COASTAL DELINEATION FROM AERIAL PHOTOGRAPHS*

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MR. PRESIDENT, Members of the Canadian Institute of Surveying and Photogrammetry, and Guests: In accordance with a custom initiated several years ago by your organization and the American Society of Photogrammetry of sending delegates to each other's Annual Meetings, I am honored to have the privilege, this year, of attending this excellent meeting. I might also add that the members of the American Society of Photogrammetry, in fact, the whole field of surveying and mapping, have gained a tremendous worthwhile knowledge from the down-to-earth experience of our Canadian friends who have attended our meetings. This exchange of knowledge, I am sure, will continue to be of great value to both of our countries.

The topic that I am going to present is "Coastal Delineation from Aerial Photographs." The time allotted precludes an exhaustive treatment of this subject, neither will it permit any discussion of the processes involved in the development of the many different types of coasts throughout the world. It is intended that this discussion will cover the major problems involved in coastal delineation, with suggestions as to what can be done by those concerned with these problems, plus a general treatment of the coastal items to be mapped.

If this paper were to have an alternative title it could well be named, "A Plea for Common Understanding and Solution of Coastal Delineation Problems." Such a plea would certainly be appropriate to a group such as this, for the solution to these problems must be considered as a joint responsibility of topographic mapping agencies as well as hydrographic charting services. It is only by close co-operation of the workers in these branches of surveying and mapping—the photogrammetrist, the field engineer, and, the cartographer—and by proper evaluation and correlation of data compiled by each, that an accurate nautical chart can be developed.

It is essential, at this time, to point out that this subject is not only of prime interest to the armed forces, but to the modern Merchant Marine as well. All mapping agencies can, therefore, be of maximum service if equipped with a proper understanding of the problems involved. Prior to the last war, the Army was primarily interested in topographic maps, with little interest in the water areas adjacent to the coasts. The reverse conditions usually existed in the Navy and among hydrographic surveyors. They were interested in the depths of water, shoals, hazards to navigation, and only interested in the topography to the extent whereby bearings, landfalls, etc., would be helpful to the navigator. All services are now thinking in terms of amphibious operations, with the Army interested in the water areas, as well as land areas and beaches, and the Navy thinking in terms of putting ships and boats safely on the beaches. The Merchant Marine also has a need for beach information in that they have obtained surplus landing crafts from military sources since the war. These crafts are now being used to load cargo in open coastal areas formerly denied to conventional ship type vessels. Therefore, the question of Coastal Delineation has become a very important one. As can readily be seen, coastal delineation problems are of added significance when we consider the development of the entirely new map-chart during the last war. This new map-chart is primarily for amphibious operations. It is a combination of a regular topographic map and a

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nautical chart. It is so designed as to allow sufficient sea room for ships to navigate and also cover enough land area to permit naval and air force support to cover troop movements inland a sufficient distance to allow the Army to establish a beachhead. This type of map-chart has the additional advantage of incorporating all information required by the Army, Navy, and Air Force in areas where the three services are operating as a single team.

Development of these map-charts brought forth many problems, such as: "Will the hydrographic data match the coast line which has been photogrammetrically compiled by a topographic unit?"; "Will the contours compiled by a topographic unit match the coast line which has been obtained by a hydrographic unit?"; "What type of beaches are within the area?"; "What type of vegetation and terrain?"; "Where are the best places to land and force entry?". To properly answer these and many other such questions clearly indicates the need for all of us to become familiar with and acquire an understanding of the other fellow's problems.

At the time a topographic survey along a coastal area is being conducted, there may be no requirements for an amphibious map-chart of the area. But, at some future date, there may be vital need for such a map-chart in the defence of our countries. Therefore, if, when the survey is being made, an understanding of the requirements for accurate coastal information exists, and if the proper information is obtained, the results could be correlated with the hydrographic data to produce an accurate map-chart. The same care and consideration should also apply to the hydrographic engineer. He must obtain coastal information in greater detail than ever before. Whenever accurate topographic surveys do not exist adjacent to where the hydrographic survey is being conducted, the hydrographic engineer should not only obtain the proper detail along the beaches and the water areas immediately adjacent thereto, but should go inland and obtain adequate data so that an accurate topographic compilation can be made by the photogrammetric engineer.

I am sure that we will all agree that aerial photographs are a tremendous aid in almost all mapping projects. I am sure we will also agree that aerial photography, photogrammetric equipment and compilation procedures in common use today have certain inherent weaknesses. The main theme of this discussion will be the weakness of photo-interpretation of items depicted on the photographs and the fact that depths of water cannot be determined by visual inspection. Detail along the coast is of great importance in amphibious operations. Yet we rely as a general rule on the visual image obtained by use of multiplex or other photogrammetric instruments for interpretation of coastal detail such as pinnacle rocks, reefs, amount of water over shoal areas, whether reefs uncover at low tide and to what extent, whether the beaches are made up of sand, gravel, boulders, or a combination of all, and other data of extreme importance. Of course, it is realized that all these details can be obtained by a field inspection. However, this is not always possible due to remoteness of an area, adverse weather conditions, economic factors, and other problems too numerous to mention.

Coastal delineation problems are not as great if we are mapping in areas within the continental confines of our respective countries and can automatically perform, as part of the survey routine, a field inspection survey. Then, misinterpretations, omissions, etc., can be corrected.

You probably are aware that, in the United States, we have two hydrographic services—the U. S. Coast and Geodetic Survey, which is responsible for the survey of coastal areas of the United States and its possessions, and the U. S. Navy Hydrographic Office, which is responsible among other things, for

hydrographic surveys required by the U. S. Navy and Merchant Marine for the balance of the world. Due to the remoteness of the survey area, economic factors, etc., it is impracticable for the Hydrographic Office to conduct field inspection surveys after photogrammetric manuscript data have been compiled. This lack of field inspection surveys is, in all probability, a major problem to many of you in your work. If the hydrographic engineer understands the problems of photo-interpretation and properly annotates the photographs in the field, the photogrammetrist will be helped to a great extent when he compiles the coastal data. As it is impractical to clarify every feature, the photogrammetrist will have to use considerable judgment and rely on previous experience and established procedures to extract maximum information from the photographs. Usually it is not practical to smooth plot hydrographic and photogrammetric data on the same sheets. The combining of these data is performed by the cartographer to form the nautical chart or the new map-chart. He, therefore, should understand the problems of photo-interpretation of coastal data and realize that some items shown on the manuscript sheet are of an indefinite nature and he should use considerable judgment in compiling the chart.

There are many, many times when the photogrammetrist, whether working for a topographic or hydrographic agency, is required to compile coastal data without benefit of recent hydrographic surveys, field annotated photographs, or field inspection of complete manuscript sheets. This, then, presents a real problem to both the photogrammetrist and cartographer in producing usable nautical or map-charts.

It is not practical or desirable, in this limited discussion, to explore all weaknesses of coastal delineation or ways and means of helping all concerned with this problem. These items and methods of identifying them on the photographs as well as proper symbolization are discussed in detail in H.O. Publication 592, "Manual of Coastal Delineation from Aerial Photographs." Generally, by following the identification guides listed in the Manual, all backshore, and most of the foreshore features, can be identified on the photographs without much difficulty.

In order that you may be familiar with some of the terms used and be able to visualize different areas, the following definitions are given:

COAST: The general area between land and sea.

SHORELINE: The high water mark of the coast.

FORESHORE: The zone between the high and low water mark, or any area along the coast that covers at high tide and uncovers at low tide.

OFFSHORE: The zone from the low water mark to an indefinite distance seaward, or the seaward area that never uncovers.

BACKSHORE: The zone between the shoreline and marine cliff.

MARINE CLIFF: The seaward edge of the wave-cut cliff that lies nearest the sea and which may vary in magnitude from an inconspicuous slope to an escarpment hundreds of feet high.

BEACH: The zone from the low water mark to the inland limits of wave-deposited debris.

These definitions are my own and do not necessarily represent the official opinion of the U. S. Navy Department.

The shoreline appearing on most nautical charts, is as near as can be determined, the high water line. The exception to this rule is where vegetation, such as mangrove, nipa palm, and prominent marsh grass grows in the area between low and high tide. The outside limit of this growth is delineated as the shoreline. Along many of the coasts of the world the high water mark of the sea will

be on the marine cliff, in which case there will be no backshore area and the landward edge of the beach will be the marine cliff, which will also be the shoreline. When this condition exists, the photogrammetrist has little difficulty in locating the horizontal position of the shoreline on the manuscript sheet, since small errors in the interpretation of the position of the high water mark on the photograph will not affect its accuracy on the manuscript sheet. In other areas where the coast is exposed to heavy wave erosion and weathering conditions, the shoreline will be some distance in front of the marine cliff. This distance will vary from a few feet to a hundred or more feet, depending upon whether the shore is being formed by ocean abrasion; by sea currents, which are depositing debris to and from other areas; whether wave and sea currents can transport the debris being eroded, and weathered from the cliff; or from numerous other combinations of conditions. In areas where the seacoast has a very gradual slope, there will be a considerable difference between the horizontal position of high water line and low water line. This difference between these horizontal positions may be considerable in areas where there are great variations between low and high tides, especially when this condition is coupled with a gradual sloping coast. Under these conditions, the exact position of the high water mark is very difficult to determine on aerial photographs. Usually, if the area is studied under a magnifying stereoscope, two lines of slight discoloration will be seen along the beach. The inshore line is the line of wave-washed debris and will usually be more distinct than the outer line, which is the high water line. In some areas where the force of the waves is broken up before reaching the shore, the debris and high water line will be the same. In other areas where waves of different magnitude and force are beating against the coast, the debris line will be at varying distances from the high water line. Therefore, when field annotated photographs are not available, the characteristics of the wind and offshore depths of water should be studied before trying to determine the high water line along a low flat coastal area. It is almost impossible to distinguish either the debris or high water lines from single photographs.

There is one important phase of delineating coastal features on aerial photographs that should be stressed—*the difficulty of determining the approximate depths of underwater features.* The photogrammetrist, cartographer and the field engineer should always keep this in mind when, as a team, they are preparing and compiling data for nautical charts or for the new map-charts. The present types of aerial photographs and equipment make it extremely difficult to determine the approximate depths of underwater features. The photogrammetrist will, and should, according to the best of his ability, interpret and show on the manuscript sheets, all features of the coastal area that seem to uncover at low tide. The areas out beyond this uncovering limit, that appear dangerous to navigation, should also be delineated. These will be shown on the manuscript as danger lines. For example: along a rocky reef, he should show that part of the reef that appears to uncover. This, of course, will be shown in its proper symbolization. Out beyond this, that portion of the reef which shelves out into deep water can often be seen. The extremities of this visible shelf should be shown as a danger line. It must be remembered by the cartographer that, although these features are delineated to the best ability of the photogrammetrist, the accurate interpretation of such features is limited by the quality and scale of the photographs. It is quite likely that when this information is combined with the hydrographic data it will conflict with the soundings. If the soundings are reliable, then the uncovering portion of the reef and danger line should be adjusted to agree with the soundings. If, in the cartographer's opinion, the

sounding data are not very reliable, he should use extreme caution in shifting the photogrammetric data.

These problems are considered of sufficient importance to relate, at this point, two personal experiences: A few years ago I was delineating coral pillars in an atoll on a pair of photographs and was of the opinion that most of them would uncover at low tide. Later, I discovered that the sounding party had stopped the sounding boat over most of these pillars and had obtained depths of from two fathoms (12 feet) to 15 fathoms (90 feet). In another instance, I was delineating a coastal area which had a rock ledge extending into the water. The best interpretation of the photographs seemed to indicate that only a small part of the ledge would uncover and the balance indicated an underwater danger. Soundings revealed that the ledge actually uncovered out to the limit of the visible shelf.

These examples are given in order to stress the point that approximate depths of underwater features are very hard to determine from aerial photographs.

Since the exact depths of underwater features cannot be accurately determined from aerial photographs, the photogrammetrist should delineate and transfer to the manuscript sheet all discolored areas lying in the offshore zone. Usually, it will not be possible to determine whether or not these areas are actually danger areas. Nevertheless, these discolored areas should be shown on the manuscript sheets. When the cartographer combines these data with that of the hydrographic survey, it should then be decided how the area shall be charted. For example: The photogrammetrist may be able to detect a submerged sand bar, rocky reef, coral reef, etc., in the offshore zone of the area. The cartographer may decide when compiling the chart that, due to the characteristics of the coast, everything inside the six-fathom curve would be considered dangerous, and should construct the chart to show this condition. If the soundings in the area were considered reliable, and the danger area delineated by the photogrammetrist falls outside the six-fathom curve, the cartographer should disregard this danger. If, on the other hand, the soundings were not reliable, then the cartographer should, to be safe, show the danger area on the chart.

Another condition that may exist is that the photogrammetrist may delineate a danger area which, when combined with reliable soundings, will be larger than the soundings indicated. In this instance, the danger area should be contracted to agree with the soundings. It is entirely possible that a reverse condition will exist, where the area should be expanded to agree with the soundings. The main point is that it is impossible to determine the exact depth or the exact limits of submerged areas from aerial photographs, considering the quality of photographs and techniques in use today. Therefore, it is not only essential that the photogrammetrist realize this limitation in coastal delineation, but the cartographer should also realize it, and use photogrammetric compilations with this understanding.

Submerged rocks are, to a certain extent, similar to a danger area except they are usually small. These small rocks are very difficult to locate on the photographs, especially if proper precautions are not taken when the prints are being processed. The photogrammetrist should employ every precaution to assure locating every sunken rock within the area covered by the photographs. If these submerged rocks fall in between sounding lines and the area is not wire dragged, they are very apt to be missed entirely in the hydrographic survey. These rocks are very dangerous to navigation when they lie in or near the normal ship channel, especially when they are near the surface of the water, yet too deep to cause the waves to break.

Experience has proven beyond any doubt that coastal features cannot be delineated, within a suitable degree of accuracy, from small scale photographs by using any of the stereoscopic plotting instruments, such as the K.E.K. Plotter, Multiplex, etc. This is due to either a fuzzy image being produced by the instruments or to insufficient stereoscopic magnification that will prohibit seeing shore detail with sufficient clarity to enable proper interpretation. It is, therefore, recommended that all coastal features be delineated on photography by studying the area, using a magnifying stereoscope. The type of stereoscope may be either a reflecting or refracting type. The type is not important, just as long as the photo image is enlarged two or three diameters and remains clear.

To summarize: The problem of Coastal Delineation from Aerial Photographs is a very difficult one. Difficulties in photo interpretation, especially in foreshore and offshore areas, should be understood by everyone who is either collecting field data, compiling photogrammetric manuscripts, or combining field and photogrammetric data. In coastal areas where accurate field surveys are made; where the field engineer edits as many of the coastal features as possible by annotating the photographs in the field; where the photogrammetrist uses this field information as well as considerable judgment in the delineation process; and where the cartographer employs caution and skill in combining the photogrammetric data with the hydrography, a nautical chart or a map-chart will result which will be safe for peacetime navigation as well as for amphibious operations. In areas where there are no recent field surveys, the responsibility of the photogrammetrist and cartographer is very great and both should proceed with their work with extreme caution. In that we do not know where or when an amphibious map-chart will be required by the armed services in defense of our respective countries, all survey data along coastal area, whether compiled by a topographic mapping agency or a hydrographic charting agency, should be procured in a manner that will permit the delineation of coastal features to a high degree of accuracy.