N73- 28225

Paper A 18

ERTS-1 IMAGERY AND HIGH FLIGHT PHOTOGRAPHS AS AIDS TO FIRE HAZARD APPRAISAL AT THE NASA SAN PABLO RESERVOIR TEST SITE

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INTRODUCTION

Some unusual circumstances currently are combining to produce a condition of critical fire hazard in many parts of California. The hazard is especially great in a very hilly portion of the NASA San Pablo Reservoir Test Site, immediately east of the Oakland-Berkeley metropolitan complex in which nearly 1 million people currently are living and working.

Part of the circumstances which are now of concern had their origins more than 200 years ago with the accidental importation from Spain of various herbaceous annual plants -- especially "wild oats" (Avena fatua). These plants probably were introduced accidentally by the Spanish explorers and missionaries and soon became well established. In fact they now comprise the bulk of the vegetation in most of California's foothill country. In the summer time these annual plants turn from green to golden brown (we never admit that they die) and constitute a great fire hazard.

Another part of the circumstances which currently are contributing to California's fire hazard originated a little over 100 years ago with the intentional importation from Australia of eucalyptus trees (mainly Eucalyptus globulus or "blue gum"). Some say they were introduced by the Australian prospectors who came all the way from "down under" to join California's gold rush. Others point out that the first formal planting of eucalyptus in California was in 1856 and that the main planting was during the period 1910-1913. During that brief period more than 8 million trees were planted by one group alone in the Oakland-Berkeley hills along a 25-mile ridgeline. As will presently be seen these trees can constitute a very real hazard even under normal climatic conditions and an extreme fire hazard under certain abnormal climatic conditions.

The circumstances which have just been described would constitute no greater cause for alarm this year than at any time in the past several years were it not for two remarkable abnormalities of climate which have developed during the past few months in many parts of California and especially in and around the NASA San Pablo Reservoir Test Site.

One of these abnormalities pertains to precipitation. The test site

area, like much of the rest of California, currently is experiencing what has already been termed the "wettest rainy season in history". Consequently the wild oats and other herbaceous annuals are growing more luxuriantly there now than ever before. By the summer of 1973, when such vegetation will have turned brown and become tinder dry, it probably will constitute the largest volume of "flash fuels" that the rangelands in this area have ever known.

The other abnormal climatic factor pertains to temperature. During a 9-day period in mid-December of 1972 the test site area experienced the coldest temperatures in recorded history. Even at the semi-sheltered botanical gardens of the University of California the temperature hovered around 10°C below zero for most of this period. Consequently the frost-susceptible eucalyptus trees, most of them for the first time in their 60- to 100-year old lives, were severely damaged by frost. In fact one estimate indicates that more than 2 million of these trees were killed during the December cold snap. The tall dense eucalyptus timber stands, with their tremendous crown canopies of tinder dry foliage that is loaded with volatile oils, are so flammable as to be regarded by some authorities as virtual "funeral pyres" for the whole Oakland-Berkeley metropolitan complex. With reference to the height of these stands, some of them in the test site area exceed 200 feet. They are reportedly the tallest hardwood trees in the North American continent and perhaps in the entire Northern Hemisphere. The fact that long strips of shaggy bark hang from the trunks and larger branches of these trees adds to the likelihood that fire brands could spread spot fires over great distances. The fire hazard is further increased by the presence beneath these eucalyptus stands of very large amounts of flammable forest litter. In fact in some portions of the area the amount of this litter exceeds 100,000 pounds per acre. The threat to homes that have been built either within or near the eucalyptus stands is obvious enough because of the possibility that fires might start next summer either directly within these stands or in surrounding grasslands from which such fires could readily spread to the timber stands, themselves, and then to the shake-roofed wooden houses.

The threat is believed by some, however, to be even greater than the above facts might indicate, because eucalyptus is a notorious fire type. In its native Australia it has been known to develop "fire storms" capable of producing spot fires at distances of more than 10 miles from the main fire. Among the notable topographic characteristics of the Oakland-Berkeley hills are their steep slopes, deeply incised canyons and elevations in excess of 2,000 feet, all of which make them unusually favorable for the development of such storms. Furthermore, there are times during the summer months when hot dry winds, coming all the way from the Nevada deserts via the hot Central Valley of California, make the situation even more critical. Such winds blow strongly past the Oakland-Berkeley hills and directly from there toward the nearby cities of Oakland and Berkeley. It is in this regard that the high concentration of wooden-roofed houses

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in the Oakland-Berkeley metropolitan complex is of great concern. Still fresh in the memory of many of the older residents of the area is the great Berkeley fire of 1923 which, aided by such winds, burned 625 homes, even though the area then was only sparsely settled. There are even some residents who can recall the great San Francisco fire of 1906, which occurred a scant 10 miles across the Bay from the presently threatened area. As for the possible consequences of a "firestorm" which might develop next summer, some authorities consider them to be potentially far more serious than those which occurred in Hamburg, Germany during World War II, snuffing out the lives of 30,000 people.

A series of hearings recently has been held leading to the conclusion that most of the dead trees will have to be removed promptly, but there is a considerable amount of uncertainty as to the magnitude and cost of that undertaking. Estimates range from $4 million upward and there is general agreement that state and federal emergency funds must be obtained. This, in turn, has created the requirement for a quick assessment of the enormity of the problem and has raised the question of whether ERTS-1 imagery or high flight aerial photography might facilitate the task.

TYPES OF IMAGERY USED IN THE PRESENT STUDY

During the past 8 years NASA has flown large amounts of aerial photography of the NASA San Pablo Reservoir Test Site, of which the present area of concern is a part. This photography has included all of the black-and-white film-filter combinations and all of the color films which investigators have considered for possible use in making earth resource surveys. Furthermore it has been obtained at various seasons of the year and at altitudes ranging from less than 1,000 feet to more than 65,000 feet. In addition, side-looking airborne radar (SLAR) images and thermal infrared images (by day and by night) have been obtained of this same area. In fact there is a strong possibility that this area has been the most thoroughly remotely-sensed spot on the surface of the earth.

Since the launch of ERTS-1 in July, 1972, cloud-free coverage of this same area has been obtained on at least 8 different occasions by the ERTS-1 multispectral scanner system and on at least one occasion by its return beam vidicon system.

Perhaps the most useful imagery of all in relation to the present study is that which was obtained almost simultaneously on January 4, and again on January 22, 1973, by both ERTS-1 and a NASA "high flight" aircraft based at the NASA Ames Research Center and covering the entire NASA San Pablo Reservoir Test Site and its environs.

The report which follows incorporates the result of the author's first-look analysis of the most useful of the above-mentioned types of

imagery and of the associated terrestrial photos and low altitude oblique aerial photos which he has taken of the study area.

RESULTS OBTAINED TO DATE FROM A STUDY OF THE AVAILABLE IMAGERY

One benefit accruing to anyone who writes reports on the usefulness and limitations of photography is that the photographs usually "speak for themselves". That certainly is the case with respect to the photographs comprising Figures 1 through 8, even though the black-and-white reproductions are less interpretable than the color originals from which they were made. However, the reader usually can benefit from an explanation of certain specific points which the author has found to be valid during the course of his photo interpretation and associated field work. Such explanations appear, where appropriate, in the captions which accompany the above-mentioned figures and hence need not be repeated here.

The main value of the ERTS imagery relates to the fact that both the annual grasses and the eucalyptus plantations are scattered very widely throughout the state of California. Merely from an examination of ERTS imagery it has been possible to select areas in which vegetation stress was developing to the point where a closer look with aerial photography was warranted. For other areas no aerial photography was needed.

It also is evident from the accompanying photographs that much can be told, on both ERTS-type imagery and high altitude aerial photography, about topographic conditions and about the density and location of housing and other structures which are of primary concern in relation to fire hazard appraisal. These particular factors are better assessed on the high altitude aerial photos than on the ERTS imagery, however.

Obviously, to the extent that smaller areas can be resolved on aerial photos, more detailed mapping of areas exhibiting plant stress can be made on such photos than on space photos. Of greater significance, however, is the fact that the evidence of plant stress can be detected at as early a date on ERTS-1 photos as on aerial photos. This fact can be of great value in those instances where early warning relative to the loss of vigor in plants can permit both timely and effective remedial measures to be taken at a fraction of the cost that would be entailed if the condition of vegetation stress were not to be discovered until a later date by which time it had reached a more advanced stage and/or affected a much larger number of plants.

As evidenced by the accompanying image examples and the interpretations of them indicated in the captions, it seems quite rational to conclude from this study that ERTS-type imagery, when used in concert with limited amounts of aerial photography and direct on-site observation, can greatly facilitate the making of fire hazard appraisals of the type dealt with in this paper.

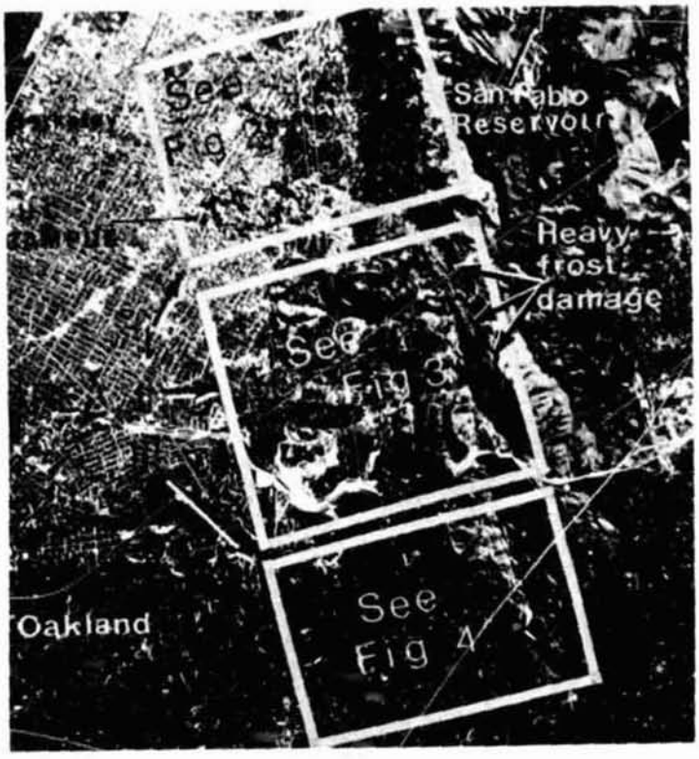
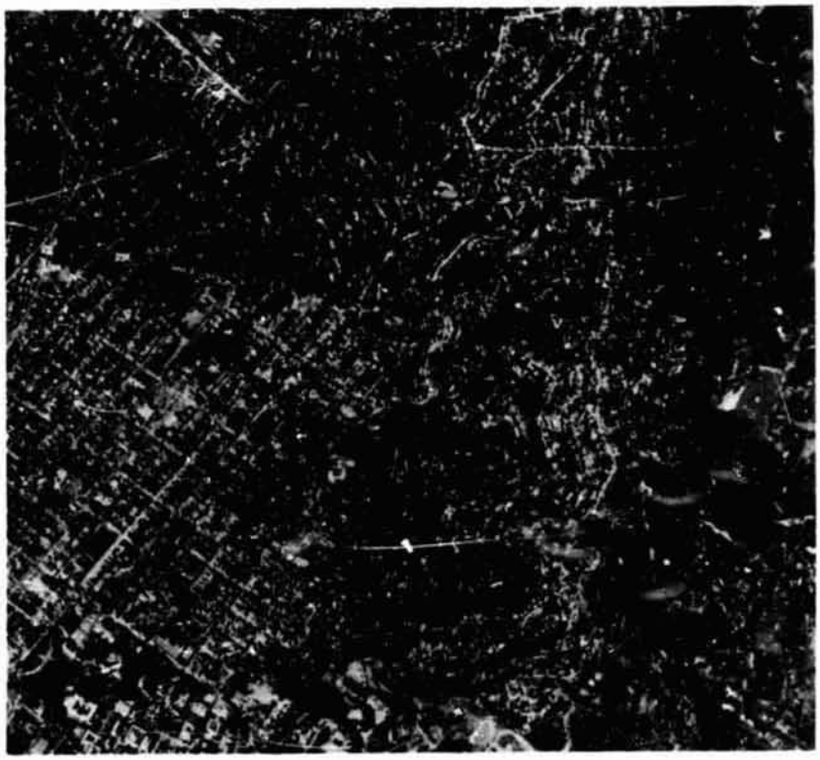


Figure 1. Black-and-white reproduction of part of an Infrared Ektachrome "high flight" photo of the NASA San Pablo Reservoir Test Site. This photo was taken by one of NASA's U-2 aircraft from an altitude of 65,000 feet on January 22, 1973, approximately six weeks after the area experienced a killing frost. This is part of the photographic coverage which routinely is being obtained of the test site in support of the NASA-funded ERTS-1 studies that are being conducted there by personnel of the Forestry Remote Sensing Laboratory of the University of California. The fact that frost-damaged stands of eucalyptus trees can be discerned on this photograph is quite apparent if one compares the 3 rectangular areas with large scale photos of the same areas as shown in Figures 2, 3 and 4, respectively.



See Figs 5bcd

Figure 2. Black-and-white reproduction of part of an Infrared Ektachrome photo of the NASA San Pablo Reservoir Test Site, taken from an altitude of 25,000 feet on January 22, 1973. Compare with Area I, as outlined on Figure 1, and also with Figures 5a b c d.

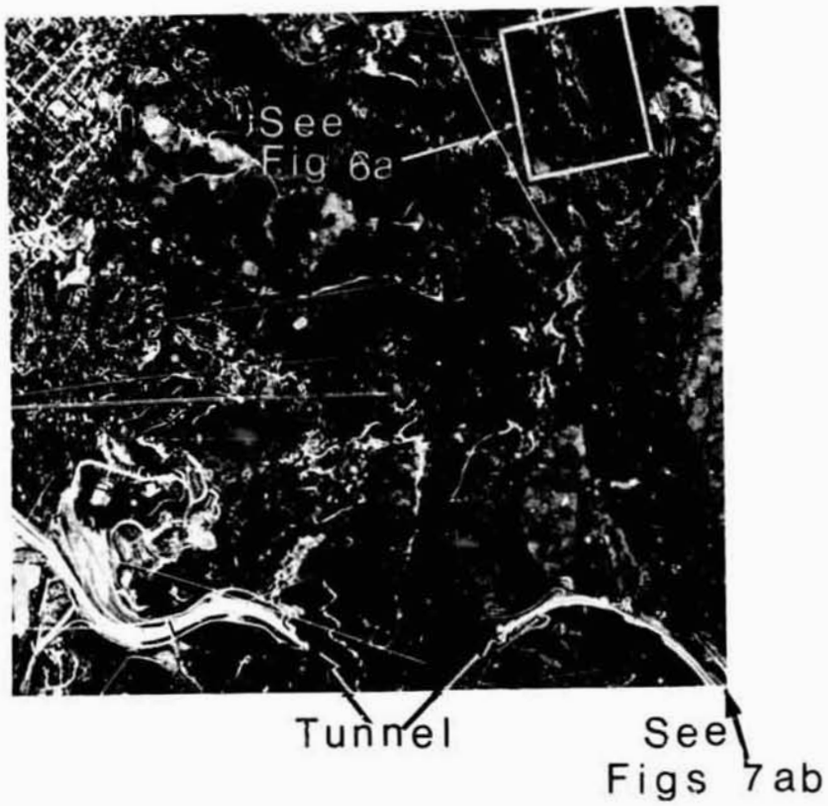


Figure 3. Black-and-white reproduction of part of an Infrared Ektachrome photo of the NASA San Pablo Reservoir Test Site, taken from an altitude of 25,000 feet on January 22, 1973. Compare with Area II, as outlined on Figure 1, and also with Figures 6a, b, c, d and 7a, b.

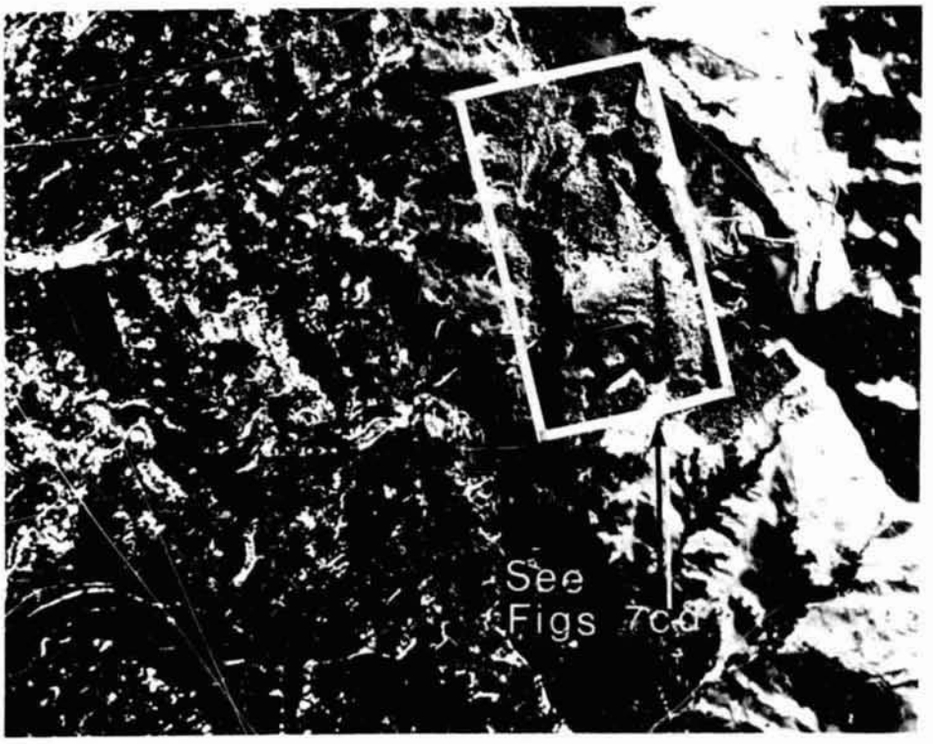


Figure 4. Black-and-white reproduction of part of an Infrared Ektachrome photo of the NASA San Pablo Reservoir Test Site, taken on January 22, 1973. Compare with Area III, as outlined on Figure 1, and also with Figures 7c, d.

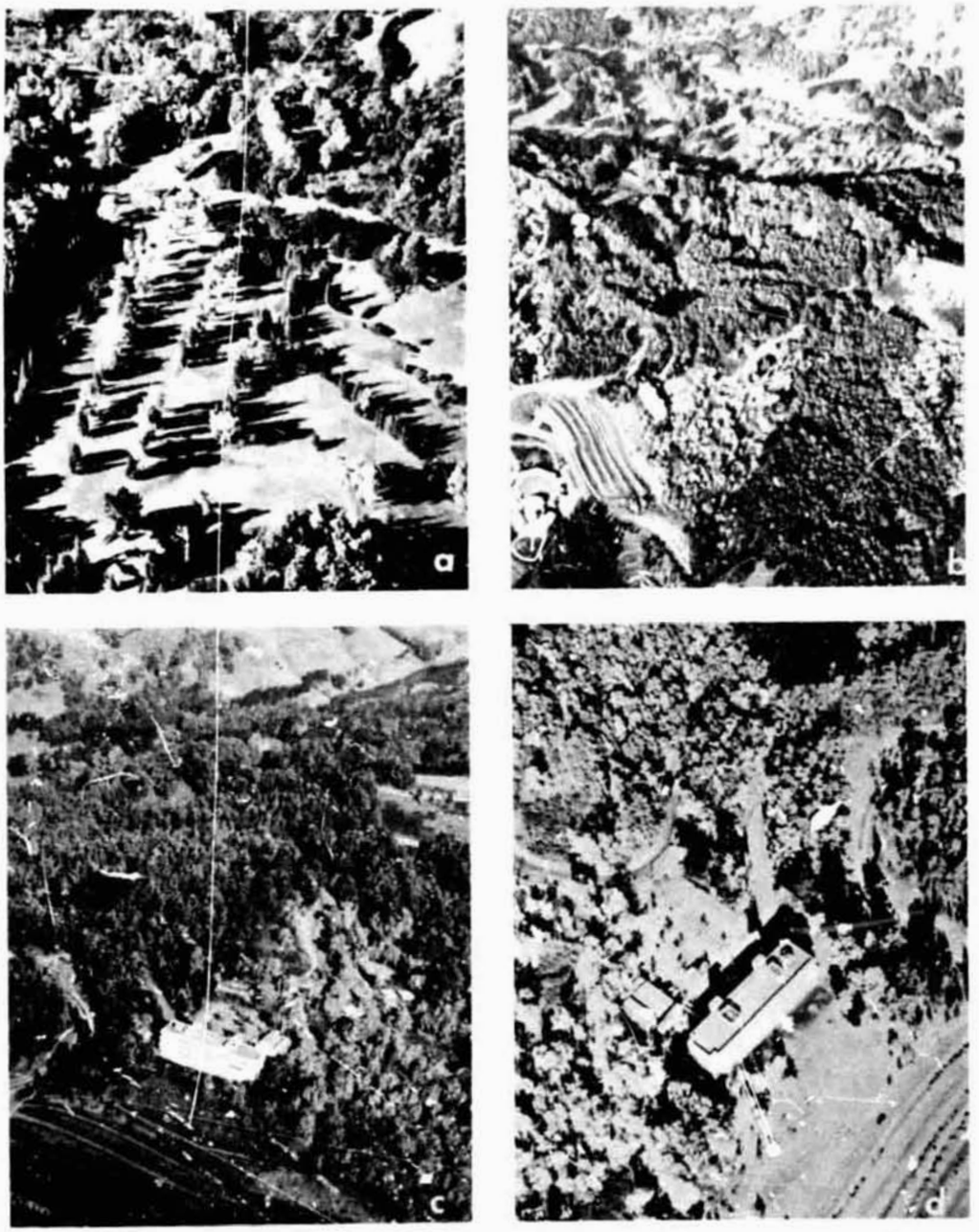


Figure 5. a: The light-toned trees on the golf course are frost-damaged eucalyptus. The dark-toned trees are healthy conifers. b, c and d: Three aerial oblique views of the NASA-built Space Sciences Laboratory of the University of California. Note frost-damaged eucalyptus trees.

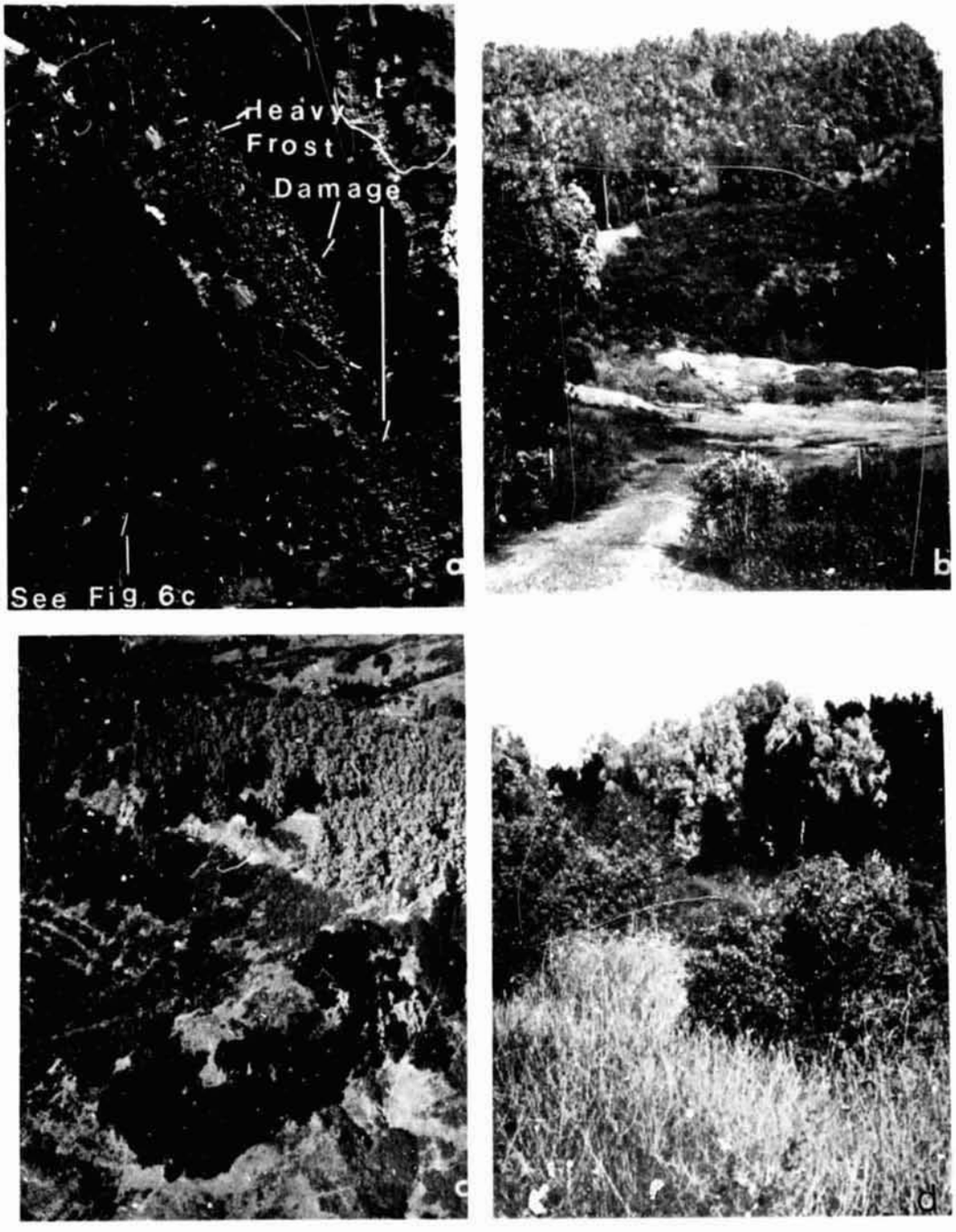


Figure 6. Compare areas shown here with same areas as annotated in Figures 1 and 3.

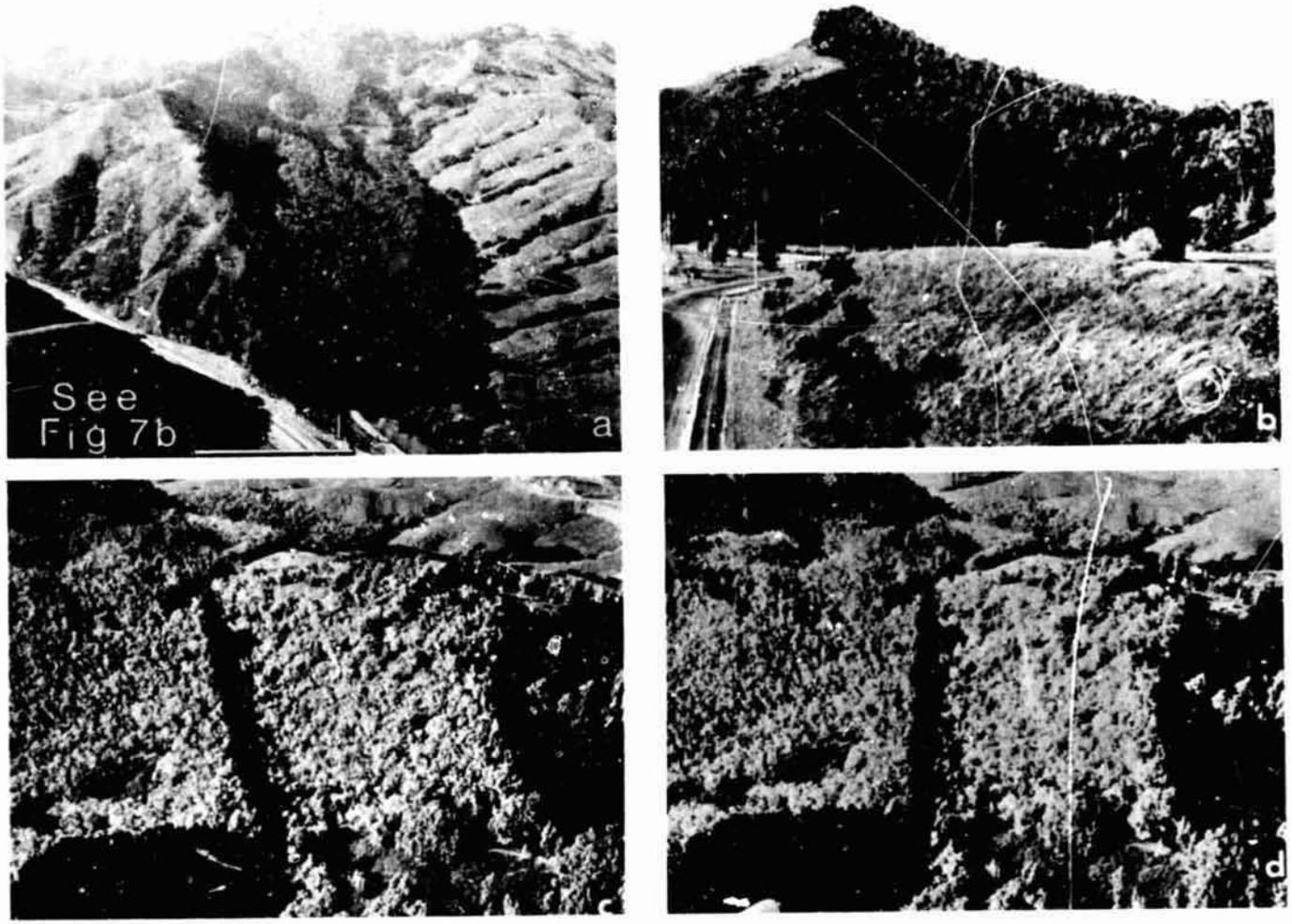


Figure 7. a & b: Some area as labeled on Figure 3, showing moderate frost damage in foreground and heavier damage in background, at higher elevation. c and d: Prints from Ektachrome and Infrared Ektachrome photos, respectively, showing area outlined in Figure 4.

Figure 8. a. January 1973 high flight imagery of essentially the same area as shown in Figure 1. b. July 1972 ERTS imagery (band 5 of same area), taken before frost damage. c. January 1973 ERTS imagery (band 5 of same area), taken after frost damage. Note that grasslands labeled "a" are lighter in tone in July when they are brown than in January when they are green. Conversely, note that eucalyptus stands labeled "b" and "c" are darker in tone in July when they are green than in January when they are brown, due to frost damage. (Enhancements by Ralph Algazi and Jeff Schriebman, University of California).