Airplanes And Hydrologists—
A Beneficial Alliance

In Cooperation With The Department Of Environmental Conservation,
The U.S. Geological Survey Has Been Using Airplanes To Collect
Valuable Data About New York State's Water Resources

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HYDROLOGISTS quite often work outdoors and sometimes they have more than their feet in water (Figure 1). Now they can be found several thousand feet in the air. One place this is happening is in New York State. In a cooperative program with the Department of Environmental Conservation, the U.S. Geological Survey has been using airplanes for the collection of water data.

This Federal agency is responsible for appraisal of quantity and quality of our national water resources, for studies of areas of existing or potential water problems, and for basic research in hydrology. The Geological Survey shares with State and local water agencies the responsibility for planning and financing water-resource investigations.

Most water records to date have been collected on the ground. One of the oldest routine Survey programs has been stream gaging, where streamflows are measured at specified locations on various rivers. By building up a catalog of information, one can relate stage (water level) to discharge (flow, such as cubic feet per second), so that water quantity can be rapidly assessed. These data are needed, for example, for high-water prediction during spring runoff or for evaluation of low-flow conditions during summer drought. This information in turn is used for regulating streamflow to prevent floods or to maintain minimum discharge for various purposes. Many years of work have been involved in building this rapid-response capability.

Another program has been the mapping of areas subject to flooding. The area varies with the severity of the flood, which statistically may be called "50-year," "100-year," or even "annual." Flooding is really a natural process and the flood plain should be considered as the river's land. The airborne-data collection capability becomes very useful in mapping flooded areas, even after high water has subsided. The vertical aerial photograph of the Black River near Lowville shows a particular flood in April 1971 (Figure 2). The picture delineates the area of the flood plain under water and illustrates the mechanics of river flow. Note the flow lines of muddy water (from sediment picked up at the edge of the flood plain) converging where the...
water velocity increases at a channel constriction. If this stream were not regulated, the flooded area would probably have been more extensive.

A special project of the Geological Survey has been the study of Oneida Lake in central New York. This lake is undergoing "eutrophication" (a normal geologic process of filling-in with organisms and sediments, which can be hurried by man’s activities). The aerial photograph (Figure 3) indicates the shoal areas of the eastern shore, but especially significant are the white streaks on the water surface. These streaks, which are almost parallel to the wind direction as indicated by the smoke, are called “wind streaks.” They are formed by accumulations of foam or small material where water converges because of vertical circulation caused by the wind. These streaks must have been forming here for a long time, because the Indian name for the lake, Seughka, means “Striped with blue and white lines...” This wind-driven circulation is important in shallow Oneida Lake because it drags up nutrients that would otherwise lie quietly on the bottom and makes them available for feeding organisms such as algae.

A recent Survey program includes aerial thermal infrared (beyond-the-red)* mapping, whereby a catalog of water-temperature information is being compiled to augment data collected at intermittent point-sampling stations. This catalog is at the point where stream gaging was many years ago.

Instead of using color as an indicator of water flow or quality as in photography, we can use temperature. Because "state-of-the-art" technology permits measurement from the air, the hydrologist gains much new information. Airborne electronic equipment senses the heat radiated from the water surface and can be used day or night. Nighttime is often favored because the radiant temperature is more closely related to thermometer-read temperature in the water (the sun heats the water surface during the day). The usually calmer atmosphere at night also permits better data collection.

The infrared imaging process can be likened to making a photograph of the picture on a television screen. The problems of heat-signal detection can be compared to those of putting the right TV antenna in the right location. The electronics system includes an amplifier for magnifying the signal, a television (cathode ray) tube for converting the signal to light, and various knobs including those analogous to TV contrast and brightness to control the gray shades of the picture. Finally, the camera that photographs the light signal must be set and the film and prints must be developed. The final product is the photographic “image” in which gray shades
represent heat values: In a “positive” print, warm areas are printed as light tones and cold areas as dark tones.

**Air Force Cooperates**

Infrared imagery pictures of many New York State areas were made available to the Survey by the Reconnaissance Branch of the Rome Air Development Center at Griffiss Air Force Base in Rome, New York. These areas include Cayuga and Seneca Lakes, Lake Ontario shoreline, St. Lawrence River, and Oneida and Oneida Lakes. In addition, infrared equipment was loaned by the Infrared Components and Techniques Section of Air Force Avionics Laboratory.

Water-circulation patterns can be described on infrared imagery. For example, the image of the northern part of Onondaga Lake, near Syracuse (Figure 4), shows that cooler (darker) surface water is apparently entering the lake through its normal outlet. On the evening of July 8, 1970, when this image was acquired, there was a 7-knot wind blowing toward the outlet. The pictured feature may be a reverse inflow into the lake resulting from complex water-level regulations in other parts of the Oswego River basin. The outlet has been difficult to “gage” (measure flow) because of the small elevation gradient and the difficulty of separating wind and flow effects at low water velocities.

The infrared image of the eastern part of Oneida Lake near Sylvan Beach (Figure 3) was collected on the night of October 7, 1970. Fish Creek (at left) is cooler (darker tones) than the lake (lighter tones). That condition is normal at this time of year after the lake has absorbed heat from the summer sun. The flame-like pattern in the near-shore area probably represents shallow water, warmed during the day, that is mixing with the bottom sediments. The mixing, and resulting water-current pattern, is an example of another natural geologic process that is sometimes called "beach erosion."

Infrared pictures such as these whet the scientist’s appetite for the actual radiant temperatures that the photographic gray shades represent. After all, the surface of a water body is very important because of the energy exchanges that take place there. (Consider how lakes may modify local climates by delaying fall frosts or by causing early winter snowsqualls.) Heat is absorbed daily from the sun and is lost (radiated) from the water at night; evaporation also takes place here. However, the activity at the air-water surface has been hard to measure by traditional means. As thermal infrared data become cataloged and interpreted, our understanding of the energy exchange will increase.
Now, in changing a picturing system to a measuring system, a considerable amount of extra equipment and operating time is needed. Extra care must be taken to ensure "high-fidelity" — the faithfulness of the picture you see to what is actually there. Besides changing the electronic circuitry from a.c. to d.c., so that there is a constant relationship of voltage to heat signal received, and calibrating the controls for brightness and contrast, temperature reference sources must be included in the airborne system.

The electronic signal may be recorded on magnetic video tape for later printing on film, as well as displayed on a TV-like screen during the flight (Figure 6). The "real-time" display is important to the hydrologist so that he or she may inspect the data as it is collected and adjust flight plans as required.

Infrared imagery of the St. Lawrence River on the night of December 10, 1970, was interesting because ice was just be-
beginning to form. Data collected in the area of the Eisenhower Lock not only delineated areas of ice cover but also showed about a 2° Celsius (about 3½° Fahrenheit) difference in surface temperatures between the open water outside the lock and the ice-water mixture in the Wiley-Dondero Ship Canal. Information of this kind pertains to the length of the shipping season for the St. Lawrence Seaway.

Infrared imagery of the Hudson River Estuary near Kingston in the early-morning hours of April 24, 1971 (Figure 7), shows detail that has not yet been fully interpreted. The discharge of Rondout Creek is some 2° Celsius warmer than the main river body, as shown by the imagery coding symbols. The surface temperature profile is “noisy” over parts of the river and “smooth” at others. This difference is shown in the image as spotty versus smooth gray tones. The “smooth” area shoreward from the Esopus Meadows light is very shallow water with little apparent current. Flow lines that are indicated by natural temperature (rather than by color as in the flood photograph) again reflect the influence of channel shape on water velocity. Note that the land is much cooler (darker in the bottom picture) than the water. With the measuring system, it is impossible to get fine thermal detail and great temperature range at the same time, so the land information was sacrificed.

**Department Program Expanded**

Through coordinators S. P. Mathur and R. E. Maylah of the Department of Environmental Conservation, the Division of Pure Waters water-quality surveillance program was expanded to include the Geological Survey aerial infrared thermal data. Surface waters in New York State include about 70,000 miles of stream, 3,500,000 acres of inland lakes, and many square miles of ocean. Because it is virtually impossible to collect complete data over such extensive areas by ground-based personnel alone, the airborne data are most useful and economical. The information ties in with the automatic-monitoring network to add space-continuity to the time-continuity of the point samples. By distinguishing the relationship of the sampling point to the main water body, it also tells where sampling crews can be directed to collect meaningful water-quality samples.

The aerial view in the future may use more sophisticated equipment and be tied in with a view from farther out in space. The program office of the Geological Survey Earth Resources Observation System, in cooperation with the National Aeronautics and Space Administration, is looking toward the day in the near future when an orbiting satellite will be able to collect similar information from about 500 miles from earth. Until that time, and during periods of cloud cover, the airplane — even the venerable DC-3 (Figure 8) — will continue to serve capably as a mobile hydrologic laboratory.