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Special Color Analysis of Runway Conditions

Regions of cracking or depressions in the runway at Thule Air Base, Greenland were determined from color aerial photography.

Introduction

Under the Special Color Analysis Techniques (SCAT) program, Rome Air Development Center (RADC) and Calspan Corporation have developed, designed and fabricated an experimental photointerpretation console. The console provides the photointerpreter with an ability to measure and display subtle color differences found in the spectral bands of color film. The SCAT program also has developed interpretation keys that relate the spectral differences to target properties such as material type and surface condition. SCAT analyses have been successfully used on targets such as industrial storage pile analysis, material discrimination, trafficability studies, runway spalling and cracking analysis, crop stress and crop identification, and studies of oil refinery capabilities. A description of the SCAT console and photointerpretation techniques is contained in Reference 1.

The SCAT program also includes an ongoing effort to apply the SCAT console to target problems of interest to the US Air Force. Determination of runway and soil moisture conditions at Thule Air Base (see Cover Photo) was established as a target effort on the SCAT program. (Figure 1 is a black-and-white copy of a color photo of Thule Air Base, Greenland.)

Abstract: *An investigation of the condition of the runway and taxiways at Thule Air Base has been conducted by interpretation of aerial color imagery. The aerial imagery was analyzed by using a photointerpretation console that has been designed to enhance subtle spectral differences caused by phenomena such as moisture and surface cracking. The results of the analysis indicate extensive cracking and possible runway deterioration. The aerial data delineate regions of cracking or depressions over the entire runway. These data agree well with the ground survey information available, and extend definition of deterioration regions to the entire runway surface. In addition, the aerial data indicate subsurface moisture flow patterns across the runway area that correlate well with the regions of runway cracking.*

A brief description of the interpretation methods utilized will be helpful in understanding the results of the analysis effort. The photointerpreter uses the interpretation console to generate a display that is a measure of the relative value of target reflectances in two spectral bands of the color film. Visual evaluation of the original film only yields a subjective impression of all three color film bands

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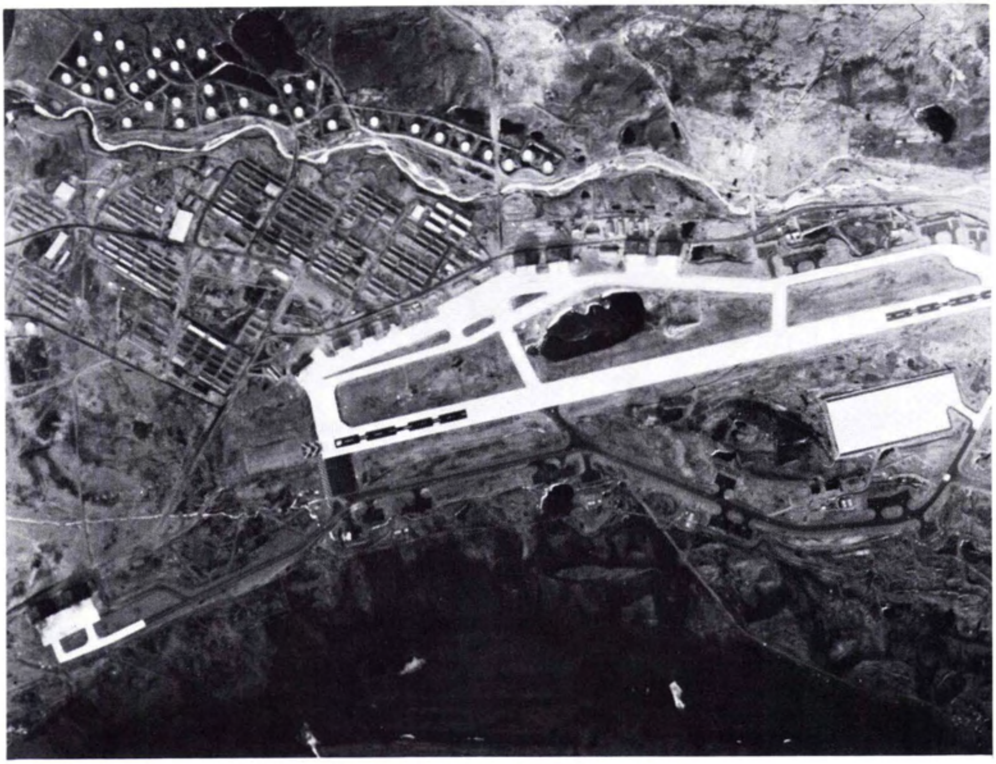

FIG. 1. Thule Air Base, Greenland.

modified by conditions of exposure and processing. It is difficult to discriminate changes between spectral bands visually, and impossible to establish a quantitative measure of the changes.

To overcome these difficulties, the interpreter carefully calibrates the color imagery to account for illumination conditions, flare light effects, exposure and processing parameters. Selecting the two color film layers most sensitive to the problem under study, the interpreter then generates a photographic display in which the tonal changes are related to the relative values or ratios of target reflectances in the two spectral bands. The tonal changes in the ratio display are then color encoded, yielding a quantitative measure of changes in the relative value of the target reflectances. The color encoding step assigns a color to selected ranges of ratio values pertinent to the problem under study.

The most sensitive color film bands for runway analysis and soil moisture detection are the red and blue bands. These are the color film bands used in analyses of the Thule AB runways. By studying absolute values and changes in the relative values of the red and blue target reflectances, the interpreter can delineate regions of unusual moisture content and regions of unusual surface texture, or cracking.

Figure 2 illustrates how the ratio display depends upon the individual red and blue layer information. The areas with highest densities (darkest areas) on both the red and the blue separation negatives are very dissimilar from the patterns appearing as the combined ratio display when the red and blue separation negatives are physically superimposed on one another, forming a red to blue ratio. The dark areas on the ratio display (area 6) represent the lowest red to blue reflectance ratios, indicating those portions of the runway with unusual surface texture (Reference 2).

RESULTS OF RUNWAY ANALYSIS

As a result of a request to RADC for support in obtaining visual photography and infrared scanner imagery of Thule Air Base, RADC Flight Test Division's C-131s over-flew that installation in 17/18 Sep 74. Figure 1 is an image of that airfield and is a copy of the scene used for the subsequent analysis of Thule's runway condition. Spectral information contained in that scene was enhanced by using the SCAT console in order to provide

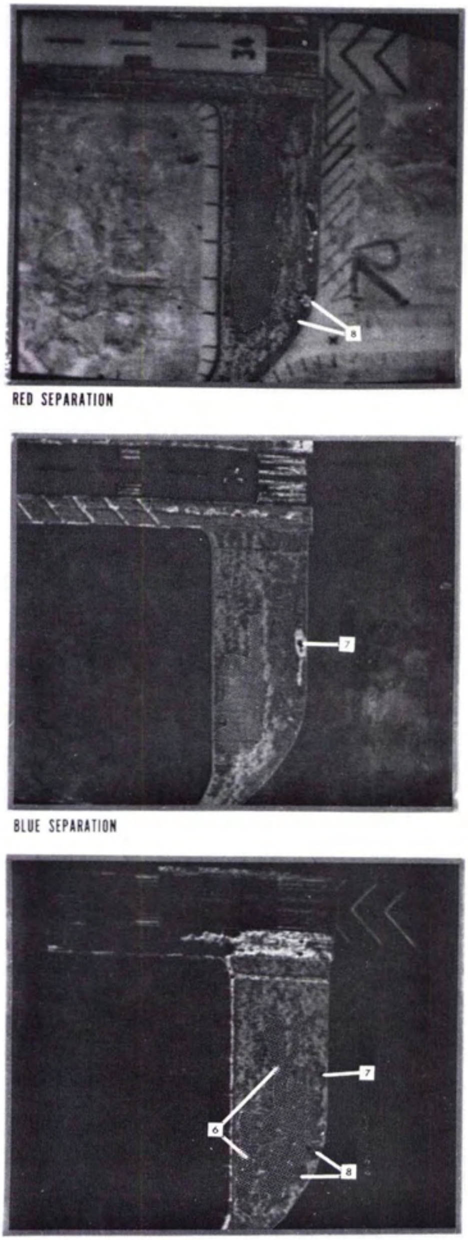

FIG. 2. Comparison of red, blue, and red/blue ratio information.

the information reported herein. Figure 3 consists of a base map annotated to represent locations of runway deterioration, while Figure 4 outlines the areas of high soil moisture content. The information used to draw these maps is taken from the ratio displays of Plate 1. For ease of reference in subsequent discussions, the soil areas have been divided into six major areas and 1000 foot markers have been annotated on the runway.

The runway map (Figure 3) is also annotated with black circles which show the actual ground locations of known surface cracking. Photos of these cracks and depressions at various locations along the runway are presented in Figure 5. The depressions, called "bird baths," can appear overnight, and often reach a depth of one foot. Figures 5a and 5b show depressions which are located at the 1500-foot and 2500-foot markers on the runway map.

The problem areas delimited on the runway map were transferred from the ratio displays. The areas annotated at the 750-foot and 8000-foot markers coincide with bird baths that were outlined on a map provided by Thule personnel.

The ratio analysis technique also indicated problem areas on the East end of the runway in the overrun and apron areas. This was verified by Figures 5c and 5d and ground survey information.

The analysis located many more problem areas along the runway length than were noted on the maps provided by base personnel. The shaded areas on the map, which coincide with the darker blue areas on the ratio display (Plate 1), are probably areas with a denser cracking pattern or deeper cracks, both of which suggest a very unstable subbase. The tapered runway edges showed deterioration where they met adjacent soil areas. This is probably due to water erosion along and under the thinner shoulders of the runway.

When the runway and the soil moisture maps (Figures 3 and 4) are combined, an overview of the subsurface flow patterns, which may be causing runway failure, becomes apparent.

The following discussion of the soil moisture map is presented in reference to the six major soil areas adjacent to Thule's main runway.

Area 1 of the soil map (Figure 4) is a shallow, rectangular basin with the moisture pattern appearing primarily on its periphery. The pattern extends beneath the taxiway into areas 1a and 1b. At several points adjacent to the main runway, patterns appear that suggest

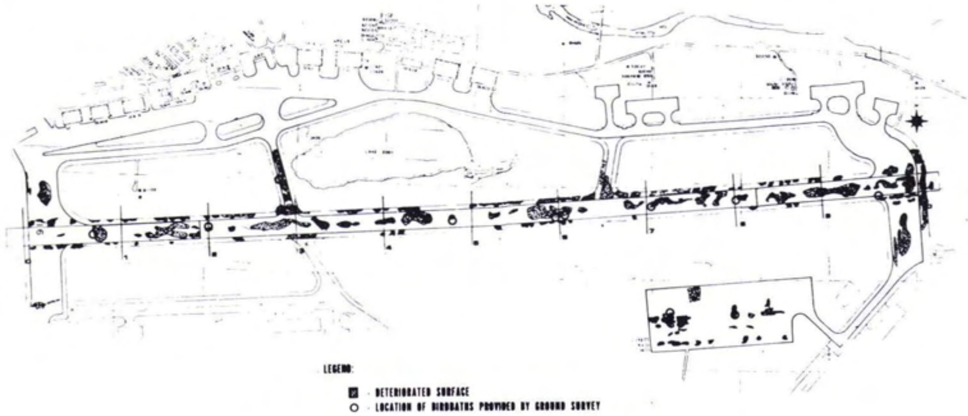

FIG. 3. Runway surface deterioration map, Thule.

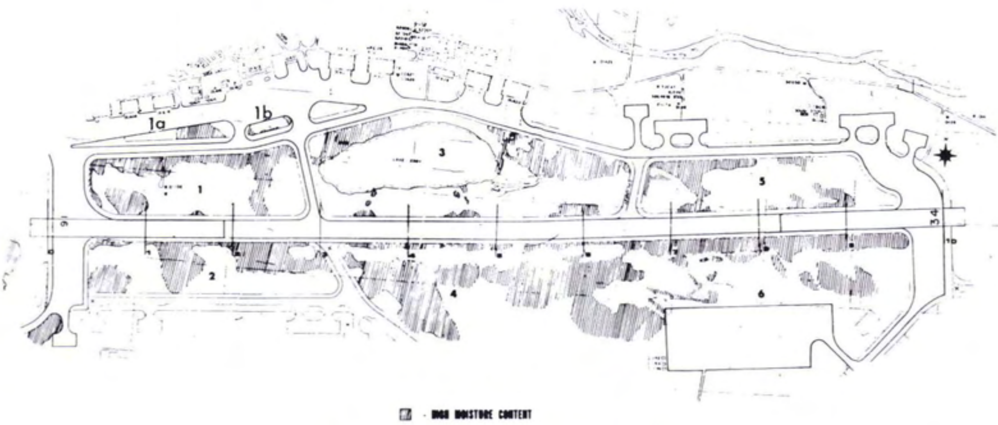

FIG. 4. Soil moisture map, Thule.

a substrata flow of moisture between areas 1 and 2. These patterns occur at footage markers 1500 and 2400, and coincide with runway surface deterioration at these locations, as shown in areas A and B of the soil display (Plate 1). The pattern in area 1 seems to branch across the western north/south taxiway and join with Lake Eddy in area 3 (area C on Plate 1).

A second major flow pattern appears to exist between areas 2 and 3. This moisture pattern occurs in the northeast corner of area 2 and extends into the southwest corner of area 3, continuing into Lake Eddy. This is suggested by the yellow pattern presented in areas B and D on the soil display (Plate 1). Cracking in the runway surface at area 3 in the runway display (Plate 1) reinforces this interpretation. A third pattern, which also appears to have its terminus in Lake Eddy, exists at the 4500-foot marker between soil areas 3 and 4. This pattern coincides with area E on the soil display, as well as with a bird bath shown on both the runway display and the ground survey provided from Thule.

A fourth flow pattern across the runway is suggested at the 6000-foot marker where moisture is found on both sides of the runway, and evidence of runway deterioration (refer to areas I and K on soil display Plate 1).

A final moisture pattern exists over the length of area 6 paralleling the south edge of the main runway. Lesser moisture patterns exist in area 5 which suggest some subsurface crossflow with area 6. Runway cracks at markers 8000 and 9000 bolster this interpretation. This pattern is suggested by areas J and L on the soil display.

The overall moisture pattern indicates a general southeast to northwest movement of subsurface water. Such movement is consistent with the position of the river north of the airfield, and with the high ground located south of the field.

Discussion of Ratio Displays

Plate 1 is a working mosaic of the ratio displays generated for the runway and the

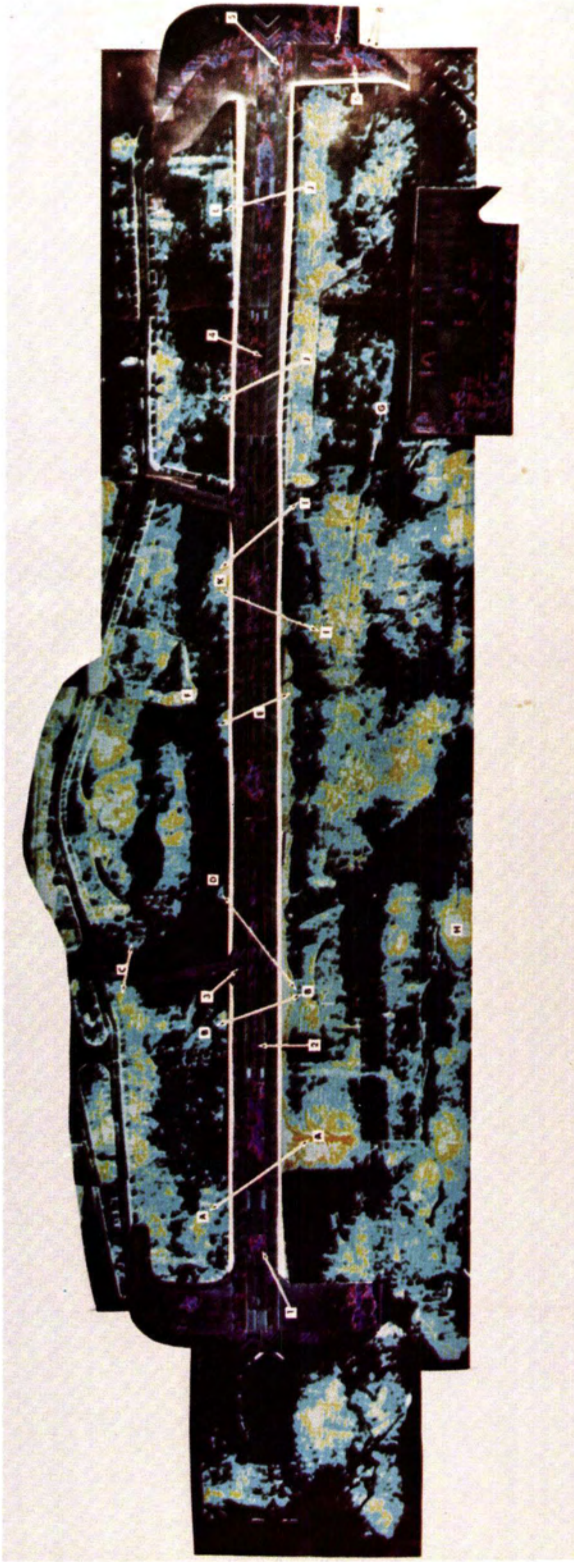

PLATE 1. Working mosaic of runway and soil ratio displays.

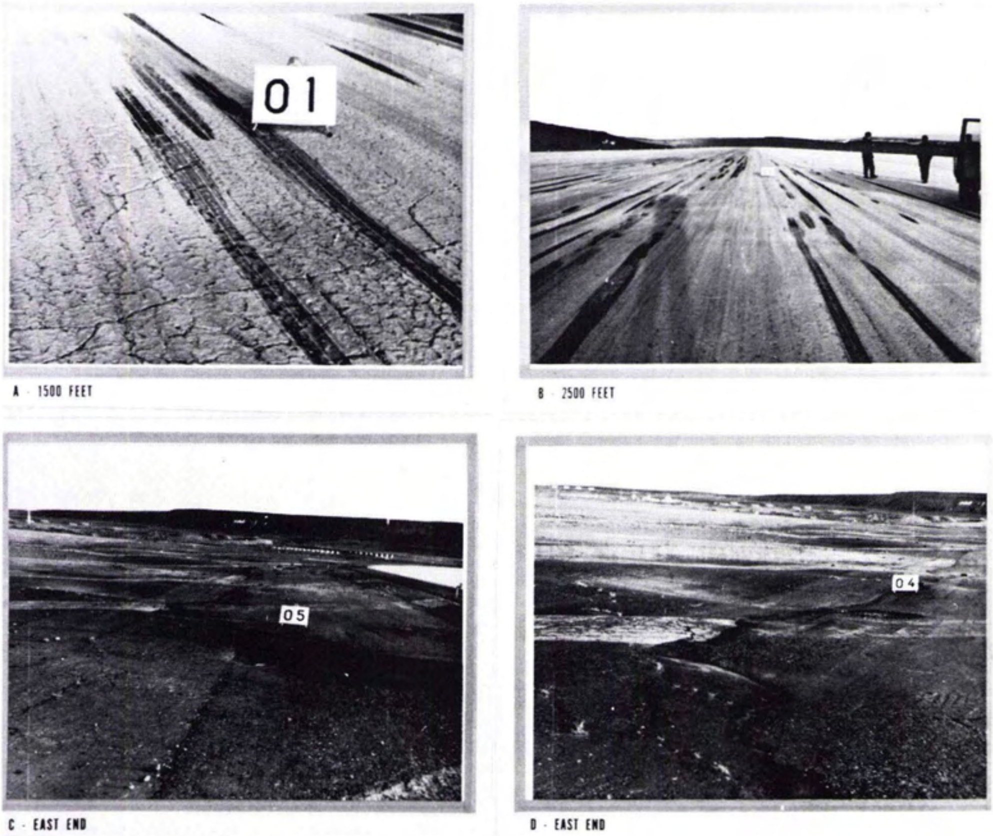

FIG. 5. Ground photos of birdbaths and cracks in runway surface.

soil areas. Due to the scale of the original imagery, ratio displays were generated in sections and mosaicked together for this report. The individual displays and the mosaic were used by the interpreter to perform his analysis of the runway conditions and moisture patterns depicted in Figures 3 and 4.

The key to this analysis is the red-to-blue reflectance ratio of the materials being imaged. The runway at Thule is constructed of dark, asphaltic concrete overpainted in white. White paint exhibits a high red-to-blue ratio. Because cracking occurs in the white surface, the dark sub-base shows through the white paint and the percentage of white area is lessened, thus lowering the red-to-blue ratio. The cracking also roughens the texture of the white surface, adding blue light to the scene, which also lowers the red-to-blue ratio. When a ratio mask for the runway was generated and displayed, the areas of highest cracking (lowest ratios) were displayed in blue and red.

A similar procedure was used in the ratio masks for the soils. As more moisture is added to soil, the red-to-blue ratio increases[1]. These areas of high moisture content (highest ratio) were assigned the colors of white, yellow and cyan. Thus, the colors on the displays are ordered from lowest-to-highest ratio by blue, red, cyan, yellow and white, respectively. For example, the yellow stripes on the runway (having a high red-to-blue ratio) are encoded in white.

The runway display (Plate 1) shows areas of high texture (cracked areas) in blue and red. Area 1 is a patch of extreme cracking, evidenced by the high red-to-blue ratio presentation encoded in blue. This area coincided with a "bird bath" that was annotated on a base map provided by Thule personnel.

Areas 2 and 3 were points which required careful inspection on the original imagery, as well as on the ratio display. The linear blue pattern coincided with black tire marks present on the original scene. Their position in the runway center and general appearance indicate the pattern is caused by tire marks and not by surface cracking. The large blue patch of area 3 also contained many tire marks; however, the extent of the blue area indicates that this area is affected by cracking in addition to the presence of tire marks. The entire taxiway appears to be deteriorated on large-scale original imagery and this is reinforced by the amount of blue present along the taxiway.

Area 4 clearly shows what tire marks look like when found completely isolated on relatively good pavement. This is a point where an aircraft turned on the runway, as evidenced by the curved pattern on the display.

Area 5 appears to be a spot where deterioration took place and was subsequently patched. The linear pattern on the display coincides with a trough-like feature on the original imagery which appears to be an asphaltic patch.

Areas 7 and 8 of the runway display also were examined carefully in order to determine whether these areas contained cracks, or actual marks on the runway. This area is enlarged in Figure 2. Areas 7 and 8 are apparent on both spectral layers as well as the ratio display because these areas are tire marks and engine blast marks, respectively. They appear as dark areas on the original imagery and hence are highly visible in each color layer, as well as on the ratio display. The red and blue film layers were used in this manner to key the interpreter to possible false alarms.

The soil display illustrated in Plate 1 presents the areas adjacent to the runway which evidence high soil moisture content. These areas of high red-to-blue ratio are presented in white, yellow and cyan. The patterns presented in this display already have been discussed in conjunction with the soil moisture map, Figure 4. However, as in the case of the runway display, certain peculiarities exist on the soil display which must be interpreted before they can be considered to be actual moisture areas.

One such anomaly occurs in area F. The area outlined is a man-made mound with steep, sloping sides. The sides of the mound are light reddish soil which has a high red-to-blue ratio independent of the presence of any moisture. The base ratio level from which moisture changes are measured for this soil is therefore much different from the other soil in the target scene. This same phenomenon occurs at area G, where the side slope of a gully is reflecting higher in the red than any of the surrounding soils.

On the soil display, ponds with water and/or ice present a low red-to-blue ratio. Area H is a pond, but is displayed by a high red-to-blue ratio. This is because the pond is shallow and the bottom of the pond is visible. The bottom material is a high red reflector, thus raising the red-to-blue ratio of the target.

An independent analysis of actual ground water samples and engineering tests was conducted by the Air Force Systems Command Civil Engineering Center at Tyndall Air Force Base, Florida. A third study to evaluate the runway surface roughness was conducted by the Air Force Systems Command Weapons Laboratory in Albuquerque, New Mexico.

The results of all the analyses of Thule AB were presented at a joint conference in Colorado Springs, Colorado so as to ascertain the extent of moisture damage and develop remedial measures. Figure 6 shows the general moisture trends which resulted from the conference. When compared to the patterns previously presented in Figures 3 and 4, it can be seen that SCAT analysis confirms this flow pattern.

At the time of the SCAT analysis, RADC had a chart of the air base showing the location of borings taken as part of the engineering tests conducted by the Air Force Systems Command at Tyndall Air Force Base, Florida. Eight of the boring sites were located in the main runway area which underwent SCAT analysis. After looking at the boring sites in relation to the moisture and deterioration patterns provided by our analysis, Tyndall was informed via telecon as to the findings. The SCAT analysis showed that seven of the eight borings were probably wet and one was dry. Tyndall confirmed our re-

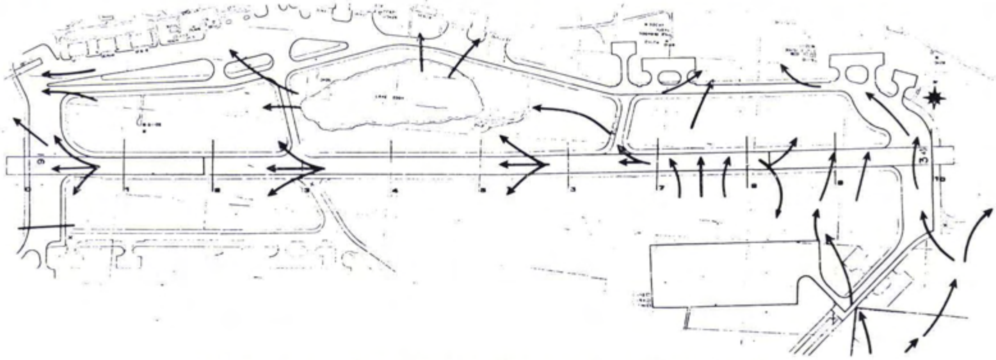

FIG. 6. Subsurface moisture flow trends at Thule Air Base.

sults with the exception that the boring described as dry had contained moisture, but was not nearly so moist as the other seven sites.

A second evaluation of the runway surface roughness was conducted by the Air Force Systems Command Weapons Laboratory in Albuquerque, New Mexico. A profilometer trace down the centerline of the main runway was provided in this study. It resulted in a contour map and a roughness profile of the centerline. Comparison of these data with the surface texture map of the runway provided by SCAT analysis correlated very closely along the centerline.

The coincidence of SCAT results with the on-site tests proves that soil moisture content and runway surface roughness can be accurately determined from remote data collection. Further it is significant to note that the SCAT analysis was done in a much shorter time and at an appreciably lower cost than either of the other two studies. The SCAT analysis of color film provides a reasonable alternative to ground analysis through the employment of remote sensing techniques.

Acknowledgments

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