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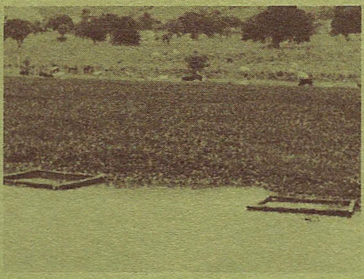

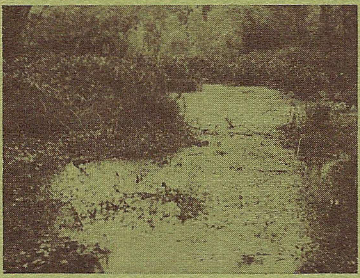

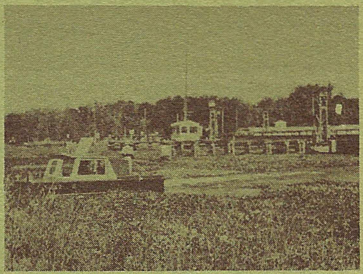

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AQUATIC PLANT CONTROL RESEARCH PROGRAM

Information Exchange Bulletin

REMOTE SENSING
A RAPID AND CHEAP METHOD FOR DETECTING AND MONITORING AQUATIC PLANT INFESTATIONS

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INTRODUCTION

In 1975 responsibility for the research efforts in the control of aquatic plants was assigned to the U. S. Army Engineer Waterways Experiment Station (WES) with a priority to be given to rapid transfer of available technology to the operational elements of the Corps. A portion of this effort is devoted to developing the capability to identify and assess rapidly the nature and extent of aquatic plant infestations. Because accurate ground surveys of these infestations are very often impractical and expensive, remote sensing technology was applied to the problem. Remote sensing imagery provides a synoptic view of an area and the ability to survey large areas very quickly and at a relatively low cost per unit area.

Personnel of the Corps of Engineers Districts and Divisions and of WES met at the WES in September 1975 to discuss the information needs of Corps personnel actively engaged in aquatic plant control. Their needs included knowledge of areal extent and species composition acquired at two scales and frequencies: yearly regional surveys and more frequent detailed surveys. Particular emphasis was placed on the following species: hydrilla, Eurasian watermilfoil, egeria, waterlettuce, waterhyacinth, duckweed, waterchestnut, and alligatorweed. Acquisition of the data outlined above requires the ability to (a) differentiate aquatic plants from their common surroundings such as water or terrestrial plants; (b) differentiate from one another the various aquatic plant species; and (c) differentiate, for given species, variations in plant biomass. Obviously, each successive differentiation is more difficult, especially for submersed aquatic plant species. It is necessary that these differentiations be made by Corps District personnel on a timely basis without additional requirements for manpower or sophisticated machinery.

The overall objective of the WES remote sensing work described herein was to develop two capabilities, both of which could be applied within the existing District resources: (a) a reconnaissance technique, or a means to look at very large areas to rapidly identify potential aquatic plant problems, and (b) a detailed survey capability that would be used to assess the type and extent of aquatic plant infestations at a level that would be meaningful for application or evaluation of control measures.

APPROACH

Before applying remote sensing techniques to a data acquisition problem, the user must first consider if the needed information can be acquired by remote sensing and, if so, the best remote sensing system for his purposes. He must also take into account the critical mission parameters (how high to fly, at what time of day or time of year to fly, etc.) and the economics of the project (how much will it cost to acquire the imagery and the information desired from the imagery?).

To answer these questions, a series of experiments that involved both simulation modeling and field tests were set up to evaluate candidate remote sensing systems.

EVALUATION OF SENSOR SYSTEMS

Reconnaissance Survey Capability

The remote sensing techniques considered to have the most immediate potential for reconnaissance surveys of aquatic plant infestations are Landsat, high-altitude aerial photography, and synthetic aperture radar imagery. Landsat provides repetitive coverage of large areas at a relatively low cost. High-altitude aerial photography is more expensive than Landsat but provides more detailed information. Radar imaging systems can cover large areas rapidly and are not influenced by time-of-day or weather conditions.

The candidate reconnaissance survey sensor systems were evaluated by field tests at the following sites: Lake Boeuf and Lake Theriot, Louisiana; Lake Marion, South Carolina; Lake Seminole, Florida; Ross Barnett Reservoir, Mississippi; and Lake Tohopekaliga, Florida.

Landsat and high-altitude aerial photo imagery of the test sites were obtained from the EROS Data Center, Sioux Falls, South Dakota. Synthetic aperture radar imagery was obtained by the U. S. Air Force Tactical Air Command. In addition, ground truth data on the existing aquatic plant infestations were obtained. The information provided on the imagery was then compared with the ground truth data to determine the types of information that could be acquired with the respective sensor systems. Examples of Landsat multispectral scanner (MSS) imagery and high-altitude aerial photography for Lake Boeuf, Louisiana, are shown in Figures 1 and 2, respectively. A low-altitude oblique aerial photograph of the lake surface is shown as Figure 3 for comparison. As illustrated in Figure 1, Landsat MSS imagery can be used to depict areas with emergent aquatic plant infestations or topped out submersed aquatic plant infestations if the infestations are large enough to be resolved by the sensor system. However, plant infestations that are submersed and not topped out cannot be reliably detected with the current Landsat MSS imagery. The imagery allows a limited capability for discriminating aquatic plant species, particularly if the investigator has some prior knowledge of the aquatic plant species that exist in the study areas. High-altitude aerial photography (Figure 2) such as that obtained by NASA using the U-2 aircraft can be used at its original scale of approximately 1:120,000 for rapidly surveying a large area for potential problems; the same images can be enlarged five times or more to examine smaller areas in more detail. This appears to be a particularly powerful tool unless extremely detailed information is desired. The best film-filter combination for high-altitude photography has been determined to be color infrared film with a No. 12 (yellow) filter.

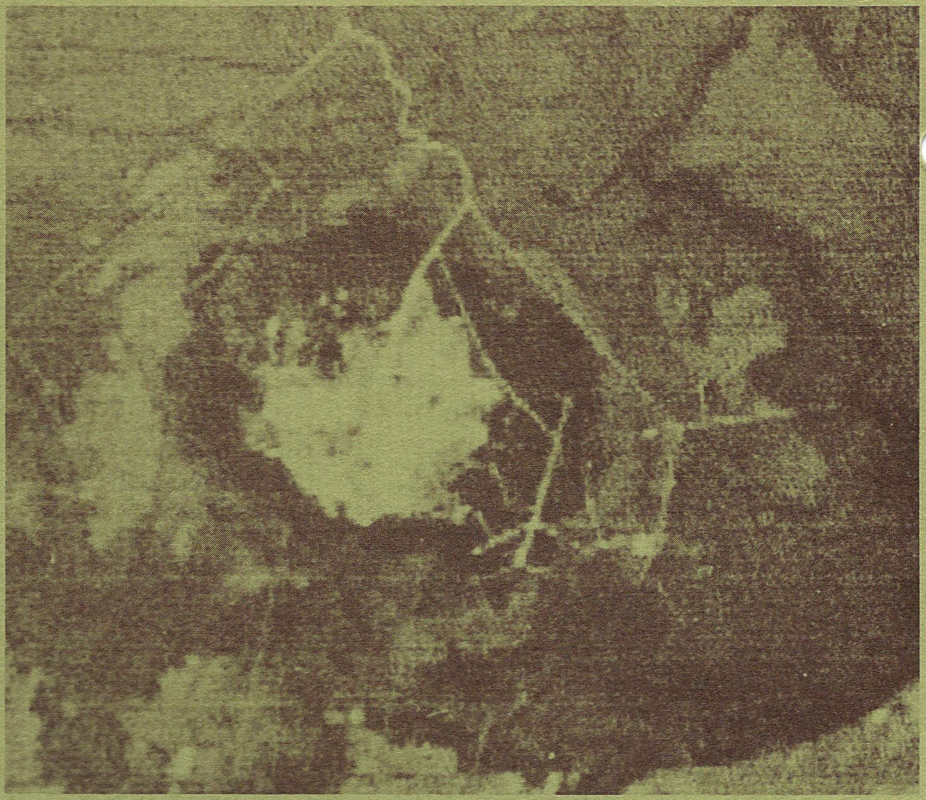

Figure 1. Landsat MSS image of Lake Boeuf, Louisiana

Figure 4 shows a side-looking airborne radar image of Lake Tohopekaliga in Florida. This imagery, taken with an Air Force RF-4C jet radar system, provides some aquatic plant information concerning surface infestations, but not for submersed species.

Detailed Survey Capability

For detailed studies, aerial photography is currently the only practical means for obtaining the desired aquatic plant information. Both simulation modeling experiments and field studies were conducted to determine the best aerial

Figure 2. High-altitude (c. 60,000 ft) U-2 photo of Lake Boeuf, Louisiana

photographic systems for use in aquatic plant mapping. The model studies were used to screen the multitude of film-filter combinations available and pick those that have the most potential for detecting aquatic plant infestations from their respective backgrounds and for discriminating among the aquatic plant species of interest. The model studies were conducted with a WES computer model that inputs the spectral reflectance characteristics of the aquatic plant species of interest and the surrounding water and outputs a prediction of the contrast expected between the plants and their water background or other plant species. The spectral reflectance characteristics of over 20 species of aquatic macrophytes and their surroundings, measured in various locations around the United States at various times of the year, were put into the model. Film-filter combinations with the most potential for discrimination were selected. Based on the model studies, over 94 percent of the target species and surrounding combinations tested would have yielded sufficient contrast between the target and the surroundings on color infrared photography to be detected by the human eye. Color aerial

Figure 3. Low-altitude oblique aerial photo of Lake Boeuf, Louisiana

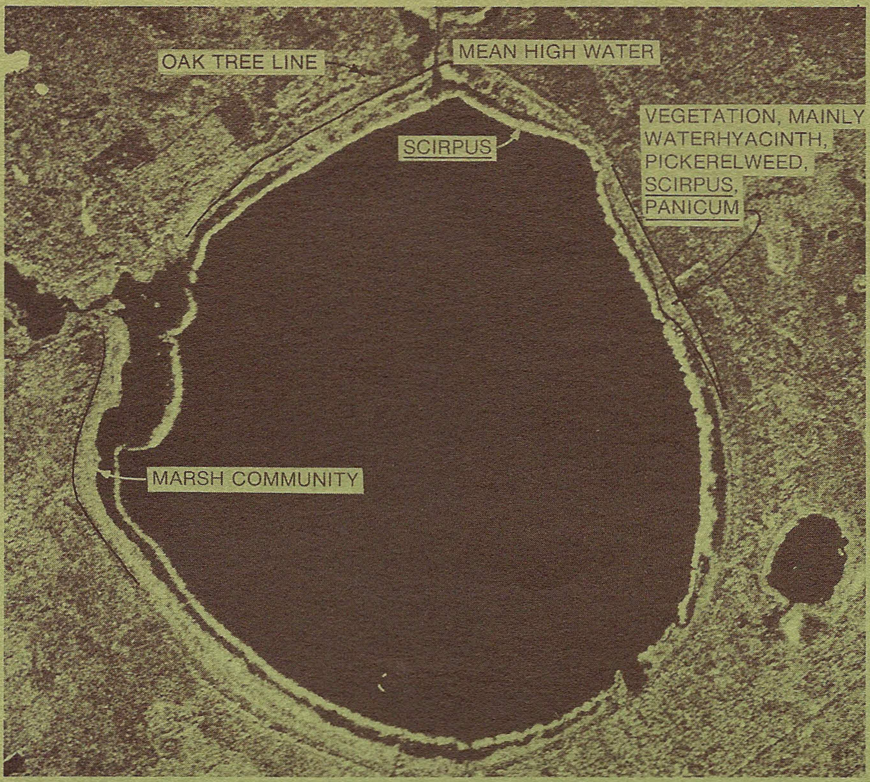

Figure 4. Side-looking airborne radar image of Lake Tohopekaliga, Florida

photography and black-and-white infrared photography with a red filter were also designated as potentially good film-filter combinations for the aquatic plant mapping problem.

Field studies were conducted at the sites mentioned previously in the discussion of reconnaissance survey techniques to further evaluate these prime film-filter combinations. Photographs obtained with color infrared film and a yellow No. 12 filter were established to be the best photographic sensor system for use in aquatic plant mapping, both to detect the presence of surface and submersed aquatic plant infestations and to discriminate between various aquatic plant species. When used at a scale of from 1:10,000 to 1:20,000, such imagery is a valuable source of information on the locations and areal extent of aquatic plant infestations and their species content. Experiments to date have not established the ability to predict biomass from the imagery.

Conclusions

Conclusions reached on the basis of the field studies are as follows:

- Color infrared photography with a yellow filter provides the most generally applicable tool for mapping aquatic plant infestations, both surface and submersed.
- The information derived from the imagery is very much a function of the knowledge of the interpreter. The optimum situation is to have an individual who is very familiar with the aquatic plant situation at a particular water body to interpret the imagery for that area. This will provide the maximum amount of information for the least amount of time and money.
- Standard visual photointerpretation procedures are considered for the present time to be the most cost-effective means of extracting information from the aerial photography. This requires no sophisticated machinery and a minimum of training on the part of the individuals who do the interpretation.
- The most important aspect of applying aerial photography to detailed surveys is being able to plan the mission to optimize the imagery for the information desired. This means considering such things as climatic conditions, growth stage of the plants, water clarity, cloud cover, and time of day. Imagery should be obtained periodically, first to assess the aquatic plant problems and define their extent, and thereafter to monitor control measures or progression of the infestations.

DEMONSTRATION PROJECTS

To test the operational procedure developed in the model and field studies, two large-scale demonstration projects were planned. The sites chosen were Lake Marion, South Carolina, a part of the Santee-Cooper project of the South Carolina Public Service Authority, and Lake Seminole, a Corps of Engineers reservoir located on the Florida/Georgia border at the union of the Flint and Chattahoochee Rivers. The surface area of Lake Marion is estimated to be approximately 400 sq km, and the principal noxious aquatic plants are Brazilian elodea and water primrose. The surface area of Lake Seminole is approximately 150 sq km with a variety of aquatic plants evident, principally, giant cutgrass, waterhyacinth, Eurasian watermilfoil, hydrilla, and various waterlilies.

Image Acquisition and Interpretation

For the purposes of these studies the WES arranged for the Georgia Air National Guard to fly photo missions of the study areas. Two missions were flown over upper Lake Marion, one in November 1976 and one in June 1977. The imagery was acquired at a scale of 1:20,000. Lake Seminole was covered by the same type of aerial photography in April and June of 1977. The imagery received at WES was in the form of 12.7- by 12.7-cm transparencies on a continuous roll.

A technician skilled in aerial photointerpretation, but not in aquatic plant characteristics, examined the images and transferred the location and outline of the various plant assemblages to a 1:24,000-scale base map. The technician received interpretation keys from a botanist who had made at least one ground visit to the lakes being mapped and had collected ground truth data on the target species. A map of the aquatic plant infestations of each lake was produced from each set of aerial photographs. The area infested by each species was measured and recorded. Figure 5, which is an example of the maps produced, shows a portion of Lake Seminole, Florida, with the areas of aquatic plant infestations outlined and coded by species.

Map Evaluation

Shortly after the mapping exercise was finished, the maps were taken to the respective lakes and compared with actual conditions, that is, the species composition and areal extent of the respective plants. The most prevalent error on the maps was in delineation of submersed aquatics. Although most patches of submersed aquatics were correctly identified by species, the submersed patches in reality usually covered a wider area than that detected on the color infrared aerial photography. The discrepancy tended to vary with the depth and clarity of the water. In clear water the errors were very small; however, as the depth of the water above the plants increased and the clarity of the water decreased, the errors increased. The surface aquatic plant infestations were mapped accurately and with a notable level of detail, primarily because either the technician or the botanist assisting the technician was fairly well acquainted with the study areas and had prior knowledge of some of the target species infestations.

Cost Summaries

The cost of producing a vegetation map from aerial photography, of course, varies with the areas imaged and the scale of the imagery. In general, the costs include the cost of film, the cost of the aircraft flight, processing of the film, collection of ground truth data, production of maps from imagery, and field verification of those maps. In addition to the size of the area to be mapped, the desired precision of the end product influences both the scale and the detail by which information is transferred to a map. Some guidance on general estimates of costs involved in producing maps such as those shown in Figure 5 (for a 150-sq-km area) are as follows:

Film. Color infrared film in a 12.7- by 12.7-cm format currently costs approximately $100 per 100-ft roll. One roll was used for each mission (23-cm-wide film costs approximately $210 per 100-ft roll).

Aircraft Flight. Costs of aircraft flights vary with the type of aircraft, distance from the aircraft's home base, and flight time necessary to cover the target area. For the studies reported herein, the equipment and services of the Georgia National Guard were supplied as a training mission at no cost; however, the cost of such a mission performed by private contractor might be estimated at $1500 per mission.

Processing of Film. Processing color infrared film to produce a continuous roll of positive transparencies costs approximately $1.00 per ft. Cost of processing for this study was about $100.

Collection of Ground Truth Data. Each of these field studies involved about three man-days of efforts, a total of approximately $650.

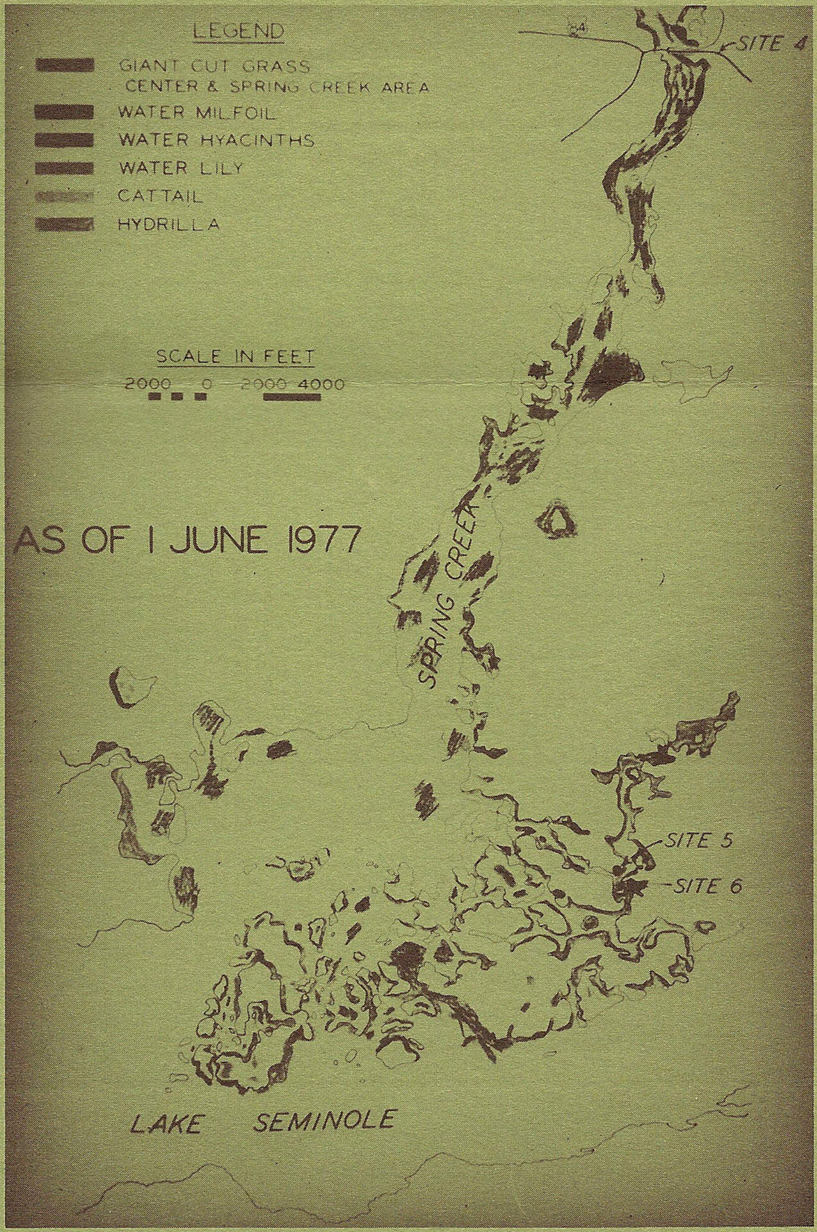

Figure 5. Sample aquatic plant infestation map

Production of Maps from Imagery. After the film had been processed, each of the map sets required a minimum of five man-days to produce, costing approximately $1000.

Field Verification of Maps. This parameter depends on how much precision is required. When meticulous ground measurements are required, costs will increase proportionately. In the exercises noted herein, about three man-days were taken to check the maps at a cost of approximately $650. When the general guidelines for costs of the study to produce the maps at Lake Seminole were summarized, it was estimated that, using WES personnel, an aquatic plant infestation map costs approximately $4000 for a lake of this size. If the process had been conducted by personnel familiar with the conditions at Lake Seminole, it is possible that the number of days for field checking and initial ground truth data collection would have been reduced significantly.

This bulletin is published in accordance with Army Regulation 310-2. It has been prepared and distributed as one of the information dissemination functions of the Mobility and Environmental Systems Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Aquatic Plant Control Research Program (APCRP) can be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, State agencies, universities, research institutes, corporations, and individuals. Contributions are solicited and will be considered for publication so long as they are relevant to the management of aquatic plants as set forth in the objectives of the APCRP, which are, in general, to provide tools and techniques for the control of problem aquatic plant infestations in the Nation's waterways. These management methods must be effective, economical, and environmentally compatible. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Mobility and Environmental Systems Laboratory, ATTN: W. N. Rushing, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39180, or call 601-636-3111, Ext. 3542.

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