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Color Photographs for Water Resources Studies

In several projects photos have enabled broad regional studies not possible from on-the-ground coverage.

(*Abstract on page 258*)

AERIAL PHOTOGRAPHY is now widely used by the Water Resources Division, U.S. Geological Survey, in its studies of the water resources of the nation. Prior to 1961, when the Phoenix Research Unit of the Water Resources Division began developing a capability for obtaining aerial photography, project chiefs on water-resources studies occasionally used existing black-and-white aerial photographs to obtain simple estimates of land-use and other parameters related to water resources. Since 1961 the Phoenix Research Unit of the Water Resources Division has provided photography planned especially to meet limited project needs of the Division.

Aerial photography is obtained by the Phoenix Research Unit using either of two planes: a twin-engine Beechcraft BE-18, or a single-engine Beechcraft T-34. Both have been adapted for aerial photography. The BE-18 is equipped to take simultaneous pictures from two cameras. To date, all work has been done using modified Fairchild K-17 cameras. The film is developed in the Phoenix laboratory, using the Morse rewind system.

In 1962, the total amount of photography obtained by the Phoenix Research Unit was less than 500 frames of panchromatic film. In fiscal year 1966, however, the Unit flew more than 9,100 frames of photography for water resources studies. Of these, 36 percent were regular color film, and 30 percent were infrared color. An additional 4,057 frames of panchromatic film were taken of the San Andreas fault area in southern California for geologic studies.

THE INTENSIVE USE of color film for water resources studies—about two-thirds of the photography in 1966—indicates its value for these studies. Early experiences, particularly in the Florida Everglades, indicated clearly the superiority of color film to panchromatic film. This does not mean that panchromatic and regular infrared film are not useful; quite the contrary. For specific purposes, such as shoreline delineation, they may be unexcelled. However, for overall interpretation potential, color film provides the best capabilities.

Two factors in particular make color film ideal for use in water resources studies. These are depth penetration through water, and

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excellent discrimination of water indicators, such as vegetation. Depth penetration is particularly important in studies of lakes or open-water areas such as the Florida Everglades, where knowledge of bottom conditions such as types and orientation of vegetation or sediments are important factors in understanding the hydrologic regimen. Discrimination of vegetation, both aquatic and terrestrial, often provides the photo-interpretation key by which limited observations of hydrologic data can be extended to regional characteristics for large areas.

EXPERIENCES WITHIN the Water Resources Division have shown that meaningful interpretation of the photographs depends upon adequate ground-control data. Usually such data must be obtained in the field at the time of the photography. In the Water Resources Division, these field data are obtained by the project personnel who are thoroughly familiar with the water problems of the area. These personnel are mainly hydrologists with professional training as engineers, geologists, or water chemists. The photographs are later interpreted by the same project personnel, occasionally with some assistance from the Phoenix Unit or the staff hydrologists of the Division. In the interpretation of the photographs, all available field data are used, and interpreted in terms of the personal knowledge and observations of the project personnel. In many cases, the available hydrologic data collected over periods of years—even over decades—can be meaningfully interpreted and extended areally on the basis of current ground-control data and photographs.

Most of the color photographs obtained to date for water resources studies have been at medium altitude—generally between 4,000 and 6,000 feet. The resultant scale of the photographs of 1:8,000 to 1:12,000 is generally sufficiently large to permit detailed interpretations of water-related features but for extremely detailed study of small areas photographs have been obtained from as low as 1,000 feet. To date, limited studies of high-altitude photography from aircraft and spacecraft indicate that only gross inferences are possible. For the type of information necessary for quantitative water resources studies, photography below 8,000 feet is usually required.

ABSTRACT: *Air-photo interpretation is very well suited to water resources studies where limited observations of hydrologic data must be extended to regional characteristics for large areas. It is also useful in monitoring the hydrologic regimen of an area to detect possible changes. Color aerial photography is generally superior to black-and-white photography for these water resources investigations. Depth penetration through water, and excellent discrimination of water indicators, such as vegetation, are its main assets. Meaningful interpretation of the photography depends on adequate ground control data. Experiences of the Water Resources Division, U. S. Geological Survey, indicate that the best interpretation is done by professional personnel—engineers, geologists, and water chemists intimately associated with a particular water resources project for which the photography has been obtained.*

AERIAL PHOTOGRAPHY has been used successfully in more than 100 water resources projects to date. In 1966, photography was obtained for 42 projects; color photography was obtained for 28 of these. As previously stated, 66 percent of the photography during 1966—5,976 frames—were either color or infrared color. Some of the better-known areas in which color photographs are being used in water-resources studies are the Florida Everglades, Great Salt Lake, prairie pothole areas of North Dakota, Lake Erie, and the Potomac River. They are being used in such diversified studies as offshore springs, coastal estuaries, pollution, urbanization effects, water availability, and flow regimens.

THE WATER RESOURCES DIVISION first used color photography on a large scale in its studies of the water resources of the Florida Everglades. More than 3,200 frames of photography were obtained over the Everglades National Park area in south Florida during April 1964. Since then, more than 700 additional frames of both color and infrared color have been obtained. The photographs

PLATE I. Area of Florida Everglades showing rock reef; from regular color transparency at original scale of 1:6,000.

PLATE II. Same area as Plate I; from infrared color transparency at original scale of 1:6,000.

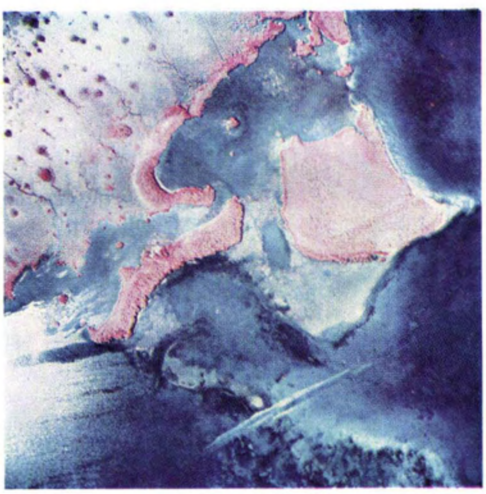

PLATE III. Coastal area along Florida Bay showing mangroves and brackish-water marshes, from infrared color transparency at original scale of 1:10,000.

PLATE IV. Shoreline area east of Cutler, Florida showing areas of fresh-water discharge; from regular color transparency at original scale of 1:12,000.

PLATE V. Part of Prairie Pothole area in North Dakota showing differences in salinity of potholes; from regular color transparency at original scale of 1:12,000.

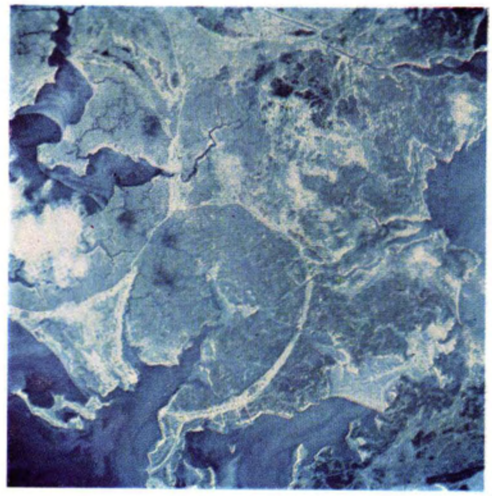

PLATE VI. Area near Salisbury, Maryland showing circular sand ridges; from infrared color transparency at original scale of 1:20,000.

PLATE VII. Part of Great Salt Lake, Utah showing underwater features; from regular color transparency at original scale of 1:12,000.

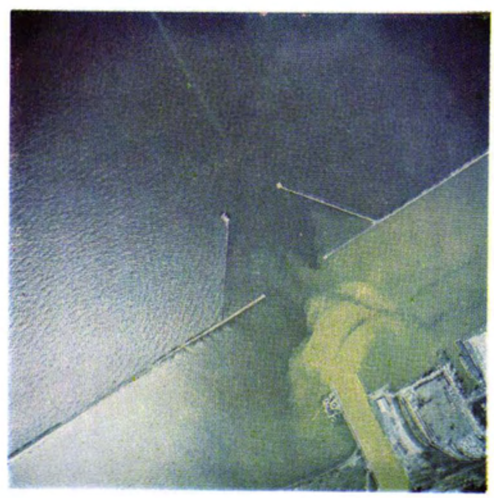

PLATE VIII. Lake Erie at Cleveland, Ohio showing discharge of Cuyahoga River; from regular color transparency at original scale of 1:8,000.

are currently being used to assess the flow regimen of the Everglades and to evaluate possible changes in the ecology as related to changes in the water regimen. Some interpretations of the photographs as related to the fresh-water environment of the Everglades have been previously reported. (See "Water Resources of the Florida Everglades" in PHOTOGRAMMETRIC ENGINEERING, November 1966).

A further significant item now being studied is the presence of rock reefs across the Everglades which serve as natural barriers to the flow of fresh water. The rock reefs are easily identified by the oriented hammock and sawgrass which form on the slightly higher elevations of the reefs. Excellent examples are shown in Plates I and II. Plate I shows a typical Everglades environment in regular color. The three main ecological communities are the hammocks containing trees which appear as darker green, coarsely-mottled areas on color film, the sawgrass which appears as lighter grey-green more evenly-textured areas on color film, and the open water which appears as light orange-brown areas on color film. Direction of flow is from top to bottom. A line of small hammocks and dense sawgrass on the rock reef that forms a barrier to flow can be readily seen across the center of the photograph. Plate II shows the same area in infrared color. The small hammocks along the reef are more easily identified on infra-red color film because the red color of the trees is in sharp contrast to the blues and greens of the rest of the photograph.

INFRARED COLOR photographs are also excellent for delineating the mangrove shoreline and brackish water marshes of south Florida. Plate III shows an area along the Florida Bay coastline at 1:10,000 scale. The dense, coastal mangrove jungle is clearly shown by deep red areas on infra-red color film. Inland from the coastal jungle, hammocks of trees, generally mangrove in the periphery and fresh-water types in the interior, appear as circular red areas. Marshes of halophytic grasses and scattered dwarf red mangroves up to five feet tall appear as light grey areas with the individual mangroves clearly visible in the photograph. Inland from the marsh area, and just visible in the photograph is the typical sawgrass of the fresh-water Everglades, shown in the extreme upper right of the figure. Drainage channels are recognizable by the dense growths of mangrove along the poorly-defined banks. Mud flats, exposed at low tide, appear on the infra-red color film as light blue areas mottled with pink where aquatic plants are exposed, as contrasted to the deeper blue tones of water areas.

The hydrologic environment of the area can be inferred from the vegetative cover. The areas of dense mangrove and the estuarine channels are systematically inundated by tidal action. The brackish-water marsh is an intermediate zone where salinity varies seasonally with the fresh water outflow from the Everglades. The water in this zone varies from almost fresh during high runoff in autumn to salty during low runoff in spring. The water in the sawgrass area is perennially fresh, and varies seasonally in depth.

Color photographs are also being used in Florida to identify areas of fresh-water discharge along the coastline. Plate IV shows an area just east of Cutler, Florida. Areas of ground-water discharge into Biscayne Bay can be identified by the presence of *Diplanthera*, a grass that tolerates only moderate salinity, and therefore can grow only in those coastal areas where dilution of sea water by fresh water discharge reduces salinity. In the photograph, the grass can be seen extending seaward from the shoreline for about 300 feet as a solid mass. Beyond this, scattered patches of *Thalassia* occur. Because *Thalassia* will tolerate only very high salinity, the area of fresh-water discharge can be identified as occurring only in the near vicinity of the shoreline.

VEGETATION AS an indicator of salinity of water is also being studied in the prairie pothole areas of North Dakota. The potholes are depressions of various sizes and depths which were formed when retreating glaciers left huge blocks of ice in their wake. Today, these depressions contain water which ranges in salinity from near-zero to three times that of sea water. Some preliminary observations from aerial photographs indicate that salinity of the ponds can be determined from the photographs. Plate V shows a typical group of pothole lakes. Water in the individual lakes ranges from fresh to very saline. Although this photograph was obtained in October after a killing frost, vegetation still can be used to infer both salinity of the water and the ground-water conditions that govern the extent of salinity.

The lake in the lower left of the photograph is highly saline. Note the complete lack of aquatic vegetation and also the presence of white salt deposits along the shoreline. Although the water in the lake in the center of the photograph is saline, the area along part of the shoreline is only slightly brackish as the result of fresh-water inflow from a spring originating in the small clump of trees near the lake. Evidence of ground-water inflow can also be seen in the small lake in the lower right of the photograph. Dense vegetation—trees along the shoreline and aquatic vegetation in the lake—mark an area of fresh water discharge to the lake. In the upper right is a shallow dry pothole covered with fresh-water vegetation.

IN EASTERN MARYLAND, aerial photographs are being used to identify and locate topographic features similar to the famous Carolina Bays along the coastal regions of North Carolina. As seen in Plate VI, the bays in the Maryland area consist of sand ridges surrounding poorly-drained depressions. Shown here is a bay located along Chesapeake Bay near Cambridge, Maryland. Note especially that cultural development is entirely along the sand ridge. Although surface drainage within the bay is internal, artificial waterways for navigation have been constructed through the sand ridge to connect the headwaters of streams draining in different directions. Ice is visible in many of the coves. Farther inland, though still as pronounced, the bays consist of similar sand ridges with less permeable clay soils in the depressions. Because the depressions collect and store runoff from rainfall, they are significant factors in controlling the hydrologic regimen of the area, and in regulating storm runoff.

IN STUDIES OF the Great Salt Lake, color photography is being used to identify circulation patterns as well as movement and deposition of sediments in the lake. As in other studies, areas of ground-water inflow to the lake can be identified by denser vegetation growing in the vicinity of the discharge area. Of particular interest are bioherms growing on the lake bottom, as shown in Plate VII. Bioherms—coral-like reefs several feet high formed by minute living organisms such as corals and algae—occur in formations similar in shape and size to desiccation cracks formed in soils. This suggests that at one time these areas of lake bottom were exposed, dried out, and cracked, and that following subsequent inundation, the organisms occupied the cracks in the bottom and began growing and forming the bioherms.

In preliminary reconnaissance studies of Lake Erie, color photographs have been used to identify flow patterns, especially as related to the discharge of polluted wastes to the lake. It has been especially useful in the appraisal of water-quality data obtained at specific locations in the lake. The photography has been invaluable in assessing the circulation patterns in the vicinity of the mouths of rivers so that continuous water-quality monitors may be located in representative lake environments. A common flow pattern is shown in Plate VIII. Shown here is the Cuyahoga River as it enters Lake Erie at Cleveland, Ohio. The industrially polluted river water diffuses as it is carried eastward on the lake surface by the prevailing wind. Evidence of the warmer river water overriding the cooler lake water is seen in the boat wakes in which the upper layer of water has been mixed sufficiently with the underlying lake water so that the wake appears quite similar to lake water.

COLOR PHOTOGRAPHY has been used successfully by the Water Resources Division for water resources studies since 1962. In each case, however, photography has been introduced to the project after the initial planning phase and while the study was in progress. In several projects—notably those in the Florida Everglades and in the prairie pothole area—the use of photography has made possible broad regional approaches to the water problems that would not be possible by on-the-ground coverage. It is quite likely that future water resources studies of large areas will include provisions for aerial photography in the initial planning of projects. It is also expected that color aerial photography will play an increasingly important role in future water resources investigations.

ACKNOWLEDGEMENTS

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Interpretations of the photography were made by personnel of the Water Resources Division, U.S. Geological Survey.