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Detection of Environmental Disturbance Using Color Aerial Photography and Thermal Infrared Imagery

The three types of imagery (color, color IR, and thermal IR) used in various combinations were often more effective than any one type alone for the identification of indicators of environmental disturbance.

Abstract: *Normal color and color infrared aerial photography at a scale of 1:10,000, and thermal infrared night imagery at a scale of 1:11,000 of an area in the vicinity of the Great Canadian Oil Sands Ltd. and Syncrude Ltd. oil sands plants in Alberta were analyzed. Several indicators of environmental disturbance were noted and the benefits of using the three types of imagery together were detailed. The consideration of ecological process in using the indicators of environmental disturbance to postulate causes and plan corrective measures was shown to be important.*

Introduction

The principal interest in environmental monitoring is change over time, which requires observations over a period of time. For example, it is of concern whether areas of apparently healthy vegetation are stressed or will undergo stress in the near future. Early detection of indicators of such environmental disturbance, and identification of the processes responsible for the disturbance, allow mitigative measures to be considered before implementation costs become prohibitive. For mitigative measures to be successful, it is important that the environmental processes be understood; otherwise, the indicator may be removed without arresting the process of environmental disturbance.

In an operational monitoring program the advantage of preliminary identification of the sites to be sampled can be measured in terms of the time and money saved in planning the field work and selecting those test sites which would be of greatest value. Further, the information gained from sample data, if suitably stored, can improve the accuracy of future interpretations.

The research reported here is extracted from a larger study on environmental monitoring of the Athabasca Oil Sands region of Alberta, Canada (Aronoff, 1978; Aronoff *et al.*, 1978; Ross and Aronoff, 1980). That work, carried out for the Alberta Oil Sands Environmental Research Program (AOSERP) which has the responsibility for environmental management of a 30,000 sq km area (Figure 1), recommended a continuing monitoring program using remote sensing techniques to detect processes such as soil erosion and deposition, changing water levels, and vegetation stress. The environmental monitoring program outlined in the larger study included periodic acquisition and analysis of satellite imagery; aerial photography of

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Photogrammetric Engineering and Remote Sensing,
Vol. 48, No. 4, April 1982, pp. 587-591.
0099-1112/82/4804-609$02.25/0

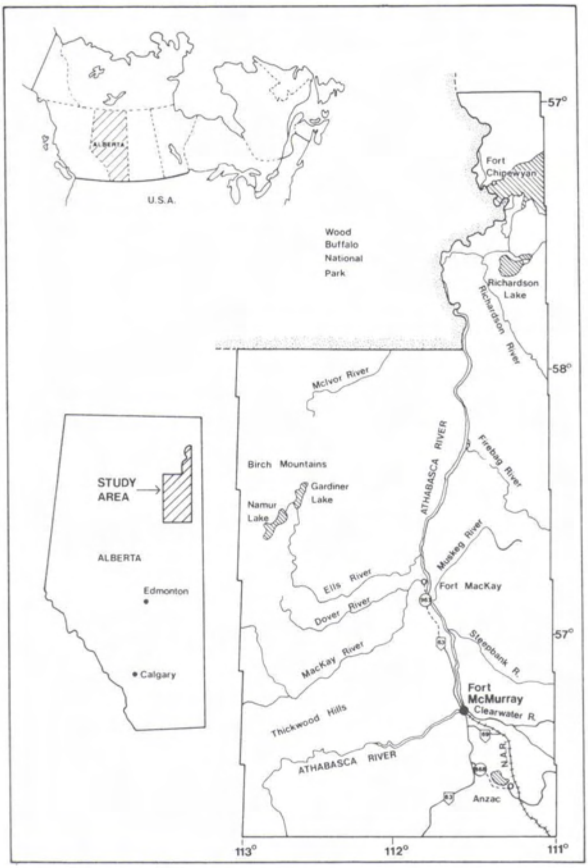

FIG. 1. Location of the Athabasca Oil Sands region.

small, medium, and large scales; and thermal imagery. The combination of image types, scales, and frequency of acquisition was specified on the basis of priority levels. Areas of the 30,000 sq km AOSERP study area in which there were greater risks of environmental disturbance, or for which more detailed information was required, were given a higher priority level. This paper reports the use of color infrared and normal color photography, and thermal infrared night imagery for detection of environmental disturbance. In combination, the information derived from analysis of the imagery can be used to evaluate the detected disturbances and the mitigative measures.

IMAGE DATA AND TEST SITE

The specifications of the imagery used are presented in Table 1. Wild RC-8 cameras were used for the aerial photography, at a contact scale of 1:10,000. A Daedalus Dual Channel Thermal Infrared Line Scanner was used to collect the thermal infrared data in the 8 to 14 μm band. The thermal infrared imagery was processed to a 5-inch wide negative roll transparency with an approximate scale of 1:11,000.

The sites used are from an area in the vicinity of the Syncrude and the Great Canadian Oil Sands Ltd. (GCOS) plant sites in Alberta (Figure 1). They were selected because they provide clear illustrations, and are located in an area and within the coverage of imagery with which the authors are familiar (Aronoff *et al.*, 1978). Selection does not imply a positive or negative value judgement of the condition discussed.

WATER RELATED DISTURBANCE

SILTATION FROM A POINT SOURCE

The brown "cloudy" area at **B** (Plate 1, a normal color aerial photograph) in the northern portion of Mildred Lake may be due to the high sediment load of runoff from drainage channels at **A**, since turbid water generally has a higher reflectance than clear water (Bartolucci *et al.*, 1977). The relatively clear water in the lake appears dark blue to black. Note that the aquatic vegetation at **C**, although of the same general color as area **B**, has a distinctly different pattern and texture. The aquatic vegetation is more clearly visible on color infrared film (represented as red on black colored water) but the siltation was best imaged on normal color film.

NON-POINT SOURCE ANOMALIES

Color differences in water features often do not have the distinct pattern of a point source, but instead appear as relatively homogeneous areas of distinctively colored water. Areas **A** and **C** in Plate 2 are portions of the Athabasca River represented

TABLE 1. IMAGERY SPECIFICATIONS

Figures	Date	Time GMT	Sensor	Filter (nm)	Lens (mm)	FH
2,3	16 Sept 1976	19:50	TC	420	153	1530
5,6,7	16 Sept 1976	19:50	FCIR	525	153	1530
4	17 Sept 1976	7:25	TIR	—	—	910

FH = flying height above ground level in metres.
FCIR = color infrared film (Kodak #2443).
GMT = local time + 7 hours.
TC = normal color film (Kodak #2445).
TIR = thermal infrared line scanner.

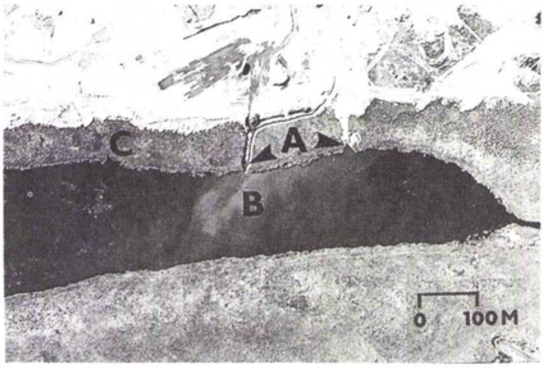

PLATE 1. Normal color airphoto of a portion of Mildred Lake. Scale of the original photo was 1:10,000.

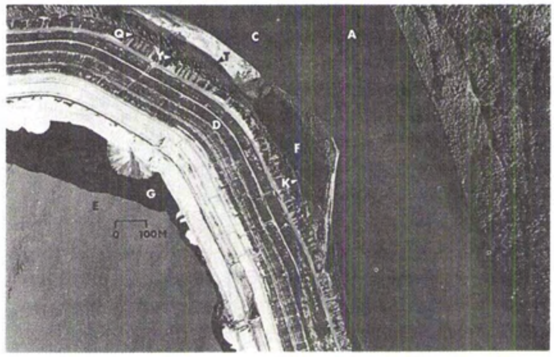

PLATE 2. Normal color airphoto of the Athabasca River and the southeast corner of the GCOS tailings pond. Scale of the original photo was 1:10,000.

PLATE 3. Color infrared airphoto of an area in the northern portion of the GCOS lease. Scale of the original photo was 1:10,000.

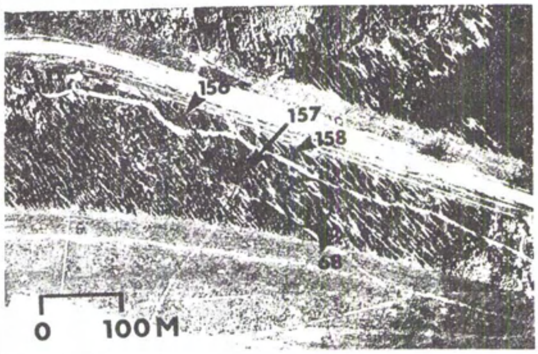

PLATE 4. Color infrared airphoto of an area adjacent to the Syncrude lease. Scale of the original photo was 1:10,000.

PLATE 5. Color infrared airphoto of an area adjacent to the GCOS and Syncrude leases. Scale of the original photo was 1:10,000.

in different shades of brown on the normal color film. The lighter color of the water at C appears to be related to a higher tubidity in that portion of the river. In this case, however, no source can be identified and there is no plume shaped pattern.

Similarly at F in Plate 2 anomolously dark colored water is partially enclosed yet no potential source can be identified. The darker color of this water could be related to several factors. This water could be relatively clear such as at A, it may be discolored by the input of a fluid, or it may have a surface film of a substance such as oil. The thermal infrared imagery shown in Figure 2 provides some additional information for interpretation of this feature. This is a night image in which white represents thermal radiance less than 11 centigrade degrees and black represents radiance greater than 15 centigrade degrees. The six intermediate grey levels each represent a range of 0.66 degrees from 11 degrees (light grey) to 15 degrees (dark grey).

Area F is lighter toned than the water at C adjacent to it, indicating that F is cooler than and/or has a lower emissivity than the water at C. Water of widely varying qualities has been reported to have virtually the same emissivity, but oil films have been reported to have significantly lower thermal emissivity, making oil covered water appear cooler than the surrounding water (Chandler, 1971; Kennedy and Wermund, 1971).

The feature at K on the thermal infrared night image (not discernible on the normal color photograph) appears to be a relatively warm water stream flowing into area F. The proximity of the stream to the GCOS tailings pond (E) and its warm temperature suggest that it may contain effluent from the tailings pond (G is bitumen floating on the pond). This in turn suggests that area F may be covered by an oil film.

The small pond at Y in Plate 2 and Figure 2 appears to be the same temperature as the river channel at T. However, the ponds at Q and P appear much darker in the original image (warmer), suggesting that they may be receiving heated effluent. (The feature at M in Figure 2 is an open channel on the tailings pond dike D. R and S are sandbars.)

The thermal infrared night image and normal color film imaged different types of water much better than did color infrared photography.

ANOMALOUS AQUATIC VEGETATION

On color infrared aerial photographs, living aquatic vegetation on the water surface appears pink in color with a very fine texture and generally no pattern, e.g., at A and B in Plate 3.

In itself the presence of this vegetation is not remarkable. However, this image was acquired during the fall and these were the only examples of living aquatic surface vegetation on the many ponds in this area. B is a sewage pond, which would contain warm water high in nutrients and would be an excellent growth medium for vegetation. A is a natural pond and, in view of the fall season, the presence of living aquatic vegetation indicates that the water quality of the pond is significantly different from other natural ponds in the area. The close proximity of the sewage pond suggests that some of the effluent is leaking downslope into A. Note also the presence of the dead Spruce trees (dark cyan in color) at C bordering the pond and compare with the living Spruce trees (magenta color) at G.

The evidence suggests that pond A has experienced a changed nutrient, water level, and/or temperature regime which has promoted the growth of aquatic vegetation and is adversely affecting the Spruce dominated community, particularly on the downslope side of the pond.

Vegetation Disturbance

IDENTIFICATION OF STRESSED VEGETATION

In northeastern Alberta fall leaf color change has begun by early September, when the aerial photography used here was acquired. Fall leaf color change proceeds unevenly, and on aerial photography stressed deciduous vegetation cannot be distinguished from healthy vegetation which has begun to senesce. However, defoliated coniferous trees can be identified on color infrared photography. Dead defoliated Jackpine were easily identified in Plate 4 (plots 156, 157, and 158) by their cyan color as opposed to the brown color of the living Jackpine in plot 68. (Plate 4 is a reproduction of part of the original aerial photograph with a

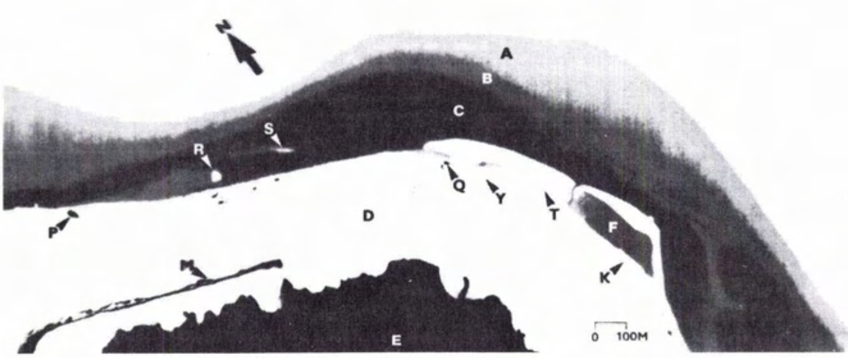

Fig. 2. Thermal infrared night image of the Athabasca River and the southeast corner of the GCOS tailings pond. Scale of the original imagery was 1:11,000.

magnification of about 2×.) However it was found that care must be taken in identifying defoliated Black Spruce because often there is some live foliage concentrated at the top of an otherwise defoliated tree. When examined closely (at 15× magnification) these trees appeared cyan in color with a spot of magenta at the top.

STRESSED VEGETATION ASSOCIATED WITH EROSION

Vegetation stress is commonly related to the removal or deposition of soil by erosion. In Plate 3 deep gullying can be seen at D on a deposit of sand tailings, leading to the native vegetation below. Though not visible in the reproduced print, deposition of material in amongst the defoliated trees at E was evident. Defoliated Spruce trees at H and F may also be related to erosion and redeposition of the tailings.

VEGETATION STRESS ASSOCIATED WITH ROADS

Vegetation stress associated with roads is commonly related to erosion (discussed in the previous section) and interruption of drainage.

Improper culvert installation appears to be a common problem associated with road construction. In Plate 5 the culverts are difficult to see, although they were easily identified on the original transparencies. The three culverts are located through the road embankment (R) at C. These culverts appear to have been placed at too high an elevation, and ponding of water has occurred at P, probably killing the Spruce trees in the area by flooding. Compare the dead cyan colored trees at D to the living dark magenta colored trees at T. The water now ponding at P probably used to seep into area B, which also appears to contain a few defoliated trees (possibly related to the changed water regime).

Conclusion

This paper has shown how certain types of environmental disturbance can be detected using color infrared and normal color aerial photography and thermal infrared imagery. While indicators of environmental disturbance can be identified from aerial photography, and their causes postulated, confirmation requires ground investigation. The observations in this paper have been hypotheses which, in some cases, were not ground checked because access on the ground was either denied or was not feasible at the time of overflight.

It was found that the three types of imagery used in various combinations were often more effective than any one type alone for the identification of indicators of environmental disturbance, and for postulating their causes.

Further, it was found that interpretation of remotely-sensed imagery aided in the identification of the ecological processes related to the observed environmental disturbance.

Acknowledgments

The authors thank the Alberta Oil Sands Environmental Research Program for funding this research and the Canada Centre for Remote Sensing for providing technical assistance and the use of their facilities.

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(Received 25 February 1980; revised and accepted 20 November 1981)