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DEVELOPMENT AND APPLICATION OF OPERATIONAL TECHNIQUES FOR THE INVENTORY AND MONITORING OF RESOURCES AND USES FOR THE TEXAS COASTAL ZONE

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16 Abstract

The development of techniques for interpretation of LANDSAT images and and the development of a modified land use classification scheme constitute the most significant contribution during the second quarter

The image interpretation procedure now adopted for this investigation is initiated by photographically enlarging a black and white, 1 1,000,000 scale transparency of LANDSAT Band 7 to a scale of 1 125,000 The film enlargements are then used to prepare a map base by transferring water boundaries and other easily distinguishable features to a mylar film Additional information is added to the mylar base from a false color composite and single bands using a Zoom Transfer Scope The line boundary map is then interpreted to fit the Level II, Land Use Classification Scheme that was modified to be consistent with investigation priorities.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1 0 INTRODUCTION

1.1 Scope And Purpose Of Report

This progress report covers activities during the second three months, August 25, through November 25, 1975, for LANDSAT Investigation #23790 This investigation is funded for 19 months to develop techniques in Texas state agencies for using LANDSAT data to inventory and monitor coastal resources and uses. The General Land Office (GLO) is the Texas agency coordinating this investigation Other participating agencies are the Bureau of Economic Geology (BEG), Texas Water Development Board (TWDB), and Texas Parks and Wildlife Department (TPWD)

1 2 Summary Of Work Performed

During the second reporting period most of the accomplishments have dealt with the development and implementation of techniques for extracting information from LANDSAT data Some progress has also been made in the design of the data acquisition component of the LANDSAT-based monitoring system and in the coordination of this project with state programs such as the Texas Natural Resources Information System (TNRIS) Task Force

Specific accomplishments for the second quarter have been 1) to survey existing literature for techniques to interpret LANDSAT data, 2) to update the BEG Coastal Atlas as a regional base for the Texas coast, 3) to evaluate and select interim techniques for interpreting LANDSAT images, 4) to develop a modified Anderson's classification scheme consistent with investigation priorities, 5) to refine interim ADP techniques for classification of LANDSAT tapes, and 6) to re-evaluate scheduling alternatives for completing the investigation

2 0 PROBLEMS

2.1 Technical Problems

The lack of documented techniques for direct interpretation of LANDSAT film products has been a problem in developing mapping techniques for this investigation To date, most techniques which have been termed "conventional", as opposed to "computer aided", have involved optical or electro-optical color enhancement processes These processes are techniques for which we had not intended to acquire the special equipment to implement Discussions with personnel as NASA/JSC and Earth Satellite Corporation confirmed the impression from the literature, some of which is annotated in Appendix A, that mapping by simply enlarging LANDSAT images has not been widely attempted Therefore more time was spent than was anticipated in developing and evaluating several approaches to mapping, as described in Section 3 3

A problem also was encountered in obtaining up-to-date information on available imagery prior to placing an order for imagery of test sites 2, 4, and 5 Some errors were found in the original inventory for these sites and LANDSAT catalogs on hand in Austin were not sufficient to correct the inventory An EROS accessions list of available imagery, based on scene centerpoints which we submitted, eventually was found to be the best data source from which to order. The effect of this problem was to delay acquisition of data for the other test sites until late in this reporting period and required rescheduling part of the investigation as discussed in Section 3.1

There is also a minor problem with using LANDSAT-2 tapes in the version of DAM at the Texas Water Development Board This has prevented using DAM to register and scale the 25 February 1975 data tape as part of the procedure outlined in Section 3.3.4. Regional Applications Project staff at NASA/JSC have been contacted for assistance with this problem

2.2 Staffing Changes

Texas Water Development Board (TWDB). Sammuel McCulloch joined the TWDB staff in November and will support the perfecting of data handling procedures and lend staff support in other applicable areas, such as in developing and implementing the ADP procedures and classification algorithms He will also provide assistance in comparing ADP techniques with image interpretation techniques as part of the development of the quasi-operational monitoring system Mr McCulloch has a B A degree in geology from Texas Christian University and an M S. in geodesy, photogrammetry, and cartography from the Ohio State University. He has had twenty years' experience with the U S Air Force and the Defence Intelligence Agency, in the acquisition of remote sensing imagery and imagery processing, interpretation, and quality assessment. His assignments dealt with the application of operational remote sensing systems to military intelligence problems and the development of new systems

<u>Texas Parks and Wildlife (TPWD)</u> Steve James resigned from TPWD and was replaced in October by George Clements, a field biologist stationed at Seadrift, Texas, on San Antonio Bay Mr Clements has been employed by TPWD for the past three years, conducting bay phytoplankton studies and monitoring shell dredging operations in central Texas bays, and is experienced with field operations.

Mr. Clements, unfortunately, is arriving on the project late and is not as familiar with the terminology and project objectives as the other participants Every effort is being made to orient Mr Clements to our needs and during this next quarter it is anticipated that he will be providing field support both by accompanying BEG and TWDB staff in the field, and independently, by verifying in the field interim products mailed from Austin. In addition, negotiations are underway for a TPWD botanist to be assigned part-time from the Austin office to assist in the correlation of coastal vegetation with LANDSAT marsh classes, and to provide consultation with the image interpretation and ADP classification process

3.0 ACCOMPLISHMENTS

3 1 Task Definition And Scheduling

3.1 1 Scheduling Alternatives

During this reporting period, data acquisition and development of ADP and image interpretation techniques required more time than was anticipated, so that alternative schedules were evaluated for examining test sites 3, 4, 5, and 2 Instead of examining LANDSAT data for all four sites during this quarter, work was continued on site 3 with the objective of looking at more scenes and different seasons, if time and technique permitted. Later, appraisal of the remaining time and task priorities in this investigation indicated that two of the three remaining test sites (sites 2 and 5) could be examined in the next six months. Site 2 (West Galveston Bay) to the northeast of site 3, and site 5 (Lower Laguna Madre) at the southern end of the Texas coast are important to document the different wetland types resulting from humid and semi-arid climate extremes. The last area, site 4, which is in the same sub-humid climatic zone as site 3 is to be included in the simulation of the quasi-operational monitoring system planned for Summer 1976 (Figure 1).

The next six months will be spent perfecting the monitoring system design, especially the techniques for interpreting LANDSAT data and displaying the results, and preparing for the cost-

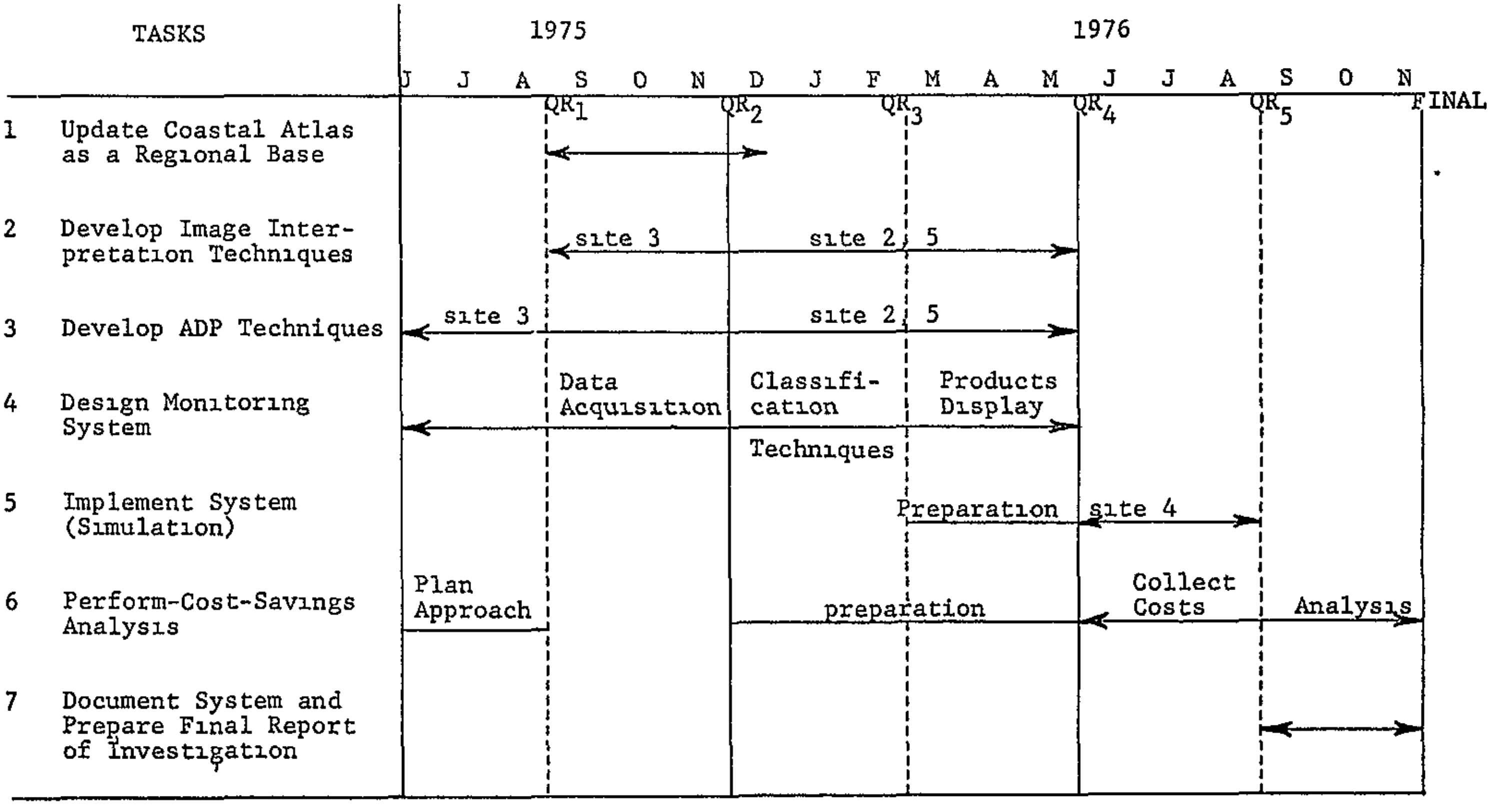

Figure 1 Generalized Schedule For LANDSAT Investigation #23790.

savings analysis (Figure 1). It is important that whatever capability we have developed for using LANDSAT data be finalized by May 1976. Between June and August 1976 those techniques will be applied to site 4 (and possibly other localities) in a short simulation of the monitoring system.

3.1.2 Program For The Next Reporting Interval

The following activities are planned for the next quarter

1) Techniques developed for interpreting LANDSAT data in test site 3 will be applied to test site 2 in West Galveston Bay Because this next quarter coincides with the dormant period for coastal vegetation, a look at winter data for test site 5 in Southern Laguna Madre may also be attempted.

2) ADP techniques for registration and scaling of LANDSAT classification products will be adapted from existing systems as discussed in Section 3.3.6.

3) The interim status of ADP and image interpretation techniques for the monitoring system design will be evaluated prior to consideration of the optimum technique or mix of techniques to use on the Texas coast

4) Preparation for the cost-saving analysis will begin by collecting costs of examining site 2 (West Galveston Bay area), and researching the costs of existing products that will be compared to LANDSAT products generated during this investigation

3 2 Updating Coastal Atlas To Provide A Regional Base For The Texas Coast

Six of the Environmental Geology sheets (1 125,000 scale) contained in the University of Texas, Bureau of Economic Geology, Environmental Geologic Atlas of the Texas Coastal Zone (Series), are available as a regional base to support LANDSAT interpretation contained in the Bureau of Economic Geology, Environmental Geologic Atlas of the Texas Coastal Zone (Series), are available as a regional base to support LANDSAT interpretation (see References). The seventh sheet in the series, the Brownsville-Harlingen Sheet, is not yet available as published copy Updating of the six available sheets is complete using the February 1975, coastal strip photography flown for this investigation by NASA (Mission 300) All additions and deletions have been noted, and the changes found are now being transferred to plastic overlays. Most changes are minor revisions which relate to realignment of channels, dumping of dredge spoil, erosion and deposition along shorelines and changes in the configuration of tidal inlets

The update of the Coastal Atlas sheets has centered around the units on the 1 125,000 Environmental Geology sheet, since wetlands, beaches, mudflats, etc are well defined at this scale Each unit on the color sheets has been numbered and changes detected on test site 1 photography have been assigned a number, corresponding to the existing legend, indicating the new category Where a change in land use is also involved the alphabetic abbreviation taken from the LANDSAT land use classification system in Section 3 3 3 may also be added. Within this updated (26 November, 1975) classification system categories are included which correspond to all major divisions on the Bureau of Economic Geology Current Land Use Map The final product will consist of a set of overlays with changes identified according to number code or alphabetic abbreviation Use of color will be avoided so that the original mapped category can be easily seen through the overlay on the Environmental Geologic Sheet Sam Shannon has been responsible for delineating changes and producing the overlays

3 3 Development Of Techniques For Extracting Information From LANDSAT In Test Site 3 (San Antonio Bay area)

3 3 1 Field Orientation

On September 18 and 19, 1975, the research team participating in this LANDSAT investigation met at Port Lavaca for a field trip organized by Dr Holz in test site 3 (Figure 2). Test site 3 is located on San Antonio and Espiritu Santo Bays, on the middle Texas Gulf Coast The Regional Applications project scientist from the Johnson Spaceflight Center, Dr Ed Weisblatt, also was present and assisted with part of the field trip

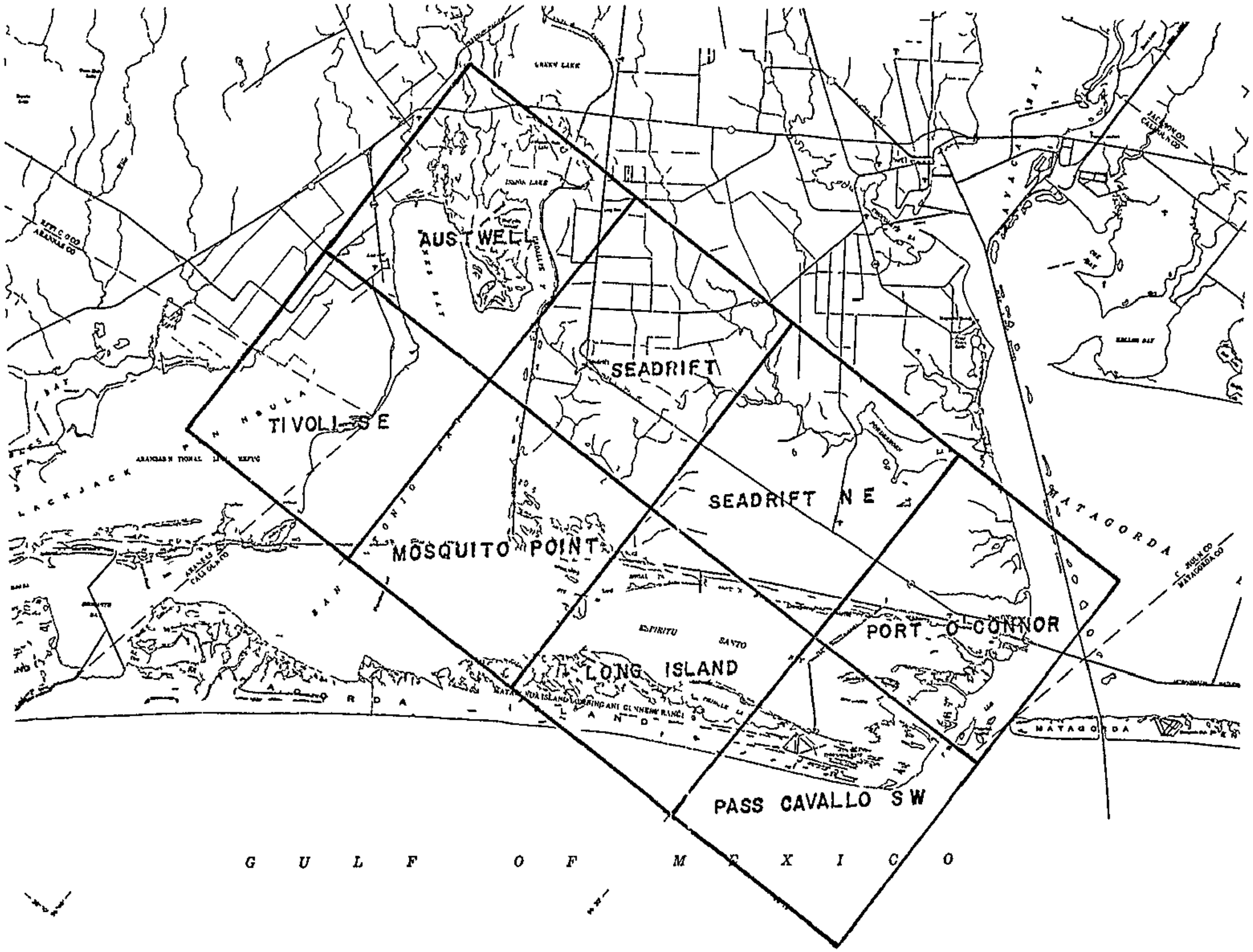

Figure 2. USGS 7.5 minute topographic maps overlaying test site 3, San Antonio Bay area.

The primary purpose of this field trip was to orient members of the team with field problems associated with identifying and verifying land cover and water bodies on aircraft and LANDSAT imagery. An evening workshop during this trip provided for interchange of ideas among team members trained in diverse disciplines Visiting field localities together for representative land use and wetland classes provided an opportunity to develop a common experience and language for the site, and, in general, proved to be a valuable learning experience

During a period of clear weather in early October following this field trip, a small airplane belonging to the General Land Office was used to fly over the same areas visited on the ground and obtain oblique photography Although not always available, some use of this plane is anticipated for brief field checks when verifying seasonal and other changes detected from LANDSAT data

Reactions among the team members to the orientation field trip have been excellent and similar trips to the other sites will be organized by TPWD and BEG staff when work begins on each site

3 3 2 Image Interpretation Techniques

During September an annotated bibliography was prepared covering applications of LANDSAT imagery in the coastal zone (Appendix A) with emphasis on surveying image interpretation techniques Although few techniques were found (Section 2 1) that were applicable to this investigation this survey was helpful in planning several approaches for developing useful image interpretation techniques

Initial evaluation of mapping techniques utilized imagery of test site 3, dated 29 March, 1974, (1614-16261) and 25 February, 1974 (2034-16200) The approaches which were considered included (1) mapping directly from 1 250,000 scale prints (B&W), (2) using the Zoom Transfer Scope to enlarge and project 9" B&W or color products at a 1 125,000 scale, and (3) production of 1 125,000 B&W enlargement of band 7 on a transparent film base, followed by mapping with the false color composite and other single bands under the Zoom Transfer Scope These procedures all yield a line boundary map on which features could then be classified according to an Anderson-type system

The 1 250,000 print was considered to have too small a scale to map on The second procedure using the Zoom Transfer Scope (ZTS) was very time consuming and created registration inaccuracies due to the number of shifts in field of view required with the ZTS However, a map of the San Antonio Bay area has been completed and classified by this process Mapping of the San Antonio Bay and Pass Cavallo areas by the third procedure, using film enlargements of band 7, is under way and it now appears that this will be the method applied to other test sites The map can be initiated rapidly by transferring water boundaries and other easily distinguishable features from the transparency to a mylar film Tonal interpretations using the false color composite are then added A combination of positive and negative band 7 transparencies of different dates, enlarged to a 1 125,000 scale over the test site area, have also proven useful for detecting changes

3 3.3 Classification Scheme Applied To Interpretation Of LANDSAT Images

The first step in establishing a workable classification was modification of Anderson's Land Use Classification system (Anderson, 1972) Categories which were not applicable to the Texas coastal zone were deleted, while others such as the Wetland class were expanded (Table 1). It is hoped that within this wetland class the differing plant associations of topographically high and low marsh will result in LANDSAT signatures which can be consistently distinguished Note that the Water category has been broken down on the basis of subjective estimates of turbidity to provide correlation with the ADP analysis Each category has an alphabetic abbreviation and has been assigned a color, designated by numeric code, for use in mapping

The mapping procedure adopted results in a line boundary map, such as Figure 3 covering part of test site 3 This map is at a scale of 1 125,000 and is derived from the false color composite, band 7 and band 5 images Boundaries are based on form as well as radiance level and on association with other units in the area Mapping on the basis of these multiple characteristics is an

Table 1 Land Use Classification for LANDSAT Data

26 Nov 1975

Level 2 → / Level 1 ↓					
Urban & Built Up Land	General Urban (residential) (commercial) (industrial-if unable to distinguish as separate class) U (35)	Industrial (Factories) (Mills) including Tank Farms Waste treatment Ui (61)	Transportation (Roads) (Railroads) (Canals) (Airports) Ut (33)	Extractive (Mines) (Mine spoil) (Oil & Gas Wells) Ue (28)	
Agricultural Land	Cropland (active & idle) A (44)	Orchards (Groves) (Vineyards) Ao (60)			
Grassland	Range-Pasture (Prairies) (Scattered shrubs or trees) G (43)	Chapparal (sagebrush) (creosote bush) (mesquite) Gc (5)	Vegetated Dunes (minor woody vegetation) Gd (30)		
Woodland	Deciduous woodland WO (11)	Evergreen woodland WOe (16)	Mixed woodland WOm (14)		
Water	Clear WA (26)	Slightly turbid WAst (23)	Moderately turbid WAmt (21)	Highly turbid WAt (18)	
Wetland	Topographically Low Marsh Wlm (51)	Topographically High Marsh Whm (46)	Tidal Flat Wtf (7)	Mangrove wetland (if distinguishable) Wm (62)	Vegetated Spoil Ws (58)
Barren Land	Beaches B (8)	Dunes Bd (36)	Subaerial spoil (including some sparse vegetation) Bss (31)	Undifferentiated barren Bu (39)	

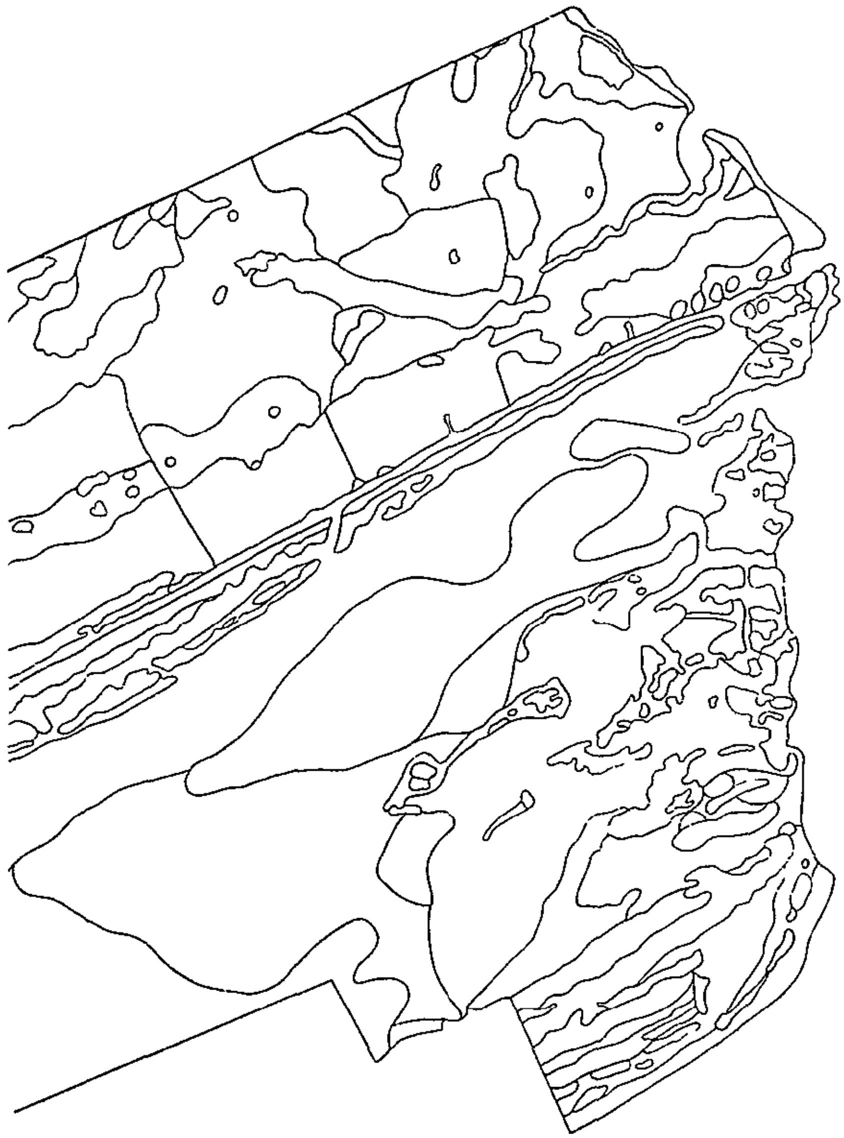

Figure 3   Image Interpretation Line Boundary Map of Part of Test Site 3, Pass Cavallo Area Areas delineated by boundaries are then classified according to the Land Use Classification Scheme

advantage which the human interpreter has over automatic data processing Using only optical enlargement techniques, however, mapping cannot be done at scales larger than 1 125,000, while computer processing can yield gray maps at larger scales The next step for completing the classification process will be to add color to indicate the land use classification for each mapped unit These interim classification results will then be verified using NASA aerial photography, the updated BEG Environmental Geologic Atlas of the Texas coastal zone and field checking

3 3 4 Approaches For Change Detection In LANDSAT Images

The types of change detection to be attempted on LANDSAT images include 1) variations in the areal extent of a category, 2) change of an area from one category to another and 3) temporal signature differences within a classified area, such as seasonal vegetation changes or changes from burning Preliminary work shows that (1) changes in areal extent of wetland and shore zones can be detected by overlaying line boundary maps made from LANDSAT images enlarged to a 1 125,000 scale, (2) category change detection probably will be based on side-by-side comparison of classified maps, and (3) temporal changes, resulting in radiance differences, are detectable by overlaying positive and negative transparencies of different dates of imagery on a light table, again using 1 125,000 scale segments of B&W band 7 images The accompanying Figure 4 explains how a change from high to low

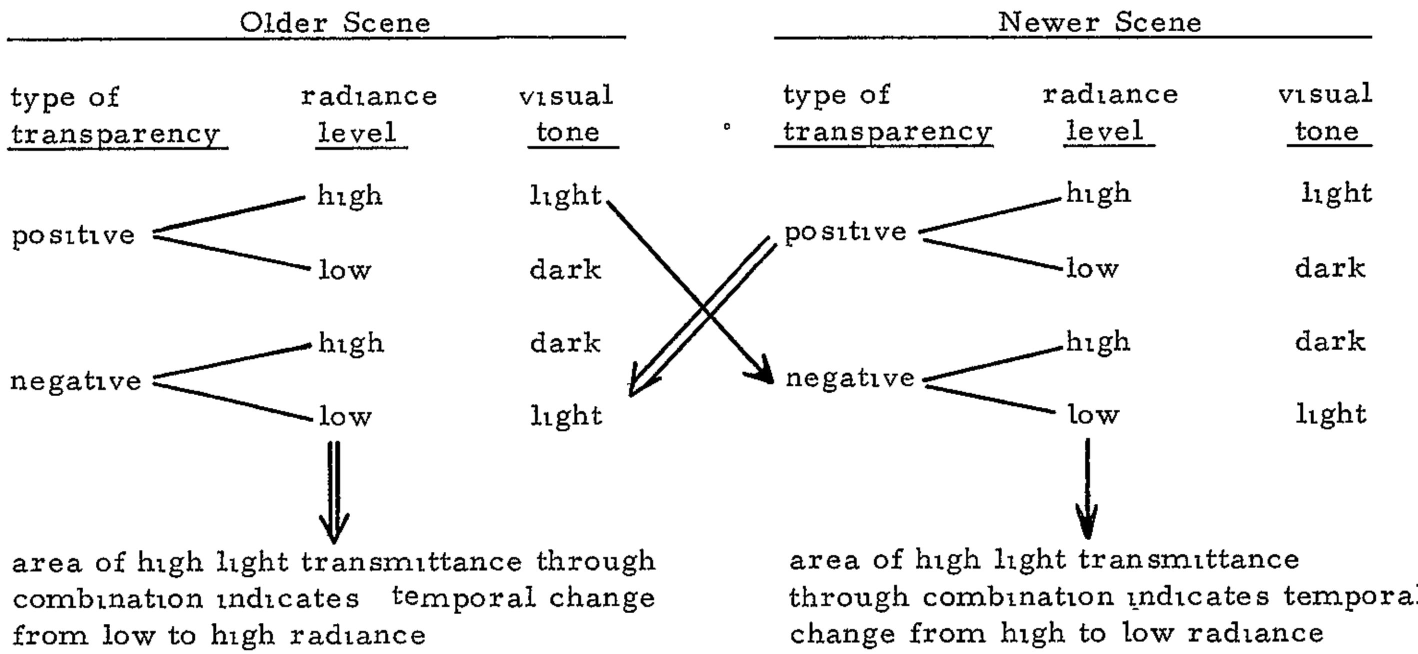

Figure 4 Example Of Change Detection Procedure For Within-Category Radiance Difference

radiance, corresponding to a seasonal change in wetland reflectance and the burning of grassland, may be detected Such changes are now being mapped for the 29 March 1974 and 25 February 1975 scenes. Changes will be verified initially by aerial photography and field checking

3.3.5 ADP Classification Of LANDSAT Tapes

Shortly after the start of the second quarter, good quality LANDSAT data tapes and associated imagery were obtained for test site 3. Four such LANDSAT scenes are now on hand at the TWDB which give both seasonal and temporal coverage of the San Antonio Bay test site These scenes and their dates are

1) 1289 - 16261 for 08 May 1973,

2) 1614 - 16261 for 29 March 1974,

3) 1703 - 16175 for 26 June 1974, and

4) 2034 - 16200 for 25 February 1975.

Computer classification during the second quarter was performed on two areas in test site 3 using the 29 March 1974 LANDSAT scene This scene was chosen because the time of year was closest to the available aerial photography of the test site flown by NASA in February 1975 and because both imagery and CCT's were available for this scene At the time that classification was begun, the 25 February 1975 scene had not yet been obtained

The first area examined in test site 3 using the 29 March 1975 scene was the Austwell USGS 7-1/2 minute quadrangle (Figure 2). Procedures used were those tentatively adopted in the preliminary examination of ADP software to generate an unsupervised classification The LARSYS ISOCLS processor was used to cluster all the data in the Austwell Quad to give statistics for spectrally distinct classes containing 100 points or more The resulting statistics were used by the CLASSIFY and DISPLAY processors to produce a five-class computer map of the Austwell area When visually compared to the Environmental Geologic Atlas of the Texas Coastal Zone--Port Lavaca area (McGowen, et al , in print) the five classes generally corresponded to pasture lands, agriculture land, one class of marsh and two classes of water Further clustering in the marsh area separated the marsh into two distinct types Unclassified areas were also re-examined and yielded three more classes one corresponding to an industrial area and the other two corresponding to two industrial holding tanks Thus, the final classification resulted in nine classes of which four were water classes and two were marsh classes These latest results compared favorably with the broad catagories on the BEG Biological Assemblages and Land Use maps (McGowen, et al , in print), although precise correlation has not yet been attempted

Using procedures similar to those described above, a classification map was produced for the Pass Cavallo area This area is found on the Port O'Connor and Pass Cavallo USGS 7-1/2 minute quad sheets (Figure 2) A procedural change in the clustering process was tried in producing this classification Using ISOCLS to cluster quad sheet size areas consumes large amounts of computer time A less expensive method was adopted.

a grayscale map was examined along with available photography Numerous, small areas were picked throughout the scene in order to cover the observed spectral variation These areas were then clustered together using ISOCLS to generate the training class statistics Classification of the Pass Cavallo area yielded thirteen classes When compared to photography and the maps of the Port Lavaca area (McGowen, et al , in print) four to six of these classes correspond to water of various depths and turbidity The other classes delineated barren land (beach, dune and spoil areas) and separated the low vegetated wetland areas from the higher and drier vegetated area A sample of this classification is shown in Figure 5

As a result of classification attempts in test site 3, classification procedures have been modified The current LANDSAT Classification Schedule is given in Figure 6 This schedule should help to guide and document future classifications Modifications to the Schedule will be made as ADP procedures are developed

Near the end of the second quarter an enhancement was made to the computer classification systems A fast table-lookup classifier, ELLTAB (Jones, 1974), was modified to produce output compatible with the LARSYS DISPLAY processor The resulting classifications are identical to those produced by the CLASSIFY processor in LARSYS However, a considerable savings in processing time should be realized since the table-lookup classifier in ELLTAB is reported to be 17 times faster than the maximum liklihood classifier found in LARSYS

Figure 5 Part of the classification map of the Pass Cavallo area with all water classes (except $) blanked out Unclassified pixels are displayed as a #

Figure 6 LANDSAT Classification Schedule

Scene ID

Date

Test Site

Description.

- ☐ 1 Select LANDSAT scene and locate data tapes.
- ☐ 2 Examine available imagery
- ☐ 3 Estimate scan line and sample numbers for the area of interest
- ☐ 4 Merge data tapes if necessary
- ☐ 5 Generate a grayscale map of the area using channel 3 (GRAYMAP)
- ☐ 6 Obtain meteorological data (precip, wind, tides)
- ☐ 7 Locate control points for the scene.
- ☐ 8 Classify water using DAM.
- ☐ 9 Transfer water bodies to the grayscale map.
- ☐ 10 Select training areas from the imagery and the grayscale map (consult with BEG and others)
- ☐ 11 Cluster training areas (ISOCLS)
- ☐ 12 Histogram each training class to make sure it has a normal distribution (HIST)
- ☐ 13 Refine a training class if indicated by step 12
- ☐ 14 Select best 2 and 3 channel combinations (SELECT)
- ☐ 15. Classify the area (CLASSIFY or ELLTAB)
- ☐ 16. Display the classified results (DISPLAY)
- ☐ 17 Outline homogeneous areas.
- ☐ 18. Examine the classification map.
- ☐ 19. Stop if satisfied with the results
- ☐ 20 Retrain on unclassified or poorly separated areas (ISOCLS)
- ☐ 21 Go to step 15

3 3 6 ADP Approaches For Registration And Scaling Classification Results

An important part of comparing computer-generated LANDSAT products with conventional map data, such as GLO submerged land tracts, involves registration and scaling Without this capability, ADP change detection procedures also would be impossible Since registration and scaling are not provided in the version of LARSYS in use at TWDB, several approaches to this problem are currently being investigated

The DAM package, used to detect water, contains fairly sophisticated programming for registration and scaling. After establishing a network of control points (an association between pixels and geographic coordinates) a registered line printer map can be produced at any scale from 1 20,000 to 1 250,000 The possibility of extracting these registration and scaling procedures from the DAM package is one approach being explored

Another promising registration procedure involves extracting boundaries from the classification maps. The extracted class boundaries can then be registered and scaled within the Geographical Information System (GIS) which is being developed at the TWDB The GIS is a powerful system for capturing, manipulating and displaying map type data. Using the GIS, pen plot classification maps could be generated at any desired scale Moreover, other map type data, such as county boundaries, could be overlayed on the classification maps. In addition to the above, inquiries are also being made into other existing registration procedures, including the one used at LARS, Purdue

3 3 7 <u>Correlation Of ADP Spectral Classes And The Image Interpretation Classification Scheme</u>

Image interpretation and ADP techniques for extracting information from LANDSAT scenes are being developed somewhat independently by BEG and TWDB staff However, an important part of the development of these techniques is correlating information (classes) extracted from LANDSAT images and tapes, with each other and with supporting data and ground truth The responsibility of the image interpreter in the correlation process is to provide guidance for identification and field verification of the spectral classes Later, both techniques will be evaluated, partly on the basis of the correlation process, to determine the best technique or mix of techniques to use for particular information products.

The first step in achieving correlation of ADP classes and image interpretation results was the evolution by the BEG staff of a modified Level II classification scheme discussed in Section 3.3 3. This scheme was intended to be the goal for both the ADP and image interpretation classification efforts, and it was designed partly for this correlation task For example, the classification scheme contains four classes of water based on degree of turbidity These classes are subjective in that the turbidity visible in each scene is classified relative to that scene only The end members of non-turbid and highly turbid waters may be the most similar in spectral response from scene to scene, but the intermediate classes may not be In order to provide correlation between the image interpretation and ADP results, most similar classes will be combined so that the computer classification produces no more than four water classes Note that although these classes are defined on the basis of turbidity, water depth is significant since clear water in shallow areas appears to give a response similar to very turbid water over greater depths Other classes, such as the urban categories, require more information than spectral data to classify, and will be more difficult to correlate

The next step in achieving correlation was visually comparing ADP and image interpretation classification results with each other, and with supporting data such as the February 1975 aerial photography flown by NASA for this investigation (Mission 300) This comparison helped determine which ADP classes appeared to correspond to high and low marsh, beaches, dune and interdune areas, and also which areas required field checking For example, a preliminary field check of the ADP classes was made at Pass Cavallo on November 24, 1975. Several classes were found to correspond to wetland vegetation or vegetation/bare substrate mixtures. The best correlation was found in topographically high marsh, dominated by seacoast bluestem and _Spartina patens_, which corresponded to a unique class relative to the surrounding area. Also unique was a class that corresponded to mixed _Spartina spartinae_, _Distichlis_ (?) _sp_. and other grasses Some areas also appeared to be misclassified or may have changed since the LANDSAT scene was collected and will require further work

Additional field work will be initiated as the correlation process continues and classification problems are identified

3 4 <u>Design For Data Acquisition</u>

The LANDSAT imagery order of 31 July 1975 included a complete set of imagery formats for scene 1614 - 16261, dated 29 March 1974 These products were evaluated in detail for their relative utility in direct image interpretation. The result is a purchase package, outlined in Table 2, of selected imagery formats for one scene, which allows for a variety of approaches in direct mapping The entire package is recommended only where no cloud cover was indicated and the individual bands were of good quality. Only selected items (B&W film positives) are to be ordered where the data were of lesser quality or the location of cloud cover required further examination of the scene

The following comments apply to the item by item listing

1) <u>1 1,000,000 false color transparency</u> - Excellent for discrimination within vegetated areas, since the tones of blue and red are easier to work with than shades of gray Comparison may easily be made with the color infrared aircraft photography High reflectance barren areas, industrial sites and spoil are readily distinguished from high reflectance vegetation. Seasonal vegetation changes and plant vigor have been detected on the basis of change from red to reddish black tones

Table 2

Suggested Purchase Package For

LANDSAT Imagery Scenes

	Item	Scale	Band	Cost
1)	color transparency	1 1,000,000	composite	$12 00
2)	B & W print	1 250,000	5	15 00
			7	15 00
3)	B & W positive transparency	1 1,000,000	4	5 00
			5	5.00
			6	5.00
			7	5 00
4)	B & W negative transparency	1 1,000,000	5	6.00
			7	6 00
	Cost of color master available			$74.00
	Additional cost of color master . . .			$50.00
	Possible cost if color master needed			$124 00

2) B&W prints, 1:250,000, bands 5 & 7 - Bands 5 and 7 are most useful for culture, sediment patterns (5) and definition of the land-water boundary (7), as has been documented by many other researchers. Prints at this scale are useful for quick reference to a larger scale image, in mapping at a 1:250,000 scale and for display/discussion sessions.

3) B&W positive transparency, 1:1,000,000, bands 4, 5, 6, 7 - These formats form the basic products from which mapping may be done using optical enlargement, such as with the Zoom Transfer Scope. Mapping entirely from these products on the ZTS is slow and introduces inaccuracies unless a LANDSAT map base is first prepared using the 1:250,000 band 7 print or a film positive at 1:125,000 produced from the band 7 negative. With respect to the individual bands, 4 is of low utility but may be used in defining built-up areas and industrial sites. Band 5 readily records suspended sediment patterns in water bodies, interior drainage patterns and high reflectance features such as airports, industrial sites and strip mines. Bands 6 and 7 offer the best land-water boundary discrimination, including the details of coastal wetland drainage. The preparation of a map base showing land-water boundaries is best done with band 7 data.

4) B&W negative transparency, 1:1,000,000, bands 5 and 7 - These products may be used to produce: (1) paper prints for field or discussion use, and (2) film positives at a larger

scale for use in mapping Also, river drainage seems even easier to detect on the band 5 negative than on the positive

Each image product format, discused in items 1-5 above, has a specific use in direct image interpretation at this stage of the project. Further recommendations will be made with regard to ordering in an operational framework when at least two more test sites have been evaluated

Computer compatible tapes at this stage of the investigation are ordered for only the scenes with 0% cloud cover and of good quality. Examination of LANDSAT imagery is used to determine if CCT's will be ordered for scenes with some cloud cover and/or poor quality data, when a specific time period or season is required and good data is not available

Accession lists were obtained from the EROS Data Center in October for all four test sites based upon the center points of LANDSAT scenes known to cover the test sites A synopsis of all good scenes (no more than 20% cloud cover and a quality rating of at least 5 in each channel) is given in Appendix B The listings in Appendix B are sorted by test site and by season within a given site This list was used to select and order seasonal and temporal coverage for all test sites The data ordered also has been noted in Appendix B

A preliminary schedule for acquisition and distribution of LANDSAT data for this investigation is shown in Figure 7. Indexing of aircraft and satellite imagery as part of TNRIS development is summarized in Appendix C

Figure 7. Schedule For Acquisition And Distribution Of LANDSAT Data

- ☐ 1 Obtain current LANDSAT accessions list from EROS Data Center (TWDB).
- ☐ 2 Select LANDSAT imagery according to criteria for cloud cover and quality (BEG).
- ☐ 3 Select LANDSAT tapes according to criteria for cloud cover and quality (TWDB)
- ☐ 4 Approve order for LANDSAT data (GLO)
- ☐ 5. Order LANDSAT data (TWDB).
- ☐ 6 Receive and index LANDSAT data (TWDB)
- ☐ 7. Distribute LANDSAT imagery to BEG (TWDB)
- ☐ 8. Distribute LANDSAT tapes to Tape Library at TWDB (TWDB)
- ☐ 9 Select additional LANDSAT tapes from imagery*(TWDB)
- ☐ 10 Go to step 4

3.5 Coordination

This investigation has two important coordination functions related to the application of LANDSAT technology to Texas coastal problems First, this investigation is designed to develop techniques for monitoring resources that could support the NOAA - funded Coastal Management Program being developed in the General Land Office (GLO) for the State of Texas, and also support the GLO management responsibilities for the more than four million acres of state-owned submerged lands in the bays and Gulf of Mexico Coordination with these GLO coastal management activities is necessary to insure that the information products generated by this investigation are compatible with existing information use or needs During the next six months we plan to establish some estimate of LANDSAT support capability and also schedule more active interaction with these programs

The second coordination function relates to the transfer of capability developed by this investigation to other state agencies The mechanism for this transfer and also for coordinating this investigation with coastal programs in other agencies is the Texas Natural Resources Information System (TNRIS) which is a task force of the Interagency Council of Natural Resources and Environment (ICNRE), with assistance from the Governor's Office, Division of Planning Coordination This investigation is partly funded by the TNRIS through manpower and computer capability located in the TWDB. Techniques developed by TWDB and BEG staff for this investigaiton will be available when documented to other agencies through the TRNIS

A first step towards coordinating this investigation with other agencies besides those participating occured on November 14, 1975, when a progress report on this investigation was presented to the TNRIS Task Force consisting of representatives from 14 resource agencies Also, on November 20th a summary of this LANDSAT Investigation was presented to about 60 persons from several state agencies and Councils of Governments as part of a Short Course on Remote Sensing sponsored by the TNRIS Remote Sensing Committee During the Short Course a great deal of interest was expressed in the Land Use Classification Scheme and image interpretation techniques discussed in Section 3 3

4 0 SIGNIFICANT RESULTS

The development of techniques for interpretation of LANDSAT images (Section 3.3.2) and the development of the modified land use classification scheme (Section 3 3 3) constitute the most significant contribution during the second quarter

5.0 PUBLICATIONS

None

6 0 RECOMMENDATIONS

None

7.0 FUNDS EXPENDED

GENERAL LAND OFFICE (GLO)

• LABOR	$6,909 00
• OVERHEAD	3 50
• TRAVEL	315.31
TOTAL EXPENDITURES REIMBURSED DURING THE 2nd QUARTER	$7,227 81

BUREAU OF ECONOMIC GEOLOGY (BEG)

• LABOR	$ 0
• MATERIALS & SUPPLIES	0
• EQUIPMENT	0
• TRAVEL	0
TOTAL EXPENDITURES REIMBURSED DURING THE 2nd QUARTER	$ 0

TEXAS PARKS & WILDLIFE DEPARTMENT (TPWD)

• LABOR	$2,915 62
• MATERIALS & SUPPLIES	59.22
• TRAVEL	62 50
EXPENDITURES DURING THE 2nd QUARTER	$3,037 34
Less this amount to conform to the total amount of $4,673.00 specified in the contract for the 74-75 State biennium.	-26.19
TOTAL EXPENDITURES REIMBURSED DURING THE 2nd QUARTER	$3,011.15

TEXAS WATER DEVELOPMENT BOARD (TWDB)

- LABOR $4,233 00
- COMPUTER 600 00

TOTAL EXPENDITURES REIMBURSED DURING THE 2nd QUARTER $4,833.00

CONSULTING SERVICES

- Dr. John A Schell $ 210 08

TOTAL EXPENDITURES REIMBURSED DURING THE 2nd QUARTER $ 210.08

Dr John A. Schell, Acting Director, Texas A&M University, Remote Sensing Center, is replacing Dr. John Rouse as consultant for our investigation, while Dr Rouse is on leave from TAMU RS Center to NASA headquarters

8 0 DATA USE AS OF NOVEMBER 30, 1975

	IMAGERY Account #G23790 Amount	CCT Account #G B3790 Amount	AIRCRAFT Account #G W3790 Amount
Value of Data Allowed	$1,900 00	$6,400 00	$9,216.00
Value Ordered	$1,149 00	$ 600 00	$6,420 00
Value Received	$ 359 00	$ 600 00	$6,420 00
BALANCE	$ 679 00	$5,800 00	$2,796 00

9.0 AIRCRAFT DATA

The enlarged 1.60,000 scale photography (AMPS Camera, Mission 300) flown by NASA for the small test sites, unfortunately has been of limited usefulness at test site 3, because the high degree of sidelap yielded a relatively small area of ground coverage The two flight lines for site 3 were almost completely superimposed, due to a malfunctioning inertial navigation system on the RB-57 aircraft, so that some important wetland areas between Seadrift and Espiritu Santo Bay were not covered by the AMPS photos. The 1·120,000 scale, color IR, coastal strip photography (6" Zeiss Camera, Mission 300) was used to support the LANDSAT interpretation in site 3 where AMPS coverage was incomplete, and has been used extensively for the update of the regional base described in Section 3 2 So far, both the AMPS and the 6" Zeiss data have been found to be good quality photography, and have been referred to frequently in support of image interpretation and ADP classification efforts.

REFERENCES

Anderson, J R , Hardy, E E and Roach, J T , 1972, A land-use classification system for use with remote sensor data, U S Geol Survey Circ 671, 16p

Jones, Clay, 1974, Implementation of an Advanced Table Look-Up Classifier for Large Area Land-Use Classification in Proceedings 9th International Symposium on Remote Sensing Of Environment, University of Michigan, Ann Arbor, Michigan

McGowen, J H , Proctor, C V , Jr , Fisher, W L , Groat, C G , and Evans, T J , in-print, Environmental Geologic Atlas of the Texas Coastal Zone--Port Lavaca Area Univ Texas, Bur Econ Geology, Austin

University of Texas, Bureau of Economic Geology, 1972- , Environmental Geologic Atlas of the Texas Coastal Zone, 7 vols , Austin, L F Brown, Jr., Project Coordinator

Brown, L F , Jr , et al , Houston-Galveston Area. 1972
Fisher, W L., et al , Beaumont-Port Arthur Area 1973
McGowen, J H , et al , Bay City-Freeport Area. in print
Groat, C G , et al., Brownsville-Harlingen Area in print.
Brown, L F , Jr , et al., Corpus Christi Area in print.
Brown, L F , Jr., et al , Kingsville Area. in progress.
McGowen, J H , et al , Port Lavaca Area in print

APPENDIX A

PRELIMINARY BIBLIOGRAPHY ON THE APPLICATION OF LANDSAT IMAGERY TO THE COASTAL ZONE

APPENDIX A

Preliminary Bibliography on the Application of
LANDSAT Imagery to the Coastal Zone

Alexander, R H , 1973 ERTS Regional-Scale Overview Linking Land Use and Environmental Processes in CARETS Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p 931-937

The pattern of tones and textures of ERTS-1 images was found to most closely correspond to land-use maps when compared with pre-existing maps of various types for the same area

Anderson, R R , Carter, V & McGinness, J , 1973, Applications of ERTS Data to Coastal Wetland Ecology with special reference to plant community mapping and typing and impact of man 3rd ERTS Symp , Wash D C , Dec 10-14, 1973, p 1225-1242

ERTS-1 imagery is shown to be useful in wetland studies for test areas in North Carolina and Georgia The authors explain why different data enhancement techniques were used and how each type aided the program

Anderson, R R , Carter, V & McGinness, J , 1973, Mapping Atlantic Coastal Marshlands, Maryland, Georgia, Using ERTS-1 Imagery NASA, Symp of Significant Results obtained from ERTS-1, 1 603-608, March 5-9, 1973

ERTS-1 data was used as an inexpensive source of information for mapping the extensive coastal marshes of the Eastern United States This paper is a report on the feasibility of this approach The study found that the following information was available 1) upper wetland boundary, 2) drainage pattern in wetland, 3) plant communities, 4) ditching activities associated with agriculture, and 5) lagooning for water-side housing developments

Anderson, D M , Gatto L W , McKim, H L & Petrone, A , 1973, Sediment Distribution and Coastal Processes in Cook Inlet, Alaska Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p 1323-1339

Bands 6 and 7 allowed determination of the coastline of Cook Inlet, while bands 4 and 5 showed the suspended sediment and current patterns in the estuary Circulation was seen to be primarily counterclockwise Previously unmapped tidal flats and certain cultural features were identified

Anderson, R R & Wobber, F J , 1973 Wetlands Mapping in New Jersey Photogramm Eng v 39, p 353-358

Color and Color IR aerial photographs were shown to be a practical way to map or inventory wetlands Determinable features include the mean high water mark, the upper wetland boundary, and species associations in the area

Barrell, E C , Curtis, L F , eds , 1974 Environmental Remote Sensing Applications and Achievements, Edward Arnold, publishers, 309 p Chapter 7 - Coastal Vegetation Surveys, p 127-143

Ecological zones in the coastal region have distinct vegetation coverage which is discernable on aerial photographs The vegetation assemblages in six zones are discussed these are inter-tidal, mudflat, salt marsh, shingle beach, sand dunes and cliffs
The examples given are for the English coast

Bowker, D E (et al), 1973, Correlation of ERTS multispectral imagery with suspended matter and chlorophyll in lower Chesapeake Bay Symp Significant Results obtained from ERTS-1, NASA Goddard Space Flight Center, Greenbelt, Maryland, March 5-9, 1973

ERTS data is shown to be useful in monitoring estuarine waters for the assessment of siltation, productivity and water type Major areas of suspensate concentrations have been determined for Chesapeake Bay

Carter, V , and Schubert, J , 1974, Coastal wetlands analysis from ERTS MSS digital data and field spectral measurements, Proc 9th Int Symp on Remote Sensing of Environment, p 1241-1260

In utilizing vegetation distribution in the coastal area to map wetlands, signature analysis of vegetation types and physical features found in the zone have been tabulated Also, seasonal variation and its effect is discussed The system utilizes computer analysis of the data

Clark, D K , Zaitzeff, J B , Strees, L V , Glidden, W S 1974, Computer derived coastal water classifications via spectral signatures Proc 9th Int Symposium on Remote Sensing of Environment, p 1213-1239

ERTS-1 MSS data is shown to be highly effective in the detection, classification and delineation of water masses Technical details of the processing of the color and black and white photographs is given, along with good definitions of terms The enhancement and color slicing techniques used in the study are explained

DeBlieux Chas , 1962, Photogeology in Louisiana Coastal Marsh and Swamp Transactions, Gulf Coast Assoc Geol Societies, 12th Ann Mtg Oct - Nov 1962, p 231-241

Aerial photographs of the Louisiana coastal zone show several structural features which exhibit surface expressions This method may be useful in the search for stratigraphic and structural traps for oil and gas

Denathieu P G & Verger, F H 1973 The Utilization of ERTS-1 Data for the Study of the French Atlantic Littoral 3rd ERTS-1 Symp Wash D C , Dec 10-14, 1973, p 1447 -

By utilizing ERTS-1 data it was possible to accurately determine the direction of transport of sediments from rivers emptying into the Atlantic Ocean along the southwest coast of France Ocean currents and a turbidity front at a depth of about 50 meters were observed

Dolan R & Vincent, L , 1973 Coastal Processes Photogramm Eng , V 39 p 255-260

High altitude aircraft photographs are used in conjunction with ground truth to study the crescentric forms seen on long, sandy coasts These features indicate where surge and overwash may occur during storms

Dolan, R Vincent L , 1973 Evaluation of Land Use Mapping from ERTS in the Shore Zone of CARETS Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p 939-948

ERTS-1 data provided a basis for land cover and land use mapping within the shore zone MSS bands 4, 5, 6, & 7 are compared for their respective utility in delineating various features Problems in mapping are discussed for urban and built-up areas, forest areas, water, nonforest wetland, and barren land

Estes, J E , Thaman, R R , & Senger, L W , 1973, Application of ERTS-1 Satellite Imagery for Land Use Mapping and Resource Inventories in the Central Coastal Region of California 3rd ERTS-1 Symp , Dec 10-14, 1973, p 457-490

ERTS-1 data was used to construct land use, landform, drainage and vegetation maps of central California Kelp distribution offshore was also mapped The appendix lists the various categories mapped from the ERTS data

Feinberg, E. B , Yunghans, R S., Stitt, J. & Mairs, R L , 1973, Impact of ERTS-1 Images on Management of New Jersey's Coastal Zone 3rd ERTS-1 Symp , Dec 10-14, 1973, p 497-503

The New Jersey Department of Environmental Protection utilizes ERTS data to monitor and manage that state's Coastal Zone Primary uses of ERTS are to

1. detect land use change
2. monitor offshore waste disposal
3. pick sites for outfalls of sewage treatment plants
4 allocate funds for shore protection

Flores, L M , Reeves, C A , Hixon, S B. and Paris, J F , 1973, Unsupervised Classification and Areal Measurement of Land and Water Coastal Features on the Texas Coast Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p 1675-1681

By using two classification algorithms with digital ERTS data it was possible to determine from 17 to 30 different classes, most representing mixtures of water, land and vegetation The two areas studied were the Trinity River Delta and the Galveston Area

Fontanel, A , Guillenot, J & Guy, M , 1973, First ERTS-1 Results in Southeastern France Geology, Sedimentology, Pollution at Sea Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p 1483-1511

Note there are 4 parts to this paper #1, Linear Trends Observed in the Western French Alps, #2, Some Results from the Study of the Dynamic Behavior of Coastal Sedimentation in the Gulf of Lions, #3, Study of Pollution at Sea in the Western Mediterranean, #4, Processing of ERTS Imagery

Pt #2 - p 1492-1499 ERTS-1 data clearly showed past shorelines of the Rhone Riv Delta and allowed them to be accurately mapped Many of these had not been known prior to ERTS data usage Fault control is also indicated in the area of ERTS data coverage.

Gallagher, J L , Reimuld, R J , & Thompson, D E., 1972 A Comparison of Four Remote Sensing Media for Assessing Salt Marsh Primary Productivity Proc 8th Int'l Symposium Remote Sensing of the Environment, Ann Arbor, Mich., 2-6 Oct 1972, p. 1287-1296

Four types of imagery from fixed wing aircraft are compared Kodak Aerochrome Infrared, Ectachrome MS Aerographic, Kodak Infrared Aerographic and imagery from a Bendix thermal mapper

Imagery interpretation was done with and without enhancement, and ground truth was used to evaluate results

Grimes, B H. and Hubbard, J C. E., 1971, A Comparison of Film Type and the Importance of Season for interpretation of Coastal Marshland Vegetation Photogramm Record., v-7, p 213-222.

Color aerial photographs were found to be the best film type to use in England for the determination of coastal, marshland vegetation October was found to be the best time of the year for determination of vegetation while February was best for seeing topographic features Mudflats were best seen on false color imagery

Heath, G R and Parker, H D, 1973, Forest and Range Mapping in the Houston Area with ERTS-1 Data. Symp on Significant Results Obtained from ERTS-1, Mar 5-9, 1973, p 167-172

The paper discusses procedures and results for two types of investigations using ERTS-1 data forestry investigation in which species and condition of timber stands was determined, and a range investigation concerned with vegetation mapping in the Gulf Coast marsh Species of Spartina could be differentiated with or without computer aided analytical techniques The boundary between S patens and S spartina in the area closely coincides with the wetlands inner boundary

Hunter, R E, 1973, Distribution and movement of Suspended Sediment in the Gulf of Mexico off the Texas Coast NASA, Symp on Significant Results Obtained from ERTS-1, March 5-9, 1973, p 1341-1348

Sediment plumes observed on ERTS imagery differ very slightly in amount of suspended sediment Data along the Texas coast shows the extent and form of these plumes, some of which extend for many kilometers parallel to the shoreline These plumes permit interpretation of nearshore currents.

Kevlin, R. T., 1973, Recognition of Beach and Nearshore Depositional Features of Chesapeake Bay NASA, Symp on Significant Results from ERTS-1, March 5-9, 1973, p. 1269-1274

ERTS-1 support aircraft imagery was used to map such nearshore features as longshore bars in Chesapeake Bay Also mapped were welded beach ridges and recurved spits.

Klemas, Y. et al , 1974, Correlation of coastal water turbidity and current circulation with ERTS-1 and Skylab imagery Proc 9th Int. Symp on Remote Sensing of Environment p. 1289-1317.

Imagery and digital tapes of ERTS-1 data, along with extensive ground truth as to the exact amount of suspended sediment in an area, have given an indication of reflectance signatures for various sediment concentrations The study of sediment patterns has also allowed determination of circulation patterns in Delaware Bay

Klemas, D , Bartlett, D , Rogers, R and Reed, L , 1974 Inventories of Delaware's Coastal Vegetation & Land-Use Utilizing Digital Processing of ERTS-1 Imagery Proc 9th Int Symp. on Remote Sensing of Environment, p 1399-1410.

Computer analysis of digital ERTS-1 data allowed production of maps of various vegetative types with accuracies of 83-90% when compared with previous, conventional vegetation maps
The investigators plan to update and refine the system until higher accuracies are attained

Klemas, V , Bartlett, D , Philpot, W , Rogers, R , & Reed, L , 1974, Coastal and Estuarine Studies with ERTS-1 and Skylab Remote Sensing of Environment, v 3, p 153-174.

The repeating nature of the ERTS and Skylab imagery covering Delaware Bay allowed detection of changing conditions in and around the bay Coastal vegetation, land use, current circulation, water turbidity and ocean waste dispersion were studied Ground truth allowed correlation of sediment concentration with reflectance on the images The method used to determine currents from ERTS-1 data is discussed

Klemas, V., Daiber, F & Bartlett, D., 1973, Identification of Marsh Vegetation and Coastal Land Use in ERTS-1 Imagery NASA, Symp on Significant Results obtained from ERTS-1, March, 5-9, 1973, p 615-627

ERTS-1 data was used in combination with high-and low-altitude aircraft coverage and ground truth to determine the accuracy of using ERTS-1 data alone to distinguish stands of vegetation. Plant communities can be

discriminated, but the major problem is the limiting nature of resolution capabilities
U-2 and RB-57 coverage were used to map small vegetation communities and the larger stands more accurately

Klemas, V., Otley, C W & Rogers, R , 1973, Monitoring Coastal Water Properties and Current Circulation with ERTS-1 3rd ERTS-1 Symp Wash D C., Dec 10-14, 1973, p. 1387-1411.

Currents in Delaware Bay detectable from ERTS-1 data were seen to coincide with predicted and measured currents in the bay Convergent boundaries between different water masses were detected, some exhibited convergent shear Waste disposal distribution was mapped Results from the ERTS study are being used to predict potential oil slick movement and to estimate sediment transport

Klemas, V , Srna, R , Treasure, W , & Otley, M , 1973, Applicability of ERTS-1 Imagery to the Study of Suspended Sediment and Aquatic Fronts Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p 1275-1290

ERTS images of Delaware Bay were studies and compared with ground truth and aircraft coverage. Suspended sediment patterns and several types of aquatic interfaces, or frontal systems, were observed

Magoon, O T , Berg, D W , & Hallermeier, R J , 1973, Application of ERTS-1 Imagery in Coastal Studies Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p 1697-1698

Use of MSS ERTS images has enabled more accurate determination of tidal inlet configuration (as well as information on longshore transport), updating of navigation charts in uninhabited, remote areas, and the near-shore water movement patterns
No enhancement techniques were used

Mairs, R L , Wobber, F J , Garefalo, D , and Yunghans, R , 1973, Application of ERTS-1 Data to the protection and Management of New Jersey's Coastal Environment Symp. Significant Results Obtained from ERTS-1, March 5-9, 1973, p 629-633

Using MSS bands 4 & 5 it was possible to detect the extent, drift and dispersion of waste disposal in coastal waters

Moore, G K , and North, G. W , 1974, Flood Inundation in the Southeastern United States from aircraft and satellite imagery Proc 9th Int Symposium on Remote Sensing of Environment, p. 607-620

ERTS-1 data is useful in flood mapping if the flood is imaged Otherwise, color-infrared photography is the most useful for determining the extent of flooding in forested areas during winter months

Orr, D G and Quick, J. R , 1971, Construction Materials in Delta Areas, Photogramm Eng., v 37, no 4, p 337-351

Black and white, color and color infrared aerial photographs were used to locate depositional features on the Mississippi River delta This is shown to be a practical way of locating new sand, gravel and clay deposits in this area

Pirie, D M & Stellar, D D , 1973, California Coastal Processes Study 3rd ERTS-1 Symp , Wash D C., Dec 10-14, 1975, p 1413

ERTS-1 data was used to analyze nearshore currents, sediment transport and river discharge along the California coast Seasonal patterns in sediment transport were found to be related to current systems and coastal morphology Sediment plumes at times extended much farther offshore than previously thought Sediment distribution was determined with computer enhancement of the data

Polcyn, F C. & Lyzenga, D R., 1973, Updating Coastal and Navigational Charts using ERTS-1 Data 3rd ERTS-1 Symp , Wash D C., Dec 10-14, 1973, p. 1333-1346

Farily accurate water depth data, up to 30 feet in the Bahamas and up to 200 meters in Lake Michigan, was obtained from ERTS-1 data Processing of original ERTS data into depth information costs approximately $1 50 per square mile Details of the process were not given

Reimold, R J , Gallagher, J L Thompson, D. E 1973, Remote Sensing of Tidal Marsh, Photogramm Eng v 39, no 5, p 477-488

Aerial photographs of a Georgia salt marsh were studied to determine the feasability of species determination and to evaluate productivity levels within each species zone. Thermal imagery was also employed

Ruggles, F. H., 1973, Plume Development in Long Island Sound Observed by Remote Sensing (ERTS-1). Symp Significant Results Obtained from ERTS-1, March 5-9, 1973, p. 1299-1303.

ERTS data was utilized to study the circulation patterns of sediment plumes in eastern Long Island Sound.

Seher, J S., Tueller, P. T., 1973, Color Aerial Photos for Marshland Photogramm. Eng v. 39, no 5, p 489-499.

Color and color-infrared aerial photographs were used to evaluate fresh water marsh vegetation Late summer was found to be the best time for data aquisition in the Nevada area Early morning imagery was superior, lacking sun reflections and wave effects.

Slaughter, T. H , 1973, Seasonal Changes of Littoral Transport and Beach Width and Resulting Effect on Protective Structures NASA, Symp on Significant Results Obtained from ERTS-1, March 5-9, 1973, p 1259-1267

The direction of littoral transport and resulting beach width along Maryland's shoreline changes seasonally This makes erosion rates difficult to determine Ground truth combined with ERTS-1 coverage points out the need for a year-long study to see a complete seasonal cycle This would aid in protective structure design along waterfront properties, as the full potential for erosion would be shown

Steller, David D , Lewis, Larry V & Phillips, Donald M., 1972, Southern California Coastal Processes as Analyzed from Multi-Sensor Data Proc 8th Int Symposium on Remote Sensing of Environment, Oct 2-6, 1972, Ann Arbor, Mich., p 983-998

Airborne imagery was used to detect and measure suspended sediment and tracer dyes in the nearshore zone off southern California The methods discussed were developed to study sediment transport and coastal effluent distribution in the area

Steller, D. D & Pirie, D M , 1974, California Nearshore Processes Proceedings of 9th Int. Symp on Remote Sensing of Environment p 1261-1278

The suspended sediment present in turbulent nearshore waters, along with the repetition of ERTS-1 data over a year-long period, have allowed the current circulation patterns near the California coast to be determined.

Tuyahov, A J. & Holz, R K , 1973, Remote Sensing of a Barrier Island. Photogramm. Eng. v. 39, 177-188

Three types of imagery are compared for their effectiveness in determining the environments of Padre Island, Texas. Color, color infrared, and thermal infrared are compared in delineating vegetation stands, vegetated vs. non-vegetated dunes, tidal flats and hurricane washover channels.

Williams, R. S., Jr , 1973, Coastal & Submarine features on MSS Imagery of Southeastern Massachusetts Comparison with Conventional Maps NASA, Symp. on Significant Results Obtained from ERTS-1, March 5-9, 1973, p. 1413-1422.

ERTS-1 data provides the necessary geologic and hydrographic information needed to update conventional maps of coastal areas where conditions vary rapidly The data obtained through ERTS is both accurate and relatively inexpensive, and provides constant update

Williamson, A. N and Graban, W. E., 1973, Sediment Concentration Mapping in Tidal Estuaries Proc 3rd NASA ERTS-1 Symp , Dec. 10-14, Wash D C , p. 1347.

Methods are discussed for the determination of the amount of suspended sediment in water and, how ERTS data may be used to exactly locate and delineate surface water

Wubber, F. J & Anderson, R R , 1973, Simulated ERTS Data for Coastal Management Photogramm Eng , v 39, p 593-598

ERTS data is shown to be potentially very useful in mapping wetland boundaries, monitoring land use changes in wetlands, studying offshore currents, and in dredge site planning.

Wright, F F , Sharma, G D & Burbank, D C., 1973, ERTS-1 Observations of Sea Surface Circulation and Sediment Transport, Cook Inlet, Alaska, Symp. Significant Results Obtained from ERTS-1

Suspended sediment, visable on MSS 4 & 5, allowed the determination of sediment and pollutant trajectories, areas of probable commerce fish concentration, and the circulation regime

Yost, E , Hollman, R , Alexander, J & Nuzzi, R , 1973, An Interdisciplinary Study of the Estaurine and Coastal Oceanography of Black Island and Adjacent New York Coastal Waters. 3rd ERTS Symp , Wash D C., Dec 10-14, 1973, p. 1607.

Water samples were taken to correspond with the timing of ERTS-1 coverage This allowed various percentages of reflectance to be "quantified" as to the amount of suspended sediment present in the water.

APPENDIX B

LANDSAT COVERAGE OF THE TEST SITES 2, 3, 4, 5

FOR LANDSAT INVESTIGATION #23790

APPENDIX B

LANDSAT COVERAGE OF THE TEST SITES 2, 3, 4, 5

FOR LANDSAT INVESTIGATION #23790

		SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 2				
	Summer June - August				
*	1	1037 - 16251	08/29/72	20%	8888
	2	1343 - 16253	07/01/73	20%	8888
	3	1361 - 16252	07/19/73	20%	8888
**	4	1703 - 16175	06/26/74	10%	8858
	Fall Sept - Nov				
*		1073 - 16351	10/04/72	30%	8888
	Winter Dec - Feb				
*	1	1217 - 16261	02/25/73	20%	8888
	2	1901 - 16110	01/10/75	10%	8808
	Spring Mar - May				
	1	1253 - 16262	04/02/73	20%	8888
**	2	1289 - 16261	05/08/73	00%	8888
*	3	2051 - 16140	03/14/75	00%	8855
*	4	5027 - 16050	05/16/75	10%	5588
	Test Site 3				
	Summer June - August				
	1	1343 - 16253	07/01/73	20%	8888
	2	1361 - 16252	07/19/73	20%	8888
*	3	1038 - 16305	08/30/72	20%	8888

	SCENE ID	DATE	CLOUD COVER	QUALITY
	4 1362 - 16305	08/30/72	20%	8888
**	5 1703 - 16175	06/26/74	10%	8858
	Fall Sept - Nov			
	1 1092 - 16312	10/23/72	20%	8888
	2 1110 - 16313	11/10/72	00%	8888
	3 1452 - 16291	10/18/73	00%	7828
	Winter Dec - Feb			
**	1 1146 - 16314	12/16/72	00%	8888
	2 1164 - 16312	01/03/73	10%	8888
	3 1182 - 16313	01/21/73	00%	8888
**	4 2034 - 16200	02/25/75	00%	8888
	5 2016 - 16200	02/07/75	10%	5888
	6 2034 - 16200	02/25/75	00%	8888
	Spring Mar - May			
	1 1253 - 16262	04/02/73	20%	8888
**	2 1289 - 16261	05/08/73	00%	8888
	3 1236 - 16320	03/16/73	10%	8888
	4 1290 - 16315	05/09/73	00%	8888
	5 1308 - 16314	05/27/73	20%	8888
	6 1614 - 16261	03/29/74	10%	8888
	7 1974 - 16133	03/24/75	00%	8858
*	8 5028 - 16104	05/17/75	10%	8885

	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 4			
	Summer June - Aug			
*	1 1326 - 16315	06/14/73	10%	8888
	2 1740 - 16225	08/02/74	20%	8888
	3 1758 - 16221	08/20/74	20%	8888
*	4 5082 - 16080	07/10/75	10%	8888
	Fall. Sept - Nov			
*	1 1092 - 16314	10/23/72	10%	8888
	2 1110 - 16320	11/10/72	10%	8888
	3 1452 - 16293	10/18/73	10%	8828
	Winter Dec - Feb			
**	1 1146 - 16320	12/16/72	20%	8888
	2 1164 - 16315	01/03/73	20%	8888
*	3 1182 - 16315	01/21/73	00%	8888
	4 2016 - 16202	02/07/75	00%	5885
*	5 2034 - 16202	02/25/75	00%	8888
	Spring Mar - May			
	1 1236 - 16323	03/16/73	20%	8888
	2 1254 - 16323	04/03/73	10%	8888
	3 1290 - 16321	05/09/73	20%	8888
*	4 1308 - 16320	05/27/73	10%	8888
*	5 1974 - 16135	03/24/75	10%	8858
	6 5028 - 16111	05/17/75	10%	5588

	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 5			
	Summer June - Aug			
	1 1362 - 16315	07/20/73	20%	8888
	2 1380 - 16314	08/07/73	20%	8888
	3 1722 - 16235	07/15/74	20%	8888
*	4 1740 - 16231	08/02/74	10%	8888
*	5 1758 - 16223	08/20/74	10%	8888
	Fall Sept - Nov			
*	1 1110 - 16322	11/10/72	10%	8888
*	2 1776 - 16215	09/07/74	20%	5855
	Winter Dec - Feb			
*	1 1182 - 16322	01/21/73	00%	8888
	2 1506 - 16293	12/11/73	10%	8888
*	3 2034 - 16205	02/25/75	00%	8888
	4 1452 - 16300	10/18/73	20%	8888
	Spring Mar - May			
	1 1614 - 16270	03/29/74	20%	8888
	2 1974 - 16142	03/24/75	10%	8888
	3 2070 - 16203	04/02/75	20%	8588
*	4 1290 - 16324	05/09/73	20%	8888

* Imagery on Order

** Tapes and imagery on hand

APPENDIX C

INDEXING OF AIRCRAFT AND SATELLITE DATA AS PART OF TNRIS DEVELOPMENT

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INDEXING OF AIRCRAFT AND SATELLITE DATA AS PART OF TNRIS DEVELOPMENT

Several projects for cataloging, storing, and indexing imagery have been started by the TNRIS Systems Central staff All LANDSAT imagery has been sorted and stored in several bound volumes with an index sorted by date of coverage at the front of the first volume. In addition, a map of Texas has been prepared by Graphic Arts showing LANDSAT coverage available at TWDB. LANDSAT tapes are assigned a unique code number and put in the tape library at TWDB

Aerial photography received from the Texas Governor's office, Division of Planning and Coordination, for NASA Mission 248 has been indexed, Missions 260 and 300 have also been received and are being indexed In addition, a tape and computer printed listing of all available NASA flight line photography in Texas has been received from the EROS Data Center. The tape has been converted from IBM EBCDIC to a UNIVAC COBOL Tape and a program has been written to select and sort data from the new tape The printed listings produced by the program are in the same format as the listing received from EROS So far, the program has been used to select and sort data by flight line

TNRIS is also in the process of acquiring a microfilm browse file of LANDSAT and NASA flight line data With this browse file a user will be able to preview available aerial imagery

In order to keep track of the large amount of data in this area, a computerized indexing system is being designed for the storage, retrieval and updating of available imagery. With this system a user will be able to get a listing of all available imagery covering any given geographic location in Texas Design specification for this indexing system is in progress