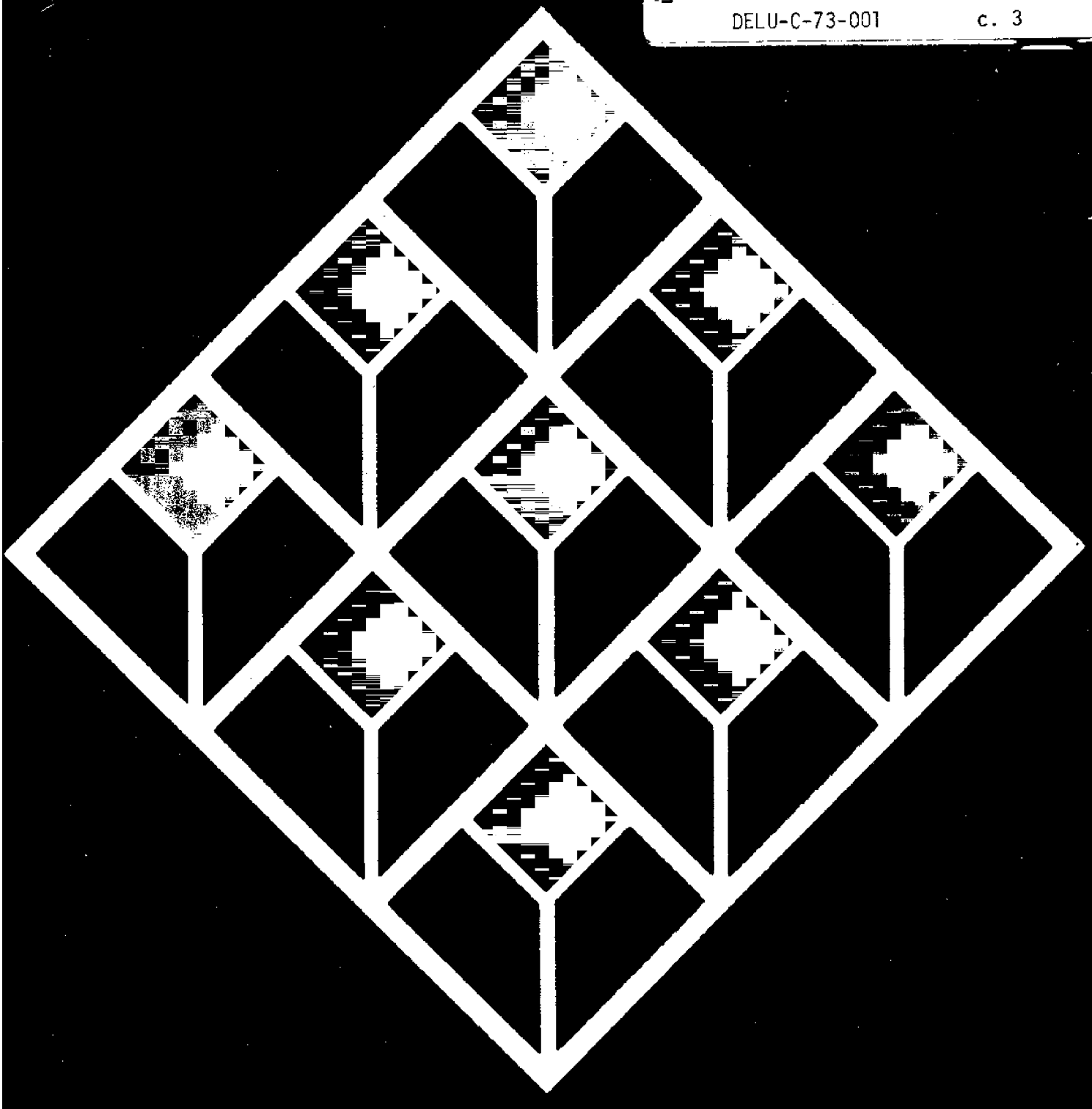

COASTAL VEGETATION OF DELAWARE

Coastal Vegetation of Delaware, the Mapping of Delaware's Coastal Marshes. June 1973; DEL-SG-15-73; College of Marine Studies, University of Delaware, Newark, Delaware, 19711; This work is partially a result of research sponsored by NOAA Office of Sea Grant, Department of Commerce, under Grant No. 2-35223.

COASTAL VEGETATION OF DELAWARE

The Mapping of Delaware's Coastal Marshes

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F. C. Daiber
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A. O. Fornes

College of Marine Studies
University of Delaware

March, 1973

Table of Contents

List of Figures

ACKNOWLEDGEMENTS

The authors wish to thank all those whose cooperation and advice made this project possible. We particularly thank Dr. Richard Economy and Mr. Richard Berman of the General Electric Space Center at Valley Forge, Pennsylvania, who provided access to the General Electric Multispectral Data Processing System and invaluable advice throughout the study period. We are also grateful to Mr. Frank Danberg and Mrs. Linda Patille for the graphics and drafting. This project was partly funded through National Science Foundation - RANN, Grant GI-33369; Office of Naval Research Geography Programs Contract No. N00014-69-AO407; and NOAA, Office of Sea Grant, Department of Commerce Grant No. 2-35223. The National Aeronautics and Space Administration provided RB-57 aircraft imagery in various color bands to make this effort possible.

INTRODUCTION

The commitments to environmentally sound coastal land management that have been generated in federal and state governments over the past few years have produced a demand for accurate and complete bodies of scientific data on which to base policy decisions. Coastal wetlands in particular have been the subject of much controversy and litigation, and the lack of survey-type information over broad areas of wetland is apparent. Accurate maps showing the boundaries of tidal wetlands are required for the enforcement of existing coastal zoning laws, while more detailed information about tidal marsh environments is necessary if more comprehensive zoning is to be formulated in the future. For this reason a baseline mapping project was undertaken in Delaware's coastal wetlands as a prelude to an evaluation of the relative value of different parcels of marsh and the setting of priorities for use of these marshes.

In view of severe limitations of time and manpower, the mapping approach used relied heavily on aerial photography and multispectral analysis, utilizing conventional ground reconnaissance only to aid and check the photo-interpretation. Work such as that of Kolipinski[1], Garvin[2], Wobber[3], and others has shown that multispectral image analysis can significantly help, yet not replace, the human interpreter. Suitable imagery from NASA and other sources was available, and access to General Electric's Multispectral Data Processing System was obtained.

Coastal wetlands of the type found along the entire East Coast of the United States are well suited to remote sensing techniques, particularly multispectral analysis. The uniform flatness of marsh topography eliminates variations in reflectance due to sloping surfaces and shadows. The most common marsh plant species are few in number, thus simplifying photo-interpretation. Environmental changes generally take place over large horizontal distances in the marsh; therefore zones of relatively uniform vegetation are usually large enough to be discernible even on very high altitude imagery. Finally, the major plant species are different enough in their morphologies to have distinct reflectance characteristics, particularly in the near-infrared portion of the spectrum. The net result is that multispectral imagery can be used to make detailed wetlands maps showing vegetation growth patterns which are related to local environmental factors.

DESCRIPTION OF DELAWARE'S WETLANDS

There are approximately 115,000 acres of tidal wetland in the state of Delaware, forming an almost continuous band along the western shore of Delaware Bay from Cape Henlopen north to Wilmington.[4] The width of this band varies from a few hundred yards to three to four miles with an average width on the order of one mile. In addition, there are small fringes of marsh associated with the barrier beach-lagoon complexes along the Atlantic Shore in the southern portion of the state. The most abundant plant species found in the marshes are salt marsh cord grass (*Spartina alterniflora*), salt marsh hay (*Spartina patens*), spike grass (*Distichlis spicata*), reed grass (*Phragmites communis*), high tide bush (*Iva frutescens*), and sea myrtle (*Baccharis halimifolia*). There are, of course, many other species present but in most cases their occurrence is limited to small patches scattered within areas dominated by one or more of the above-mentioned primary species.

As previously stated, the major species display distinct morphologies allowing them to be distinguished from one another on the basis of reflectance characteristics. A brief description of the preferred environments, morphology and resulting reflectance of each species category follows.[5]

Major Categories:

1. *Spartina alterniflora* (Salt marsh cord grass).

   The dominant marsh grass species of the Eastern United States, *S. alterniflora*, occupies the low or wettest portion of the marsh. Two ecotypes are distinguished in Delaware: a tall form which inhabits the borders of the tidal creeks and drainage ditches, and a short form found over great expanses of the remaining low marsh areas.[7] The narrow stalks and leaves of *Spartina alterniflora* provide a relatively sparse reflecting surface when viewed from above with the result that this species appears darker than the other major species in color infrared imagery. (See Figure 2.) The tall form provides a slightly more dense reflecting surface than the short form, allowing discrimination of the two ecotypes.

2. *Spartina patens* and *Distichlis spicata* (Salt marsh hay and spike grass).

   These two species occupy areas of marsh topographically higher than those occupied by *Spartina alterniflora*. Although short with thin stems, both species grow in a very dense mat which produces high reflectance in the infrared. (See Figure 2.) Often, but not always, the two species are found together and are indistinguishable on color infrared imagery. Because they appear to occupy very similar environmental niches, the two species are lumped together into one category.

3. *Phragmites communis* (Reed grass).

   Naturally found in small patches on mounds and other topographic highs within the marsh, *Phragmites* now occupies extensive areas where artificial filling or drainage has produced a suitable environment. Growing up to ten feet high with broad leaves, *Phragmites* has the highest reflectance of any of the marsh grasses and thus appears lightest on the photos.

4. *Iva frutescens* and *Baccharis halimifolia* (High tide bush and sea myrtle).

These low shrubs are generally found in a narrow band just above the reach of the highest tides. They are frequently found together, and their broad leaves and sparse growth pattern combine to give them distinct reflectance characteristics in the infrared.

5. Fresh water impoundments.

Built to attract ducks and other water fowl, these areas are generally identified by their straight, artificial boundaries and the continuous presence of standing water. They contain many fresh water plants including species of *Peltandra* (Arrow arum), *Typha* (Cattail), *Pontederia*, and *Sagittaria* (Arrowhead).

It should be noted that these groups were identified on the basis of reflectance in three color bands (green, red and infrared) and not simply in the infrared as might be inferred from the general descriptions above.

MAPPING APPROACH

The primary imagery used in compiling vegetation maps was obtained by a NASA RB-57 aircraft in September of 1970 (Mission 144, Site 244). Of the various types of imagery available from Mission 144, it was decided that nine-inch color infrared photos would provide optimal discrimination of vegetation types. Visual interpretation was performed on color infrared prints obtained with a Zeiss RMK 30/23 camera at a scale of 1:60,000. (See Figure 2.) For automated analysis it was found that color infrared transparencies taken with a Wild Heerbrug RC-8 camera at 1:120,000 scale had better light characteristics and thus yielded better results despite the larger scale. Resolution in these high altitude photographs was sufficient to produce first generation vegetation maps registered onto U.S.G.S. topographic maps at a scale of 1:24,000 and for more detailed automated pattern recognition at considerably smaller scales. A more detailed second generation set of maps is being compiled from low altitude (11,500 feet) NASA imagery obtained in August, 1972.

To collect ground truth for the interpretation of the NASA photographs, visits to field sites on foot and by small boat were carried out throughout the summer of 1972. In addition, low altitude aerial photography was obtained from light planes. Taken from altitudes of 500 to 2,000 feet, this imagery was sufficiently detailed for easy identification of major plant communities and thus provided ground truth over larger areas than it was possible to obtain on foot or by boat. In some areas detailed field work, including measured transects, was used as a check of automated pattern recognition capabilities.

The classification scheme used in mapping developed naturally from the structure of the marsh plant communities and from the discrimination capability of the imagery used. Therefore, the five major categories described not only represent the dominant species and communities present in the marshes of Delaware, but also are the vegetation types which are most readily discriminated in the imagery used for interpretation.

In areas where a significant amount of another species than that shown as predominant in the NASA imagery was present, this is noted on the maps by capital letters. These were identified by field observation, although further studies may show that some such associations can be identified from aerial imagery.

In addition, mapping categories were established for areas ditched for mosquito control, and for marsh areas lost to dredge-fill operations after the most recent revision of the U.S.G.S. topographic maps. Marshes lost to development were easily identified on NASA imagery while Department of Agriculture photos at a scale of 1:20,000 (See Figure 3) were used to delineate ditched areas.

AUTOMATED ANALYSIS

While the discrimination and mapping of gross vegetation features are most readily accomplished by a human interpreter, detailed interpretation can benefit from the use of automated multispectral analysis. Such automated analysis was performed utilizing the General Electric Multispectral Data Processing System (GEMSDPS), which is an analogue-digital hybrid designed as an analysis tool to be used by a human operator and benefit from his observations.[6]

This accurate and highly flexible system has been designed to allow the operator to adjust the signature analyzer and other processing units for optimum discrimination and to see the results of these adjustments immediately. He can thus very rapidly combine his knowledge of the scene gained in the field with precise, unbiased electronic analysis and thereby measure the spectral characteristics of a region of any size in the scene; he can search the scene for regions with similar characteristics and read out the percentage of the total scene occupied by areas with the specified spectral signature. By repeating the same procedure for other areas in the scene, the operator can quickly produce a composite photo-map enhancing all of the spectrally classified areas of interest.

MAPS OF DELAWARE'S WETLANDS

The fifteen maps of Delaware's coastal zone which follow were prepared to show the dominant species or groups of species of vegetation present. Five such categories of vegetation are used indicating marshes dominated by 1) salt marsh cord grass (*Spartina alterniflora*), 2) salt marsh hay and spike grass (*Spartina patens* and *Distichlis spicata*), 3) reed grass (*Phragmites communis*), 4) high tide bush and sea myrtle (*Iva* species and *Baccharis halimifolia*), and 5) a group of fresh water species found in impounded areas built to attract water fowl. In addition, major secondary species are indicated where appropriate. Multispectral analysis and enhancement were performed on selected areas thought to be representative of the relative species abundance and growth patterns present in the surrounding marsh. The enhancements themselves, then, are small-scale inserts designed to supplement the generalized vegetation maps by showing detailed growth patterns and the relative abundance, in percentages of each species present. Figure 3b, for example, is an enhancement of the area enclosed by box #1 on the Little Creek quadrangle. Zonation of different vegetation species which could not be displayed on the large scale map is shown with *Spartina alterniflora* forming an outer fringe and *Spartina patens* occupying the higher, center portion of marsh. The original maps were at a scale of 1:24,000 registered to U.S.G.S. topographic and soil maps. Inserts show those areas which were automatically analyzed, and the results of that analysis, providing a general picture of Delaware's coastal vegetation and a detailed description of selected marsh areas.

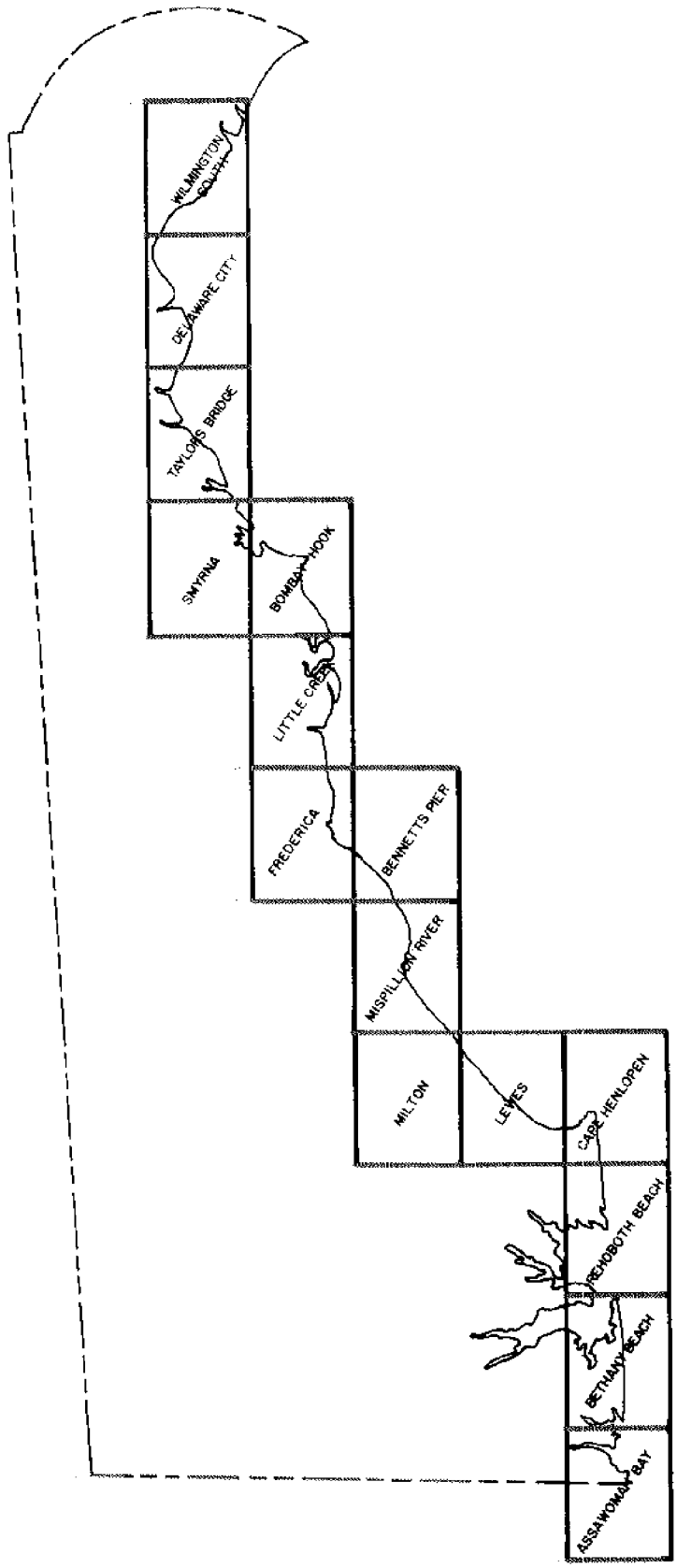
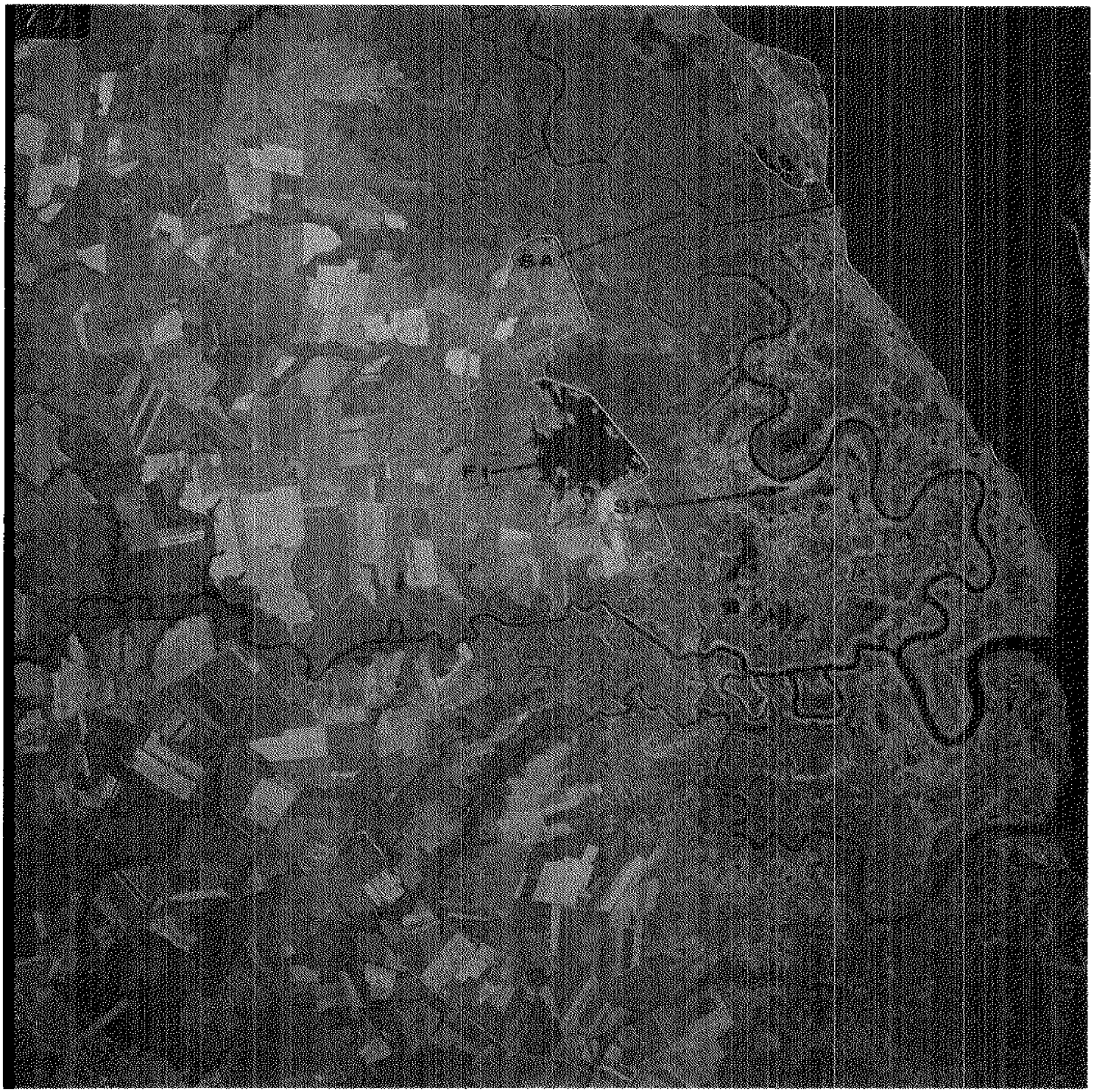


FIGURE 1 Index Map Showing Map Quadrangles

FIGURE 2



Sample NASA-RB-57 Color-infrared Photograph

Original size 9" x 9"
Original scale 1:60,000

SA - *Spartina alterniflora*
SP - *Spartina patens*
F1 - Fresh water impoundment

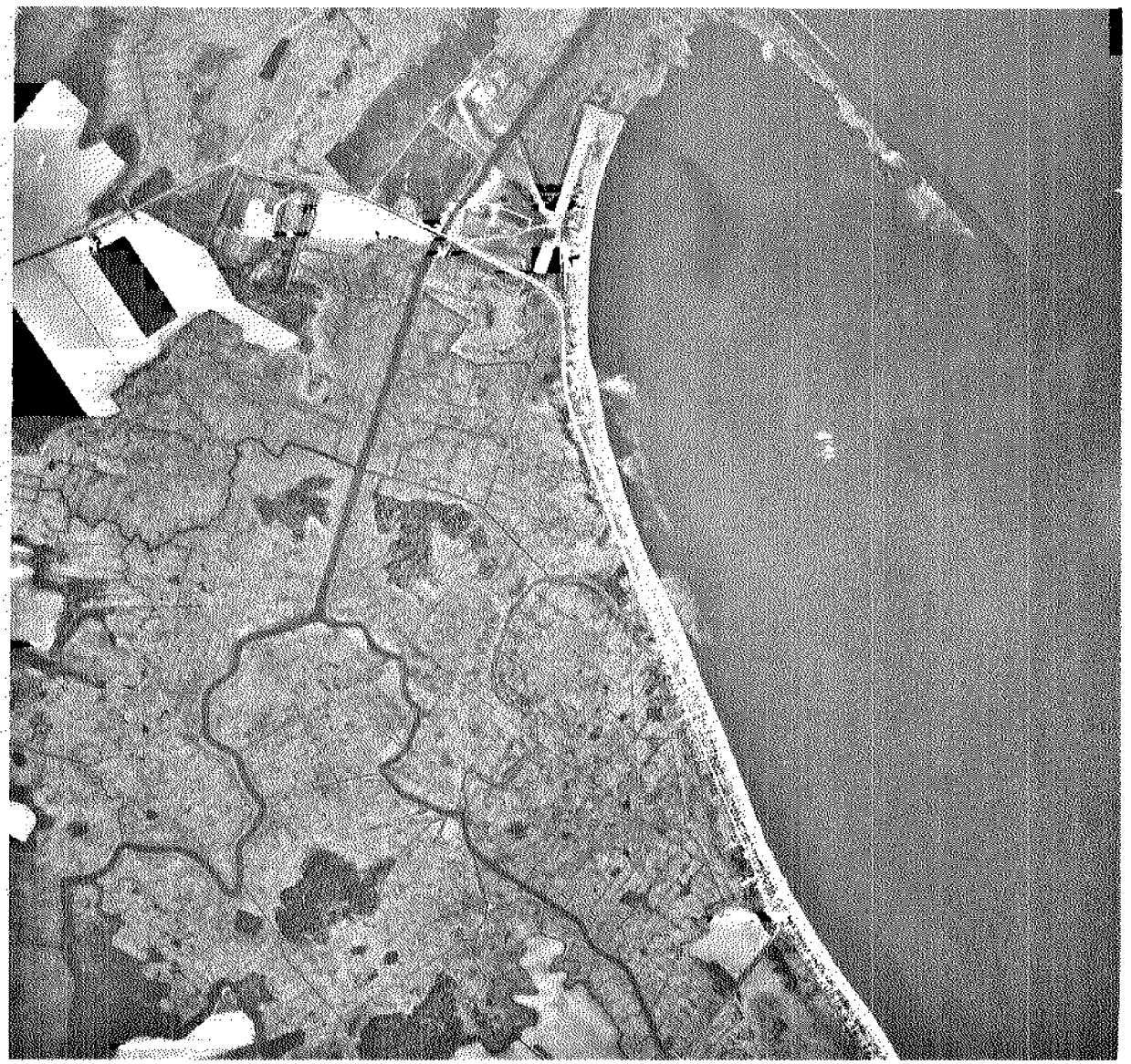
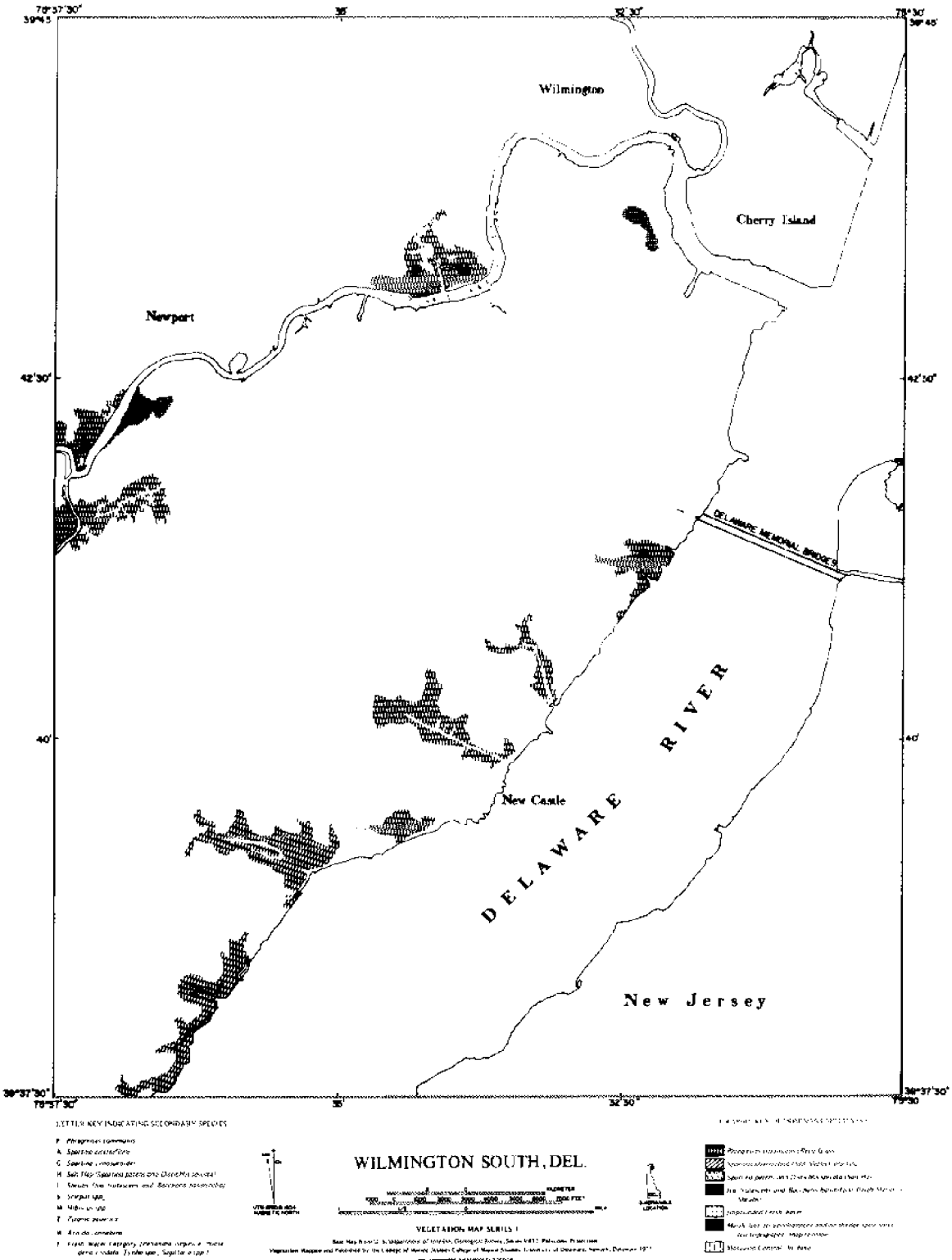
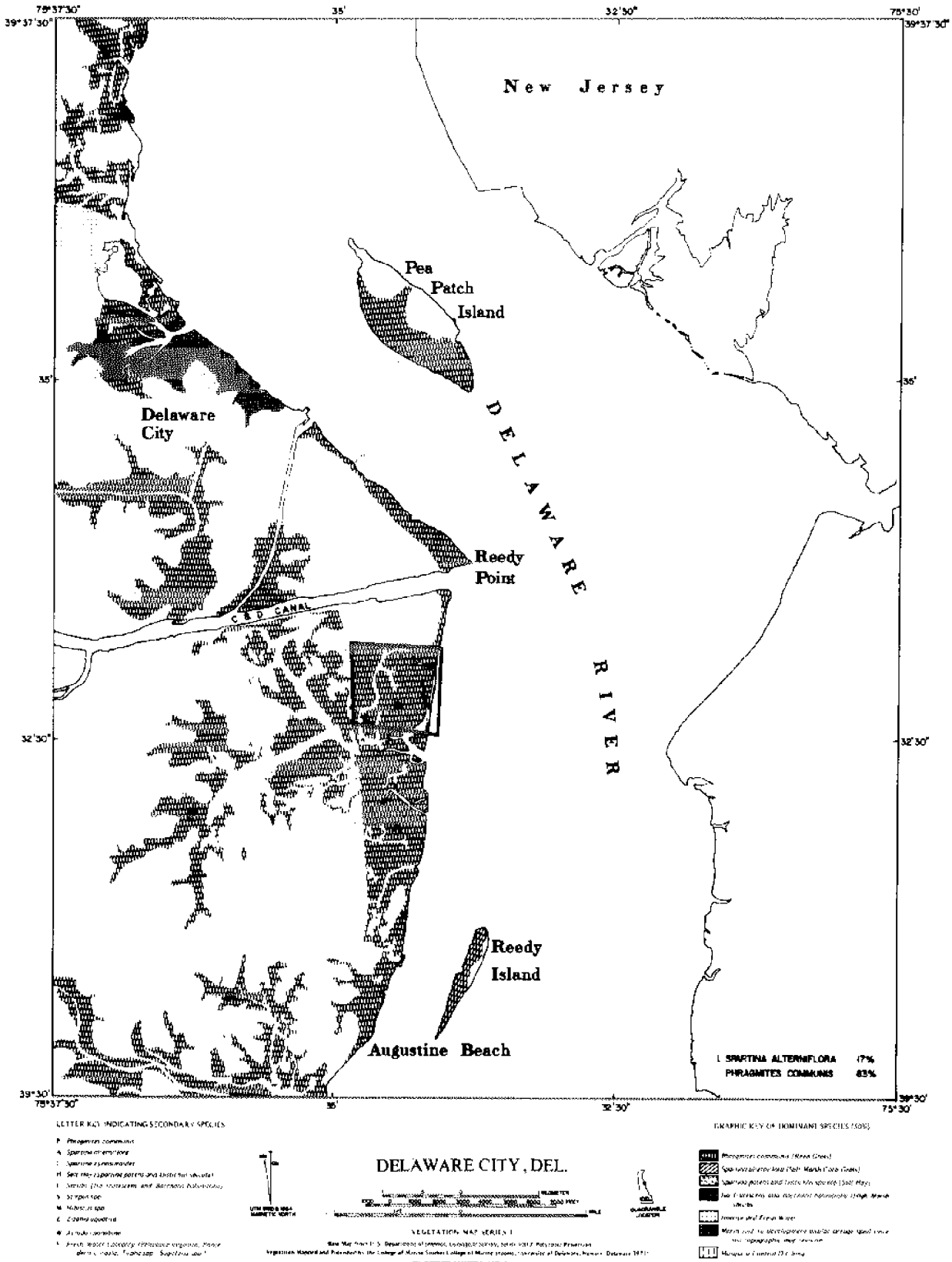
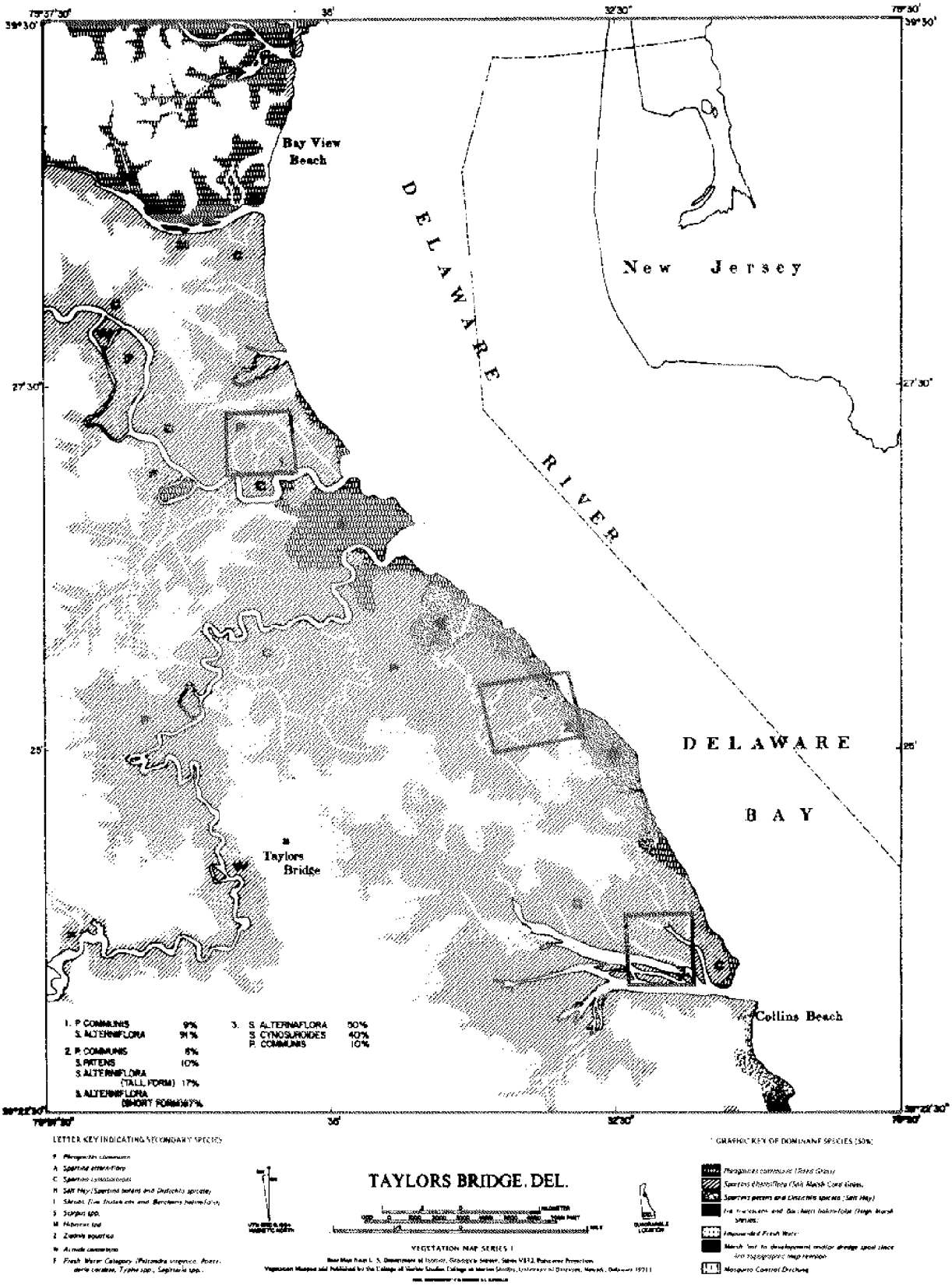


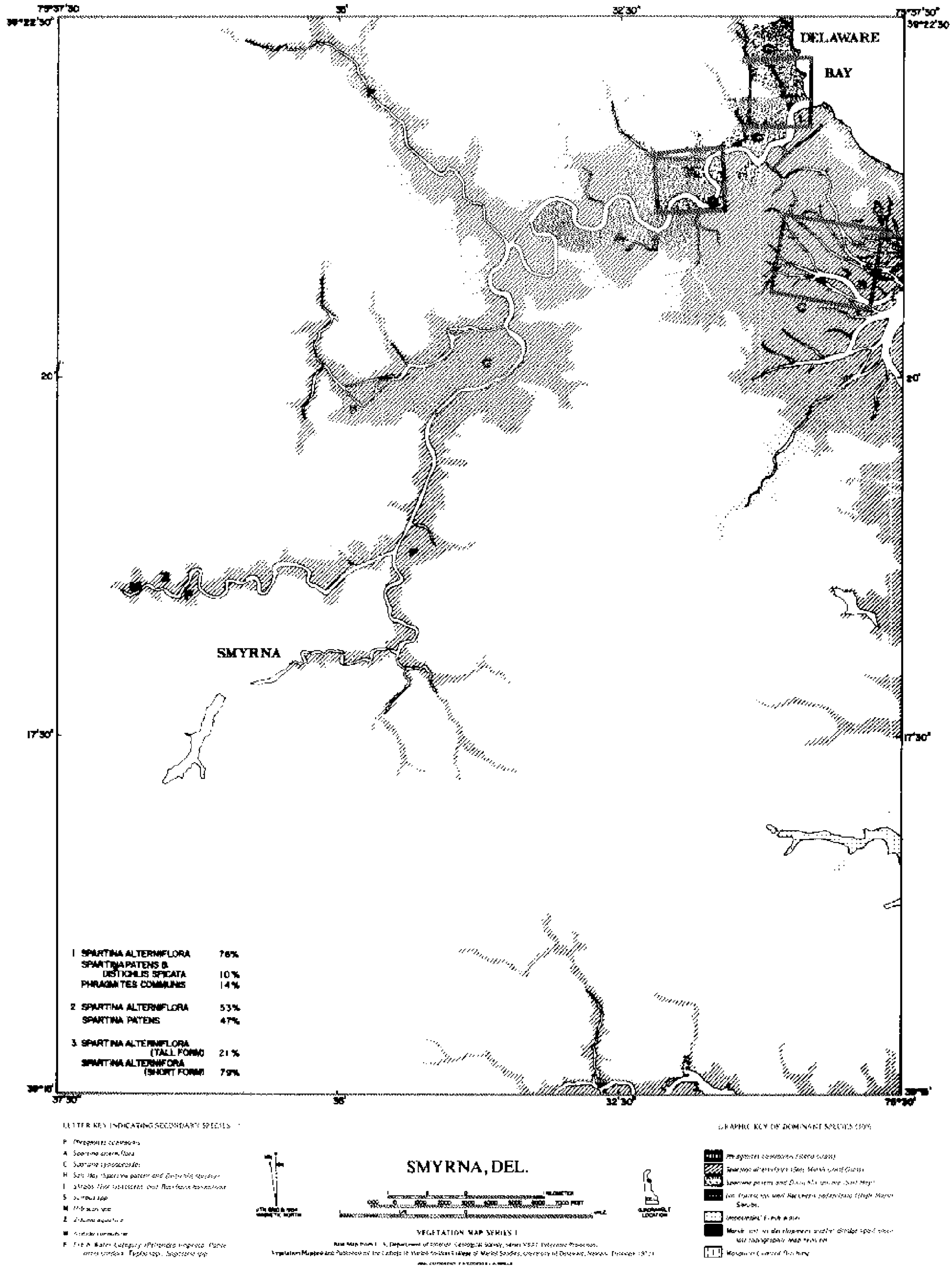
FIGURE 3 Sample: Black and White Dept. of Agriculture Photo

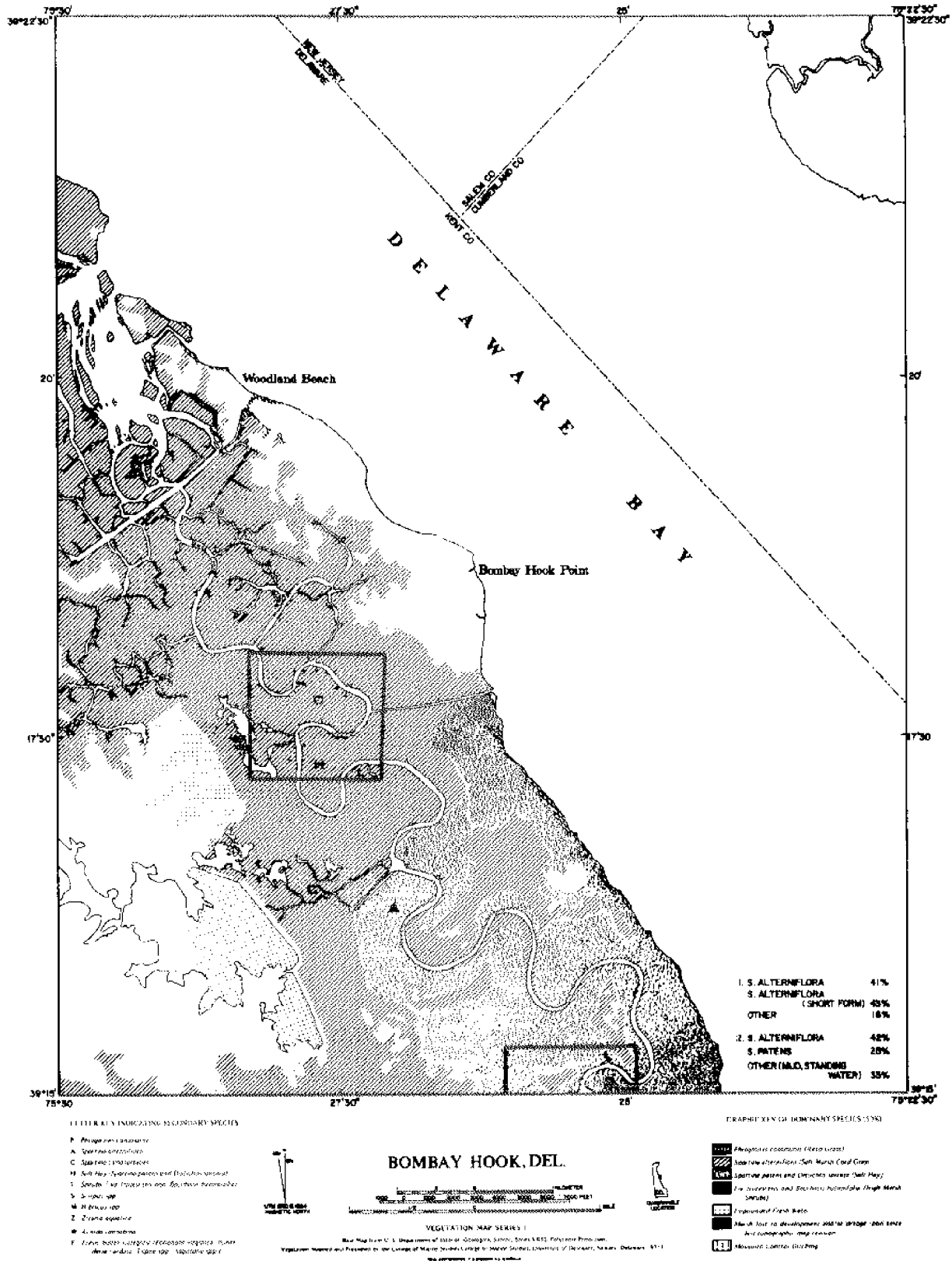
Original size 9" x 9"
Original scale 1:20,000

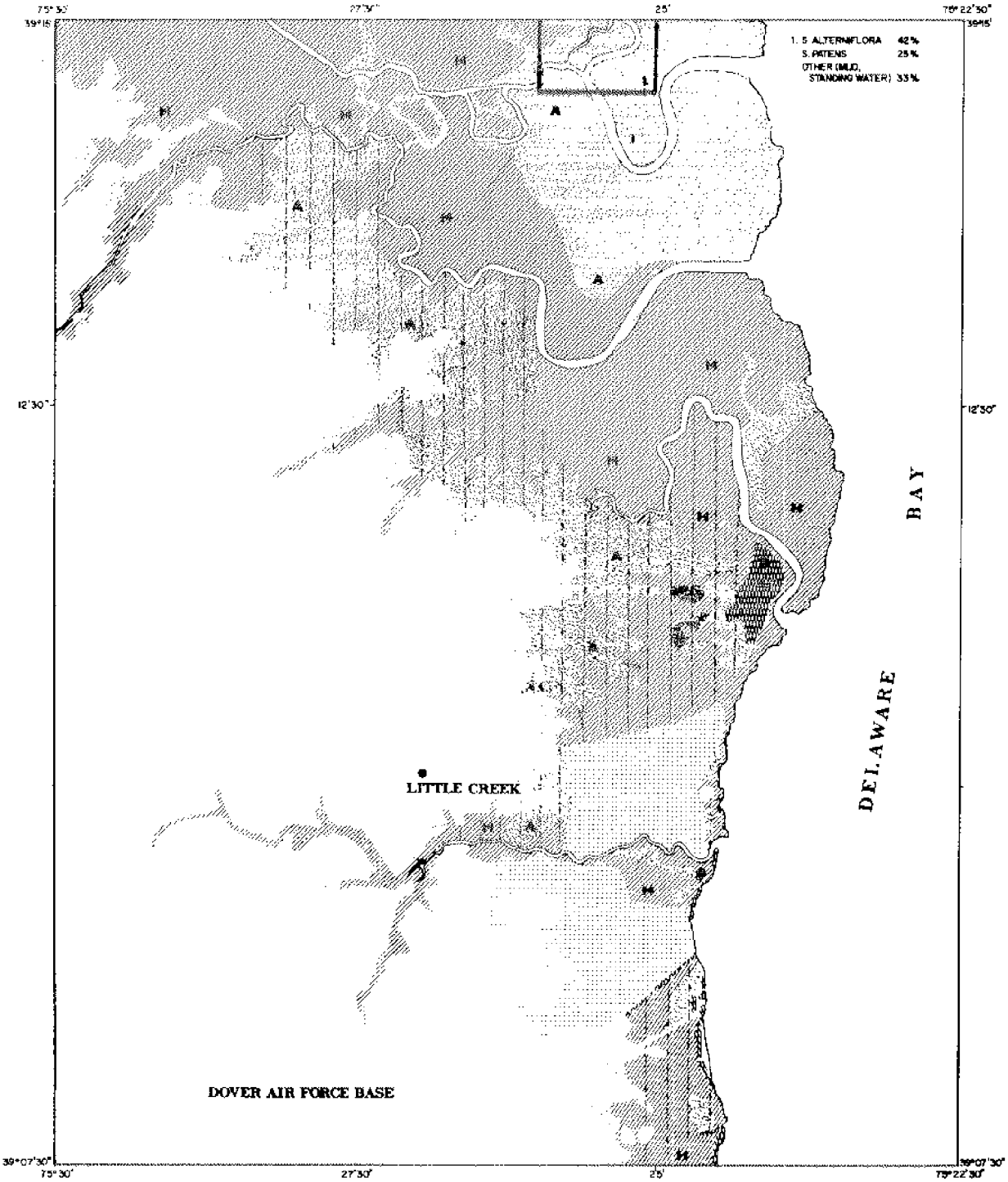

Wilmington
Cherry Island
Newport
DELAWARE MEMORIAL BRIDGE
New Castle
DELAWARE RIVER
New Jersey
WILMINGTON SOUTH, DEL.
VEGETATION MAP SERIES 1

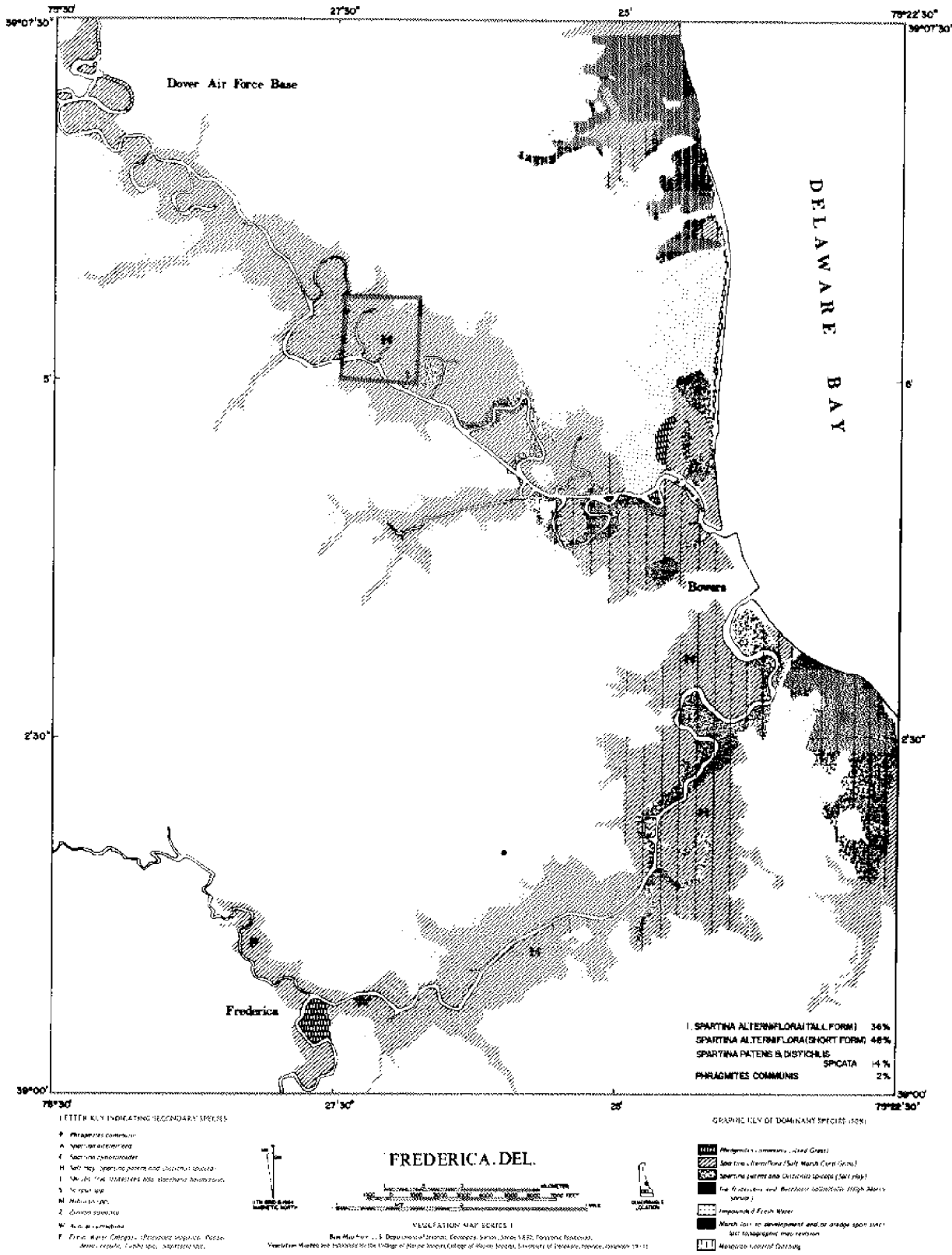

New Jersey
Pea Patch Island
Delaware City
DELAWARE RIVER
Reedy Point
C & D CANAL
Reedy Island
Augustine Beach
1 SPARTINA ALTERNIFLORA 17%
PHRAGMITES COMMUNIS 83%
DELAWARE CITY, DEL.
VEGETATION MAP SERIES I

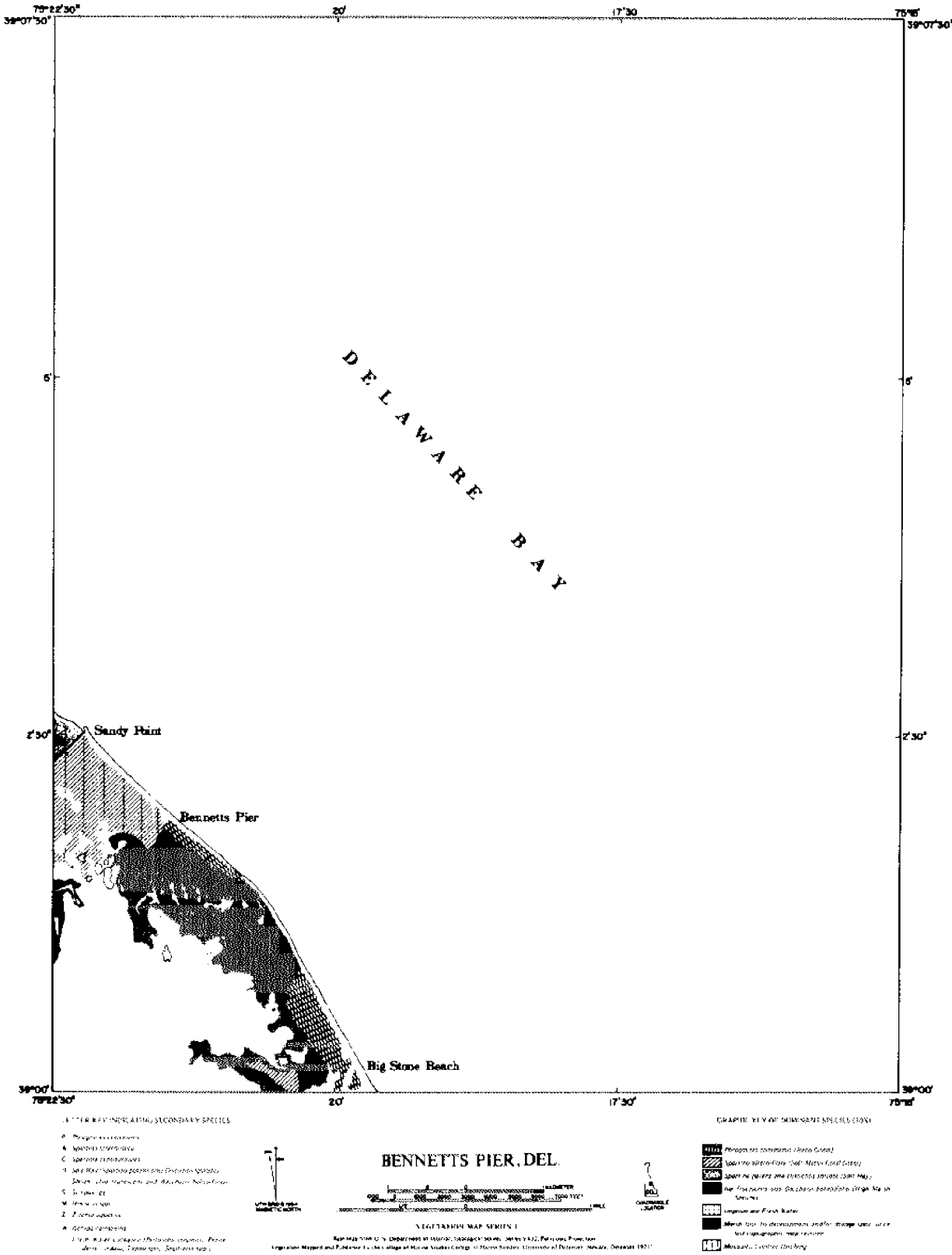

Bay View Beach
DELAWARE RIVER
New Jersey
DELAWARE BAY
Taylors Bridge
Collins Beach
1. P. COMMUNIS 9%
S. ALTERNIFLORA 91%
2. P. COMMUNIS 8%
S. PATENS 10%
S. ALTERNIFLORA (TALL FORM) 17%
S. ALTERNIFLORA (SHORT FORM) 65%
3. S. ALTERNAFLORA 50%
S. CYNOSUROIDES 40%
P. COMMUNIS 10%
LETTER KEY INDICATING SECONDARY SPECIES
GRAPHIC KEY OF DOMINANT SPECIES (50%)
TAYLORS BRIDGE, DEL.
VEGETATION MAP SERIES I

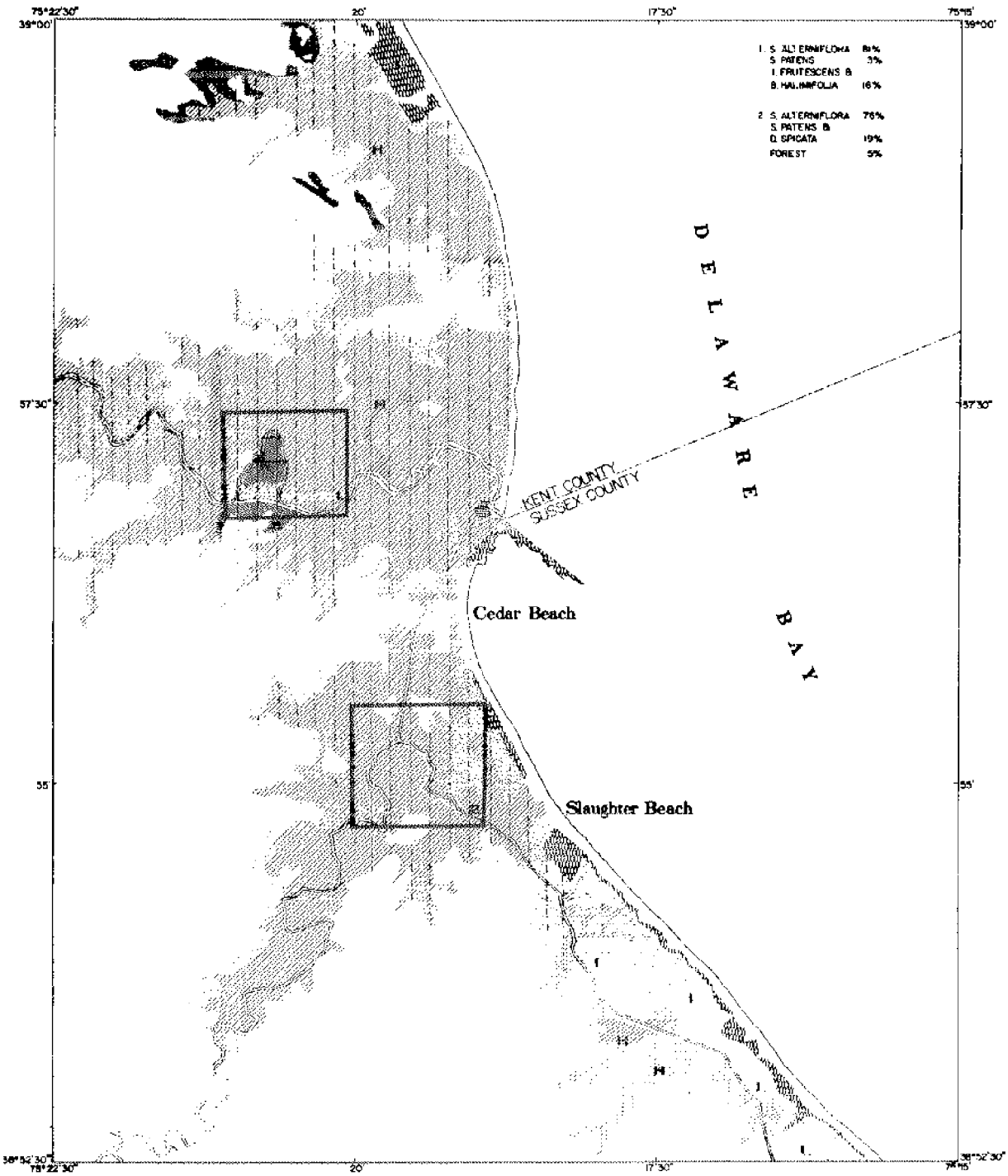

DELAWARE
BAY
SMYRNA
1 SPARTINA ALTERNIFLORA 76%
SPARTINA PATENS & DISTICHLIS SPICATA 10%
PHRAGMITES COMMUNIS 14%
2 SPARTINA ALTERNIFLORA 53%
SPARTINA PATENS 47%
3 SPARTINA ALTERNIFLORA (TALL FORM) 21%
SPARTINA ALTERNIFORA (SHORT FORM) 79%
SMYRNA, DEL.
VEGETATION MAP SERIES


DELAWARE BAY
Woodland Beach
Bombay Hook Point
1. S. ALTERNIFLORA 41%
S. ALTERNIFLORA (SHORT FORM) 41%
OTHER 18%
2. S. ALTERNIFLORA 42%
S. PATENS 25%
OTHER (MUD, STANDING WATER) 33%
BOMBAY HOOK, DEL.
VEGETATION MAP SERIES I


1. S. ALTERNIFLORA 42%
S. PATENS 25%
(OTHER (MUD, STANDING WATER) 33%
LITTLE CREEK
DOVER AIR FORCE BASE
DELAWARE
BAY
LITTLE CREEK, DEL.
VEGETATION MAP SERIES I


Dover Air Force Base
DELAWARE BAY
Bowers
Frederica
1. SPARTINA ALTERNIFLORA(TALL FORM) 36%
SPARTINA ALTERNIFLORA(SHORT FORM) 48%
SPARTINA PATENS & DISTICHLIS SPICATA 14%
PHRAGMITES COMMUNIS 2%
FREDERICA, DEL.
VEGETATION MAP SERIES I

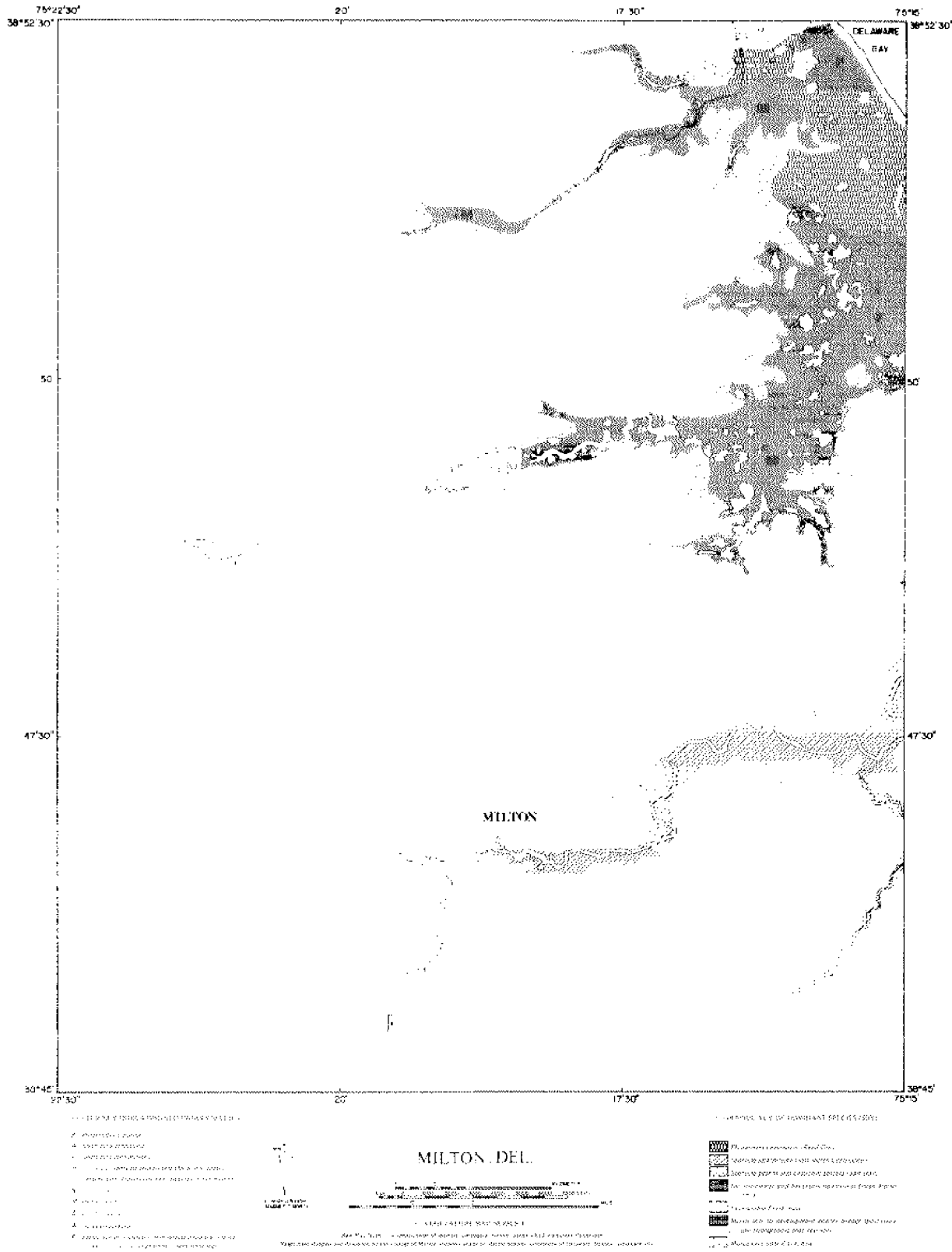

75°22'30"
20'
17'30"
75°15'
39°07'30"
6'
DELAWARE BAY
2'30"
Sandy Point
Bennetts Pier
Big Stone Beach
39°00'
75°22'30"
20'
17'30"
75°15'
BENNETTS PIER, DEL.
VEGETATION MAP SERIES I

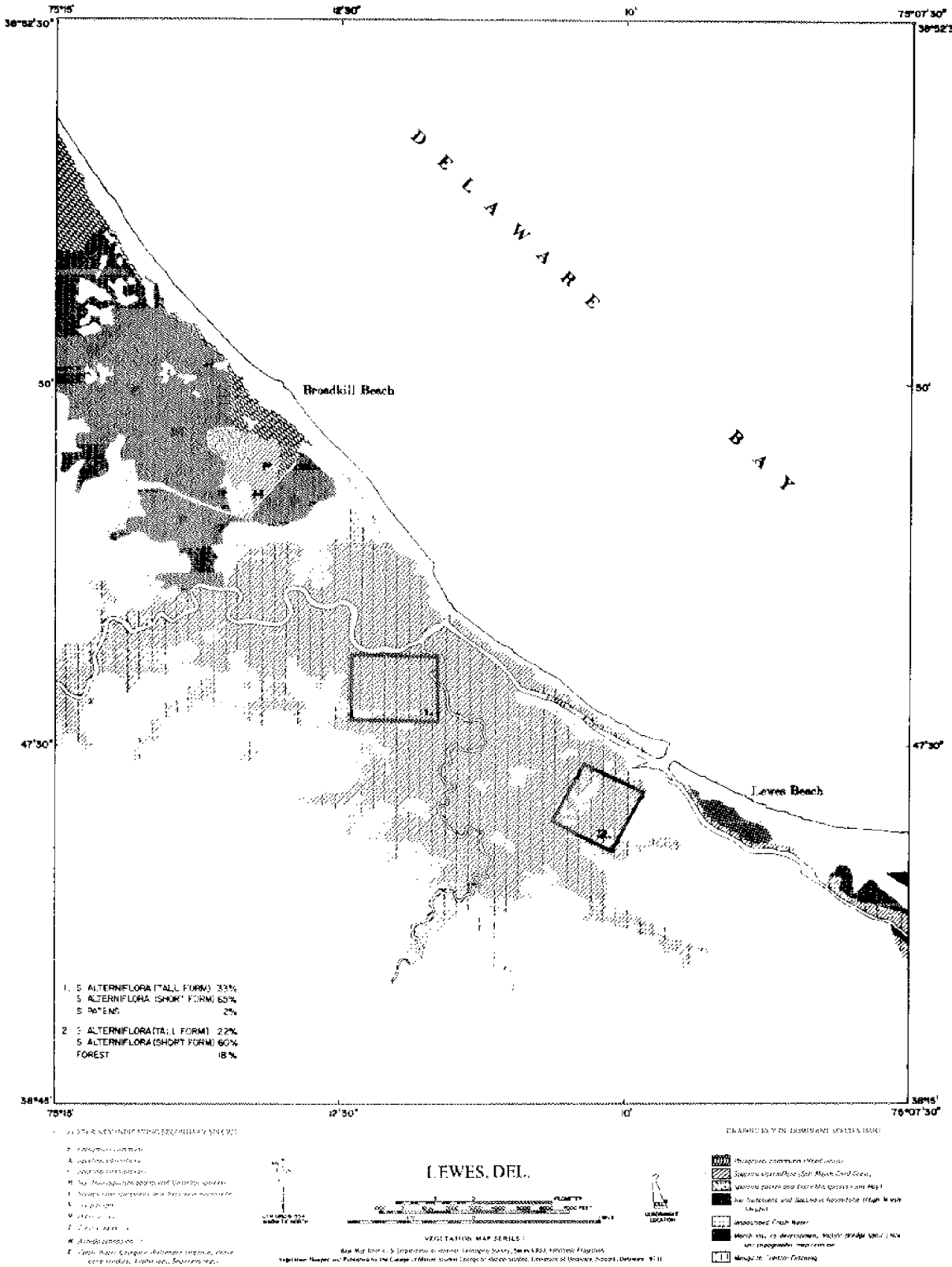


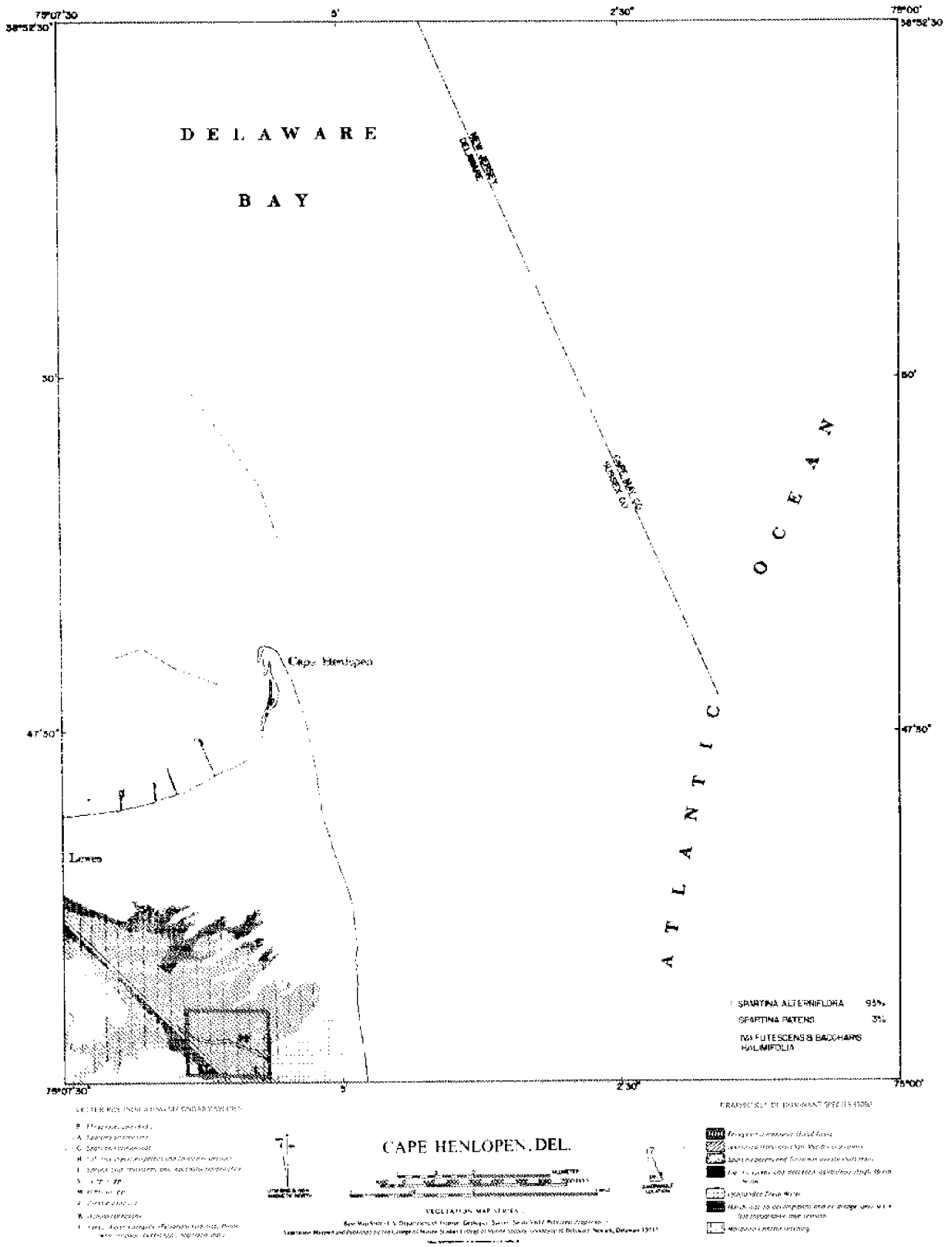
MISPILLION RIVER, DEL.

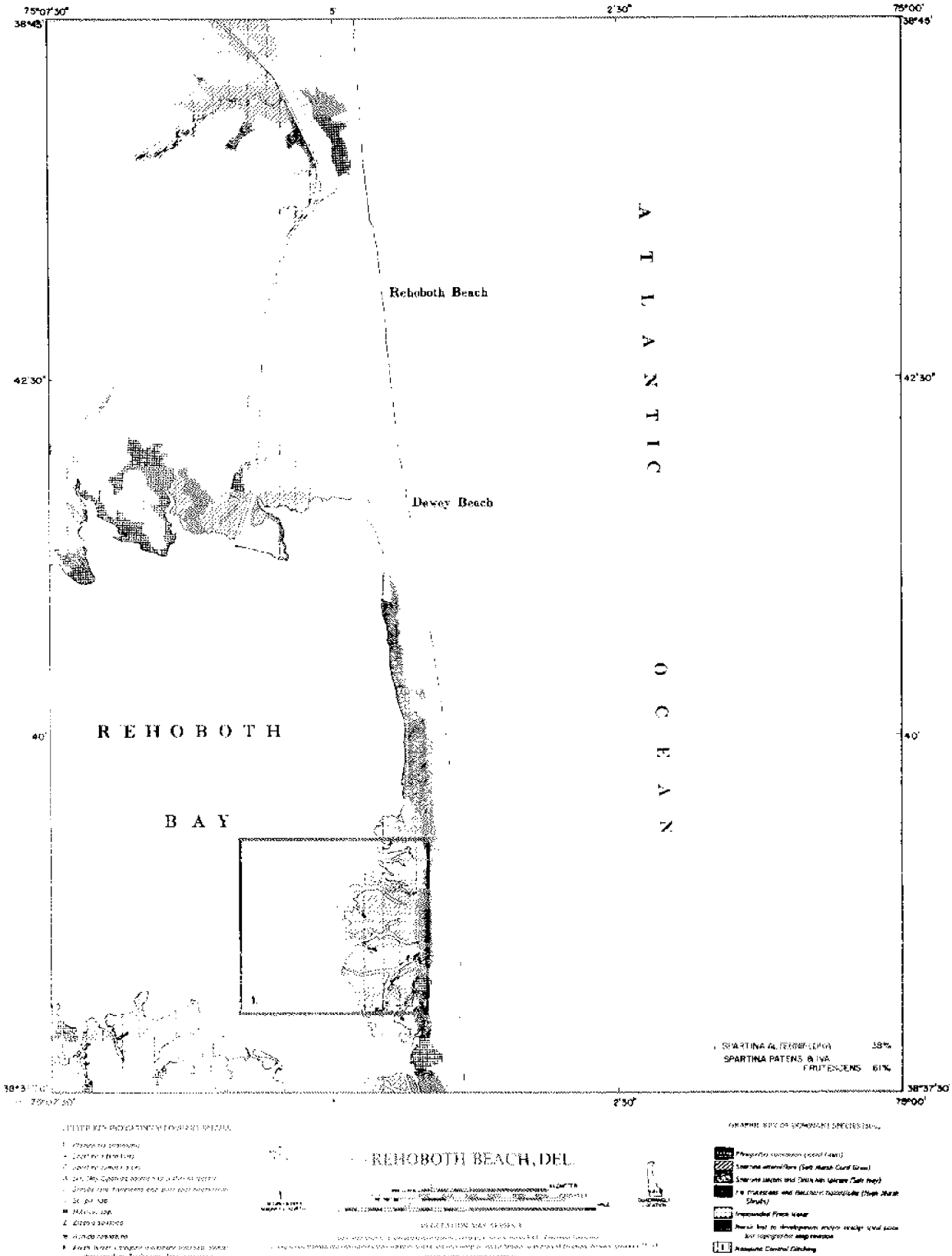
VEGETATION MAP SERIES I

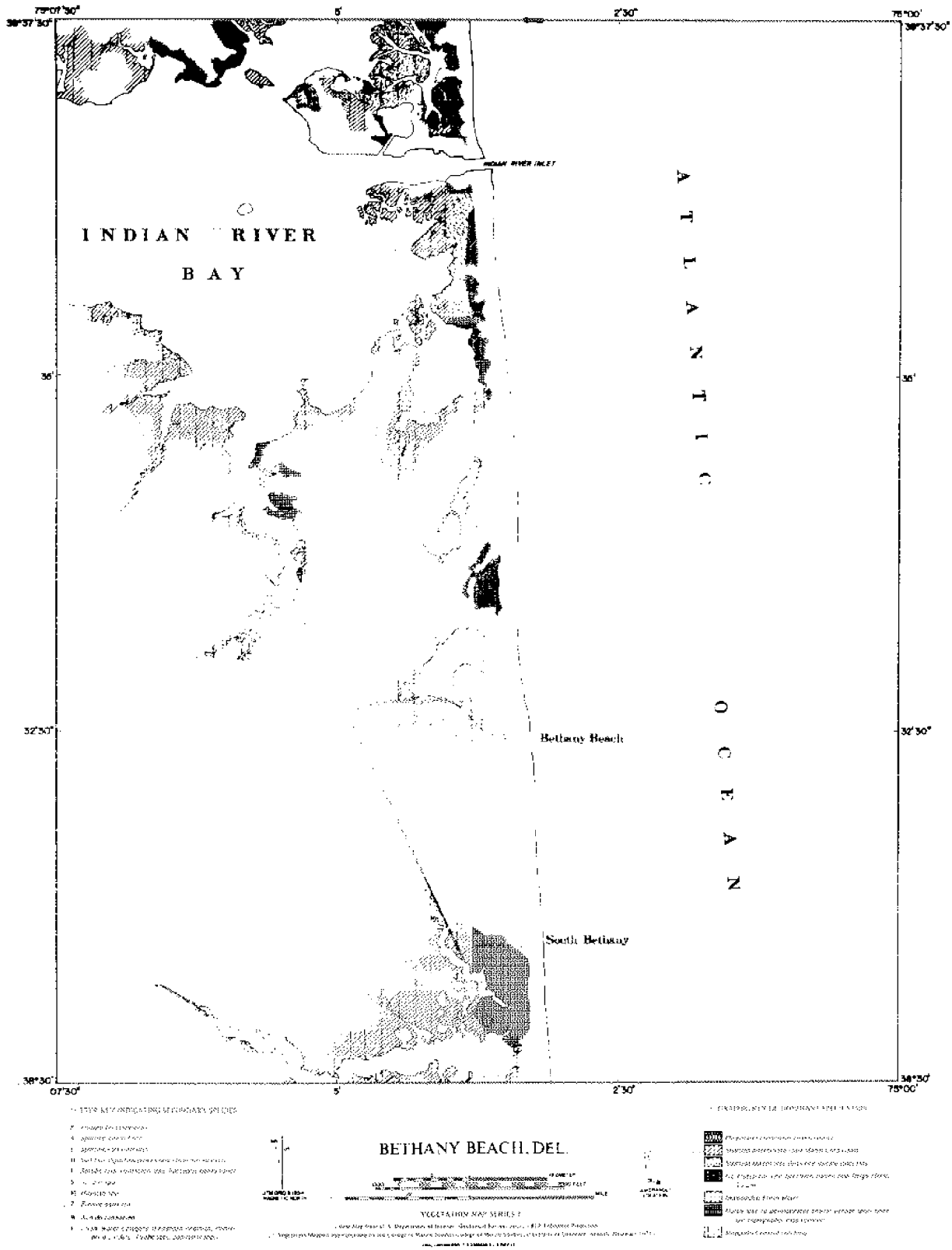
19

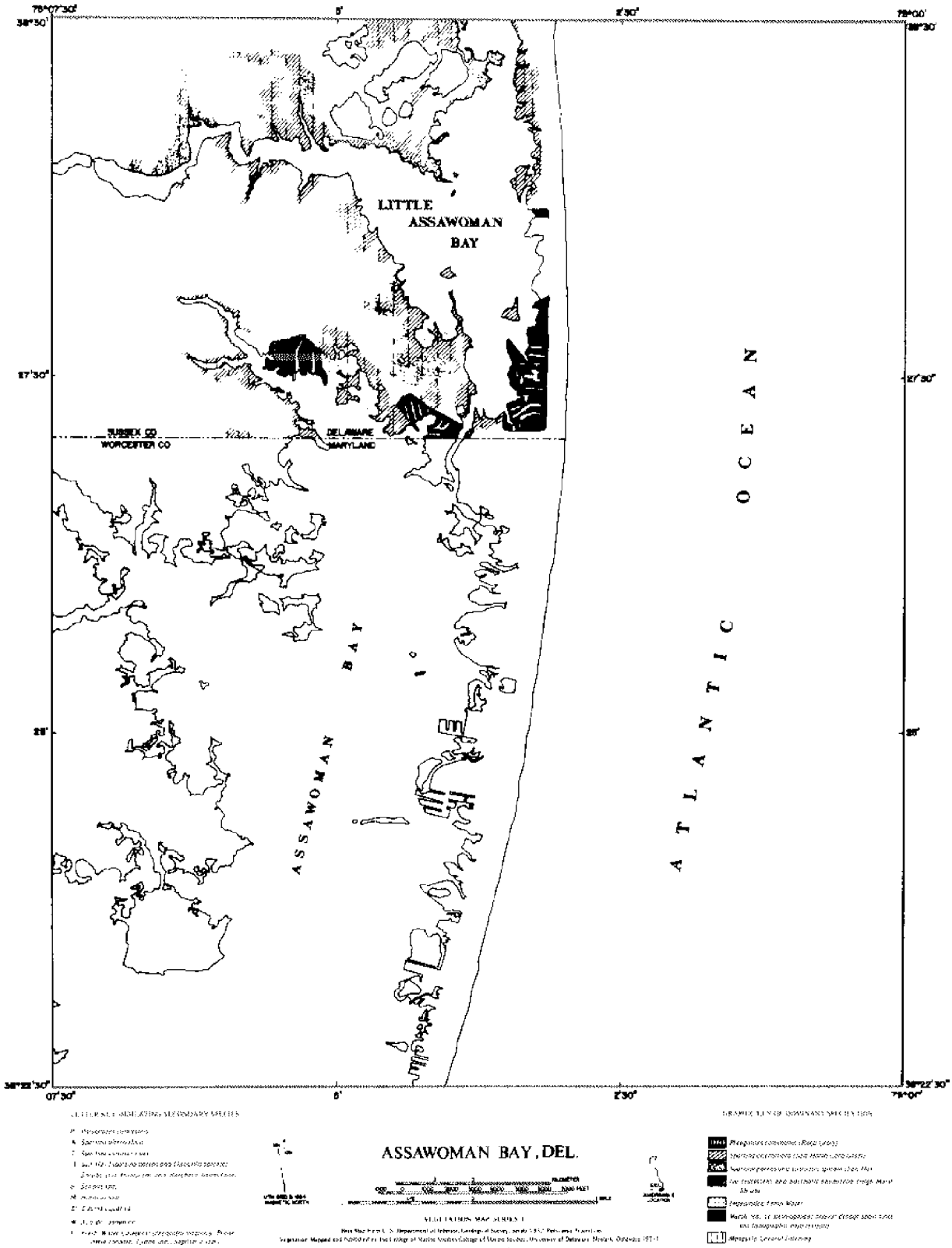

75°22'30"
20'
17'30"
75°15'
38°52'30"
DELAWARE
BAY
50'
47'30"
MILTON
38°45'
MILTON, DEL.

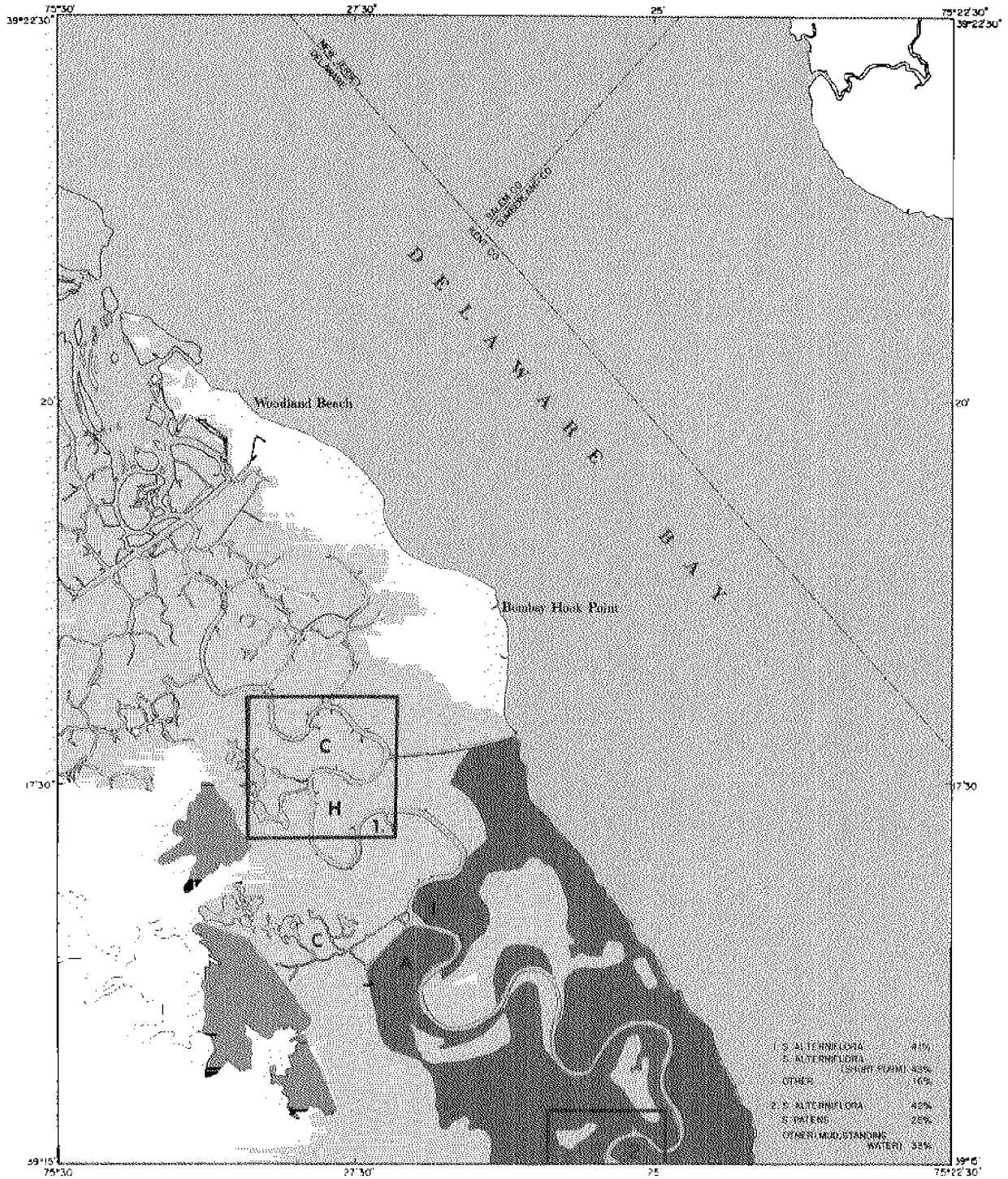

75°15'
12'30"
10'
75°07'30"
38°52'30"
DELAWARE
BAY
Broadkill Beach
Lewes Beach
50'
47'30"
38°45'
1. S. ALTERNIFLORA (TALL FORM) 33%
S. ALTERNIFLORA (SHORT FORM) 65%
S. PATENS 2%
2. S. ALTERNIFLORA (TALL FORM) 22%
S. ALTERNIFLORA (SHORT FORM) 60%
FOREST 18%
LEWES, DEL.
VEGETATION MAP SERIES


75°07'30"
5'
2'30"
75°00'
38°52'30"
DELAWARE
BAY
ATLANTIC
OCEAN
Cape Henlopen
Lewes
47'30"
50'
SPARTINA ALTERNIFLORA 95%
SPARTINA PATENS 5%
IVA FUTESCENS & BACCHARIS HALIMIFOLIA
CAPE HENLOPEN, DEL.


75°07'30"
5'
2'30"
75°00'
38°45'
42'30"
40'
38°37'30"
Rehoboth Beach
Dewey Beach
REHOBOTH
BAY
ATLANTIC
OCEAN
SPARTINA ALTERNIFLORA 39%
SPARTINA PATENS & D.V.A. FRUTESCENS 61%
REHOBOTH BEACH, DEL.


INDIAN RIVER BAY
ATLANTIC OCEAN
Bethany Beach
South Bethany
BETHANY BEACH, DEL.
VEGETATION MAP SERIES 2


LITTLE
ASSAWOMAN
BAY
SUSSEX CO
WORCESTER CO
DELAWARE
MARYLAND
ASSAWOMAN BAY
ATLANTIC OCEAN
ASSAWOMAN BAY, DEL.


75°30'
27'30"
25'
75°22'30"
39°22'30"
20'
17'30"
39°15'
Woodland Beach
Bombay Hook Point
DELAWARE BAY
C
H
I
J
BOMBAY HOOK, DEL.
1. S. ALTERNIFLORA 41%
2. S. ALTERNIFLORA (SHORT FORM) 43%
OTHER 16%
2. S. ALTERNIFLORA 42%
S. PATENS 25%
OTHER/ MUD/STANDING WATER) 33%

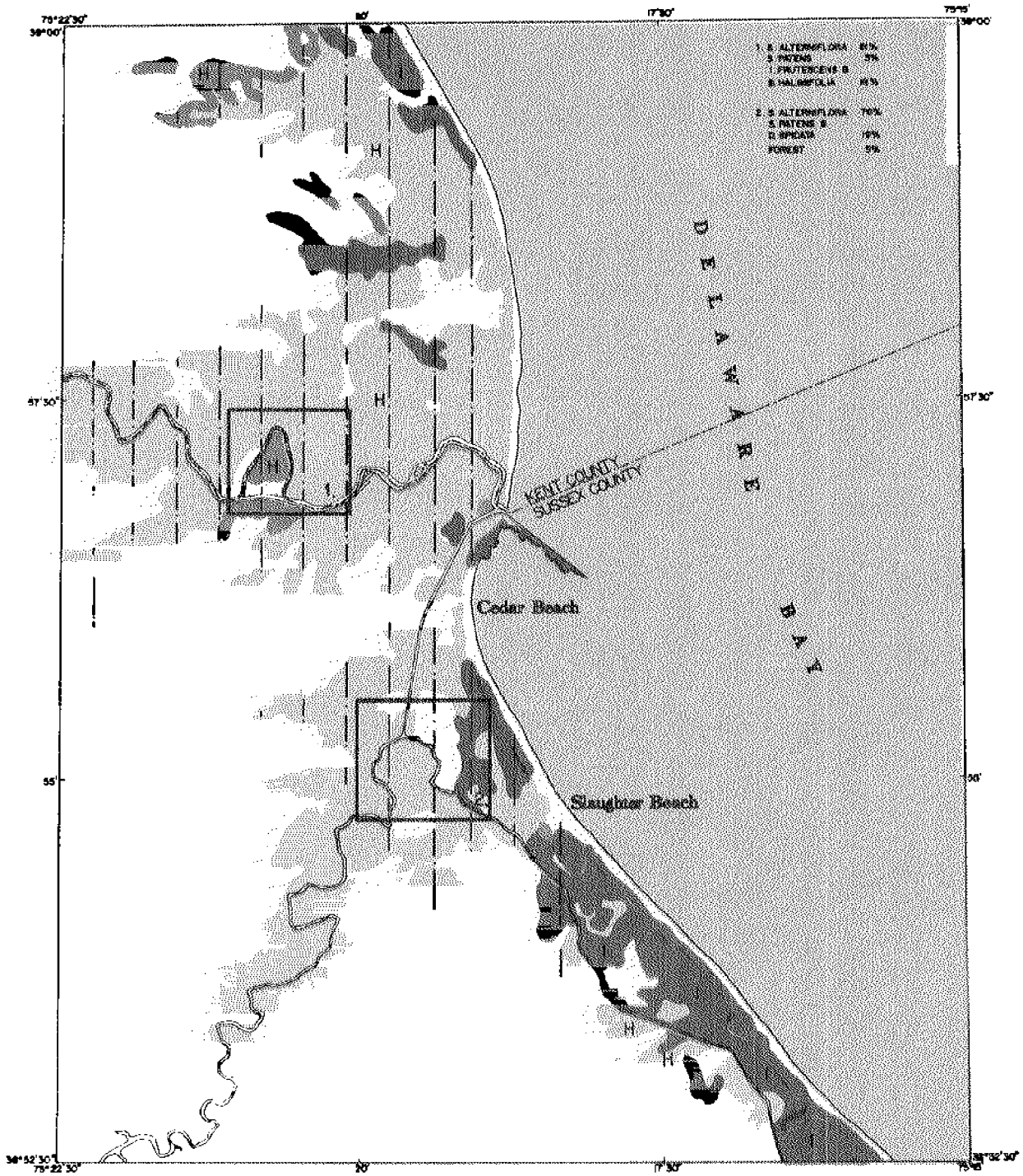
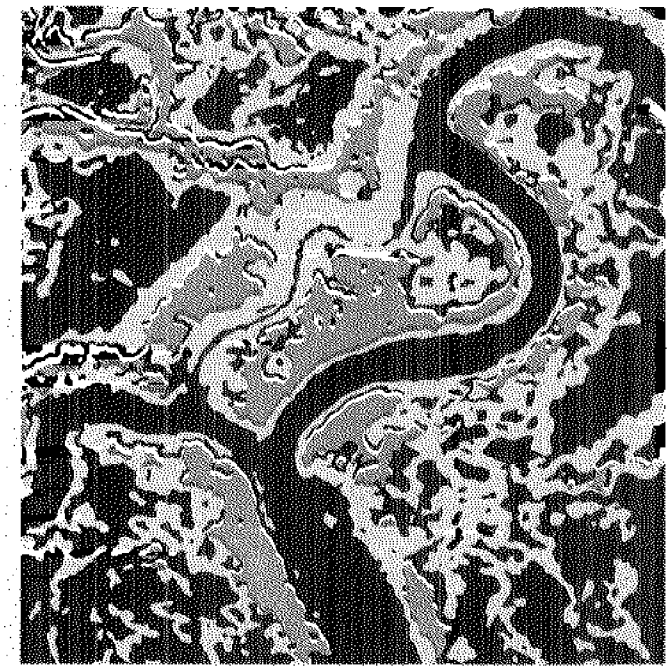

KENT COUNTY
SUSSEX COUNTY
Cedar Beach
Slaughter Beach
MISPILLION RIVER, DEL.

FIGURE 4

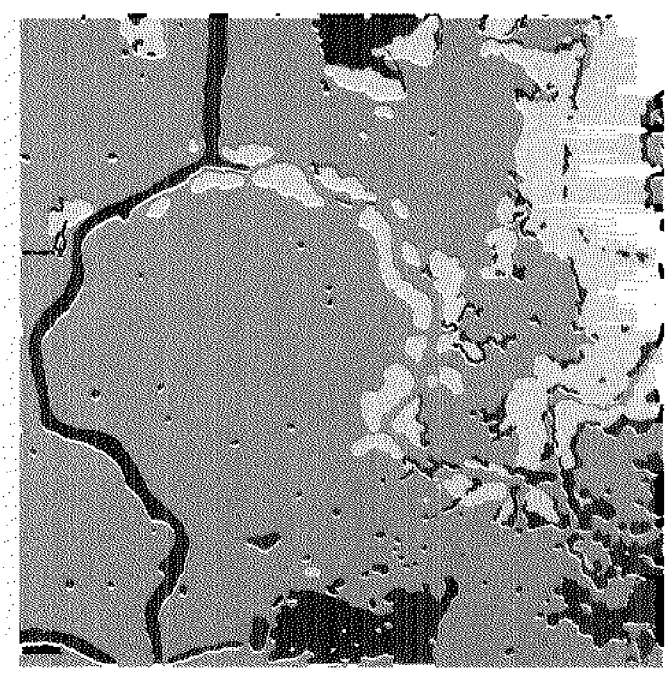


A)
Enhancement of area in box #1, Little Creek Quad.

Black - water and mud

Blue - *S. patens* and *D. spicata*

Yellow - *S. alterniflora* and *S. cynosuroides*



B)
Enhancement of area in box #2, Mispillion R. Quad.

Black - water and forest

Blue - *S. alterniflora*

Yellow - *S. patens*

REFERENCES

1. Kolipinski, M. C.; Higer, A. L.; Thomson, N. S. and Thomson, F. J., "Inventory of Hydrobiological Features Using Automatically Processed Multispectral Data."

2. Garvin, L. E. and Wheller, R. H.,"Coastal Wetlands Inventory in Maryland" in Coastal Mapping Symposium, Am. Soc. of Photogrammetry, 1972.

3. Wobber, F. T. and Anderson, R.R., "Operational Wetlands Mapping Using Multiband Aerial Photography", in Coastal Mapping Symposium, Am. Soc. of Photogrammetry, 1972.

4. Delaware Natural Resources Inventory, Delaware State Planning Office, 1970.

5. Chapman, V. J., Coastal Vegetation, Pergamon Press, Ltd., 1964.

6. "General Electric Multispectral Data Processing System -- System Description" -- General Electric Space Center, Valley Forge, Pennsylvania.

7. Daiber, F. C., "Tide Marsh Ecology and Wildlife: Salt Marsh Plants and Future Coastal Salt Marshes in Relation to Animals." Pittman-Robertson Report to Division of Fish and Wildlife, Dept. of Natural Resources and Environmental Control, State of Delaware, 1972.