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II. Coastal Zone Management

E. Lee Tilton, III[a]

INTRODUCTION

This NASA Earth Resources Survey Symposium marks a major milestone in the application of remote-sensing technology. For the first time in a major symposium, the area of coastal zone management has been recognized and emphasized as a significant applications area. The intent of the symposium session was to give the audience an indication of the real problems of coastal zone management from the viewpoint of Federal and state organizations responsible for the legislation, enforcement, and management of coastal zone activities. This purpose was accomplished by having a panel of Federal and state representatives concerned with coastal zone affairs discuss their problems relating to information required for decisions.

Another intent of the session was to present examples of remote-sensing technology as applied to coastal zone management problems. This purpose was accomplished by a series of presentations describing demonstrations being performed by a variety of agencies in a variety of geographical areas requiring different information needs. The summary for each of the coastal zone management session presentations is included in Volume II of these proceedings. These discussions and presentations will be summarized here.

COASTAL ZONE CHARACTERISTICS AND INFORMATION NEEDS

Because of the obvious influence, both present and future, of the Federal Coastal Zone Management Program on the definition of survey and information needs in U.S. coastal zones, the program was a central theme in the panel discussions and will be used here as a focus for this summary. The framework of the program is provided by the Coastal Zone Management Act of 1972, which is administered by the Office of Coastal Environment, National Oceanic and Atmospheric Administration, Department of Commerce. As a result of comments on the act received from the states, the act was modified and guidelines were published in the Federal Register on November 29, 1973. The following quotation is from the Federal Register.

"The act recognizes that the coastal zone is rich in a variety of natural, commercial, recreational, industrial, and esthetic resources of immediate and potential value to the present and future well-being of the nation. Present state and institutional arrangements for planning and regulating land and water uses in the coastal zone are often inadequate to deal with the competing demands and the urgent need to protect natural systems in the ecologically fragile area. Section 305 of the act authorizes annual grants to any coastal state for the purpose of assisting the state in the development of a management program for the land and water resources of its coastal zone (development grant). Once a coastal state has developed a management program, it is submitted to the Secretary of Commerce for approval and, if approved, is then eligible, under Section 306, to receive annual grants for administering its management program (administrative grants)."

The act essentially places the responsibility for managing U.S. coastal zones with the individual states and provides them with the opportunity to tailor their program to individual needs. As will be seen, their needs vary widely with population, location, and coastal configuration. As defined by the act and Section 920.49 of the guidelines, final definition of coastal zone boundaries must be made by the states before June 30, 1977. Most of the states currently are formulating their programs. Thirty states, as well as Puerto Rico, the Virgin Islands, Guam, and American Samoa, are included in the definition of coastal states. The characteristics of the 30 states are summarized in table II-I.

Information for state area and population was taken from reference II-1, which was based on the 1970

[a]NASA Earth Resources Laboratory, Bay St. Louis, Mississippi.

TABLE II-I.– COASTAL STATE STATISTICS

State	Area, sq. stat. mi.	Total counties	Coastal counties/ percent of total	Coastal zone counties/ percent of total	Total population	Coastal county population/ percent of total	Coastal zone county population/ percent of total	No. of major coastal bays or estuaries	No. of major coastal rivers	Coastal water body	General coastline length, stat. mi.	Tidal shoreline length, stat. mi.	Ratio[a]
Maine	33 215	16	8/50.0	--	993 663	464 883/46.8	--	3	4	Atlantic Ocean	228	3 478	15.3
New Hampshire	9 304	10	2/20.0	--	737 681	209 382/28.4	--	0	1	Atlantic Ocean	13	131	10.1
Massachusetts	8 257	14	9/64.3	--	5 689 170	4 260 448/74.9	--	7	2	Atlantic Ocean	192	1 519	7.9
Rhode Island	1 214	5	5/100	--	947 723	947 723/100	--	3	0	Atlantic Ocean	40	384	9.6
Connecticut	5 009	8	4/50.0	--	3 032 217	1 883 434/62.1	--	2	3	Atlantic Ocean	--	618	--
New York	49 576	62	18/29.0	--	18 190 740	12 740 484/70.0	--	5	1	Atlantic Ocean	127	1 850	14.6
								2	1	L. Ontario	294	331	1.1
								0	0	L. Erie	77	77	1.0
New Jersey	7 836	21	13/61.9	--	7 168 164	4 995 116/69.7	--	6	5	Atlantic Ocean	130	1 792	13.8
Delaware	2 057	3	3/100	--	548 104	548 104/100	--	1	1	Atlantic Ocean	28	381	13.6
Maryland	10 577	23	15/65.2	--	3 922 399	2 050 276/52.3	--	7	6	Atlantic Ocean	31	3 190	102.9
Virginia	40 817	96	28/29.2	--	4 648 494	1 621 879/34.9	--	1	4	Atlantic Ocean	112	3 315	29.6
N. Carolina	52 586	100	20/20.0	--	5 082 059	509 457/10.0	--	6	4	Atlantic Ocean	301	3 375	11.2
S. Carolina	31 055	46	7/15.2	--	2 590 516	497 984/19.2	--	6	7	Atlantic Ocean	187	2 876	15.4
Georgia	58 876	159	6/3.8	--	4 589 575	281 155/6.1	--	8	6	Atlantic Ocean	100	2 344	23.4
Florida	58 560	67	36/53.7	38/56.7	6 789 443	5 401 711/76.6	5 470 194/80.6	2	1	Atlantic Ocean	580	3 331	5.7
								17	13	Gulf of Mexico	770	5 095	6.6
Alabama	51 609	67	2/2.9	--	3 444 165	376 690/10.9	--	3	2	Gulf of Mexico	53	607	11.5
Mississippi	47 716	82	3/3.7	--	2 216 912	239 944/10.8	--	3	2	Gulf of Mexico	44	359	8.2
Louisiana	48 523	64	14/21.9	26/40.6	3 643 180	1 505 337/41.3	2 315 441/63.6	18	7	Gulf of Mexico	397	7 721	19.4
Texas	267 338	254	17/6.7	--	11 196 730	2 944 719/26.3	--	14	13	Gulf of Mexico	367	3 359	9.2
California	158 693	58	19/32.8	--	19 953 134	15 008 518/75.2	--	5	7	Pacific Ocean	840	3 427	4.1
Oregon	96 981	36	7/19.4	--	2 091 385	428 927/20.5	--	4	7	Pacific Ocean	296	1 410	4.8
Washington	68 192	39	15/38.5	--	3 409 169	2 322 010/68.1	--	12	11	Pacific Ocean	157	3 026	19.3
Alaska	586 412	24	21/87.5	--	302 173	176 357/78.0	--	10	6	Pacific Ocean	5 580	31 383	5.6
								5	15	Arctic Ocean	1 060	2 521	2.4
Pennsylvania	45 333	67	4/6.0	--	11 793 909	1 904 056/16.1	--	0	1	L. Erie	51	51	1.0
										Delaware R.	50	50	1.0
Ohio	41 222	88	8/9.1	--	10 652 017	2 931 941/27.5	--	2	2	L. Erie	246	312	1.3
Michigan	58 216	83	43/51.8	--	8 875 083	4 915 571/55.4	--	3	3	L. Huron	622	934	1.5
								5	6	L. Michigan	862	1 058	1.2
								3	0	L. Superior	583	917	1.6
								1	1	L. Erie	80	143	1.8
Indiana	36 291	92	3/3.3	--	5 193 669	738 709/14.2	--	0	0	L. Michigan	45	45	1.0
Wisconsin	56 154	72	15/20.8	--	4 417 933	1 914 709/43.3	--	2	0	L. Superior	150	325	2.2
										L. Michigan	425	495	1.2
Illinois	56 400	102	2/2.0	--	11 113 976	5 876 167/52.9	--	0	1	L. Michigan	63	63	1.0
Minnesota	84 068	87	3/3.5	--	3 805 069	237 467/6.2	--	0	0	L. Superior	180	189	1.1
Hawaii	6 450	5	5/100	--	769 913	769 913/100	--	7	0	Pacific Ocean	750	1 052	1.4
Total 30 states	2 078 537	1850	355/19.2	--	167 808 365	78 703 071/46.9	--	173	143	–	16 111	93 534	–
Total U.S.	3 615 122	--	--	–	[b]203 184 772	--	--	--	--	--	--	--	–

[a]Tidal shoreline length divided by general coastline length.

[b]1970 census.

census. The only exception was the population of election districts of Alaska; this value was taken from reference II-2, based on the 1960 census. County information was taken from references II-3 to II-5 as well as from a 1972 U.S. Geological Survey map (scale 1:2 500 000). Note that a distinction is made between a coastal county and a coastal zone county because the coastal zone will generally cover more than just the coastal counties under the comprehensive definition given for coastal zone in the act. Separate examples are given in table II-I for Florida and Louisiana where a preliminary definition has been proposed by each state. The difference can be significant, as in the case of Louisiana, the southern or coastal area of which is almost entirely marsh and extends several counties (parishes) inland (fig. II-1).

An estimate of the number of major coastal bays and rivers for each state was made from references II-6 and II-7. The criterion for selection of a river was that it should be longer than 30 statute miles and wider than 0.5 statute mile at some point in its course. Bays and estuaries were counted if they were larger than 25 square statute miles in area.

The information for general coastline and tidal shoreline was taken from references II-8 and II-9. Work done by Robert Hagen in 1948 (under the direction of P. H. Judd) and updated by G. E. Roper and E. F. Kulp, Jr., in 1952 entitled "Shoreline of the Great Lakes and Connecting Rivers" was also consulted. The following definitions for these two terms are taken from reference II-8. "General coastline figures are lengths of general outline of the seacoast. Measurements were made with a unit measure of 30 minutes of latitude on charts as near the scale of 1:1 200 000 as possible. Coastline of sounds and bays is included to a point where they narrow to width of unit measure, and the distance across at such point is included. ... Tidal shoreline figures were measured in 1939-40 with a recording instrument on the largest scale charts and maps then available. Shoreline of outer coast, offshore islands, sounds, bays, rivers, and

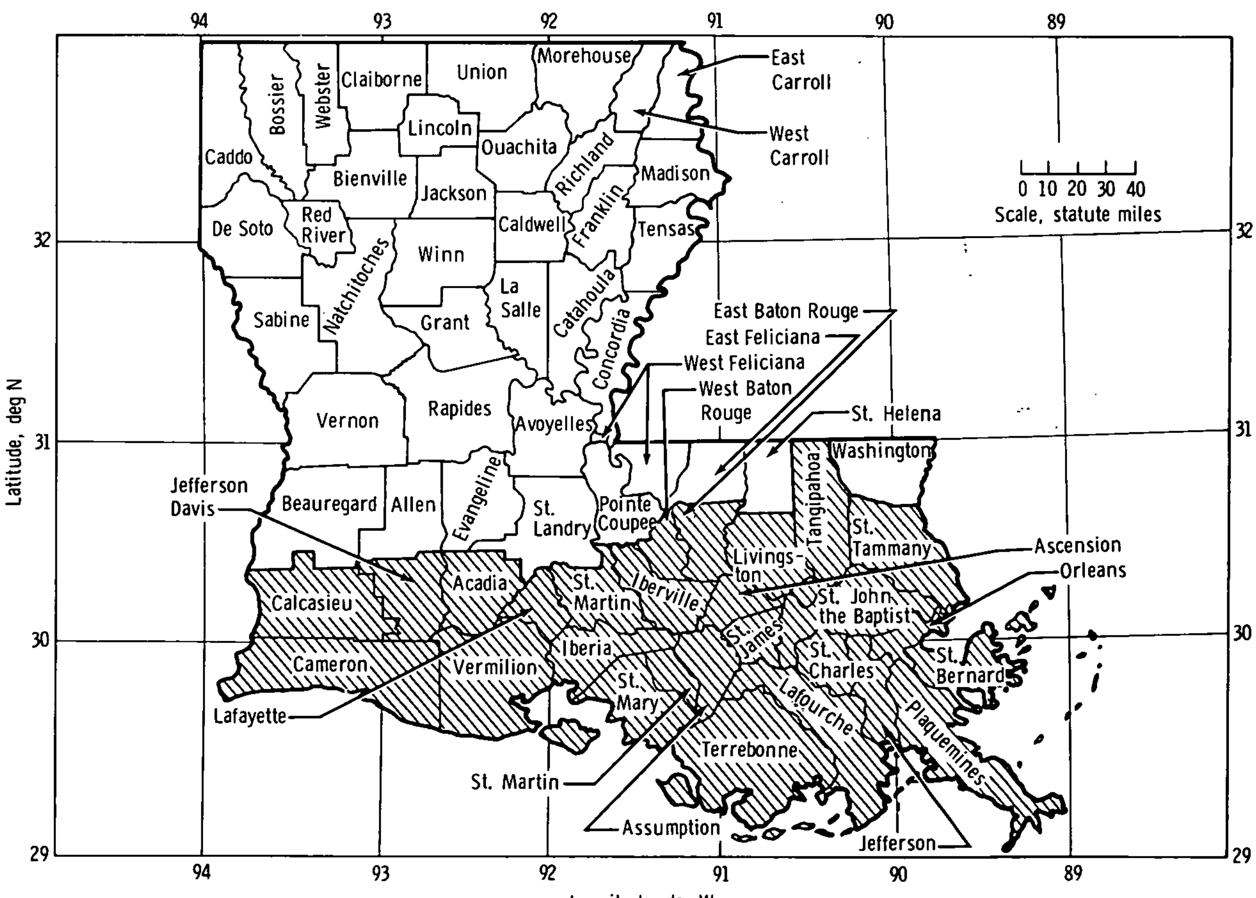


Figure II-1.– Map of Louisiana coastal zone parishes (shaded area).

creeks is included to the head of tidewater or to a point where tidal waters narrow to a width of 100 feet." Although the definitions of these two parameters are reasonably straightforward, their accurate and standardized measurement has been difficult to obtain.

In general, 82.6 percent of the U.S. population resides in coastal states, 38.7 percent of the U.S. population resides in the 355 coastal counties, and in 14 of the 30 coastal states, more than half the state population resides in the coastal counties. Within these coastal counties are 173 major bays or estuaries and 143 major rivers emptying into coastal waters. Based on past measurements, the general coastline of the United States totals approximately 16 111 statute miles with a tidal shoreline of 93 534 statute miles. Note that the ratio of tidal shoreline to general coastline is one measure of coastal zone complexity and is also an indirect measure of the marine productivity of a coastline. Thirteen of the 30 states have ratios greater than 10.

Most of the states either have, or are in the process of passing, local or state legislation governing activities in the coastal zones. A very large variation exists in the types of agencies responsible for preparation and enforcement of coastal legislation. In addition, most current legislation is very limited both in its coverage of coastal activity and in its definition of the coastal zone. For example, much of the state legislation covers only that area below the watermark of ordinary high tide, whereas the 1972 act calls for a much more comprehensive definition. Coastal zone areas being considered in Florida range as far as 25 statute miles inland and in Louisiana as far as 50 and 60 statute miles inland. These larger coastal zone areas generally encompass productive coastal waters and marshes as well as those areas of dense human population which interact with and affect coastal waters. Present activity in the states is concerned with the identification and classification of land and water uses to determine where coastal zone and land use boundaries will be drawn.

On the seaward side, the act defines the territorial waters of each state as part of the coastal zone. The territorial limit is generally 3 nautical miles from the coast. However, two states, Florida and Texas, presently claim 9 nautical miles as their limit, and there is a general desire among the coastal states to increase the territorial limit. In fact, it is likely that U.S. territorial waters will soon extend 200 nautical miles from shore. To gage the area of interest, one could choose the following general definition: the coastal zone is a strip having a width of 50 nautical miles, of which 10 nautical miles is seaward from the general coastline and 40 nautical miles is inland from the general coastline. This definition is not wide enough in some states and is too wide in others, but, using it and the general coastline length from table II-I, the coastal zone is estimated to consist of approximately 15 percent of the total area of the United States or approximately 600 000 square statute miles. Therefore, the coastal zone is very large and complicated and consists of approximately 80 percent land or wetlands. It is reasonable to assume, then, that extensive use would be made of surface classification techniques. As will be seen later, a key element in the use of these techniques is the correct interpretation of vegetation changes through the use of remote-sensing data.

Before the technical aspects of the applications of remote sensing in the coastal zone are discussed, it should be noted that the panel discussions revealed other aspects that should be considered. The general adoption of remote sensing for coastal zone management by organizations responsible for coastal zone management is affected by a number of nontechnical factors. For example, capabilities of remote-sensing techniques may have been oversold in the past, partly because of the glamour associated with this new vantage point in the sky. Nevertheless, this oversell is responsible for a number of groups being leery of this new technology and the problem does indicate a definite need for better communications between the technologists and the users. In fact, this whole general area of better communications between those developing the technology and those requiring the technology is significant and requires increased attention. Neither the technologist nor the user will benefit unless the user is educated in the advantages and limitations of the technology and unless the technologist is educated in the problems and needs of the user. Achievement of this understanding will require maintenance of a dialog between the two from very early stages of the technique development throughout demonstration of the technique application to specific problems. It is not adequate to merely publish a report and expect that the technology will be used.

The panel discussions also revealed that the mere existence and availability of good technology do not assure its use, even if the user is aware of its existence and availability. The reasons for this hesitancy are often political and depend on the specific application. For example, budgetary limitations, public opinion, and other pressing affairs of state are all important factors when an organization, such as a state, is considering the expenditure of public funds on new technology.

Another area requiring significant attention throughout the transfer process is the cost of the technology to the user, not just in the sense of tax dollars for development but in the sense of everyday operational expenses for application of the techniques. Again, this area must be treated from the very beginning of technique development because only this awareness throughout the development will yield cost-effective hardware, software, procedures, and information products on a timely basis. Consideration of all the preceding factors is essential to the successful transfer of this new technology to the user community and must be an integral part of the transfer mechanism.

APPLICATION OF REMOTE SENSING TO COASTAL ZONE SURVEY

It would be useful here to briefly discuss the general application of remote-sensing technology to coastal zone survey and monitoring before some specific examples are shown.

Remote sensing is defined as the acquisition of electromagnetic spectral data with instruments on aircraft or satellites for the purpose of deriving information about the character and condition of the land, wetlands, water surfaces, and intervening atmosphere of the Earth. Significant advances have been made in recent years in the demonstrated usefulness of such data. Techniques are available for land use classification, vegetation classification, water surface temperature measurement, and salinity measurement; other techniques are being developed for measurement of water color, sea state or wave climate, and shoreline extent and erosion. (See "Marine Resources," vol. I-C.) Not all these techniques are adaptable for satellite use (as opposed to aircraft), but additional advances in capability are occurring almost monthly. Currently, airborne and satellite multispectral scanners having channels in the visible, near-infrared, and thermal-infrared parts of the spectrum are the most useful instruments for monitoring changes in land use, vegetation, shoreline, surface water temperature, and water color. Other candidates are active microwave systems for sea state and other scanner channels in the middle- and far-infrared bands for atmospheric sounding of parameters needed to correct the surface measurements.

These instruments can provide data that, with suitable processing and interpretation, can result in accurate, relatively inexpensive, and timely information in many areas of interest related to coastal zone management. Unfortunately, the direct translation of coastal problems into information needs and, in particular, information that can be supplied through remote-sensing techniques is not straightforward. Many state and local agencies are not yet prepared to define their needs in terms of measurements that might be made from an aircraft or a spacecraft, partly because of a lack of familiarity with remote-sensing capabilities and partly because of the inherent difficulty in defining the information requirements for coastal zone management.

Problems in the coastal zone may generally be divided into the three geographic categories of land, wetlands, and water. In each category, the primary concern is the management of resource use. The use may generally be classified as (1) developing (exploiting or changing) the resource, (2) conserving (renewing or controlling) the resource, or (3) preserving (protecting or leaving unchanged) the resource. The resources may be categorized as historic, cultural, esthetic, ecological, or economic. In all cases, the gathering of information through monitoring is required for effective management. The problems and information requirements for land, wetlands, and water are described briefly in the following discussion.

Land problems in the coastal zone primarily stem from high population densities and competing interests for use of the limited coastal lands. Thus, the problem is to determine the best possible use of the land considering its limited availability, its attractiveness because of special-purpose uses unique to the coastal zone (esthetic and recreational advantages, accessibility to water transportation, etc.), and its vulnerability to natural disasters, and considering the ultimate effect on the ecological balance of the coastal zone. Because of the high population densities on the coastlines of the United States, one of the major problem areas is the planning of residential and industrial complexes for maximum use of the limited coastal land resources while still protecting the environment.

It is estimated that monitoring and complete classification of coastal zone land use should occur at least every 3 years with a classification update each year being desirable to support land use planning. The type of information desired is that indicated in reference II-10, although no specific format for the information is required or dictated by the Coastal Zone Management Act. Reference II-10 contains the following major (Level I) classifications for land use: urban and built-up land, agricultural land, rangeland, forest land, water, nonforested wetland, barren land, tundra, and permanent snowfields and icefields. This type of classification scheme generally includes wetlands and water and, with some modifications at a detailed level, could be used to classify coastal lands.

The wetlands are usually transitional zones between land and water in coastal areas. In some states, the wetlands are very small parts of the coastal zone; in others, such as Louisiana, they are dominating geographical factors (ref. II-4). The wetlands are sensitive ecological regimes that contribute heavily to coastal marine productivity and that are affected by such problems as salinity intrusion, deterioration, and erosion, all of which are influenced to a large degree by man's activities such as dredging, leveeing, and extracting mineral resources. Characterization and change detection in the wetlands can be determined largely through correlations with vegetation. Both monitoring of the vegetation types and extent and measuring land and water area and shoreline length provide desirable types of information for effective coastal zone management. Changes in vegetation can be used as an aid in the analysis of changes in ecological factors. In addition, some of the erosion and deterioration processes are occurring with such rapidity that semiannual surveys of the coastal wetlands would be very useful and, in some cases necessary, for interpretation of changes.

Coastal waters represent a very dynamic environment resulting primarily from the introduction of river waters and watershed runoff and from the effects of tidal action and wind-driven circulation. In some coastal areas, storms also are important and frequent contributors to the shaping of coastal geometries. The dynamics of coastal waters may be divided into two parts: the daily or even hourly changes caused by tides and winds, and the longer term changes characterized, for example, by seasonal levels of temperature, turbidity, and salinity, by river flows, by prevailing currents, and by shoreline erosion.

Like the physical processes taking place, the chemical processes of the coastal waters are also quite dynamic and are more directly influenced by man's activity because of industrial and agricultural effluents as well as waste products from residential areas. These chemical influences affect the biological productivity of coastal waters in various ways and also affect the quality of the water for man's use. Information required for management of coastal zone resources includes that derived from the monitoring of water quality parameters and the measurement of circulation, temperature, turbidity, and salinity for the purpose of water quality standards enforcement, from the evaluation of sites for location of development activities, and from the detection of natural changes in the physical environment.

With regard to the remote sensing of land, wetland, and water parameters, a person is generally concerned about the selection of the proper spectral, spatial, and temporal coverage for the parameter in question. For example, with regard to spectral coverage, if one is interested in the measurement of water surface temperature, the remote-sensing instrument used must be sensitive to radiation in the thermal-infrared part of the spectrum. If one is interested in the characteristics and classification of vegetation types in the marsh, he must acquire data in the visible and near-infrared parts of the spectrum. For spatial coverage, one is usually interested in the highest vantage point possible (i.e., satellite) so that synoptic coverage can be obtained over large areas. However, as one goes to higher altitudes, the ability to discern small objects (the resolution) decreases. For example, from satellite altitudes, one can easily classify the extent of forest land; however, if one is interested in the extent of water hyacinths in small navigable waterways, he must use aircraft remote-sensing systems with higher resolution. For temporal coverage, at least two factors are involved. If a highly dynamic area, such as coastal waters and current patterns, is involved, coverage must be obtained at very short intervals, perhaps within hours or even minutes, to determine the measurements of interest. In the case of land covers, such as forests, the activity, or changes, are much less dynamic and need not be covered at such short intervals. Another factor to be considered in temporal coverage is the ability to discriminate between parameters of interest. For example, it is easier to discriminate pine trees from hardwoods in the winter when the hardwoods have dropped their leaves than it is in the summer when the pine trees and hardwoods are all green. A third, indirect temporal factor is the interference of weather. That is, measurements must be made when the remote sensors are capable of detecting the selected parameters. For example, satellite measurements of the surface of the Earth in the visible portion of the spectrum require cloud-free conditions because the visible radiation will not pass through the clouds. However, measurements in certain parts of the microwave region of the spectrum can be made through the clouds and essentially constitute an all-weather measurement. All these factors must be considered when determining what data and information can be usefully gathered using remote-sensing techniques.

Generally, it may be said that a number of useful remote-sensing techniques exist for application to coastal zone management problems. For example, techniques are available for using remote-sensing data, such as those obtained from Landsat, to obtain surface classifications such as the acreage and boundaries of forest, urban, agricultural, forested wetland, nonforested wetland, and water categories. Accuracies are generally consistent with, or exceed, those obtained using conventional techniques. The most significant advantages of remote sensing, however, are the timeliness and the reduced cost with which these measurements may be obtained using automatic classification techniques. Surface classification updates may be obtained on a seasonal or an annual basis when weather conditions are suitable. It is possible to obtain accurate measurements of boundary lengths, such as shoreline, and to obtain accurate measurements of water parameters, such as surface temperature and salinity. Surface salinity measurement techniques require further technology advancements; such measurements are possible only from low-altitude aircraft currently. In cold regions, such as the Great Lakes, it is possible to determine the extent and the thickness of ice to provide information for better navigation using aircraft remotely sensed data relayed by means of communications satellites. Soon, techniques being developed should enable capabilities such as the measurement of surface winds on the oceans, more accurate measurements of the shape of the Earth, the delineation of salinity regimes in the marshes, better measurement of environmental conditions relating to the assessment of living marine resources, and better interpretation of coastal zone water processes such as circulation and organic and inorganic constituents.

As an example of the use of remote-sensing data in the coastal zone, a 10-category land use and vegetation map of the Delaware Bay coastal zone was presented. The primary objective of this effort was to inventory coastal wetlands according to major plant species types and the spatial relationship of other major natural and manmade cover types. This information was prepared using a semiautomated analysis system, Landsat multispectral scanner data, and a variety of hardware and software components to allow flexibility in input data display and output.

Surface classifications of major ecological zones of southern Louisiana have been prepared using Landsat-1 digital data and automated surface classification techniques. Both a photomap and the surface classifications were transformed by computer from the Landsat coordinate system (scan lines and element number) into the universal transverse Mercator geographic reference system (northings and eastings). The New Orleans District of the U.S. Corps of Engineers is evaluating the usefulness of the environmental maps in developing plans for the region. Indications are that the cost of preparing these maps is many times less than those of present methods.

In areas of the world for which little information exists, such as Alaska, these types of surface classification techniques can be used extensively to classify surface features and to determine acreage of these features in the early planning and development stages of the coastal zone. Because the information is digital, such parameters as acreage and shoreline length can be quickly and accurately determined. For example, figures II-2 and II-3 are computer displays of Mobile Bay at two different tidal stages. The Geological Survey of the State of Alabama is using this information to determine changes in water acreage and shoreline length at the different tidal stages. Another example of the application of this particular technique is shown in figure II-4, in which Landsat data have been used to show changes in land acreage and shoreline length from the Mississippi River Crowfoot Delta during a period of 11 months.

Remote-sensing techniques also are under development and in use for a variety of problems associated with the monitoring and management of coastal waters. For example, the primary ocean current trends in the California coastal area as developed from a series of both aircraft and satellite images are shown in figure II-5. The high-altitude-aircraft and satellite imagery produces extremely complete and near-synoptic

Figure II-2.– Computer display of Alabama shoreline (1172 kilometers long) on December 28, 1972.

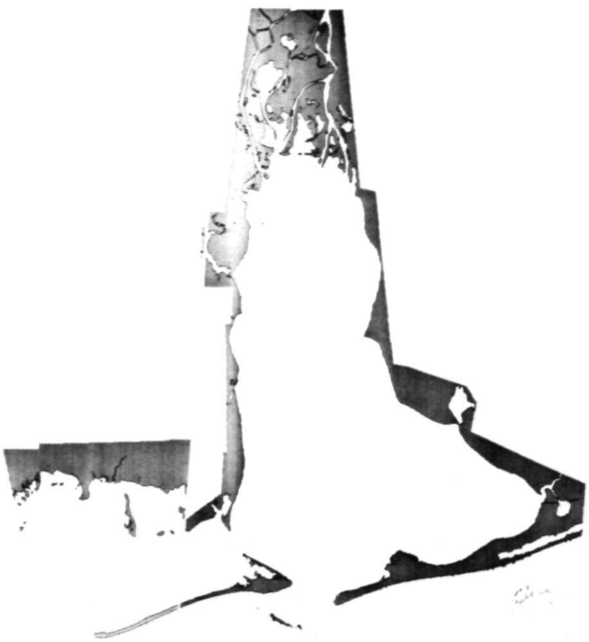
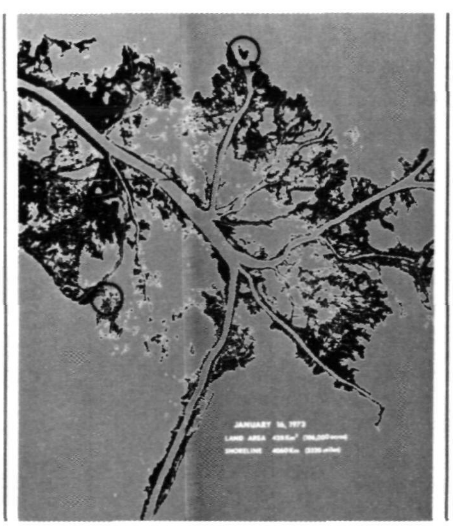


Figure II-3.– Computer display of the same area shown in figure II-2 a year later (December 5, 1973). Note that the shoreline length has decreased (to 879 kilometers).

views of the ocean surface and reveals large-scale phenomena and relationships that often cannot be seen from low altitude or from a surface perspective. Thousands of individual image frames were analyzed by the San Francisco District of the U.S. Corps of Engineers to extract the bits of current vector directions that have been assembled into generalized seasonal current charts. Another example is presented in figure II-6, in which aircraft thermal-infrared imagery reveals the distribution of oil on the surface of the Mississippi River after a major oilspill. Such information is being used by the Environmental Protection Agency for enforcement and regulation purposes. A final example is shown in figure II-7 of the use of remote sensing in a coastal zone. Shown here is an example of an ice chart which, through the efforts of NASA, the U.S. Coast Guard, and the National Weather Service, was prepared and transmitted to Great Lakes vessels in near-real time during the 1974-75 winter navigation season. The data are acquired by an all-weather microwave system on an aircraft. More than 150 similar charts were generated during the season for various key shipping areas in the Great Lakes and used by shippers to find the path of least resistance through the icefields to eliminate costly delays.



(a) January 16, 1973: land area, 428 square kilometers (106 000 acres); shoreline length, 4060 kilometers (2520 statute miles).

(b) December 5, 1973: land area, 411 square kilometers (101 000 acres); shoreline length, 4000 kilometers (2490 statute miles).

Figure II-4.– Landsat multispectral scanner data processed by the water search and shoreline analysis programs. A decrease in land area of 17 square kilometers and a decrease in shoreline length of 60 kilometers at the mouth of the Mississippi River is indicated for a period of less than 1 year.

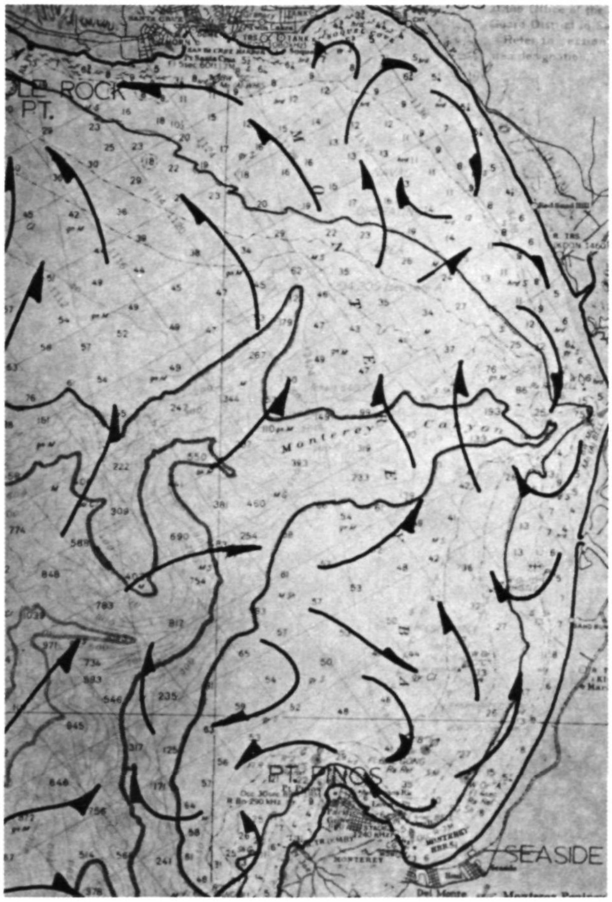


Figure II-5.– Map of ocean current trends in a coastal area developed from aircraft and satellite imagery.

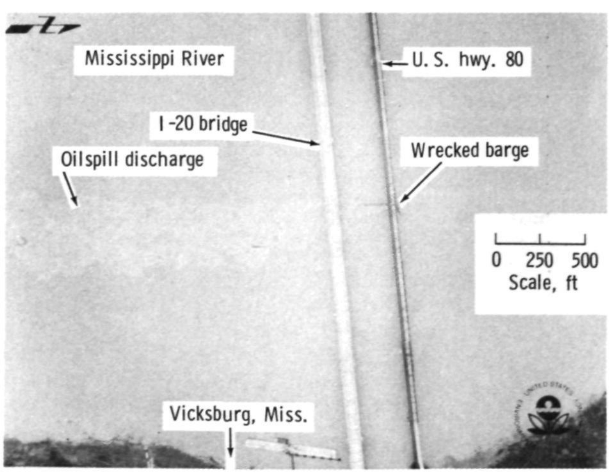


Figure II-6.– Oilspill detected by aerial thermal-infrared imagery west of Vicksburg, Mississippi, on March 6, 1975.

New applications are being found and demonstrated almost daily for remote sensing in the coastal zones. Many complex and critical information needs today can be met, or supplemented, in a timely and cost-effective manner from data acquired by aircraft and satellites and suitably processed and formatted to meet a variety of monitoring and management functions.

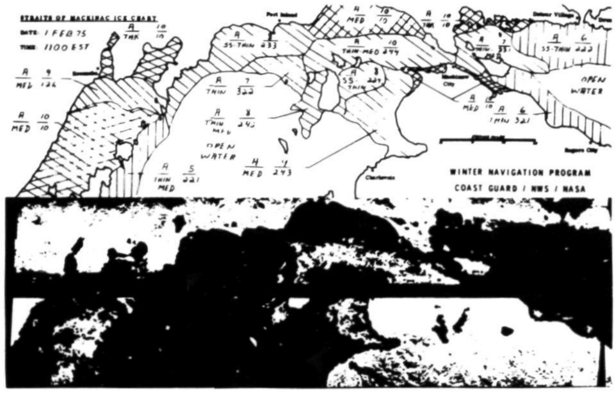


Figure II-7.– Ice chart transmitted by facsimile network to ship captains in the Great Lakes. The side-looking airborne radar image is at the bottom. The hand-drawn map at the top was prepared quickly by an analyst to aid the data user.

REFERENCES

II-1. Long, L. H., ed.: The World Almanac and Book of Facts. Newspaper Enterprise Association, 1972.

II-2. Business Control Atlas of the U.S. and Canada. American Map Company (New York), 1968.

II-3. Statistical Inventory of Key Biophysical Elements in Florida's Coastal Zone. State of Florida Coastal Coordinating Council, May 1973.

II-4. Louisiana Advisory Commission on Coastal and Marine Resources: Louisiana Wetlands Prospectus. Louisiana State Univ., 1973.

II-5. Hammond's World Atlas, Classics Edition. G. S. Hammond & Co., 1956.

II-6. Dunlop, Richard; and Snyder, Edwin, eds.: Texaco Travel Atlas. Rand McNally, 1970.

II-7. Nautical Chart Catalog 1. U.S. Dept. of Commerce, 1973.

II-8. Coastline of the United States. U.S. Dept. of Commerce NOAA/P1 71046-1971, 4th ed., 1961.

II-9. Kelley, R. W.; and Colburn, W. H.: Great Lakes Shoreline Measurements. Third ed., revised. Intra-Departmental Report, Department of Conservation, State of Michigan, 1964.

II-10. Anderson, James R.; Hardy, Ernest E.; and Roach, John T.: Land Use Classification System for Use With Remote-Sensor Data. U.S. Geol. Survey Circular 671, 1972.