NOAA Technical Memorandum
NMFS-SEFC-73

MAPPING OF SUBMERGED VEGETATION USING REMOTE SENSING TECHNOLOGY

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
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Malcolm Baldridge, Secretary
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John V. Byrne, Administrator
National Marine Fisheries Service
William Stevenson, Acting Assistant Administrator for Fisheries

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SECTION 1

INTRODUCTION

This document describes a cooperative program to develop and evaluate techniques for mapping submerged seagrasses using aircraft-supported remote sensors. Subm rged seagrasses are emphasized for several reasons: their wide geographic and habitat-type distribution have heretofore precluded adequate distributional maps; most marine ecologists agree that these plants are essential to the well being and productivity of most commercially important fishery resources in the Gulf of Mexico; and, because of their shallow subtidal and, to some extent, intertidal existence, these plants are subject to man-induced stresses both from the shore (pollutant effluents) and water (dredge and fill).

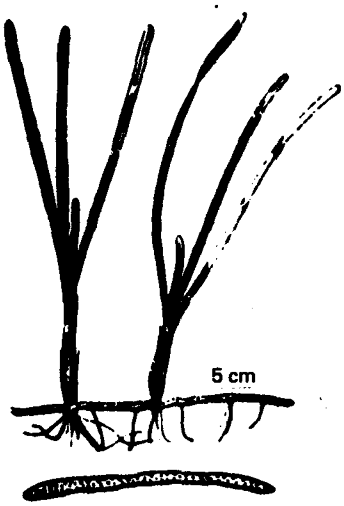
1.1 BACKGROUND

1.1.1 Seagrasses

Studies of marine grasses in the Gulf of Mexico date as far back as 1802. Reviews have been published by Thorne (1954) and Humm (1956), and studies on systematics and ecology by Phillips (1960, 1962, and 1967), Voss and Voss (1955), Moore (1963), Heck (1976), Zimmerman and Livingston (1976), and Thayer and Phillips (1977). Examples of important species (Figure 1) include *Thalassia testudinum*, *Ruppia maritima*, *Halodule wrightii*, *Halophila engelmannii*, *H. baillonis*, and *Syringodium filiforme*.

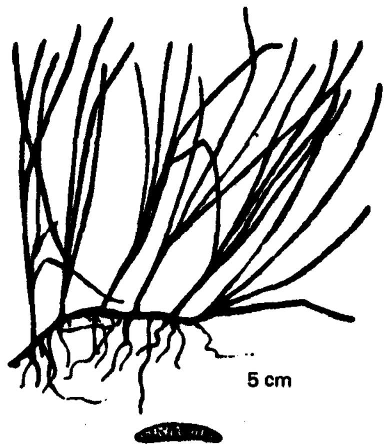
Seagrasses are sensitive to environmental changes, especially changes induced by man such as organic and inorganic wastes, heated effluents, saline and freshwater discharges, siltation caused by dredging, and beach erosion. Seagrasses are important for stabilization of nearshore bottoms, are used directly and indirectly as food sources for many aquatic and terrestrial animals (e.g., waterfowl),

Seagrasses (with leaf cross sections)



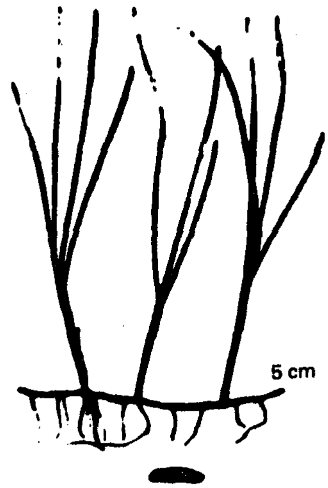
Thalassia testudinum

Occurs throughout the Gulf in depths to 13 m. Thriving in areas where the salinity is 25-36 °/oo, but withstanding a range between 10-48 °/oo. Grows on sand, mud, marl, shelly and coarse calcium carbonate substrates.



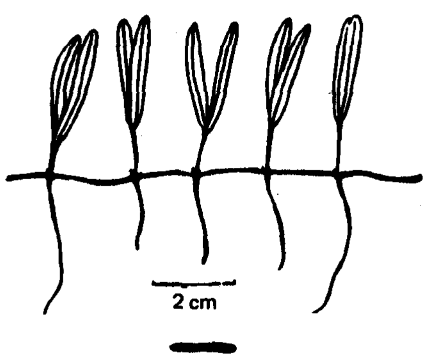
Ruppia maritima

Occurs throughout the Gulf in depths to 10 m in areas where salinity is less than 25 °/oo. Grows on sand and mud.



Halodule wrightii

Occurs throughout the Gulf in depths to 10 m in areas where salinity is between 10 °/oo and 40 °/oo. Grows on sand, mud, marl, shelly and coarse calcium carbonate substrates.

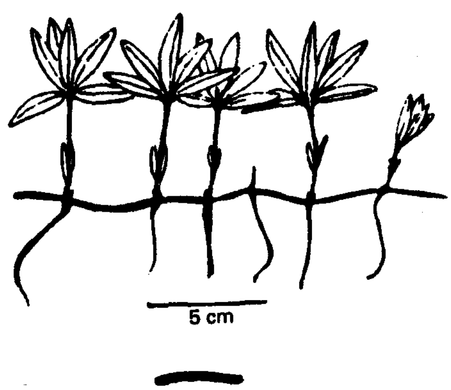


Halophila engelmanii

Occurs throughout the Gulf in depths to 13 m, thriving in areas where salinity is 25-38 °/00, but withstanding salinity as low as 9 °/oo. Grows on sand, mud, mangrove roots, and limestone.

Syringodium filiforme

Occurs throughout the Gulf in depths to 25 m, usually in areas where salinity is between 20 °/oo and 38 °/oo, but withstanding as little as 10 °/oo. Grows on sand, mud, and coarse calcium carbonate substrates.



Halophila baillonis

Occurs through the Gulf in areas where salinity is between 24 °/oo and 38 °/oo and most commonly in depths from 10 to 30 m, but occasionally extending to less than 0.5 m. Grows on sand, mud, and marl.

Figure 1. Example of Important Seagrass Species in the Gulf of Mexico (Earl, S.A., 1972).

and provide protection for larval and juvenile stages of important fishery resources such as shrimp, lobsters, and croakers.

1.1.2 Remote Sensing Systems

The remote sensing data sources for the program were the Solid State Array Spectroradiometer (SAS) and the RS-18 multispectral scanner which acquires four spectral channels of data. The SAS acquires 21 spectral channels of data at wavelengths from 4000 to 6880° A. Table 1 shows channel/wavelength assignments for both systems. The SAS system acquired 346 spacial elements for each spectral element as shown in Figure 2.

1.2 OBJECTIVES

The overall objective of the program was to develop and evaluate techniques for mapping submerged seagrasses with high resolution, multispectral remote sensors. Specific objectives include:

- Evaluate a 21-channel Solid State Array Spectroradiometer (SAS).
- Determine if common seagrasses and other bottom types can be detected and differentiated with high resolution spectral data.
- Develop and document applicable computer algorithms for processing, analyzing and classifying spectral data into charts of seagrass distribution.
- Determine any deleterious effects of water depth and optical properties on spectral signatures of seagrasses.

1.3 PARTICIPANTS

The program was designed as a cooperative investigation involving three principal organizations:

- Johnson Space Center (JSC) of the National Aeronautics and Space Administration (NASA).

  Earth Resources Laboratory (ERL), National Space Technology Laboratories (NSTL), NASA.

Table 1. SAS and RS-18 Channel/Wavelength Assignment

SOLID STATE ARRAY SPECTRORADIOMETER			
Channel	**Wavelength °A**	**Channel**	**Wavelength °A**
1	4000	12	5584
2	4144	13	5728
3	4288	14	5872
4	4432	15	6016
5	4576	16	6160
6	4720	17	6304
7	4864	18	6448
8	5008	19	0592
9	5152	20	6736
10	5296	21	6880
11	5440		

RS-18 MULTISPECTRAL SCANNER	
Channel	**Wavelength °A**
1	4000-5000
2	5000-6000
3	6000-7000
4	8000-11000

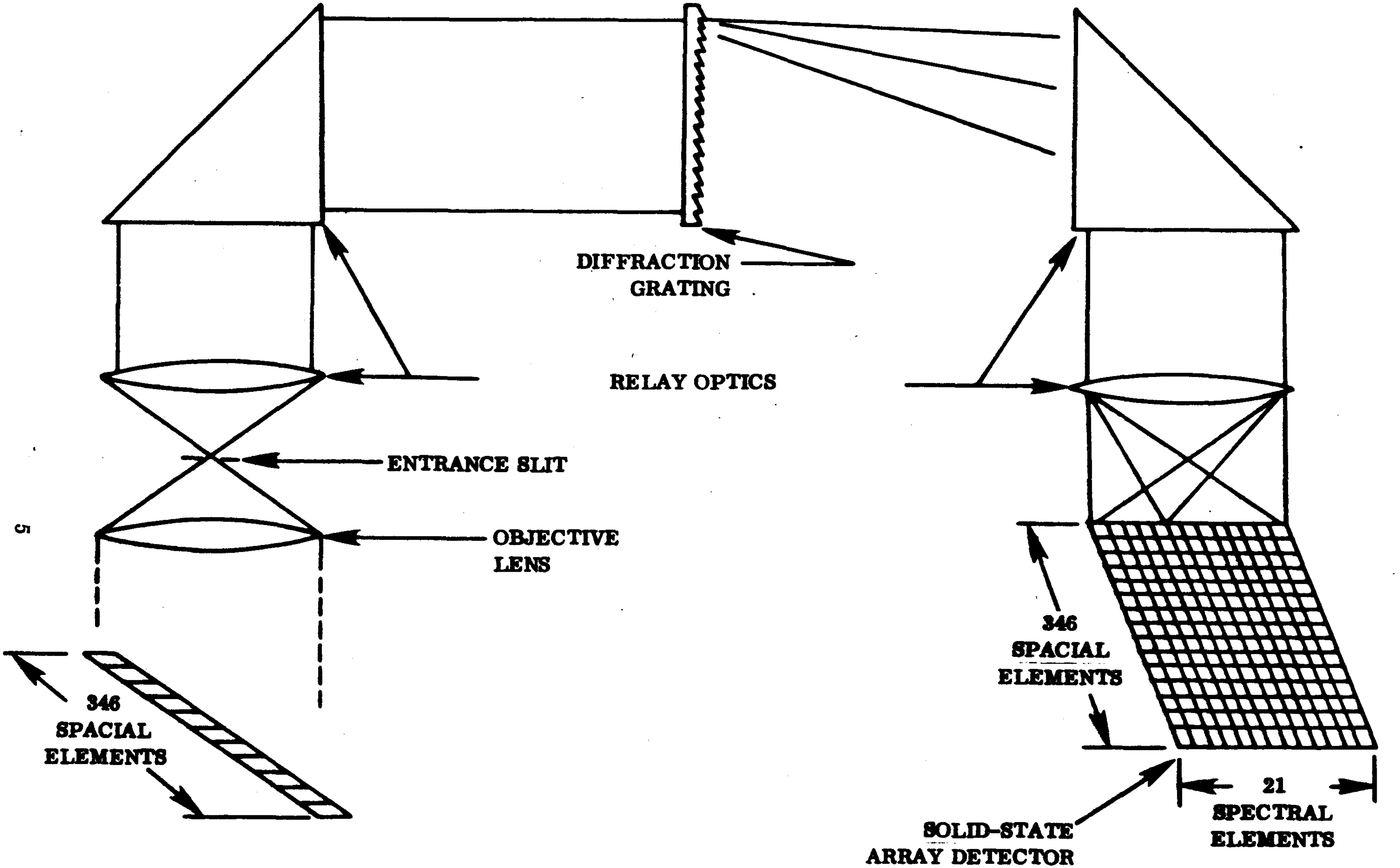


Figure 2. Solid-state Array Spectroradiom ter Optics Concept.

- Mississippi Laboratories, Southeast Fisheries Center (SEFC), National Marine Fisheries Service (NMFS).

Primary participants contributed to the achievement of the overall and specific objectives through a partnership approach while satisfying specific agency objectives. These specific agency objectives included:

- Johnson Space Center:
  - Evaluate flight hardware system performance characteristics.
  - Develop capabilities to acquire and process SAS type data into calibrated radiance measurements.
  - Establish operational procedures for aircraft support of SAS applications.

  Earth Resources Laboratory:
  - Evaluate high resolution remote sensing of water color for coastal marine applications.
  - Develop and evaluate data processing, management and analysis techniques for SAS type data.
- Mississippi Laboratories:
  - Evaluate the feasibility of using remotely sensed data for environmental assessment and habitat protection applications.
  - Develop capabilities to process and analyze remotely sensed spectral data for marine applications.

Other agencies and groups participating in the program included:

  Beaufort Laboratory, Southeast Fisheries Center, National Marine Fisheries Service
- Southeast Regional Office, National Marine Fisheries Service

  New Orleans Outer Continental Shelf Office, Bureau of Land Management

- National Coastal Ecosystem Team, U.S. Fish and Wildlife Service
  Florida State Department of Natural Resources

1.4 BENEFITS

There are several underlying reasons for the need to inventory seagrass beds on a large scale, and current methods cannot be used from a logistical, temporal, or economic standpoint. Traditional methods used for surveying seagrasses generally involve skin and SCUBA divers, underwater photography, core and grab samples, and dredge and trawl surveys. All are slow, expensive, and cumbersome to employ. Aerial photography has been, and continues to be, used; however, extraction of useful information from photographs is slow and tedious requiring skilled photointerpreters. None of these methods are applicable to synoptic surveys and all are temporally and economically prohibitive to apply.

Seagrasses have received increased investigative interest recently because of their potential role as indicators of the impact of man's activities on estuarine and coastal ecosystems. Information on changes in seagrass distribution, abundance, and diversity could significantly aid in formulation of effective decisions and guidelines for coastal zone management. In fact, changes in seagrass distribution resulting from perturbations have been used in part to reduce or eliminate the artificial stress on the system.

Before seagrasses can be utilized as a meaningful indicator of the ecological consequences of the impact of man on coastal ecosystems, a technique must be developed to provide distriubtion and abundance data accurately and economically. Potentially, aerospace color remote sensing could satisfy this requirement. Vegetation and land-use classification charts derived from remotely sensed color data are relatively commonplace now through advances in sensor and data processing and analysis technology. This project was designed to investigate the potential for utilizing this technology, with appropriate modifications for mapping the distribution of seagrasses.

1.5 PROGRAM MANAGEMENT

1.5.1 Responsibilities

Each agency cooperating in the program identified one person for coordination and management of all task elements and responsibilities assigned to that respective agency. They were referred to as co-investigators. The co-investigator for the Mississippi Laboratories served as Technical Coordinator for the program. The primary responsibility of the Technical Coordinator was to provide program coordination and integration.

The organizational structure and principal responsibilities of the primary participants of the program are shown in Figure 3. Responsibilities and functions of the other participants are presented in Table 2.

1.5.2 Schedule

The original functions/tasks identified in the "Seagrass Remote Sensing Program Plan" have been retained in the overall program. However, the FY 78 project year addressed only the St. Joseph Bay, Florida, test area. The Econfina River, Florida, test area was addressed in a FY 79 project managed by NASA (ERL). This report addresses only the FY 78 project year. In addition, the completion of the data synthesis/data analysis, and compilation/integration of the multiple inputs from each participating agency was underestimated in time/effort in the original plan and delayed on several occasions by project personnel being assigned to other segments of the overall program and other programs having higher priority.

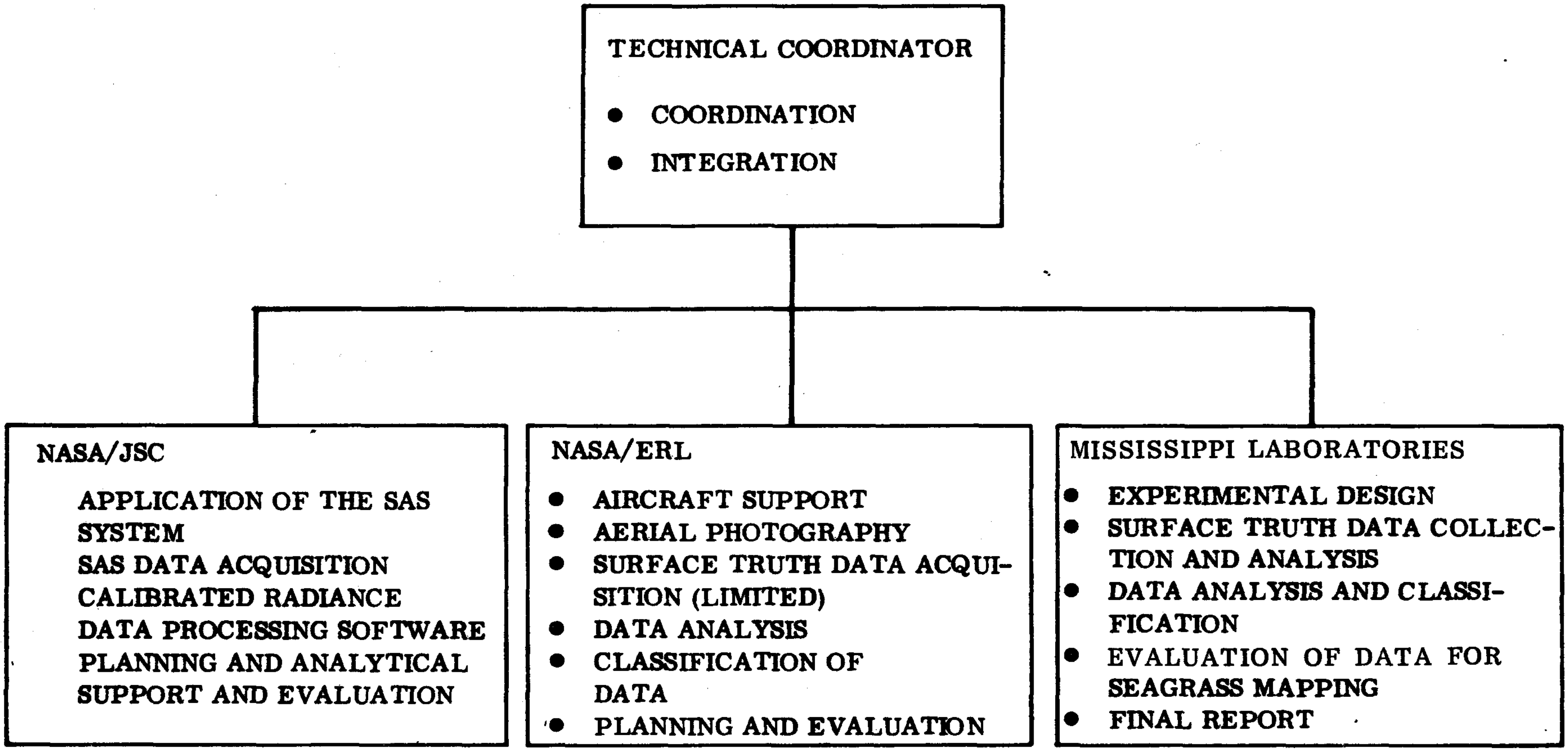


Figure 3. Organizational Structure and Responsibility Summary for Principal Participants in the Seagrass Mapping Program.

Table 2. Program Functions of the Other Participating Organizations.

ORGANIZATION	FUNCTIONS
National Marine Fisheries Service	
• Beaufort Laboratory	Experimental design, analytical assistance, seagrass expertise, and system evaluation
• Southeast Regional Office	Advisory support, evaluation, and administration
• Southeast Fisheries Center (headquarters)	Administrative assistance
U.S. Fish and Wildlife Service/ National Coastal Ecosystem Team (NSTL)	Advisory support in planning, experimental design, and evaluation
Bureau of Land Management/ Outer Continental Shelf Office (New Orleans)	Advisory support in planning, experimental design, and evaluation
Florida State Department of Natural Resources	Evaluation

SECTION 2

TECHNICAL PLAN AND FIELD OPERATIONS

2.1 APPROACH

The program was designed to investigate the feasibility of using an aircraft-mounted Solid State Array Spectroradiometer, a RS-18 Multispectral Scanner, and several data processing/analysis techniques to map seagrass beds. The planned program implementation approach is shown in Figure 4.

In its simplest form, this approach was to identify selected training sites with styrofoam markers to saturate or increase the radiance levels in certain picture elements (pixels) of the remotely sensed data, thereby locating surface sites in the remotely sensed data; collect surface truth data to provide identification of these training sites as grass beds (type/species/depth), or bottom (sand, mud, oyster reef, etc./depth); develop statistics for each class of training site (grass bed or bottom); and use this information to perform a computer classification of each pixel of data along flight lines into the most likely class, thus producing color coded classifications of the test areas as the end product.

Functions necessary to accomplish the objectives were the acquisition of pre-mission reconnaissance information related to the test site (St. Joseph Bay, Florida), acquisition of surface truth and aircraft remotely sensed data from the site, processing and analyzing these data, documenting and evaluating the results, and preparing and submitting the project report.

2.2 TEST SITES

Several test sites from St. Andrews Bay, Florida, to the Florida Keys were considered originally. Through discussions with Dr. Richard Iverson and Dr. Gordon Thayer, the St. Joseph Bay (Figure 5) location was selected based on the following:

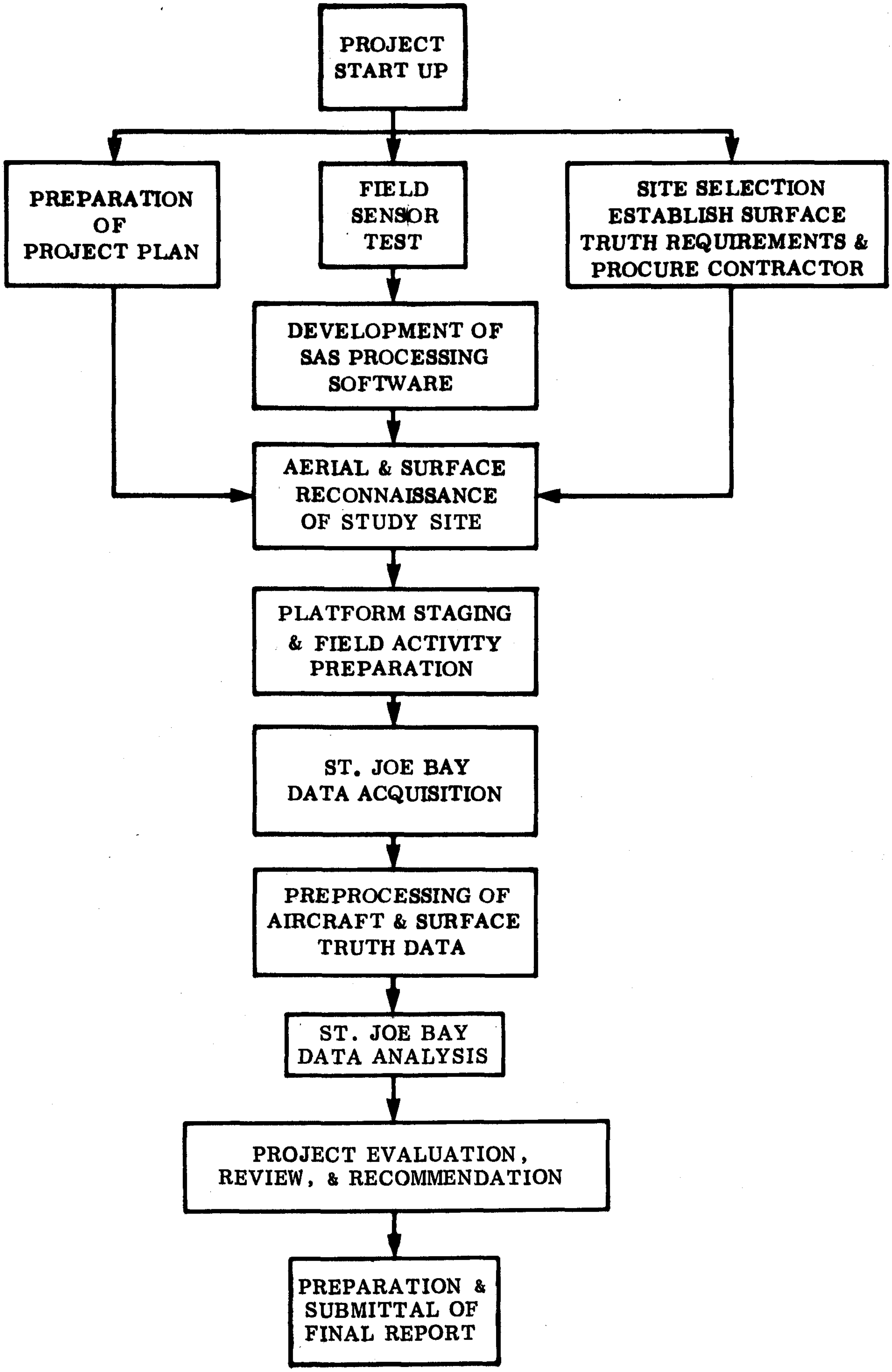


Figure 4. Approach to Program Impl m ntation

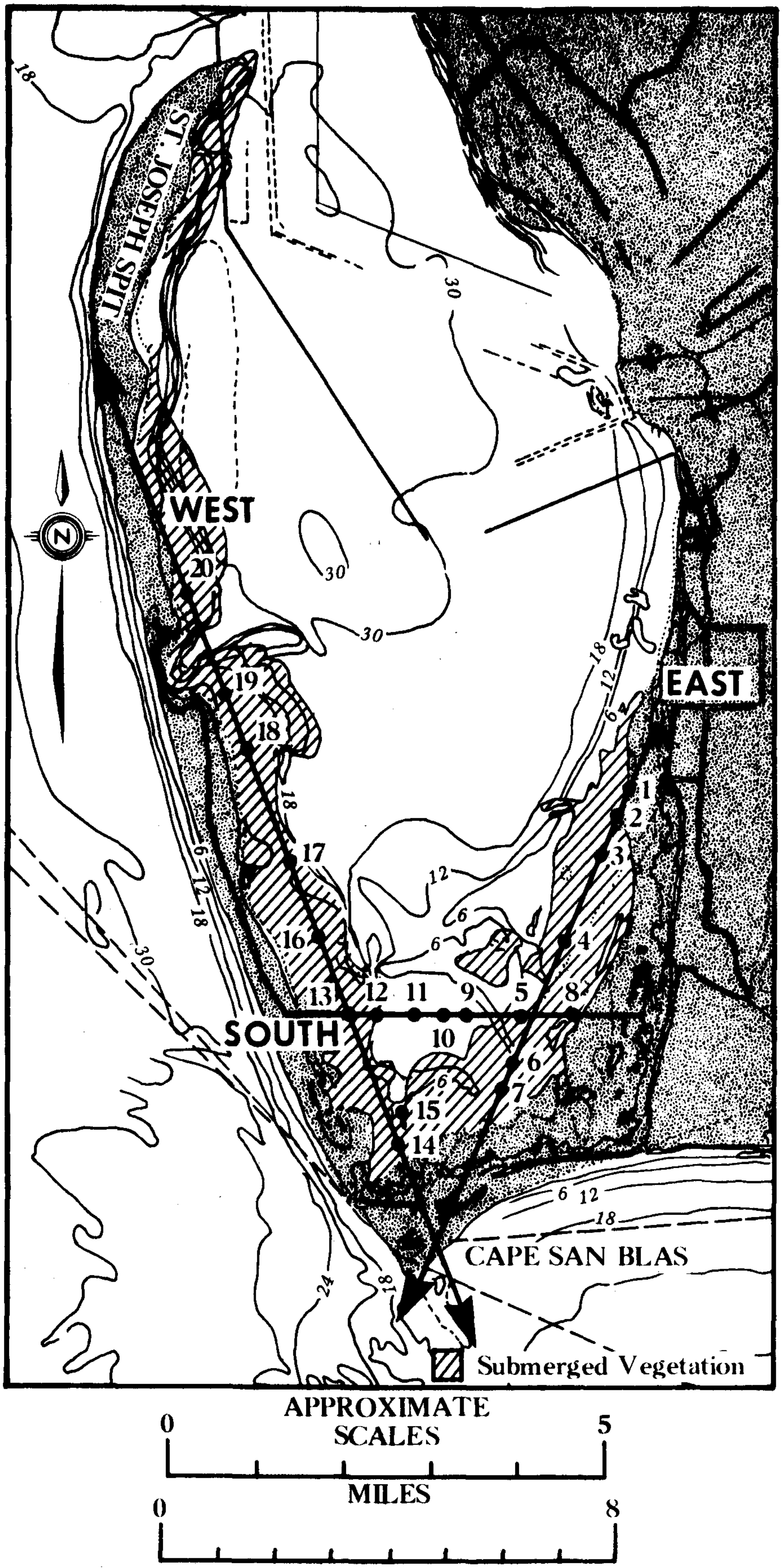


Figure 5. St. Joseph Bay Test Site

1. Data acquisition would have to be accomplished early enough to allow time to analyze the data, and document and evaluate the results by the end of the project year.

2. Test sites would contain seagrass patches 1/4 acre in size, or larger, to be used as ground truth for the pattern recognition analysis.

3. Water at the proposed sites would be free of pronounced color or turbidity effects.

4. Attention would be directed toward sites where scientific research previously had been performed and a body of information about the site was available.

5. Attention would be directed toward sites which provide reasonable field staging facilities (e.g., boat launching facilities, rental vessels, etc.).

The project was designed to characterize the fine-scale features of submerged vegetation in St. Joseph Bay, Florida. The general features of the bay, including an estimate of bottom coverage of <u>Thalassia testudium</u>, had been determined during a general survey of the near shore region of the Gulf of Mexico (McNulty, 1972) (Figure 5). St. Joseph Bay receives negligible fresh water input and contains very small populations of phytoplankton. The sediments are primarily sand or muddy sand and settle out of the water column rapidly; therefore, water clarity is usually excellent. Broad expanses of nearly monospecific stands of <u>Thalassia testudinum</u> are located around the periphery of the bay. Drift algae accumulate in portions of the bay during the spring and fall with some stands of attached macroalgae present throughout the growing season. Rental vessels and launching facilities exist on the east side of the bay and provide an excellent staging area for field work.

2.3 DATA REQUIREMENTS

Collection of surface truth data from 20 locations (Figure 5) was planned. Generally, two to three sites were selected for each unique ecological class and each pre-defined depth zone. Depth zones from the shoreline to 15 feet were in 5-foot increments. Collection of seven data parameters for non-grass locations and ten data parameters for grass locations were required at each surface truth site. The detailed information to be collected at each site is listed in the data acquisition section.

The second data type required was aircra remotely sensed data. Two sensors were used in the experiment and the data from both sensors were processed. The principal planned source of data was th State Array Spectroradiometer (SAS). Supporting data were acquired with iss camera using standard aerial color film and no haze filter, and an RS-18 Multispectral Scanner.

2.4 SENSORS

2.4.1 Solid-State Array Spectroradiometer (SAS)

2.4.1.1 Characteristics

The SAS uses a solid-state array detector to achieve a pushbroom type scan which yields both spatial and spectral data. The array detector is a 346 by 42 element CID sensor. This configuration allows the acquisition of 346 spatial samples (ground resolution elements) which are divided into 21 spectral samples (42 elements are combined by pairs) (Figure 2). The optics of the system are such that a 13.6° field-of-view is spectrally dispersed by a grating and imaged on the array. The present configuration images 4000°A on channel 1 and 6880°A on channel 21. All data samples are digitized to an 8-bit accuracy and output in a Bi-Phase L tape recorder compatible format at a rate of 300 kbs. This bit rate forces a frame rate of 3.6 frames (scans) per second. With this frame rate, the aspect ratio (ratio of length to width of a ground resolution element) is about 10.5 to 1.

2.4.1.2 Calibration

The SAS is calibrated by using an integrating sphere light source. The sphere uniformly illuminates the entire 13.6° field-of-view. This provides a quick, simple, and reliable means of calibrating the entire system simultaneously. Various neutral density filters are placed between the SAS and the sphere to provide data at different light levels which allows the computation of transfer functions for each element in the array. In the calibration process, a least squares fit equation is computed for each detector element and stored on a calibration tape. In processing the mission data tape, the count from the raw data tape is used in the appropriate transfer function equation to calculate the corresponding input radiance. Then, a standard equation is used to calculate a new count based on the input radiance. By this method, for any spectral channel, the same counts on the corrected data tape represent the same input radiance regardless of which actual element on the array obtained the data. This correction is necessary due to the fact that each element on the array is an individual detector and thus has its own transfer function.

2.4.1.3 Performance

The SAS was successfully operated on the data-gathering mission. The system performed normally within its design limitations. Analysis of the data revealed several problem areas:

1. More dynamic range was needed to accommodate the varying light levels as received from the target areas.
2. A reduction in noise level was required in order to achieve the full 8-bit data accuracy.

The walk-on sensor concept was demonstrated by the 20-minute installation and checkout time utilized.

2.4.2 RS-18

2.4.2.1 Characteristic

The RS-18 is a five channel optical/thermal infrared scanner. Originally constructed as a thermal scanner, it was modified for this project and configured with three visible (400-500 nm, 500-600 nm, and 600-700 nm) and a near infrared band (800-1100 nm). The instantaneous field of view of the scanner is 2.5 miliradians, corresponding to a spot 2.5 m across from an altitude of 1000 m. The scan width is 100°, giving a total scan of approximately 2400 m at that altitude. The signal from the scanner is recorded in a pulse code modulated format after digitization. The instrument is operated in an uncalibrated mode, so that signal level is a measure of relative radiance only within each spectral band.

Data for the investigation were acquired at an altitude of 1520 m. The picture element size was, therefore, 3.8 m, and the total scan width was 3630 m. Because the extreme angles of the scan introduce problems in analysis (geometric distortion, variation of target reflectivity, and atmospheric problems), the scan was restricted for this project to 70°, resulting in a total scan width of 2130 m.

2.4.2.2 Performance

The performance of the RS-18 during the data acquisition activities was very good. Data were of excellent quality in channels two through four, but the signal level in the first channel, centered in the blue portion of the spectrum, was very low. This was not unexpected, as the instrument uses a silicon detector which has a low sensitivity at short wave-lengths. As expected, the near infrared channel provided no information relating to the submerged vegetation, but did provide the capability for readily discriminating land and water.

2.4.3 Zeiss Camera

A nine-inch format Zeiss RMK 15/23 camera, equipped with a six-inch lens and 2A and AV filters, with standard color film SO397 was used to acquire supporting data.

2.5 DATA ACQUISITION

Selected ground truth and remotely sensed data were acquired to satisfy data requirements for mission objectives. Most of the ground truth data were acquired on 5/17/78, while the remotely sensed data were acquired on 5/18/78 and 5/19/78. This acquisition was feasible based on the stability of bottom types and grasses. Water samples, light measurement, and depth measurements were the only ground truth data collected on 5/18/78 as near as possible to the time of remotely sensed data because of the potential variation in these measurements over periods of several hours.

2.5.1 Ground Truth Data

Data were acquired at 20 locations (Figure 5). The sites were predetermined and 1.2 m x 2.4 m x 7.6 cm numbered styrofoam markers were anchored at each site. Data were collected at each site to identify indigenous seagrasses and describe respective environments. Data were collected on seagrass field acquisition forms (Appendix A) and included site identification number, date, time, photography frame number, photometry readings, site description by bottom type and percentage, description by grass species and percentage, environmental sample numbers (water and sediment), and depth. Data requirements and sampling procedures (Appendix A) were prepared and provided to data acquisition personnel for use in data collection and data recording field activities. Data were collected at 20 sites numbered SJB1 through SJB20. A sample copy of the data acquisition form is shown in Appendix A.

2.5.2 Remotely Sensed Data

2.5.2.1 Platform

The platform utilized in the experiment was the Beechcraft E-18S operated by the NASA Earth Resources Laboratory. It has two 450-horsepower Pratt and Whitney radial engines with two-blade Hamilton standard propellers. Its operational ceiling is normally 3000 m, although it may operate for as long as one hour at 3600 m.

The maximum range is as much as 1700 km, depending on mission requirements. Normal operating speed is 290 to 330 km/hr, with a true air speed capability of 200 to 330 km/hr. The aircraft is operated by a two-man flight crew, and the sensors were operated for this experiment by a two-man flight systems crew.

Navigation information was provided by an ONTRAC III VLF Navigation System, and was recorded on the flight sensor data recording system through a fixed data inserter. The recorder is a 14-track, one-inch magnetic tape recorder, Ampex AR700. The sensor data stream is digitized either within the sensor electronics or by an external analog to digital converter, and is recorded in pulse code modulated format. Direct and FM recording are also available, with 1.0 MHz and 250 KH frequency response for these two modes.

The sensor systems on the aircraft can be configured to carry one 70-mm Hasselblad camera, one Zeiss RMK 15/23 camera with a 15.24-cm focal length lens, and either the RS-18 scanner or the SAS. Because of the limitation to a single scanner, it was necessary to make separate sorties to acquire all of the required data.

2.5.2.2 Flights

A summary of the flights conducted over St. Joseph Bay is presented in Table 3. RS-18 data were collected first, followed by a second flight with the SAS. The altitude for the RS-18 flights was 1520 m, and 3050 m for the SAS flights. The first flight line was flown on May 18, 1978, at 10:32 AM EDT, but the mission was aborted since cloud shadows covered much of the target area. The weather cleared during the day, and the mission was repeated early in the afternoon. The first line was flown beginning at 1558 EDT and was completed at 1601. The second line was flown from 1603 to 1605, and the third line was flown between 1610 and 1613. The sensor operator observed that the two channels of the RS-18 saturated frequently over flight line one, so gains were reduced for the second and third lines, and the first line was flown a third time, with data being acquired between

Table 3. Summary of Remote Data Acquistion Conditions

FLIGHT LINE	RUN	DATE	START TIME (EDT)	SUN ELEVATION	SUN AZIMUTH	ξ	ACCEPTABLE DATA ACQUIRED
1	1	5/18	1032	46.8	92.6	65	NO
1	2	5/18	1558	56.8	260.4	110	YES
2	1	5/18	1603	55.5	261.4	171	YES
3	1	5/18	1610	54.2	262.4	242	YES
1	3	5/18	1617	52.7	263.5	104	YES
1	4	5/18	1749	32.5	275.4	115	NO
2	2	5/18	1756	31.2	276.1	186	NO
3	2	5/18	1802	30.0	276.7	257	NO
1	5	5/18	1808	28.7	277.4	117	NO
2	4	5/18	1814	27.4	278.0	188	NO
3	4	5/18	1820	26.1	278.7	259	NO
1	6	5/19	1041	48.8	93.6	61	YES
2	6	5/19	1047	50.1	94.4	191	YES
3	6	5/19	1052	51.4	95.3	75	YES
1	7	5/19	1059	53.0	96.3	59	YES
2	7	5/19	1105	54.3	97.3	188	YES
3	7	5/19	1109	55.1	98.0	83	YES

1617 and 1620. With all inflight indicators pointing to a successful data acquisition flight, the aircraft returned to the airport where the RS-18 was removed.

The SAS was installed and the aircraft returned to the test area the same afternoon. Data were acquired with the SAS and photographic sensors from 1749 to 1752 on flight line one, from 1756 to 1798 on flight line two, and from 1802 to 1805 on flight line three. The lines were reflown between 1808 and 1822 to insure good data acquisition in the event of a momentary sensor malfunction. Inflight indicators suggested a possible malfunction of the SAS might have resulted in total loss of data, so a second sortie was made on May 19 after further adjustment and checkout of the SAS. The lines were repeated twice, with flight line one being flown between 1041 and 1044 and between 1059 and 1103, flight line two being flown between 1047 and 1049 and between 1105 and 1107, and the third flight line being flown between 1052 and 1054 and between 1109 and 1111. No symptoms of malfunction were given by the inflight indicators.

The flight lines were designed to maximize the coverage of the benthic vegetation features as they would be observed by the sampling teams. The sampling stations with markers were planned to be close to nadir if the flight lines were flown perfectly. The lines were all flown very close to the planned lines, but deviation from the planned lines two and three resulted in the loss of several surface sample points in terms of SAS coverage. All sampling locations were included in the RS-18 coverage.

2.5.2.3 Meteorological Conditions

The first two days of the flight window were not suitable for conducting the data acquisition mission because of clouds and thunderstorms in the test area. Winds were also excessive, with velocities estimated as great as 30 knots. High wind velocities cause the sun glint contamination to be more severe than would be experienced at low wind velocities, and cause resuspension of bottom sediments, resulting in degradation of water clarity which affects the visibility of the bottom of the bay from the remote sensing platform. The winds calmed somewhat on the second day and velocities were low on the third and fourth days of the window. On the third day, the cloud cover began to dissipate, and by the afternoon of the third day, skies were almost completely clear. There were no clouds over the test area on the afternoon of the third day or any time on the fourth day of the flight window, the times at which data were acquired by the two sensors.

Sun elevation and azimuth are important considerations when collecting imaged data over water bodies. Sun glint, i.e., specular reflection of the solar disk, may be orders of magnitude greater in intensity than the light reflected from the bottom or vegetation covering the bottom of the water body. The ideal situation for remote sensing with a scanner-type sensor is for the sun to be directly in front of or behind the aircraft, and for the elevation of the sun to be less than about 55°. The sun elevation for the two days of aircraft data collection is plotted in Figures 6 and 7, and the azimuth and elevation for each of the flights are listed in Table 3. Table 3 also lists the angle between the flight line heading and the solar azimuth. Optimum values for ξ are 0° and 180°. Sun glint was a problem only on the first flight of line three, the line covering the eastern portion of the bay.

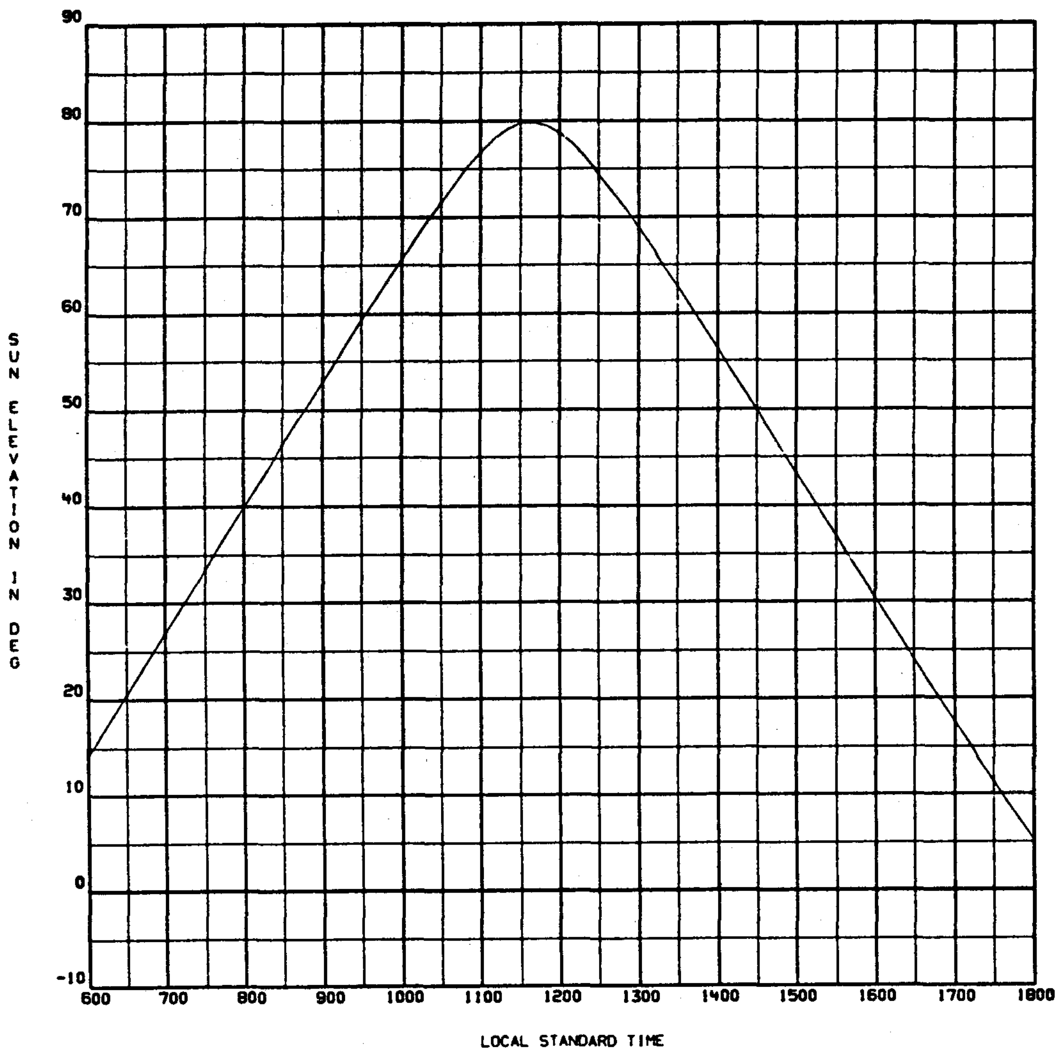


Figure 6. Sun Elevation St. Joseph Bay, Florida, (29 45.0 N 85 25.0 W) May 18, 1978

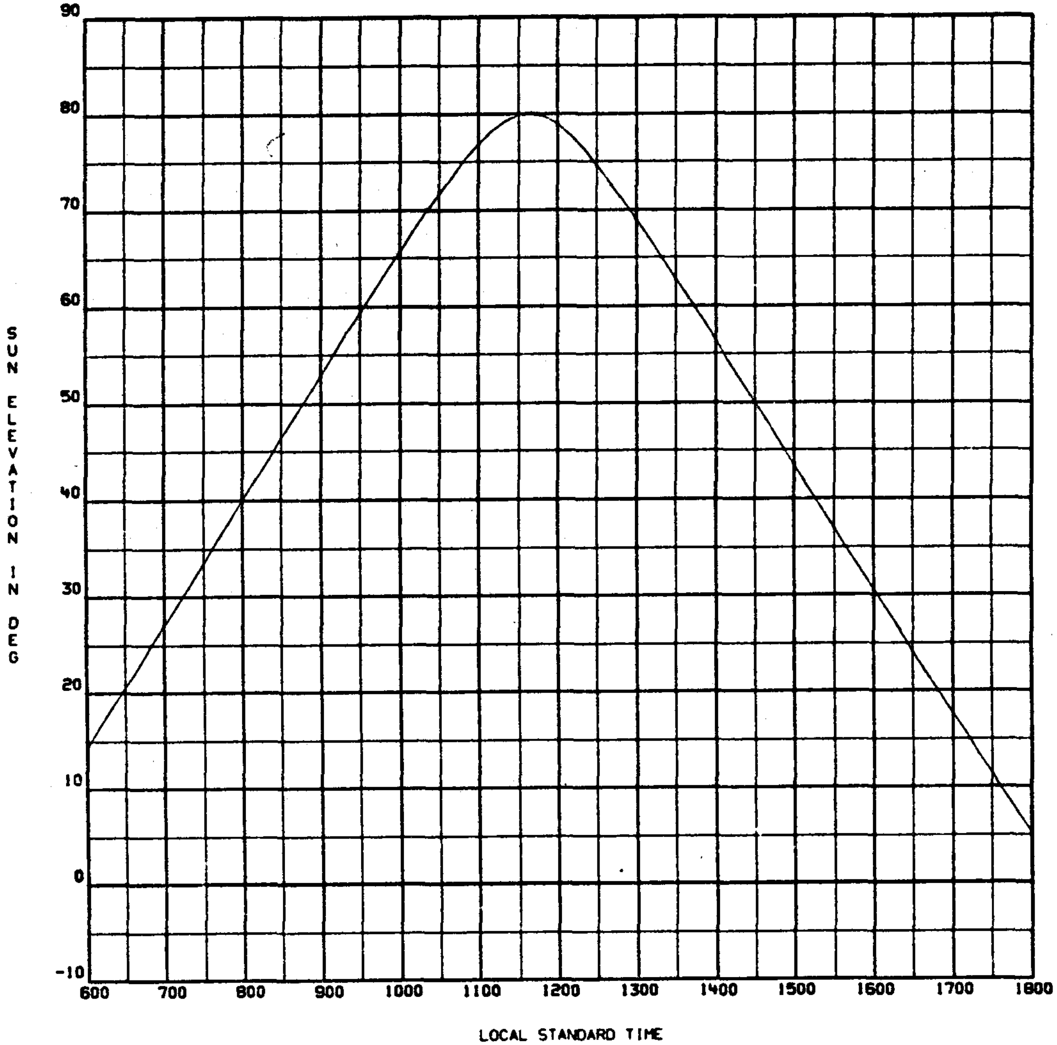


Figure 7. Sun Elevation St. Joseph Bay, Florida, (29 45.0 N 85 25.0 W) May 19, 1978

SECTION 3

DATA PROCESSING AND ANALYSIS

3.1 GROUND TRUTH PROCESSING

Vegetation samples of Thalassia testudinum plus epiphytes from 15 stations were transmitted to Dr. Gordon Thayer for chlorophyll a and phaeophytin analysis. Values shown in Table 4 are on a per gram wet weight basis and the weights were for leaf portions only. With the exception of possibly two samples, SJB7 and SJB17, all chlorophyll a and phaeophytin data are similar, indicating that chlorophyll a absorptance should vary with density of grass stand, but not on an equal weight basis from station to station.

Data from each of the 20 seagrass field acquisition forms (Appendix A) were keypunched along with the data in Table 4 and processed through a computer program which produced a summary report by station containing basic ground truth information (Appendix B). A ground truth document containing the summary report, und rwater photographs (near and far shots), and a photograph of the bottom sample for each station was prepared and used throughout the study.

3.2 PHOTOGRAPH PROCESSING AND ANALYSIS

Two cameras were flown on the data acquisition mission, a 70 mm Hasselblad with a 6-inch focal length lens loaded with a color infrared film (Kodak 2443) and equipped with a wratten #3 filter and a haze filter, and a 9-inch format Zeiss RMK 15/23 camera equipped with a 6-inch lens and 2A and AV filters and loaded with standard color film. The wratten #3 filter is an infrared blocking filter, which, when used with the SO397 infrared film, gives an excellent response in the blue portion of the spectrum and provides good mapping of submerged features.

Table 4. Chlorophyll *a* and Phaeophytin Analysis Results from Vegetation Collected in St. Joseph Bay, Florida, May 1978

SJB	Chlorophyll *a* (μg) per g sample	Phaeophytin (FO/FA)	Sample Wet weight (Diluted in 51 ml)
1	4.14	1.78	5.225
2	6.83*	1.81	4.566
3	5.30	1.90	4.417
5	3.28	1.81	4.628
6	3.06	1.79	3.114
7	10.25	1.76	3.211
8	5.93	1.88	2.042
10	3.33	1.83	2.475
12	3.09	1.82	2.520
13	3.49	1.79	2.731
14	5.24	1.83	1.241
16	4.40*	1.83	1.847
17	2.68	1.71	0.679
19	3.62	1.80	2.871
20	5.29	1.73	3.027

* Average of 2 samples

The coverage obtained with the Hasselblad was not as complete as that obtained with the large format camera, which provided a record of almost the entire scene imaged by the RS-18 scanner. The coverage obtained with the Zeiss camera on the six data flights used in subsequent analyses included nearly the entire area of the bay having significant growths of bottom vegetation. Strip mosaics of the Zeiss photography taken at 3050 m east, south and west portions of the bay are presented in Figure 8.

The images of the bay benthos are of excellent quality. It is possible to see variations in depth and density of vegetation. The aerial photography was used to extend the observations made at specific locations by divers, so that "truth" data were available for nearly the entire area imaged with the electronic sensors.

3.3 REMOTELY SENSED DATA PROCESSING

3.3.1 RS-18 Data Processing

The data from the RS-18 scanner are recorded in pulse-code modulated format on-board the aircraft. Before any computer manipulation can be performed on the data, they must be decommutated to computer-compatible form. This was performed for the segments of the data stream corresponding to the times when the aircraft was over the target areas on the flight lines and it appeared that there were no problems with the data. Line one run three, line two run one, and line three run one were decommutated. The output of the decommutation software was then processed to correct for overscan resulting from the operational characteristics of the instrument and platform. The overscan results in scan lines being separated (pixel center to center) by one-half of the instantaneous field of view at the aircraft velocitiy and altitude flown during data collection. The data were then in a form suitable for detailed processing.

Locations at which truth data were acquired by the team of divers were easily identified when the scanner data were displayed on the image processing

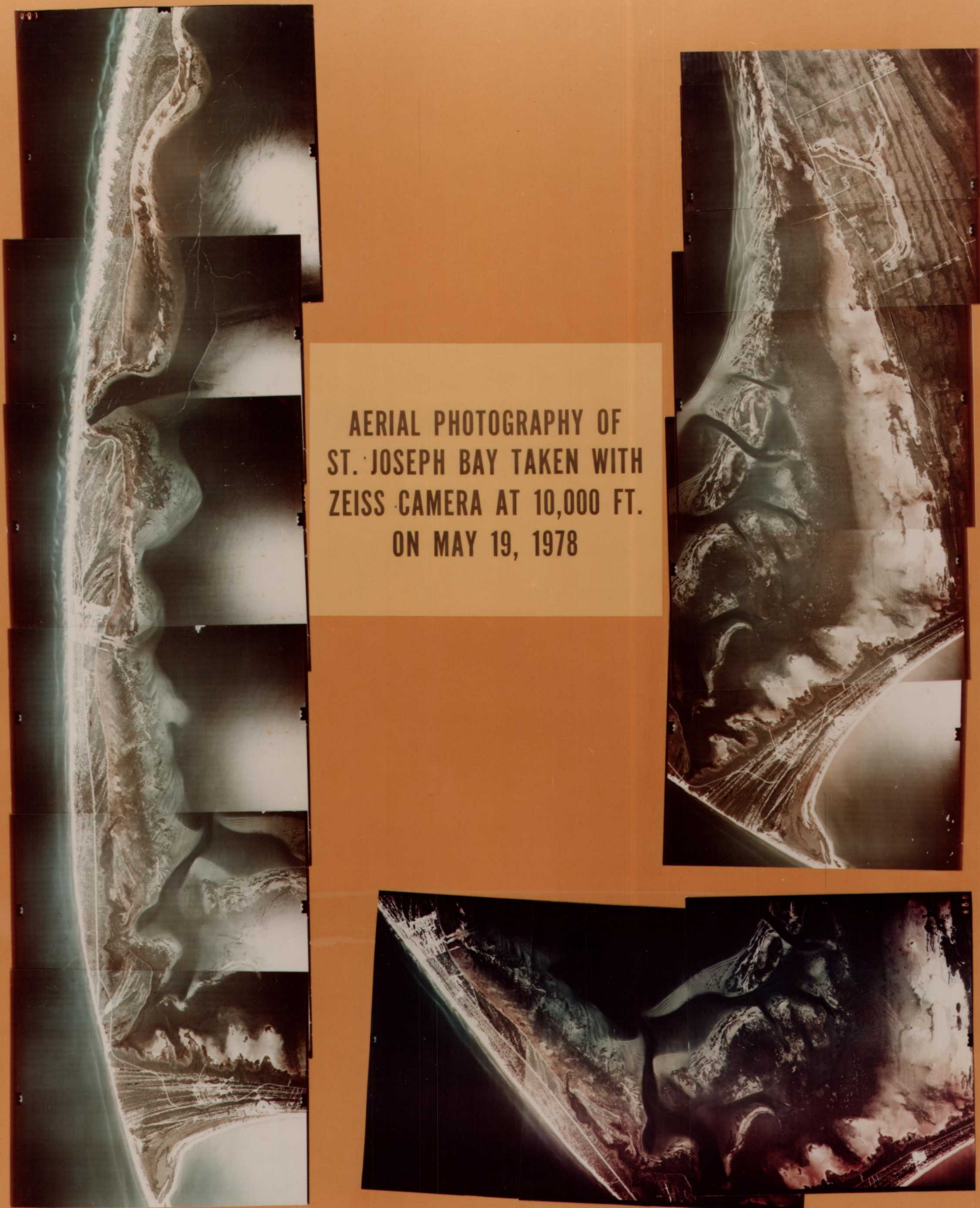


Figure 8. Aerial Photography of St. Joseph Bay Taken with Zeiss Camera at 3050 m (10,000 ft.) on May 19, 1978.

system. The 1.2 m x 2.4 m sheets of styrofoam deployed at these locations were visible at each sampling station. Training samples were selected at these locations so that spectral signatures could be associated with the truth information. When the scanner image appeared heterogeneous in the vicinity of the marker, care was taken to include only the area in the direction from the marker at which the sampling was performed, and pixels that appeared inconsistent with the truth information were eliminated. Thus, for example, if the truth data indicated a dense growth of Thalassia and there were several bright pixels in contrast to the darker pixels typical of dense benthic vegetation in the study area, they were identified as bare sand spots and excluded from the training data being developed for dense vegetation. Channels two and three, covering the green and red portions of the spectrum, were used in selecting the training fields. When a sampling station was imaged under two flight lines, training fields were selected for that location in both data sets.

After selecting the training fields, the mean count value (corresponding to the mean radiance upwelling from the field) and its standard deviation were computed for each spectral channel for each field (Table 5). Standard deviations were examined to determine whether the field was contaminated by variation of the bottom cover or if an electronic problem had occurred and caused obviously erroneous data to be recorded. If the deviation exceeded approximately 10% of the mean, the training field was again viewed, any "wild" points were eliminated, and the statistics were recomputed.

After proceeding with the analysis of the training sample statistics, it became evident that the variation of the scene as a whole was not adequately depicted by training samples located at the sampling stations. Consequently, additional training fields (Table 6) were taken in areas identified using the photography. These areas were located in deep water where the bottom was not visible and

Table 5. RS-18 Training Field Statistics

Training Field	Number of Picture Elements	CH-1		CH-2		CH-3		CH-4	
	N	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ
TF 1E	301	23.2	1.40	40.4	1.12	37.7	1.98	8.4	.50
TF 2E	132	23.9	1.72	41.7	1.36	38.3	1.08	8.1	.34
TF 3E	30	24.6	1.87	46.6	1.35	43.8	.94	8.2	.46
TF 4E	39	28.4	1.23	80.0	1.47	76.2	1.63	8.2	.56
TF 5E	212	25.2	1.59	48.5	1.30	40.4	1.28	7.9	.46
TF 6E	121	24.7	1.45	47.7	1.28	38.1	.91	8.0	.35
TF 7E	228	24.5	1.59	43.9	1.11	38.5	.97	7.7	.48
TF 8E	144	24.8	1.55	47.1	1.42	41.0	1.02	7.8	.45
TF 5S	88	24.8	1.65	50.0	1.21	42.1	1.32	8.4	.55
TF 6S	28	25.5	1.82	51.3	2.03	44.6	2.31	9.4	.57
TF 8S	79	24.6	1.54	47.2	1.07	41.5	.97	8.4	.50
TF 9S	125	31.4	1.69	102.1	2.66	97.1	3.37	8.5	.55
TF 10S	27	26.5	1.42	63.7	2.68	58.1	2.75	8.4	.50
TF 11S	178	24.8	1.65	47.4	.96	36.4	.86	7.9	.52
TF 12S	29	25.3	1.31	57.3	1.99	52.4	1.64	7.4	.79
TF 13 S	69	25.8	1.60	57.9	1.87	51.3	2.36	8.6	.73
TF 15 S	276	24.8	1.45	47.3	1.16	36.9	1.36	8.5	.68
TF 13 W	40	25.7	1.53	55.9	2.36	49.5	2.56	7.7	.45
TF 14 W	31	26.8	1.91	59.6	2.34	54.5	2.14	8.6	.48
TF 15 W	146	25.5	1.70	47.3	.89	35.9	.96	8.1	.40
TF 16 W	48	25.8	1.23	56.2	2.34	50.7	2.11	7.8	.43
TF 17 W	37	26.8	1.66	70.8	2.82	55.6	1.94	7.8	.52
TF 18 W	100	32.7	1.65	112.9	2.37	103.8	2.24	7.9	.36
TF 19 W	58	25.4	1.63	49.4	1.56	41.2	1.54	8.0	.37
TF 20 W	74	24.4	1.48	42.3	1.48	33.9	1.30	7.8	.42

Table 6. RS-18 Training Field Statistics

Training Field	Number of Picture Elements	CH-1		CH-2		CH-3		CH-4	
	N	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
TF 21	3057	25.5	1.54	41.9	1.10	31.7	1.01	8.0	.433
TF 22	2743	24.0	1.53	38.5	1.15	29.2	.98	7.8	.42
TF 23	1019	26.7	1.57	72.7	3.28	48.5	3.01	7.8	.62
TF 24	626	26.6	1.53	69.96	2.09	55.6	1.88	8.03	.360
TF 25	1030	24.9	1.57	52.9	1.35	36.6	1.03	7.73	.456
TF 26	84	25.9	1.44	60.3	1.13	43.2	.88	8.00	.219
TF 27	144	24.9	1.56	57.8	1.19	43.2	.99	7.88	.390
TF 28	567	25.2	1.59	55.1	1.54	42.7	1.34	7.99	.345

intermediate depth areas (approximately 2 to 4 m) wh re the the bottom was visible but had no significant vegetation cover.

3.3.2 SAS Data Processing

The PCM data stream from the SAS recorded on the aircraft magnetic tape was decommutated to computer-compatible form at the NASA Johnson Space Center. The calibrations were applied for each wavelength for each element of the scan line to provide a calibrated image, with the count level corresponding linearly to the radiance observed at the aircraft. The computer-compatible tapes were reformatted for direct use by the software at the Earth Resources Laboratory. This reformatting included splitting of the data into two separate files, the first containing SAS spectral channels 1 through 12 and the second containing channels 13 through 21. This was done because the ERL software is limited to 12 spectral channels. The next step in the processing was to prepare a display tape in order that training fields could be selected. The aspect ratio of the SAS pixels was approximately 10 to 1 for the flight condidtions described in Section 2.5.2, with the pixels being approximately 2.5 m wide (along scan line) and 25 m long (along flight line). To make the image more easily discernable, each scan line was repeated ten times. It was then possible to identify features in the imagery and correlate them with the aerial photography.

The sampling station markers were not readily discernible in the SAS imagery; therefore, their approximate locations were determined from correlation of features in the imagery and in aerial photography, in which the markers could be identifi d despite the 3050-m altitude of the aircraft. Most of the markers could then be found in the SAS image, although the increase in radiance level due to the white marker was equivalent only to several counts increase in the signal level. The training fields were then outlined to include the area actually sampled by the team of divers, and to exclude as much variation as possible to achieve maximum homogeneity for the training field. Training field mean count levels and standard deviations w r computed for ach field located in the data as shown in Table 7. When the standard deviation in any channel (except channel 1) of a field exceeded approximately 10 percent of the mean value for the field, the field was again displayed to determine the reason. "Wild points," due to electronic noise or variation in bottom cover, were excluded from the field and the statistics were recomputed.

Because of the narrow overall field of view of the scanner and deviation from the planned flight lines, some of the sampling locations were not included in the SAS imagery and, therefore, could not be used as training fields. This increased the need for additional training fields. In most cases, they were selected in the vicinity of the site that had been visited, using the aerial photography to verify the homogeneity of the area.

3.4 RS-18 DATA ANALYSIS

Two analysis techniques were used to process the RS-18 scanner data. The first technique used spectral information from the training fields and a discriminant function analysis computer program (Dixon, 1977) to develop algorithms to be used in a supervised pattern recognition approach. The second technique consisted of using spectral data at the training fields combined with unsupervised data groupings in a hybrid supervised - unsupervised maximum likelihood pattern recognition approach.

3.4.1 Discriminant Function Supervised Technique

The first step in this process was the grouping of the training fields into meaningful categories or classes. The initial grouping of the training fields into classes was made on uniformity of surface truth information relating to vegetation density, the presence or absence of algae, the depth of water, and uniformity of

Table 7. SAS Training Field Statistics

TRAINING FIELD	NUMBER OF PICTURE ELEMENTS	CHAPTER 1 $\bar{X}$	CHAPTER 1 σ	CHAPTER 2 $\bar{X}$	CHAPTER 2 σ	CHAPTER 3 $\bar{X}$	CHAPTER 3 σ	CHAPTER 4 $\bar{X}$	CHAPTER 4 σ
TF 20W	915	.9	1.3	42.8	2.6	84.7	4.4	114.6	6.1
TF 19W	164	5.8	3.8	54.7	4.4	85.2	6.1	98.6	3.0
SH 3NS	1525	.8	1.3	42.1	2.7	84.3	4.6	115.1	6.5
DW 2CH	1641	.1	.3	42.4	4.9	77.3	28.6	97.6	3.2
SH 50S	1167	.3	.7	42.2	3.4	82.7	4.5	114.8	6.0
TF18WE	1146	13.3	4.5	62.9	5.6	97.7	10.6	122.5	6.2
TF 17W	696	18.3	6.8	70.9	6.0	92.3	4.3	103.7	3.9
TF 16	1281	15.3	7.7	66.0	9.4	93.0	7.1	109.2	4.9
TF 13W	3560	8.5	5.9	59.3	7.4	89.4	7.7	105.4	3.5
TFD15C	1838	.4	.9	50.9	4.1	77.2	2.3	104.4	3.6
TF 14W	1504	1.2	2.0	53.9	4.0	82.8	3.1	113.7	5.3
TF 06S	1026	1.0	.1	45.8	3.3	74.2	2.6	102.4	4.4
TF 13S	2232	.1	.2	41.9	3.4	84.1	4.4	120.3	6.1
TFSE3A	958	.0	.1	28.8	3.3	71.1	3.7	102.7	5.6
TF 07E	1643	.0	.0	35.7	4.0	77.6	4.3	112.8	6.1
TF 06E	2271	.1	.1	33.5	3.5	75.1	4.2	108.9	6.3
TF 05E	1455	.0	.0	34.6	4.7	72.9	4.0	105.2	5.6
TF 08E	1812	.0	.1	33.2	4.3	71.2	30.6	94.4	3.4
TF08EA	666	.0	.0	37.1	4.8	72.9	26.9	97.1	2.8
TF 04E	497	.1	.2	39.1	3.1	84.1	4.0	124.6	5.4
TFSE3B	2005	.0	.1	28.8	3.4	71.0	4.0	102.8	5.5
TFSE2A	2112	.0	.1	27.7	4.1	69.5	3.7	99.8	5.6
TFSE1A	2051	.0	.1	24.8	3.5	66.5	3.6	94.3	5.7
Land 1	3818	16.4	5.6	62.7	5.8	94.7	9.4	111.8	5.1
Land 2	3526	31.9	8.4	90.8	21.2	139.8	37.4	159.7	33.0
Land 3	7263	12.9	7.1	61.7	8.0	92.0	7.1	106.2	4.1

Table 7. SAS Training Field Statistics (continued)

TRAINING FIELD	CHAPTER 5		CHAPTER 6		CHAPTER 7		CHAPTER 8		CHAPTER 9		CHAPTER 10	
	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ
TF 20W	138.8	6.2	153.9	4.0	163.7	3.4	190.3	3.4	215.8	3.5	200.6	3.6
TF 19W	141.6	3.4	163.8	4.0	182.6	4.6	212.6	4.0	236.5	2.2	212.7	3.5
SH 3NS	137.2	5.0	155.7	4.6	167.2	4.0	197.5	3.5	230.3	3.8	223.4	4.0
DW 2CH	127.7	3.7	146.9	3.6	161.9	3.9	189.2	3.4	210.5	3.6	188.4	2.8
SH 50S	140.9	5.0	155.9	3.9	169.1	3.8	197.1	3.3	230.2	3.9	221.8	3.7
TF18WE	182.0	11.0	229.0	13.7	244.7	9.2	243.0	6.6	250.1	5.1	218.7	5.6
TF 17W	147.7	5.4	184.0	6.8	197.9	9.3	229.0	7.7	247.3	5.6	210.0	6.2
TF 16	156.9	7.3	195.7	10.8	213.9	11.6	234.1	7.6	247.2	5.6	211.9	6.9
TF 13W	150.2	5.1	182.0	7.4	199.6	7.2	226.2	11.4	242.5	7.1	209.4	5.4
TFD15C	136.9	4.9	156.8	4.3	173.1	6.4	193.8	4.3	219.0	4.9	197.3	4.1
TF 14W	148.9	6.2	169.9	8.1	181.6	6.7	195.6	5.1	224.2	5.2	206.3	6.2
TF 06S	136.4	4.5	156.7	4.2	173.8	5.0	193.5	3.9	221.2	4.6	201.8	3.6
TF 13S	149.9	5.4	166.0	5.4	178.8	5.1	198.5	3.9	230.6	5.0	224.3	4.8
TFSE3A	125.9	4.5	139.4	3.5	149.1	3.2	175.7	2.6	205.0	3.4	196.3	3.4
TF 07E	141.6	5.5	156.3	4.2	167.8	3.8	192.7	3.4	221.3	4.3	207.2	3.7
TF 06E	141.1	5.9	158.4	4.3	174.0	3.9	198.7	4.4	228.9	4.3	217.3	4.2
TF 05E	135.7	6.1	153.0	4.7	169.6	4.2	194.1	4.3	223.1	4.4	208.1	5.4
TF 08E	127.7	4.0	149.4	3.7	165.6	4.4	196.4	5.1	221.7	4.9	200.3	3.8
TF08EA	131.5	4.5	154.6	3.7	173.3	6.3	199.3	5.0	224.8	5.5	203.5	5.0
TF 04E	159.0	5.4	183.1	5.7	197.2	5.3	207.6	3.5	243.0	4.7	243.4	4.9
TFSE3B	125.8	5.0	136.9	3.6	146.7	3.3	170.9	3.0	195.5	3.4	183.5	3.2
TFSE2A	123.9	5.1	134.7	3.8	145.0	3.2	167.3	3.2	190.7	3.4	176.7	4.0
TFSE1A	113.6	5.5	124.2	3.7	131.3	3.3	151.8	3.0	171.0	3.1	155.4	3.5
Land 1	155.7	7.5	183.5	11.4	199.7	11.2	226.2	15.9	246.9	7.1	216.9	6.0
Land 2	212.0	25.1	234.0	15.0	238.2	12.0	239.9	8.0	248.9	5.4	215.3	6.2
Land 3	147.7	6.4	174.7	9.0	189.1	8.9	219.2	14.4	244.9	7.4	213.8	6.3

Table 7. SAS Training Field Statistics (continued)

TRAINING FIELD	CHAPTER 11 $\overline{X}$	σ	CHAPTER 12 $\overline{X}$	σ	CHAPTER 13 $\overline{X}$	σ	CHAPTER 14 $\overline{X}$	σ	CHAPTER 15 $\overline{X}$	σ	CHAPTER 16 $\overline{X}$	σ
TF 20W	184.9	3.8	195.1	4.6	176.0	4.9	144.0	4.8	119.6	3.6	95.5	3.7
TF 19W	205.7	2.8	227.8	2.2	202.2	5.8	180.9	5.7	135.1	3.7	106.0	4.0
SH 3NS	217.5	4.1	238.1	4.7	222.8	4.2	187.4	4.7	145.5	4.3	116.4	4.3
DW 2CH	173.3	2.8	185.3	3.0	161.0	2.8	133.5	2.8	101.0	2.6	78.7	2.1
SH 50S	213.6	3.3	235.2	3.4	218.9	3.7	178.4	4.4	137.3	2.8	109.1	2.4
TF18WE	214.6	4.2	254.7	1.7	254.2	2.1	254.5	2.1	238.5	5.0	193.6	9.5
TF 17W	200.7	5.2	238.7	7.0	7.0	37.9	194.1	18.6	142.8	13.0	110.5	9.0
TF 16	206.4	7.8	247.9	6.8	117.3	122.8	221.6	9.7	167.2	6.9	131.8	5.9
TF 13W	205.1	5.5	244.4	6.0	172.3	91.5	192.2	6.9	144.5	5.3	113.9	4.5
TFD15C	182.7	3.5	202.0	3.5	180.3	3.1	144.4	3.5	108.6	2.9	84.4	2.6
TF 14W	190.8	4.4	211.7	4.0	205.9	3.9	182.9	5.1	146.7	5.0	116.0	4.3
TF 06S	187.4	3.3	208.5	3.2	198.3	3.6	165.7	3.3	123.9	2.2	97.2	2.7
TF 13S	212.4	5.1	222.3	5.2	204.3	5.0	172.9	7.1	139.9	6.0	110.7	5.5
TFSE3A	182.9	3.8	190.6	3.7	170.5	3.6	139.0	3.4	113.3	3.4	87.2	3.0
TF 07E	190.5	3.6	201.1	3.9	180.0	3.8	150.7	3.5	123.6	2.9	97.2	2.6
TF 06E	202.5	3.8	216.6	3.9	197.4	4.5	158.2	4.6	119.9	3.1	93.1	2.7
TF 05E	193.6	4.8	208.2	4.2	188.9	4.4	153.6	4.6	119.5	3.6	93.5	3.0
TF 08E	187.0	4.1	206.0	5.2	180.6	5.8	152.3	5.3	115.6	4.0	89.7	3.5
TF08EA	190.1	4.5	213.6	4.9	197.5	3.6	169.2	4.1	131.7	4.5	102.9	3.7
TF 04E	231.9	5.4	243.3	4.3	231.9	4.1	230.8	7.3	193.1	8.9	157.3	8.5
TFSE3B	167.9	3.0	174.9	3.1	154.7	2.9	125.2	3.1	102.1	2.7	77.7	2.2
TFSE2A	160.7	3.7	167.9	3.5	148.7	3.6	121.4	3.2	98.9	3.3	75.9	2.7
TFSE1A	140.7	3.2	145.7	3.9	129.0	3.2	104.3	3.4	85.8	3.3	65.9	3.1
Land 1	155.7	4.9	183.5	4.0	240.2	20.5	215.2	17.4	173.6	16.7	143.0	14.4
Land 2	211.6	6.1	252.6	5.0	217.1	88.4	251.4	5.7	232.7	10.8	198.3	11.2
Land 3	209.8	7.0	250.5	6.7	189.3	99.1	211.2	14.1	169.7	11.9	138.3	10.1

Table 7. SAS Training Field Statistics (continued)

TRAINING FIELD	CHAPTER 17 $\overline{X}$	CHAPTER 17 σ	CHAPTER 18 $\overline{X}$	CHAPTER 18 σ	CHAPTER 19 $\overline{X}$	CHAPTER 19 σ	CHAPTER 20 $\overline{X}$	CHAPTER 20 σ	CHAPTER 21 $\overline{X}$	CHAPTER 21 σ
TF 20W	78.9	3.1	74.8	3.6	98.1	3.6	85.0	3.3	40.7	2.2
TF 19W	86.8	3.1	85.8	2.8	100.0	2.1	85.0	3.3	47.6	2.5
TF 3NS	97.5	3.9	91.8	3.7	112.0	4.2	94.7	4.7	44.9	2.9
DW 2CH	64.3	2.1	62.8	1.9	73.9	3.3	63.7	3.5	28.1	2.3
SH 50S	91.0	2.5	85.8	2.7	104.6	3.1	88.3	2.9	42.3	2.4
TF18WE	161.8	10.7	165.6	12.5	189.4	18.2	159.1	16.0	94.3	10.8
TF 17W	90.2	8.1	91.0	8.5	104.7	9.2	93.3	8.5	53.2	4.6
TF 16	108.4	5.2	111.0	5.5	128.2	6.6	110.7	8.1	64.9	4.0
TF 13W	93.3	3.9	94.2	4.3	109.7	4.8	95.8	4.4	54.8	3.5
TF 15C	69.0	2.1	66.2	2.2	82.4	2.4	73.0	2.7	33.8	1.5
TF 14W	95.7	4.1	93.1	4.0	112.6	5.0	99.6	4.9	55.3	3.1
TF 06S	79.6	2.6	76.9	2.4	92.0	3.3	80.2	3.4	37.9	2.0
TF 13S	91.5	5.1	86.1	5.1	108.5	4.9	93.8	5.3	49.7	4.1
TFSE3A	70.6	3.0	64.7	2.8	84.2	3.1	70.2	3.0	37.2	2.7
TF 07E	79.2	2.3	75.7	2.5	95.5	3.4	81.7	2.9	42.8	2.4
TF 06E	76.1	2.6	72.2	2.5	87.8	4.0	76.9	2.8	35.4	1.7
TF 05E	76.7	2.7	73.7	3.0	89.7	4.0	79.0	3.2	37.9	1.9
TF 08E	72.6	2.9	71.6	3.1	80.9	3.9	67.4	3.7	30.5	2.5
TF08EA	84.0	3.2	82.9	3.5	96.5	4.4	81.7	4.3	40.0	3.5
TF 04E	131.8	6.8	126.4	7.8	151.8	8.4	131.5	8.0	71.2	5.6
TFSE3B	61.6	2.2	57.4	2.7	75.3	2.8	62.8	2.8	31.7	2.1
TFSE2A	61.1	2.4	58.1	2.6	75.4	3.6	63.6	3.0	32.3	1.9
TFSE1A	53.0	3.3	49.5	3.5	65.2	3.9	54.6	3.7	26.9	2.3
Land 1	119.5	12.2	122.2	13.1	152.1	18.1	144.7	19.3	95.7	13.5
Land 2	170.8	12.1	178.6	13.4	226.9	18.2	220.2	17.9	156.0	20.5
Land 3	114.6	8.2	115.7	9.1	139.5	11.7	130.7	12.0	89.0	8.4

the remotely measured upwelling light radiance. The surface information separated into eleven categories is listed in Table 8. Four depth ranges were identified; very shallow (less than 1 meter), shallow (1-2 meters), deep (2-3 meters), and very deep (greater than 3 meters). The rooted vegetation density was partitioned into four categories: bare (no appreciable Thalassia), sparse (less than 20% cover), medium (20-40% cover), and dense (greater than 40% cover). The floating algal associations were identified as dense red algae, sparse red algae, cream algae, and no algae.

The first approach was to classify data for each of the three flight lines utilizing training field data from the corresponding line. The training classes developed for each flight line along with the sample stations used in each class are shown in Table 9. Flight line 1 (west side of St. Joseph Bay), was selected as the first line to be classified because of the diversity of water depths, vegetation types and vegetation densities. Statistics used to classify the data from flight line 1 came primarily from this line with the exception of one dense grass training field which came from flight line 3 (east side of St. Joseph Bay) and was included to complete the vegetation range. Although priority was given to processing flight line 1, several of the processes required to classify flight lines 2 and 3 (south side of St. Joseph Bay) were handled in parallel with those of flight line 1, which resulted in the classification of these lines in rapid succession following the classification of flight line 1. Means and standard deviations from channels 2 and 3 for each training field for each class and line (as grouped and shown in Table 9) were input to the discriminant function program which provided an analysis on individual training field separability and produced a classification algorithm for each class ultimately identified. Training field statistics from channel 1 and channel 4 were not included based on the information gained in the initial data review cycle.

Table 8. RS-18 Discriminant Function Analysis - Sample Grouping from Surface Truth Information

	CLASS DESCRIPTION	SAMPLE STATIONS
1.	Very shallow water, no grass, no algae	4,9,18
2.	Deep water, no grass, no algae	11,15,21,22,25
3.	Shallow water, medium grass, very dense red algae	20
4.	Very Shallow water, dense grass, sparse red algae	1,2,3,7,8
5.	Shallow water, medium grass, cream algae	19
6.	Very shallow water, sparse grass, sparse red algae	17
7.	Shallow water, medium grass, sparse red algae	5,6,13,16
8.	Very shallow water, medium grass, no red algae	14
9.	Shallow, no grass, no algae	23,24
10.	Deep, no grass, no algae	26,27,28
11.	Very shallow, sparse grass, no algae	10,12

Table 9. RS-18 Discriminant Function Analysis - Classes for Flight Lines

Flight Line 1

Class Description	Sample Station	Area (hectares)
Dense Grass	2E	37.4
Medium Grass	19W	152.4
Sparse Grass	13W, 14W, 16W, 17W	468.7
Bare Bottom Visible 1	18W	210.3
Bare Bottom Visible 2	23W, 24W	254.9
Bare Bottom Visible 3	26W, 27W, 28W	220.3
Bottom Not Visible	15W, 21W, 22W, 25W	678.4
Red Algae	20W	374.5
Land	Channel 4	2112.9

Flight Line 2	Sample Station	Area (hectares)
Dense Grass	2E	24.4
Medium Grass	5S, 6S, 8S	151.3
Sparse Grass	10S, 12S, 13S	174.9
Bare Bottom Visible 1	9S	98.6
Bottom Not Visible	11S, 15S	409.3
Land	Channel 4	1

Flight Line 3	Sample Station	Area (hectares)
Dense Grass	1E, 2E, 3E, 7E	468.5
Medium Grass	5E, 6E, 8E	152.9
Sparse Grass	12S	333.4
Bare Bottom Visible 1	9S	511.1
Bottom Not Visible	11S	19.8
Land	Channel 4	460.4

The next step in the process was to utilize algorithms produced by the discriminant function software for each class and a land/water classifier to classify the RS-18 data from each flight line. A classification program was developed to check the data value from channel 4 to determine if it was a land or water pixel. If it was land (based on exceeding the count level for the water region), it was classified as land and the program proceeded to the next pixel. If it was a water pixel, then the data from channel 2 and channel 3 for the pixel were processed through classification algorithms and the pixel classified into one of the remaining classes. The resulting classifications for the three flight lines are shown in the color coded computer-generated image (Figure 9). In addition, the area for each class in each line was computed and is shown in Table 9. The most dramatic problem in the classifications is the confusion of the classes of red algae and bottom not visible. While the red algae is separable from the various densities of grass (Thalassia) and the bare bottom visible/different depth classes, it appears to have an overlapping spectral signature with the deep water (bottom not visible) and causes a significant portion of the deep water area on the west side of the bay to be classified as red algae. An additional problem is the classification of the area to the left on the east line as "Bare Bottom Visible 1." This area is primarily the deeper water and should have been classified as "Bottom Not Visible." Sunlight in this area raised the recorded radiance levels in each channel, making it appear as a shallow bare bottom area. A review of the signatures in all four channels for all training fields grouped into eight classes was made to see if further separability could be achieved by using channels 1 and 4. The graphic results shown in Figure 10 indicated that the probability of accomplishing separability this way with the current training field statistics was very low. Indeed, channel 1 and channel 4 were limited with respect to separability of any of the classes. A graphic display (Figure 11) of class means located as center points and vertical/horizontal lines depicting plus or

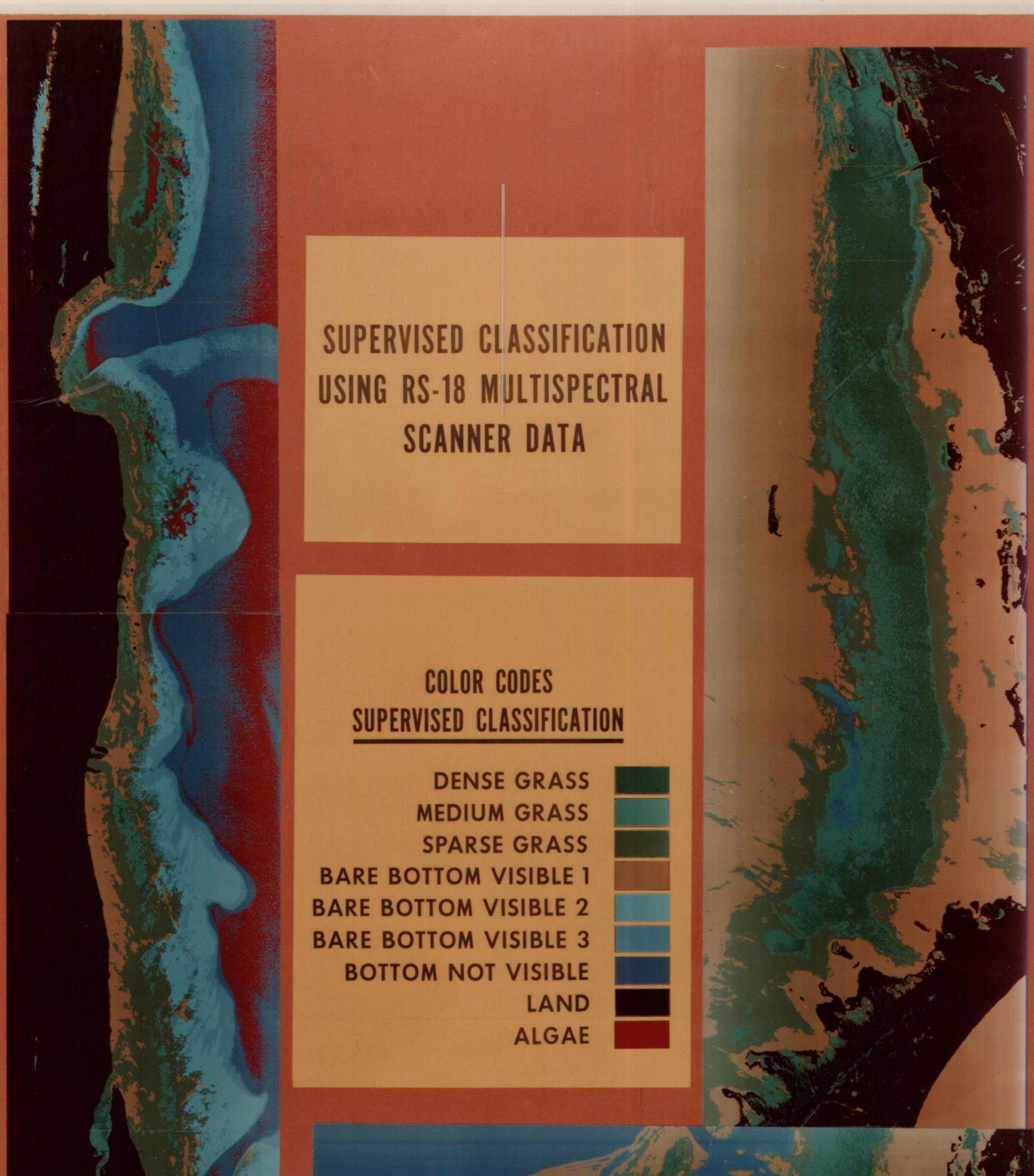


Figure 9. Supervised Classification Using RS-18 Multispectral Scanner Data

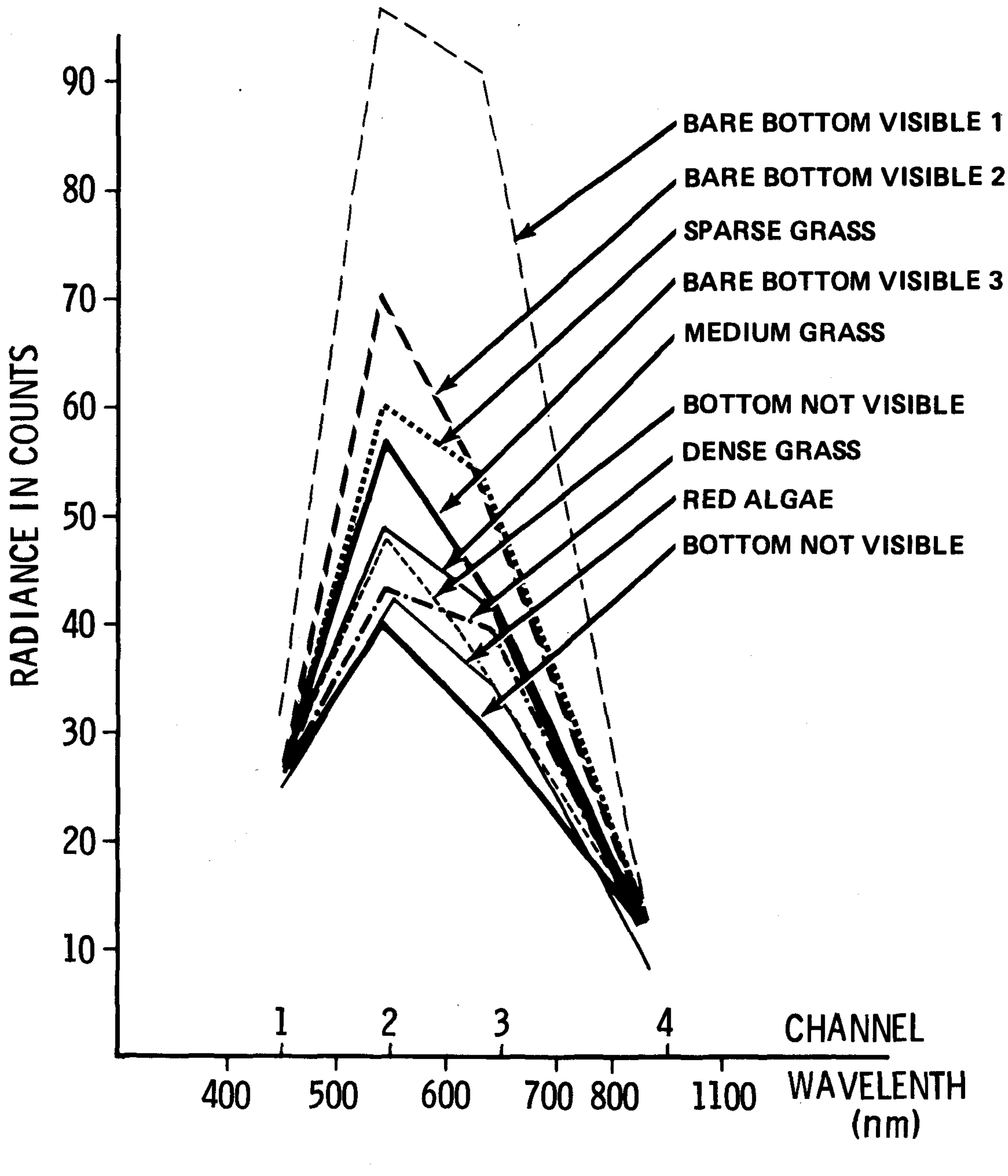


Figure 10. RS-18 Class Signature for Channels 1-4 St. Joseph Bay, May 18, 1978

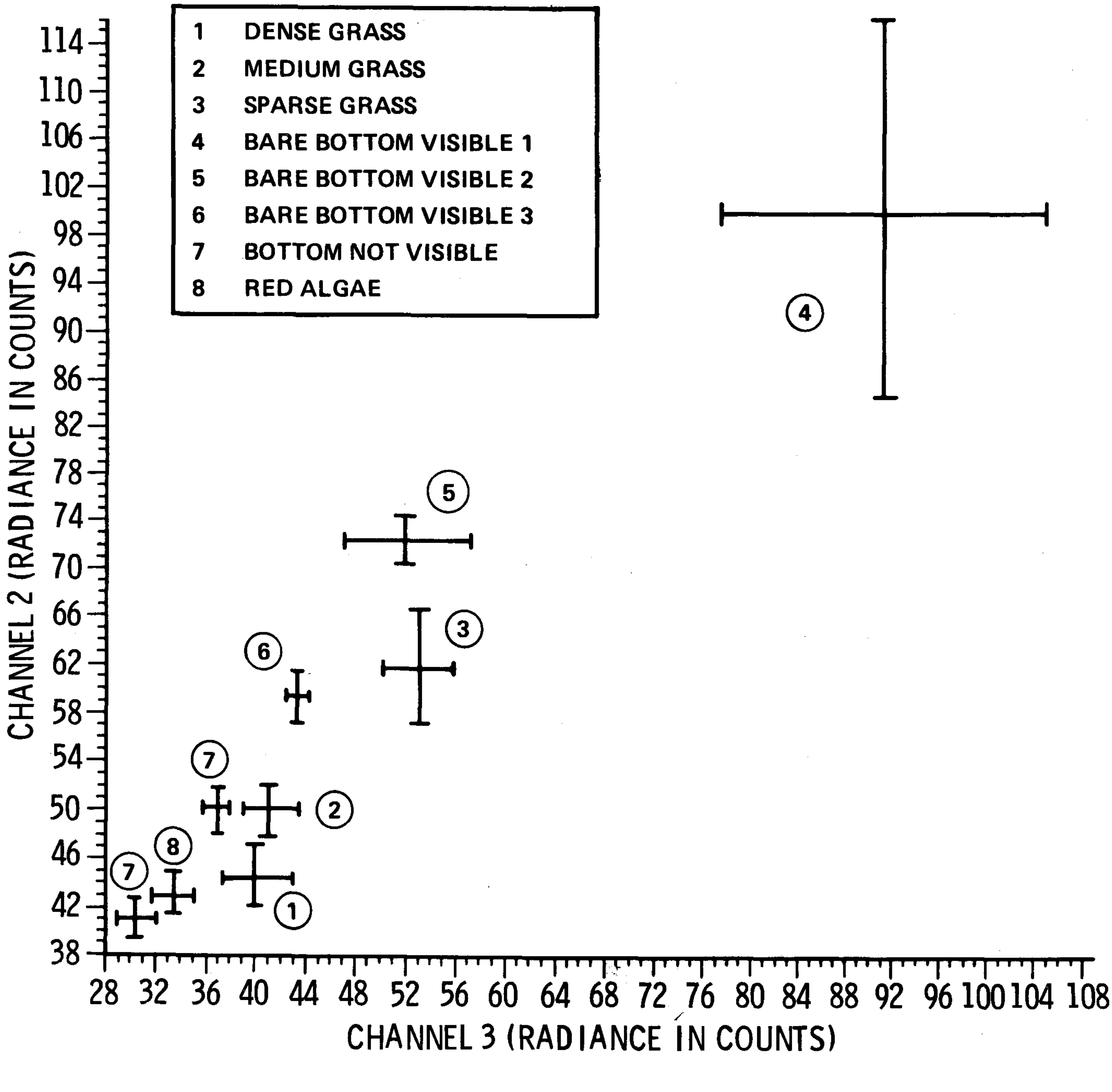


Figure 11. RS-18 Mean/Standard Deviation Class Signatures Channels 2 and 3 St. Joseph Bay, May 18, 1978

minus one standard deviation shows the red algae/deep water (bottom not visible) data overlap in a part of the data range in channels 2 and 3. Rather than expend further system time to select and refine classification statistics for the bottom not visible and red algae classes, the problem would be addressed in the hybrid supervised/unsupervised parallel effort without additional training statistics. The supervised classification effort was redirected to the area of classifying the data from each of the three flight lines using algorithms developed with class statistics from a composite of all training fields excluding the red algae training field. With this approach, more information could be gained on the importance of training field variability from one flight line to another (aircraft flight path relative to sun position, vegetation bottom cover homogeneity along flight lines, potential difference in aircraft altitude as the aircraft switched from one line to another, etc.) and its relationship to classified scene results. Answers to the question regarding whether it is better to group training fields to form composite classes to classify all lines or use classes developed from training fields from individual lines to classify the corresponding line might be resolved even though the experiment was not designed, nor the data collection optimized, to do this type of analytical work. Proceeding along this line, the compositie training field set (excluding red algae) was used in forming the classes in Table 10. The same procedure previously described was used to classify all three flight lines and th results are shown in Figure 12. Area computations by class and by flight line are shown in Table 11.

The classification shown in Figure 12 is a more uniform classification from one flight line to another, as seen by comparing the west and south lines with the corresponding lines in Figure 9. The classification in Figure 12 utilized the composite set of training fields from all lines (which better defined total scene variability to classify each line), while the classification in Figure 9 utilized training fields selected from individual lines (which did not necessarily define

Table 10. RS-18 Discriminant Function Analysis - Classes for Flight Lines 1, 2 and 3 (Composite Training Field Sets)

Class Description	Sample Station
Dense Grass	1E, 2E, 3E, 7E
Medium Grass	5E, 6E, 8E, 5S, 6S, 8S, 19W
Sparse Grass	10S, 12S, 13S, 13W, 14W, 16W, 17W
Bare Bottom Visible 1	4E, 9S, 18W
Bare Bottom Visible 2	23W, 24W
Bare Bottom Visible 3	26W, 27W, 28W
Bottom Not Visible	11S, 15S, 15W, 21W, 22W, 25W
Land	Channel 4

Table 11. RS-18 Discriminant Function Analysis - Class Areas for Flight Lines 1, 2, 3 (Composite Training Field Sets)

	Flight Line 1	Flight Line 2	Flight Line 3
Class Description	Area (hectares)	Area (hectares)	Area (hectares)
Dense Grass	112.9	40.2	454.7
Medium Grass	110.1	165.8	159.6
Sparse Grass	372.7	170.9	327.4
Bare Bottom Visible 1	278.3	98.9	513.9
Bare Bottom Visible 2	272.3	64.1	7.1
Bare Bottom Visible 3	235.9	119.2	7.8
Bottom Not Visible	1015.2	199.3	15.2
Land	2112.4	.9	460.4

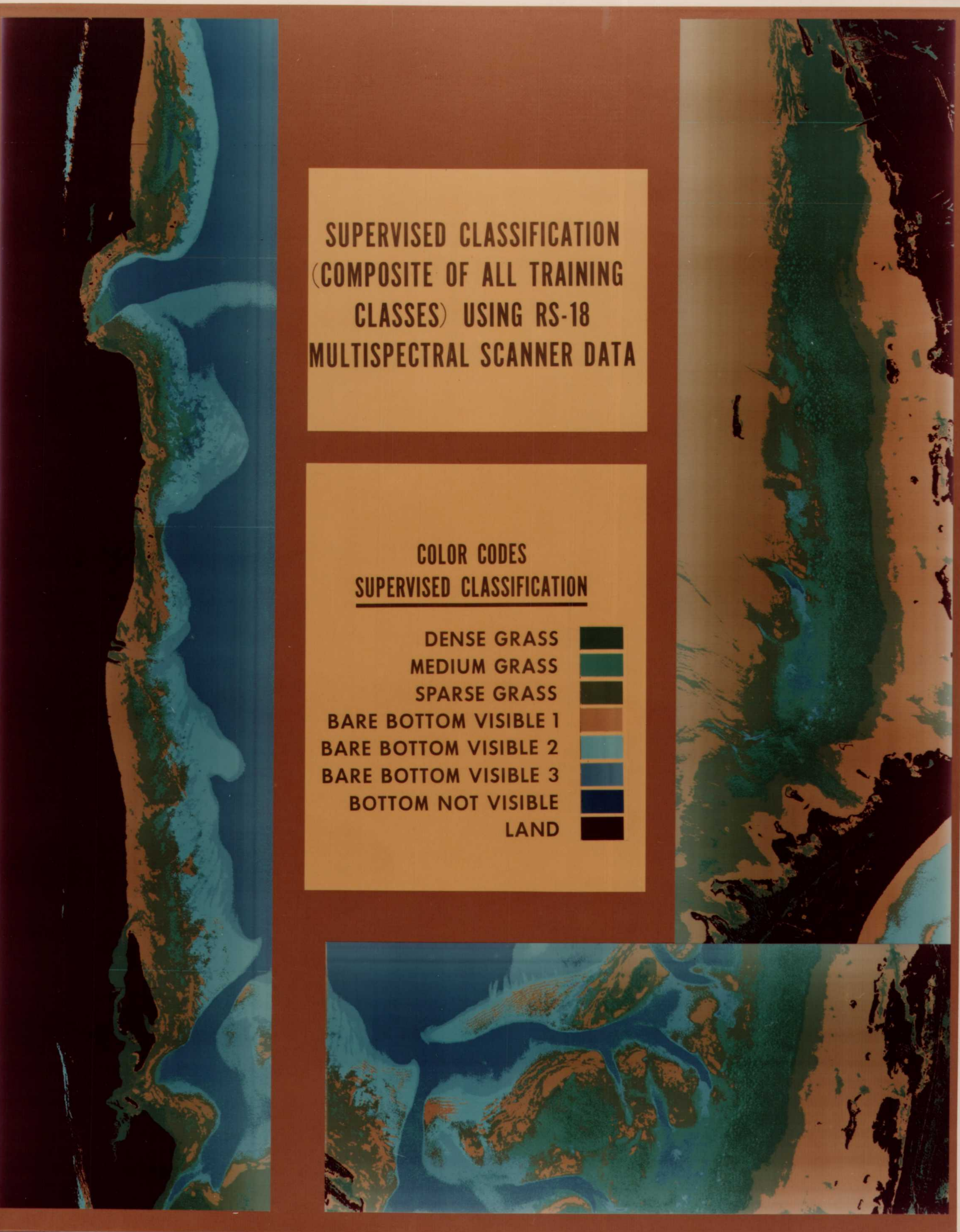


Figure 12. Supervised Classification (Composite of all Training Classes) Using RS-18 Multispectral Scanner Data.

the total scene variability within a given line) to classify each respective line. However, the classifications shown in Figure 9 provide more detail in specific areas as demonstrated in the medium grass line that runs almost the full length of the east line and the breakdown of the grass beds into medium and sparse grass in the lower section of the west line which does not appear in Figure 12. Both refinements have been observed and verified by field surveys. The best classification can be accomplished by selecting a set of training fields from each line which completely define all classes found on that line, and classifying the data from that line with only that set of training fields. However, if this is not feasible logistically, economically, time wise, etc., it has been shown that a classification with a minimum deviation in detail and improved definition of the total scene variability can be achieved using the composite training field procedure.

3.4.2 Hybrid Technique

The hybrid analysis of RS-18 data utilized statistics computed from training fields at the surface truth locations and a statistical analysis of the entire data set. The two sets of statistics were merged and the entire data set was then classified on the basis of both the specific data (surface truth related information) and the information derived from the data as a whole.

The training fields were grouped into categories similar to those developed previously, but varied in number and definition as established by a second analytical team working in parallel. The surface information was separated into twelve categories (Table 12). Three depth ranges were identified: shallow (less than 1 meter), deep (1-2 meters) and very deep (over 2 meters). The rooted vegetation density was broken into bare (no appreciable Thalassia), very sparse (less than 10% cover), sparse (10-25%), medium (25-35%) and dense (over 35%). The floating algal associations were identified as dense red algae, sparse red algae, cream algae and no algae. The categories derived from grouping the spectral

Table 12. RS-18 Hybrid Analysis - Sample Grouping from Surface Truth Information

	Class Description	Sample Station
1.	Shallow water, medium density grass, no algae	12, 14
2.	Very deep, no grass or algae	11. 15
3.	Shallow, dense grass, dense red algae	13, 16
4.	Deep, sparse grass, dense algae	17
5.	Shallow, bare	4, 9, 18
6.	Deep, medium grass, dense cream algae	19
7.	Deep,medium grass, very dense red algae	20
8.	Shallow, dense grass, sparse algae	7, 8
9.	Deep, dense grass, sparce red algae	5
10.	Shallow, sparse grass, no algae	10
11.	Shallow, dense grass, no algae	1, 2, 3
12.	Deep, medium grass, sparse red algae	6

data from the RS-18 training field statistics were based on the signal level in channels 2 and 3, and were similar, but not identical.

The final grouping was made considering both the spectral and surface data. Groupings were made separately for each of the three flight lines, and are listed in Table 13. A class corresponding to bare bottom was not developed at this stage of analysis.

The RS-18 data also were subjected to statistical analyses including nearly the entire data set using an unsupervised training field selection algorithm implemented in the computer program SEARCH. This technique scans the data set (or subset as specified) with a 6-element by 6-scan line window and locates all areas of that size which meet specified criteria for homogenity. The standard deviation and coefficient of variation are computed for each spectral channel for each 36-element area and compared with a specified criterion from homogeneity. If the standard deviation and coefficients of variation fall within the user-defined limits, the training field is automatically grouped with previously identified training fields strictly on the basis of minimum separability; i.e., the training field is grouped with the category of training fields from which it is least separable on the basis of spectral information alone. The classes represent spectrally separable combinations of depth, vegetation density, type and color (chlorotic conditions or extensive epiphytic involvement may, for example, change the color of the vegetation significantly), water color, surface reflection, and algal density and color. Land features were included in two of the flight lines and are thus included in the statistical analysis for the flight lines. No land was included in the analysis of the remaining flight line, although some land was imaged.

While the unsupervised training sample selection provided a statistical analysis of the entire data set, the supervised training field statistics represented a narrow range of well-determined surface (i.e., water depth and benthos) conditions.

Table 13. RS-18 Hybrid Analysis - Sample Grouping from Surface Truth Information and Training Sample Spectral Data

Flight Line 1	Training Samples
W1 Shallow, medium grass, no alage	12S, 14W
W2 Shallow, dense grass, dense red algae	13W, 16W
W3 Deep, sparse grass, dense algae	17W
W4 Intermediate depth, medium grass, some algae	5E, 6E, 8E, 19W
W5 Deep, medium grass, dense red algae	20W
W6 Shallow, sparse grass, no algae	10S
Flight Line 2	
S1 Shallow, medium grass	12S, 13S, 14W
S2 Deep, sparse grass	17W
S3 Shallow, very dense grass	1E, 2E, 7E
S4 Shallow, sparse grass	10S
Flight Line 3	
E1 Shallow, medium grass	12S, 14W
E2 Intermediate depth, medium grass	3E, 4E, 6E, 8E, 19W
E3 Shallow, very dense grass	1E, 2E, 7E
E4 Shallow, sparse	10S

Consequently, the two sets of data were merged to provide th hybrid (unsupervised augmented with supervised data) classification statistics. Each of the three flight lines was then classified using a maximum likihood classifier, MAXL4, on the NASA Earth Resources Laboratory image processing system. The resulting product was analyzed to identify the classes developed by SEARCH. A first cut at categorizing the SEARCH classes was made using the surface truth information and aerial photography. A second visit to the study area was made to acquire less detailed, but more geographically comprehensive, information to better identify the unsupervised classes and categorize them into meaningful groups. This grouping of classes was necessary because the unsupervised training field analysis subdivided the desired categories too finely. The object of the categorization was to identify and map density of benthic vegetation and to discriminate the dense algal communities, but the individual classes resulting from the SEARCH spectral analysis subdivided the general categories by depth, water color, surface reflection, etc. With the additional surface truth data, it was possible to override the extra information and generate the desired product, shown in Figure 13.

The final categories for each flight line, which were formed by combining training field classes and unsupervised classes along with the area in each category, are listed in Table 14. The overlap between flight lines was eliminated from the area computation, so the total figures represent the actual areas of each category of vegetation density in the surveyed portion of St. Joseph Bay.

3.5 SAS DATA ANALYSIS

The analysis techniques used to process the RS-18 data were also used to process the SAS data. The discriminant function supervised technique was a much more complex task with the SAS because of the 21 channels of data as compared to the RS-18 four-channel data set. The results of the analysis were used to some extent to direct the hybrid analysis approach into reducing the 21 channels of data to four in order to reduce the complexity of the task.

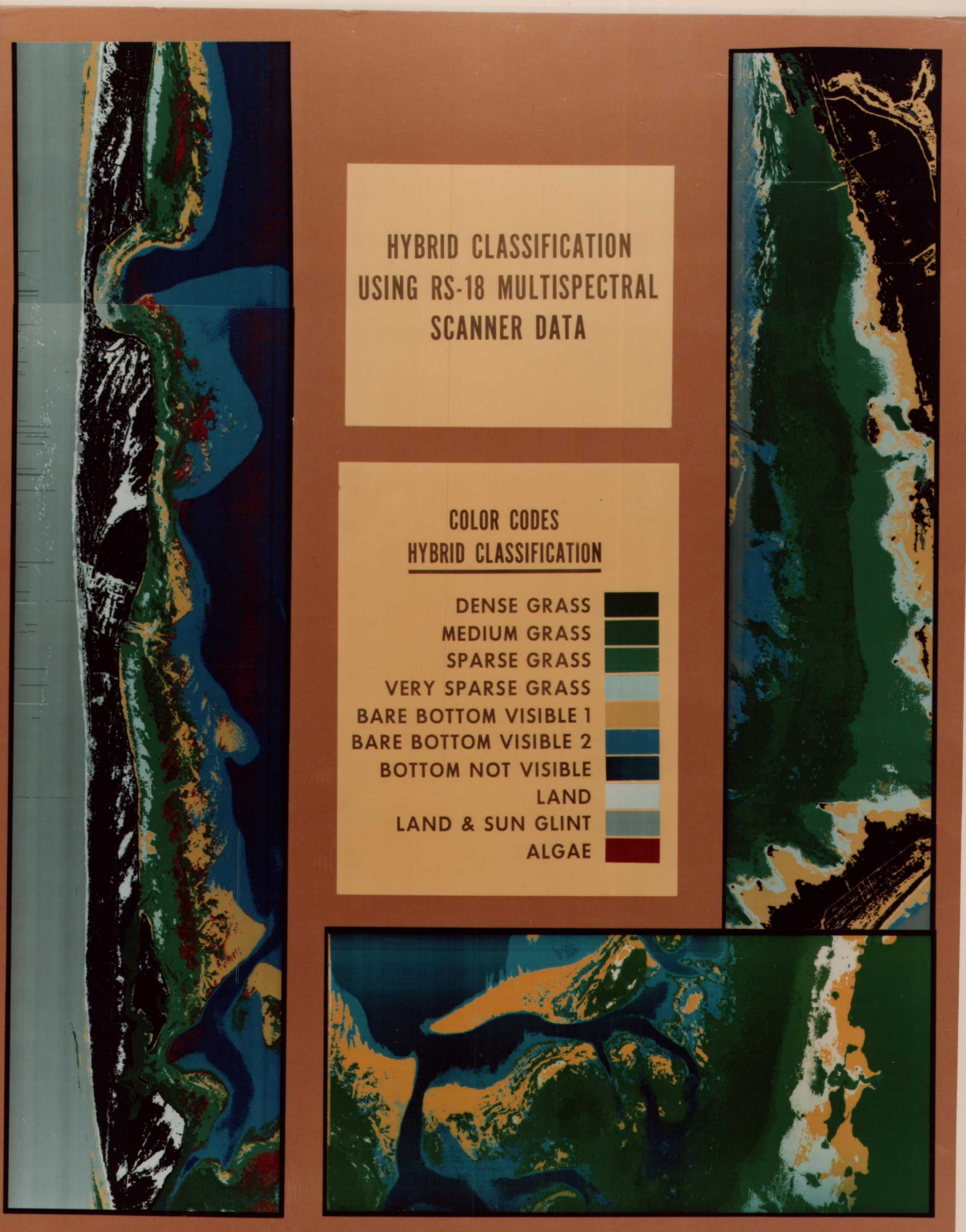


Figure 13. Hybrid Classification Using RS-18 Multispectral Scanner Data.

Table 14. RS-18 Hybrid Analysis - Classes and Areas

Flight Line 1

Class Description	Classes	Area (hectares)
Dense Grass	17,18,23,33	183.3
Medium Grass	9,27,W5	165.9
Sparse Grass	11,13,25,34,W1,W6	285.3
Bare Bottom Visible 1 (Sand shallow)	1,4,7,8,10,12,19, 21,22,28,29,30	248.5
Bare Bottom Visible 2	5,6,16	453.3
Bottom Not Visible	3,20,24	763.3
Land	2,26,31,32	2105.7
Red Algae	W2, W3, W5	244.0

Flight Line 2

Class Description	Classes	Area
Dense Grass	11, S3	55.0
Medium Grass	5,6,7,28,34,S1	229.5
Sparse Grass (deep water)	S2	9.7
Sparse Grass	10,16,24,25,S4	29.9
Very Sparse Grass	13,20,27,29,30,31	5.7
Bare Bottom Visible 1 (Sand shallow)	1,2,3,14,15,18,19 21,26,32	122.6
Bare Bottom Visible 2	8,9,12,17	173.2
Bottom Not Visible	4,22,23	232.3

Flight Line 3

Class Description	Classes	Area
Dense Grass	8,31,E3	482.4
Medium Grass	27,E2	269.9
Sparse Grass	14,40,E1,E4	339.1
Very Sparse Grass	5	133.1
Bare Bottom Visible 1	4,7,10,16,17,18,19	238.4
Bare Bottom Visible 2	15,22	53.0
Land	1,3,12,37	414.0
Severe Glint Contamination	2,6,9,11,13,20,24,28	---

3.5.1 Discriminant Function Supervised Technique

Grouping the training samples into categories was accomplished with little difficulty, using knowledge gained in the RS-18 analyses. The training samples were grouped into 9 classes shown in Table 15. Forty-five discriminant function and classification/display runs were made using various channels and combinations of channels. Two of the supervised classifications of a segment of the west flight line are shown in Figure 14. Supervised classification B used data from channels 3, 4, 9, 11, 12, 14, 20, 21 and contains significant "noise problems" (pixel by pixel variation between classes) with overall scene misclassification among the classes. Supervised classification A used data from channels 9-14 and 16-21 to form a two-channel RS-18 simulated data set. This resulted in the elimination or smoothing of the individual pixel variation between classes and improved the classification, but the misclassification problem was still quite discernable. The classification has little utility as considered from the submerged vegetation assessment standpoint but provides insight into the problems that occurred from the instrument development standpoint.

3.5.2 Hybrid Technique

The grouping procedure used with the SAS data to aggregate the training samples into categories was the same as that applied to the RS-18 data. The first phase of the grouping process, based on surface truth information alone, was only performed once. The second pass, based on the radiance data, met with severe difficulty. It was very apparent that the signal to noise ratio of the SAS data was poor, as can be seen in the tabulation of the means and standard deviations for the training sample data. After careful analysis, only ten categories could be identified; they are listed in Table 16.

The statistics for these groups were processed by the computer program SEPARATION, which selects the optimum spectral channels for discriminating the groups. The program optimizes the separability, rather than maximizing

Table 15. Discriminant Function Analysis - SAS Training Sample Grouping

Class/Description	Training Samples
1. Land	Land1, Land2, Land3
2. Dense Grass	TF07E, TFSE3A, TFSE3B, TFSE2A, TFSE1A
3. Medium Grass	TF19W, TF06S, TF06E, TF08EA, TF05E, TF08E
4. Sparse Grass	TF17W, TF16, TF13W, TF14W, TF13S
5. Bare Bottom Visible 1	TF18WE, TF04E
6. Bare Bottom Visible 2	SH3NS
7. Bare Bottom Visible 3	SH50S, TF015C
8. Bottom Not Visible	DW2CH
9. *Red Algae	TF20W

*Not used in supervised classifications.

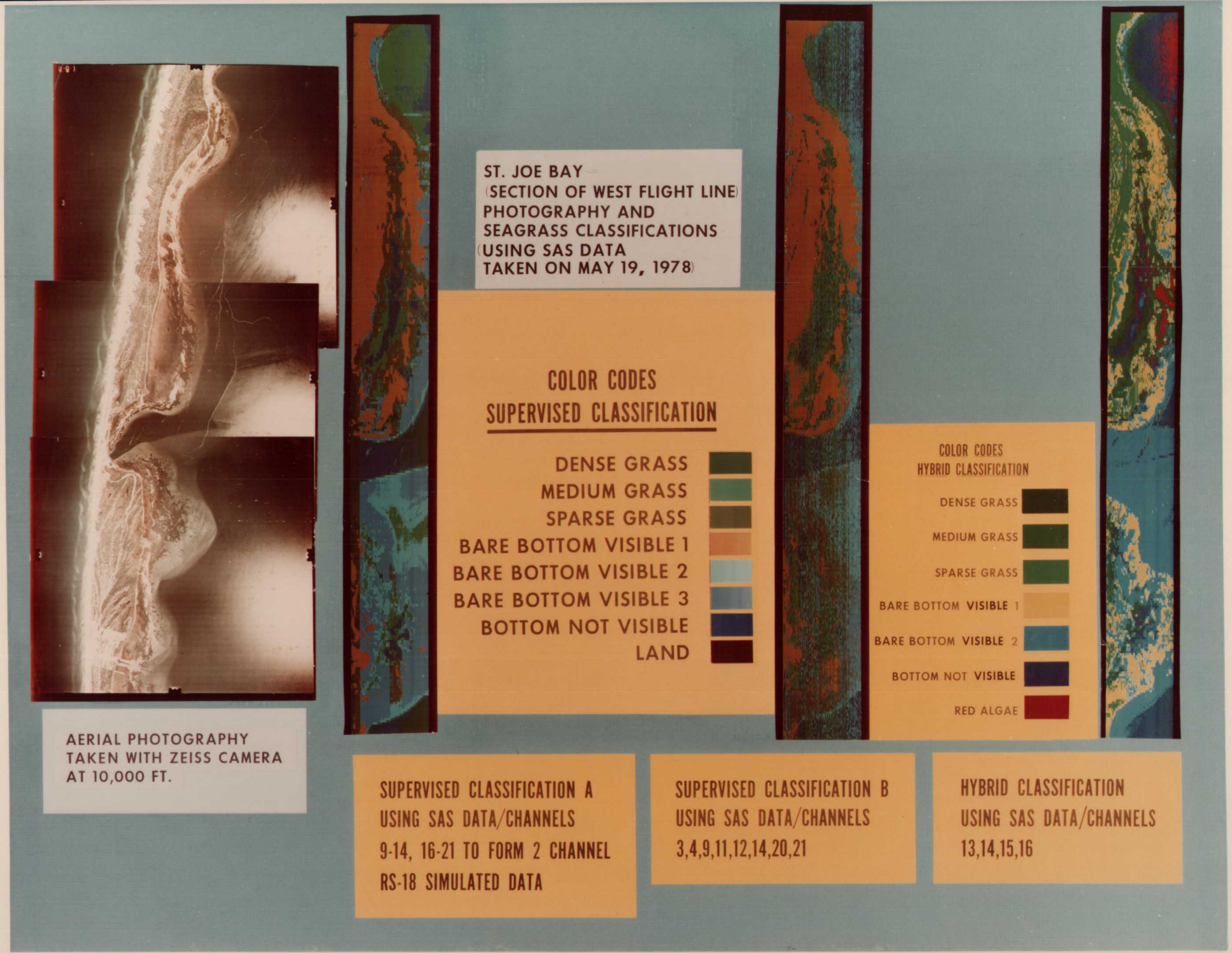


Figure 14. St. Joe Bay (Section of West Flight Line) Photography and Seagrass Classifications (Using SAS Data Taken on May 19, 1978).

Table 16. Hybrid Analysis - SAS Training Sample Grouping

CLASS	TRAINING SAMPLE
1	15
2	DW2CH*
3	20
4	5,6,7,8
5	13,14,17,19
6	1,2,3
7	18
8	4
9	SH3NS*, SAND4*
10	16

* Training samples selected from photography.

it, by saturating the measure of separability at a maximum value specified by the user. The level was set for this data well below that necessary to discriminate the bare sand bottom in shallow water from deep water with the bottom not visible and from the dense growths of vegetation, so that the channels would be optimized for discriminating the groups that were very difficult to resolve. The analysis determined that the optimum four channels were 13, 14, 15, and 16, corresponding to spectral bands centered at 572.8, 587.2, 601.6, and 616.0 nm.

Because it was again apparent that the variance represented by the training sample data was not representative of the variance of the entire data set, the unsupervised training sample selection was again performed using SEARCH. The analysis identified 31 separable categories on the western flight line (Flight line 1). These data were merged with the statistics from the supervised training sample analysis to input to the maximum likelihood classifier. The classification product was displayed, and the same technique used with the RS-18 classification was used to assign names to the categories.

The final product is displayed in Figure 14. It is readily apparent that the classification is "noisy," with pixel by pixel variation between classes. Confusion between nearly every pair of categories is evident, with the worst problem being the discrimination of dense vegetation with algae from deep water with the bottom not visible and discrimination of vegetated bottom from the bare bottom in intermediate depth water.

SECTION 4

RESULTS AND DISCUSSION

The 21-channel Solid State Array Spectroradiometer was successfully used as a remote sensor in an experiment in that the system operated without problem and obtained data. Analysis of the data utilizing two different techniques and several data set variations failed to produce a usable classification product for the user community. It was determined that several improvements are necessary before the SAS could be considered an operational sensor. These are:

1. A wider field-of-view is highly desirable so that the ground track and aircraft attitude would not be so critical.
2. A greater dynamic range for the signal is necessary in order to accommodate the varying signal levels encountered in a mission.
3. A higher data rate would lower the aspect ratio; thereby giving better ground resolution in the along-track direction.
4. Aircraft attitude data included in the SAS data stream would allow correction of the data for pointing errors.
5. An overall system noise reduction is required to achieve true 8-bit data resolution.

This information will provide design goals for an improved version of the SAS which will lead to new generation remote sensors being added to the present inventory of operational remote sensors.

The 4-channel RS-18 Multispectral Scanner provided data of excellent quality in channels 2 through 4. Classification products (Figures 9, 12, and 13) were produced utilizing the RS-18 data and ground truth training data. Evaluation of the classification accuracy in a quantitative way is a difficult problem both conceptually and technically. It is not clear how to define criteria for accuracy in an unambiguous manner, nor is it clear how such criteria would be measured. It is not generally feasible to obtain ground truth information with enough spatial resolution to provide the same information density as obtained with remote imagery. Use of photography to test the classification results introduces an unknown factor caused by subjectivity in the photointerpretation process. We have evaluated the quality of maps generated from the classification process by comparing field observations made at ground truth sample locations with corresponding benthic projections for those sample locations on the maps. Figure 15 contains an example of a classification evaluation. In the discriminant function classification, Location 1 (emergent marsh grass) was classified as a vegetated area and was not broken out as a separate class of vegetation because no training fields were selected from this area. Location 2 was found to be sparse _Thalassia_ and was classified correctly. Location 3 (classified correctly) was discolored sand with no vegetation. Location 4 was a small stand of dense _Thalassia_ located in a larger stand of sparse _Thalassia_ and was classified correctly. Location 5 was a broad band of sparse _Thalassia_ and was classified correctly. Location 6 was a band of medium density _Thalassia_, classified as sparse _Thalassia_ in the composite class discriminant function classification and as m dium density _Thalassia_ in the within line class discriminant function classification. Location 7 was a wide area of very dense, tall _Thalassia_, and Location 8 was at the edge of a bare spot in the midst of the dense _Thalassia_. Both 7 and 8 were classified correctly. Sun glint effects were particularly strong offshore on the east flight line but these effects were minimized within the analytical procedure.

In the hybrid classification, Location 1 was an area of very shallow water with marsh grasses (not _Thalassia_) and was classified as a veg tated area. It was not broken out as a separate class of vegetation because the unsupervised

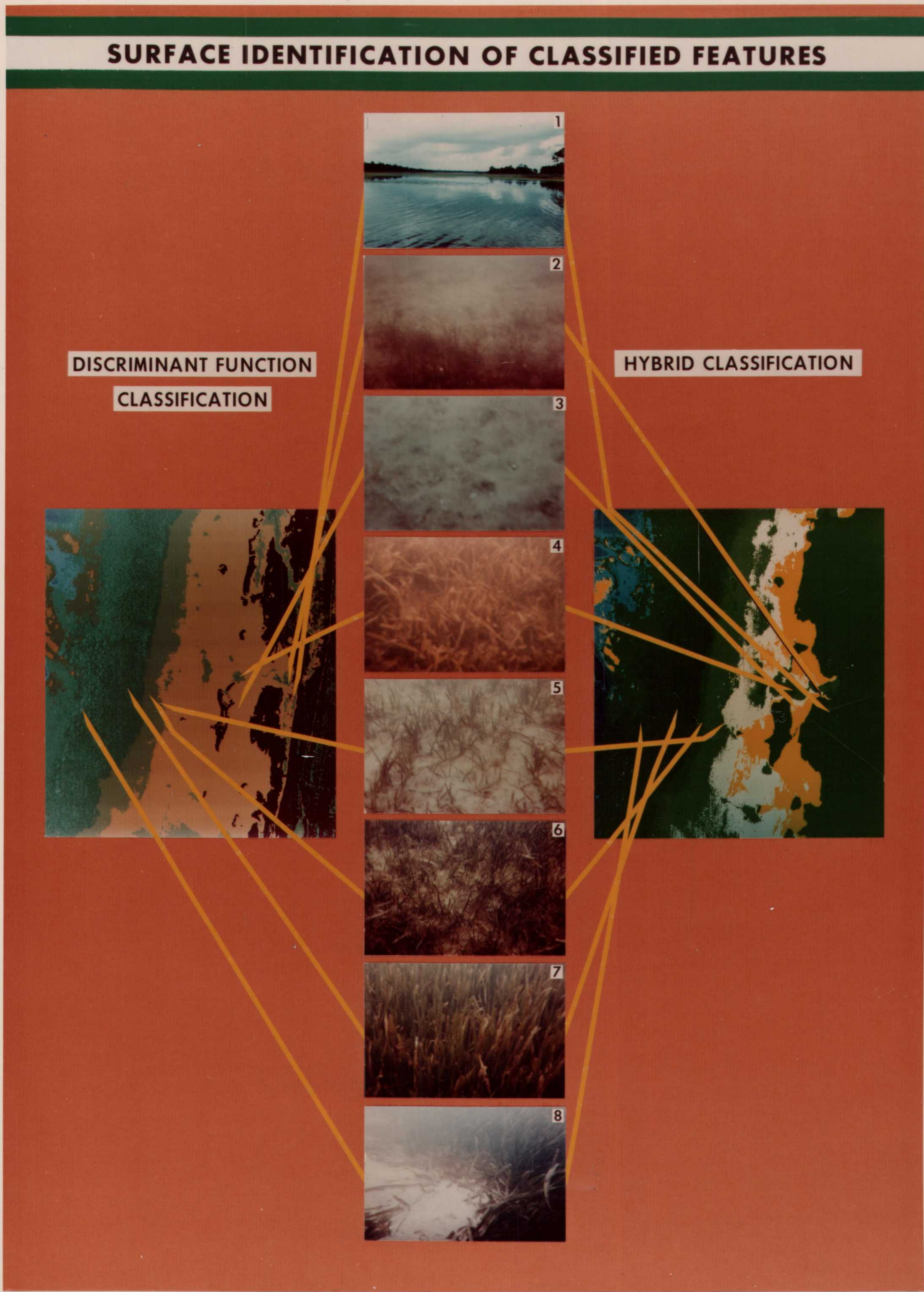


Figure 15. Surface Identification of Classified Features.

training sample selection was not performed on this part of the flight line, and given the signatures developed over the bay itself, the most likely classification of the emergent grasses was an intermediate density Thalassia. The misclassification of the land area evident in the product also results from limiting the SEARCH analysis of that flight line to the bay area. Location 2 was found to be sparse Thalassia and was classified correctly. Location 3 had no vegetation, but was discolored sand. This area was correctly classified as well. Location 4 was a small stand of dense Thalassia located in a larger stand of sparse Thalassia. Location 5 was a broad band of sparse Thalassia, Location 6 was a band of medium density Thalassia, and Location 7 was a wide area of very dense, tall Thalassia. Location 8 was at the edge of a bare spot in the midst of dense Thalassia. Locations 4 through 8 were correctly identified in the remotely sensed product.

From the qualitative comparison of the classification results with ground truth information, we conclude that the classification maps are both detailed and generally accurate. Details such as holes in the seagrass beds along the eastern shore were detected and their bare or sparsely vegetated states were correctly identified. There were some imperfections in the maps. Dense seagrass, which also contained large quantities of red algae, was confused with deep, relatively clear water where the bottom was not visible. The very turbid water in the deep channel behind Pig Island at the southwest corner of the bay was misclassified as shallow water over dense vegetation.

Seagrasses are perennial in St. Joseph Bay and local observers report that the distribution of seagrasses appears not to have changed for many years. We, therefore, compared the area of vegetated bottom observed by McNulty et al. (1972) with the area obtained from this analysis to test that idea.

The areas in each class for the three flight lines computed, using the three classification techniques, are different because the number of classes differed between classification techniques (Table 17a). The major difference between the three classification techniques was that the elimination of the red algae class in the supervised classification, using composite training fields, caused a decrease in vegetation coverage and an increase in water coverage. The composite training field classification technique was shown to be inferior to the individual line training field classification technique from the standpoint of individual line classification detail, but superior from the standpoint of class uniformity across scene segments. A general summary, which lumped all plant types, indicated reasonable agreement on vegetation coverage for the individual line training field and hybrid classification (Table 17b). There were between 2300 and 2400 hectares of vegetation covering the portion of St. Joseph Bay surveyed in this investigation. The entire bay was not included in this study since the flight lines did not include the extreme northern area along the west shoreline or the northeastern portion of the bay (Figure 5). Seagrass beds and attached algal stands are not as well developed in these areas as in the portion of the bay through which the flight line passed, but they are present. Therefore, the results of this investigation would be expected to yield a lower estimate of spatial vegetation coverage than the estimate of 2560 hectares by McNulty et al. (1972). Examination of the vegetation map of St. Joseph Bay prepared by McNulty et al. (1972) also revealed a simplification of vegetation distribution patterns, probably a consequence of problems of interpretation of aerial photography used in that investigation. The similarity in vegetation coverage observed during 1972 and during 1978 supports local impressions about the constancy of the bay macroplant community distribution.

The advantage of the multispectral scanner sensor used in this investigation over surface-based mapping or mapping from conventional aerial photography is clear in resolution of different water depths, different bottom types, and different types and densities of submerged vegetation coverage.

Table 17. Summarized Coverage Classification Results Obtained with Different Classification Techniques

Class Description	Supervised Classification (Composite Training Fields) Area (hectares)	Supervised Classification (Individual Line Training Fields) Area (hectares)	Hybrid Classification Area (hectares)
A. Subcategories			
Land	2574	2574	2520
Dense Grass	608	530	720
Medium Grass	436	457	665
Sparse Grass	871	977	664
Very Sparse Grass			139
Bare Bottom Visible 1	891	819	640
Bare Bottom Visible 2	334	255	680
Bare Bottom Visible 3	363	221	
Bottom Not Visible	1230	1108	996
Red Algae		375	244
B. General Categories			
Land	2574	2574	2520
Vegetation	1915	2339	2432
Bare Bottom Visible	1598	1295	1290
Bottom Not Visible	1230	1108	996

SECTION 5

RECOMMENDATIONS

Results from the St. Joseph Bay Experiment were quite successful. The environmental conditions of clear water, bright sandy bottom and monospecific vegetation (Thalassia) were ideal. While the capability to map monospecific benthic vegetation in a fairly stable environment using remotely sensed data and advanced computer techniques has been demonstrated, the objective of evaluating the feasibility of utilizing remotely sensed data and advanced computer techniques to map benthic vegetation (multispecies) in a more complex environment (open coastal application) remains unaccomplished.

It is recommended that the planned extension of the research in mapping benthic vegetation to a multispecies, multibottom, environment be reinitiated with new field operations and sufficient remotely sensed data backup to ensure adequate data for analysis.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Dr. Andrew Kemmerer (NMFS), Ted Sampsel (NASA-Johnson Space Center), and Gene Zetka (NASA-ERL) for their contribution in the initial program planning and successful efforts in securing program funds necessary to perform the research. Dr. Paul Fore and Dr. Howard Tait (U.S. Fish and Wildlife Service), Melissa Smith (BLM) and Dr. Donald Ekberg (NMFS/Southeast Region) served as focal points for each respective group and provided a united effort from both the technical interest and funding standpoint. In addition, Dr. Richard Iverson's (Florida State University) and Dr. Gordon Thayer's (NMFS) knowledge in the area of seagrasses and their technical assistance was drawn upon on numerous occasions. Finally, we would like to thank all personnel that worked on the project, in particular, Harry Hoff (Lockheed Electronics) for his contributions in the area of data processing and C. M. Cottle (Lockheed Electronics, JSC) for his dedicated effort which was essential to the successful operations of the SAS sensor.

REFERENCES

Dixon, W. J. (ed). 1977.
BMD Biomedical Computer Programs. Univ. Cal. Press, Los Angeles. 773 pp.

Earl, S. A. 1972.
Benthic Algae and Seagrasses, FOLIO 22 American Geographical Society, pp. 15-18.

Heck, K. L. 1976.
Community Structure and the Effects of Pollution in Sea-Grass Meadows and Adjacent Habitats, Marine Biology 35, 345-357.

Humm, H. J. 1956.
Seagrasses of the northern Gulf coast, Bull. Mar. Sci. Gulf Carib., 4, 305-308.

McNulty, J. K., W. N. Lindall, Jr., and J. E. Sykes. 1972.
Cooperative Gulf of Mexico estuarine inventory and study, Florida: Phase I, Area description. NOAA Technical Report NMFS CIRC-368. 126 pp.

Moore, D. R. 1963.
Distribution of the seagrass Thalassia testudinum, Bull. Mar, Sci. Gulf Carib., 11. 329-342.

Phillips, R. C. 1960.
Observations on the ecology and distribution of Florida seagrasses, Prof. Paper Ser., No. 2, Florida State Board Conserv. Mar. Lab., 72 pp.

Phillips, R. C. 1962.
Distribution of seagrasses in Tampa Bay, Florida, Spec. Sci. Rept. No. 6, Florida State Board Conserv., 12 pp.

Phillips, R. C. 1967.
On species of the seagrass, Halodule, in Florida, Bull. Mar. Sci., 17, 672-676.

Thayer, G. W. and R. C. Phillips. 1977.
Importance of Eelgrass Beds in Puget Sound, Marine Fisheries Review, Vol. 39, 18-22.

Thorne, R. F. 1954.
Flowering plants of the waters and shores of the Gulf of Mexico, U.S. Fish. Bull. 89, pp. 193-202.

Voss, G. L. and N. A. Voss. 1955.
An ecological study of Soldier Key, Biscayne Bay, Florida, Bull. Mar. Sci. Gulf Carib., 5, 203-229.

Zimmerman, M. S. and R. J. Livingston. 1976.
Seasonality and Physico-Chemical Ranges of Benthic Macrophytes from a North Florida Estuary (Apalachee Bay), Marine Science, Vol. 20, 33-45.

APPENDIX A

SITE ______ GRASS ☐ NO GRASS ☐

DATE [MONTH | DAY | YR] TIME ______ LOCAL

PHOTOGRAPHY

SURFACE (FRAME NO.) ______ GREY SCALE (FRAME NO.) ______ PLAN (FRAME NO.) ______

PHOTOMETRY

INCOMING RADIATION ______ SURFACE RADIATION ______ BOTTOM RADIATION ______

SITE DESCRIPTION

BOTTOM TYPE (GENERAL) ______ PERCENT OF BOTTOM COVERED BY GRASS ______

BOTTOM TYPE ______ % ______

BOTTOM TYPE ______ % ______

BOTTOM TYPE ______ % ______

BOTTOM TYPE ______ % ______

REMARKS ______

GRASS SAMPLES

SPECIES	%	SPECIATION (SAMPLE NO.)	CHLOROPHYLL (SAMPLE NO.)

ENVIRONMENTAL

SUSPENDED PARTICULATES AND ABSORPTION SPECTRUM (BOTTLE NO.) ______ BOTTOM SEDIMENT (SAMPLE NO.) ______ DEPTH (FT) ______

NFEL 02-101

DATA REQUIREMENTS AND SAMPLING PROCEDURES FOR ST. JOE BAY

Twenty sampling sites will be selected along three transects within St. Joe Bay. To identify indigenous seagrasses and desoribe respective environments, fifteen sites will represent areas with varying amounts of grass coverage and five sites will depict areas void of grass. Data requirements and sampling procedures are listed below. Sampling activities are to occur in the order listed to reduce modification of environmental conditions due to diving activities.

A. Sites With Grass

Requirement	Procedure
1. Location of Site (Predetermined)	1. Record number of styrofoam marker in "site" column.
2. Date and Time of Sample	2. Record date and local time sampling activity began in appropriate column.
3. Photographs of Site (Color Print Film)	
a. Surface	3a. Place camera just below surface and photograph top of seagrass. Record frame number in column marked surface photo.
b. Bottom Type/Grey Scale	3b. Place grey scale on bottom. Photograph contrast between grey scale and surrounding sediment. Record frame number in "grey scale" column.
c. Plan	3c. Photograph grass bed showing horizontal view including grass posture. Record frame number in "plan" column.
4. Photometry	
a. Incoming Radiation	4a. Photo cell oriented upward, record measurement of incoming radiation just below sea surface. Enter reading in column marked "incoming radiation".
b. Surface Back-radiation	4b. Photo cell oriented downward, place cell just below sea surface and record measurement of back radiation. Enter reading in "surface radiation" column.

A. Sites With Grass (Continued)

Requirement	Procedure
c. Bottom radiates	4c. Photo cell oriented upward, place cell at grass level and record measurement of radiation. Enter reading in column marked "bottom radiation".
5. Description of Site	5. Randomly place 0.25 $meter^2$ sample grid in Test Site. Within 0.25 $meter^2$ grid, determine and record the following in appropriate columns of log form.
a. Bottom Type	5a. Bottom Type 1. General characteristics - sand, mud, shell, etc. 2. Specific type of bottom material and percent of area composed of each type. 3. General remarks on bottom cover such as clean, slime, detritus, etc.
b. Vegetation	5b. Vegetation 1. Percent of area covered by grass. 2. Species of grass. 3. Percent of each species. 4. General remarks on patchiness or uniform coverage.
6. Grass Samples	
a. Speciation	6a. Collect two plants of each type for species identification. Place sample in plastic bag and label with date, time, and site number. Use plant press to preserve sample. Enter sample number in "Speciation" column.

A. Sites With Grass (Continued)

Requirement	Procedure
b. Chlorophyll Determination	6b. Collect two plants of each species for chlorophyll determination. Place one plant each in plastic bags and label with date, time, and site number. Enter sample number in "chlorophyll" column. Place grass sample in ice chest with dry ice.
7. Environmental Samples	
a. Suspended Particulates and Absorption Spectrum	7a. Collect 500 ML sample of Water one foot above seagrass. Label sample bottle with date, time, and site number. Record bottle number in column marked "suspended particulates and absorption spectrum".
b. Bottom Sediment	7b. Collect one-half pint of bottom sediment by scraping top 1/2 inch of sediment. Place sediment in plastic bag and label with date, time, and site number. Record sample number in "bottom sediment" column.
c. Water Depth	7c. Use calibrated lead line to determine water depth. Measure depth to nearest one-half foot and record in column marked "water depth".

B. Sites Without Grass

Requirement	Procedure
1. Location of Site (Predetermined)	1. Record number of styrofoam marker in "site" column.
2. Date and Time of Sample	2. Record date and local time sampling activity began in appropriate column.
3. Photographs of Site (Color Print Film)	
a. Surface	3a. Place camera just below surface and photograph bottom. Record frame number in column marked "surface photo".
b. Bottom Type/Grey Scale	3b. Place grey scale on bottom. Photograph contrast between grey scale and surrounding sediment. Record frame number in "grey scale" column.

B. Sites Without Grass (Continued)

Requirement	Procedure
c. Plan	3c. Photograph showing horizontal view of bottom. Enter frame number in column marked "plan" photo.
4. Photometry	
a. Incoming Radiation	4a. Photo cell oriented upward, record measurement of incoming radiation just below sea surface. Enter reading in column marked "incoming radiation".
b. Surface Back-radiation	4b. Photo cell oriented downward, place cell just below sea surface and record measurement of back radiation. Enter reading in "surface radiation" column.
c. Bottom Back-radiation	4c. Photo cell oriented downward, place cell one foot from bottom and record measurement of back radiation. Enter reading in column marked "bottom radiation".
5. Description of Site	5. Randomly place 0.25 meter^2 sample grid in Test Site. Within 0.25 meter^2 grid, determine and record the following in appropriate columns of log form.
a. Bottom Type	5a. Bottom Type 1. General characteristics - sand, mud, shell, etc. 2. Specific type of bottom material and percent of area composed of each type. 3. General remarks on bottom cover such as clean, slime, detritus, etc.
6. Environmental Sample	
a. Suspended Particulates and Absorption Spectrum	6a. Collect 500 ML sample of water one foot above bottom. Label sample bottle with date, time, and site number. Record bottle number in column marked "suspended particulates and absorption spectrum".

B. Sites Without Grass (Continued)

Requirement	Procedure
b. Bottom Sediment	6b. Collect one-half pint of bottom sediment by scraping top 1/2 inch of sediment. Place sediment in plastic bag and label with date, time, and site number. Record sample number in "bottom sediment" column.
c. Water Depth	6c. Use calibrated lead line to determine water depth. Measure depth to nearest one-half foot and record in column marked "water depth".

SITE SJB1 | GRASS ✓ | NO GRASS ☐

DATE 5 | 17 | 78 (MONTH DAY YR) | TIME 0940 LOCAL EDT

Film no. 51

PHOTOGRAPHY F4 @ 125

SURFACE (FRAME NO.) 4, 5, 6 | GREY SCALE (FRAME NO.) 1, 2, 3 | PLAN (FRAME NO.) 7, 8, 9

Date 5/18/78 Time 3:45 EDT

PHOTOMETRY

INCOMING RADIATION (5 D) 16.5 | SURFACE RADIATION (5.4) 21 | BOTTOM RADIATION (B 4) 20.75

A-8

SITE DESCRIPTION

BOTTOM TYPE (GENERAL) Muddy Sand | PERCENT OF BOTTOM COVERED BY GRASS 50

BOTTOM TYPE	%
mud	17.5
sand	17.5
shell hash	15
grass	50

Red Algae .5
Bryozoans 2.5

REMARKS Photos: 1st photo at indicated f stop; 2nd photo 1 f stop lower; 3rd photo 1 f stop higher
Vericolor II film

GRASS SAMPLES

SPECIES	%	SPECIATION (SAMPLE NO.)	CHLOROPHYLL (SAMPLE NO.)
Thalassia	94	SJB1	2X SJB1
Red algae	1		
Bryozoans	5		

ENVIRONMENTAL

SUSPENDED PARTICULATES AND ABSORPTION SPECTRUM (BOTTLE NO.) 31 & 32 | BOTTOM SEDIMENT (SAMPLE NO.) | DEPTH (FT) 2'

NEFL 02.101

APPENDIX B

SJB01 GRAS SITE EAST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 940 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - MUDDY SAND 50 % VEGETATION DEPTH

BOTTOM TYPE	PERCENT OF BOTTOM
VEGETATION	50.0
MUD	17.5
SAND	17.5
SHELL HASH	15.0

VEGETATION

SPECIES	PERCENT Veg	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	94.0	SJB01	SJB01	4.14	1.78	5.225
BRYOZOANS	5.0					
RED ALGAE	1.0					

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F4 @ 125	S1	4	S1	1	S1	7
F3.5 @ 125	S1	5	S1	2	S1	8
F5.6 @ 125	S1	6	S1	3	S1	9

********** THE FOLLOWING DATA WERE COLLECTED AT 1645 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
16.50		21.00	20.75

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
31	32	SJB01	2FT 0IN

SJB02 GRAS SITE EAST FLIGHT LINE FLAG

********** THE FOLLOWING DATA WERE COLLECTED AT 1020 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - MUDDY SAND 60 % VEGETATION DEPTH 3 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
VEGETATION	60.0
DEAD GRASS	20.0
MUD AND SAND	15.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	95.0	SJB02	SJB02	6.83	1.81	4.566
BRYOZOANS	5.0					

COMMENTS DEAD GRASS WAS BROWN(20%)

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F4 @ 125	S1	10	S1	13	S1	16
F3.5 @ 125	S1	11	S1	14	S1	17
F5.6 @ 125	S1	12	S1	15	S1	18

********** THE FOLLOWING DATA WERE COLLECTED AT 1700 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
16.00		22.00	21.00

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
11	12	SJB02	1FT 10IN

SJB03 GRAS SITE EAST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1035 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - MUDDY SAND 40 % VEGETATION DEPTH 2 FT 6 IN

BOTTOM TYPE	PERCENT OF BOTTOM
VEGETATION	40.0
SAND AND MUD	35.0
DEAD GRASS	15.0
SHELL HASH	10.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	85.0	SJB03	SJB03	5.30	1.90	4.417
BRYOZOANS	10.0					
RED ALGAE	5.0					

COMMENTS 15% OF BOTTOM COVERED WITH DEAD GRASS

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F5.6 @ 125	S1	19	S1	22	S1	25
F4 @ 125	S1	20	S1	23	S1	26
F8 @ 125	S1	21	S1	24	S1	27

********** THE FOLLOWING DATA WERE COLLECTED AT 1710 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
18.00		23.75	20.25

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
13	14	SJB03	2FT 4IN

COMMENTS MARKER IN 5" HOLE(30" DIAMETER)*GRASS ALL AROUND*BOTTOM SOFT

SJB04 NOGRAS SITE EAST FLIGHT LINE FLAG

********** THE FOLLOWING DATA WERE COLLECTED AT 1050 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 1 % VEGETATION DEPTH 4 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	70.0
SHELL HASH	15.0
MUD	10.0
VEGETATION	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
RED ALGAE	50.0					
ACETAEULARIA(GREEN ALGAE)	50.0					
THALASSIA	0.0					

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F8 @ 125	S1	28	S1	31	S1	34
F5.6 @ 125	S1	29	S1	32	S1	35
F11 @ 125	S1	30	S1	33	S1	36

********** THE FOLLOWING DATA WERE COLLECTED AT 1720 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
18.50		20.75	19.50

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
18	19	SJB04	2FT 2IN

COMMENTS NO GRASS FOR AT LEAST 50′ IN ALL DIRECTIONS

SJE05 GRAS SITE EAST FLIGHT LINE SOUTH FLIGHT LINE FLAG

********** THE FOLLOWING DATA WERE COLLECTED AT 1117 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 35 % VEGETATION DEPTH

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	50.0
VEGETATION	35.0
MUD	5.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	90.0	SJB05	SJB05	3.28	1.81	4.628
RED ALGAE	5.0					
ACETABULARIA(GREEN ALGAE)	5.0					

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F4 @ 125	N1	1	N1	4	N1	7
F3.5 @ 125	N1	2	N1	5	N1	8
F5.6 @ 125	N1	3	N1	6	N1	9

********** THE FOLLOWING DATA WERE COLLECTED AT 1730 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
16.80		20.63	20.00

SUSPENDED PARTICULATES 1ST BOTTLE	2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
15	16	SJB05	4FT 1IN

SJB06 GRAS SITE EAST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1130 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 25 % VEGETATION DEPTH 7 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	60.0
VEGETATION	25.0
MUD	10.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	93.0	SJB06	SJB06	3.06	1.79	3.114
RED ALGAZ	5.0					
ACETAEULARIA(GREEN ALGAE)	2.0					

COMMENTS GRASS PATCHTY*LARGE MASS(30"BY 60") DEAD GRASS 20" WEST OF MARKER

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F4 & 125	N1	10	N1	13	N1	16
F3.5 & 125	N1	11	N1	14	N1	17
F5.6 @ 125	N1	12	N1	15	N1	18

********** THE FOLLOWING DATA WERE COLLECTED AT 1750 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
15.80		19.75	

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
22	26	SJB06	6FT 1IN

COMMENTS BLACK MUD BOTTOM*DEAD LEAVES ON BOTTOM

SJB07 GRAS SITE EAST FLIGHT LINE FLAG

********** THE FOLLOWING DATA WERE COLLECTED AT 1211 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - MUDDY SAND 70 % VEGETATION DEPTH 3 FT 6 IN

BOTTOM TYPE	PERCENT OF BOTTOM
VEGETATION	70.0
DEAD GRASS	20.0
MUD AND SAND	5.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	90.0	SJB07	SJB07	10.25	1.76	3.211
BRYOZOANS	5.0					
SPONGES	5.0					

COMMENTS 20% COVERAGE OF DEAD GRASS(BROWN)*LOTS OF ANIMALS

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F5.6 @ 125	N1	19	N1	22	N1	25
F4 @ 125	N1	20	N1	23	N1	26
F8 @ 125	N1	21	N1	24	N1	27

********** THE FOLLOWING DATA WERE COLLECTED AT 1805 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
15.75		19.50	19.50

SUSPENDED PARTICULATES 1ST BOTTLE	2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
27	29	SJB07	2FT 4IN

COMMENTS DENSE GRASS

SJB08 GRAS SITE SOUTH FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1230 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 30 % VEGETATION DEPTH 3 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
VEGETATION	40.0
SAND	40.0
SHELL HASH	15.0
MUD	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	95.0	SJB08	SJB08	5.93	1.88	2.042
RED ALGAE	5.0					

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F5.6 & 125	N1	28	N1	31	N1	34
F4 & 125	N1	29	N1	32	N1	35
F8 & 125	N1	30	N1	33	N1	36

********** THE FOLLOWING DATA WERE COLLECTED AT 1740 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
16.30		20.30	20.25

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
17	20	SJB08	2FT 4IN

COMMENTS DENSE GRASS

SJB09 NOGRAS SITE SOUTH FLIGHT LINE FLAG

********** THE FOLLOWING DATA WERE COLLECTED AT 1407 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - WHITE SAND 1 % VEGETATION DEPTH 3 FT 6 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	98.0
SHELL HASH	1.0
VEGETATION	1.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
ACETABULARIA(GREEN ALGAE)	100.0					

COMMENTS BOTTOM WHITE*SEDIMENT SAMPLES BLACK DUE TO REDURED LAYER

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F11 @ 125	S2	1	S2	4	S2	7
F8 @ 125	S2	2	S2	5	S2	8
F16 @ 125	S2	3	S2	6	S2	9

********** THE FOLLOWING DATA WERE COLLECTED AT 1833 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
17.75		20.00	20.00

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
23	24	SJB09	2FT 4IN

SJB10 GRAS SITE SOUTH FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1420 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - WHITE SAND 15 % VEGETATION DEPTH 1 FT 6 IN

BOTTOM TYPE	PERCENT OF BOTTOM
MUSSEL BEDS	60.0
SAND	25.0
VEGETATION	15.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	100.0	SJB10	SJB10	3.33	1.83	2.475

COMMENTS GRASS PATCHY*PATCHY MUSSEL BEDS ABOUT 3" IN DIAMETER

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F8 @ 125	S2	10	S2	13	S2	16
F5.6 @ 125	S2	11	S2	14	S2	17
F11 @ 125	S2	12	S2	15	S2	18

********** THE FOLLOWING DATA WERE COLLECTED AT 1840 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
16.75		20.00	20.00

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
21	25	SJB10	1FT 3IN

COMMENTS SPARSE GRASS

SJB11 NOGRAS SITE SOUTH FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1434 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 0 % VEGETATION DEPTH 9 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	90.0
SHELL HASH	10.0

COMMENTS SAND SURFACE - 70% LIGHT - 30% DARK

	PHOTOGRAPHY SURFACE		GREY SCALE		PLAN	
CAMERA SETTING	FILM	FRAME	FILM	FRAME	FILM	FRAME
F4 @ 125	S2	19	S2	22	S2	25
F3.5 @ 125	S2	20	S2	23	S2	26
F5.6 @ 125	S2	21	S2	24	S2	27

********** THE FOLLOWING DATA WERE COLLECTED AT 1849 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
15.00		20.25	

SUSPENDED PARTICULATES 1ST BOTTLE	2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
30	28	SJB11	9FT 4IN

COMMENTS DEEP WATER

SJB12 GRAS SITE SOUTH FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1453 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - MUSSELS AND SHELL HASH 25 % VEGETATION DEPTH 4 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
MUSSELS	50.0
VEGETATION	25.0
SHELL HASH	15.0
SAND	10.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	100.0	SJB12	SJB12	3.09	1.82	2.520

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F4 @ 125	S2	28	S2	31	N2	1
F3.5 @ 125	S2	29	S2	32	N2	2
F5.6 @ 125	S2	30	S2	33	N2	3

********** THE FOLLOWING DATA WERE COLLECTED AT 1855 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
16.00		19.33	20.00

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
45	46	SJB12	2FT 8IN

SJB13 GRAS SITE SOUTH FLIGHT LINE WEST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1515 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 45 % VEGETATION DEPTH

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	50.0
VEGETATION	45.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	66.7	SJB13	SJB13	3.49	1.79	2.731
RED ALGAE	33.3					

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F2.8 @ 125	N2	4	N2	7	N2	10
F2.5 @ 125	N2	5	N2	8	N2	11
F3.5 @ 125	N2	6	N2	9	N2	12

********** THE FOLLOWING DATA WERE COLLECTED AT 1150 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
	15.50	22.00	21.25

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
33	34	SJB13	3FT 2IN

SJB14 GRAS SITE WEST FLIGHT LINE FLAG

********** THE FOLLOWING DATA WERE COLLECTED AT 1540 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 20 % VEGETATION DEPTH 2 FT 6 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	60.0
VEGETATION	30.0
MUSSELS	10.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	66.7	SJB14	SJB14	5.24	1.83	1.241
SEA SQUIRTS	33.3					

COMMENTS THALASSIA EVENLY DISTRIBUTED

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F2.8 @ 125	N2	13	N2	16	N2	19
F2.5 @ 125	N2	14	N2	17	N2	20
F3.5 @ 125	N2	15	N2	18	N2	21

********** THE FOLLOWING DATA WERE COLLECTED AT 1906 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
15.75		19.00	19.50

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
5	6	SJB14	2FT 3IN

COMMENTS MEDIUM GRASS

SJB15 NOGRAS SITE WEST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1845 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 0 % VEGETATION DEPTH

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	80.0
SHELL HASH	20.0

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM FRAME	GREY SCALE FILM FRAME	PLAN FILM FRAME
STROBE		N3 35	
STROBE		N3 36	
STROBE		N3 37	

********** THE FOLLOWING DATA WERE COLLECTED AT 1914 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
15.00		19.30	

SUSPENDED PARTICULATES 1ST BOTTLE	2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
3	4	SJB15	18FT 6IN

SJB16 GRAS SITE WEST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1630 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 45 % VEGETATION DEPTH 3 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	50.0
VEGETATION	45.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	66.7	SJB16	SJB16	4.40	1.33	1.847
RED ALGAE	33.3					

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F2.5 @ 125	N2	22	N2	25	N2	28
F1.2 @ 125	N2	23	N2	26	N2	29
F2.8 @ 125	N2	24	N2	27	N2	30

********** THE FOLLOWING DATA WERE COLLECTED AT 1135 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
	16.00	22.00	21.50

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
35	36	SJB16	2FT 6IN

SJB17 GRAS SITE WEST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1643 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 25 % VEGETATION DEPTH 7 FT 6 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	70.0
VEGETATION	25.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
THALASSIA	60.0	SJB17	SJB17	2.68	1.71	0.679
ALGAE	40.0					

COMMENTS PATCHY SEAGRASS

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F2.5 @ 125	N2	31	N2	34	N3	1
F1.2 @ 125	N2	32	N2	35	N3	2
F2.8 @ 125	N2	33	N2	36	N3	3

B-18

********** THE FOLLOWING DATA WERE COLLECTED AT 1120 EDT ON MAY 16,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
	16.00	21.00	19.75

SUSPENDED PARTICULATES 1ST BOTTLE	2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
37	38	SJB17	5FT 7IN

SJB18 NOGRAS SITE WEST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1704 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 0 % VEGETATION DEPTH 4 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
SAND	100.0

	PHOTOGRAPHY SURFACE		GREY SCALE		PLAN	
CAMERA SETTING	FILM	FRAME	FILM	FRAME	FILM	FRAME
F5.6 @ 125	N3	8	N3	11	N3	14
F4 @ 125	N3	9	N3	12	N3	15
F8 @ 125	N3	10	N3	13	N3	16

********** THE FOLLOWING DATA WERE COLLECTED AT 1115 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
	17.75	21.75	20.25

SUSPENDED PARTICULATES 1ST BOTTLE	2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
39	40	SJB18	3FT 6IN

SJB19 GRAS SITE WEST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1722 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - SAND 60 % VEGETATION DEPTH 5 FT 0 IN

BOTTOM TYPE	PERCENT OF BOTTOM
VEGETATION	60.0
SAND	40.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
ALGAE	60.0					
THALASSIA	40.0	SJB19	SJB19	3.62	1.80	2.871

COMMENTS GRASS VERY PATCHY*ALGAE IS LIGHT CREAM COLOR

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F2.8 @ 125	N3	17	N3	20	N3	23
F2.5 @ 125	N3	18	N3	21	N3	24
F3.5 @ 125	N3	19	N3	22	N3	25

********** THE FOLLOWING DATA WERE COLLECTED AT 1055 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
	15.00	22.00	21.75

SUSPENDED PARTICULATES 1ST BOTTLE	2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
41	42	SJB19	5FT 0IN

SJB20 GRAS SITE WEST FLIGHT LINE

********** THE FOLLOWING DATA WERE COLLECTED AT 1740 EDT ON MAY 17,1978 **********

GENERAL BOTTOM TYPE - VEGETATION 70 % VEGETATION DEPTH 5 FT 6 IN

BOTTOM TYPE	PERCENT OF BOTTOM
VEGETATION	70.0
SAND	25.0
SHELL HASH	5.0

VEGETATION

SPECIES	PERCENT	SPECIATION SAMPLE NO.	CHLOROPHYLL SAMPLE NO.	CHLOROPHYLL-A (UG/G)	PHAEOPHYTIN (FO/FA)	WET WEIGHT
RED ALGAE	70.0					
THALASSIA	30.0	SJB20	SJB20	5.29	1.73	3.027

COMMENTS ALGAE IS DARK RED

PHOTOGRAPHY

CAMERA SETTING	SURFACE FILM	SURFACE FRAME	GREY SCALE FILM	GREY SCALE FRAME	PLAN FILM	PLAN FRAME
F2.5 @ 60	N3	26	N3	29	N3	32
F2.5 @ 125	N3	27	N3	30	N3	33
F4 @ 125	N3	28	N3	31	N3	34

********** THE FOLLOWING DATA WERE COLLECTED AT 1045 EDT ON MAY 18,1978 **********

PHOTOMETRY

SURFACE DOWN	BOTTOM DOWN	SURFACE UP	BOTTOM UP
	15.75	21.50	21.00

SUSPENDED PARTICULATES 1ST BOTTLE	SUSPENDED PARTICULATES 2ND BOTTLE	BOTTOM SEDIMENT SAMPLE NO.	DEPTH
43	44	SJB20	5FT 4IN

COMMENTS DEEP WATER*SECCHI DEPTH 11'