Bernard W. Hostrop
Tad Kawaguchi
U.S. Forest Service
Ogden, Utah 84401

Aerial Color in Forestry

There is a significant reduction in the cost of photo interpretation; it is possible to assign less critical tasks to less skilled personnel.

Abstract: *The most significant improvement in photogrammetry in recent years has been the introduction of aerial color photographs. At the same time, electronic printing of aerial negatives has enhanced the information content in reproducing both black-and-white and color materials. Color photographs play an important role in the development of areas for new timber harvest methods, soil and watershed studies, development of range and reforestation areas, planning land development, and streambed and fish habitat studies. Color provides a significant increase in accuracy of species identification, identification of dead trees, and facilitates the identification of property corners. Image-point selection and identification are improved by as much as 60 percent.*

Introduction

Aerial photography and maps have long been vital tools in national forest administration and research for such activities as soil science, hydrology, watershed studies, mineral resources analysis, wildlife surveys, and timber conservation. As a service organization to the Intermountain Region (Region 4 of 9 forest regions in the continental U.S. and Alaska), the Division of Engineering's Surveys and Maps Branch must constantly endeavor to improve the quality of these management and research tools, as well as to insure their validity from year to year as changes constantly occur.

To the Surveys and Maps Branch, certainly the most significant improvement in photogrammetry in recent years has been the introduction of aerial color which went into full operation in the Photography & Reproduction Department in early 1969. At the same time, electronic printing of aerial negatives was established as regular practice because CRT-scanned exposure had proved its capacity to enhance information content in printing aerial black-and-white negatives in the Branch's laboratory.

Enthusiastic response from both administrative and field personnel in the 18 national forests in Region 4 has led to planned production of 100,000 color prints for resource photography alone in the year 1970. The Intermountain Region covers the states of Utah, Nevada, Idaho south of the Salmon River, and western Wyoming and so includes among others the Boise, Payette and Humboldt National Forests. Other regions in the U.S. Forest Service, none of which presently have the capacity to produce color prints in large volumes, are placing more and more print orders with the Surveys and Maps Branch as they recognize the value of aerial color in forest management and research.

Functions of Aerial Photography in Forestry

The major continuing activity of the Photography and Reproduction Department of the Surveys and Maps Branch, both in volume and variety of application by the U.S. Forest Service, other branches of the government and the public, is resource photography. All forests in the region are flown at a scale of 1:15,840 (4 inches to 1 mile) on a rotating basis every 10 years, with special high-use areas flown as needed. Independent aerial survey firms are given a flight line index and altitudes, and are requested to make bids on contracts for photographing usually an entire forest, covering rarely less than 1,000 square miles.

Special photography, conducted internally by the Surveys and Maps Branch using the Division of Engineering's airplane, is done on order for cooperative projects with such government departments as the Bureau of Land Management, Soil Conservation Service, U.S. Geological Survey, Bureau of Reclamation, and the five major operating groups in the U.S. Forest Service (Range, Timber, Wildlife, Watershed and Recreation). The photography is usually large-scale and covers areas under 100 square miles, and so is relatively difficult for independent contractors to fly profitably. Most special assignments are usually made in behalf of recreation planning or specific bridge and road construction projects.

Using the resource photography, the Surveys and Maps Branch operates eight major maps programs for engineering, recreation, watershed, range, cadastral surveys, and other special purposes. Planimetric maps (2 inches to 1 mile) have been regularly updated on a rotating basis and are now being replaced with an overprint edition of the U.S. Geological Survey's 1:24,000, $7\frac{1}{2}$-minute topographic series. The regular U.S. Forest Service maps ($\frac{1}{2}$ inch to 1 mile), also periodically updated, include information on drainage patterns, secondary roads and other details of interest to recreationists, hunters, fishermen and rangers. These maps, which range in size up to 48×52 inches for the Boise National Forest, are available to the public at $1.00 each. Recreation maps, which are less detailed and free to the public, are developed from the Forest Service maps.

Topographic mapping (1:24,000) is closely coordinated with the U.S. Geological Survey mapping program in order to avoid duplication of effort. Topographic maps are reduced to an inch-to-mile scale as positive masters on Cronoflex sheets. Ordering by print numbers on the master sheets, the public can buy paper prints at a nominal price per square foot. In a potential new service still under study, a controlled positive mosaic would be added to the topographic maps to provide both topographical information and added photographic detail.

After flying an aerial project and processing the film, the contractor provides the Surveys and Maps Branch with black-and-white contact prints. These prints are inspected by the Aerial Photography and Planning Section and, if accepted, the contractor provides a flight line spot index on negative photostat maps at a scale of 1 inch per mile. Two sets of contact color prints are sent to the national forest involved as standard practice and one color set is sent to either the Division of Timber Management or the Division of Range Management. After that, prints of aerial resource photography can be ordered from the index by any government branch or the public at established rates.

Aerial Color First Introduced

The Surveys and Maps Branch had used aerial color prints for limited application since the early 1960's, having the printing done by an independent color laboratory. As the volume and scope of application increased, the overall cost of commercial color prints became such that it was economically feasible to establish a large-capacity internal print production facility.

Processing of the aerial negatives is made part of the basic flight contract for resource photography and, for special photography, is distributed among several commercial color laboratories. These firms have continuous color negative processing equipment, which permits processing longer rolls of film while requiring minimal variation in filtration in printing. Long rolls can also be processed by rewinding, but experience has shown that there is then excessive change in color balance and too much filtration is needed.

Our present specifications call for 300-foot rolls of polyester-base film capable of being processed to a negative. The only such film now available is Eastman Kodak Ektachrome MS 2448 and MS 2445 (high speed). The print paper is presently Eastman Kodak Professional paper and RC (Resin Coated) paper.

As soon as the color printing facility was ready for operation, a presentation was made by the Surveys and Maps Branch to the management of the 18 forests in the Intermountain Region. Although many of those present had not yet had any experience with color, others were already prepared for full-scale use of color resource photography on their forests. Because of such changes as flood and erosion damage, shifting stream bottoms, burned-over areas, and the expanding transportation system, various national forests in Region 4 had requested new resource photography with the hope that it could be done in color. As expressed by a Forest Supervisor, the Boise National Forest in particular was very much interested in using color photogrammetry in the following activities:

- Development of areas for new timber harvest methods, such as high-lead, skaggit, and balloon logging.
- Soils and watershed studies in conjunction with the South Fork of the Salmon River and the Idaho Batholith studies.
- Development of range and reforestation areas.
- Development and location of the Forest transportation system.
- Planning land development of areas to take care of the increased recreation impact.
- Streambed and fish habitat studies, where mining operations, timber harvests, and/or road locations affect the stream.
- Impact and coordination planning for the Garden Valley and Twin Springs Dam projects.

With budgetary considerations in mind, it was explained to the representatives of individual forests that they could expect that the cost of color prints would average 30 percent higher than black-and-white prints. But experience had shown, they were told, that the additional cost was more than justified both by time savings in ground work and photo interpretation, and by the substantially greater amount of useful detail available in the prints. For applications in which the advantages of color were not needed and for large duplicate print orders, electronic black-and-white prints could still be obtained at low cost.

The first major color project with the new facility was actually undertaken for U.S. Forest Service Region 5, headquartered in San Francisco. The Sierra Project, as it was called, involved making 2500 9-by-9-inch contact prints.

Electronic Color

When the Photography and Reproduction Department began planning for color print processing in the summer of 1968, the first tests of aerial color involved making 1:1 prints on an enlarger and then processing the prints individually in a high-temperature drum processor. Anticipating a large-volume production, a seven-minute processing cycle per print was clearly inadequate. Therefore, an Eastman Kodak Model 4C3 continuous paper print processor was ordered for installation in early 1969.

The quality of the enlarger-produced prints was considered inferior in two major respects. First, too much of the photographic detail that was available in the color negative was lost in the print. Secondly, meticulous attention to filtration still could not eliminate excessive variation in color balance from print to print along a flight line. Test prints were originally made by an independent service on a multiple-lamp contact printer, but they were unacceptable for the same reasons as the constant-light prints. There was a tendency toward "hot spots" with halos (at that time we were using a 6-inch Zeiss aerial camera; presently, our camera is a Zeiss RMK-A with an $8\frac{1}{4}$-inch lens, and the same camera type is required of our contractors).

FIG. 1. A LogEtronics Mark II Electronic Contact Printer is used for volume production of black-and-white prints in the Photography and Reproduction Departments of the Surveys and Maps Branch. Average annual production of 9×9-inch black-and-white contact prints has been between 50,000 and 60,000.

It seemed then that a scanning-type electronic printer was necessary to obtain the information detail and color balance control that were needed. The Photography and Reproduction Department had been operating a LogEtronics black-and-white contract printer (Figure 1) since 1963 primarily in printing glass diapositives for our photogrammetry section, eliminating a previous problem of too much loss in shadow detail in constant-exposure prints. With the improved detail, greater accuracy was obtained in planimetric and topographic maps, and plotting was faster and less tiring. After making a series of tests of electronic color prints, a LogEtronics Mark III color contact printer (Figure 2), which can also make black-and-white prints, was specified for the new color

FIG. 2. A LogEtronics Mark III Color Contact Printer is being set up to expose a frame from an aerial roll negative. The 9½-inch wide roll of paper is mounted on an automatic roll transport capable of accepting 1,000-ft rolls. The printing paper is advanced the required print width automatically when the platen of the printer is lifted after exposure, as the operator is doing here. Nominal output of the Mark III printer is from 250 to 300 production prints per 8-hour day, including time for test prints.

facility. Expecting continued production of black-and-white prints in far larger quantities than the Mark III printer could handle

FIG. 3. The rolls of Kodak Professional color paper are processed in the Department's Model 4C3 continuous print processor.

with the color work, a LogEtronics Mark II black-and-white contact printer was specified at the same time.

The three prints of Plates 1, 2 and 4 demonstrate the differences in print quality—both aesthetic and in relative information detail—in three types of aerial prints: multiple-lamp black-and-white contact print (Plate 1), scanning-type electronic black-and-white print (Plate 2), and scanning-type electronic color print (Plate 4). The negative is a 1:15,840 aerial view of Snow Basin in Utah, part of a flight line exposed on October 20, 1969. The electronic print in Plate 2 certainly shows considerably more surface detail in both highlight and shadow regions than the multiple-lamp print in Plate 1. However, the electronic color print in Plate 4 in turn tells far more about the topography, vegetation and soil structure of the area than the electronic black-and-white print in plate 2.

MAKING COLOR TEST PRINTS

In making electronic color prints, a primary concern that could not be predicted was the time and materials that would be consumed in making test prints. In the test printing procedure now used, the 125-foot or 300-foot film roll is placed on the Mark III color contact printer, and the roll is wound through to detect any major changes in the flight-line exposure. In the perhaps four flight lines on a 300-ft roll, 12 negatives—one at the beginning, middle and end of each flight line—are marked with masking tape for test prints, recording the estimated filtration needed for each negative. The marked prints are then exposed, processed and examined to determine if any change in filtration is necessary. In a 250-ft roll developed in a continuous paper print processor (Figure 3), examination of the test prints would typically produce the following conclusions: no change needed on first flight line, minor filtration change on second flight line, no change needed on third flight line, and major change on fourth flight line. Production prints would then be run on the first three flight lines, and another set of three or four test prints would be made on the fourth flight line. The printing paper is mounted on an automatic roll transport which advances the required print width when the platen is raised after exposure.

Even with major filtration changes, the maximum has been three sets of test prints for a flight line. Only one test print has been found necessary for about three-quarters of the flight lines printed. The filtration is marked on the film rolls for reprinting. The

PLATE 1. Portion of aerial photograph showing Snow Basin in Utah. The original scale was 1:15,840 and this is approximately 1:20,000. The original photograph was an aerial negative, Ektachrome MS 2448 film (Plate 4). This print was produced with a multiple-lamp black-and-white printer.

average production rate for one operator exposing paper rolls with one electronic color printer is between 250 and 300 prints per eight-hour shift. The continuous print processor is capable of handling 1000 prints per shift. A new Mark III electronic color printer was installed in July, 1970. This printer has a light-tight paper transport and step-and-repeat cycle for repeated exposures. Its production rate should be about 500 prints per shift.

Value of Color—Increased Technical Detail

The value of aerial color in providing increased technical detail in foıestry is demonstrated in the pair of photos in Plates 3 and 5 The black-and-white print in Plate 3 and the electronic color print of the same negative in Plate 5 were analyzed by a soil scientist for the Wasatch National Forest. He drew mapping lines in india ink in the overlapping sections of black-and-white and color stereopairs with a mirror stereoscope (Figure 4) in order to separate identifiable soil zones. In doing the mapping, he made the following observations:

- ★ Color is excellent where mapping soils is based on variability in vegetation
- ★ More soil mapping detail is possible with color.
- ★ Color reinforces map lines based on land shape (Plate 5). The color emphasizes moisture-vegetation differences at breaks in slopes.
- ★ Color photos are particularly useful where soil differences are expressed only in very subtle surface differences, such as slight changes in density of ground cover and intensity of geologic erosion plate 5. These small differences cannot be consistently mapped if one is given only tonal shades of gray.

In summary, the soil scientist finds color most useful in aerial views in which there is relatively uniform topography and vegetation. Conversely, he considers that black-and-white prints are usually adequate for low-intensity reconnaissance soil surveys for which the detail need not be so great and where there is a strong relationship between soil types and gross landscape features, as is generally true of Plate 5.

His final comment after completing the mapping in Plate 5 was simply that color aerial photography is prettier than black-and-white photography and so may have genuine value in getting the overall job done. He believes that it may be aerial color's most valuable asset that the user's interest is better held, he has a more positive attitude about the forest inventory data he is presented with and is inclined to want to learn more about the land he manages.

The use of aerial color in geological in-

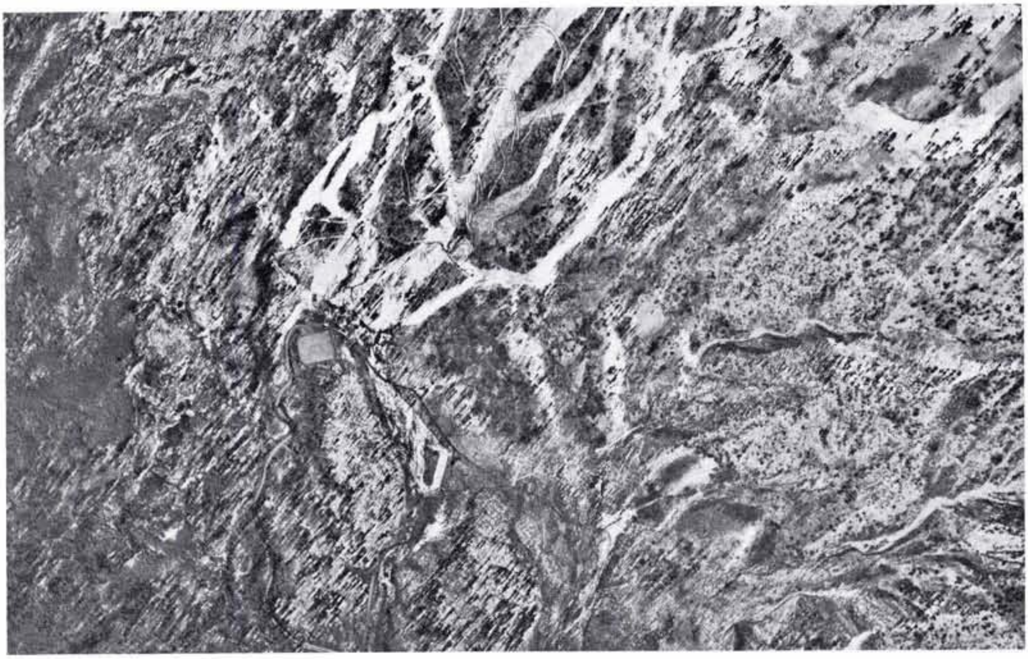

PLATE 2. From the same negative as Plate 1 but produced with a Mark II electronic black-and-white printer.

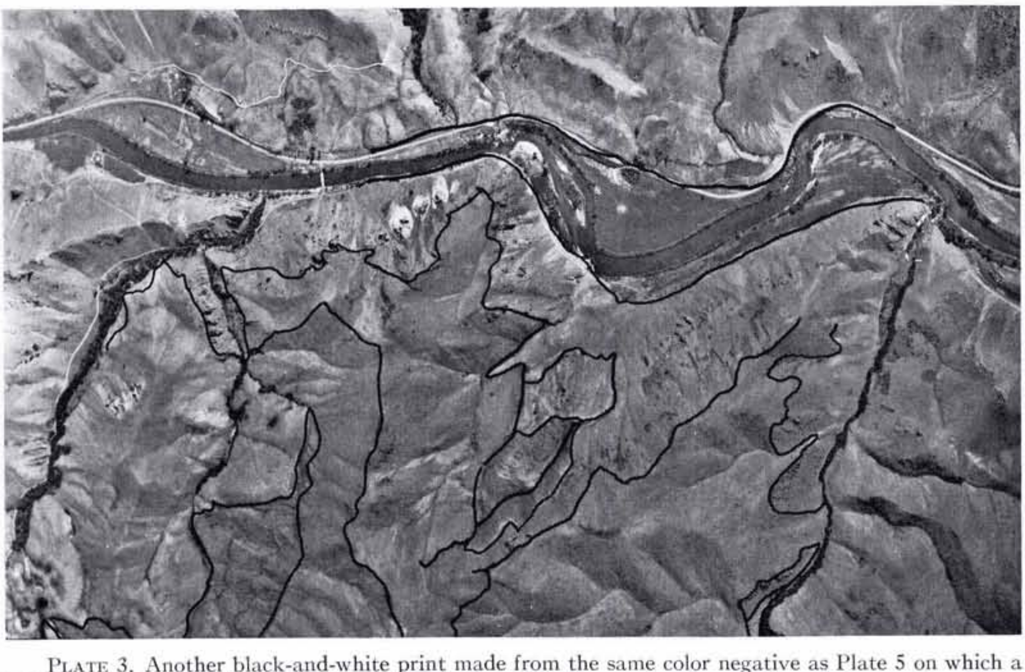

PLATE 3. Another black-and-white print made from the same color negative as Plate 5 on which a U.S. Forest Service soil scientist has mapped the soil in the overlapping portion of stereopairs using a mirror stereoscope.

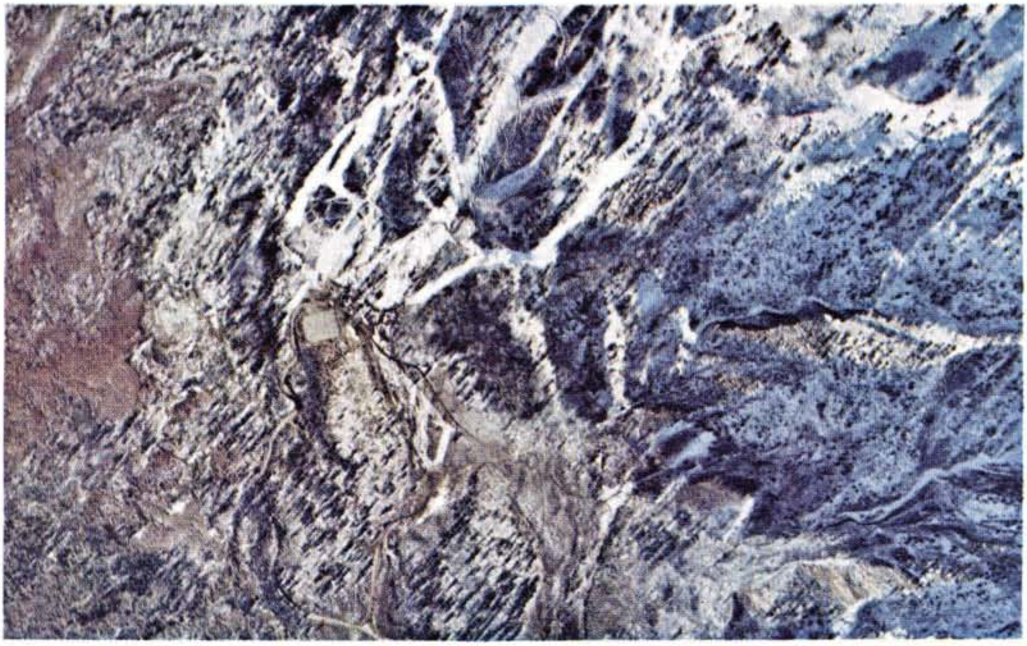

PLATE 4. Same negative as Plates 1 and 2 but produced with a Mark III electronic color printer.

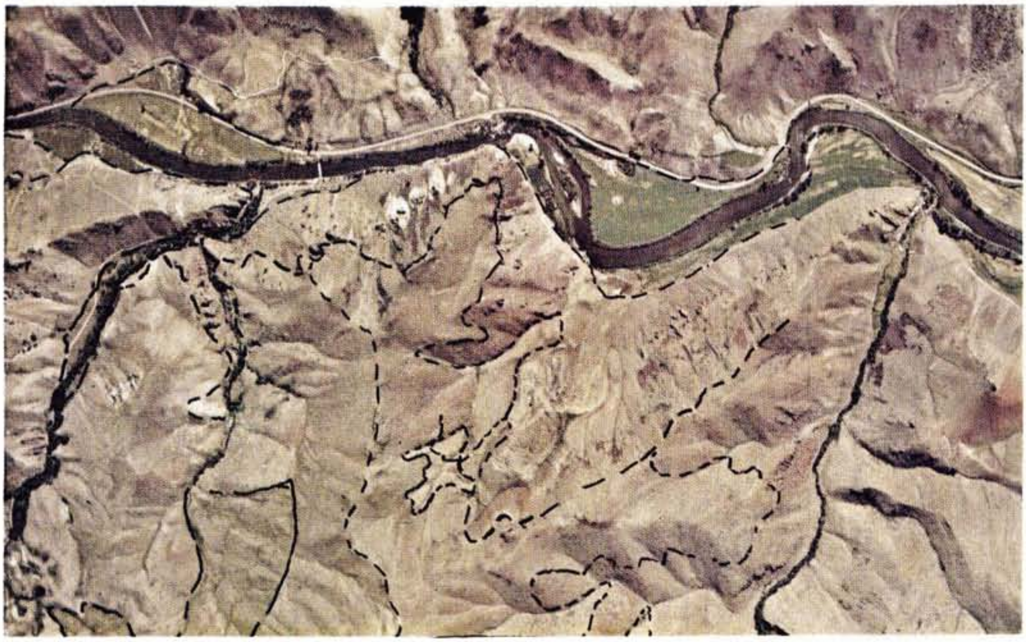

PLATE 5. Same negative as Plate 3 but produced with a Mark III electronic color printer.

FIG. 4. A U.S. Forest Service ranger is using a mirror stereoscope to study a color stereopair of a forest area he manages.

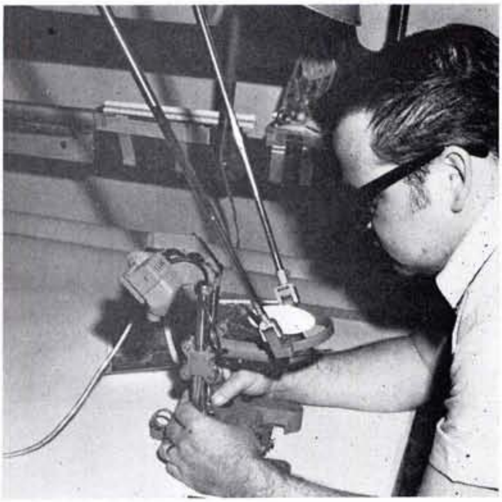

FIG. 5. A Surveys and Maps Branch technician is operating one of the Branch's KPP-3 Kelsh Plotters, using color glass diapositive plates. Paper color prints of the same views are kept for reference.

vestigation was evaluated in connection with the original Sierra project. Members of the U.S. Geological Survey commented that the 1:24,000 color prints were particularly useful for interpretation of geological structures in highland areas above the timberline or where vegetation was sparse. The color photos were considered invaluable in detecting outcrops of metamorphic rocks and zones of altered granite, all rock types of prime interest in terms of potential mineral resources. They helped also in planning sample locality grids that would be best suited to test the mineral potential of such anomalous areas.

According to the mineral analysts, mineralized zones in the Kaiser Peak and Mount Abbot quadrangle of the Sierra Project are typically light-yellow, orange or reddish-brown. Such zones show up on black-and-white photos faintly or not at all; if they do appear, they can easily be misinterpreted as zones of light gray grantic rock. In contrast the 1:24,000 color photos depicted such areas quite clearly, and permitted a much more thorough mineral investigation than would otherwise have been possible.

With regard to the value of aerial color in timber management, the following advantages were cited by timber specialists for the Payette (Idaho) National Forest:

¶ Color provides a 30 to 40 percent increase in the chance of correct species identification.
¶ Dead and dying trees are more readily identifiable, and insect and disease centers can be located with as much or more accuracy than by personal aerial observation.
¶ Land-line corners can be more easily located.
¶ Ground cover identification is improved as much as 50 percent over black-and-white photos.
¶ Classification of physiography is improved; soil and rock conditions are much more apparent.
¶ Image-point selection and identification is improved by as much as 60 percent.

VALUE OF COLOR—TIME SAVINGS

The Survey and Maps Branch's experience has shown that the greater information recorded in electronic color prints substantially increases the amounts of interpretation that can be done with photographs at a desk. Roughly half the work that formerly had to be done in the field in ground surveys can now be done at far less cost with resource photography (Figure 5).

There is also a significant reduction in the cost of photo interpretation. As described earlier, a skilled aerial interpreter can identify various types of soil, vegetation and minerals faster and more accurately, not only reducing the time for interpretation but minimizing the need for correcting information in subsequent ground surveys. In addition, it is possible to assign less critical interpretation tasks to less skilled personnel. Although the Surveys and Maps Branch has at the time of writing been using aerial color in survey mapping for only a few years, definite improvements in accuracy and reduction in plotting time have been achieved.