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LANDSAT APPLICATION OF REMOTE SENSING TO SHORELINE-FORM ANALYSIS

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16. Abstract

Landsat imagery of the southern end of Assateague Island, Virginia, was enlarged to 1:80,000 and compared with high altitude (1:130,000) and low altitude (1:24,000) aerial photography in an attempt to quantify change in land area over a nine-month period. Change in area and configuration was found with Landsat and low altitude photography. Change in configuration, but no change in area was found with high altitude photography. Due to tidal differences at time of image obtention and lack of baseline data, the accuracy of the Landsat measurements could not be determined. However, they were consistent with the measurements from the low altitude photography.

Field data such as beach slope and sand-grain size were collected at 270 sites along Cape Hatteras and Assateague Island National Seashores. The data are being studied with our data on shoreline change and coastal orientation.

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We wish to express our continuing appreciation to Paul Alfonsi at the NASA-Wallops Flight Center for providing us with the aerial photography which was used during the field trip. The low altitude aerial photos used in the area-measurement study were also supplied by NASA-Wallops.

PREFACE

Objective

Our objective is to quantify relationships between shoreline form and coastal dynamics and to predict areas of vulnerability to shoreline erosion and storm surge penetration along the mid-Atlantic coast. We are using Landsat enlargements, aerial photography, and field data to accomplish these objectives.

It is evident that measurements of coastal change such as shoreline erosion and accretion are best made with the highest resolution low altitude photography available. An advantage of high altitude photography and satellite imagery is that it gives us a regional view of the coastline without having to make elaborate mosaics. In a monitoring program of coastal change, it is thus desirable to work with small scale imagery for rapid, regional assessments, and with large scale imagery to accurately quantify change. The question then arises as to the necessity of using both Landsat and high altitude photography for the small scale images. The advantages of Landsat are lower cost, frequency of image obtention, and more area included per frame. The major advantage of high altitude photography is in resolution. Thus, we would like to determine if Landsat can be used in lieu of high altitude photography in situations of monitoring coastal change where high resolution is not critical.

With these thoughts in mind, we decided to compare Landsat with high and low altitude photography in an attempt to quantify changes in subaerial land area, which could easily be seen in Landsat images of coastal inlets over a period of months. We also wanted to determine if such measurements could be made on unenhanced Landsat imagery that was routinely distributed by EROS Data Center.

Scope of Work

We selected the southern end of Assateague Island as our study site because we noticed a significant change in subaerial landmass from 1975 to 1976 on Landsat imagery of that area. Since we had Landsat, high, and low altitude photography taken during approximately the same time periods of May, 1975, and February, 1976, we chose that nine-month period in which to make our measurements. We made contact tracings of the study area from the low and high altitude photography at 1:24,000 and 1:130,000, respectively. Tracings were made with Landsat enlarged to 1:80,000. Area measurements were made with a planimeter. Differences in tidal height at time of image obtention were taken into consideration during analysis.

Summary of Conclusions

With Landsat imagery, we were able to measure a 14.5% increase in subaerial land area at our study site between 5/31/75 and 2/24/76 with a tidal difference of -.50 meters, and a 2.5% increase in subaerial land area between 5/22/75 and 2/24/76 with a tidal difference of -.05 meters. This compared to an increase of 8.7% as measured with low altitude photography between 4/17/75 and 2/19/76 with a tidal difference of -.43 meters. Although we cannot define the accuracy of the Landsat figures due to lack of baseline data, they compare favorably to the low altitude photo figures. We have found that unenhanced Landsat imagery can be used to detect and measure changes in coastal land area through the use of simple photographic enlarging and overlay mapping techniques. More work needs to be done to determine the maximum change in area necessary before it is visually perceived on Landsat. We conclude that Landsat can be used in lieu of high altitude photography to monitor regional coastal change. However, it must be used in conjunction with low altitude photography to accurately measure site-specific change. As the resolution of Landsat improves in future satellites, the reliability of change measurements will improve.

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INTRODUCTION

In our studies of coastal environments, remote sensing has been our primary source of data. Low altitude aerial photography has allowed us to make fairly accurate measurements ($\pm$ 10 meters with 1:20,000 photos) of shoreline change. Landsat has allowed us to make measurements of coastal orientation - measurements that do not require high resolution imagery. Although our high altitude photography (1:130,000) has served us well as a regional reference during analysis and discussions of our barrier island study sites, we have not used it as a source of quantifiable data. Since both Landsat and high altitude photography can be classified in the small scale range, they are most appropriate in measuring regional or large scale changes of 100 meters or more. Such changes in landmass commonly occur in the coastal zone near tidal inlets. The question then arises; "Can Landsat be used in lieu of high altitude aerial photography to detect and measure, however approximately, these changes? How great must the change be before it is detected with Landsat? Can these changes be detected and measured through relatively unsophisticated techniques with unenhanced Landsat imagery routinely available from Eros Data Center?" If Landsat could be used in lieu of high altitude photography the cost savings would be significant.

In an attempt to answer these questions, we decided to measure the change in subaerial land area at the southern end of Assateague Island, which occurred between May, 1975, and February, 1976. Measurements were made with Landsat (enlarged to 1:80,000), high altitude aerial photography (1:130,000), and low altitude photography (1:24,000). This report describes our methods and results.

We have also included a section in this report which describes the field work we completed this summer on Cape Hatteras and Assateague Island National Seashores. The data from the field trip is being combined with our data on shoreline erosion and coastal orientation so that we may better understand the process/response relationships of our shoreline-form analysis.

ACCOMPLISHMENTS

During the reporting period from 6/2/76 to 9/1/76, we investigated the usefulness of Landsat imagery as a source for detecting and quantifying change in coastal land area through simple visual, mapping, photographic enlarging, and planimetric measuring techniques. The results of this study are presented in this report.

A six week field trip to Assateague Island and Cape Hatteras was completed during June and July, 1976. Beach data were gathered at 270 sample sites; the field trip is described in this report.

In related activities, we are working on various publications relating to research funded by NASA and the National Park Service (see the section entitled "Publications"). We have also begun the mapping of historical change in shoreline on Cape Lookout National Seashore using methods described in a recent quarterly report for this project, dated 27 April.

COMPARISON OF LANDSAT, LOW ALTITUDE, AND HIGH ALTITUDE AERIAL PHOTOGRAPHY FOR AREA MEASUREMENTS

In the past, people who have done research into changes in coastal geomorphology have depended upon historical charts, maps, aerial photography, and whatever field data was available, primarily from academic institutions or government sources. Studies were usually site-specific or very localized. Now with the advent of high altitude aerial photography and satellite imagery so easily accessible to the public, coastal studies have become more regional in nature. Our study into Landsat application of remote sensing to shoreline-form analysis, is just such a regional study.

Although we have been concentrating on low altitude photography, in the range of 1:20,000 scale, to provide accurate measurements of shoreline changes, we have questioned whether Landsat and/or high altitude photography (1:130,000) could provide useful quantifiable data on shoreline change by using relatively unsophisticated mapping techniques that we have developed (NASA quarterly report dated 27 April 1976). We realize that the accuracy of such data would not be as reliable as that from low altitude photography; however, in certain situations where "ball park" figures would suffice, the lower resolution of the small scale imagery may not be critical.

To go a step further, even though the present resolution of Landsat imagery is in the range of 80 to 120 meters, it has certain advantages over high altitude photography such as cost, frequency of site coverage, and amount of land area included in a single frame. Landsat is especially useful in the coastal zone because of the relatively clear demarcation between land and sea. Due to these advantages, we wondered if Landsat could be used instead of high altitude photography to detect and measure regional changes, realizing that our results could only improve as the resolution of future Landsat imagery is improved.

Therefore, we have undertaken a study to see how accurately changes in area could be quantified using Landsat imagery as compared with area measurements from low altitude (1:24,000) and high altitude (1:130,000) color infrared aerial photography. We chose Chincoteague Inlet, Virginia, as our study site - more specifically, the southern end of Assateague Island, known as Fishing Point (Fig. 1).

To provide a sufficient time lapse for measurable area changes to develop, we selected imagery spanning a 9-month period from May, 1975, to February, 1976. This was the longest period for which we had all three scales of imagery flown conterminously. Specific dates of the imagery are given in Table 1.

The various sets of imagery were flown under different tidal conditions. Therefore, relative tidal heights were considered in our conclusions. Obtention times were determined from the NASA/Ames Flight Summary Report for high altitude photography, the NASA/Wallops Remote Sensing Mission Summary for low altitude photography, and the data blocks printed on the Landsat images. Tidal data were calculated from the NOAA Tide Tables.

Of the four Landsat MSS bands, band 7 penetrates water the least. We therefore chose band 7 for all measurements, since we felt that this band would render the shoreline most accurately. However, we have included an image of band 5 for purposes of comparison (Figures 2, 3, and 4).

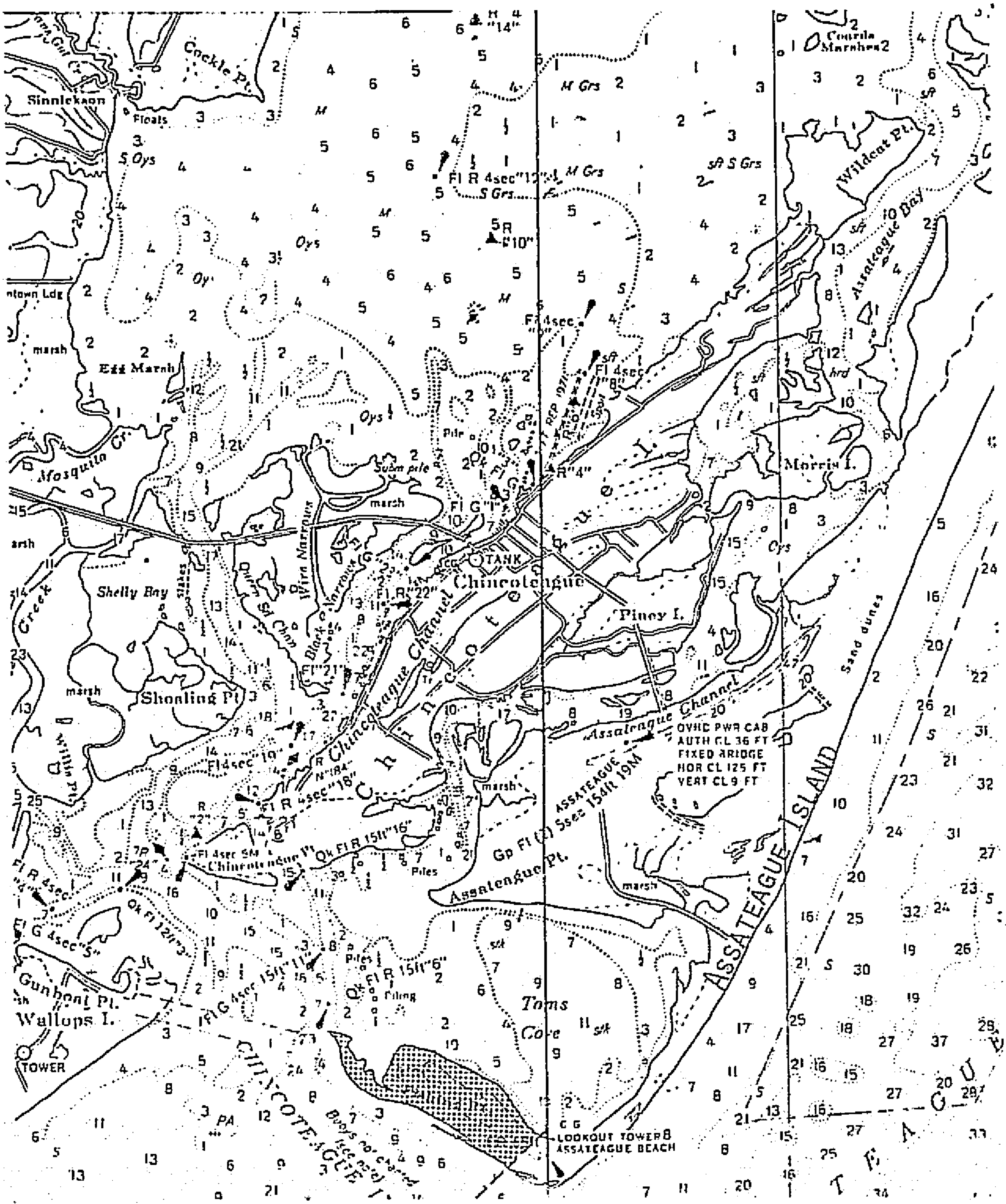

Figure 1. Study site: southern end of Assateague Island (stippled).

TABLE 1. IMAGERY USED FOR AREA MEASUREMENTS

Imagery Date		Scale at Which Area Measurements Were Made	Tidal Height Correction (M)[1]	Measured Area (KM^2)
First Time Period				
Low Altitude	4/17/75	1:24,000	.68	2.563
[2]Landsat	5/31/75	1:80,000	.48	2.291
High Altitude	5/8/75	1:130,000	.02	2.535
[2]Landsat	5/22/75	1:80,000	.03	2.560
Second Time Period				
Low Altitude	2/19/76	1:24,000	.25	2.786
High Altitude	2/25/76	1:130,000	-.03	2.535
Landsat	2/24/76	1:80,000	-.02	2.624

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[1]Tidal height correction is height of tide at time of image obtention when added to datum (mean sea level).

[2]Landsat images taken on two different dates were used to more closely match the the tidal height correction factors of the aerial photography.

Figure 2. Band 5 of Landsat frame #2129-15021 taken on 5/31/75. Band 5 depicts the test site (the southern end of Assateague Island) with an irregular shoreline and with dark areas in its interior. Chincoteague Island is barely visible.

Figure 3. Band 7 of Landsat frame #2129-15021 taken on 5/31/75. The shoreline appears smoother on this band than on band 5 in Figure 2, and some of the darker areas are not visible in the interior of the test site. Note that more of Chincoteague Island is visible in this band.

Figure 4. Band 7 of Landsat frame #2398-14534 taken on 2/24/76. The western tip of Fishing Point forming the "toe" of the "boot," has enlarged considerably when compared with Figure 3, which was taken nine months earlier.

METHOD OF AREA MEASUREMENTS

Area measurements were made at scales of 1:80,000 for Landsat imagery, 1:130,000 for high-altitude photography, and 1:24,000 for low altitude photography. The C&GS nautical chart #1220, scale = 1:80,000 served as our base map for fixed reference points. The boundary of our study site was the shoreline of southern Assateague Island and a line drawn at an angle of 45° East of North to intersect the Coast Guard pier as seen on the C&GS chart at 37°52'N. The pier and the line served as a reference point and fixed boundary independent of geographical features (Figure 1).

The first step in obtaining area measurements from Landsat was to photographically enlarge the 2¼" square negative from a scale of 1:3,369,000 to a scale of 1:80,000. The enlargements were made using a Realist 620 2¼" format slide projector (the projector's lens produced no measurable distortion at this scale of enlargement). The Landsat image was projected onto the C&GS chart, and a "best fit" was obtained by matching features such as surrounding islands and shorelines as closely as possible. The chart was then replaced by a strip of photographic paper, and a print of the area was made at 1:80,000. Exposure time was determined with an Analite enlarging meter and controlled with a Gra-Lab model 300 darkroom timer connected into the circuit of the projector. Exposure times varied from 2 to 6 seconds, depending upon the density of the negative. Processing times were normal in Dektol. Kodak Polycontrast Enlarging Paper with a lightweight base was used for the enlargements. The lightweight paper was chosen because the thinness of the base allowed more light to pass through, thus making it easier to later obtain tracings of the image.

A light table (Richards Model GFL-918) and a K&E Kargyl Reflecting Projector, Model RP-T-4B, were used to make contact tracings of the shoreline from the aerial photography. Our fixed boundary was then transferred from the C&GS chart to the aerial photo tracings with the aid of the enlarging-reduction capability of the reflecting projector. The tracings made from the Landsat imagery were more easily matched to the high altitude tracing than to the C&GS map. Therefore, the former was used to transfer the boundary to the Landsat tracings.

A Salmoiraghi Model 236 Metric Planimeter was used to measure the areas of the test site scribed on the various tracings. Ten measurements were made of each tracing and an average was taken of these values. These averages, adjusted for scale differences, are listed in Table I. Figure 5 shows the relative scales at which the three types of imagery were measured.

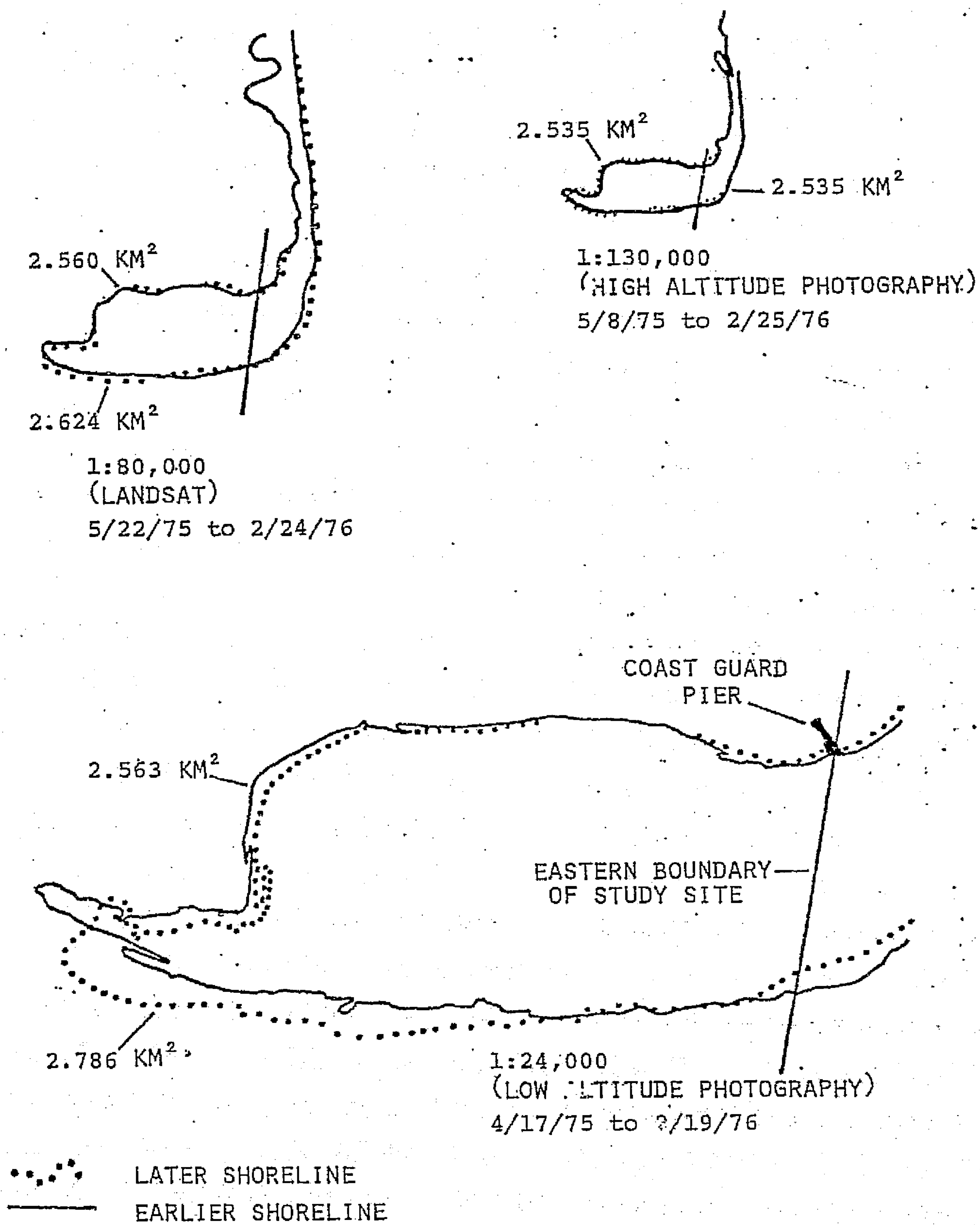

Figure 5. A comparison of the southern end of Assateague Island made at the 3 scales used in our analysis with changes in area as noted.

SIGNIFICANT RESULTS

The area measurements are presented in Table 1. The low altitude aerial photography showed an 8.7% increase in area from this time period 1 to time period 2 with a tide difference of -0.43 meters. High altitude photography showed no change in area with a tide difference of -0.05 meters. Landsat imagery showed a 14.5% increase in area with a tide difference of -0.50 meters (first comparison) and a 2.5% increase in area with a tide difference of -0.05 meters (second comparison). We do not have sufficient base-line data to state whether the increase in area was due to a real net increase in subaerial landmass between the two time periods, or simply a ramification of differences in tide levels. However, as the following table shows, with tidal differences considered, the changes in area shown by Landsat are consistent with what one would expect when comparing them to the changes shown by the low altitude photography.

TABLE 2: AREA CHANGES ACCORDING TO TIDAL DIFFERENCES

Imagery		Tidal Difference	Area Increase
Landsat	5/31/75 to 2/24/76	-.50 meters	14.5%
Low Altitude	4/17/75 to 2/19/76	-.43	8.7
Landsat	5/22/75 to 2/24/76	-.05	2.5
High Altitude	5/8/75 to 2/25/76	-.05	0.0

No increase in area was measured with high altitude photography at 1:130,000. This is probably due to the small scale at which these measurements were made. It should also be mentioned that we were measuring changes in area but not changes in geometric configuration of the study site. The latter could occur without being reflected in the former.

For both time periods, areas measured with Landsat were less than those measured with low altitude photography, even though the tide heights were greater for the photography. These results are contrary to expectations if we assume there was negligible change in real subaerial landmass between the two image obtention times at each of the two time periods. This might be explained by the fact that the colcr IR emulsion is sensitive to shorter light wave lengths than band 7 of Landsat, thus, penetrates water to a greater depth. If this is true, it is possible that the photo interpreter may visually interpret the shoreline to be farther seaward on a color IR photo than on a Landsat band 7 image.

PROBLEMS

Our major problem was in trying to locate all three scales of imagery with obtention times as close together as possible for the first and second time periods. However, by determining relative tidal heights, we were able to reach some useful conclusions. Another problem was to be expected. As we increased the enlargement of the Landsat images, film grain, scan lines, and noise along the coastline became more apparent. We felt 1:80,000 was the maximum limit that we could enlarge the 70mm negative and still discern a somewhat clear shoreline.

CONCLUSIONS

Unenhanced Landsat imagery can be used to detect and measure changes in coastal subaerial land area over time. We have not determined the minimum amount of change in area necessary before it can be visually detected and measured with Landsat. The smallest amount of change we measured was a 2.5% increase in area from 2.560 KM^2 to 2.624 KM^2

Landsat should be included in any program of monitoring changes in the coastline over long periods of time. Advantages of Landsat over aerial photography are lower cost, more area coverage per frame, and routine coverage every eighteen days. Landsat should be supplemented by low altitude aerial photography on an as-needed basis to provide more accurate measurements of change.

The lay person can make valuable use of the inexpensive Landsat transparency by enlarging it to its fullest resolution using low-cost photographic equipment.

When mapping a shoreline from color infra-red photography and Landsat band 7 imagery of the same coastline taken at the same point in time, the visual interpreter may have a tendency to locate the color infra-red shoreline farther seaward than that from Landsat.

RECOMMENDATIONS

To more successfully evaluate the usefulness of Landsat to measure area change affected by coastal erosion or accretion, images should be obtained during the same tidal conditions. To obtain reliable absolute area measurements with Landsat, a control set of data must be available. Low altitude aerial photography or field measurements taken at the same time as Landsat obtention would be adequate.

SUMMER FIELD WORK

(The following report was written by Jeff Michel, a student research assistant, who is now in his senior year at the University of Virginia).

Introduction

This report is a summary of the field work conducted at Cape Hatteras and Assateague Island National Seashores from May 23 to June 20, 1976. The purpose of the field trip was to collect data at 270 randomly chosen sites along 200 km of the mid-Atlantic coast. The data are being analyzed along with historical data on overwash penetration and shoreline change and with wave climate data as part of our continuing studies of sedimentary coastal processes.

The research team consisted of Vicki Womack, Carol McNulty, Cub Kahn, and myself; all undergraduates from the University of Virginia. Although neither I nor the three other students had participated in any field work as extensive as this, what was lacking in experience was well made up for by the enthusiasm shown by everyone. This is not to say, however, that our enthusiasm totally compensated for our inexperience. Tactical problems were encountered during the first week or so, such as where to park the car, when to buy ice for the coolers, and whether or not we had adequate zinc oxide for Carol's nose. Living semi-primitively for a number of week: occasionally presented minor problems which often seemed to snowball, but they were always surmountable. The remainder of the report presents the type of data which we collected, the real tactical problems that we encountered in the field, the way in which they were handled, and, finally, whether the way in which they were handled was in fact the correct way or whether we were introducting additional error to the data being collected.

Data Collection

Prior to the trip 180 random sites were chosen at Cape Hatteras from Ocracoke Inlet to Nags Head, North Carolina, and

90 at Assateague from Chincoteague Inlet, Virginia, to Ocean City, Maryland. The sites coincided with transects we had previously established for our shoreline change studies. We marked these sites on a set of 1974, 1:20,000 scale color infra-red aerial photography flown by NASA-Wallops.

In the field we oriented ourselves with the aid of the photography by identifying vegetation patterns, the bayside coastal configuration, and any buildings or streets that were present. We feel we were able to locate ourselves to within ten meters of each transect. Then we measured the height and slope of the dunes, the width and slope of the subaerial beach, and the slope of the swash zone, and the width of any cusping that may have been present (Figure 6). Holes were dug at the base of the dune and at the berm line for sand samples. Our equipment consisted of a leveling rod, an Abney Level and a Jacob Staff with swivel platform for the level. Other equipment included a 100 m tape, a shovel, and baggies for the sand samples.

Dune slope measurements were taken in two ways. The first was by a direct reading from the Abney Level. The second was by computing the slope from measurements of the dune height and horizontal distance from the peak to the base of the dune.

The slope of the subaerial beach was computed in the same manner. When the width of the beach was over 50 meters, two measurements were taken and then added together, because beyond 50 meters, accuracy in reading the height of the leveling rod began to fail. The base of the dune was defined as that point where the dune first began to rise from the subaerial beach surface. There was usually a poorly defined zone of transition from the dune to the beach where the slope was becoming more gradual. This zone was never over .5 meters in height or 2 meters in width, so it was disregarded altogether and does not enter into the data. On the other end, the berm line was defined as the break in slope from the gentle subaerial beach to the steeper swash zone. Where the berm was undefined due to a constant slope, the mean high water mark was used. A direct slope measurement using the Abney was not done for the subaerial beach.

BEACH DATA AT CAPE HATTERAS NATIONAL SEASHORE
June, 1976 (Measurements in Meters)

Site No.__________ Map No.__________ Transect No.__________

Date________ Time_______ High Tide_______ Low Tide______ Tide Range_______

Measurements

	Foredune	Subaerial Beach		Swash Zone		Total Beach
Rod Height	______	______		______		______
Level Height	______	______		______		______
Elevation	______	______	+	______	=	______
Distance	______	______	+	______	=	______
Comp. Slope	______ %	______ %		______ %		______ %

Meas. Slope ______ ° ______ % ______ ° ______ %
(Fore dune) (Swash Zone)

Visual Description

Beach: Straight______, Cusping______, Sand Wave_____, Cape______

Distance Between Nodes: ______ ______

Foredune: Scarped______, Sloping______, Throat of Fan_____, Absent____

Overwash Fan: Width at dune______, Length______, Flats______

Sand Samples	Base of Dune	Berm Crest
Mean Grain Size:	______	______
Standard Deviation:	______	______
Sample Size:	______	______

Comments:

Figure 6. Sample data sheet for field work.

The mid-swash zone was a subjective choice of where the water level would be half way between high and low tides. Tide tables and estimated tide ranges were used for mid-swash zone placement. Slope measurements were calculated in the same manner as before and direct Abney level measurements were again taken.

When cusping was present in the swash zone, a measure of the distance between cusps (crest to crest) was taken, and an Abney measurement was taken at both the crest and the trough of the cusp. Finally, a hole one meter deep was dug at the base of the dune and one at the berm line, and sand channel samples were taken out of it.

Occasionally, one of the random transects was located on an overwash. In this case, the dune measurements were disregarded and measurements of the width and depth of the fan were taken. The width of the mouth was defined as the length of the breach between the dunes along the same line the dune would have taken had it been there. The depth measurement was taken from the mid-point of the width measurement back to the first evidence of stable vegetation (grasses), and the subaerial beach measurement was taken from the same mid-point forward to the berm. This mid-point was the location of one of the sand samples.

I would like to make mention of a few physical observations that were noted during the course of the trip. The first is the phenomena of cusping and sandwaves. These phenomena were observed all along the coastlines that were studied. Cusping 15 to 40 meters between apexes was much more apparent in Cape Hatteras than in Assateague. But even in Hatteras the cusping was usually observed only shortly following days of high wave energy. Cusping was also observed to be a very transient feature which appeared and disappeared with a period of a day.

The second phenomenon, sandwaves, were also detected throughout the six week field study. The lengths and depths of the observed sandwaves correlated with the wave activity in the area ("Quantification of Shoreline Meandering," Linwood Vincent, 1973). Although shoaling was indistinguishable through sight observations from the beach, it could be seen that during periods of high wave energies such as those encountered in Cape Hatteras, the sandwaves were well over 500 meters in length. By the time we reached Assateague, however, the weather had stabilized considerably and the accompanying wave energies had diminished. Sandwaves in this area were observed to be less than 500 meters in length.

There were also two trends which were readily observable, and consistent, for almost all of the north/south trending islands which were studied (Ocracoke, Hatteras Point to Oregon Inlet, and Assateague Island). The first of these trends was the tendency for the beach to narrow from south to north. This was not the case, however, along the coastline from Hatteras Inlet to Hatteras Point, where the island is oriented in more of an east/west direction. Although the subaerial beach is very wide at Hatteras Inlet and Hatteras Point, the overall width of the beach between these locations remained relatively constant. The stretch of beach from Oregon Inlet north to Nags Head also lacked any significant trends.

The second trend which we noted concerns the dune formations on these barrier islands. Aside from the protective straight line of man-made dunes found on all the islands, there was a large number of forming beach dunes found on all the islands; there was also a large number of forming beach dunes found predominantly on the more southerly parts of the islands. Particularly on Cape Hatteras from Hatteras Point north to Avon, a continuous and natural dune line could be seen. This natural dune line was much lower (1 to 2 meters) than the larger man-made dunes found immediately behind it (2 to 4 meters), and the slope was more gentle. North of Avon to Salvo the natural dune line became breached in many places and any real consistency in the dune line was lacking. North of Salvo to Oregon Inlet, the beach dunes disappeared altogether and only the larger man-made dunes were evident, although a few widely scattered beach dunes were observed on the overwash flat near Oregon Inlet. The same pattern occurred, to a lesser degree, at Assateague and Ocracoke. Here there was never a consistent natural dune line, rather an appearance and disappearance of scattered beach dunes.

Problems

The simultaneous occurrence of natural and man-made dunes brings up one of the first problems which we encountered in the field: it became necessary to determine which dune to measure at the transect under study. Where there was a consistency of the natural dune line, the measurements were taken from this point; but, as the dunes became highly breached, the consistency was no longer there. It seemed incorrect to be jumping from one dune line to another within a period of a few hundred meters, but there was also the possibility of a cause/effect relationship concerning beach dune formation on one transect and the absence at another. This problem was resolved by carefully locating ourselves on the photography and, then, when two dune lines were present at this point, measuring both of the dunes along with the distance between them on the data sheet. Therefore, where only one dune measurement is recorded in the data, that measurement is the height and the slope of the primary dune line in that area. Where two recordings are noted, there is an inconsistency in the line of beach dunes immediately in front of a continuous man-made dune line.

A second problem which we encountered was the elements; during the first two and a half weeks at Cape Hatteras National Seashore, we were plagued with storms on the average of one every 5 to 6 days. We attempted to take measurements during these storms, only to find that the wind and rain made our measurement and recording attempts futile, at best. It was also noted that a strong storm visually altered the subaerial characteristics of the beach for at least two tidal cycles. Unfortunately, our enthusiasm prompted us to take some measurements on days following storms so as to make up for lost time in the field. Stormy days, and days following them, on which data were collected, were noted on the data sheets, and I feel that these days should not be considered during the analysis of the data because it is the average conditions which are necessary for reliable data in this case, and not the extreme event. This also brings to mind a suggestion for any future research teams to that area; for any real consistency of the data, the weather and ocean conditions should be stable. During the four weeks we were on Cape Hatteras, wave energies were constantly changing, as were the beach face characteristics. It appeared that a stabilization had occurred by mid-June, so a research team such as ours would encounter better conditions from mid-June to August rather than from mid-May to June as we did. As far as the data which we collected is concerned, with the exception of data collected during stormy weather, it is both reliable and usable for Cape Hatteras. The weather presented no problems to us while we were on Assateague; therefore, all Assateague data are consistent in this regard.

Another difficulty which the meteorological variations brought about was a changing berm line. Perhaps, because we were there too early, we did not find this to happen while we were on Cape Hatteras; but, on Asseateague, the problem was very evident. In back of the primary berm line, there was very often a secondary berm line before the subaerial beach. The two berms represented the decaying winter berm and the forming summer berm; but which one was to be measured for the purpose of our data measurements? To be safe, we measured both berms and entered the data separately on our data sheets. Again, this should be considered before any data analysis can be done because this narrow area was usually steeper than the subaerial beach, yet it was flatter than the swash zone. Therefore, the addition of this area to either the subaerial beach or swash zone measurements could introduce additional error into the data.

Another minor problem which we encountered concerned the holes dug for the grain samples on overwash fans, overwash flats, and on days following heavy rains. On such occasions we often encountered water before we reached the standard one-meter depth, which we had decided to use for consistency, in these measurements. When water was present, the depth of the water table was recorded onto the data sheets. Fortunately, this happened rarely; but, again, this should be considered when evaluating the validity of these particular samples.

I would like to make a suggestion for any future field work in the area. We estimated that we could have finished our work in about half the time had we had a four-wheel-drive vehicle, without snow tires, to drive on the beach.

Although there may have been some faults or errors in our measurements, they really only include a small percentage of the data. I feel very confident in the accuracy of the measurements, mainly due to the competence of the field team. Finally, on behalf of Vicki, Carol, and Cub, I would like to thank Mr. Jeff Heywood for his assistance in the field and for his timely supply runs, and to Dr. Robert Dolan for making this invaluable experience in field work possible.

Jeff Michel

LANDSAT USER BENEFITS

We have found that changes in land area along the coast (specifically at tidal inlets) can be detected and measured with unenhanced Landsat imagery by relatively unsophisticated techniques of photographic enlarging, overlay mapping, and planimetric measuring. However, more work needs to be done to determine the accuracy of the measurements. We feel that Landsat can be used in lieu of high altitude photography to monitor large scale changes in coastal land area. We measured an increase in area of as little as 2.5% of an original landmass of 2.56 km^2. More work must be done to determine the minimum degree of change necessary to be visually perceived and measured on Landsat. Its advantages over high altitude aerial photography are in lower cost to the user, repetitive coverage of a given site, and more area included in a single frame. The main disadvantage is lower resolution. However, if more accurate measurements of change are required, the user should rely on low altitude aerial photography.

PROGRAM FOR NEXT REPORTING INTERVAL

Most of our efforts during the next reporting period will be directed toward completing the historical mapping of shoreline change and overwash penetration for Cape Lookout National Seashore. These data will be correlated with coastal orientation obtained from Landsat imagery as described in the quarterly reports dated 27 April and 18 June, 1976. We will also begin processing of the data obtained during the summer field trip.

PUBLICATIONS

We will soon submit a paper to Science magazine entitled "Shoreline Configuration and Shoreline Dynamics - A Mesoscale Analysis." It will summarize our research as reported in the previous two NASA quarterly reports. If accepted, the paper will appear under the authorship of R. Dolan, B. Hayden, J. Heywood, and L. Vincent.

A paper entitled "Vegetation Changes Associated with Barrier-Dune Construction on the Outer Banks of North Carolina, " by P.M. Schroeder, R. Dolan, and B. Hayden has been accepted for publication in Vol. 1, No. 2 or No. 3 of Environmental Management magazine. The research was conducted under grants from NASA and the National Park Service and employed mapping techniques described in the NASA quarterly report dated 27 April 1976.

We are currently in the "mock-up" stages of an in-house publication entitled Atlas of Environmental Dynamics - Assateague Island. Although the project is funded primarily by the National Park Service, much of the data and analysis are the result of research funded by NASA.

We recently released an in-house publication for review entitled Handbook for Remote Sensing - Mid-Atlantic Coast National Seashores, Assateague Island, Cape Hatteras, Cape Lookout, under the authorship of P. Alfonsi, R. Dolan, B. Hayden, and J. Heywood, and sponsored jointly by NASA/Wallops Flight Center and the National Park Service. It is a 100-page document that summarizes the use of several types of imagery including Landsat, in the investigation of coastal environments.