BIOGRAPHICAL SKETCH

Harvey K. Nelson

Karvey K. Nelson has served as Director, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, for the Bureau of Sport Fisheries and Wildlife since its establishment in 1963. Preceeding his appointment to this position he had 13 years experience with the Bureau's migratory bird research and management programs in the north central United States, 8 years of which he served as Assistant Regional Supervisor, Division of Wildlife Refuges, with headquarters at Minneapolis, Minnesota. He is a graduate of the University of Minnesota and did his graduate work at Michigan State University. He has received a number of honors and awards from the U.S. Department of the Interior and has received graduate scholarships at George Washington University, Washington, D.C. He also serves as Adjunct Professor of Zoology at North Dakota State University and the University of North Dakota. He is the author of numerous scientific papers and popular articles on waterfowl management and research subjects.

BIOGRAPHICAL SKETCH

John E. Johnston

John E. Johnston is the Inter-Bureau Liaison and Coordinating Representative for the Department of the Interior/U.S. Geological Survey, Earth Resources Observation Systems (EROS) Program. Prior to this position, Mr. Johnston spent a year with NASA's earth resources programing office. He holds a B.S. degree in Geology from the University of North Carolina and did graduate work there and at the University of Kentucky, while with the U.S. Geological Survey. He is the author of numerous reports pertaining to surveying resources, and has a particular interest in the methodology of surveying and measuring earth resources.

BIOGRAPHICAL SKETCH

A. T. Klett

Albert T. Klett has been employed as a Wildlife Research Biologist with the Bureau of Sport Fisheries and Wildlife at the Northern Prairie Wildlife Research Center, Jamestown, North Dakota since 1965. Prior to that he worked with Bureau's wetland preservation program in the prairie region for 3 years, served as a Wildlife Biologist for the North Dakota Game & Fish Department during the period 1953 to 1962 and worked for the Utah Game & Fish Department for 3 years. He attended Utah State University and received his Master's Degree there in 1953. He is the author of more than 20 scientific papers and popular articles concerning research and management of upland game birds, waterfowl and furbearing animals.

APPLICATION OF REMOTE SENSING TECHNIQUES FOR APPRAISING CHANGES IN WILDLIFE HABITAT

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INTRODUCTION

Most Americans consider wildlife as an important national resource. Historically, the Indians, Eskimos, and pioneers depended on the native fish, mammals, and birds for survival. Wild animals are still a source of food and clothing in some areas. Today, since the agricultural and industrial development of the continent, wildlife is valued for its contribution to such recreational pursuits as nature study, bird watching, photography, and sport hunting. Many species are beneficial to mankind and there is a growing awareness of the ecological importance of wild animals. Many Americans feel that the presence of a variety of wildlife in the environment adds important dimensions to the quality of life.

In general, economic development has resulted in a decline in the number of many wild animals, and some species have become endangered or extinct. Laws of various types have been enacted to protect wildlife. Species that migrate across international boundaries have been given additional protection through treaties between Canada, the United States, and Mexico.

The Bureau of Sport Fisheries & Wildlife, in the U. S. Department of the Interior, is the agency responsible for the protection of migratory birds in the United States. Most migratory birds are given complete protection. One exception is the gamebird group that may be hunted under regulations set annually by the respective governments. These migratory gamebird groups include waterfowl, cranes, rails, shorebirds, and doves. Government administration of game management and public hunting at the Federal and State level is traditional in North America. Although we are largely dependent on operations of private land owners and management of public domain lands for preservation and maintenance of wildlife habitats, governmental agencies establish restrictions on areas open to hunting, bag limits, shooting hours, season length, and species that can be taken. One significant aspect of game management in the United States and Canada is that the Federal government assume major responsibility for migratory species. State and provincial governments have primary jurisdiction over most resident species.

In 1965, 1,650,000 U. S. waterfowl hunters spent $87,136,000.00 for 13,526,000 recreation-days (U.S.D.I., 1965) utilizing one aspect of the waterfowl resource (Figure 1). In addition, as shown in Figure 2, bird watchers and other groups obtained millions of days of satisfying recreation (Clement, 1964). Unlike most resident small game species, waterfowl populations may be influenced greatly by hunting regulations (Geis, 1963). Populations also fluctuate with changes in weather and water conditions on the breeding grounds (Crissey, 1969; Geis et al., 1969). Efficient management of this renewable resource depends upon annual adjustment of hunting regulations to insure that a sufficient number of birds remain after the hunting season to provide for production the following year.

An estimate of the size of the fall flight must be available at the time hunting regulations are set. This estimate must be reasonably accurate since, for a number of species, hunting is the largest cause of mortality once the young have attained flight age. Regulations based on faulty estimates of current waterfowl numbers could result in loss of hunting opportunity or reduction of the breeding population to undesirably low levels. A need exists, therefore, to accurately predict the magnitude of the annual fall flight from the breeding grounds (Figure 3).

To meet this need, the U. S. Bureau of Sport Fisheries & Wildlife, (BSF&W), the Canadian Wildlife Service (CWS), and the various provinces and states have developed systematic procedures for predicting fall waterfowl populations (Geis et al., 1969; Crissey 1957; U.S.D.I. 1969). Aerial surveys conducted in May and July are used to provide indices for habitat conditions and waterfowl breeding populations and production. The stratified sampling plan for the United States and Canada is shown in Figure 4. Sample ground surveys are also made to provide correction factors for the aerial data, and the corrected data are then used to make predictions. Hunting season recommendations, presented at the annual national waterfowl regulations meeting, must be prepared in early August, but the last aerial surveys often are not completed until the end of July. Administrators, therefore, are often pressed to evaluate the data and develop recommendations in time to meet this deadline.

Although these surveys have been generally successful for providing essential data for management, biologists have proposed that remote sensing techniques might be used to improve and extend current methods. William A. Fischer (1967) of the USGS has pointed out that information obtained by remote sensing techniques from aircraft or spacecraft are particularly valuable if: (1) The problem is on a regional or global scale (2) Repeated observations on such a scale can provide a "motion picture" of time dependent changes (3) Data collection, reduction, and interpretation are more economical than those obtained by current, conventional methods (4) The problem can be solved without direct samples of the material sensed (5) A map or plan showing a pattern of distribution of the remote sensed element will aid in solution of the problem. Other capabilities of remote sensing and automatic data processing include rapid processing of large volumes of data and data collection over inaccessible regions and terrain.

Many of these characteristics of remote sensing technology have application to the waterfowl production and habitat surveys. The area surveyed is transcontinental in scope, extending from coast to coast and from the far north into the central United States. A large important portion of the North American waterfowl breeding range is located in the prairies of north central United States and south central Canada, an area subject to extreme variability in surface water conditions. Repeated observations are needed seasonally and annually to monitor changes in surface water and other environmental conditions. Some portions of the migratory bird breeding grounds, especially in Northern Canada and Alaska, are inaccessible to ground surveys and pose problems for surveys from small aircraft. Other indices of water conditions and waterfowl production would be helpful in meeting the inflexible time schedule required for the establishment of annual hunting regulations.

Remote sensing technology has not advanced to the point that small mammals and birds can be recognized and counted. However, because of the relationship between reproductive success and habitat quantity and quality, particularly surface water conditions in ponds and small lakes, biologists have speculated that a reliable production index for waterfowl could be derived from an inventory of such water areas during the nesting and rearing period. Remote sensing from aircraft or spacecraft might provide such an inventory or perhaps some other annual indices to wetness that could be used as a base for predictions.

For the project under consideration here, an attempt was made to investigate the potential of airborne, multispectral, line-scanner data-acquisition and computer-implemented automatic recognition techniques for providing useful information about waterfowl breeding habitat in North Dakota. Previous to this project, field-oriented investigations had been carried out by personnel of the Willow Run Laboratories, University of Michigan over agricultural areas (Hasell 1968; Nalepka, 1970), over portions of the International Biological Program (IBP) Grasslands Biome site (Wagner et al. in press), over selected areas of an urbanized landscape (Colwell 1970), and over hydrobiological features in the Everglades National Park (Higer et al. 1970). These investigations demonstrated that techniques for airborne data acquisition using multispectral line scanners, and data processing techniques using analog and digital computers, provide useful information about landscape materials, features, and processes not obtainable from conventional aerial photographic techniques. The study was planned by the BSFW and the USGS and carried out with the support of NASA through contracts with the University of Michigan. The principal information presented in this paper is based on two reports resulting from the study (Burge et al. 1970; Nelson et al. 1970).

OBJECTIVES

Arrangements were made with the University of Michigan to fly a multispectral remote sensing mission over the Woodworth study area in May 1968 (Figure 5). The mission was part of an experiment to determine what characteristics of wetland habitats and adjacent uplands could be detected multispectrally and processed automatically with the special computer equipment at the University of Michigan's Willow Run Laboratories. The specific kinds of information sought were:

1. Number of ponds containing water.
2. Number of dry ponds.
3. Number of ponds by size class and wetland type.
4. Identification of major land use types.
5. Distribution of ponds within different land use types.
6. Identification of major associations of marsh plants.
7. Measurement of pond depth, area and shoreline perimeter.
8. Area and distribution of cultural features.
9. Effects of increased flight altitude on accuracy of measurements.

Fortunately these objectives are of mutual interest to hydrologists, geologists, geographers, agriculturalists and others. These overlapping interests justify work on projects of secondary economic importance such as waterfowl ecology. The results can be used to advantage in a number of disciplines.

THE STUDY AREA

The topography of the test site is typical of the stagnation moraine that lies along the eastern edge of the Missouri Coteau in North Dakota. The 15.5 km^2 area has been studied intensively by biologists from the Northern Prairie Wildlife Research Center, BSF&W, since 1964 (Kirsch, 1968). Pond basins of various sizes and types are numerous, averaging nearly 40 per km^2 (Figure 6). During the past 4 years, the breeding population of ducks has ranged from 27-43 pairs per km^2. Most of the land in private ownership is cultivated for small grains or is used for pasture. Some lands owned by the BSFW have been maintained in a variety of idle cover types since 1963. A small percentage remains as native prairie. Ground conditions on the day of the flight presented a composite of fields in different stages of tillage, wet and dry ponds, and upland and aquatic vegetation in early stages of growth.

PROCEDURES

The mission was flown with the University of Michigan C-47 aircraft using a 17 channel multispectral scanner and four aerial cameras. The scanner channels included contiguous but discrete wavelength bands in the ultraviolet, visible, and infrared regions. Thirteen runs were completed at 610 m and 3,050 m above the terrain between 0830 and 1030 on May 31, 1968. Ground measurements of air, soil surface, and water surface temperature; soil moisture; relative humidity; water depth; and vegetative development were made at selected study sites on the morning of the flight. Data on land use, wetland types, and cultural features were collected at different times as part of the routine monitoring of the area. A further source of control data was the photographic information obtained during the flight with four film/filter combinations. These data provided the necessary background for interpreting the scanner imagery and assessing recognition success obtained with the automatic processing equipment. A number of well-documented areas were chosen for test sites.

The Willow Run Laboratories' airborne scanning spectrometer is currently configured to sense radiation simultaneously in 12 spectral bands ranging from 0.4 um (blue) to 1.0 um (near infrared) (Figure 7). The scanning spectrometer, which is mounted in the belly of an airplane, accomplishes the scanning function by means of a mirror which rotates about an axis parellel to the aircraft heading. The forward motion of the aircraft causes succeeding scans to view different portions of the scene below. Thus, by appropriately setting the aircraft velocity and mirror rotation rate, each point in the ground scene that is within the total system field of view may be scanned.

The radiation from each point of the scan is collected and directed through a prism. Radiation in different portions of the spectrum is then picked off by 12 fiber optic bundles, each of which directs the radiation to a different photomultipler. The voltages produced in each of the photomultipliers are then amplified and recorded on magnetic tape. Thus, the data recorded on tape, which is used as an input to the recognition processor, consists of 12 scanner signals, each signal corresponding to information gathered over a different spectral band. Four additional detectors were used to provide data in the 1.0- to 1.4-, 2,0- to 2.6-, 4.5- to 5.5-, and 8.0- to 13.5-um regions.

Preliminary analyses of the scanner imagery and computer recognition maps were completed at the Willow Run Laboratories in late 1969. Five of the runs were selected for processing: four from 610 m data and one from 3,050 m data. A segment of one 610 m run over a representative part of the study area was processed most intensively. The 3,050 m data used were selected because they covered most of the study area and contained the least amount of cloud shadow. Both analog and digital procedures were tested for the identification of materials; digital techniques were used to measure the perimeter and area of the ponds.

Several analog processing experiments were conducted with the 610 m imagery using six data channels in the visible and near infrared region. Materials tested for automatic recognition included open water, marsh vegetation, croplands, pastures, idle areas, hayland and cultural features. In some instances, attempts were made to identify components within these broad categories such as standing marsh vegetation, matted marsh vegetation, or a given species such as cattail. At other times materials were combined to identify a broader group, e.g. open water and marsh vegetation were combined to delineate entire pond basins (Figure 8). Spectral signatures were established by the analog computer for each test site and the signatures were then used to recognize similar materials within the recorded field of view.

The 3,050 m data were not completely analyzed. The objective was to determine in a general way some of the advantages and disadvantages of sensing from higher altitudes and to simulate results obtainable from similar sensors aborad space craft. Three channels in the 0.62 to 1.0 um region were selected because they were synchronous with one another and may have an advantage over shorter wavelength data at higher altitudes because longer wavelengths are less affected by atmospheric scattering.

One line of 610 m coverage was processed with a CDC-1604 digital computer. Outputs from this process are recognition maps that are similar to analog color coded recognition maps. In addition to maps, the digital computer was used to produce statistics on the perimeter and area of individual ponds by flight line segment and by size class distribution. Five channels in the reflective wavelength region (0.4 to 1.0 um) were selected for this digital processing. These computations were compared to measurements of shorelines and area made on aerial photographs with a wheel-type map measurer and a dot grid counter.

RESULTS

Analog Processing of 610 m Data

An important objective of this project was to determine the usefulness of multispectral techniques in identifying components of migratory bird habitat. In general, the analog processing experiments with the 610 m data were successful. The features of greatest interest were ponds, which were recognized with almost 100 percent accuracy on one line in the study area. Ponds less than 0.25 ha in size printed out clearly in the analog recognition maps. In order to recognize all ponds, it was necessary to combine the signatures for open water and two types of aquatic vegetation (Figure 8).

Technical problems prevented analysis of the data for water depth during the period of the contract. This information, however, can now be obtained for those ponds having water clear enough to permit light to penetrate to and be reflected from the bottom using a recently developed digital program.

Dry pond basins were not recognized in the visible portions of the spectrum analyzed in this study. The types of vegetation in these temporary ponds was so similar to those in surrounding area that no differentiation could be made. Recently, however, examination of video prints in the near-infrared channels indicates that dry ponds can be recognized.

Recognition of principal aquatic vegetative associations was unsatisfactory because development of plant communities is incomplete in late May. Much of the new growth was still concealed by the remains of previous growth. Also, vegetation at or just above the water surface produced a hybrid signature that made differentiation between water and aquatic vegetation difficult. Collection of data later in the season, such as mid-July, when the vegetative communities are at peak growth should permit much more accurate differentiation. Additional data were collected in July 1970 when the vegetative growth was mature. These data are now being processed for recognition of aquatic plant communities.

The recognition of land use types and upland vegetation was successful. Bare soil, new growth, and dead vegetation could be separated in most cases (Figure 8). All the bare soil areas recognized were tilled fields. Some differentiation was obtained between fields that may have been due to soil moisture, stage of tillage, or soil type. New vegetative growth was evident in a variety of land use types where agricultural operations resulted in the removal of the dead vegetation from the previous year. Attempts to recognize wild hay, overgrazed pasture, and idle alfalfa-brome grass mixtures were only partially successful. Areas of brush were not recognized because of the dominance of grasses within the brush training sets, but the appropriate spectral signature for woody species can be developed. The result is a hybrid signature similar to the example of marsh vegetation growing in water. When consideration is given to the fact that the original land use training sets were chosen from mapped information and not from on-site observations, these results are reasonable. The selection of more representative test sites would have eliminated much of the misclassification. This aspect can be corrected in future remote sensing work by establishing a more coordinated ground data collection effort.

No signatures were established for cultural features. For most purposes roads, towns and farm buildings can be recognized satisfactorily from photographs or spectral imagery (Figure 9). Automatic recognition of these features from high altitude may be difficult because of the relatively small dimensions and the great diversity of materials that would have to be detected. This conclusion is supported by findings obtained on another project at the University of Michigan (Colwell, 1970). These findings do show, however, that buildings and road materials can be mapped using data in the reflective and infrared wavelengths together.

Recognition Digital Processing of 610 m Data

The digital processor can provide mapped recognition outputs which are comparable with those obtained from the analog equipment (Figure 10). A portion of a digital recognition map is shown in Figure 12. There is, in general, a good correlation between the materials represented by the gray levels on the digital maps and the colors on the analog maps.

3,050 m Analog Imagery

As expected, recognition results from 3,050 m data were of lesser quality than those from 610 m data (Figure 11). Aerial coverage was about five times greater from 3,050 m than at the lower altitude. In general, the loss of spatial information did not exceed the lower size limit of features of interest, e.g. the smaller ponds. However, 3,050 m appears to be a practicable upper limit to the altitude at which such results can be obtained with the 3 milliradian resolution capability of the University of Michigan scanner. Recognition of ponds larger than 1 to 2 ha will probably be resolved with instruments being designed for use in space craft by 1972 or later.

Recognition results using the higher altitude data were complicated by partial cloud cover during the flight. Better results could be expected with more representative test sites and an optimum selection of synchronized channels. Fewer resolution elements cover a given area at a higher altitude and hence provide a less dense sample for a test site. Since all features are reduced in size, the probability of including extraneous or unwanted material in the test site is greatly increased. However, if large, homogeneous, and representative training sets are available, recognition of areas about four resolution elements in size (40 m x 10 m) can be achieved at the 3,050 altitude.

Quantitative Digital Processing of 610 m Data

Quantitative results on the perimeter and size of ponds were obtained using low altitude data on the digital processor (Figure 12). Computations of pond perimeters averaged higher than control measurements obtained with aerial photographs and a wheel-type map measuring device.

The map measuring device tends to smooth out irregularities in the shoreline that are included in the digital processing. Acreages derived from aerial photographs were about the same as the computed estimates. Automatic processing of multispectral data may make it possible to derive these measurements faster than by conventional methods with equal or greater precision.

CONCLUSIONS

The spectral characteristics of the components of a landscape containing waterfowl habitat can be detected with airborne, multispectral scanners. By analyzing these spectral characteristics it is possible to identify and map the landscape components through analog and digital processing methods.

The recognition results obtained with the 610 m data are reasonably accurate. Pond identification was accomplished successfully by combining the spectral signatures of open water and marsh vegetation. In addition, by operating on the digital recognition data, statistical summaries and distributions were obtained that appear to be more accurate than those obtained by standard office measurements. Progress was made in the recognition of broad categories of land use and vegetation. Recognition of land use types and further development of automatic measurement techniques will make it possible to better interpret the relationship of such parameters as land: water ratios, changes in the relative amounts of cropland and grassland, and specific land-use practices. Greater differentiation will be possible by collecting data later in the growing season, selecting large homogeneous areas for test sites, obtaining better on-site ground data, and using optimum data channels as determined by digital techniques.

At the present stage of development multispectral remote sensing techniques are not ready for operational application to surveys of migratory bird habitat and other such resources. Further developments are needed to (1) increase accuracy, (2) decrease retrieval and processing time, and (3) reduce costs.

New studies are in progress using multispectral data collected by the University of Michigan in 1970. High altitude photography, collected by NASA, is also available for comparative evaluation. Hopefully, the results of these investigations and future studies with ERTS data will assist us in attaining our previously stated goals.

LITERATURE CITED

Burge, W. G., and W. L. Brown. 1970. A study of waterfowl habitat in North Dakota using remote sensing techniques. Univ. Michigan, Inst. Sci. and Tech., Willow Run Laboratories.

Clement, R. C. 1964. Viewpoint of a naturalist. Pp. 699-705. In Waterfowl tomorrow, J. P. Linduska (editor). U. S. Gov't. Printing Office. 770 pp.

Colwell, J. E. 1970. Multispectral remote sensing of urban features. Univ. Michigan, Inst. Sci. and Tech., Willow Run Laboratories Report No. 2772-6-F.

Crissey, W. F. 1957. Forecasting waterfowl harvests by flyways. Trans. N. Am. Wildl. Conf. 22:256-268.

_______. 1969. Prairie potholes from a continental viewpoint. Saskatoon Wetlands Seminar, Canadian Wildl. Serv. Report Series 6:161-171.

Fischer, W. A. 1967. Geological applications of remote sensors. A.I.A.A. Annual Meeting and Technical Display 4:13-19.

Geis, A. D. 1963. Role of hunting regulations in migratory bird management. Trans. N. Am. Wildl. Conf. 28:164-172.

_______, R. K. Martinson, and D. R. Anderson. 1969. Establishing hunting regulations and allowable harvest of mallards in the United States. J. Wildl. Mgmt. 33(4):848-859.

Hasell, P. G. 1968. Investigations of spectrum matching techniques for remote sensing in agriculture. Univ. Michigan, Inst. Sci. and Tech., Willow Run Laboratories Report No. 8725-13-P, vol. 1.

Higer, A. L., N. S. Thomson, F. J. Thomson, and M. C. Kolipinski. 1970. Applications of multispectral remote sensing techniques to hydrobiological investigations in Everglades National Park. Univ. Michigan, Inst. Sci. and Tech., Willow Run Laboratories Report No. 2528-5-T.

Kirsch, L. M. 1968. Effect of land use on waterfowl and other wildlife on the Woodworth study area. Pp. 14. In Research Accomplishments. Northern Prairie Wildlife Research Center, Bur. Sport Fish. and Wildl. 55 pp. multilithed.

Nalepka, R. F. 1970. Investigation of multispectral discrimination techniques. Univ. Michigan, Inst. Sci. and Tech., Willow Run Laboratories Final Tech. Report No. 2264-12-F.

Nelson, H. K., A. T. Klett, and W. G. Burge. 1970. Monitoring migratory bird habitat by remote sensing methods. Trans. N. Am. Wildl. and Nat. Resources Conf. 35:73-84.

U. S. Department of the Interior. 1965. National survey of fishing and hunting. Bur. Sport Fish. and Wildl., Resource Publ. No. 27:13.

______. 1969. Standard procedures for waterfowl population and habitat surveys -- the prairies. Bur. Sport Fish. and Wildl., Div. Management and Enforcement. 68 pp.

Wagner, T. W. et al. An investigation of grassland resources using multispectral processing and analysis techniques. Univ. Michigan, Inst. Sci. and Tech., Willow Run Laboratories Report No. 34795-1-F. (In press)

DEFINITIONS *

Aerial survey: An estimate of populations and/or species composition through the use of an airplane.

Air-ground correlation: The use of data from intensive ground surveys to correct extensive observations from low flying aircraft.

Aquatic: An animal or plant living in the water.

Bird Treaty Act: A law making it illegal to hunt, kill, sell, purchase or possess migratory birds except as permitted by annual regulations adopted by the Secretary of the Interior.

Breeding population: The number of breeding pairs of birds present on a given unit of habitat.

Daily bag limit: The legal limit of game animals per day as defined by law.

Fall migration: Movement of waterfowl from nesting range to wintering range.

Forecast-fall flight: An estimate of the number of waterfowl that move from the northern nesting grounds to the southern wintering grounds.

Ground survey: A study or inventory of wildlife activities or numbers from the ground as contrasted to study or inventory from an airplane.

Habitat: A set of ecological conditions required by any one species.

Hunting: The act of attempting to take game.

Hunting season: The period during which game animals can be legally taken for sport.

Inventory: An estimate of population levels.

Migratory: To move periodically or seasonally from one region or climate to another.

Production: The yield of a wildlife population through reproduction.

Production index: Ratio of young of the year to adult segment of a population.

Protection: Safeguard against natural enemies and/or hunters.

Range: The extent of an area covered by the breeding population of a particular species.

Surface water: Water that is stored above ground in natural or artificial basins.

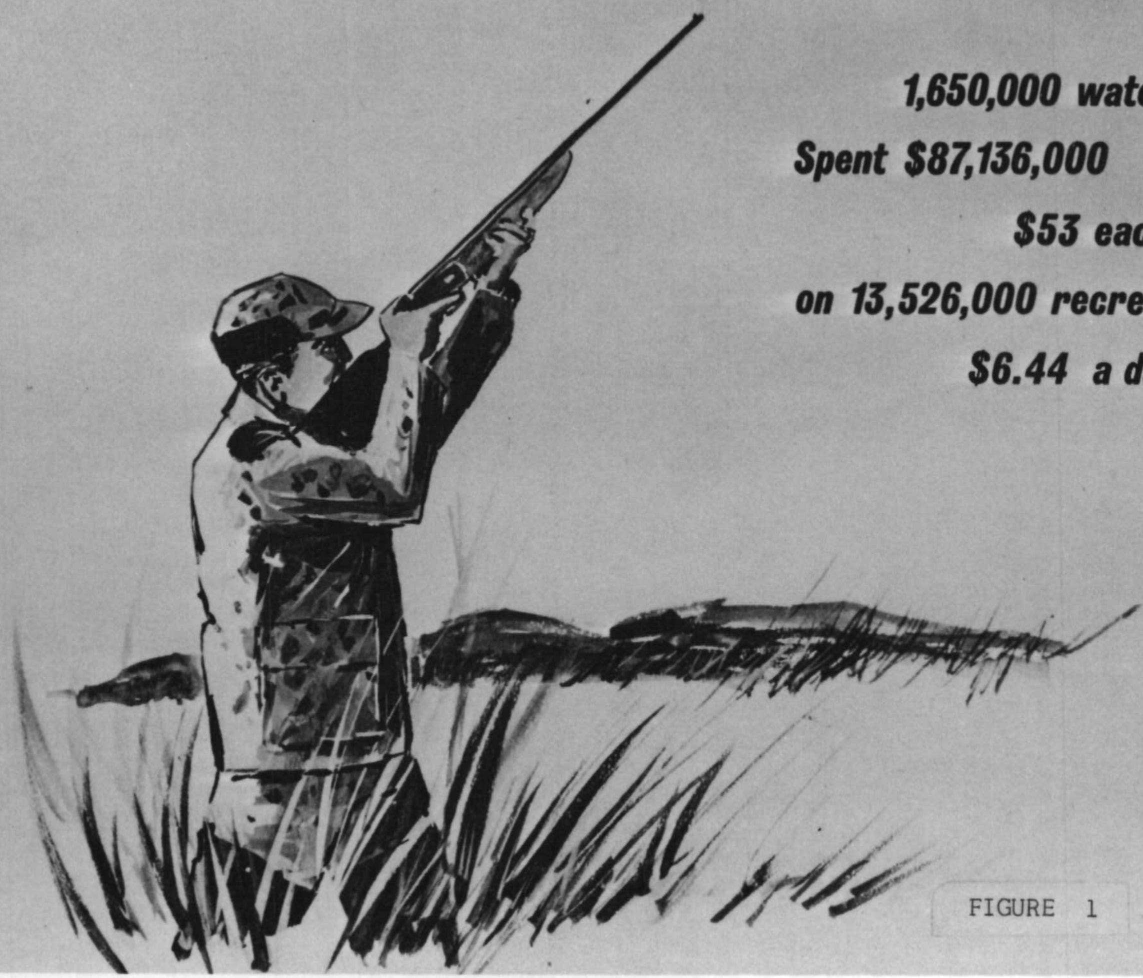
Training set: A test site; a representative feature, object or material that is used to establish a spectral signature.

Waterfowl: A grouping of birds including brant, wild ducks, geese, and swans.

Wetland classification: A system for categorizing and rating the value of wetlands based on permanency, emergent vegetation, size and use by migratory birds.

* Most definitions taken from Glossary of Waterfowl Management Terms, J. R. Singleton and Monte M. Dodson. The Central Flyway Council. Publ. by: Texas Game and Fish Commission. 1959.

Waterfowl Hunting, 1965



1,650,000 waterfowl hunters

Spent $87,136,000

$53 each

on 13,526,000 recreation-days

$6.44 a day

FIGURE 1

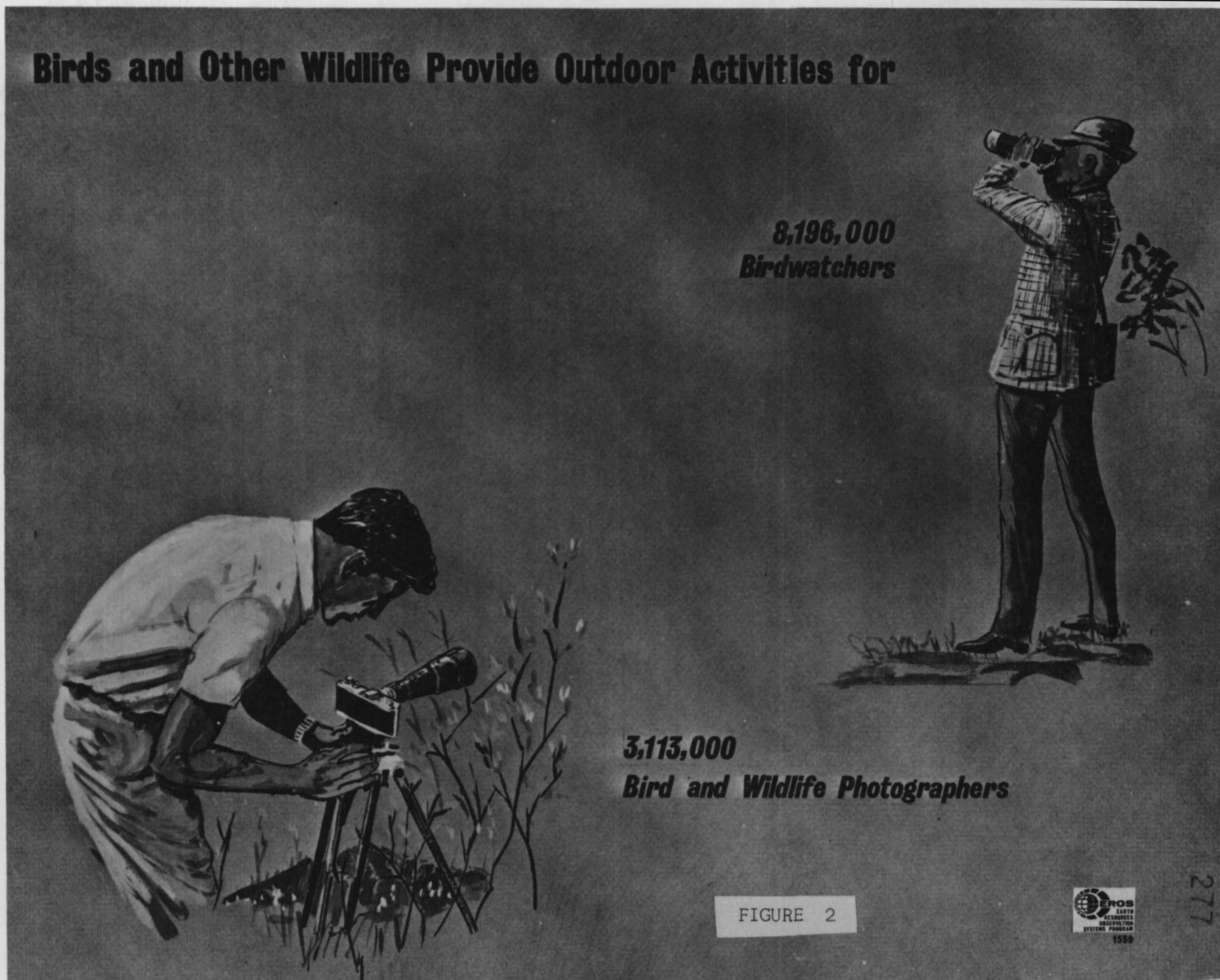

Birds and Other Wildlife Provide Outdoor Activities for
8,196,000
Birdwatchers
3,113,000
Bird and Wildlife Photographers
EROS
EARTH RESOURCES OBSERVATION SYSTEMS PROGRAM
1559

FIGURE 2

FIGURE 3. ADMINISTRATIVE WATERFOWL FLYWAYS

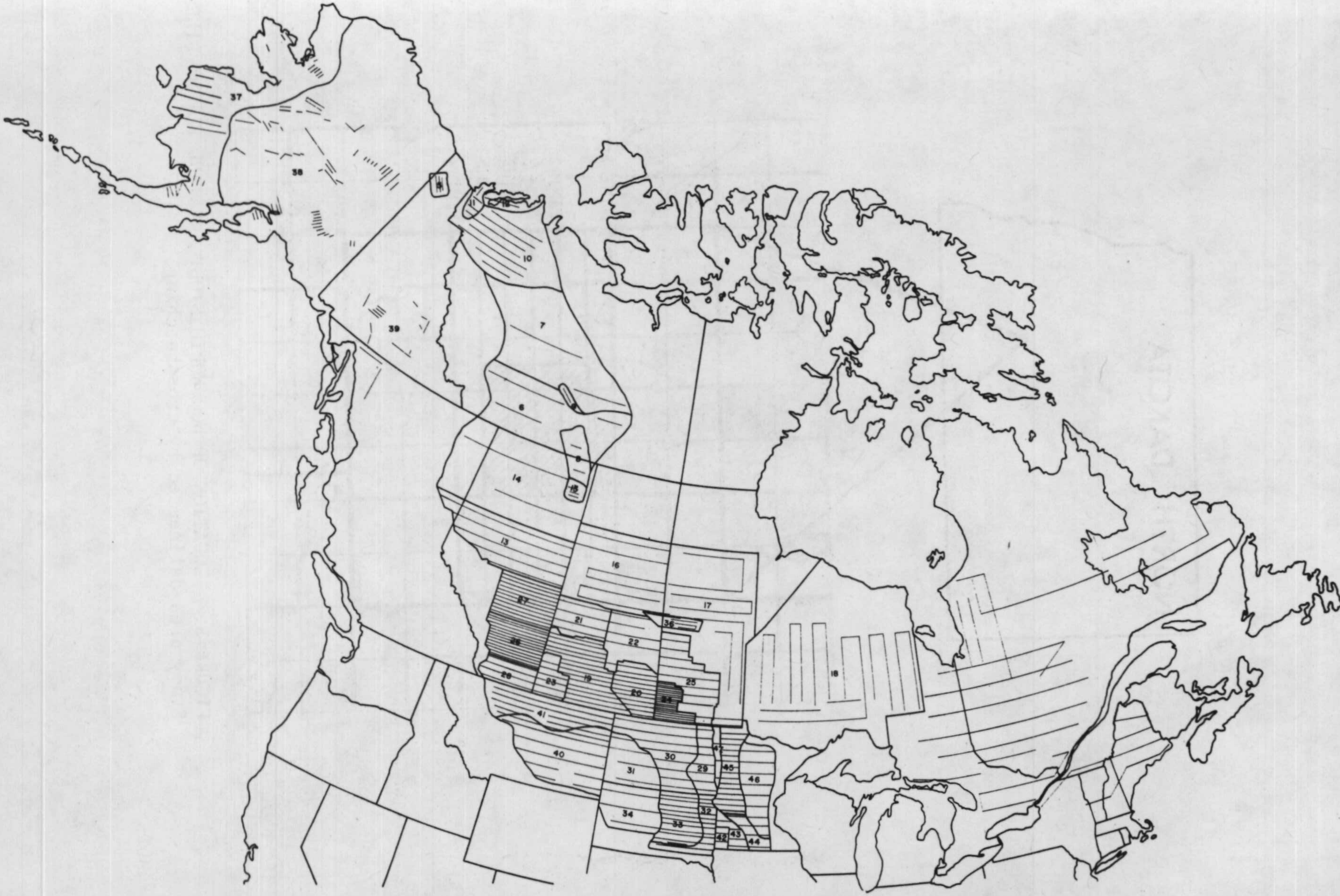


FIGURE 4. WATERFOWL BREEDING POPULATION AND PRODUCTION AERIAL SURVEY TRANSECTS AND STRATA

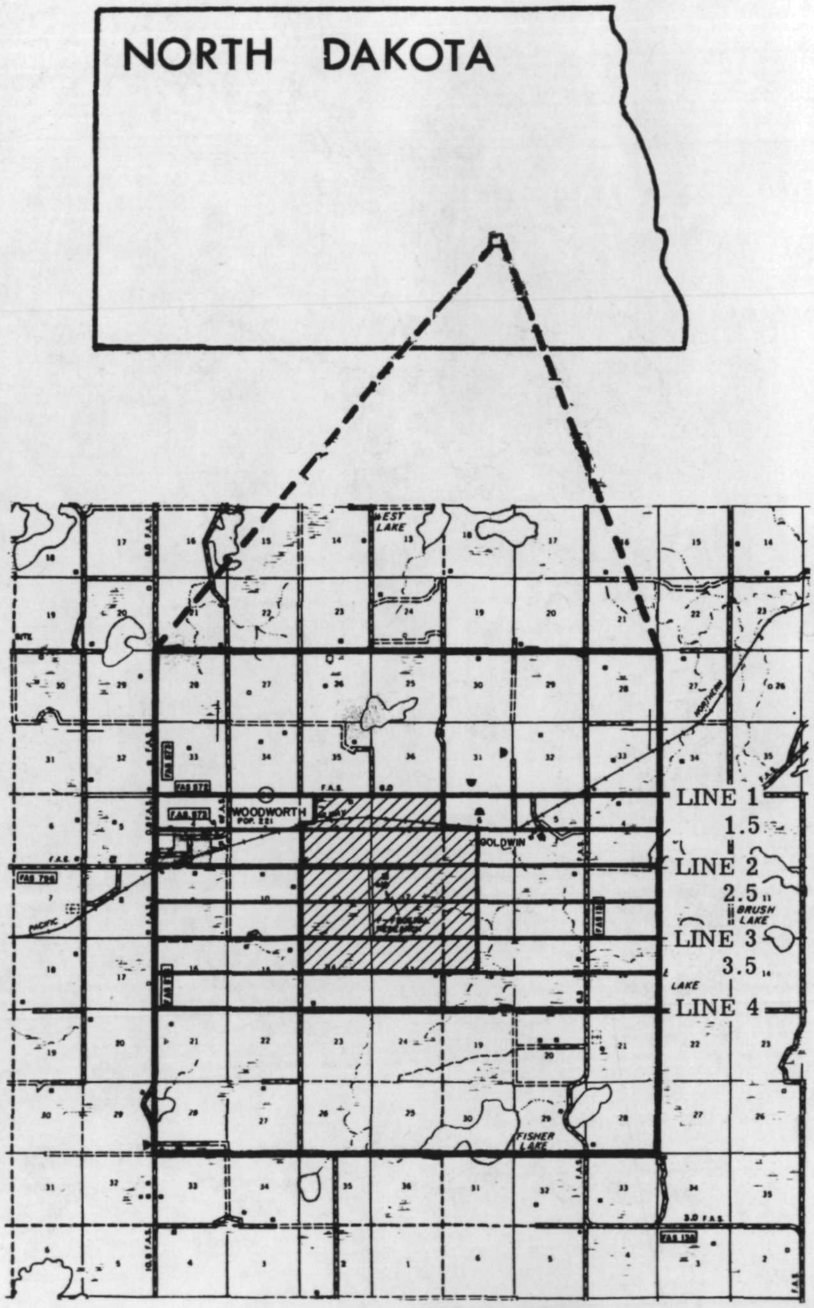


FIGURE 5. LOCATION OF WOODWORTH STUDY AREA AND FLIGHT LINES. Study area delineated by crosshatching.

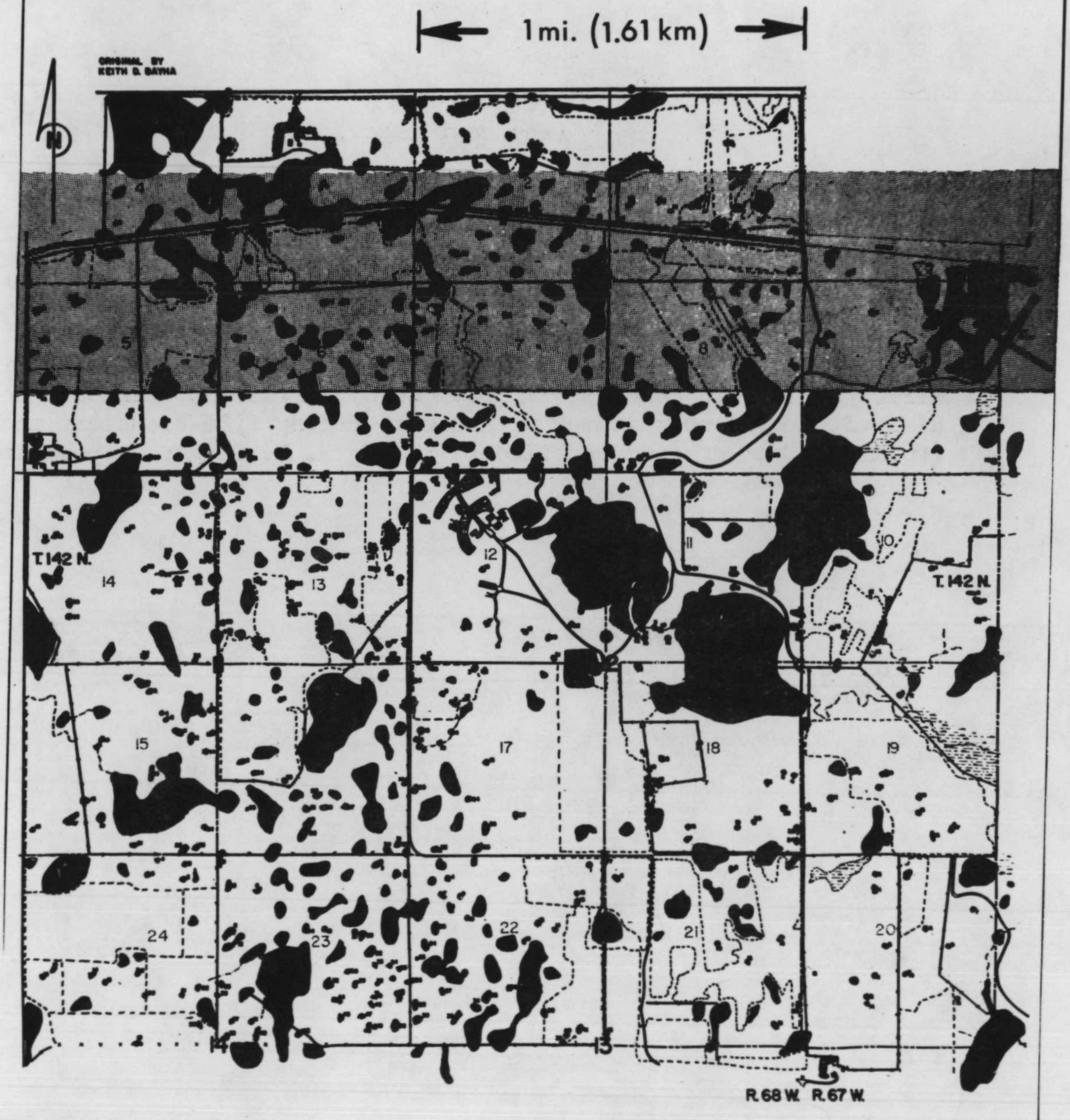
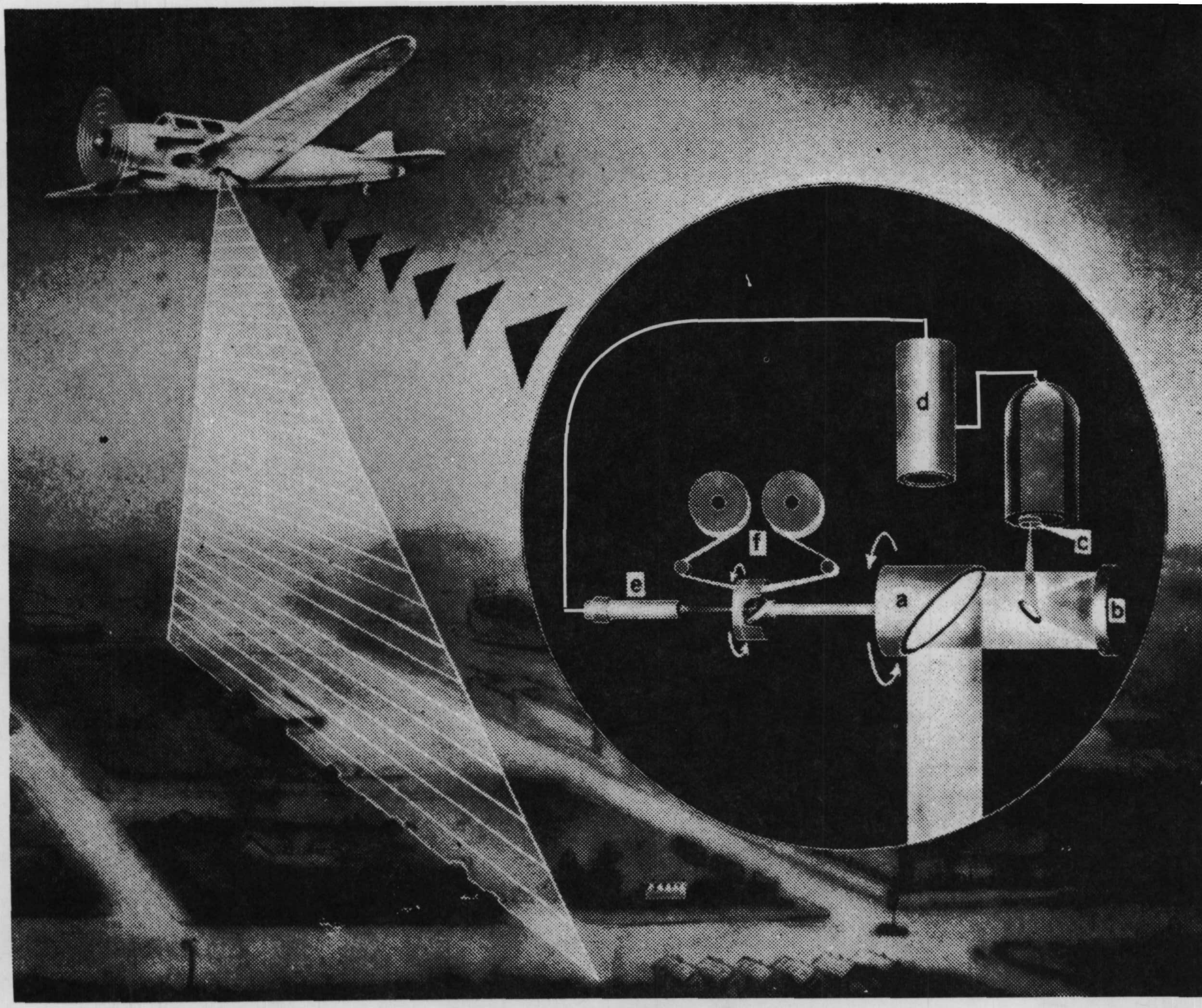


FIGURE 6. WOODWORTH STUDY AREA, NORTH DAKOTA.
Wetlands shown in black; flight line 1.5, run 9 shown stippled.

Figure 7.
(See next page.)

INFRARED SCANNING SYSTEM. Radiation from the earth is collected on the surface of a rotating miror a, reflected to the surface of a parabolic mirror b, and thence to the surface of a solid state detector c. The output of the detector is amplified d and modulates the output of a light source e. The modulated light is recorded on film f. Lateral coverage is obtained by rotation of the collecting mirror a; forward coverage is provided by forward movement of the aircraft and is coordinated with the recording film-transport mechanism. (Modified from diagram supplied by the H. R. B. Singer Corporation.)


d
f
c
e
a
b

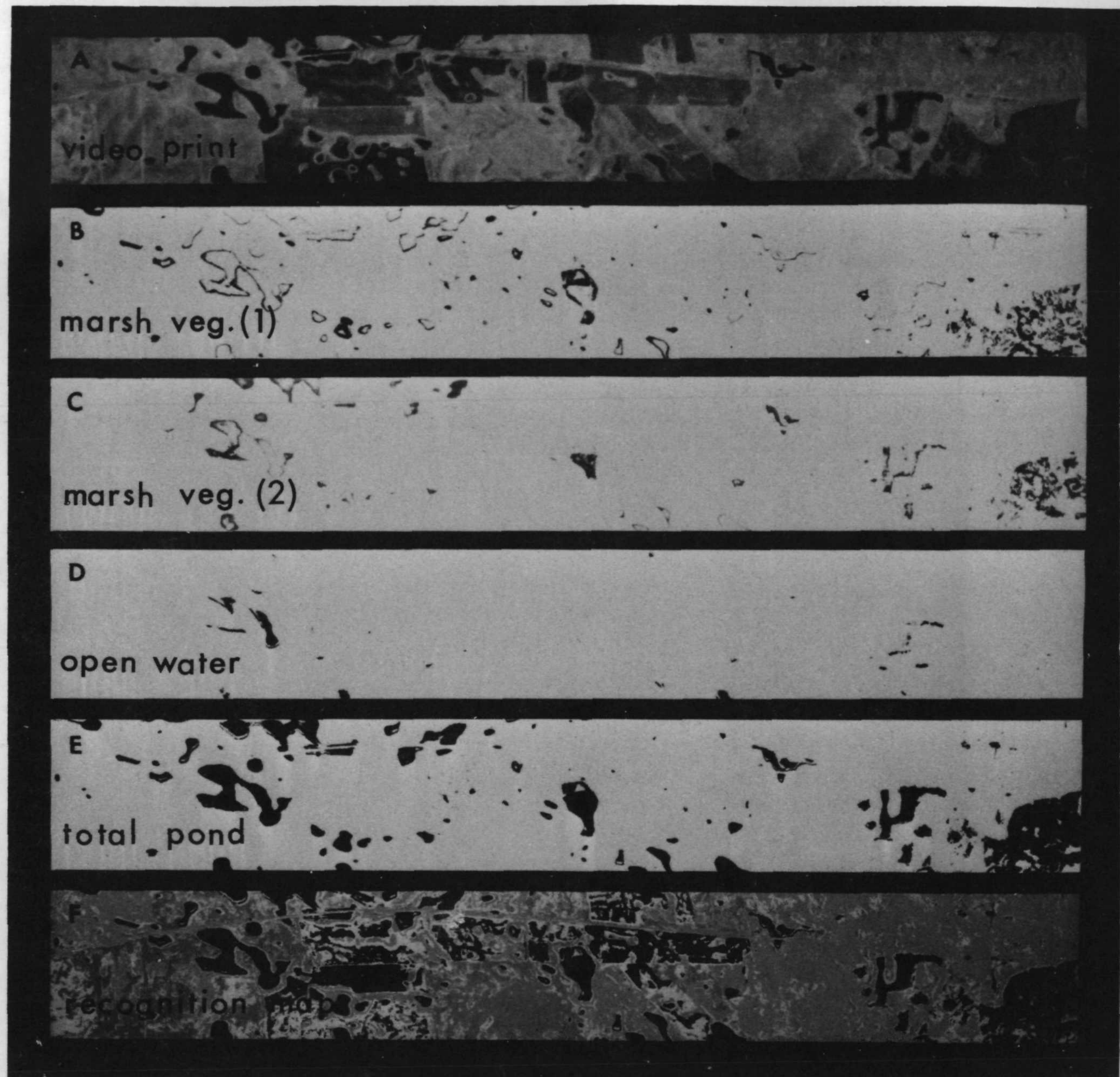


FIGURE 8. STEPS IN THE ANALOG PROCESSING OF MULTISPECTRAL SCANNER DATA, WOODWORTH STUDY AREA. Strip E is the recognition map of wet basins obtained by combining the information in strips B, C, and D. The recognition map F includes other materials in the scene.

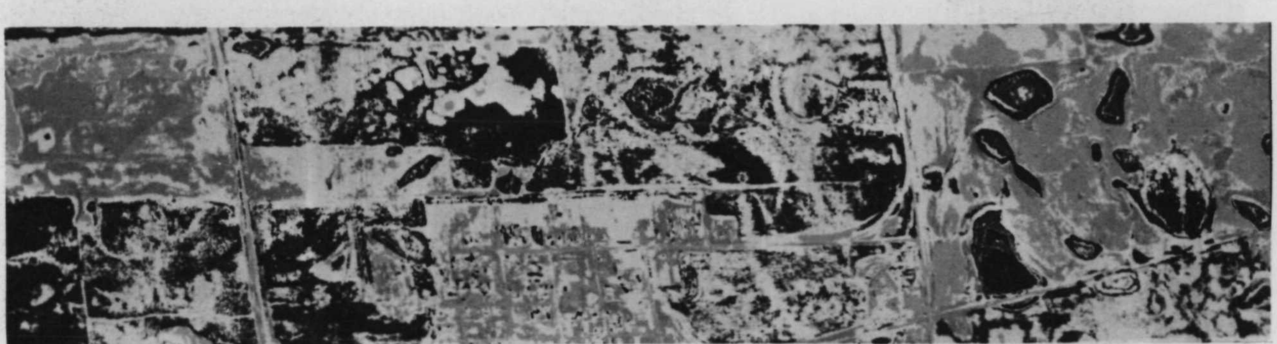


FIGURE 9. ANALOG RECOGNITION MAP OF CULTURAL FEATURES. Village of Woodworth, North Dakota

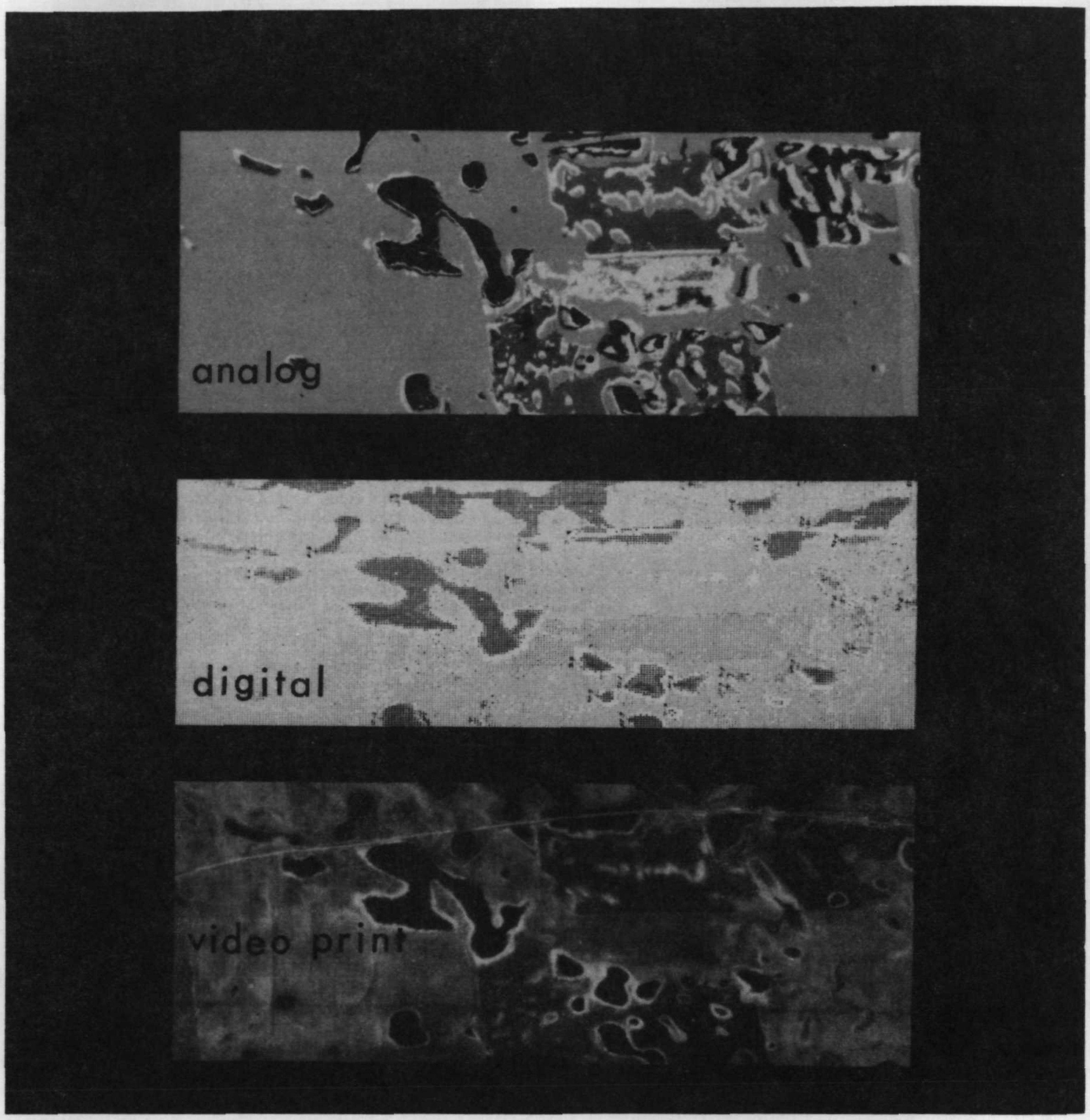


FIGURE 10. COMPUTER RECOGNITION MAPS FROM MULTISPECTRAL SCANNER DATA.

FIGURE 11. ANALOG RECOGNITION MAP FROM DATA COLLECTED AT 3,050 METER ALTITUDE

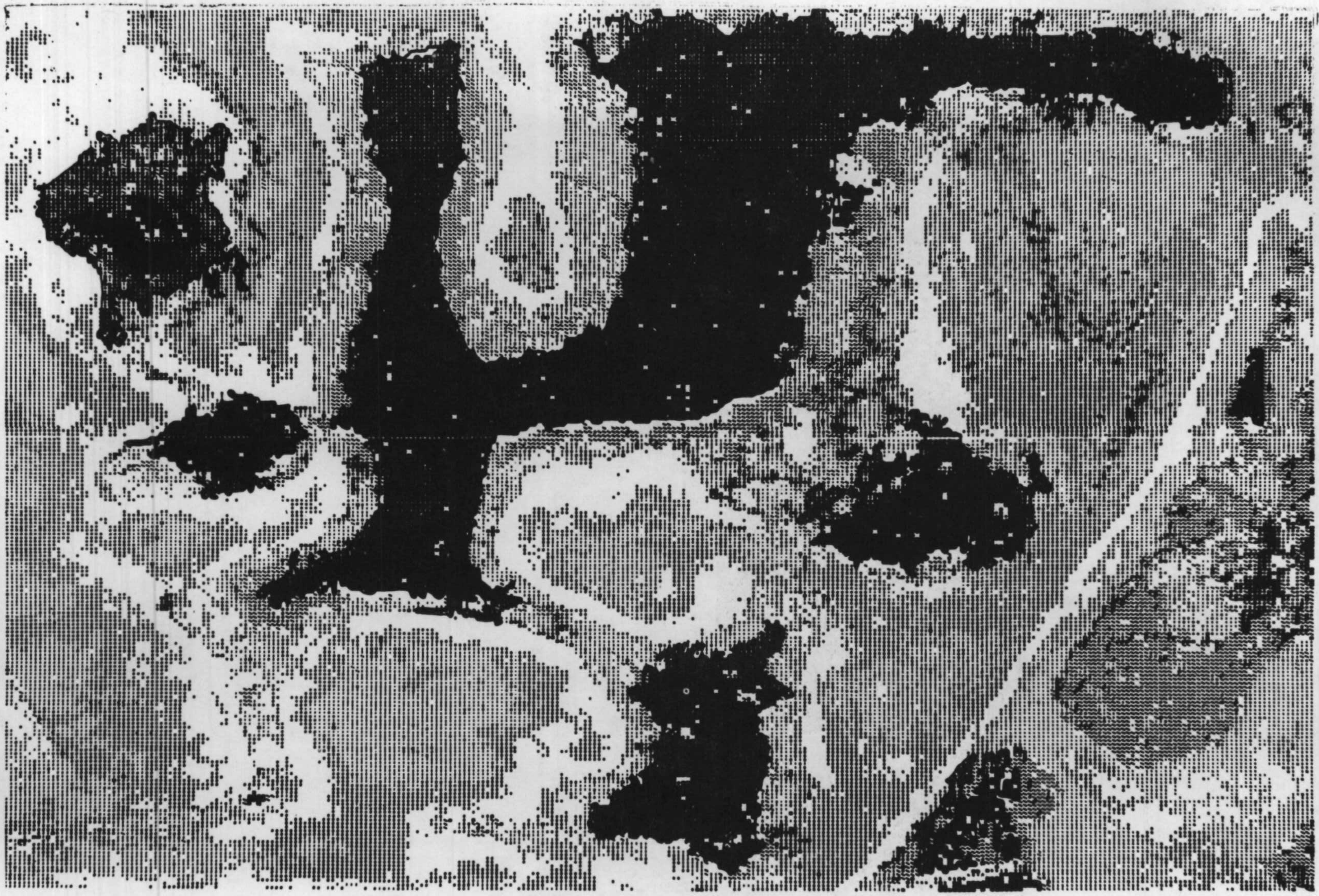


FIGURE 12. DIGITAL RECOGNITION MAP OF POND 9-1, WOODWORTH STUDY AREA, NORTH DAKOTA