MANAGEMENT APPLICATIONS FOR THERMAL IR IMAGERY OF LAKE PROCESSES

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INTRODUCTION

The project centers on the New York State part of the Lake Ontario Basin. The primary study sites are Onondaga Lake, near Syracuse, and the south shore of Lake Ontario, from Oswego eastward. Data from past and current missions of Rome Air Development Center aircraft have been used.

OBJECTIVES

This investigation addressed three general questions:

1. What useful limnologic data can be collected by remote sensing techniques? 2. How must equipment and operations be adapted for optimum data return? and 3. Can local interest in and routine use of such data be developed? In a study of available sensing techniques, thermal infrared scanning was selected because it provided much information previously unavailable to the hydrologist and because it can be adapted from detection to measurement capability, a feature necessary to continuing water management programs. This report considers only questions 1 and 3.

PROJECT APPROACH

The Lake Ontario Basin, in which the study is situated, is well suited to observation by high-altitude sensors because of its large areal extent. The size of the lake alone makes it difficult to obtain simple geometric and time control of data collected at or near the water surface. However, individual small lake phenomena can be studied from low-altitude aircraft platforms preliminary to future studies of broad-scale, basin-wide hydrologic patterns and to efforts for the International Field Year for the Great Lakes.

Figure 1 shows the study area in part of the Lake Ontario Basin in New York State. Actual study sites include the Lake Ontario shoreline near Oswego, some of the Finger Lakes, and Onondaga Lake near Syracuse.

Onondaga Lake evolved as a major study site because it is the most saline lake in the State and because of convenience and economy in operation of the study and the availability of supporting data. The site is less than ideal, however, for it is under the landing approach pattern of the Syracuse airport.

A considerable amount of imagery was made available from Rome Air Development Center because of test-flights of reconnaissance equipment over the area.

Ground-truth measurements were carried out in a limited way and were useful in analyzing logistics problems of the operation for routine surveillance programs.

USEFUL DATA RECOVERED

Illustrations that follow are thermal infrared imagery in which light tones represent hotter water.

Figure 2 is an overview of the 5-mile long Onondaga Lake (19 August 1969). At the northern end of the lake is the outlet (the Seneca River) (O) and in the southern part are a cooling-water discharge (C), industrial process effluent (I), and sewage discharges (S). This image is an inventory of artificial discharges including those not primarily thermal in nature. This thermal sensing capability is useful when visual sensing does not give information, such as when color and turbidity contrast between effluent and receiving water become minimal or when discharges are made at night. By repetitive coverage, consistent detection can be accomplished either by cataloging thermal characteristics or by summarizing random observations. This type of information can be incorporated in the New York State industrial wastewater discharges program.

Figure 3 shows the northern end of Onondaga Lake on two dates when flow through the lake outlet is reversed; that is, when the Seneca River is acting as a tributary. On 31 October, winds were recorded as calm whereas on 8 July the wind was 7 knots from the south and directed toward the outlet.

This phenomenon of cool water entering the warmer lake has been observed on infrared imagery at other times but never had been well documented by traditional means. The event had been suggested by a particular algal specie near the outlet and also by stream-gaging measurements; but the latter were difficult to make in the shallow river and were not considered to be reliable.

Reverse flow is caused by complex regulation of water levels for canals and hydro-power elsewhere in the basin. Knowledge such as this points out that water planners and managers need data on entire watersheds. The remote-sensing information also augments that provided by an intensive gaging-network being established on the lake tributaries for a water-budget study by a county agency. In return, the network provides calibration information for the remote-sensing data.

Figure 4 shows the southern end of Onondaga Lake on 31 October and 6 November 1969. (A change in image scale is referenced by letters "a" and "b"). The point of discharge of industrial cooling-water, reportedly as high as 80 million gallons per day, has changed from location "b" to "a" during the week elapsed. Area "S," the surface expression of a submerged sewage outfall, has been observed on infrared imagery taken at several different times, although only a part of the discharge may ever reach the surface because of varying discharge-velocity and temperature-density relationships. Note also the locations of the sewage treatment plant and the creek entering the lake between the plant and the cooling-water discharge. At times of high runoff, this creek carries both storm and sanitary sewage.

Two aspects of the data are relevant to water management. First, the monitoring of any quality parameters of a variable discharge by fixed-location recorders can be grossly inadequate. Imagery can delineate the general area in which ground equipment can be set up, or real time viewing with air-to-ground communication can direct field parties to specific sites.

The second factor important to management is the knowledge that hot-water and sewage discharges are in close proximity. Because dissolved oxygen (DO) saturation content decreases as water temperature increases and because there is a simultaneous increase in biochemical oxygen demand (BOD) rate, odor formation and organic waste-assimilation capacity of the water are affected. It may be necessary to study the merits of moving the hot-water discharge to a location more remote from that of the sanitary sewage, especially if water circulation is restricted.

The management situation is complex, and county legislators have been considering their contribution to an investment of some $49 million for a new sewage treatment facility plus about $2 million annual operating and financing costs. In addition, up to $150 million has been estimated necessary to correct the combined-sewage discharge through the creek.

Figures 5 and 6 are imagery of the Oswego Harbor in March and summer 1970, respectively. When water does flow out of Onondaga Lake, it eventually discharges here. The circulation patterns of water and ice and water and algae within the harbor are affected by a generating plant thermal effluent and wind, as well as by the Oswego River-canal discharge. Harbor design and maintenance and disposal of additional cooling water are topics of potential concern.

Figure 7 shows the cooling-water discharge from a nuclear generating plant on Lake Ontario. The point of discharge is about 300 feet off shore. Note that the intake lies under the zone of heated water and that nearby is another plant under construction for a different agency. New York State has recently added thermal criteria to its existing water-quality standards. These criteria define thermal discharges and specity permissible temperature differentials for future installations. In addition to providing data relevant to these standards, infrared imagery will portray to the plant managers any interaction between the adjoining systems as well as delineate heat contributions to Lake Ontario.

CONCLUDING REMARKS

Difficulties encountered in the development of an infrared survey program in New York suggest that some of the major obstacles to acceptance of remotely sensed data for routine use are factors of psychology rather than technology. Although there are legitimate objections to the limitations in this type of data, there are also severe handicaps to the traditional point-parameter systems that now operate. Problems of calibration and correlation of ground instruments of varying performance capability, time factors of equipment installation and maintenance at diverse sites, and the basic question of representativeness of a point-sample have been a part of the measuring system for so long that they are often forgotten.

The problem of acceptance of surface thermal data is compounded by the use of the term "temperature" rather than "radiance." The measurement of thermal energy is actually the topic of concern. "Temperature" has been used because we have had available equipment that measured a parameter called that. Because the remote sensor does not measure that identical parameter, the raw numbers of data are not the same and reference to the thermometric "temperature" infers disagreement and unfavorable comparison. Terminology should suit the measurement technique.

In the New York program, a quantitative infrared system will add spatial radiometric data to the chronological thermometric data now collected in the water-quality surveillance network. Therefore, in the interim preceding routine data-collection by high-altitude sensors, some water managers will become accustomed to the evaluation, use, and storage of data collected from above ground.

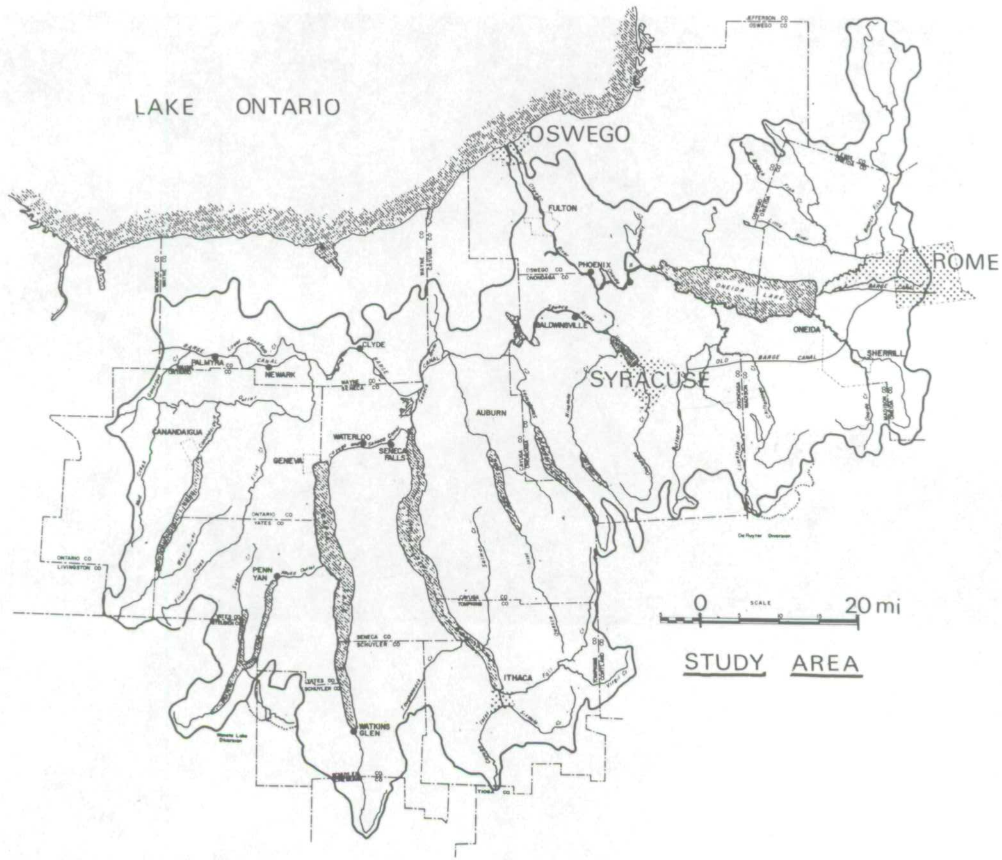


Figure 1. Study area, Lake Ontario Basin.

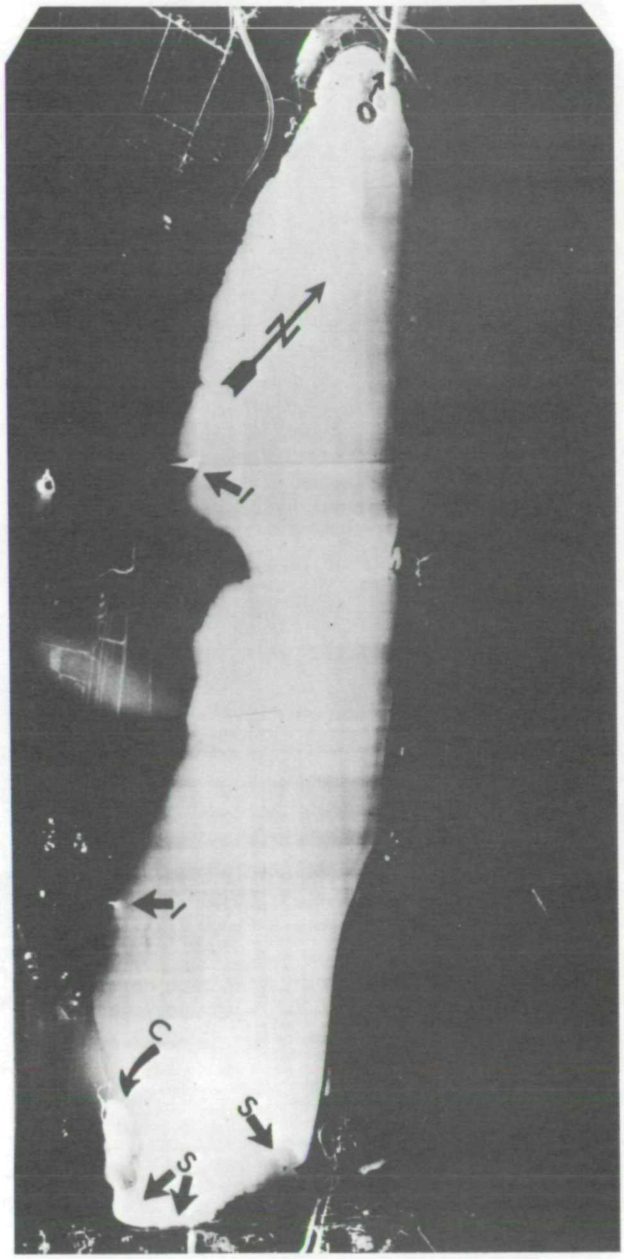
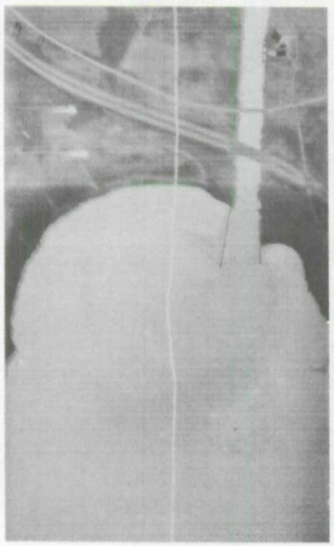
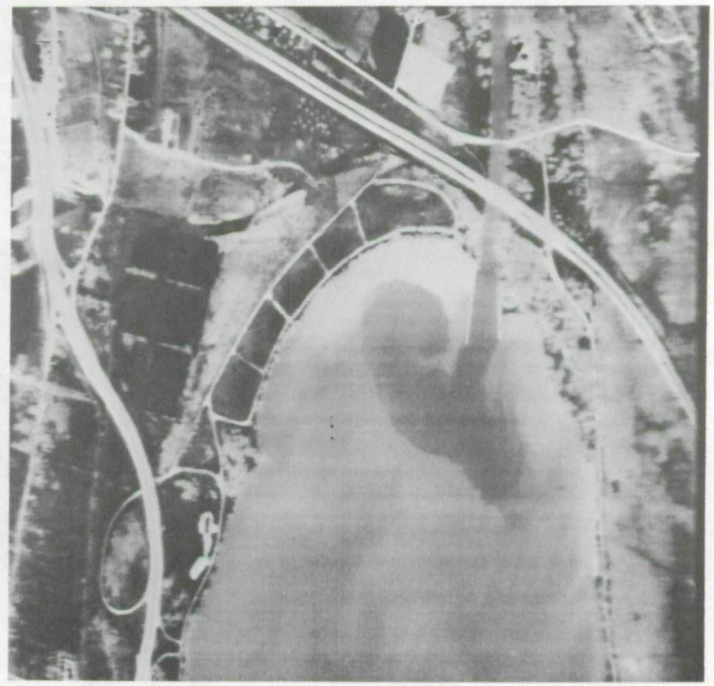


Figure 2. Overview of Onondaga Lake (IR imagery).



31 October 1969



8 July 1970

Figure 3. Northern end of Onondaga Lake (IR imagery).

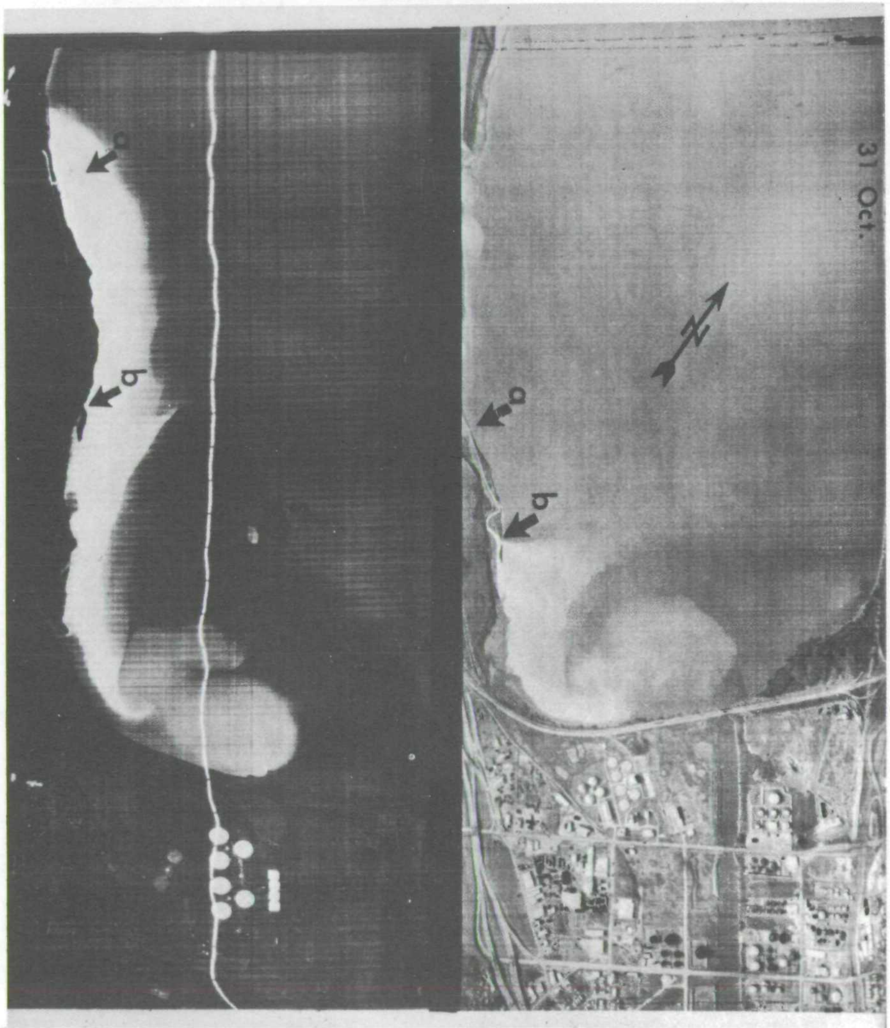


Figure 4. Southern end of Onondaga Lake (IR imagery).

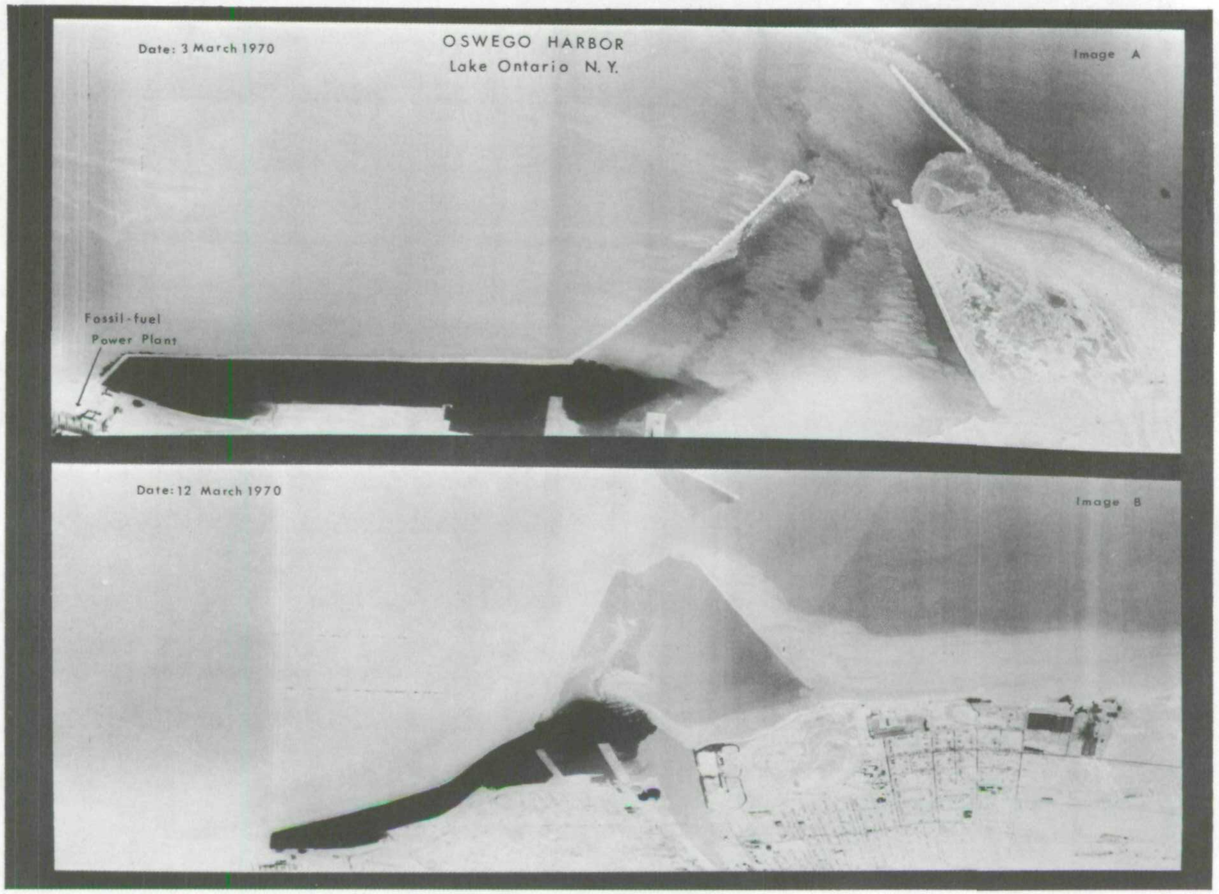


Figure 5. Oswego Harbor, March (IR Imagery).

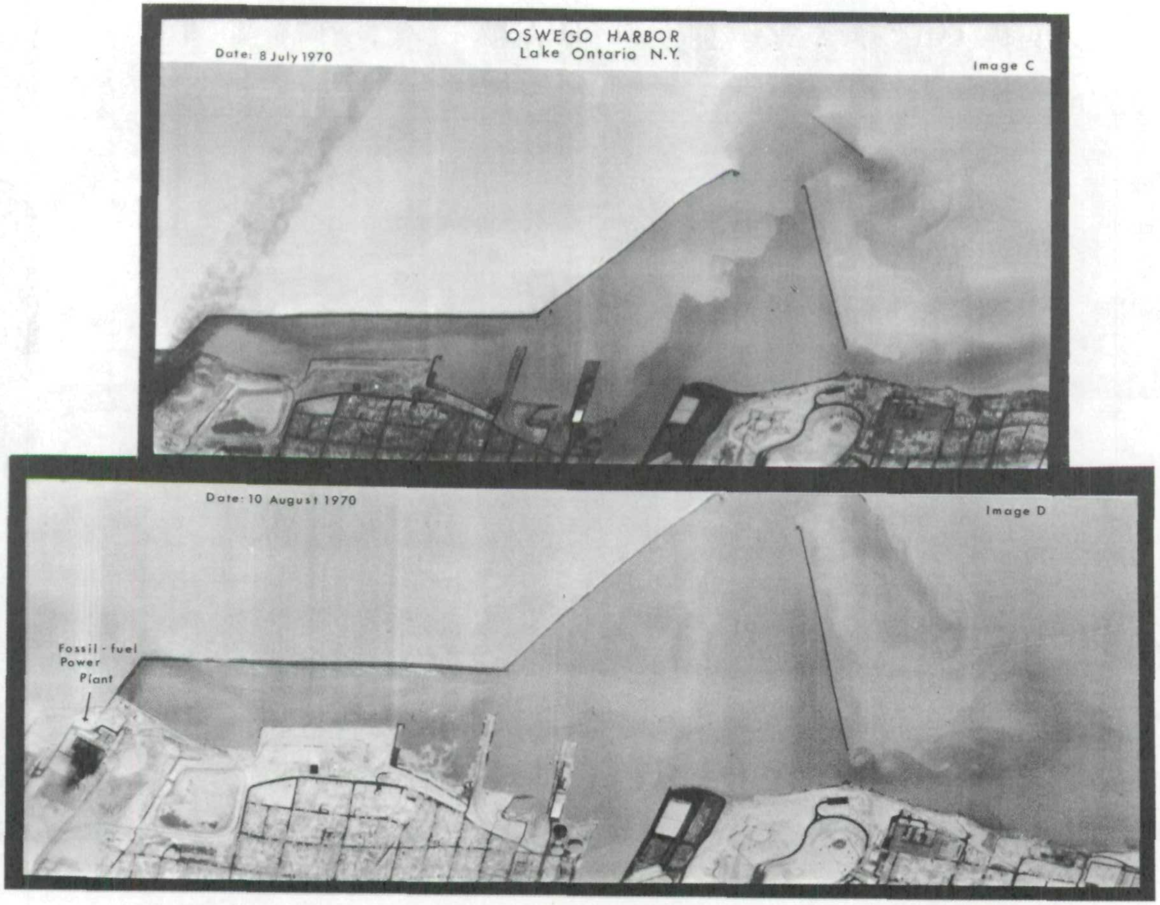
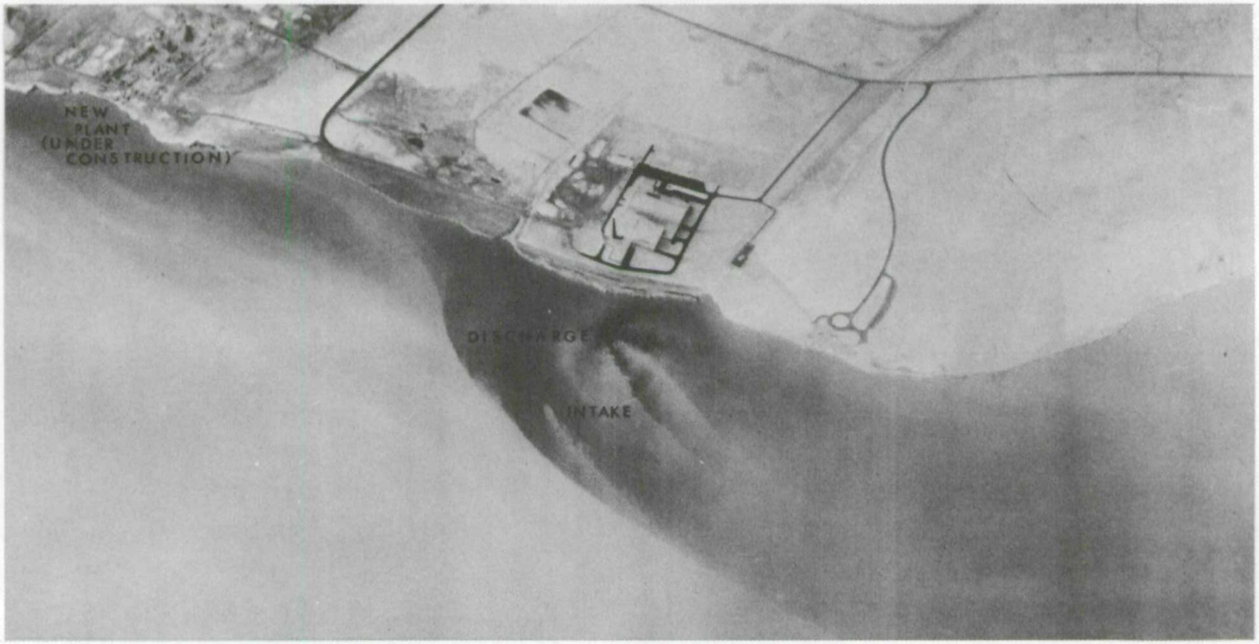


Figure 6. Oswego Harbor, summer (IR imagery).



Date: 10 August 1970 Image A

Figure 7. Nuclear power plant, Lake Ontario (IR imagery).