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LANDSAT APPLICATION OF REMOTE SENSING TO SHORELINE-FORM ANALYSIS

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16. Abstract

Data on beach-zone width, swash slope, and sand-grain size were collected at 89 locations along Assateague Island (MD/VA). Correlations were run among these data sets and for coastal orientation and historical shoreline erosion. The analysis indicates that there are organized relationships between physical beach features and shoreline form and erosion, but weak relationships between sand grain size and shoreline form and erosion.

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PREFACE

Objective

Our objective is to quantify relationships among shoreline form, coastal dynamics, and physical features along the mid-Atlantic coast. Our research is designed to predict areas of vulnerability to shoreline erosion and storm surge penetration. Sources for our data are Landsat enlargements, aerial photography, and field measurements.

Scope of Work

During this reporting period our emphasis has been on analysis of field data gathered during the summer of 1976 on Cape Hatteras and Assateague Island. We will present the initial results of the analysis of the Assateague data in this report. In addition, we have completed historical mapping of shoreline erosion and storm-surge penetration for Cape Lookout National Seashore, and have completed half of our scheduled mapping for the southern New Jersey coast.

Summary of Conclusions

Initial analysis of our data for Assateague Island leads us to believe that there are strong positive relationships between the width of the sub-aerial beach and the rate of shoreline erosion and between the slope of the swash zone and the orientation of the coast. Inverse relationships exist between the height of the foredune and the mean plus standard deviation of rate of shoreline erosion; between the slope of the sub-aerial beach and the standard deviation of shoreline erosion; and between the height of the foredune and the width of the sub-aerial beach. The relationships between sand grain size and the other variables which we measured are weak.

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INTRODUCTION

In the April quarterly report of 1976 we stated our hypothesis that there is a measurable relationship between shoreline form (coastal orientation) and coastal dynamics (shoreline erosion). Through measuring historical shoreline change from low-altitude aerial photography and current shoreline form from Landsat imagery, we were able to determine historical erosional trends and their correlation with coastal orientation. Some of these correlations were very high (greater than .9 at .01 significance level), and it was our hope that an additional data base of physical beach features would also present significant trends.

Included in the quarterly report for September, 1976 was a discussion of the field work which was recently completed on Cape Hatteras and Assateague Island during June and July last summer. That report describes the various field measurements and relevant observations. These data are now being analyzed.

ACCOMPLISHMENTS

Beach data gathered during the summer of 1976 has been processed and combined with data on historical shoreline erosion and current coastal orientation for Assateague Island. Our analysis includes correlations, multiple regression and eigenvector analysis. Results of correlation tests are presented in this report. Similar data for Cape Hatteras are now being processed.

During this time period we have also completed the historical mapping of shoreline erosion and storm surge penetration for six time periods from 1940 to 1976 for Cape Lookout National Seashore. We have currently more than half-way completed similar mapping of the southern New Jersey coast.

METHODS

Last summer, field measurements were taken of the foredune height and slope, sub-aerial beach width and slope, swash width and slope, and grain samples were taken at the base of the dune and at the berm at 89 selected sites along the coast of Assateague Island and 180 sites along the coast of Cape Hatteras (NASA Quarterly Report, 9/28/76). The sediment samples from Assateague were analyzed in two different ways. With the first method, we used a large projecting microscope and took measurements of the "b" axis of 60 random grains from each sample. In this way it was possible to determine the mean grain size and its standard deviation. With the second method, a Rapid Sediment Analyzer (RSA) was used, which made an evaluation of the hydraulic sorting of the sample possible in addition to the mean grain size. Although the microscope analysis produced slightly higher correlations than the RSA, the method was too time consuming to warrant further use. Therefore, only the RSA will be used for Cape Hatteras. To date three methods of data analysis are being used - correlation studies, multi-linear regression, and eigenvector analysis. In this report, we will present the initial results of the correlation analysis for Assateague.

Our objective is to quantify the relationships between the physical beach data and two variables we have already measured, historical shoreline erosion and current coastal orientation. With the use of Landsat imagery, we have developed a method to measure the orientation of relatively straight-line segments of the coast with respect to the north/south axis. Nodal points mark the intersection of adjacent segments. We have written a computer program which locates these nodes based on a prescribed angle between adjacent segments. The number of segments is successively reduced as the prescribed angle is increased, until the final output reduces the entire coast to one straight segment which defines the mean orientation of the coast (NASA Quarterly Report 4/27/76 and 6/18/76). This allows us to analyze relationships between shoreline form, processes, and physical features from the micro-scale (meters) to the meso-scale (kilometers). We found in our studies with erosion and orientation that the highest correlations were reached as the number of coastal segments were reduced and the mean length increased. We found this to be true also when the field data was included in the analysis.

The 89 field data points for Assateague were randomly distributed along the entire coast. The values of each variable used in correlation calculations was the mean over all data points within a segment of the coast as defined by a given iteration of the computer output. The variables used in the analysis are the following (abbreviations refer to the listings in Table 1 and Table 2):

1. EROSRT: mean erosion rate of shoreline (m/yr)
2. DMRSA: median grain size at dune (mm), measured by RSA
3. BMRSA: median grain size at berm (mm) measured by RSA
4. DSRSA: grain size sorting at dune measured by RSA
5. BSRSA: grain size sorting at berm measured by RSA
6. FHGHT: foredune height (m)
7. FSLOPE: foredune slope
8. BSLOPE: sub-aerial beach slope (dune to berm)
9. SSLOPE: swash slope
10. SWDTH: swash width (m)
11. SLSTDV: standard deviation of shoreline erosion rate (m/yr)
12. BWDTH: sub-aerial beach width (m)
13. MPSTD: mean plus one standard deviation of shoreline erosion rate (m/yr)
14. ORIENT: orientation of coastal segments (degrees).

SIGNIFICANT RESULTS

Table 1 presents correlation coefficients between variables of coastal orientation, shoreline erosion, and physical beach features for breakdown of Assateague Island into 55 straight-line coastal segments. Table 2 presents the same information for 8 coastal segments.

Correlations for 55 segments are quite low, showing few values greater than .6. Most of the correlations substantially increased when they were run for the breakdown of Assateague into

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CORRELATION COEFFICIENTS.

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	ORIENT	ERDSRT	DMRSA	BMRSA	DSRSA	BSRSA	FHGHT	FSLOPE	DSLOPE	SSLOPE	SWDTH	SLSTDV
ERDSRT	.21163											
DMRSA	.25711	.03737										
BMRSA	.46519	.00026	.27011									
DSRSA	.09417	.02561	-.57496	-.01057								
BSRSA	.10222	-.09054	-.08234	-.39466	.09769							
FHGHT	-.39848	-.40538	.05666	-.14026	-.07744	.00326						
FSLOPE	-.06361	-.14023	.08444	.08057	.00242	-.02977	.46380					
BSLOPE	-.22363	.14706	.26308	-.05431	-.13578	-.07883	.24184	.38558				
SSLOPE	.64257	.10398	.18624	.34409	.06740	.08703	-.12711	-.03216	-.02126			
SWDTH	-.63556	-.14323	-.18203	-.37557	-.09250	-.00781	.30652	.18940	.11755	-.76330		
SLSTDV	.60018	.03168	.22650	.33192	.01621	-.00575	-.24983	-.05770	-.28690	.42137	-.42028	
BWDTH	.06977	.31328	-.41676	.00874	.12894	-.01277	-.34882	-.29406	-.42447	.02703	-.00138	.06920
MPSTD	.59519	.58653	.26138	.27142	-.04916	-.07991	-.42930	-.11694	-.14176	.38555	-.40536	.79648

	BWDTH
MPSTD	.21580

Table 1: Simple Correlation Coefficients Between Variables of Coastal Orientation, Shoreline Erosion, and Physical Beach Features for Breakdown of Assateague Island into 55 coastal segments.

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CORRELATION COEFFICIENTS.

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	ORIENT	EROSRT	DMRSA	BMRSA	DSRSA	BSRSA	FHGHT	FSLOPE	BSLOPE	SSLOPE	SWDTH	SLSTDV
EROSRT	.04406											
DMRSA	-.07715	-.11807										
BMRSA	-.02183	-.47945	.10315									
DSRSA	.44744	-.14924	-.64747	-.22434								
BSRSA	.32372	-.48132	-.06811	-.03597	.74330							
FHGHT	-.65685	-.52171	.55340	.02088	-.44412	-.91543						
FSLOPE	-.44137	-.60737	.42771	.00126	-.13856	.18326	.88544					
BSLOPE	-.73912	.15825	.54837	-.20530	-.63630	-.34351	.65138	.50665				
SSLOPE	.84139	-.14505	.23968	-.07839	.30077	.43401	-.33092	-.09375	-.35445			
SWDTH	-.87904	-.04924	-.05318	.00613	-.54058	-.60119	.57979	.35405	.58239	-.80315		
SLSTDV	.93309	.22862	-.16658	-.02765	.42026	.17999	-.72614	-.55425	-.79006	.61028	-.81095	
BWDTH	.38982	.72121	-.54657	-.14180	.14472	-.35079	-.89220	-.94520	-.45287	.01810	-.22541	.53379
MPSTD	.68029	.72986	-.10419	-.29237	.21071	-.14764	-.80691	-.73498	-.46467	.34595	-.59748	.83235

	BWDTH
MPSTD	.78557

Table 2: Simple correlation Coefficients Between Variables of Coastal Orientation, Shoreline Erosion, and Physical Beach Features of Breakdown of Assateague Island into 8 coastal segments.

8 coastal segments. Some of these correlations reflect strong and important relationships. As we previously reported, the correlation between coastal orientation and the standard deviation of rate of shoreline erosion is .93 at the .01 level of significance. This is the strongest relationship in the table. Other significant relationships are orientation and swash slope (.84); standard deviation of erosion and sub-aerial beach slope (-.79); foredune height and sub-aerial beach width (-.89); foredune height and mean plus standard deviation of erosion (-.81); and rate of erosion over time and sub-aerial beach width (.72). We found low correlation between sand grain size and erosion (most values under .2, absolute value), and between sand grain size and orientation (less than .1, absolute value).

CONCLUSIONS

Based on the figures in Table II, we may conclude the following : 1) the width of the sub-aerial beach from the berm line to the base of the foredune is positively related to the mean rate of shoreline erosion; i.e. wider beaches erode faster over long periods of time than do narrow beaches.

2) The height of the foredune has an inverse relationship to the mean plus standard deviation of shoreline rate of erosion (a combined measure of the long-term trend and the episodic storm event); i.e. high values for this measurement of shoreline erosion may be found in those areas where low foredunes exist.

3) The standard deviation of shoreline erosion has a high inverse relationship with the sub-aerial beach slope; i.e. where the beach is fairly level or sloping downwards toward the base of the foredune, one would expect high variability over time in the location of the shoreline.

4) The slope of the swash zone is highly related to the orientation of the coast; i.e. as the orientation of a straight segment of the coast approaches a more northerly direction (as measured from south to north in a counter-clockwise direction), the slope of the swash zone increases.

5) The hieght of the foredune and the width of the subaerial beach are inversely related; i.e. high foredunes are usually associated with narrow beaches and vice-versa.

6) There is a weak correlation between sand grain size and the relative magnitudes of shoreline erosion along Assateague Island, or between sand grain size and coastal orientation.

7) As previously reported, there is a very strong relationship between standard deviation of shoreline erosion and coastal orientation for Assateague Island; i.e. one would expect that the variability in location of the shoreline over time would be greatest in those segments of the coast that have more of a north/south orientation than an east/west orientation.

PROBLEMS

Most of foredunes on Assateague Island have been created or stabilized and maintained by man, especially following the Ash Wednesday storm of 1962. Furthermore, the Ocean City Inlet jetties directly affect the daily sediment transport to and configuration of the northern ten kilometers or more of Assateague. We have not yet determined how these facts influence our data and have not yet considered them in our analysis. This is one reason why it is important to study the relationships among coastal variables on other barrier islands.

RECOMMENDATIONS

Our current NASA project is scheduled for termination on 1 June 1977. We recommend that the project be funded for another year in order to continue analysis of data already in hand for Assateague and Cape Hatteras, to collect and analyze field data at Cape Lookout, and to generally expand our studies of shoreline form, coastal processes, and physical features into other areas along the mid-Atlantic coast, such as the Delmarva Peninsula and Virginia Beach and Back Bay. To this end we have submitted informal proposals to NASA-Goddard and NASA-Langley.

PROGRAM FOR NEXT REPORTING INTERVAL

The work schedule between now and 1 June 1977 will depend somewhat on whether or not we get refunded beyond that date. If we do not receive additional funding, our work will be pointed towards publishing a final report in June. This will be a rather lengthy document that will summarize the entire two-year project. In it we will discuss data sources and types, procedures used, techniques developed, methods of analysis, and results achieved. If we obtain additional funding, we will spend less time on writing the June report, and we would spend more time on data acquisition and analysis.

PUBLICATIONS

A paper entitled "Shoreline Configuration and Shoreline Dynamics - A Mesosclae Analysis" by R. Dolan, B. Hayden, J. Heywood, and L. Vincent has been accepted for publication by Science magazine. The paper summarizes some of our research and results as reported in previous NASA Quarterly Reports.

A mock-up of an in-house publication entitled "Atlas of Environmental Dynamics - Assateague Island" has been completed, and final revisions are being made in preparation for publication. Although funding is provided primarily by the National Park Service, much of the data and analysis are the result of research funded by NASA.

A paper entitled "Vegetation Changes Associated with Barrier-Dune Construction on the Outer Banks of North Carolina" by P. Michael Schroeder, R. Dolan, and B. Hayden has been published in Vol. 1, No. 2 (1976) 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.