REMOTE SENSING FOR INTERPRETING SOME ASPECTS OF THE ENVIRONMENT RELATED TO THE MT. ELBERT PUMPED-STORAGE POWER PLANT

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ABSTRACT

The results of the interpretation of color infrared photography and thermal infrared imagery of the Turquoise Lake-Twin Lakes construction area are presented. The photography and imagery were interpreted to show the capability of remote sensing techniques to provide environmental information for water resource development projects. Applications of remote sensing are presented for specific identification of features related to vegetation, recreation, mining, and geology.

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Purpose of Study

The objective of this investigation was to establish to a very limited extent the potential of using remote sensing procedures such as color infrared photography and thermal infrared imagery for evaluating environmental concepts by the Bureau of Reclamation. The Mt. Elbert Pumping Plant was selected for the evaluation site for several reasons: 1) Construction was in progress, 2) a sizeable area was involved, 3) the region was environmentally fragile, 4) a variety of conditions existed, including variation in vegetative cover, high recreation use potential, mineralization and mining operations, and, 5) ground truth was available for the interpretation process from an ongoing ecology study being conducted by the Bureau.

This study represented one part of a three-fold research program undertaken by Colorado State University with the Bureau of Reclamation, Department of the Interior, Denver, Colorado, to evaluate the use of remote sensing in selected areas. The other two sites investigated were the Clarks Fork of the Yellowstone River, Wyoming and Montana (1) and the Pecos River near Roswell, New Mexico. (2)

Background

A map of the study area is shown in Fig. 1 with the area of aerial coverage identified. Mt. Elbert Pumped-Storage Power Plant is a principal feature in the Fryingpan-Arkansas Project in Colorado. (3) The project is multipurpose in concept, serving the functions of irrigation, flood control, municipal and industrial water, hydroelectric power, recreation, fish and wildlife, and other useful benefits. The project will make a substantial contribution toward meeting national and regional objectives for the protection and development of the area's water and land resources.

Environmental considerations for the powerplant represent the efforts of many people to minimize the impact of man's construction on the natural environment and, where possible, enhance the existing environment for the benefit of man.

The Bureau of Reclamation is the principal Federal agency responsible for constructing, operating, and maintaining the Fryingpan-Arkansas Project. The agency started construction of the project in the summer of 1964 with the award of contract for Ruedi Dam, one of the project's major features. Since then, other contracts have been awarded. Present work schedules call for completion of the project in 1977.

The Continental Divide, which exceeds an altitude of 12,000 feet (3,659 m), will separate the two distinct areas involved in the project. The Western Slope diversion area, where transmountain water would be obtained, is located in the Roaring Fork River basin of the Colorado River

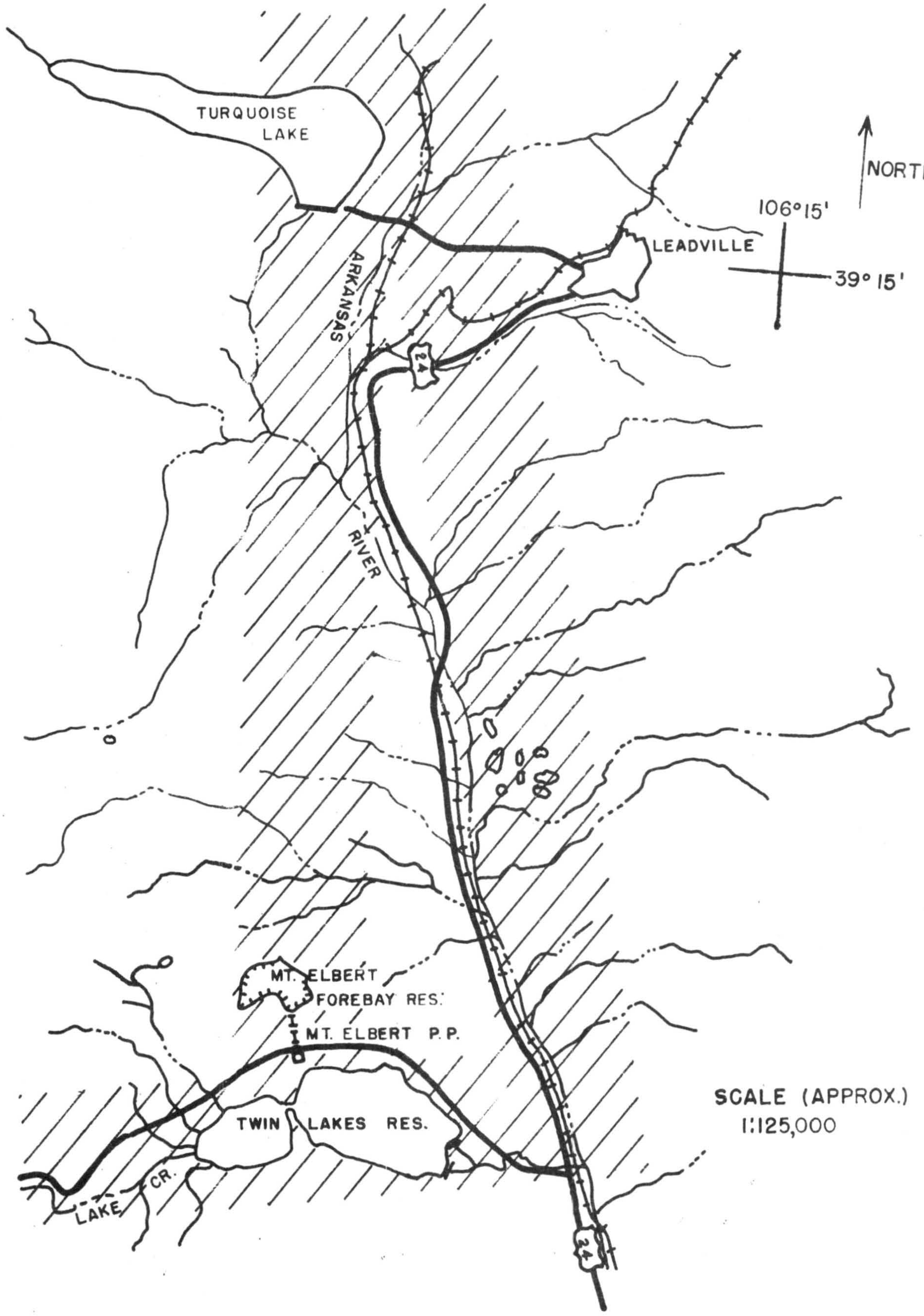

Fig. 1 - Location Map With Hatched Area Showing Aerial Color Infrared Photography and Thermal Infrared Imagery Coverage.

drainage. Water will be diverted from tributaries of the Fryingpan River and from Hunter Creek -- both tributaries of the Roaring Fork. The diversion area is mountainous and primitive, located within the boundaries of the White River National Forest at elevations above 10,000 feet (3,049 m). Most of the 100-square-mile (259 km^2) area is accessible only by trails.

Hydroelectric power will be produced at the Mt. Elbert Pumped-Storage Power Plant and the Otero Power Plant. Mt. Elbert Pumped-Storage Power Plant will eventually house two pump-turbine units, each with a rated generating capacity of 100,000 kilowatts. The pump-turbines will lift water from Twin Lakes to Mt. Elbert forebay during off-peak hours, and will generate power with water released from the forebay during daily peak power demands. This will be the Bureau of Reclamation's first use of pump-turbines which are justified primarily for peaking capacity. The power system will be interconnected with other Bureau power facilities and revenues will assist in repayment of project construction costs.

Mt. Elbert Forebay Reservoir will be created by an earthfill dike and will have a capacity of about 10,000 acre feet (12 million m^3) covering a surface area of 200 acres (81 hectares). The upstream end of the powerplant penstocks terminates in a reinforced concrete inlet-outlet structure.

Twin Lakes Reservoir will be enlarged by an earthfill structure to be the afterbay for the powerplant. The reservoir will contain 166,000 acre-feet (205 million m^3) of storage with a surface area of 3,137 acres (1,270 hectares) and a 13.8-mile (22 km) shoreline. The powerplant is being located on the north shore of the reservoir.

Scope

This report provides a preliminary evaluation of the use of color infrared photography and thermal infrared imagery for identifying selected targets involving vegetation, recreation, mining operations, and geology. Four color infrared prints are presented with certain features identified by letter designation. One thermal infrared imagery print is included.

Procedure

Color Infrared Film, Kodak Aerochrome Infrared 2443, Estar Base, was exposed in a Wild RC-8 Precision Mapping Camera fitted with a minus-blue filter. Thermal infrared imagery, obtained with a modified Texas Instruments Infrared Line Scanner, operating in the 8-11 micrometer band, also was utilized. The color infrared photography was flown on two dates: September 8, 1972 and September 22, 1972. The photographs were obtained at approximately 6,000 feet above the mean terrain, providing a photographic scale of about 1:12,000. Three flight lines were completed on each of the two missions (see Fig. 1): one flight line extended from approximately the confluence of Lake Creek with the Arkansas River to Turquoise Lake; the second flight line was taken from Turquoise Lake to the approximate midpoint of Twin Lakes; and, a third flight line extended from the confluence of Lake Creek with the Arkansas River to the upper end of Twin Lakes. Supplemental low level photography was taken over the site of the excavation for the pumping plant at the north side of Twin Lakes (scale approximately 1:4,000). One hundred and ninety two (192) color infrared photographs were obtained on the first mission and eighty (80) on the second mission.

The thermal infrared imagery was obtained on September 20, 1972 during two flights: one was an early morning flight and the second a mid-day flight. The imagery was obtained at approximately 6,000 feet above the mean terrain. The early morning flight over the target was from approximately 8:00 am until 8:20 am Mountain Daylight Time. The afternoon flight ran from approximately 2:20 pm until 3:15 pm Mountain Daylight Time. Flight lines similar to the photography missions were accomplished during the thermal infrared missions at the above time intervals. Supplemental low level imagery was obtained over the construction site near the pumping plant on the north side of the Twin Lakes. The imagery was obtained at approximately 2,000 feet above the mean terrain.

The color infrared photography was processed to a positive transparency and interpreted on a dual-strand light-table fitted with a Bausch and Lomb Zoom 240 Stereoscope. The thermal infrared imagery was processed to a negative and interpreted on a dual-strand light-table with the color infrared photography.

Interpretation

Four (4) color infrared prints and one (1) thermal infrared imagery print are utilized in this section for demonstrating the interpretation of selected features involving vegetation, recreation, mining, and geology. Under the vegetation interpretation both aquatic and terrestrial vegetation are identified. The recreation aspects involve water quality, access provisions, campground locations, and road and trail identification. The mining operations examples include mine tailings, water quality, construction, and borrow pit areas. The geologic portion of the interpretation identified terrace deposits, moraines, and erosion features.

Vegetation: Fig. 2; Reference color infrared photograph #7841

Fig. 2 displays a variety of vegetative species including aquatic vegetation, both submersed and bank type, willows, pines, aspens, sagebrush, grass, and hay meadow.

Aquatic vegetation was identified as chara (stonewort) mixed with a small representation of one species of pondweed. These plants were found in the shallow region adjacent ot the bank line near the outlet of lower Twin Lakes, and are identified as position A on the photograph. Position B indicates the location of aquatic vegetation identified as smartweed (Polygonwn spp.), an emergent aquatic weed.

Willows, identified at location C, have a characteristic color and shape and are generally found along stream banks or areas of high moisture availability. The conifers at location D have a characteristic pointed top and dark red color. Conifers also are identified as single units whereas willows grow in clusters. Aspen growth, identified at location E, is characterized by color and is often found within stands of conifers or in isolated patches or in bands corresponding to available moisture and soil conditions at certain elevations. Color changes are particularly noticeable in the fall. During the winter season and in the early spring the aspen is free of leaves and can be identified by that characteristic. The aspen also has a characteristic shape and texture.

The identification of a variety of tree species from aerial photographs is described by Heller et. al. (4).

Typical sagebrush areas are identified at F. Sagebrush in this area is identified by color, texture, and pattern. At certain times of the year the sagebrush can take on a red color, but on this photograph the plant is generally green to dark green.

Grass cover exists in the areas of the sagebrush cover, but, at this time of the year, is relatively dormant and consequently appears green to very light green. In areas where moisture is available the grass can take on a red color which indicates green vegetation.

The marshy meadow area, shown at location G, has a brilliant red color corresponding to lush, green vegetation. The darker colors within the meadow are very wet areas or areas where some of the vegetation is dead. Open water areas, that are relatively clear, appear dark on the color infrared photography.

The meadow area at G describes an area where there is high moisture availability; this feature can often be used to identify the flood plain limits of river valleys, especially during the growing season.

Terrace and moraine areas are indicated at locations H and J, respectively. These two areas can be distinctly identified by shape and pattern. Three terrace locations are identified, and three areas of moraines are identified.

Three examples of erosion and extensive head cutting are shown at location K. This erosion process seems to stem from the topographic depressions located at the uphill end of the erosion channel. Snow-melt water from these depressions coupled with both the saturated condition of the slope during the thaw and the fine soil material produced a very dramatic erosion area. These

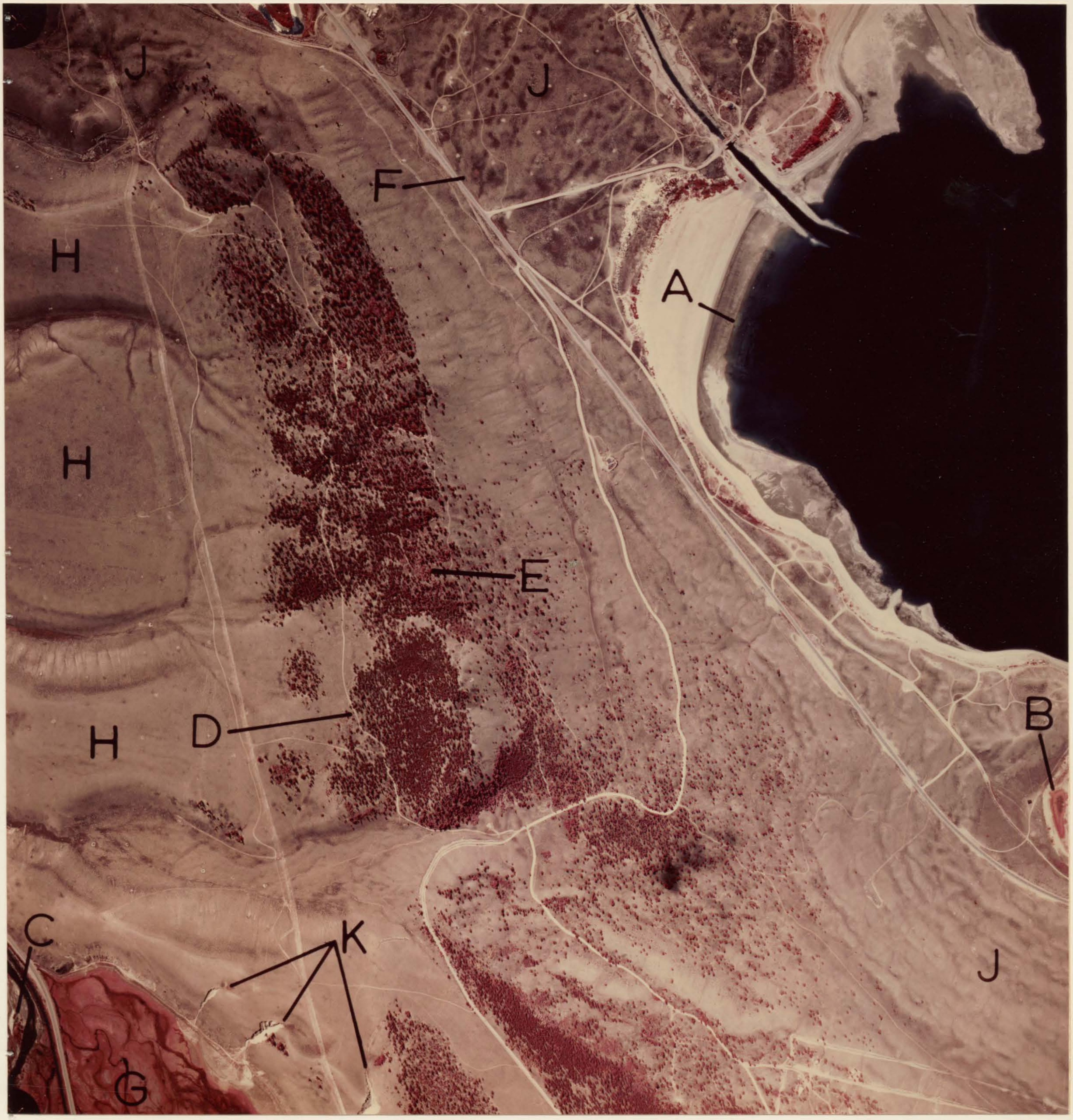

Fig. 2 - Color Infrared Photograph #7841

types of indicators point out the instability of the soil, particularly under saturated conditions and sparse vegetative cover. Excavations involving steep side-slopes, particularly where the moisture content might be high or where moisture content might increase periodically, should be avoided in areas exhibiting such instability characteristics. The fine textured material of this area has a characteristic light tone on color infrared photography when it is dry.

Twin Lakes is relatively clear and free from suspended material. This condition is characterized on the photography by the dark color wherever the depth is greater than a few feet. Experience has shown that color infrared film can be used to identify bottom features in shallow, clear water, however.

Recreation: Fig. 3; Reference color infrared photograph #8687

The color infrared photography can be particularly helpful in the planning and the monitoring of recreational facilities. Suitable recreation sites can be identified by their proximity to water bodies, streams, and vegetative cover areas. Access roads can be located most appropriately from color infrared photography since areas of high moisture content and possible unstable soil conditions can be identified. Property lines are enhanced as well as boundaries of areas suitable for recreation. Right-of-way location can be mapped and planned with color infrared photography.

The monitoring of recreational use can be facilitated with color infrared photography. Over-use in certain areas is identified by reduced vegetative cover, increased turbidity in water bodies, erosion of surfaces due to excessive vehicular traffic and over grazing by wildlife.

The following interpretation relates to certain specific aspects of recreational use. Location A shows the construction site for a boat ramp, and the accompanying parking lot is at B. Suitable water depths for launching boats can be identified with color infrared photography; and, conversely, the shallow areas along a bank line can be identified by the light-blue color near the shoreline, see Fig. 1. The topographic relief along the banks can be identified by stereo observation of adjacent, overlapping photographs.

Trailer park patterns are of a variety of different types. One example is shown at location C. This particular area has been used by transient labor forces and very few of the trailer houses remain, but the foundations and trailer pads are still in evidence. Trailers and camper counts can be accomplished with relatively small-scale color infrared photography.

The forest service campground shown at location D identifies the road network, the camp locations, and the general environmental conditions of the campground. Stereoscopic observation of such locations can facilitate the design of the drainage system, identify possible hazards due to flash flooding, and locate other potential hazards to campground users. The color

Fig. 3 - Color Infrared Photograph #8687

infrared photography can also be used to locate potential areas for water supplies for such high-use areas and plan for the proper location of sewage disposal areas.

Location E identifies an area where an individual operator has set up a parking area for campers. This is characterized by unusually high camper density, very little consideration for e thetics, and a lack of trees. A few campers are in the parking area at this time and it is possible to identify individual campers and trailer houses.

Location F identifies a golf course, and the location of the fairways are enhanced by the red tone due to the green vegetation. An example of impaired water quality is located in this area. The pond located just to the left of the letter F has a characteristic light blue color which generally indicates relatively high turbidity.

Tree species in this photograph include pine, aspen and willow. The willows are located adjacent to the stream bed. The pines are the predominate tree species and are characterized by their darker red color and conical shape. A few aspen are intermingled among the conifers, and, at this time of the year, are experiencing some color change.

Roadway surfaces are identified by their color. The asphalt roads are characterized by dark color, and the roads with aggregate surfacing have a very light tone.

The color infrared photography affords the opportunity to view relatively heavy willow cover areas and judge where the bank line would be accessible for fisherman. In addition, the characteristics of the stream can be evaluated more effectively since pools and crossings and width characteristics are in evidence. Generally, under magnification the depth distribution in a channel can be interpreted. Recent sediment deposits such as point bars or alternate bars can be identified by the light color, which generally indicates an unstable stretch of river; whereas the bars that are vegetated indicate areas of greater stability.

Mining Operations: Fig. 4; Reference color infrared photograph #8698

In the vicinity of Leadville, Colorado there is a history of extensive mining operations and exploration. The color infrared photography can be used to identify some mining operations and exploration pits. For example, mine tailings are indicated at point A. The two tailing piles are evidenced by the light colored material, and the main drainage ponds are indicated by their dark turquoise color. Upon closer examination of this area, there is another small holding pond on top of the tailings, and one can observe the leakage out of this pond through a portion of the tailings and into the tributary streams. Mine waste water and water leaching through mine tailings can often introduce serious water quality problems and alter the surrounding environment.

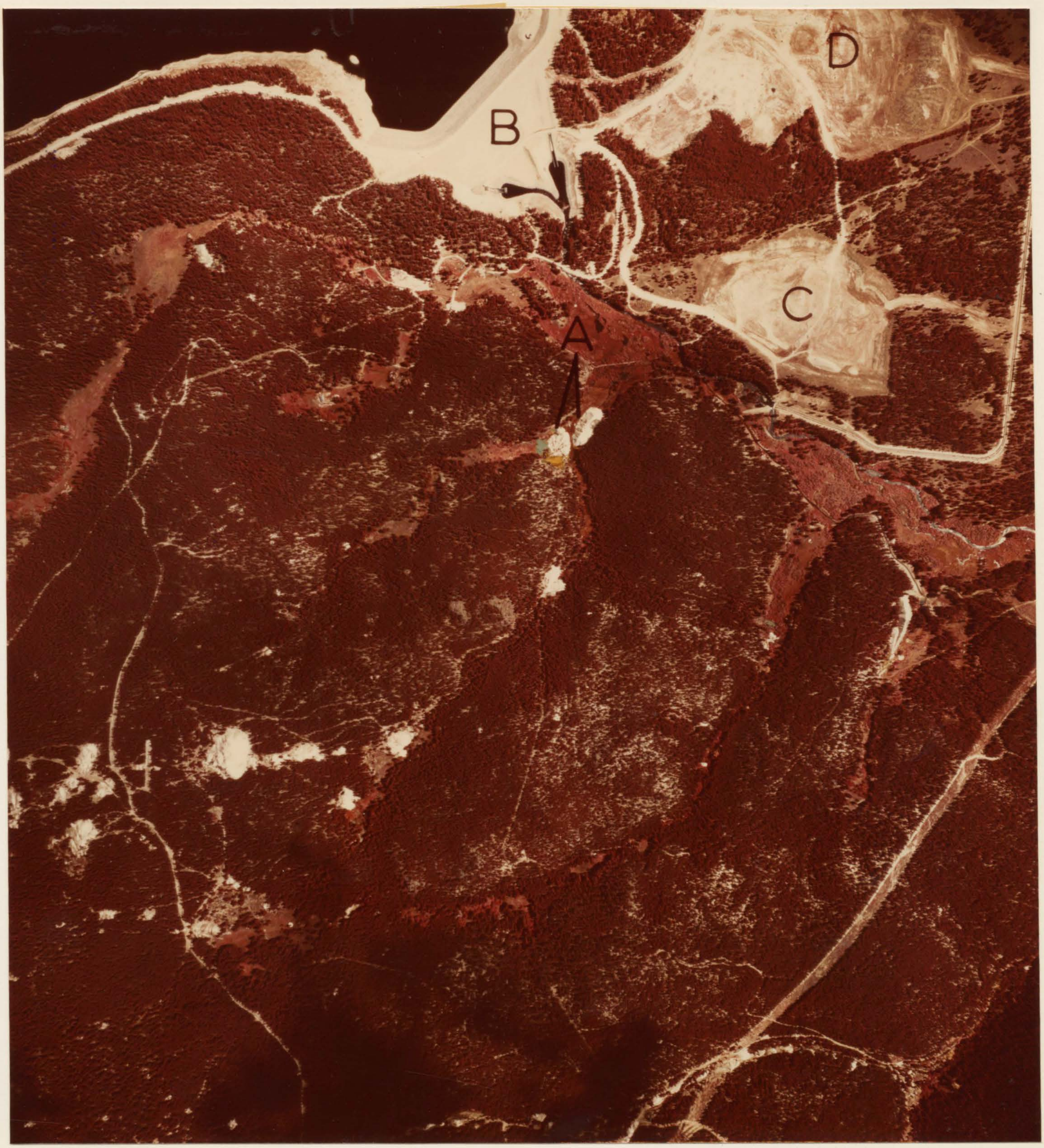

Fig. 4 - Color Infrared Photograph #8698

Open shafts and pits provide a tremendous hazard to users of recreation sites. The color infrared photography can be used very effectively to locate such potential hazards. Many light colored areas, that indicate mining operations, can be noted in this photograph. Access roads to these various mining operations and test pits are in evidence and considerable amount of damage appears to have been done to the landscape, including the grass cover and the various tree species.

Location B identifies the dam on Turquoise Lake. A large excavation pit at point C and an area at D where the cover has been removed is shown on the photograph. Such excavation areas and stripped areas often devalue the environmental quality of such areas and efforts are being made to restore such areas to their natural state in new construction by the Bureau. Color infrared photography can be used very effectively to evaluate such damage and to monitor the repair operations.

Geology: Fig. 5; Color infrared photograph #8720, also, see Fig. 6: Thermal infrared imagery #3269

Location A on Fig. 5 identifies a large slip area on the west side of the excavation of the pumping plant. The entire north shore of the Twin Lakes area is composed of moraines and slip failures on steep slopes can be expected. Areas of increased moisture content are identified within the excavation by the tone change (darkened). The very light color in the excavations is characteristic of the exposed soils and rocks of the area. Point B represents the location of Mt. Elbert forebay. This area also lies in the moraines and would be expected to have very high infiltration rates. A network of test holes are in evidence in the area of the Mt. Elbert forebay site which were drilled in order to evaluate the extent of the infiltration capacity.

At location C the aggregate plant and the washing ponds are identified. No evidence exists to show that any of the washwater is returning to the Twin Lakes. There is a very small drainage identified at Point D; this drainage was not running at the time the photograph was taken or was discharging only a small amount of water of low turbidity.

Other interesting features on this photograph includes the Lake View Campground at point E, garbage dump at point F, a land development operation at G, and the dense growth of aspens at H.

Fig. 5 - Color Infrared Photograph #8720

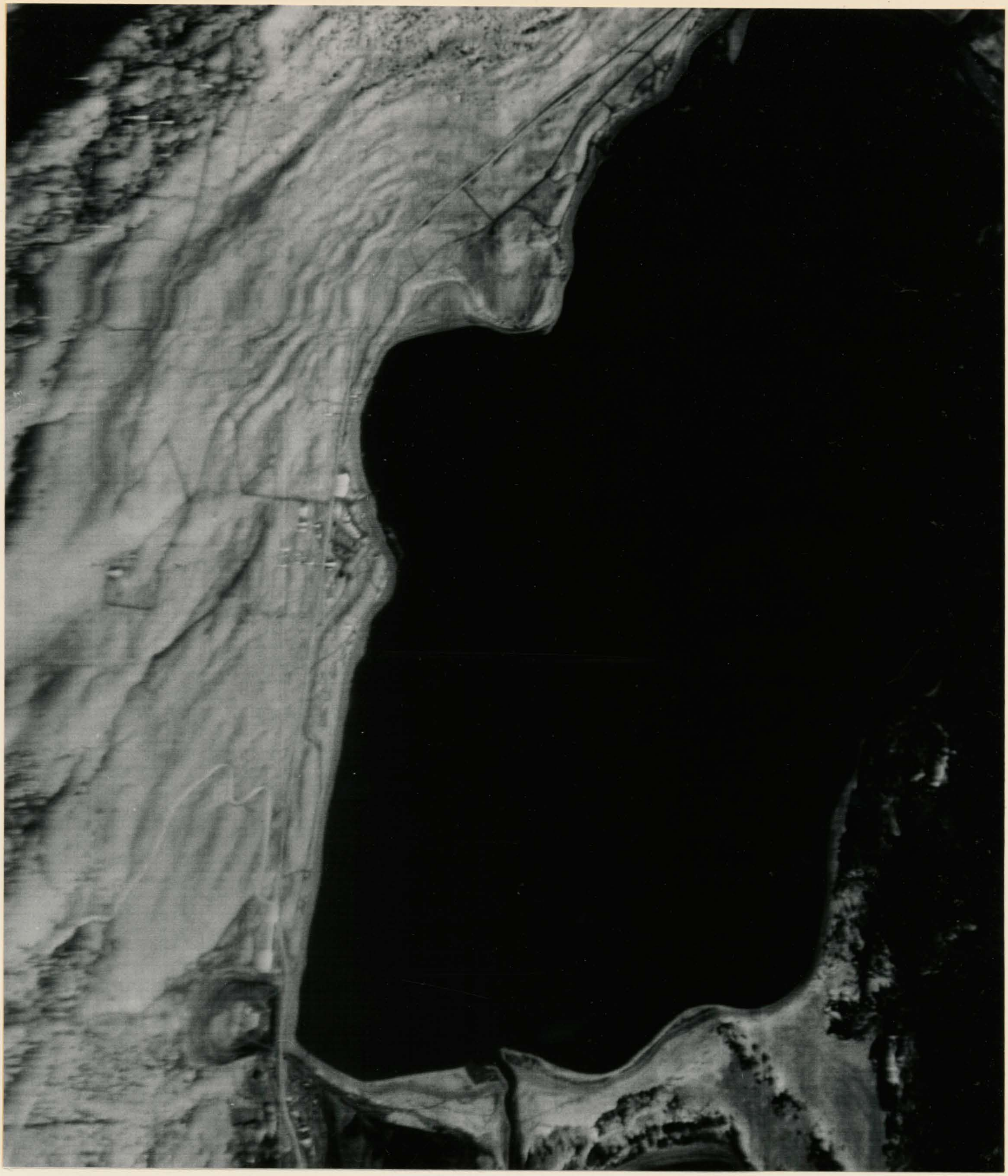

Fig. 6 - Thermal Infrared Image of a Portion of the North Edge of Twin Lakes

CONCLUSIONS AND RECOMMENDATIONS

Both color infrared photography and thermal infrared imagery can provide valuable environmental information for evaluating certain aspects of potential and ongoing water resource development projects. Proper interpretation of the photography and imagery depends to a great extent upon knowing as much about the site as possible. Consequently, any remote sensing program should be closely coupled with a well designed ground-data collection program.

Color infrared photography is ideal for identifying vegetative type, vigor, and extent. In shallow, clear-water areas, submersed vegetative growth can be located.

Color infrared photography can provide an indication of plant stress through a distinct color change of the plant. In healthy plants, this stress indicator, may be related to soil moisture content. Soil moisture may also be evaluated to a limited extent by tone changes in the exposed soil areas.

Vegetation rehabilitation projects related to construction operations at water resource project sites can be evaluated and monitored to see how well the restoration programs are progressing and if supplemental rehabilitation programs are required.

From the recreational aspect, certain characteristics may be identified, including, location of access, identification of ownership boundaries, location of suitable recreation sites which are associated with good vegetative cover and satisfactory water-use areas. Water supply and sewage disposal planning can be aided with color infrared photography primarily from stereoanalysis for evaluating the topography and by the color interpretation for identifying vegetation and drainage conditions (soil moisture content).

Water turbidity is one characteristics of water quality which is highly enhanced on color infrared photography and can be used to indirectly evaluate erosion and sedimentation processes. Dark-blue color indicates clear water; light-blue color denotes turbidity.

Color infrared photography has been found to be particularly useful for mapping the depth distribution in a river or lake where the clear-water depth does not exceed about ten (10) feet. The stability of the bed and banks can be evaluated quite well with the color infrared photography.

The location of exploration pits and mining operations and particularly the mine tailing areas are highly enhanced on color infrared photography. To a certain extent, the mining operations can be evaluated as to their effect on the environment.

Certain geologic features including terrace deposits and moraines can be identified.

Thermal infrared imagery was obtained on this project hopefully to identify any water-surface temperature differences in the Twin Lakes. The application of the use of imagery for that purpose was not demonstrated due to the relatively uniform surface temperatures at the time of the overflight. However, past experience with thermal infrared imagery has demonstrated that water surface temperature differences on the order of one degree Centigrade (1°C) can be identified and mapped using the thermal infrared imagery.

The interpretation in this report was done soley in a manual mode using a light table with a provision for stereoviewing. Again, past experience with the color infrared photography and thermal infrared imagery has demonstrated the great potential of using both analog and analytical interpretation procedures. In a more detailed analyses of photography and imagery these advanced tenchiques should be utilized.

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