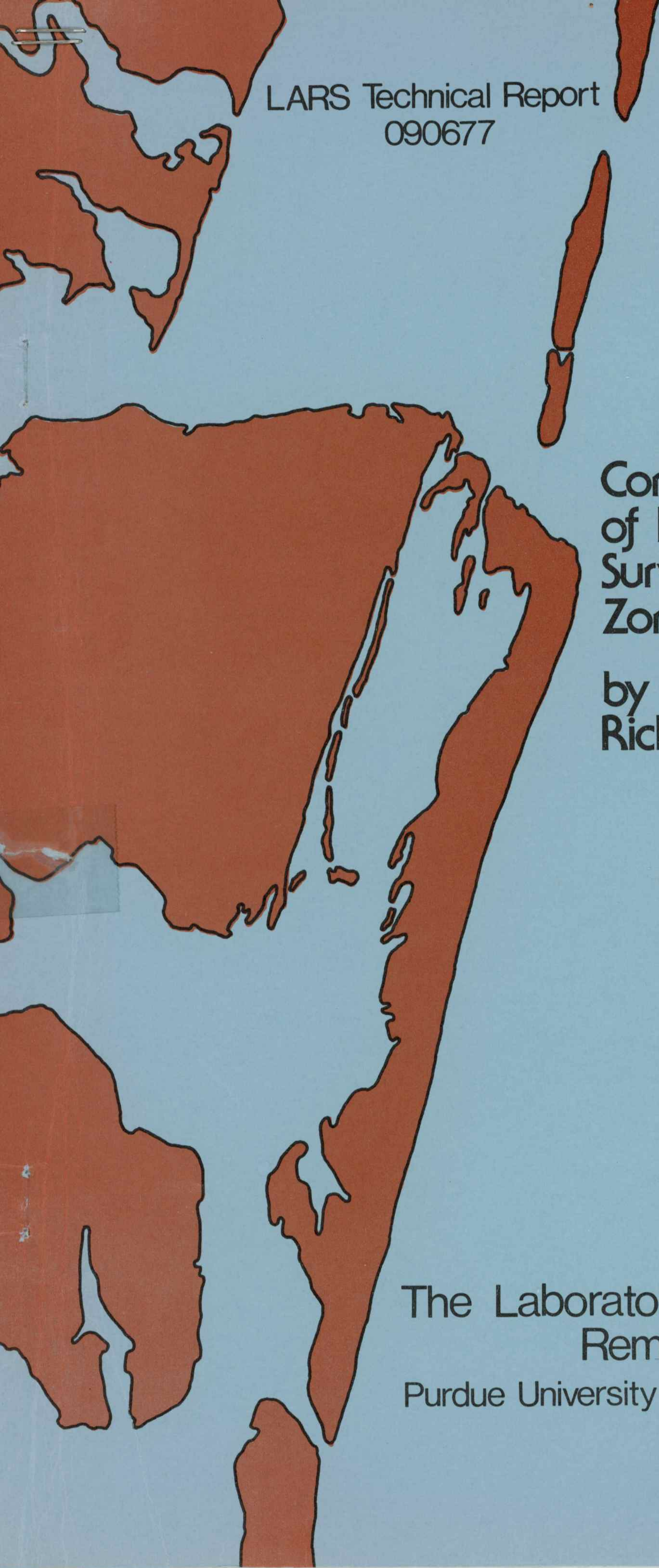

LARS Technical Report
090677

Computer-Aided Analysis of Landsat Data for Surveying Texas Coastal Zone Environments

by Stevan J. Kristof &
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The Laboratory for Applications of Remote Sensing
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16. Abstract

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COMPUTER-AIDED ANALYSIS OF LANDSAT DATA FOR SURVEYING TEXAS COASTAL ZONE ENVIRONMENTS*

S. J. Kristof and R. A. Weismiller

ABSTRACT

A study was conducted to determine the feasibility of using machine-aided processing of Landsat data to inventory environmental units within the Texas coastal zone. The analysis was conducted on geometrically corrected and spatially registered Landsat data collected on November 27, 1972 and February 25, 1975 over the Matagorda Bay area of the Texas coastal estuarine system. A clustering algorithm (nonsupervised processor) was used to divide the data into groups of sample points of similar spectral characteristics. Correlation of spectral classes with reference data on a point-to-point basis showed the coastal features exhibit unique spectral variations. Statistics developed on these groupings were input to a maximum likelihood algorithm and the test sites classified. The following terrestrial and aquatic environments were discriminated: alternating beach ridges, swales, sand dunes, beach birms, deflation surfaces, land-water interface, urban, spoil areas, fresh and salt water marshes, grass and woodland, recently burned or grazed areas, submerged vegetation and waterways.

*This work was supported by the National Aeronautics and Space Administration under contract NAS9-14016 and NAS9-14970. Journal Paper Number 6890 Purdue University, Agricultural Experiment Station.

Visual observation of results obtained from both the November 1972 and February 1975 data indicate that no major differences existed in the land resource maps. The results did show that analysis of Landsat data with computer-aided techniques is a viable technique for surveying coastal features.

INTRODUCTION

Land resources inventories of coastal environments are vital to the prudent management of these resources by national, state and local governments. Remote sensing techniques provide a means of obtaining this necessary information (2). Vytautas, et al. (6) found multispectral analysis of aerial imagery to be a valuable tool in the mapping of the Delaware wetlands. Using machine-aided processing of Landsat data, land resources inventories of large areas can be produced with a minimum of time and expenditure. Tarnocai and Kristof (5) used this technique to survey the Mackenzie River delta area in Canada. This paper examines the feasibility of using machine-aided processing of Landsat data to inventory pertinent environmental units within the Matagorda Bay region of the Texas coastal zone.

DATA

Landsat multispectral scanner (MSS) data collected on November 27, 1972 and February 25, 1975 were used for this study. These data, covering the Matagorda area (Figure 1), were geometrically corrected (1), overlaid one to the other and spatially registered to ground control points selected from U.S. Geological Survey (USGS) 7½ minute topographic quadrangle maps (Figure 2). The resulting multichannel, multidate data set when printed on a computer line printer in pictorial form had a scale of 1cm = 2400cm and could be physically overlaid on USGS topographic maps of the same scale. Thus, individual pixels could be located for accurate ground observation.

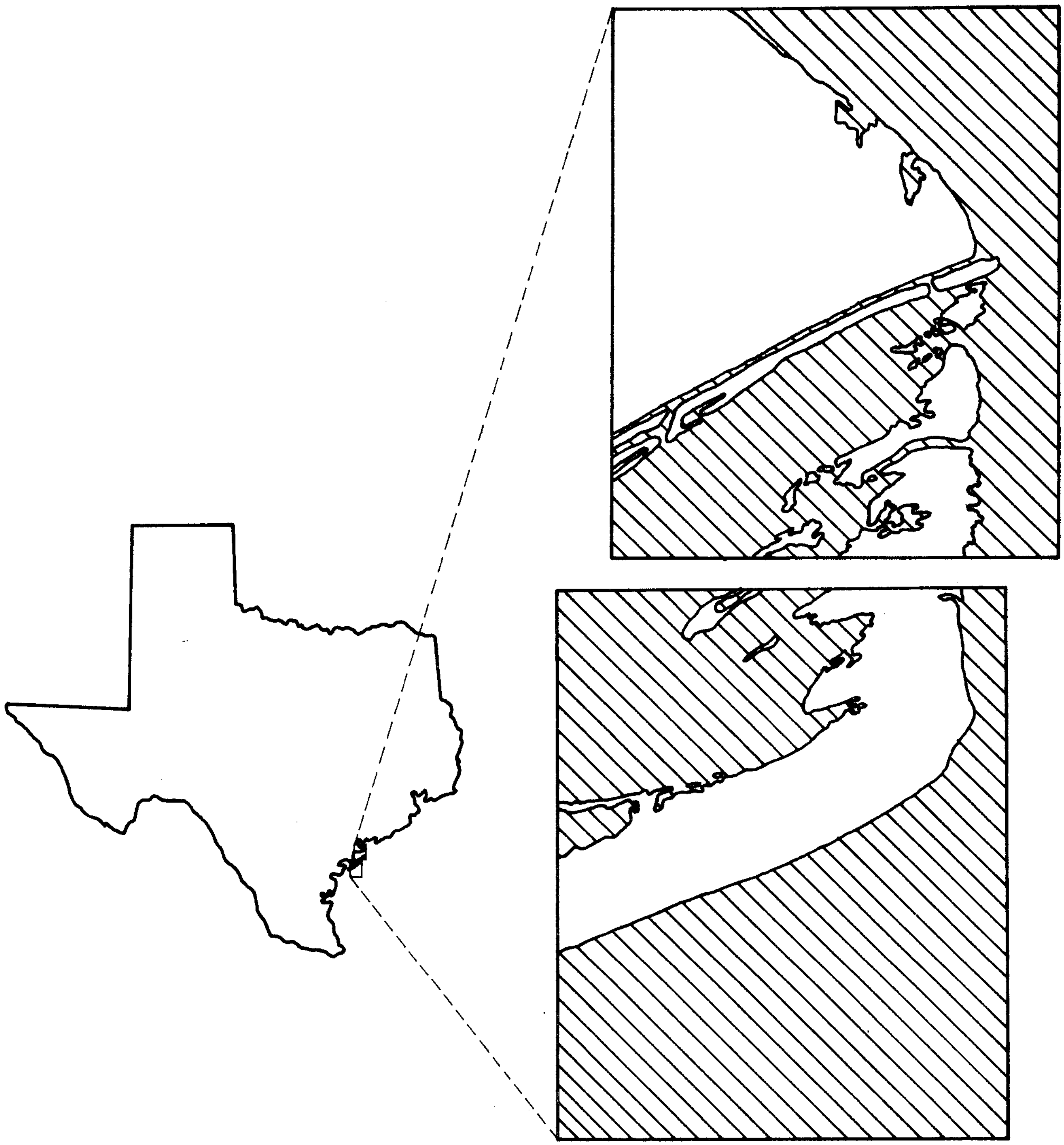


Figure 1. The Port O'Connor and Pass Cavallo area of the Texas coastal zone, south of Houston, Texas.

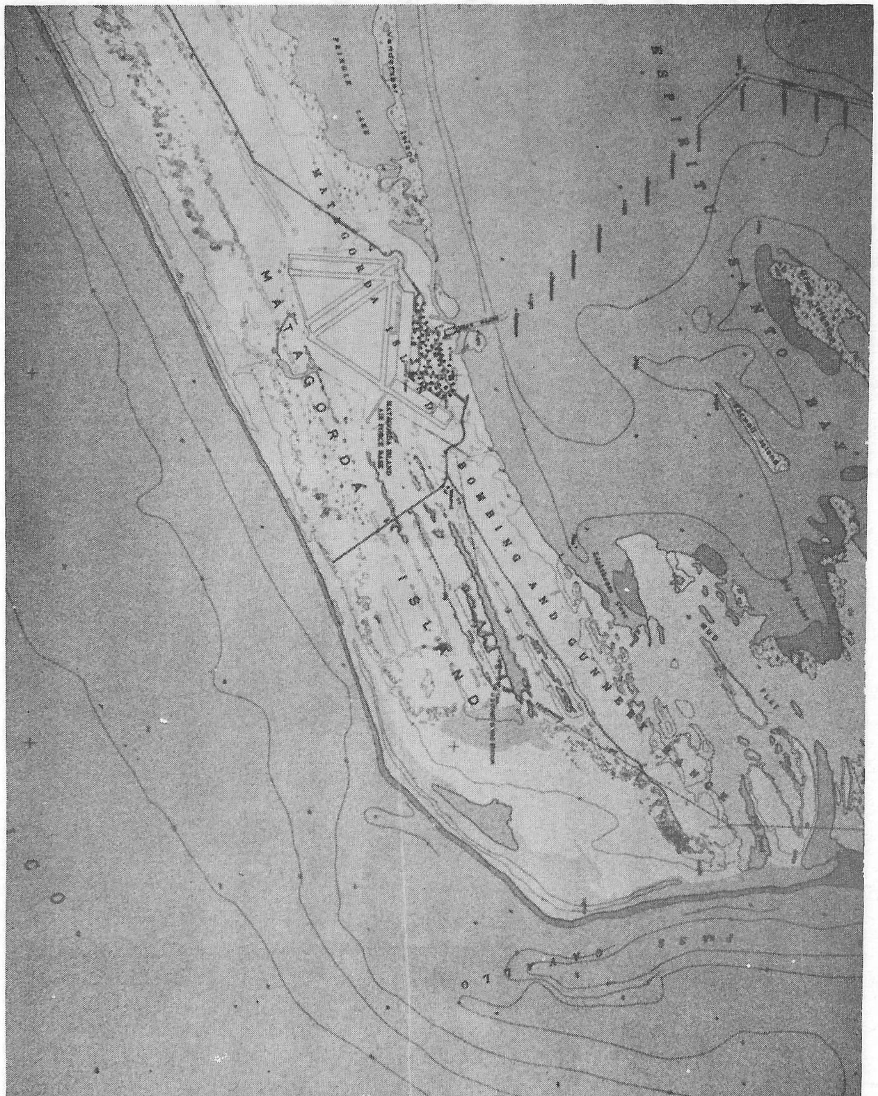
STUDY AREA

Two study areas in the Matagorda Bay region of the Texas coastal zone were selected for this investigation. These areas are represented by the Pass Cavallo and Port O'Connor USGS 7½ minute quadrangles. The Pass Cavallo area consists of Matagorda Island and several other small barrier islands. The dominant geomorphic features of the area are the alternating ridges and swales paralleling the beach of the gulfside. Since the ridges retard runoff, the swales tend to be moist and periodically impound water. The Port O'Connor area, situated between the coastal wetlands and the inland woodlands, consists chiefly of sand and clay material deposited from overbanking streams and sediments during the Pleistocene history of the area. It is traversed by elongated sand belts with very slight topographic relief. In general, the entire area appears as a broad, coarse textured terrain with fresh-water marshes and oak motte environments.

Both areas, Pass Cavallo and Port O'Connor, represent an interactive ecological region and are frequently affected by wind tides, tidal creeks, shoreline erosion, and active surface faulting. The native vegetation stands represent a collection of vegetation of similar species dominated by a single characteristic species of a small number of co-dominated species. The lower areas are covered with marshes and swamps. Salt-water marshes are characterized by pure stands of Spartina alteniflora (cordgrass), Salicornia perenis (glasswort) and Suaeda spp. (seepweed). Closed brackish-water marshes occur in the central inland area of Matagorda Island and other barrier islands and on the shoreface of the mainland sides of the bays. Periodic salt-water inundation and fresh-water runoff

Figure 2. Portions of the Port O'Connor and Pass Cavallo, U.S. Geological Survey 7½ minute topographic quadrangle maps.

PASS CAVALLO QUAD



PORT O'CONNOR QUAD

N

from adjacent higher lands constrain biologic growth in these areas. Vegetation primarily consists of Spartina patens (marsh hay cordgrass), Spartina cynosuroides (big cordgrass), Scirpus spp. (bullrush), Typha latifolia (cattail), and Juncus spp. (rushes). At higher elevations fresh-water marshes are developed and maintained by rainfall or a permanently high water table. Fresh-water marshes are characterized by Juncus spp. (rushes), Scirpus spp. (bullrush), Typha latifolia (cattail), and Spartina pectinata (sloughgrass).

Topographically low frequently inundated areas may or may not be occupied by vegetation. Aquatic vegetation is followed by zones with Salicornia spp. (glasswort) and Distichlis spicata (spike grass). The drier parts of the marsh are characterized by Spartina patens (marsh hay cordgrass) and Spartina spartinae (coastal sacahuista). Swamps are composed entirely of fresh water and are characterized by heavy growth of Quercus nigra (water oak), Nyssa biflora (gum), Ulmus spp. (elm), Vitis spp. (grapevine), and Morun spp. (mulberry).

The flat uplands which occur landward from the bays and lagoons and extend from sea level to an elevation of approximately 100 feet above MSL are not significantly affected by water intrusion. Their main herbaceous and woody vegetations are Andropogon spp. (bluestem), Sorghastrum spp. (Indiangrass), Paspalum spp., Prosopis spp. (mesquite), Sorghum halepense (Johnson grass), Celtis spp. (hackberry), Acacia farneslana (huisache), chaparral, cactus, and Quercus virginia (live oak)(3,4,8).

METHOD

Single date, unsupervised classifications of the Pass Cavallo and Port O'Connor areas using the registered data from November 1972 and February 1975 were produced for comparison to each other. False color images (Figures 3 through 10 , presented in black and white) produced from a digital display unit were used to obtain an overview of the two study areas and to obtain some detailed information about the surface features. The training areas were selected from the images to contain typical examples of each cover type of interest.

For each date, cluster analyses were conducted. Three training sites for both the land and water areas for each study area were analyzed. The training areas for the Port O'Connor area are shown in Figure 11. For each study area twenty-one spectrally separable classes resulted from the clustering process. Fourteen and fifteen land and seven and six water classes were identified for the Pass Cavallo and Port O'Connor areas, respectively. The cluster output included a cluster map showing the location of the spectral classes and a punched output of field description cards for each of the cluster classes. The 4 field description cards were input into a statistics processor to obtain the mean spectral response of each cluster class in all four Landsat channels and their covariance matrices. By summing the mean relative spectral response values of all four bands, the magnitude of the responses for each class can be obtained. The mean spectral response values were also used to calculate a ratio $A = \frac{V^*}{IR}$. By observing the magnitude M and the ratio A, the cluster classes can be tentatively identified.

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*V is the relative intensity of the visible wavelengths (0.5-0.6μm) + (0.6-0.7μm) and IR is the relative intensity of the reflective infrared wavelengths (0.7-0.8μm) + (0.8-1.1μm).

The covariance matrix and mean vector statistics of these classes were input into a maximum likelihood algorithm which classified the areas under investigation. The classification results were output in alphanumeric form using a threshold value of 0.5. Thresholding delineated those points not adequately represented by the training statistics. New training fields were selected from the thresholded areas and their covariance matrix, mean vector statistics and ratios calculated. The statistics of these new classes were merged with the previously calculated statistics and the study areas reclassified. A flow chart representing this analysis technique is shown in Figure 12.

Examination of aerial photographs, field observations, USGS topographic maps and Bureau of Economic Geology (BEG) land use and bathymetry maps and "Spectral Environmental Classifications" furnished by Lockheed Electronics Company (LEC)/Johnson Space Center, confirmed the identification of the classes as proposed by the magnitude and ratioing information. These same materials were later used for evaluation of the classification results.

RESULTS

Computer-derived classifications based upon the separation of surface features with different spectral responses are presented as land resources maps for the Pass Cavallo and Port O'Connor areas (Figures 13 through 18). The Pass Cavallo area is dominated by Matagorda Island and the surrounding coastal waters. The island is characterized by sand, brush, marshlands, and an abandoned Air Force installation. Elevation of the island ranges between 0 - 2 meters. The dominant geomorphic features are the alternating ridges and swales, sand dunes and tidal flats on the lagoon side of the

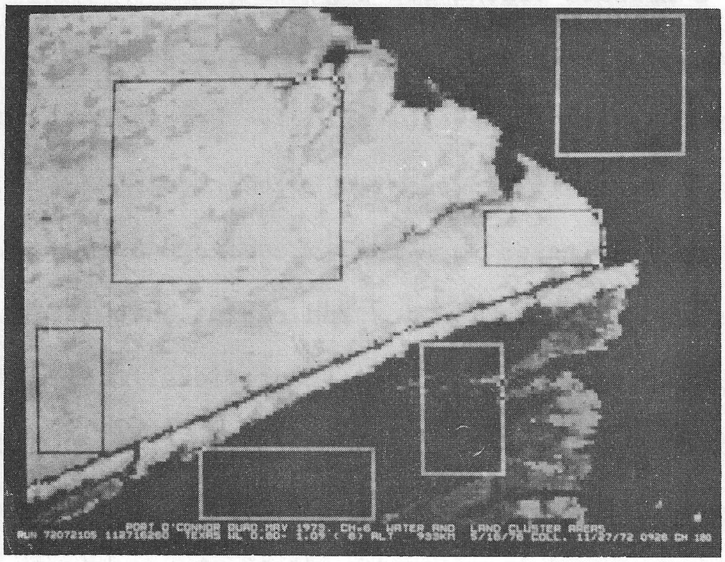

Figure 11. Six training sites selected for the Port O'Connor study area.

island. Tabular classification results (Table 1) indicate that the Pass Cavallo region is composed of 80% water, 6.4% swales and ridges, 2.1% burned and flooded, 2.3% sand and sand dunes, 1.3% housing and runways, 6.9% salt-water marshes, and 0.8% non-vegetated areas.

The Port O'Connor region is characterized by broad areas of relatively flat coastal plains occurring inland from the coastal marshes, bounded by stream disected wooded areas on the north. Extensive marsh-covered areas at 1.5 m or less above sea level stretch along Matagorda Bay proper. Tabular classification results (Table 2) show that the Port O'Connor area is composed of 50.3% water, 9.3% fresh-water marshes, 6.3% salt-water marshes, 9.9 grasses, 4.3% swamp, 4.1% burned land, 5.7% shrub and trees,

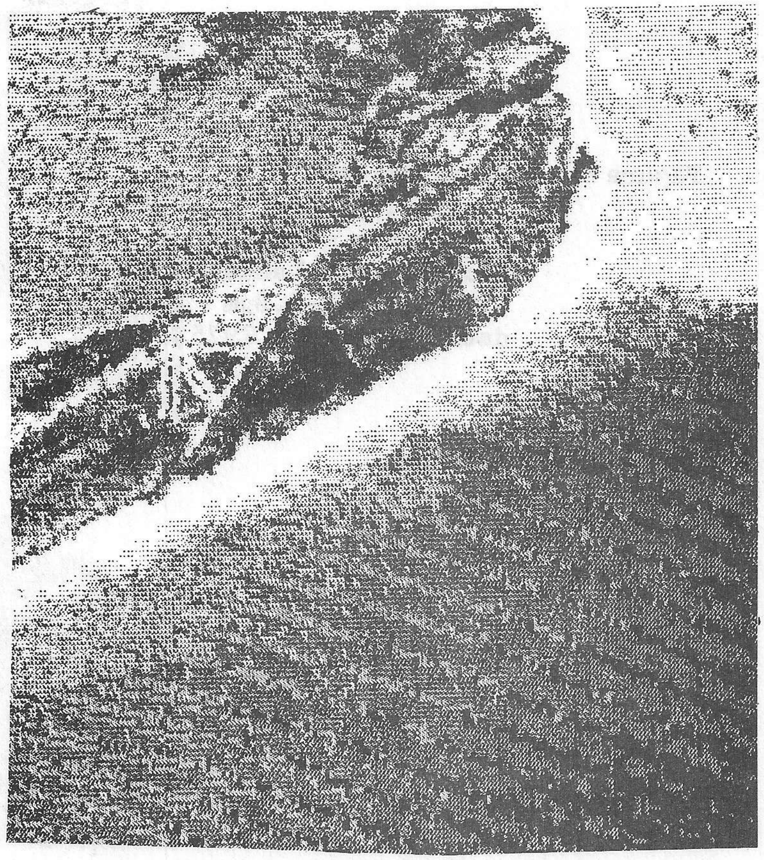

Figure 3. Image of Pass Cavallo; produced on electronic printer/ plotter from Landsat MSS band 0.5-0.6µm data - February 1975.

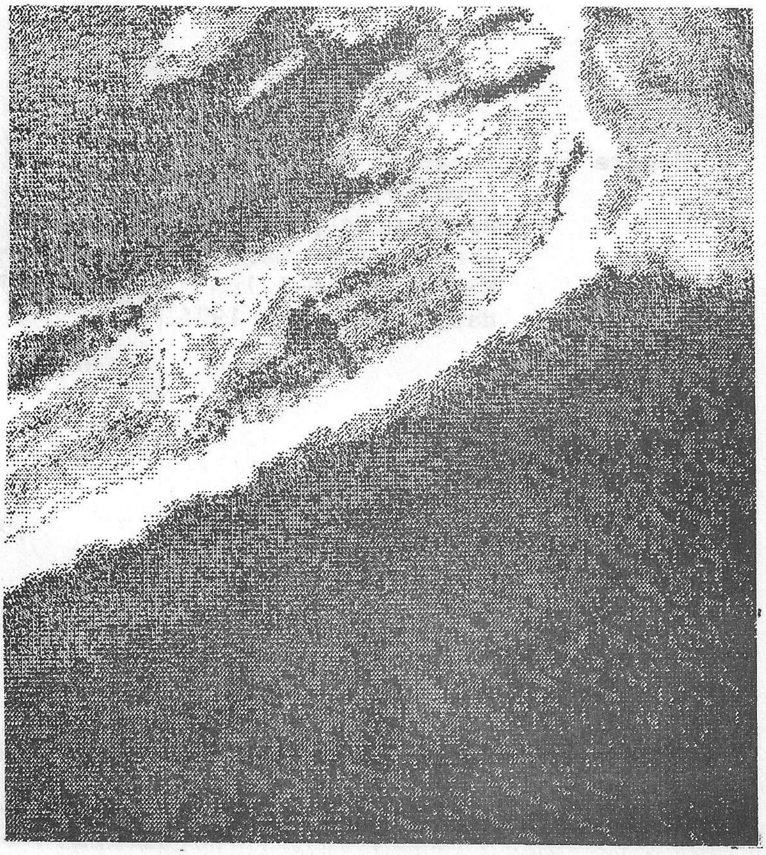

Figure 4. Image of Pass Cavallo; produced on electronic printer/ plotter from Landsat MSS band 0.6-0.7µm data - February 1975.

Figure 5. Image of Pass Cavallo; produced on electronic printer/ plotter from Landsat MSS band 0.7-0.8μm data - February 1975.

Figure 6. Image of Pass Cavallo; produced on electronic printer/ plotter from Landsat MSS band 0.8-1.1μm data - February 1975.

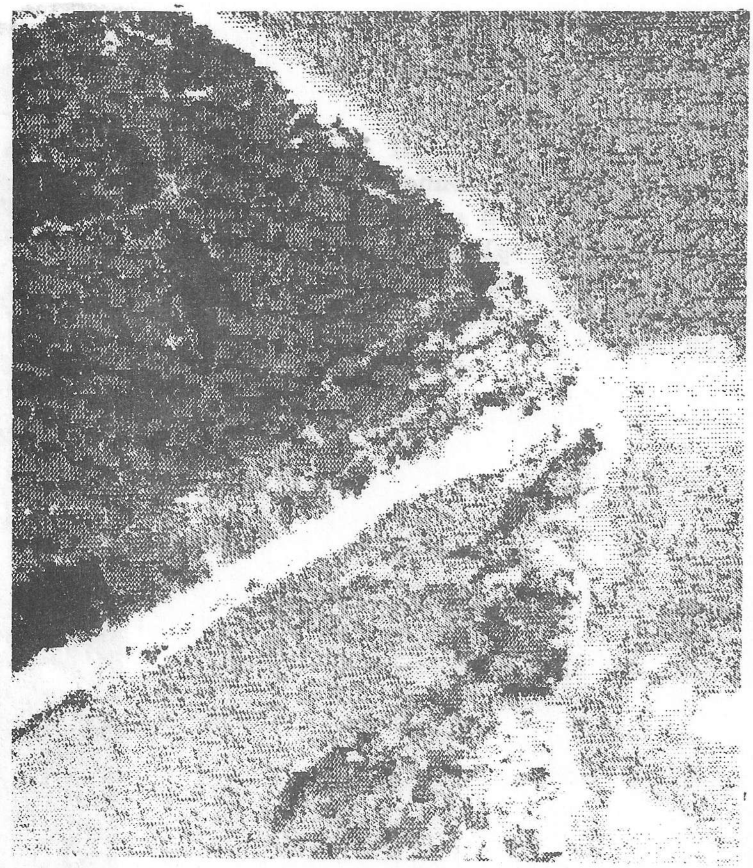

Figure 7. Image of Port O'Connor; produced on electronic printer/ plotter from Landsat MSS band 0.5-0.6μm data - February 1975.

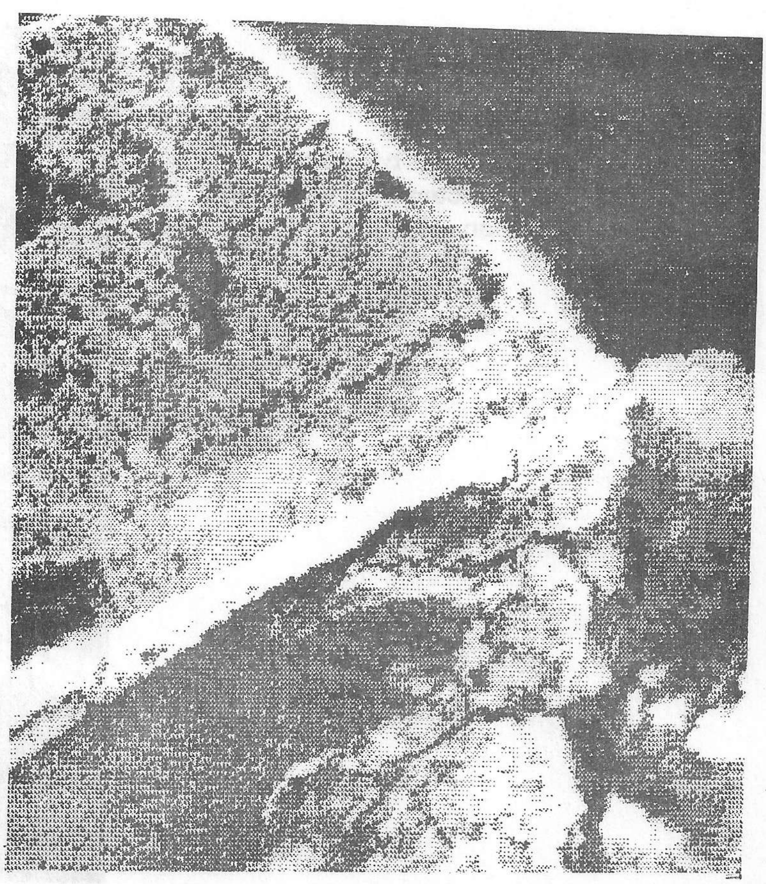

Figure 8. Image of Port O'Connor; produced on electronic printer/ plotter from Landsat MSS band 0.6-0.7μm data - February 1975.

Figure 9. Image of Port O'Connor; produced on electronic printer/ plotter from Landsat MSS band 0.7-0.8μm data - February 1975.

Figure 10. Image of Port O'Connor; produced on electronic printer/ plotter from Landsat MSS band 0.8-1.1μm data - February 1975.

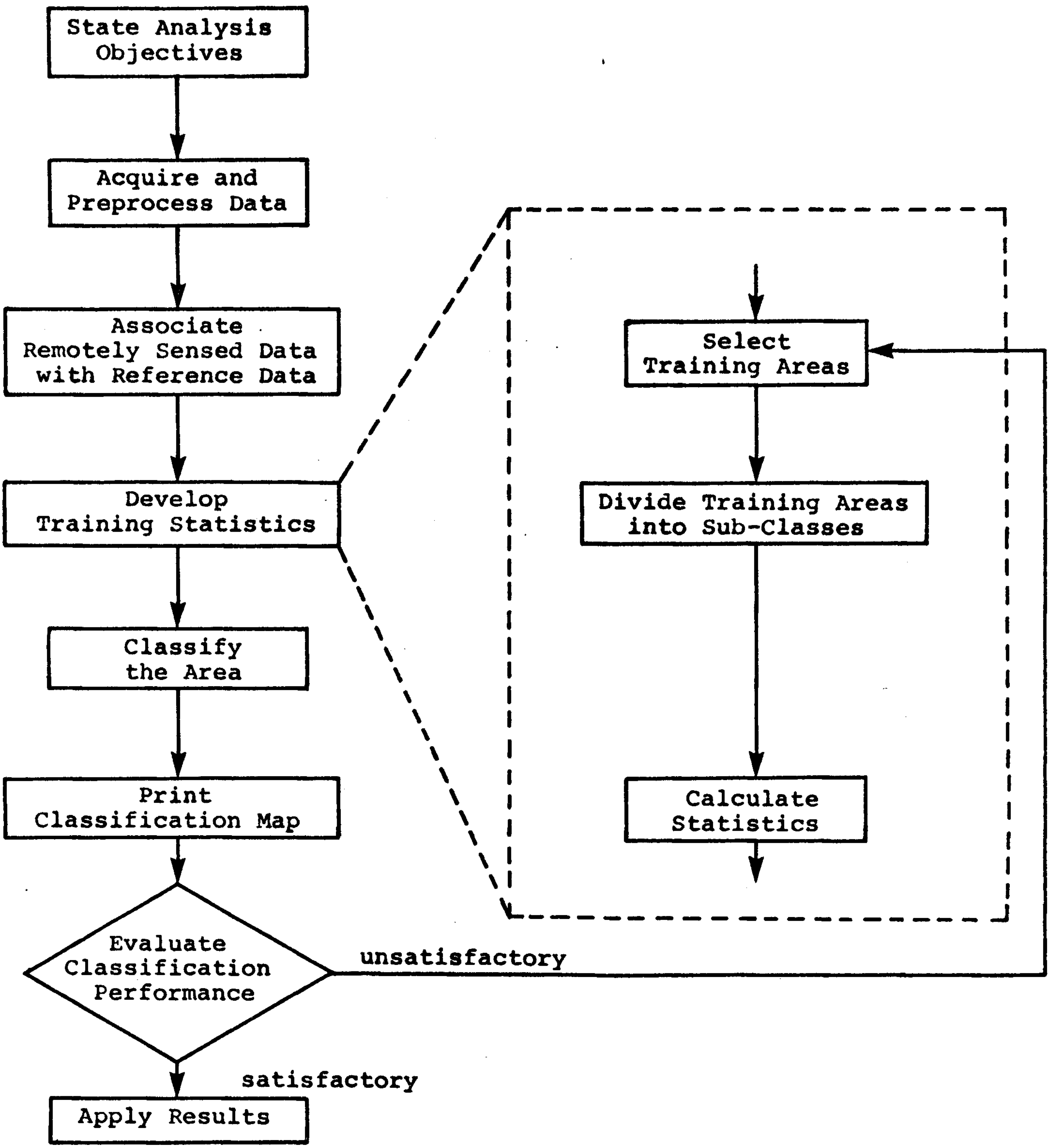

Figure 12. Analysis flowchart for land use determination.

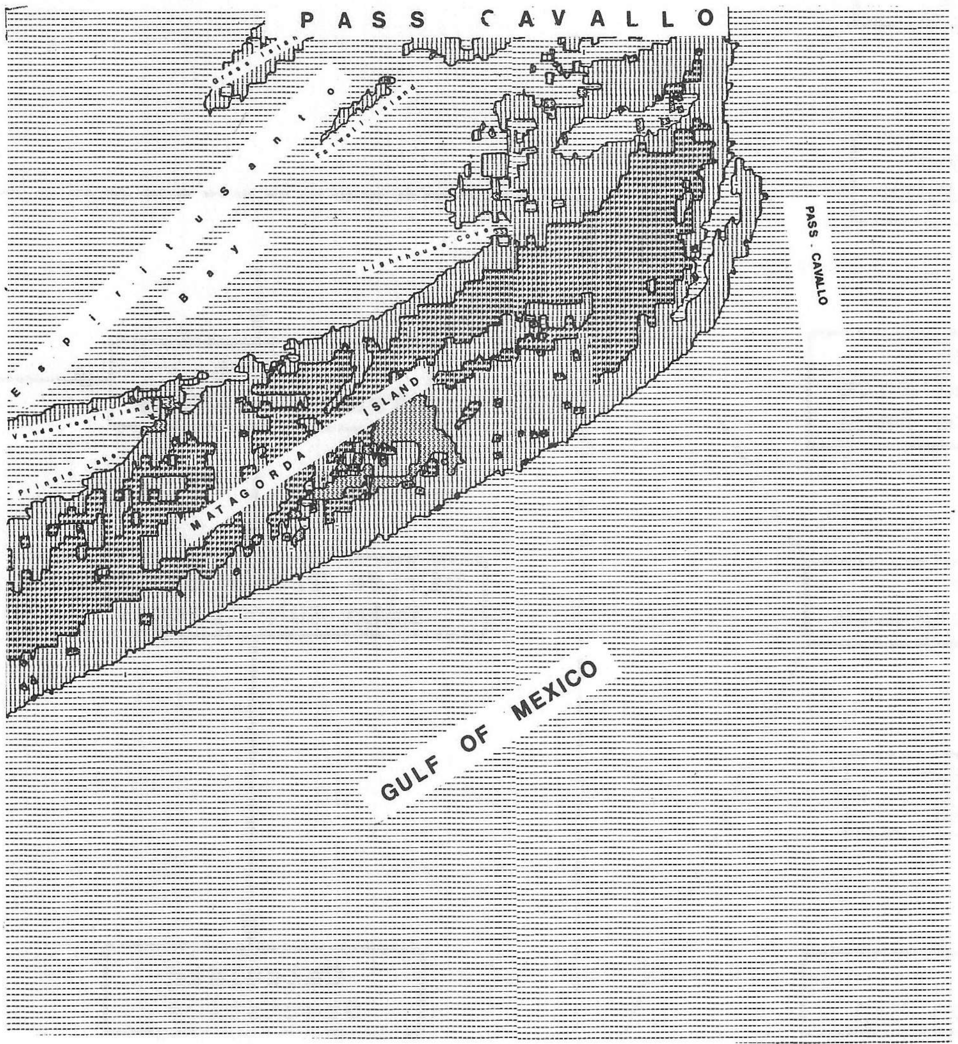

Figure 13. Level I Computer Land Resources Map of Pass Cavallo (Landsat data collected February 1975).

Legend:

M	Vegetated
I	Non-vegetated
-	Water bodies

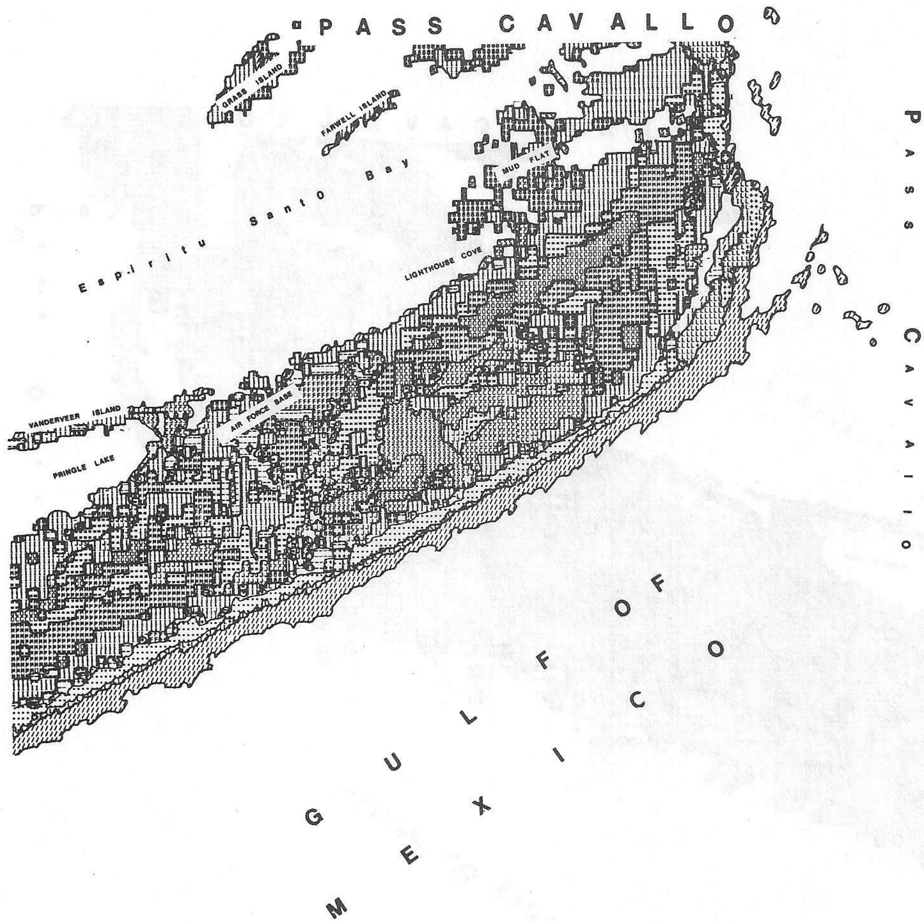

Figure 14. Level III Computer Land Resources Map of Pass Cavallo (Landsat data collected February 1975).

Legend:

·	Non-vegetated - beach sand
+	Non-vegetated - dry sand
-	Non-vegetated - manmade objects
0	Swale with native grasses environment
M	Swale with wet marsh grasses
=	Ridge - salt tolerant grasses
J	Non-vegetated - bare soils
C	Non-vegetated - wetland burned
S	Flooded land
I	Muddy sand flats - salt water marshes
8	Inundated - submerged flora
L	Non-vegetated - dry - sand - shell debris
F	Vegetated, housing, roads
/	Shallow water (0-1.8 m)

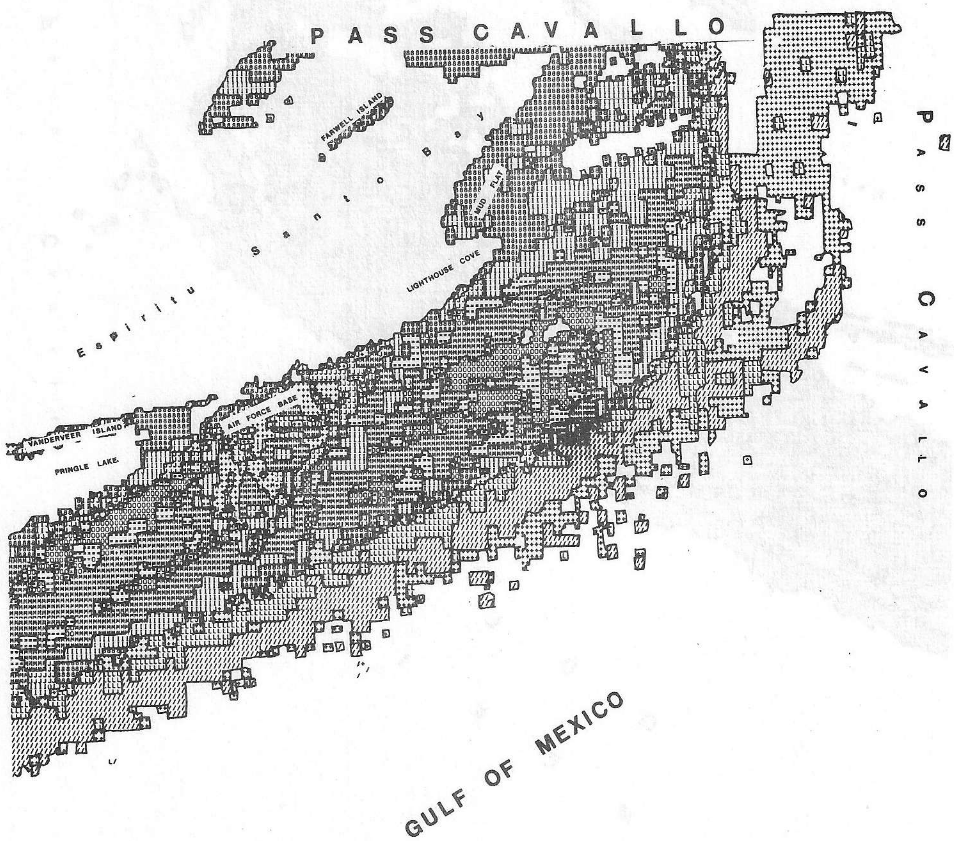

Figure 15. Level III Computer Land Resources Map of Pass Cavallo (Landsat data collected November 1972).

Legend:

/	Shallow water with sand and shell bottom
L	Non-vegetated- dry - sand
+	Non-vegetated - dry - sand
I	Mud flat - herbaceous - emergent inundated
M	Swales with wet marsh grass environment (Spartina altenaflora, Spartina spartina, Spartina patens, marsh cordgrass, etc.)
J	Housing
=	Non-vegetated - wet - ridges
8	Inundated - submergent - salt water marshes
O	Ridges - wet, probably with dry vegetation

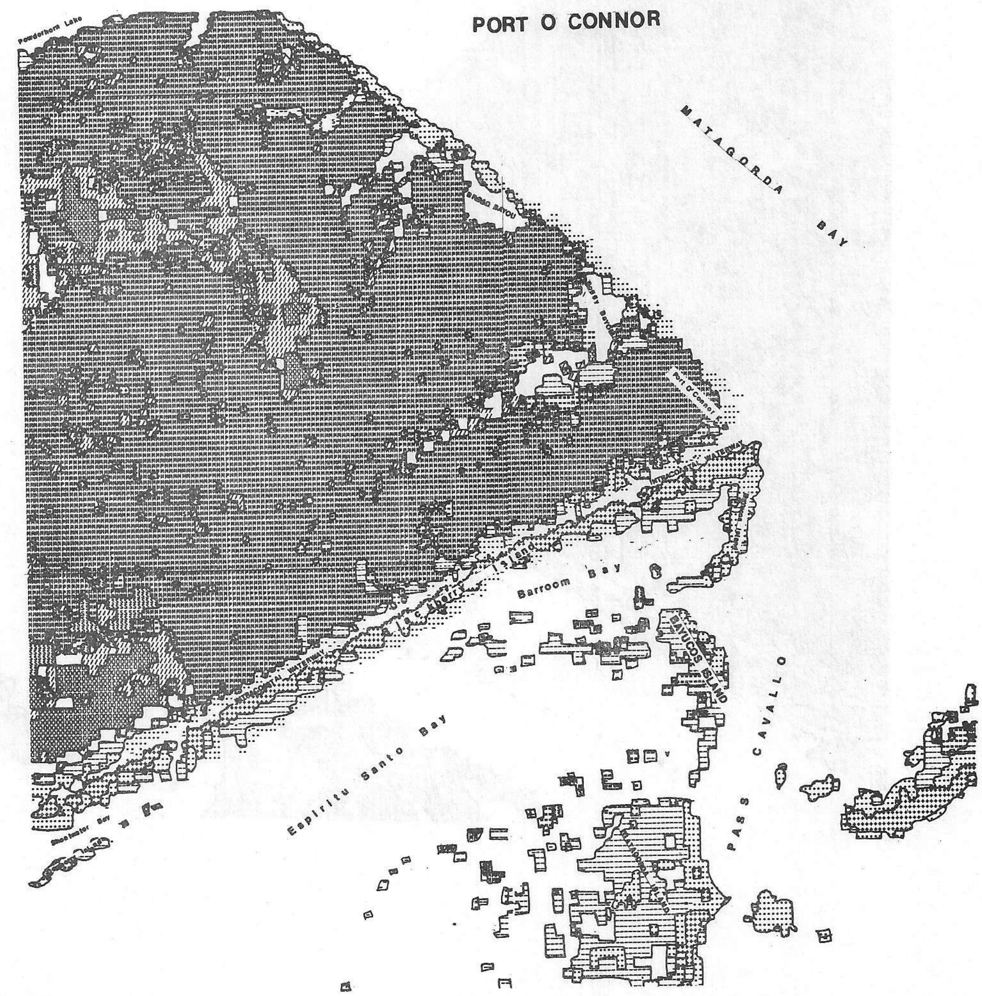

Figure 16. Level I Land Resources Map of Port O'Connor (Landsat data collected February 1975).

Legend:

M	Vegetated area
–	Bare land
/	Wet sandy areas
+	BS - dry beach sand
·	Tidal flat - inundated
O	Mixed woody/herbaceous - burned
S	Vegetated - dry - mixed - woody/herbaceous - grazed
=	BS - wet bare soils

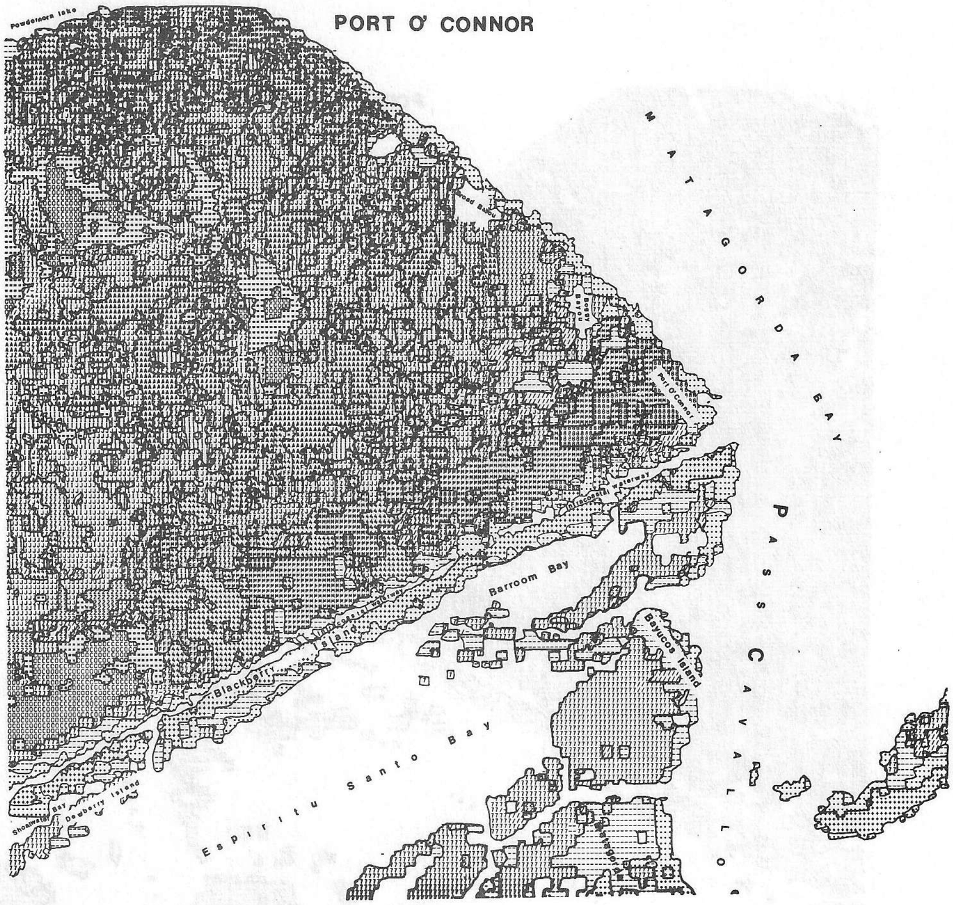

Figure 17. Level III Land and Wetland Classification of Port O'Connor (Landsat data collected February 1975).

Legend:		
	8	Vegetated - dry - urban
	M	Vegetated - dry - mixed - prairie/cultivated grass environment
	4	Vegetated - wet - herbaceous - emergent - grazed
	A	Vegetated - dry - woody/herbaceous
	-	Inundated - swamps
	Z	Vegetated - dry - prairie grasses
	J	Vegetated - fresh water marsh
	2	Vegetated - wet - shrub/trees dominant environment
	I	Vegetated - fresh water marsh
	=	Bare land - wet - burned
	0	Bare, very wet - burned
	+	Beach sand - dry
	·	Sand - sand bars
	7	Salt water marsh
	/	Bare soil - wet

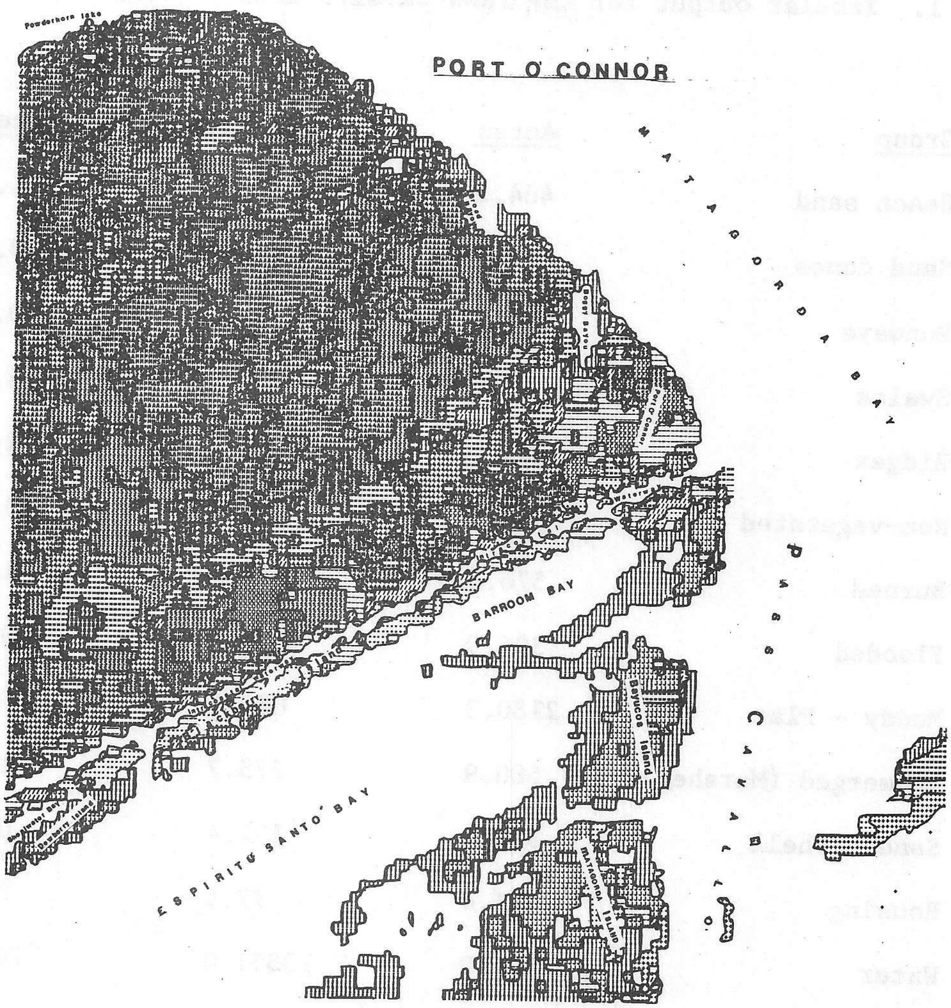

Figure 18. Level III Land Resources Map of Port O'Connor (Landsat data collected November 1972).

Legend:

C	Urban
4	Vegetated - dry - mixed - woody/herbaceous
S	Same as previous class
0	Vegetated - herbaceous - grazed
2	Vegetated - dry - herbaceous
=	Vegetated - wet - herbaceous - emergent
M	Vegetated, dry - herbaceous - mixed - grass dominant
A	Vegetated, dry - mixed - woody/herbaceous
/	Non-vegetated, semi-dry soil
J	Wet bare land
I	Wet - herbaceous - emergent - inundated
+	Dry high reflective sand
·	Dry sand
-	Urban and manmade objects
8	Herbaceous - wet woody/herbaceous
Z	Bare soil - wet

Table 1. Tabular output for the Pass Cavallo area. (February 1975)

Group	Acres	Hectares	Percentage
Beach sand	464.2	187.9	1.12
Sand dunes	171.6	69.5	0.43
Runways	371.8	150.5	0.90
Swales	1724.8	698.3	4.18
Ridges	925.1	374.5	2.25
Non-vegetated	346.5	140.3	0.84
Burned	576.4	233.4	1.41
Flooded	306.9	124.3	0.74
Muddy - Flat	2180.2	882.7	5.28
Submerged (Marshes)	680.9	275.7	1.65
Sand - Shell	324.5	131.4	0.78
Housing	191.4	77.5	0.46
Water	32976.9	13351.0	79.96
Total	41241.2	16696.8	100.00

Table 2. Tabular output for the Port O'Connor area. (February 1975)

Group	Acres	Hectares	Percentage
Urban area	325.6	131.8	0.74
Prairie grasses	4314.1	1746.6	9.87
Woody/herbaceous	1977.8	800.7	4.53
Emergent flora	1339.8	542.4	3.05
Swamp	1879.9	761.1	4.31
Fresh-water marsh	4042.4	1636.6	9.25
Salt-water marsh	2725.7	1103.5	6.25
Shrub/trees	526.9	213.3	1.21
Burned vegetation	1784.2	722.3	4.08
Beach sand	789.8	319.8	1.80
Sand	1486.1	601.6	3.48
Bare soil - wet	512.6	207.5	1.16
Water	21937.9	8881.7	50.27
Total	43642.6	17669.1	100.00

0.7% urban, 6.4% sand and bare soil, and 3.1% emergent flora.

Classification performance was determined by comparing each classification results map with several sets of reference data at a common scale, especially the "Spectral Environmental Classification" overlays. A hierarchy of land resources features (Figures 19,20) established for this investigation, based upon statistical data obtained from LARSYS processors and reference data, shows that the 21 classes for each date inventoried can be divided into three distinguishable levels. The first level consists of three major classes comprising 22.3% and 3.8% land, 27.5% and 16.3% wetland, and 50.3% and 80.0% water for the Port O'Connor and Pass Cavallo areas, respectively. The land, wetland and water groupings can be further subdivided into Level II and Level III classes as shown in Figures 19 and 20.

The land category was further divided into vegetated regions, where the vegetation is not significantly affected by water such as native and cultivated grasses; vegetative cover in housing areas; and bare, dry areas such as sand dunes, sand beaches and man-made objects. The wetland category, where the vegetation is significantly affected by being intermittently inundated with water, is divided into swamps, marshes, swales, bare land covered with shallow water, wet non-vegetated areas, and submerged vegetation.

Water categories were divided into spectral classes based upon their chemical and physical properties. Figures 21 and 22 show the spectrally separable classes of water for these two areas. These results are in agreement with the bathymetry maps prepared by the Bureau of Economic Geology, State of Texas.

Figure 19. Classification hierarchy for Pass Cavallo (Landsat data collected February 1975).

Level I	M*	A*	Level II	M	A	Level III	M	A
Land	155.29	1.27	Beach sand	210.74	1.38			
			Sand	168.67	1.33			
			Sand dunes	141.59	1.50			
			Manmade	121.28	1.24			
			Housing	134.15	0.88			
Wetland	67.64	1.13	Marsh	77.96	0.94	Salt Water Marsh	84.34	0.88
						Submerged	71.58	1.50
			Non-vegetated	57.32	1.32	Flooded	41.74	1.61
						Burned	59.33	1.25
						Bare land	70.90	1.11
Water	51.92	18.53	Shallow water	109.15	2.08			
			Inundated	59.65	1.79			
			Subaqueous - subaerial - spoil or sand and silt	51.34	2.92			
			Muddy, salt water marsh	38.35	4.49			
			Water (depth 1.8-3.6 m)	47.71	8.39			
			Water (depth 3.6-5.4 m)	35.69	17.72			
			Water (depth 5.4-9.0 m)	21.54	92.33			

*M - Magnitude response

*A - Ratio $(\frac{V}{IR})$

Figure 20. Classification hierarchy for Port O'Connor (Landsat data collected February 1975).

Level I	M*	A*	Level II	M	A	Level III	M	A
Land	133.24	1.12	Sand beach	230.09	1.38			
			Sand, sand bars	130.08	1.39			
			Rangeland	88.87	0.83	Woody	80.33	0.89
						Herbaceous	91.73	0.82
						Mixed	86.03	0.85
			Urban	123.22	0.87			
Wetland	68.49	1.13	Woods swamp	93.94	1.43			
			Marshes	71.76	0.95	Fresh water marsh	63.76	0.90
						Salt water marsh	71.54	1.01
						Submerged	59.16	1.64
			Emergent	74.59	0.93			
			Non-vegetated	61.94	1.49	Bare land	78.27	1.11
						Burned	47.32	1.46
			Salt-water marsh	59.16	1.64			
Water	48.46	9.01	Subaqueous - subaerial - spoil sand - silt	72.73	2.64			
			Mudflats - lakes	38.75	4.44			
			Water (depth 1.8-3.6 m)	48.76	7.26			
			Water (depth 3.6-5.4 m)	39.49	11.62			
			Open bay	31.87	26.48			

*M - Magnitude response

*A - Ratio $(\frac{V}{IR})$

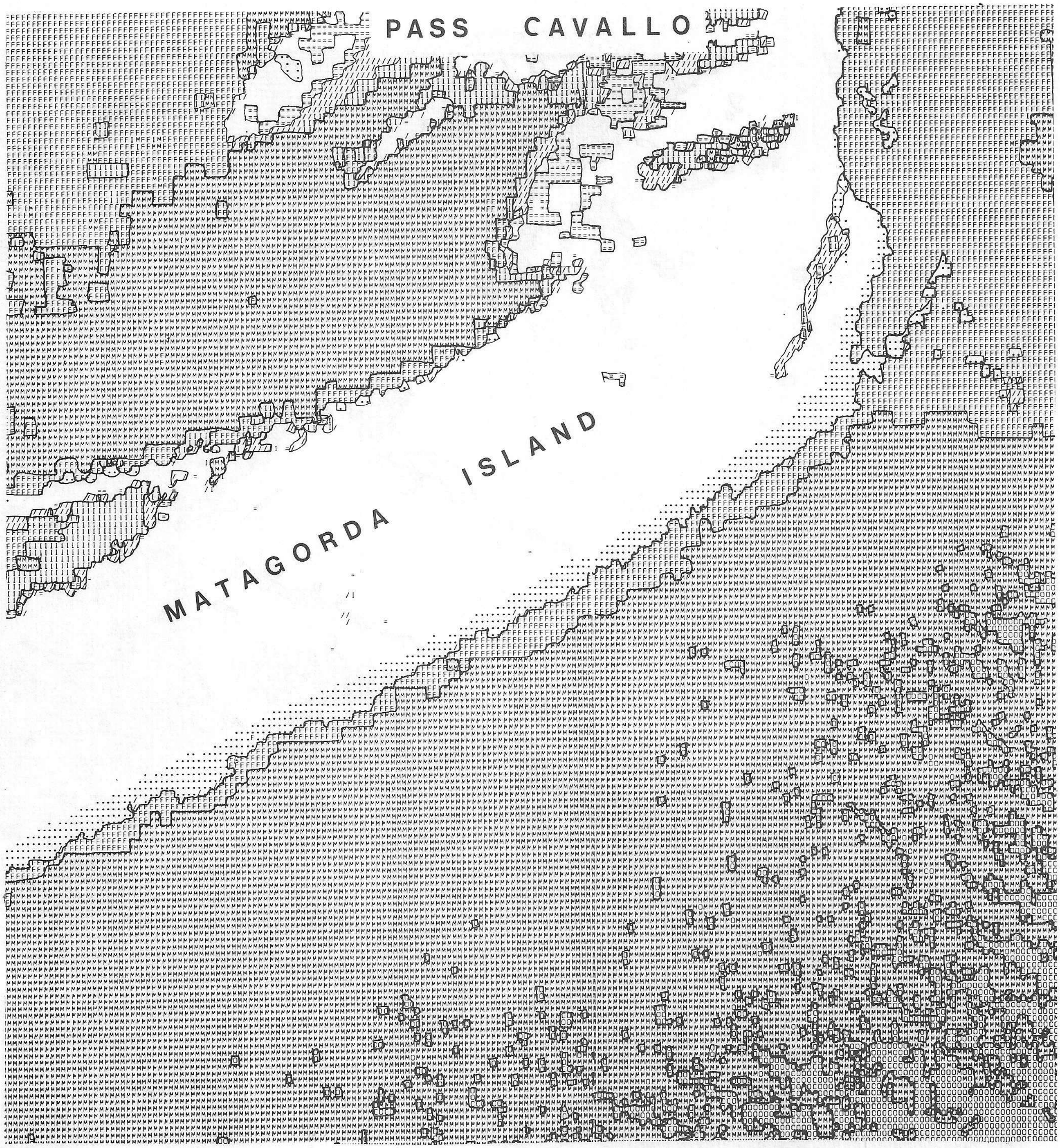

Figure 21. Spectral Classification of Water for Pass Cavallo Quadrangle (Landsat data collected February 1975).

Legend:

- · Shallow
- = Inundated
- / Subaqueous-subaerial-spoil-sand and silt
- I Lakes, submerged
- F Water (1.8-3.6 m)
- M Water (3.6-5.4 m)
- 0 Water (5.4-9.0 m)

Figure 22. Spectral Classification of Water for Port O'Connor Quadrangle (Landsat data collected February 1975).

Legend:

-	Salt water marsh
/	Subaqueous - subaerial spoil, sand - silt
J	Mudflat - lakes
I	Water (1.8-3.6 m)
F	Water (3.6-5.4 m)
M	Open bay

At Level III, the rangeland category was separated into woody (oak mottes), herbaceous (native and cultivated prairie grasses) and a mixture of woody/herbaceous. The marsh category is also divided into salt-water marshes and fresh water and both fresh and salt-water areas where vegetation is present. The non-vegetated category is separated at Level III into burned, flooded and wet bare land.

These spectral classes result from differences in the type of vegetative cover, the density of the vegetation, the wetness in the terrestrial ecosystems, geomorphic features, and the turbidity, amount of sediment and water depth in the aquatic ecosystems.

Results from the two sets of data, November 1972 and February 1975, show little differences in the type and detail of surface features that could be delineated. However, results from the November 1972 data show the area of beaches and sand dunes to be slightly larger, and burned areas were present in the February 1975 data which did not occur in the November 1972 data.

CONCLUSIONS

The results of this investigation indicate that digital analysis of Landsat data can be a valuable tool for inventorying environmental resources in coastal zone areas. The unique spectral responses of surface features within the Texas coastal zone allowed for easy separation of land, water, and wetland categories. Classes in vegetated areas were further separated based upon the density of ground cover. However, in marsh areas the reflectance from the background of water and wet soil played a major role in class separation. The spatial resolution of the Landsat scanner was adequate to recognize gross patterns of the vegetation, but was not adequate to resolve individual vegetation species. The spectral separability of water classes was a function of turbidity, depth and other physical and chemical properties. A visual comparison of results from data collected on November 27, 1972 and February 25, 1975 indicated that there were no major differences in classification performance between the two data sets.

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