasible in this dry and sandy area of the pacific northwest. Center pivot agriculture has opened this previously unfarmable area to large scale operations. Currently, the predominant cash crops include potatoes, alfalfa, processing peas, corn and dry beans. Winter wheat is often cultivated during the winter months to reduce eolian erosion on the circular plots. A continued expansion of agriculture has been observed during the period of this monitoring project, and should continue through the next decade.

SELECTED IMAGERY MODES

Three sources of imagery were selected for the monitoring program. LANDSAT Multispectral imagery, high level U-2 infrared photography, and low level color and color infrared (CIR) photography were chosen to represent varying scales of resolution.

LANDSAT

Multispectral scanner (MSS) imagery, derived from LANDSAT, was originally used to provide information in identifying the monthly flight lines and study sites, and to map seasonal vegetation cover types for ground truthing. The 1:250,000 scale imagery has also been obtained in following years from EROS to provide an overall, small scale, overview scene of the Boardman study area. This is important for the detection of ubiquitous environmental changes, the delineation of which may not be detectable from lower, larger imagery scales. An excellent example of this may be seen in the LANDSAT imagery acquired in July 1980, in which a coal dust dispersion pattern, emanating from the power plant's coal storage area, was seen clearly on the one overall image.

U-2

Color infrared photography at a scale of 1:130,000 was also acquired from EROS. Several high altitude flights were made at irregular intervals by U-2 aircraft. Photography obtained to date (Dec. 1981) is from September 1974, August 1975, and July 1978 - times before the power plant was operational. This scale imagery can be used to interpret vegetation community changes as well as land use changes and other environmental variations. Generally speaking, area wide analysis can be achieved with this type of imagery, whereas LANDSAT MSS can be utilized in regional analysis.

Low Level

Low level photography was selected as the primary source of imagery. It has been flown on a monthly basis during the growing season since the inception of this project. A private remote sensing company specializing in agricultural monitoring, Crop Protection Incorporation, was contracted to obtain color and color infrared imagery at a scale of approximately 1:36,000. This scale is obtained by flying at an altitude of approximately 2,900 meters and using an 80 mm focal length camera. This imagery provides the data needed for detailed analysis of the selected study sites and an in-depth look at species changes over time. Figure 3, an infrared frame from flight # 81-017, illustrates the type of imagery obtained through the low level mode of acquisition. Note the advantage of infrared imagery in indicating vegetational and water related characteristics.

After the Geographic Applications Laboratory receives and analyzes this imagery, a brief report is sent to P.G.E. outlining imagery quality and any important bioenvironmental changes noted for that month. This type of analysis provides an excellent, detailed comparison of specific study sites. First indications of coal dust dispersion (described below) across rangeland adjacent to the power plant were observed in this analysis.

TECHNICAL DETAILS OF THE PRIMARY IMAGERY

It has been established that the use of near infrared sensitive color emulsion, sensitive to electromagnetic wavelengths just beyond the red end of the visible spectrum, proves most effective in detecting signs of vegetational stress before normally visible clues become apparent (Casalinuovo and Sawan, 1976, Pitney, 1978). This is related to the fact that green and infrared reflected radiation are strongly reflected from most vegetation. Green is largely reflected from the chloroplast component of floral structure near the epidermis, while infrared is unaffected by the outer chloroplasts and strongly reflected by the internal spongy mesophyll. Since it is the spongy mesophyll that is usually first to

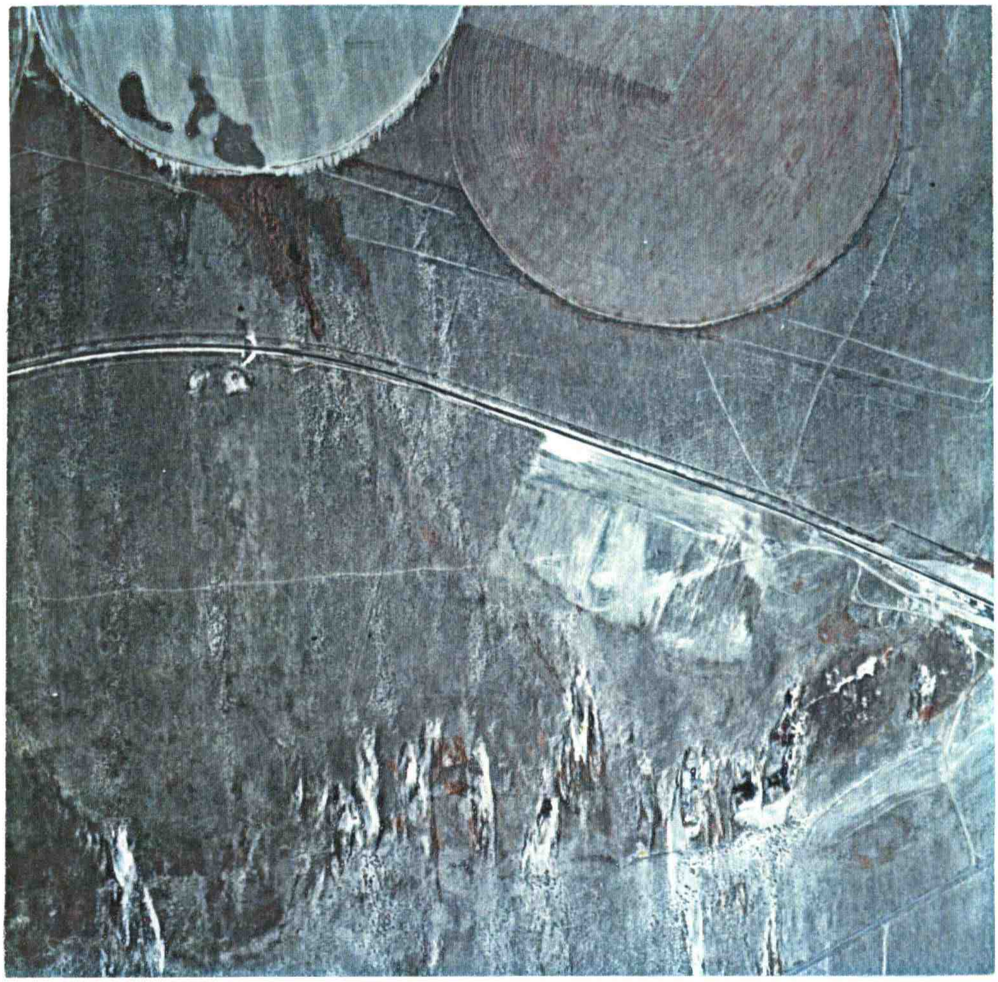

Figure 3. Example of Low Level Infrared Imagery Used as the Primary Source of Interpretive Data.

be deleteriously affected by stressful factors, it is most often the infraredcomponent of reflected energy that is first to indicate a clue to stressful conditions.[8] Ektachrome (I.E.) color infraredsensitive film (Kodak 2443) was therefore chosen as the primary form of low level imagery. This film provides sharpness of detail, penetrates light haze well, and can also detect surface water areas such as ground water seepage. Ektachrome color (Kodak 2448) was used as the second source of imagery to provide the photointerpreter with a more familiar view of the scene under scrutiny. Specific filters were used in conjuction with the cameras to reduce haze effects. Two cameras were used to obtain imagery simultaneously from a vertical aspect. This allows for easy direct comparison of the two types of imagery. 70 mm roll format imagery was selected to provide good ground detail definition and allow direct analysis without going through an enlargement process.

Overflight conditions were specified: wind speed should be less than 20 knots; there should be no blowing dust; relatively cloud-free and hazeless days were to be selected; and imagery acquisition time was to be between 0800 hours and 1400 hours to avoid local afternoon atmospheric turbulence. Excessive ground shadowing can be avoided by flying the acquisition missions around midday, when the sun's angle is at its highest. Since good ground definition is required for interpretative analysis, the visibility requirements were considered important. Direct cloud obscuration of ground and study sites is of obvious detriment. Cloud shadows and atmospheric haze also cause problems in interpretation, resulting in loss of ground object definition and color inaccuracies. Relatively calm, windless periods were also considered desirous not only for flight line accuracy, but also for general safety.

INSTRUMENTATION AND TECHNIQUES UTILIZED IN ANALYSIS

Interpretation and analysis of the acquired imagery in the Geographic Applications Laboratory requires the use of varied remote sensing equipment, which can be grouped under visual and mechanical interpretative tools. Cartographic techniques and instruments are also used as a secondary tool for data presentation.

Visual Interpretation

Each vegetational type, topographic characteristic, or artificial object has a particular distinguishing spectral reflectance or range in reflectance of the radiation spectrum. These differences are expressed in the color and color infrared imagery by characteristic patterns that are used in detecting spatial and temporal changes. Shape, size, shadows, tone, texture, and proximity to other objects are clues used in visual imagery interpretation. The following tools have aided in the process of extracting interpretive information.

Richards Light Table

This basic tool allows the roll of transparency film to be scanned by the photointerpreter by being drawn across an opaque surface lit from below. The roll of imagery is taken up on the other side of the table by another roll. Both the color and color infrared imagery may be scanned at the same time because they are on separate rolls. Rolls of varying acquisition dates may also be similarly compared for analysis of temporal changes.

Stereomicroscope

In conjunction with the Richards Light Table, a Baush and Lomb

Zoom 45 stereoscope has been utilized in viewing the imagery. The transparent film can either be viewed monoscopically frame by frame, or can be stereoscopically viewed when two adjacent frames are viewed together with the correct objective lenses. This instrument has proved extremely useful in interpretive work, particularly when the stereoscopic option is used, giving the effect of three dimensional relief.

Zoom Transferscope

A Baush and Lomb Zoom Transferscope is used when interpreted information from the imagery is transferred to another map at the same or especially at a different scale. It allows an accurate and rapidly transferred image and is especially useful in correlating areas with few distinguishing landmarks. The usefulness of this instrument was demonstrated in the locating of selected study sites on 7.5 minute U.S.G.S. topographic quadrangles from the originally acquired LANDSAT imagery.

Cartographic Representation

To clarify written explanations in the annual reports submitted to P.G.E. so far, maps were prepared to illustrate the study area location, flight line and study site positioning, and environmental impact delineations. As previously mentioned, the fifty-one study sites were also exactly located on U.S.G.S. topographic quadrangles, which are retained by the Geographic Applications Laboratory.

Mechanical Interpretation

Analogue Densitometry

In addition to the visual interpretative tachniques, attempts were made to analyze imagery mechanically. Due to variability factors of the primary imagery (described below), mechanical interpretation techniques were generally limited to the use of the I^2S Digicol Density Slicer. This analogue densitometer displays the various transmitted density levels of the transparency being studied on a television screen. Each density level from the particular image can then be assigned a color signature. By varying the color density and hue, the interpreter can detect subtleties usually undetectable by the human eye. It was through this methodology that the delineation of coal dust distribution was achieved in the 1980 report to P.G.E.[9]

Digitizing

Area calculations can be accurately achieved using the S.A.C. Digitizer/Planimeter. The computations can be made either directly from the imagery or from a map source and can be useful in estimating bioenvironmental impact coverage or other areally related phenomena.

RESULTS AND OBSERVATIONS OF THE PROGRAM

During the period this monitoring program has been carried out, demonstration of its applicability and value have been evidenced continually even though power plant operations have been in effect only since August 1980. Following is a generalized list of benefits resulting from the bioenvironmental monitoring program that have been identified so far.

(1) An early warning detection of vegetational stress.

(2) A permanent visual record on bioenvironmental conditions at a particular time that can be used for immediate or future comparative analysis.

(3) Assessment of the trends and changes in the vegetation cover over time.

(4) Aid in discriminating between natural and man-induced vegetational stress changes in conjunction with the ground-based ecological monitoring carried out by P.G.E. personnel.

(5) Re-examination or re-evaluation of a particular area when previously unnoticed or unrecognized features are later discovered to be of importance.

Observations on a more specific basis are related below as either associated or not associated with power plant operations.

Power Plant Associated

Coal-Fired power plant operation results in dispersion of certain particulates and gaseous emissions directly from the plant stack. Secondary level pollutants and effects may also be generated from piles of the pre-burned coal, ash disposal sites, cooling reservoir facilities, and so on. Major environmental concern has been generated, particularly within the last decade, over the output of sulfur dioxide (SO_2) from the coal-fired type of power plant. High concentrations of sulfur dioxide can cause swift foliar destruction, and while effects of low amounts of this gas or its byproducts may not be immediately visible, crop yields may be eventually reduced. Plants with thin leaf structure such as alfalfa and barley are usually the most severely effected. Damage to vegetation can either be through direct penetration of SO_2 particulates into the stomata, resulting in failure of the respiratory system, or through contact with acid precipitation. Acid precipitation forms in the atmosphere from chemical conversion of sulfur and nitrogen compounds under the influence of oxygen, water vapor, and sunlight to form sulfuric, nitric, or nitrous acids.[10]

Even though a low sulfur coal is burned at the Boardman Coal-Fired facility and precautions against environmental pollution are followed by P.G.E., certain amounts of particulate and gas emissions make their way into the environment. It is for this reason that P.G.E. contracted the Geographic Applications Laboratory to monitor the biological environment surrounding the power plant for any visible signs of vegetation stress. Although no major negative consequences of plant operation have yet been detected from stack emissions, other operationally related factors have been gleaned from the monitoring program.

Coal Dust

During the analysis of imagery from acquisition flight #80-009, flown August 23, 1980, it appeared that coal dust was extending beyond the confines of the Boardman Power Plant coal handling facilities and storage area in a north easterly direction.[11] This was later confirmed by P.G.E. ground personnel. The detection, identification, and consequent mapping of the coal dust dispersion pattern onto the native rangeland vegetation adjacent to the western edge of the power plant provides an example of the advantage in the use of remote sensing as an environmental monitoring technique. P.G.E. was previously unaware of this problem in spite of its proximity to the power plant. Concentration of the coal dust on the ground and vegetation was small enough so that it was undetectable at close quarters, but when viewed from a greater distance, with a more overall perspective of the area, delineation of the darker hued pattern of coal dust could be perceived. From the scale of primary imagery utilized, differing concentrations of coal dust could be defined, with the highest closest to the coal handling facility. The approximate periphery of distribution could also be delineated with the assistance of the I^2S Digicol Density Slicer.

Coal dust distribution was carefully monitored in subsequent 1980 imagery for changing characteristics. During the period between the 1980 and 1981 field seasons, the evidence of coal dust faded. It was again noted in the imagery from the second acquisition flight of 1981 (#81-012), and continued to be seen throughout 1981.[12] Figure 4 illustrates the coal dust distribution later in the summer of 1981, and indicates the cartographic technique in delineating the varying patterns of dust concentrations.

Cooling Reservoir Related Vegetation Anomalies

A further power plant related environmental modification has been the stimulation of active vegetative growth around the periphery of Carty Reservoir - the power plant's cooling facility. This has been noted in the monthly reports to P.G.E. since the beginning of the monitoring program. The growth has been generally attributed to two basic causes. (1) The Boeing Agricultural and Industrial Company built and operates the pipeline which supplies Carty Reservoir with its water from the Willow Creek arm of the Columbia River. In turn, and as part of a lease agreement between P.G.E. and Boeing, this agri-industrial company may draw off the upper ten feet of reservoir water from the normal maximum water level for crop irrigation.[13] Since water demand for agricultural purposes, and surface evaporation are highest in the later part of the summer, a consequent fall in reservoir level occurs. The area of abundant moisture between upper and lower maximums is therefore stimulative to the active growth

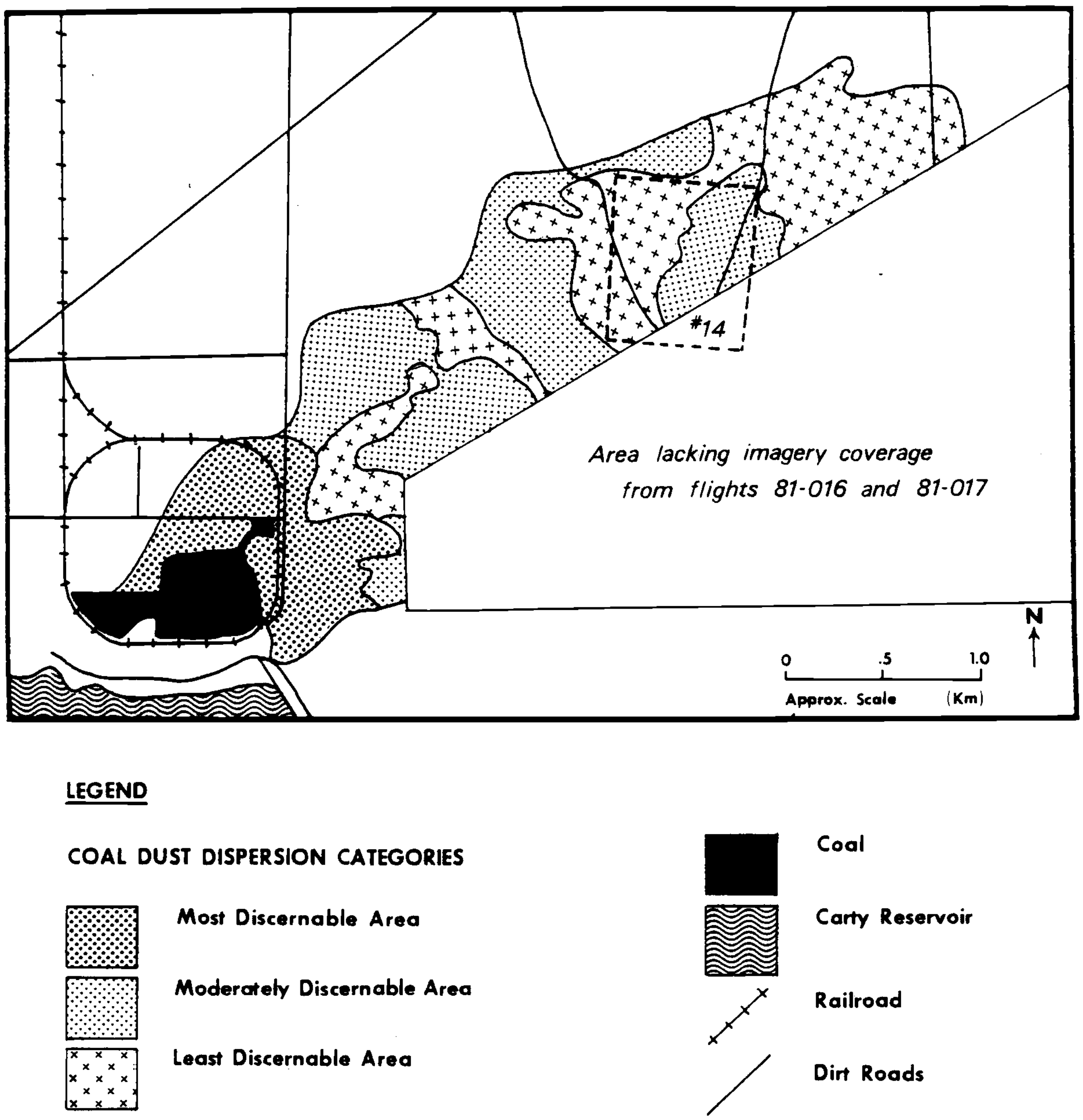

Figure 4. Areal Distribution of Coal Dust Dispersion from the Boardman Power Plant Coal Storage Site, 1981.

of natural vegetation. (2) Water has been escaping from the northern section of Saddle Dam and the West Dam (figure 5), resulting in characteristic features of vegetative growth around the dam bases. These features also lead away in linear patterns. The surveillance of these dam related anomalies through the monitoring program have been important in keeping P.G.E. personnel informed as to where these leaks are occurring, and to what degree.

Non-Power Plant Associated

Discrimination must be made between variations in the bioenvironment resulting from power plant operations and those as a consequence of other man-induced or natural factors. This is especially important to P.G.E. for two reasons: (1) They must know if counter measures have to be made as a result of adverse environmental effects they are causing and liable for; and (2) the imagery may be used as evidence in a court of law if proximal property owners have a grievance against P.G.E. The imagery is therefore notarized as to its authenticity of acquisition date and times, as well as true portrayal of ground conditions at the time of acquisition. Non-power plant associated bioenvironmental variations are noted in the monthly reports to P.G.E., and a rundown of the most outstanding variations are made in the annual report of results from the specific year's field season. The following bioenvironmental influences and observations are examples of effects that could be possibly confused with power plant related emissions, but have been shown to be unrelated.

Rangeland Fires

Major changes in the characteristic spectral reflectance of the

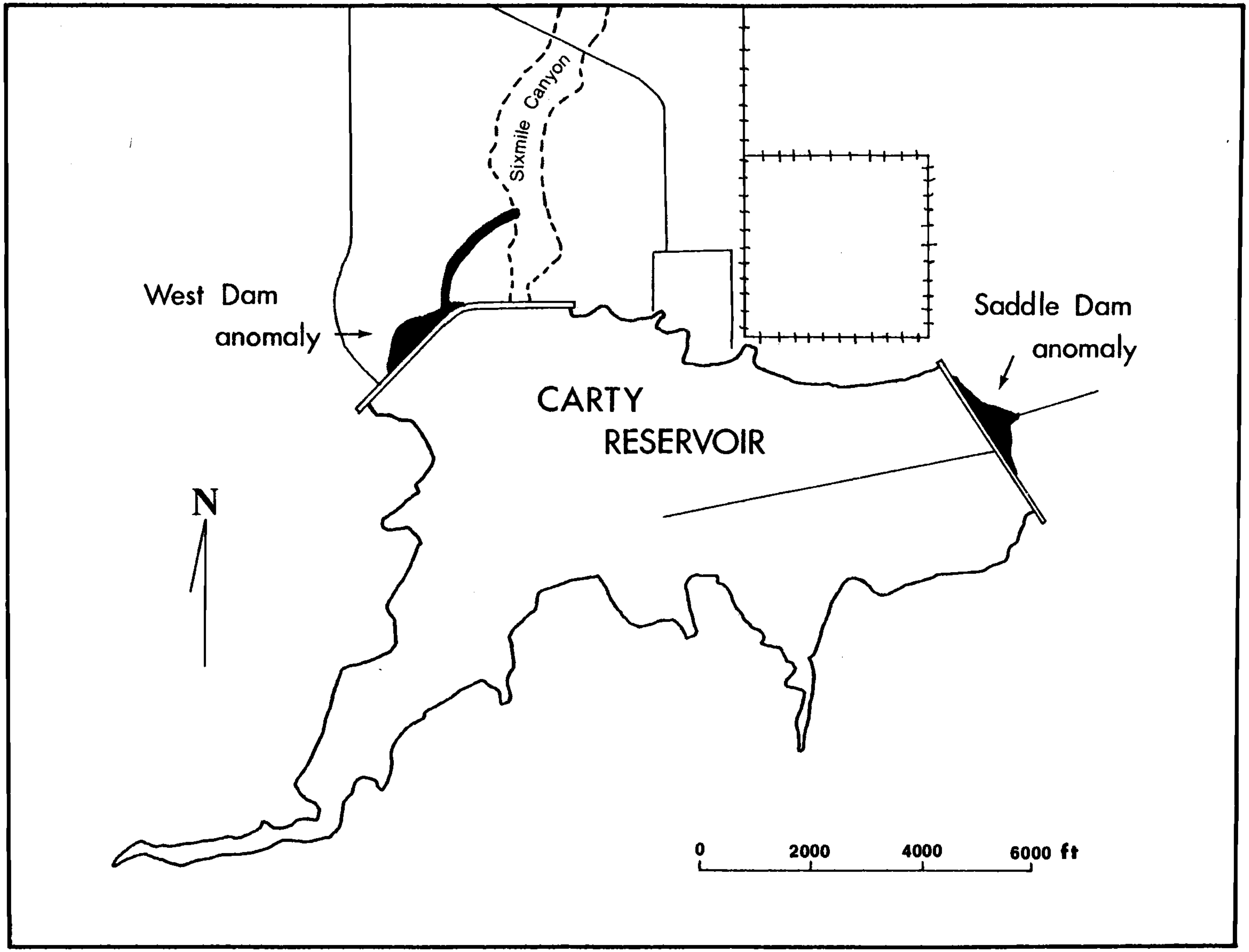

Figure 5. Location of Vegetation Anomalies in the Vicinity of Carty Reservoir

rangeland occurred east of the Boardman Coal-Fired Power Plant during the summer of 1981. The darkening of imagery tone was attributed to rangeland fires and this was confirmed by P.G.E. personnel. The effects of the two largest burns were noted in the interpretive analysis of flights 81-013, flown June 29 and 81-016, flown September 2. The smaller, first burn started north and adjacent to the main bombing target of the U.S. Naval Weapons Systems Training Facility, and was blown in an easterly direction. It was quickly contained by the construction of firebreaks in the vegetation. The second burn again started adjacent to the bombing target, and was fanned by a wind blowing southwest toward the Boardman Coal-Fired Power Plant. The unusual wind direction brought the fire within the southern section of rangeland study site #30, and close to the coal handling and storage facility. Figure 6 shows the areal extent of the first burn and the approximate extent of the second, larger burn. Unless care is taken when viewing imagery of the fire effected area, it could possibly be mistaken for coal dust. The construction of fire breaks bounding the darker-than-usual rangeland indicate the nature of this disturbance. Study of the pattern of disturbance also points to the fact that it is unrelated to the power plant's coal storage area.

Agriculturally Related Disturbances

Because of the delicate balance between natural vegetation holding the sandy soil of the Boardman area, the effect of clearing this vegetative stabilizer for agricultural expansion can possibly have disasterous consequences. With the constant and often extremely windy conditions typical of the study area, eolian erosion can be serious if countermeasures are not taken by the agricultural corporations farming the area.

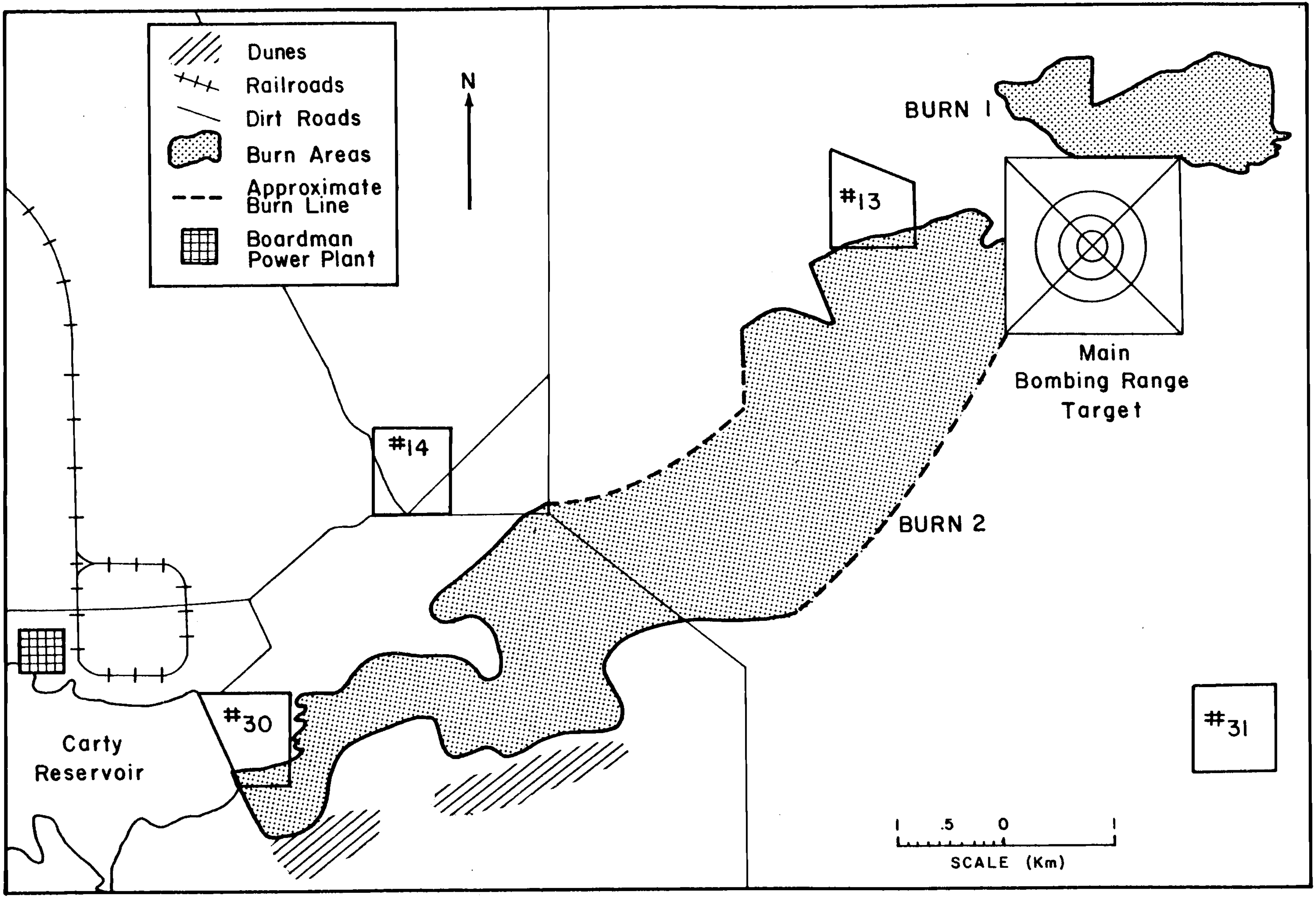

Figure 6. Areal Extent of the Rangeland Fires on the Boardman Bombing Range, 1981.

If soil is not kept tied to the ground by irrigation or planting of winter wheat when cash crops are not being grown, soil loss will result. The influence of wind erosion is generally most clearly seen at the beginning of each year's growth season. Exposed or disturbed sand dunes supply material for movement during the winter months. This is when wind velocities are the highest and irrigation at a minimum. Agricultural plots are most seriously affected on the northeast to eastern extreme edge of the rangeland-agricultural interface, or on the west to southwest extreme edge of rangeland in the study area.[14] Fluvial erosion may also occur on exposed agricultural plots during rainstorms when soil may be rapidly washed off the plot.

The application of large quantities of chemical pesticides and fertilizers through the irrigation system on center pivot plots can also produce environmental effects that could be mistaken for power plant emission-induced characteristics. According to figures supplied by the Morrow County Extension Service, sulfur, an important element for the healthy growth of crops, is added at the rate of 50-60 pounds/acre/year in the form of ammonium sulfate, or 20-30 pounds/acre/year in the form of elemental sulfur mixed with bentonite.[15] These figures, which are application rates for alfalfa in the Boardman area, indicate one example for the possiblities of chemical alteration of the bioenvironment. Again, care has to be taken to separate these influences from those of the power plant. In low level imagery acquired during 1981, sections of Sixmile Canyon were noted to contain yellow deposits (pink on infared imagery) around ponds in deflation hollows. Since the upper reaches of this intermittent stream channel were dammed to provide the catchment basin for Carty Reservoir, and location of the power plant was nearby, careful analysis of the colorful features was required.

After consultation with the Morrow County Extension Service and P.G.E. personnel, it was concluded that the yellow features were algal colonies growing in water enriched by the fertilizers applied to nearby circle pivots.

Further agricultural related effects can be expected in this area of growing agri-business, and may be related to other types of chemical applications, to fluctuations in the water table due to irrigation, and so on. Natural geomorphic features, unrelated to farming practices or the power plant, also affect agriculture to a high degree and are mentioned below.

Natural Environmental Disturbances

Sand dunes are common in the study area. Even though they are mostly inactive (or when they are active, move very slowly) their presence clearly influences crop growth throughout the study area, particularly east of the Boardman Bombing Range. This is largely due to their influence on drainage, with rapid percolation through the central axis of the dune and slower percolation of irrigation water in the intervening spaces between dune lineations. A group of pivots north of Cold Springs Reservoir and south of study site #49 display the characteristic linear streaks of uneven crop growth within these inactive dune fields. The visual effect of these features is shown as a tendency for minimal or total lack of crop growth on the dune summits where soil water is scarce. Rapid crop maturation, corresponding to the dune peaks, is a further characteristic commonly seen as a consequence of a lack of moisture. This probably results in lower crop yield potentials due to premature ripening.

Finally, the ponding of water, particularly in the northern section of the study area, is often the result of the shallow or complete lack of soils over bedrock. If this ponding corresponds with agricultural plots, yield output can be adversely affected by the drowning of roots. The characteristic appearance of this problem materializes as patchy, or large areas of stressed growth.

RECOMMENDATIONS

Remote sensing analyses carried out by the Geographic Applications Laboratory during the past three field seasons have provided a continuously greater understanding and comprehension of the requirements of this monitoring program. Suggestions are made below which, if followed, should improve the efficiency and accuracy of analyses in following years.

Considerable variation in color quality, though improving increasingly from one field season to the next, has been found to occur in different acquisition flights. This is the result of: (1) film quality variability in emulsion composition; (2) difficulties in controlling film processing procedures; (3) variations in exposure settings; and (4) variable study area atmospheric conditions. Therefore, objective catagorization of spectral signatures have not been attempted, and cannot be, unless variability is eradicated or digitally corrected. This, at present, is not possible. Therefore, use of the standardized color schemes such as the Munsell color system[16] or microdensitometric techniques[17] have not been pursued. Along with a continuing effort at reducing image variability, it is suggested that the subjective methodology utilized so far - which has proved acceptable for the purposes of P.G.E. - should be continued.

Additional flight runs are often required for missed areas of coverage and should be carried out in the future if considered important. An area east of the Boardman Power Plant was consistently missed during the 1981 field season as evidenced in figure 4 and 6, where delineation of coal dust and rangeland fire boundaries had to be illustrated speculatively in places due to lack of imagery coverage. To avoid flying extra runs it may be possible to shift existing flight lines slightly for coverage of important areas.

The currently used 1:36,000 primary image scale is excellent for normal synoptic coverage. However, it may need to be decreased to provide better resolution for detailed quantitative vegetal stress analysis and particulate pollution measurements if conditions make it necessary. Imagery at a scale of between 1:3,500 and 1:7,500 should be suitable for these purposes.

Previous analysis of LANDSAT and U-2 imagery have proved very useful as interpretive aides to the primary imagery. Continuing acquisition of LANDSAT MSS imagery at the scale of 1:250,000 is recommended. Emphasis should be placed on obtaining imagery which provides a clear portrayal of the agriculture in the area of interest. This can be achieved most efficiently by selecting mid-growth season coverage from July or August. Obviously it is desirable to acquire imagery of the highest quality. The Environmental Remote Sensing Applications Laboratory (ERSAL), located on the Oregon State University campus, provides the data necessary for selection of imagery. Acquisition of recent U-2 color infrared imagery, if available, would be valuable in the detection of extensive bioenvironmental changes that are not readily visible at the resolution level of LANDSAT imagery. New U-2 imagery would prove very useful for comparison with the pre-operational power plant imagery already owned by the Geographic Applications Laboratory. Again, this is available through ERSAL.

Site reconnaissance of the study area should be continued as ground visitation of the specific study sites by the image analyst. This is to familiarize the analyst with the conditions of the study area. This should later provide a more accurate and proficient interpretive analysis. Visitation to the Boardman Coal-Fired Power Plant and the facilities of Crop Protection Incorporated are also suggested. During the period of site reconnaissance, the image analyst should familiarize him/herself with the agricultural variety in this area of Oregon, and become acquainted with the associated cropping practices, patterns, and stages. Communication with P.G.E. personnel should be continued as often as possible after the ground visitation and throughout the field season. This ensures continual up-to-date information, reduces the chance of misunderstandings, and generally results in more accurate interpretations on the part of the analyst.

If possible, a crop/vegetation calendar should be developed for both agricultural and rangeland vegetation sites. This would comprise of a comprehensive spectral key that indicates the normal sequence of phenological changes in vegetative growth. This record of temporal change in crop and rangeland conditions would greatly assist in the detection of deviations from the normal growth patterns brought on by conditions such as moisture stress, insect and disease infestation, and by particulate derived air pollution.

It may be sagacious to extend imagery coverage in the dominating downwind direction to cover the possible effects of emission plume "looping" or other effects of particulate emissions being carried downwind, then suddenly dropping to ground level as a consequence of lower atmospheric conditions.[18] This type of condition, if predominating, can show a "clean" bioenvironment in the immediate vicinity of the power plant, thus giving the impression of an absolutely "clean" bioenvironment, near and far. If extra coverage is deemed appropriate, a wider margin of safety in detection ability may be achieved.

Finally, weather conditions and power plant operational periods are important factors in emission distribution patterns and rates. Since these data can be obtained from P.G.E., they should be utilized as interpretive aides throughout the field season if possible.

FOOTNOTES

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