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Coastal Wetland Mapping

Geodetic and tidal datums cannot be directly equated, and the accuracy of contour and tide elevations is limited by practical considerations of marsh morphology.

Introduction

With increasing environmental interest in the coastal zone, there are many published papers on applying remote sensing to wetland interpretation. Ownership and use of riparian lands in the coastal zone is adjudicated according to several State and Federal laws, and the regulation of land use is increasing to control development. The U.S. Geological Survey (USGS) has evaluated the requirements for wetland delineation on 1:24,000-scale standard topographic maps and followed the progress of other projects at larger scales. The USGS works closely with the National Ocean Survey (NOS) which has primary responsibility for coastal navigation charts, geodetic control surveys, and tidal surveys. The coastal zone is not precisely defined but is generally agreed to extend at least from the National seaward boundary to coastlands under the influence of the sea. For different purposes, the zone has been traditionally mapped by both the USGS and NOS, as well as the Army Corps of Engineers and the coastal States.

The conterminous U.S. has 21 States with ocean coastline, and it is estimated that over 40 per cent of the population lives in the coastal zone close to the wetlands. The coastal zone consists of salt marshes, mudflats, twisting tidal channels, intracoastal waterways, islands, lagoons, bays, natural and manmade levees, mosquito ditches, oceanfront and intracoastal developments, and estuaries. Within this diverse panorama the coastal wetlands are classified according to several State and Federal definitions and interpretations. They are generally composed of coastal vegetation and are under the influence, if not the daily flood, of the tide. The wetlands are the transition zone between the mainland and the sea and are influenced by

Abstract: *The U.S. Geological Survey is conducting a research project in the vicinity of Sapelo Island, Georgia, to investigate procedures for interpreting, delineating, and mapping coastal wetlands using remote sensing and photogrammetric techniques. The study area contains a variety of coastal marsh conditions, from saline to brackish, and extends from a mainland river through sea island marshes to the Atlantic Ocean. Orthophotoquads are prepared at 1:10,000 scale with a format of 2.5 minutes of latitude and 3.75 minutes of longitude. Coastal wetland boundaries and plant species associations are interpreted and delineated on the orthophoto base. In addition, the boundaries will be digitized for computer analysis. The primary objective is to evaluate the accuracy, time, and cost for mapping coastal wetlands. The results of the investigation should be of value to Federal and State agencies with responsibilities for mapping or regulating the coastal zone.*

both. The tide usually covers the wetlands at some stage; it is often measurable in inches and is of different phase and amplitude than the tide on open beach only a few miles away. Tidal rivers, streams, surface runoff mix with the ocean water to create a brackish zone of changing salinity. The freshwater flow creates a hydrodynamic stage related more to the hydrologic cycle than the lunar cycle. Plants several feet tall preclude photogrammetric measurement of the ground surface where elevation differences of a few inches are critical. It is not unusual for plant tops on the levees to be level with plant tops on lower ground behind the levee, giving the appearance of a continuous level surface. Tidal flow may reach an area by a long circuitous path through channels and breaks in natural levees.

It is well known that the coastal wetlands are some of the most valuable and highly productive areas on earth. They serve as a buffer for the mainland against ocean storms. The coastal wetlands are an essential breeding ground for many ocean fish. At least 70 per cent of the east coast fish, including 30 per cent of the U.S. commercial catch, depend sometime during their life cycle on the shallow waters bordered by the coastal wetlands. The tidal cycles distribute the nutrients and detritus which support an ever-expanding biostructure that includes man. And certainly not to be overlooked is the role of the coastal zone in man's recreation. It becomes apparent that detailed maps of the coastal wetlands should be the first step in safeguarding their intelligent use.

Maps of the Coastal Wetlands

Approximately 2500 standard 7.5-minute, 1:24,000-scale topographic maps cover the landward portion of the coastal zone of the conterminous States. The USGS is responsible for their preparation and publication. At present 2000 maps are complete; the remaining 500 are in various stages of production. These maps are the primary cartographic base for the coastal wetlands. They are produced to meet National Map Accuracy Standards (NMAS), i.e., not more than 10 per cent of the well-defined points tested shall be in error of horizontal position by more than 1/50 inch (40 ft at 1:24,000) or 1/30 inch at scales larger than 1:20,000. The relative internal accuracy of a map is likely to be better than NMAS.

In the 1:24,000 series, coastal-zone features such as marsh, sand, levees, reefs, and flats are compiled primarily by photointerpretation using field data and available nautical charts. Some of the symbols used to depict these features are illustrated in Figure 1. The coastal shoreline shown in blue is the approximate line of mean high water, except in areas of marsh grass, mangrove, or other similar marine vegetation, where the apparent shoreline at the outer edge of vegetation is shown in lieu of the mean high-water line. So many conditions affect the horizontal position of the mean high-water line that it is not feasible to map the entire shoreline within NMAS. For this reason, a statement that explains the shoreline mapped appears in the margin, along with the mean range of tide if available. Although standard accuracy cannot be achieved in mapping some parts of the shoreline, all available information and methods are used in an effort to obtain the current position. Photographs taken at high tide are used when available. Field inspection of vegetation and wave-deposited debris is standard procedure.

NMAS for vertical accuracy require that not more than 10 per cent of the elevations tested shall be in error more than one-half the contour interval, i.e., for a 5-ft contour interval, the elevations indicated by or interpolated from the contours should be correct within 2.5 ft 90 per cent of the time. In checking elevations derived from the contours, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale. On the 1:24,000-scale map, the vertical error may be offset 40 feet horizontally to adjust the elevation an amount determined by the slope.

In addition, the maps show several types of political and land-grant boundaries which may bear some legal relationship to water or tidal features. However, the map positions of these boundaries are not legal evidence of correct location and cannot substitute for a cadastral survey.

Since the 1:24,000 maps are the primary cartographic reference for the coastal-zone land areas, it is important to clarify some of their limitations, which also serve to suggest the special requirements for coastal wetland mapping.

- The maps may not be up to date, especially in areas undergoing rapid development. Consequently, recent dredging, filling, spoil piles, levees, or natural changes, such as sand erosion and accretion and channel shifts, are often missing.
- Most of the coastal maps are line maps, whereas orthophotomaps are available for only a few coastal areas. However, orthophotomap production is increasing.

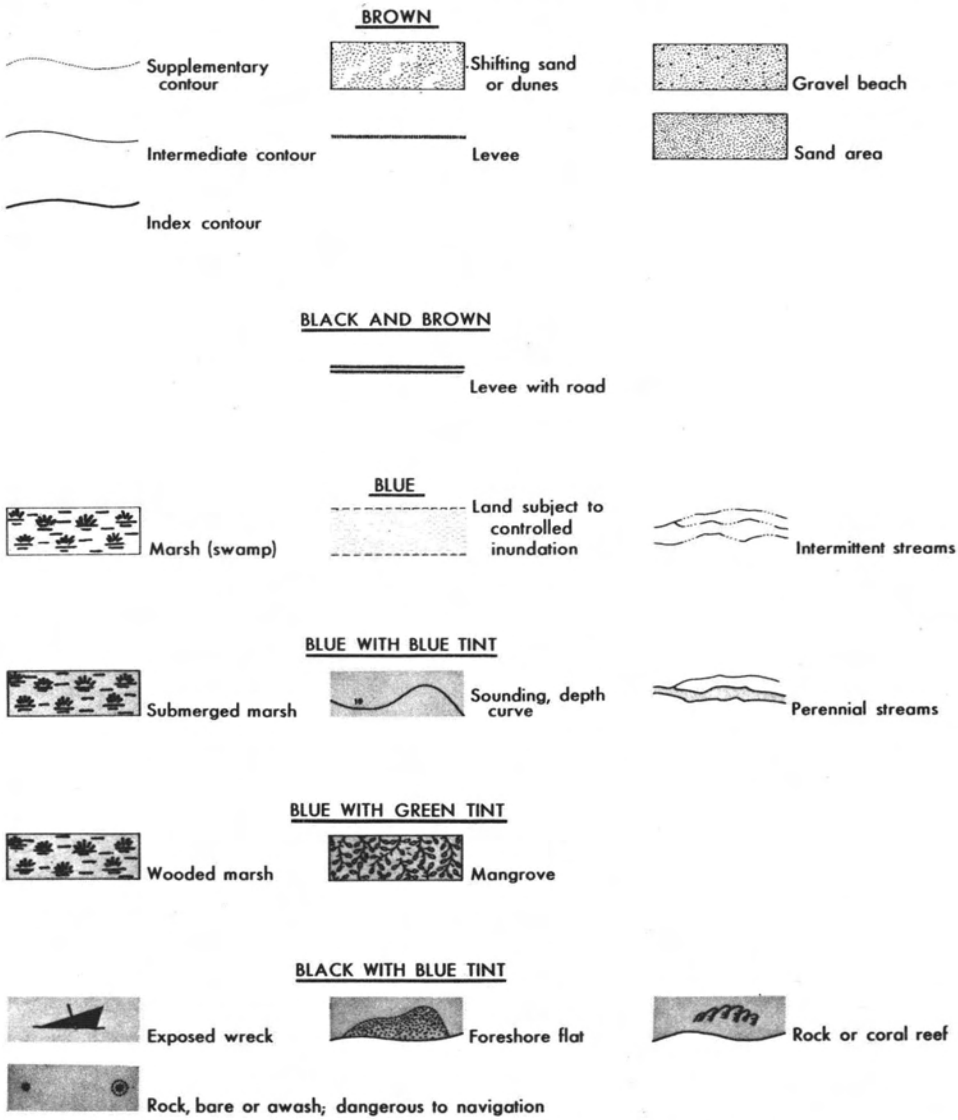

FIG. 1. Topographic map symbols for coastal zone features.

- There is no distinction between fresh, brackish, and saline marshes; all are shown by the same symbol (standard blue tuft pattern). Wooded swamps, mangrove swamps, and submerged marshes have separate symbols. However, only a generalized interpretation is possible.
- The marsh symbols bear little or no relation to the vegetation species; the field criteria may be something like "too wet to walk, too shallow to row, covered with grass." Although reasonably accurate and acceptable in the main, the criteria are unreliable at the marsh boundary; furthermore, at publication the definitive outline is lost by nature of the marsh symbol. Since the maps do not show a well-defined wetland boundary (except, of course, where it coincides with a shoreline), the map accuracy standards cannot be applied in the area between wetlands and upland.
- Cadastral boundaries of land ownership are not shown. The transfer of deed descriptions to any type of map is a difficult, time-consuming procedure and, except for public lands, is not a responsibility of Federal mapping agencies. Usually scales larger than 1:24,000 are required. In most cases of land ownership, the boundary must ultimately be traced on the ground by a surveyor.
- The tidal information is limited to a

shoreline representing an approximate line of mean high water and a statement giving the approximate mean range of tide. Depth curves and soundings are obtained from NOS charts and are based on a datum of mean low water (Atlantic and Gulf coasts) or mean lower low water (Pacific coast). The low water line, from which some private property boundaries and the Federal and State seaward boundaries are defined, is not shown.

- The datum for contour and elevation information is stated as mean sea level on maps published before 1973. However, as will be explained later, there is a distinct difference between a tidal datum and the geodetic datum used for elevations.
- Subsidence is appreciable in some coastal areas, particularly along the Gulf coast, so that the contour data is probably in need of revision.

Tidal and Geodetic Datums

Tidal datums are vertical datums defined by a stage of the tide and are used as reference planes. The law has traditionally recognized the validity of using tidal datums to establish seaward boundaries, Federal-State jurisdictions, and private ownership and to regulate navigable waters. The Submerged Lands Act of 1953 and the 1958 Convention on the Territorial Sea and the Contiguous Zone provide that the low water line as shown on large-scale maps may be used as the base line for cartographically delimiting the territorial sea. This is a pragmatic solution to a technical problem since the ordinary low water line was previously mapped on large-scale coastal navigation charts. Low water is more critical to the sailor than high water. It does not invalidate the use of other tidal datums for riparian rights. Accurate values for tidal datums, such as mean high water or mean low water, are obtained by averaging height readings at a location over the 19-year tidal epoch. However, the tidal datums have several limitations for mapping the vast coastal wetlands.

- Tides are usually measured at primary stations in sheltered areas with free access to the sea. Selected estuaries, bays, and rivers are gauged by rarely the small channels or marshlands except when tidal surveys for boundaries are done.
- The measurement of tide at a new location requires one year of records and correlation to a primary tide station for an accuracy of 0.1 to 0.2 feet. The primary tide stations require records spanning the 19-year tidal epoch.
- Ideally the tide should be measured over the entire range from low to high to record the monthly and seasonal variations. A station that only records the highest levels is subject to error in the average if some of the daily highs are missed.
- Tides in a river or estuary are combined with the stage and flow of fresh water, which gradually become the primary influence with increasing distance upstream from the ocean. The influence of the ocean may be observed at extreme high tides or low river flow, but measurement of an accurate tidal datum requires more data.
- Many tidal surveys have been conducted for safety of navigation and coastal charting and not for boundary purposes.
- The critical upper wetland boundary may be hundreds of feet horizontally and only a few inches vertically from the point where the tide can be reliably measured. The ground supporting the vegetation resembles a sponge, and its average slope may be 0.5 per cent or less, i.e., an elevation change of 0.5 foot or less per 100 feet horizontally. Therefore, a 0.1- or 0.2-foot error in elevation could easily cause a 10- or 20-foot horizontal error even if the ground were firm. The soft footing and prolific vegetation prohibit a reliable transfer of elevations except at well-defined points and with considerable expense.
- Tidal datums can only be defined by direct measurement at a location. A tidal datum defined at one location cannot be extended more than a short distance along the shore, for when the area comes under the influence of topography and new tidal conditions, another tide gauge is required.
- Local tidal conditions are ever changing. Along the southern Atlantic coast the mean tide level has increased 0.4 foot since 1924.
- While mean high tide and mean low tide are the common legal datums for establishing boundaries, the morphology, biota, and environmental value of the coastal wetlands may be more dependent on the high spring tides.
- In recent years many coastal charts and orthophotomaps have been compiled from aerial photographs taken at the desired stage of tide. Infrared photographs provide good contrast between land and water and are particularly useful for showing the waterline on an exposed beach, mudflat, or rocky coast. On the other hand, in the marshes behind the sandy beaches the tide flows beneath thousands of acres of vegetation without a unique land/water infrared signature.

The geodetic datum adopted as a standard for elevations in North America is not synonymous with local mean sea level. It is a computed network based on the 1929 adjustment of leveling using 26 primary tide stations as ties to mean sea level. The results of the 1929 General Adjustment have not been, and probably never will be, published as a unit; geodetic benchmark elevations are available from Federal and State mapping agencies. Since the 1929 adjustment, it has been determined that the ocean surface is actually tilted with respect to the computed surface. The ocean has also been rising and there are local variations in the tidal surface. Along our southern Atlantic coast the present mean tide level is about 0.2 feet above the 1929 datum, and in other areas as much as a foot higher. The geodetic bench marks should never be used directly as a reference for mean sea level. The relation between geodetic and tidal bench marks must be determined locally.

The contours on 1:24,000-scale maps are based on the 1929 geodetic datum, which has been denoted (until 1973) by the margin statement "datum is mean sea level." To avoid possible confusion with *local* mean sea level, in 1973 NOS (and USGS in turn) adopted the new datum name, "National Geodetic Vertical Datum of 1929." Even with a new vertical adjustment the recompilation of contours may not be practical. While map contours can be used only as a guide in defining a coastal zone or coastal wetland, the value of using a specified contour line for reconnaissance or regulatory purposes should not be overlooked. Because of their defined accuracy on available maps, contours offer a quick pragmatic solution until other measurements can be obtained.

Interpreting the Coastal Wetlands

The difficulties of relating an upper wetland boundary to a stage of tide appear formidable and usually entail ground surveying at a prohibitive cost. Although several regulatory acts have been proposed at the Federal level, primary control of coastal wetlands rests with the States. The Coastal Zone Management Act of 1972, Public Law 92-583, provides Federal grants to coastal States (including those bordering the Great Lakes) for planning, mapping, and managing the coastal zone. A uniform definition of the shoreward limits of the coastal zone or the coastal wetlands is not part of this law. The zone may extend inland only to the extent necessary to control the shoreland uses that have a direct and significant effect on coastal waters. It is strongly implied that the States should establish boundaries that are generally recognizable and administrable and can be identified clearly on a map. The property owners should not be deprived of riparian rights through arbitrary delineations. The upper wetland boundary should demarcate changing biota and morphology so that landowners can acknowledge and respect it without having to make difficult measurements.

Recent changes in the jurisdiction of the Corps of Engineers have extended their authority for granting permits within navigable waters to the line of mean high water.* Nevertheless, State laws regulating the coastal wetlands receive primary consideration. The statutes of many States refer to the tide, map contours, and vegetation characteristics of the wetlands. The relatively small number of species of indigenous vegetation—usually a dozen will cover most localities—is quite useful as a reliable indicator of tidal influence.

The State of New Jersey first applied color infrared photography and biological discrimination techniques for an accurate mapping of wetland boundaries and plant species. For the USGS study we decided to extend those techniques to a new area, and Georgia's Sapelo Island was selected. It provided an ideal site to pursue the research objectives of investigating procedures and evaluating accuracy, time, and costs. The site contains large areas of marsh vegetation typical of the eastern Atlantic Coast and some complicated transition zones. The tidal range is generally greater than along most of the East or Gulf Coasts and averages 7 feet. The University of Georgia has a Marine Institute on the island which has accumulated considerable background data on the region.

The Georgia Coastal Marshlands Protection Act of 1970 defines marshland to include all estuarine or tide-influenced areas 5.6 feet or less above mean tide level. As a rule any modification of areas below the 5-foot contour is carefully monitored. The act emphasizes typical plant species of saline or near-saline marshes to be used as criteria for wetlands. Specifically named are *Spartina alterniflora* (salt-marsh cordgrass), *Juncus gerardi* (black grass), and *Iva frutescens* var, *oraria* (high-tide bush). The *Juncus gerardi* was an error in legal specification since it does not grow commonly south of Virginia. *Juncus roemarianus* (needlerush) is found there. An amendment has been proposed that will correct the error and expand the plant species criteria to 13. It is also interesting to note that the present law recognizes the occurrence and extent of salt-marsh peat at the undisturbed surface as conclusive evidence of the extent of a salt marsh or a part of it.

*Further legislative decisions since this article was prepared have extended Corps of Engineers authority for dredge and fill operations above the line of mean high water.

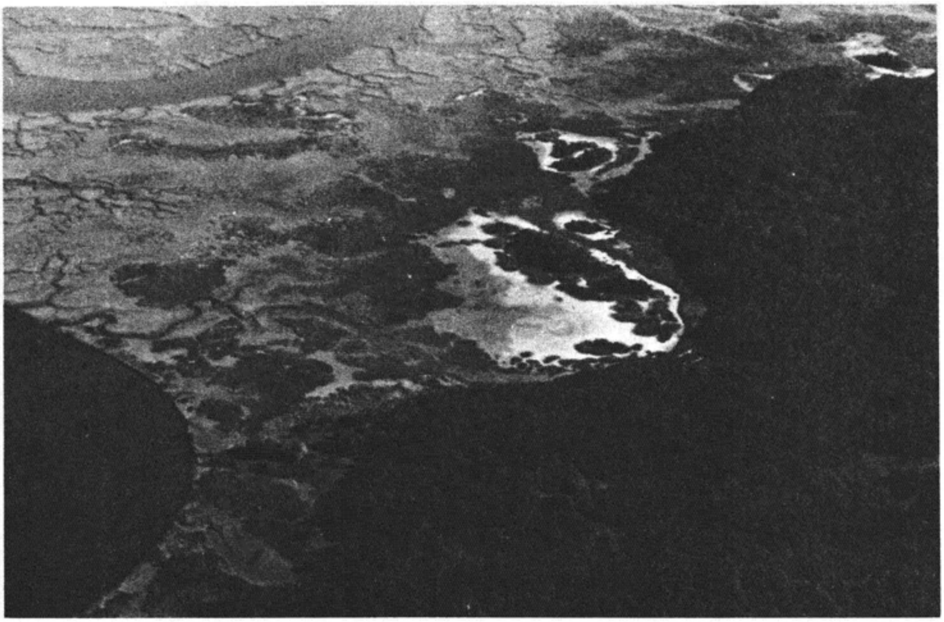

FIG. 2. Marsh area in the vicinity of Sapelo Island, Georgia.

However in many Georgia marshes, peat is absent.

Georgia includes approximately 393,000 acres of coastal marsh, a total exceeded only by South Carolina when comparing the Atlantic Coast States. These vast and highly productive marshes include fresh, brackish, and saline marshes under tidal influence. Figures 2, 3, 4, 5, and 6 illustrate the marshes in the vicinity of Sapelo Island. Some of the coastal features previously mentioned, such as natural levees, twisting tidal channels, and mudflats, can be seen. *Spartina alterniflora* often occurs in a 20- to 30-foot band of high productivity along the tidal creeks and in a low productivity form behind the levees. *Iva frutescens* is near the border between the marsh and the upland trees.

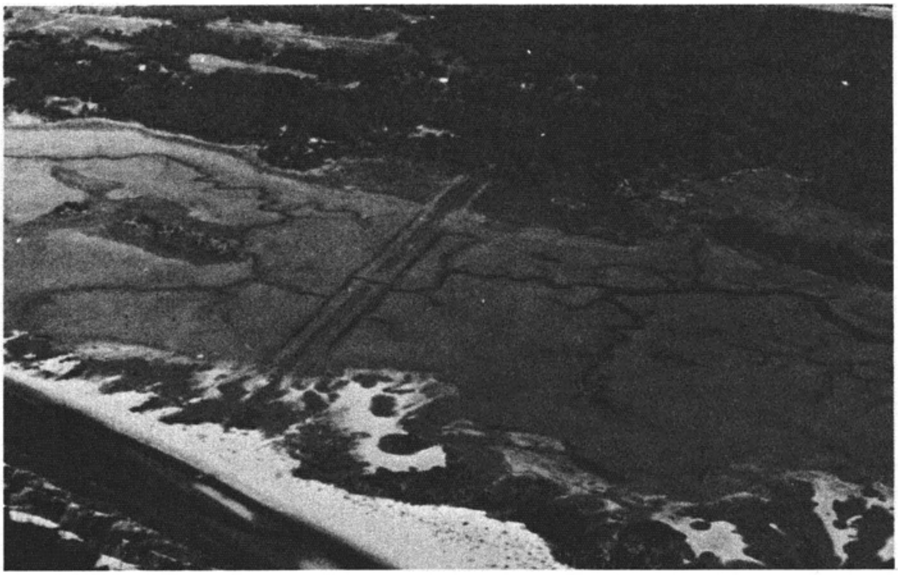

FIG. 3. Marsh area in the vicinity of Sapelo Island, Georgia.

FIG. 4. Marsh area in the vicinity of Sapelo Island, Georgia.

Georgia marshes have been under less developmental pressure for housing, recreation, industrial, and agricultural needs than coastal marshes to the north or south; e.g., in New Jersey, Delaware, or Florida. The remoteness of urban centers combined with private ownership and relative inaccessibility of the barrier islands has no doubt slowed development interests. It has been estimated that between 1954 and 1968 only 2,000 acres of coastal marsh were destroyed. However, pressure for development is accelerating rapidly, and justification for strong regulation is clear.

The species composition of a coastal marsh reflects the salinity, soil characteristics, frequency of inundation, elevation, and other factors. The Georgia marshes are generally typical of those along the Atlantic coast, with exceptions such as mangroves found abundantly in Florida and *Juncus gerardi* which replaces *Juncus roemarianus* north from New Jersey. Saline marshes contain *Spartina alterniflora* in three growth forms, the largest up to 10 feet high. Other species—*Distichlis spicata* (spikegrass), *Salicornia* spp (glasswort), *Batis maritima* (saltwort), *Sporobolus virginicus* (coast dropseed),

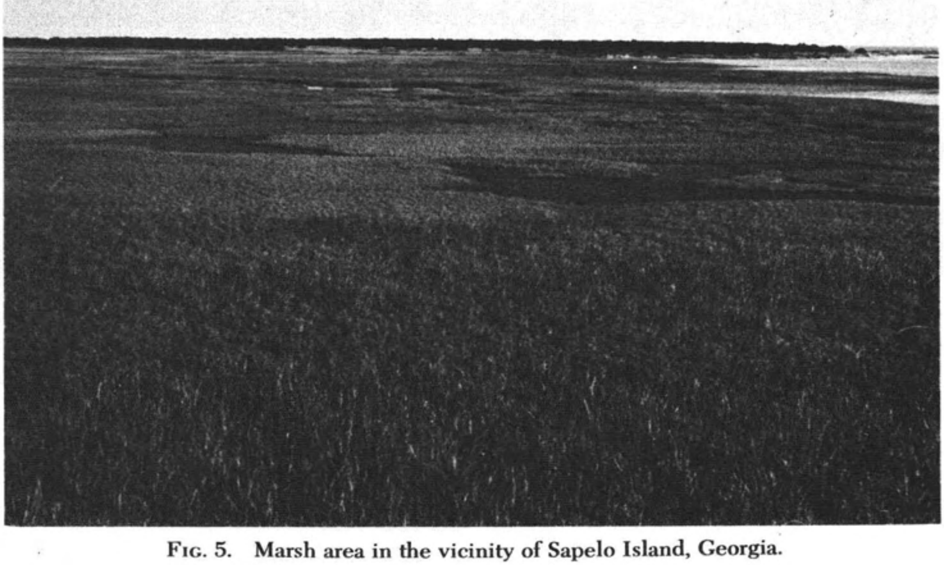

FIG. 5. Marsh area in the vicinity of Sapelo Island, Georgia.

FIG. 6. Marsh area in the vicinity of Sapelo Island, Georgia.

Limonium nashii (sea lavender), *Iva frutescens* (marsh elder), *Borrichia frutescens* (sea-oxeye), *Spartina patens* (salt meadow cordgrass), and *Juncus roemarianus*—are found where the elevation is higher or the tidal inundation less frequent.

Where large tidal rivers such as the Altamaha (Georgia) discharge large quantities of fresh water, the vegetation changes from typical *Spartina alterniflora* marsh to a *Juncus roemarianus* marsh with *Spartina alterniflora* on channel banks and tidal creek heads. Moving inland, as the water becomes fresher *Spartina alterniflora* is replaced by *Spartina cynosuroides* (giant cordgrass), and patches of *Scirpus* sp. (three square, bulrush) are found with *Juncus roemaricanus*. Gradually species diversity increases, and fresh water species such as *Typha* sp. (cattail), *Peltandra virginica* (arrow arum), *Zizania aquatica* (wild rice), and *Zizaniopsis miliacea* (giant cutgrass) compose an appreciable portion of the marsh vegetation. Wooded swamp may take the place of these fresh marshes.

The upper wetland boundary is often sharply defined by an abrupt change in topography. The marsh may extend as much as 30 feet under the canopy of large trees in the border zone. Where a broad and gradual transition occurs with a mixture of plant species present, the upper wetland boundary is more difficult to define. On the other hand, the transition zone may be extremely narrow, covered with *Borrichia frutescens, Iva frutescens, Juncus roemarianus*, and *Scirpus americanus*. Small patches of *Borrichia frutescens* are commonly found along the levees characteristic of the water edges of Georgia marshes. Open mudflats, ranging from organic clays to sand, may be quite extensive; they are easily misidentified on photographs and mapped as high ground.

With a knowledge of the plant species, the morphology of the land, the tidal cycle, and the applicable laws, one can usually position the upper wetland boundary within 10 or 15 feet horizontally during field inspection. The task is easier and equally accurate when the boundary is delineated from color infrared aerial photographs offering a much larger view. For 5 to 10 per cent of the area, the task is more difficult using either method. The transition in these areas may be very gradual and indistinct, requiring more judgment, careful surveys, and intelligent legislation. Litigation may be necessary for there is no one technique for providing unequivocal answers to wetland boundary questions.

MAPPING THE COASTAL WETLANDS

A review of present and proposed coastal wetland regulations of several States reveals that

- There is a requirement to provide an accurate cartographic base on which upper wetland boundaries and other coastal-zone features can be accurately plotted.
- It is desirable to provide the map user with an orthophotoimage for more information about features that are not specifically delineated or are necessarily generalized on the conventional map.
- Selected areas of the coastal zone require map scales larger than 1:24,000.

- There are no universal conversion factors for relating tide, vegetation, contours, and cadastral boundaries.

In many areas, available 1:24,000-scale topographic maps could be used as cartographic bases. The upper wetland boundary could be interpreted from current color infrared photographs according to the applicable regulations and compiled on the map. This procedure would provide a practical inventory at minimum cost and would satisfy general zoning regulations. It would provide a zone boundary between marsh and upland with a NMAS horizontal accuracy of about 40 feet. However, the increasingly popular orthophoto cartographic products have proved invaluable for mapping swamps, marshes, and other regions of overwhelming detail usually lost in conventional map symbolization. Compared to line map portrayal, the orthophoto of a coastal marsh provides more information on the many features associated with identifying the boundary between upland and marsh. Besides matching the accuracy of conventional maps, the orthophotos show the actual pattern of vegetation and woodland as well as the lone tree, all visible roads and trails, the intricate meanderings of waterways, and other detail useful for position determination. Information on current landuse can be derived from tonal differences in the photograph.

On the 1:24,000-scale line maps, the definitive marsh boundary is lost by symbolization and therefore cannot be measured in terms of the map accuracy statement. Thus it appears desirable to prepare orthophotos for all the coastal wetlands to provide the best medium on which to delineate the upper wetland boundary.

The photoimage base can be prepared as an orthophotomap or as an orthophotoquad. The orthophotomap entails selective cartographic treatment with various features enhanced by line drawing and color separation. Since it combines the features of a line map plus the photoimage, its production is time consuming and expensive. The orthophotoquad, on the other hand, entails minimal cartographic treatment; a few selected names and a grid reference system are included. The monocolor photograph itself provides planimetric information, and contours can be added if desired. The orthophotoquad is substantially cheaper to produce and the most up-to-date of the alternatives for base maps. Complete orthophotoquad coverage of the coastal wetlands could be completed within a few years and would serve many purposes beyond the delineation of the upper wetland

Fig. 7. Portion of an orthophoto used in the preparation of an orthophotoquad. (Northward is toward the bottom).

boundary. Since some areas of the coastal zone may require scales larger than 1:24,000, the scale chosen for study was 1:10,000. Thus, six 1:10,000 orthophotoquads, 2.5 minutes in latitude by 3.75 minutes in longitude, cover most of Sapelo Island and the marshes fronting the mainland. The 1:24,000 Doboy Sound, Georgia, 7.5-minute quadrangle covers the same area. By NMAS, the horizontal accuracy of well-defined points on a 1:10,000-scale map should be 28 feet or better for 90 per cent of the points. The relative accuracy between two points on a single map should be about 15 feet.

The black-and-white photographs for the orthophotoquads were taken on March 22, 1973, near mean high tide. The flight height was 40,000 feet, and each exposure was quad centered over the 2.5 minute by 3.75 minute format. A K&E camera with a 305-millimeter focal-length high-resolution lens was used with a Wratten 25 filter and Kodak 2402 film. The film was processed 1.8 gamma, somewhat higher than usual because of the 40,000 foot flight height. Figure 7 is a portion of one of the orthophotos used to prepare a 1:10,000-scale orthophotoquad. On such a base, detail interpreted from additional color infrared photos—the upper wetland boundary and the major marsh species associations—are delineated.

During the same flying mission, additional coverage was obtained with various combinations of films, filters, focal lengths, and flight heights. The resultant photographs are being evaluated for coastal-zone mapping, assessing not only the image quality of marsh and water features but upland detail of roads, houses, and vegetation. Although most coastal areas are relatively flat, about 35 per cent, including some adjacent uplands, have sufficient relief (50 feet or more) to require differential rectification on an orthophotoprinter. The narrow angle of the 305-millimeter-focal-length lens reduces the number of differential rectification operations because simple rectification and enlargement can be substituted. Also, for the 1:10,000-scale format, no mosaicking of images is required since each exposure can be quad-centered at flight heights above 30,000 feet. With a 153-millimeter focal-length camera, a flight height of 15,000 feet would be adequate, but the wide angle lens will increase the number of orthophotos requiring differential rectification.

Kodak 2443 color infrared film was exposed at 40,000 feet with a 153-millimeter Wild RC-8 camera and an antivignetting filter. The tidal stage was low water. The resulting 1:80,000-scale photographs were enlarged 4× to transparencies and prints at 1:20,000 scale. These are being used for preliminary classifications and delineation, although the early spring flight date was not optimum for interpreting vegetation. It appears that about 5 man-days are needed to interpret, delineate, and field check the major coastal wetland species and the upper wetland boundary over the area of one 7.5-minute quadrangle (about 63 square miles). The accuracy of the boundary is about 30 feet on the 1:20,000 enlargement. Large scale color infrared photography is scheduled and will be used to achieve the accuracy required for the 1:10,000-scale orthophoto base.

Establishing the required horizontal ground control in coastal wetland areas can be a major expense. Ground control points are established by extending geodetic positions from existing horizontal control stations to photoidentified features. Fortunately, the area around Sapelo Island has many recoverable survey stations. Analytical photogrammetric techniques are used to tie the block of photographs together.

It is our intent to show major plant species composition on the wetlands maps, since this is a basis not only for determining marsh boundaries but also for evaluating marshes for management and regulation. We are not, however, interested in detailed biological mapping. Where plant associations exist, the general composition will be indicated, but no attempt will be made to delineate each species in a mixed area. Where an entire area is covered by one species with only a 10- to 12-foot border of other marsh species along the upland boundary, only the major species will be indicated. Area disturbed by man's activity—ditches or spoil disposal—will be field checked and a uniform interpretation applied where possible.

It is not our intent to establish a precise relationship between a particular stage of tide and the marsh vegetation and morphology. The cartographic representation of wetland features is still subject to ground verification in any legal action. Nevertheless, the orthophotoquad is a valuable tool to implement Federal and State responsibilities for planning, mapping, inventory, regulation, and management.

Conclusion

The objective of the Sapelo Island research project is to evaluate requirements, procedures, and costs for coastal wetland mapping using remote sensing techniques. The 1:24,000-scale topographic maps form the primary cartographic base for the landward portion of the coastal zone, but they have limitations of accuracy and content. Geodetic and tidal datums cannot be directly equated, and the accuracy of contour and tide elevations is limited by practical considerations of marsh morphology.

Orthophotoquads at various scales are seen as an essential prerequisite for wetland mapping. Of course, Federal and State statutes will strongly influence mapping criteria. Vegetation interpretation from color infrared photographs is a practical, economical, and accurate technique for establishing wetland boundaries, helped by the fact that there are a uniquely small number of major coastal plant species. With this method, the upper wetland boundary can be delineated to meet National Map Accuracy Standards.

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Articles for Next Month

Jean-Paul Agnard, Canadian Contribution to Hologrammetry.

Ph. Hottier, Accuracy of Close-Range Analytical Restitutions: Practical Experiments and Prediction.

Harry F. Lins, Jr., Land-Use Mapping from Skylab S-190B Photography.

Dr. C. P. Lo, Photographic Analysis of Water Quality Changes.

Dr. Taichi Oshima, Recent Development of Industrial Photogrammetry in Japan.

Robert L. Pearson, Compton J. Tucker, and *Lee D. Miller*, Spectral Mapping of Shortgrass Prairie Biomass.

Barry S. Siegal and *Michael J. Abrams*, Geologic Mapping Using LANDSAT Data.