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DELINEATION OF COASTAL FEATURES AND RELATIVE TURBIDITY LEVELS IN THE MID WEST SEA OF KOREA USING LANDSAT IMAGERY

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ABSTRACT

Multispectral scanner data collected by LANDSAT-1 over the mid West Sea of Korea were analyzed and interpreted for delineation of coastal features and turbidity distribution patterns during different portions of the tidal cycle. Imagery from two successful LANDSAT-1 overpasses of the area in October 1972 and in October 1973 had been used to prepare schematic maps of coastal features and turbidity distributions.

Color composite imagery of LANDSAT MSS 4, 5 and 7 gave the best representation of shorelines, coastlines and tidal flats. MSS 5 imagery was most effective in differentiating relative turbidity levels through density slicing techniques.

Referring to the tidal power development of Garolim Bay, the basin area measurements assuming dyke construction at the bay entrance, have been carried out on the coastal feature maps compiled from LANDSAT imagery, and those results were correlated with existing data.

General areal patterns of surface turbidity distribution in the study area revealed close similarity with bathymetry of the area.

Synoptic circulation patterns were also well discriminated from the LANDSAT imagery using the suspended sediment as a tracer.

INTRODUCTION

The objectives of this work were to delineate coastal features, to extract concentration patterns of suspended sediments of Korean mid West Sea using LANDSAT data, and to evaluate general utility of remotely sensed data form orbiting satellite in oceanography through correlation with research results reported herein in the same area.

The basin area of Garolim Bay assuming a dyke for tidal power development being constructed as section A-B in Figure 1 and 2(MOST, 1974), was surveyed using two different passes of LANDSAT-1.

Coastal geomorphology of Garolim Bay, Asan Bay and other parts of mid West Coast up to Ongjin Peninsula was examined after delineation of coastal features from the cloud-free color composites collected over those areas.

Using the density slicing technique, the relative turbidity levels were clustered into four or five classes from LANDSAT MSS 5 data covering whole Korean mid West Sea area.

Multi-disciplinary survey works had been performed in the Garolim Bay for the study of tidal power generation (MOST, 1974;) and in the Asan Bay for construction purposes (MOC, 1972). Some foreign scientists had successfully delineated relative turbidity levels in sheltered bays and reservoirs using LANDSAT data (David *et al.*, 1974; Mausel *et al.*, 1973). Klemas *et al.* (1973) also had studied about coastal water properties and current circulation patterns with LANDSAT data using suspended sediment as a tracer in the Delaware Bay.

LABORATORY AND FIELD WORKS

Over the central western region of Korea including Taean Peninsula, Asan Bay, Incheon Bay, and the mouth of the Han River with a total coverage of 185km x 185km, two completely cloud-free LANDSAT-1 passes were collected on 31 October 1972 (ID 1100-01453) and on 8 October 1973 (ID 1442-01433). They were obtained through multispectral scanner (MSS) system onboard the satellite and each overpass had four outputs which were detected in four different areas of the light spectrum as band 4 (0.5−0.6μm: green), band 5 (0.6−0.7μm:red), band 6 (0.7−0.8μm: near infrared), and band 7 (0.8−1.1 μm: near infrared).

For mapping of coastal features, the false color composite imagery reproduced by three images of the multispectral scanner band 4, 5 and 7 was used. For classification of relative turbidity levels, MSS band 5 images were used. Coastal features were directly interpreted and delineated from color composites following simple procedures for enlarging from the original 7.3 inch x 7.3 inch imagery (approximate scale of 1/1,000,000), making color slides of those enlarged images, and projecting them on the screen.

Relative turbidity levels which represent concentration patterns of suspended sediments in surface water layers, could be analyzed by color analyzer or density slicer. In this work, the color analyzer of Spatial Data Co. (Model 704-16 CA) was used for density slicing of 70mm MSS 5 black and white positive films. Figure 7,8 were compiled from projected color slides which were prepared after delicate adjustment steps of the density slicing procedure. On the output display of the color analyzer, a certain boundary of different density levels was adjusted to reveal maximum similarity with actual shorelines and total turbidity levels were also adjusted in four or five classes.

All Figures concerning coastal features were drawn in existing map scales as in Figure 1 and 2 (1/25,000) and in Figure 4,5 and 6 (1/120,000). This scale adjustment was simply implemented by overlapping projected images on the existing topograpic maps or hydrographic charts. Color changes or tonal variations of color composite imagery acted as tracing criteria for mapping of shorelines, coastlines, and tidal flats developing between them.

Water bodies with little suspended sediments or algae blooms appeared in dark blue, tidal flats containing much moisture appeared in pale blue, and land areas appeared in yellowish red color zone. Turbidity of water bodies and vegetation on land areas caused some difficulties in tracing coastal feature elements. Furthermore, these color changes and tonal variations were so gradual that discrimination of different elements in mapping was not possible.

Field work on the ground was required not only for the confirmation of interpreted results but also for preliminary training in the use of analysis systems. In this work, most analyses have been done in a nonautomatic manual way by employing color analyzer for density slicing and enlarger for preparation of slides. Thus the ground informations of the study area played an important role in tracing coastal features which had especially gradual tonal changes and in the adjustment of density slicing levels.

The ideal method of obtaining ground observation data is to have the analyst in the study area at the time of LANDSAT data acquisition. But this was impossible because the data were collected two or three years earlier.

Garolim Bay was surveyed several times in 1974-1975 for the observation of tidal flate and topographic settings. Asan Bay, Gangwha

Island, and adjacent areas of Daebu Island were also surveyed in 1975.

Field survey results were interacted through all stages from image analysis to final interpretation. In the study area, human activities are so concentrated that most of upper inter-tidal zones have been developed into paddy fields or salt-farms and some huge dykes have been constructed. These artificial disturbances of coastal features could only have been observed and taken into account by field observations.

RESULTS AND DISCUSSION

1. Basin area measurements of Garolm bay: The feasibility study of tidal power plant (MOST, 1974) suggested high potential of tidal power generation in the West Coast of Korea. Among possible sites, Garolim Bay was regarded as one of the best places in that report. For a tidal power generation scheme, the relationship between basin area and tidal elevation should be solved. Conventional methods such as surface survey of whole tidal flats sounding whole bay at high water, and taking aerial photographs at every portions of tidal cycle could be employed for this purpose, but all of these methods would require too much cost and time. In this sense LANDSAT imagery obtained in different parts of the tidal cycle was applied to measure the basin area at each tidal elevation of data collection.

Figure 1 was compiled from color composite imagery of LANDSAT-1 ID 1100-01453 collected on 31 October 1972, 10h 45m 18s of Korean Standard Time(KST), when the tide was near at neap high water. As shown in Table 1, data collection time of ID 1100-01453 is 1 hour 41 minutes before arrival at high water (642 cm) at Incheon. The tide at Garolim Bay (table 1) was calculated from the tidal record at Incheon with reference to the previous results (MOST, 1974). According to calculated results, the tidal elevation at the same time as the above data collection, gave a value of 480 cm at the entrance of Garolim Bay.

Tale 1. Tide at Incheon and Garolim Bay around LANDSAT-1 ID 1100—01453 Collection.

	Incheon		Garolim Bay Entrance	
L.W.	06h13m	245cm	05h51m	201cm
H.W.	12h48m	642cm	12h26m	526cm
Data Collection Time	10h45m	550cm	10h45m	480cm

Thus the shoreline features and tidal flats shown in Figure 1 can be said to represent the coastal topography at a tidal height of about 4.8 m. Section A-B is the proposed dyke site for tidal power plant (MOST, 1974).

Measured basin area within section A-B on Figure 1, which should correspond to a tidal elevation of 4.8 m, was 85 km^2 and whole area within section A-B including tidal flats inside the coastlines drawn in Figure 1, while the tidal area corresponding to approximately high water level, was 102 km^2. This value of 102 km^2 could be correlated with that of 106 km^2 reported in the feasibility of tidal power plant (MOST, 1974), which was measured on a 1/25,000 topographic map. The result of the basin area measurements from LANDST-1 ID 1100-01453 suggests the estimation of basin area being about 90 km^2 when tidal elevation comes up to 5 m. The mean sea level of Garolim Bay was reported as about 4 m, and the high water ordinary mean tide was reported as about 6.3 m (MOST, 1974). According to these results, the tidal flats of the bay would not be exposed at sea level when it is at an elevation of about 1 m lower than high water ordinary mean tide.

Figure 2 was drawn from a color composite of LANDSAT-1 ID 1442-01433 collected 8 October 1973, 10 h 43 m 18 s KST, while the

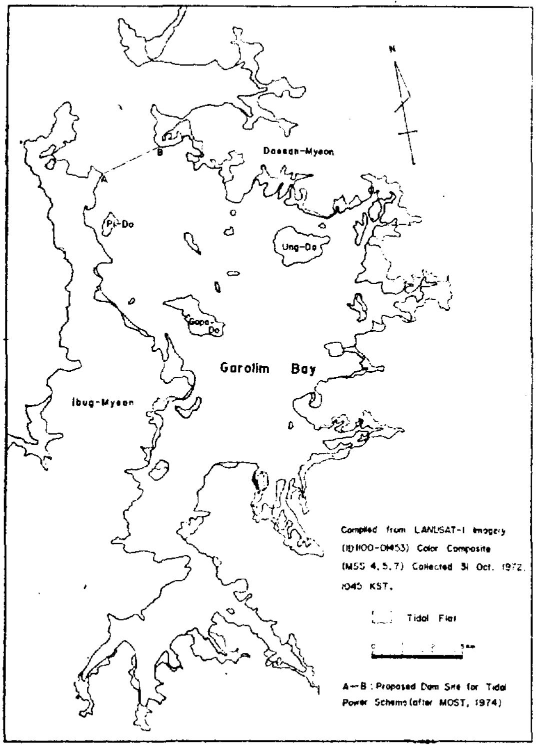

Fig. 1. Shorelines and Tidal Flats of Garolim Bay at Near High Tide.

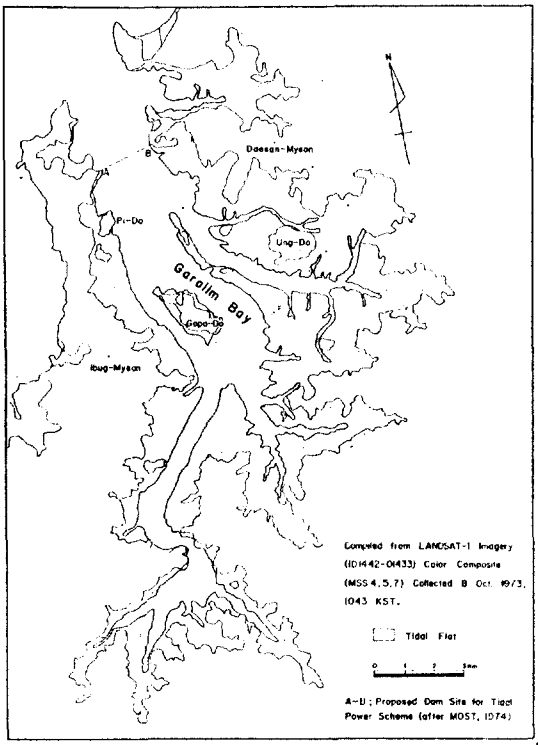

Fig. 2. Shorelines and Tidal Flats of Garolim Bay at Near Low Tide.

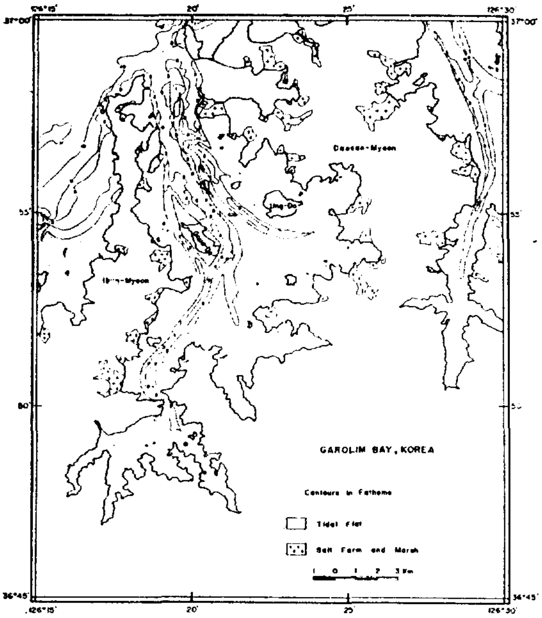

Fig. 3. Topographic Map of Garolim Bay.

Table 2. Tide of Incheon and Garolim Bay around LANDSAT-1 ID 1442-01433 Collection.

	Incheon		Garolim Bay Entrance	
L.W.	08h39m	272cm	08h17m	223cm
H.W.	14h36m	659cm	14h14m	540cm
Data Collection Time	10h43m	380cm	10h43m	340cm

tidal elevation was still low. The data collection time of 1442-01433 would be 2 h 4 m after low water at Incheon and 2 h 26 m after low water at the Garolim Bay entrance (Table 2). Due to a malfunction at Incheon tidal station during this data collection, table 2 was prepared from a predicted tidal table (HO, 1972). The tidal elevation at the moment of data collection was calculated as 380 cm at Incheon and 340 cm at the Garolim Bay entrance. The basin area within section A-B on Fig. 2, when the tidal elevation was 3.4 m, was measured as 38 km². The basin area of datum level 0 m was reported as about 25 km² (MOST, 1974). This means that the slope between datum level and 3 m level is very steep. The whole basin area inside coastlines within section A-B was measured as 105 km², which is 1 km² less than the result of previous report (MOST, 1974) and 3 km² more than that of Fig. 1.

Table 3. Correlation of Garolim Basin Area Measurements using Existing Data.

Basin Area Elevation	Results from LANDSAT Data	Existing Data from MOST Report
0m	—	25km²
3.4m	38km²	43km²
4.8m	85km²	66km²
HighWater Level	104km²	106km²

The above results of basin area measurements from two LANDSAT imagery data showed considerable differences from existing data at middle tidal elevations such as 3.4 m and 4.8 m, and little differences at high water elevation (Table 3). Both Fig. 1 and Fig. 2 were drawn in scale of 1/25,000 and the coastlines showed almost coincidence with the existing 1/25,000 topographic map. The resolution of LANDSAT imagery is good up to the scale of 1/25,000 with its quantitative accuracy being demonstrated by the values of whole basin area measured inside coast lines as 102 km², 105 km², and 106 km², respectively from ID 1100-01453, and 1442-01433, and topographic map (Table 3).

Generally shorelines can be traced more easily than coastlines from the imgery, because the boundary between water and tidal flat is usually clearer than that between tidal flat and land. Paddy fields, salt farms, and upper dry zone of tidal flats made the mapping of coastlines more difficult.

At tidal elevation of 3.4 m, the basin area obtained from imagery was 38 km² and that obtained from surveyed map was 43 km² (Table 3). At an elevation of 4.8 m, the basin area obtained from imagery was 85 km², and that obtained from surveyed map was 66 km². These differences were rather significant.

In this study, coastal feature maps of Fig. 1 and Fig. 2 should be accurate, but the data of tidal elevations might have some errors because they were not measured results but calculated from the values of Incheon.

Garolim Bay has an extraordinarily vast tidal flat distribution as shown in Fig. 3. The basin areas at datum level is about one fourth of whole area at high water level. The increment of basin area with the increase of tidal elevation is very slow at range of 0-3 m, very fast at the range of 3-6 m, and slow at higher level than 6 m. In other words, the general slope of tidal flats in range of 0-3 m is very steep, that in range of 3-6 m is very flat, and that in range of upper 6 m is steep.

If there were enough LANDSAT data collected at various portions of tidal cycle and additionally exact tidal records pertinent to those data acquisition times, much more successful results of basin area measurements at various tidal elevations could be accomplished in this work.

2. Coastal features of mid west sea: With use of LANDSAT color composite imagery, the coastal features of Garolim Bay, Asan Bay area, and Incheon-Gangwha area were mapped in diffierent scales as shown in Fig. 1, 2, 4, 5 and 6. The main point of discussions has stressed the distribution of tidal flats with regard to tidal elevations. In general, the sheltered bays and estuaries of mid West Sea seemed to typical topographic features which could be developed in drowned coasts with large tidal ranges.

There were usually developed many small cliffs along coastlines and vast tidal flats with dentritic tidal creeks on them in most inner bays of the area. LANDSAT color imagery suggested good discrimination capability of geologic structures such as strikes of bed rocks, faults, domes, etc. Thus the geologic structures identified in coastal zones gave some estimation of submarine geology and geomorphology.

In Garolim Bay, the western side showed regular linear strike in a south-west-ward direction and possessed a narrower inter-tidal zone than the eastern side. Almost all tidal flats of Garolim Bay develop under the level of high water ordinary mean tide, which are so called slikke where there is almost no vegetation (Hill, 1966). The other inner bays of West Sea also have little formations of shore or salt marsh which develop at the upper range of high water ordinary mean tide. This fact seems to be the general characteristics of sheltered bays or estuaries on the West Coast. The most important reason for this might be the active reclamations in the area.

Some sand spit formations were able to be delineated from imagery ID 1442-01433 as shown in Fig. 2. They are developing at the border of the main flood-and-ebb channels by lateral deposition of strong tidal currents. There are not any significant tidal channels which extend up to the coastal valley in Garolim Bay. This means that the Garolim Bay has not any flowing river system.

In the Asan Bay area, a coastal feature map of about 1/120,000 scale was successfully compiled from LANDSAT color composite (ID 1442-01433) collected at near low water of tidal cycle (Fig. 4). This map shows more details of shoreline and tidal flat features than 1/250,000 existing topographic map shown in Fig. 9. The most significant coastal structures delineated from imagery data were two dykes called the Asan Dyke and the Namyang Dyke (Fig. 4). These two artificial dykes revealed distinct identity with typical shapes, sizes, and locations in the imagery. Since the original data of ID 1442-01433 was obtained in October 1973, both of them were constructed before then. Namyang Dyke which is located at the northwest part of the bay encloses very extensive tidal flats which are now under development work for cultivation. The main channel inside Namyang Dyke is a fresh water reservoir or lake for irrigation of the developed area. Asan Dyke which is located at the inner part of the bay conserves fresh water discharges from Ansung River and does not enclose extensive tidal flats like Namyang Dyke.

The Sabgyo River system flowing from the south into the Asan Bay entrance has also a dyke construction plan, but it did not appear on the imagery because there was no actual construction work until after the data collection.

Asan Bay does not develop extensive tidal flats because it is not sheltered from the main tidal stream. As showe in Fig. 4 the Bay has a relatively narrow lateral deposition by either tidal currents or river water discharges. Tidal currents seemed to be strong at the bay entrance and water depth was recorded as deep as 50 m around the southern outcrop of Namyang Dyke (MOC, 1973).

Coastal features of shorelines and tidal flats in Incheon-Gangwha area are shown in Fig. 5 and Fig. 6. Fig. 5 was drawn from a color composite collected on 31 October 1972 (ID 1100-01453) while the tidal cycle was in neap and near high water. The image collection time was 2 h 3 m before a high water of 642 cm and the tidal elevation at that time was 550 cm at Incheon tidal station (Table 1).

In Fig. 5, the distribution of tidal flats in the adjacent areas of Incheon-Yeongjong-Do,

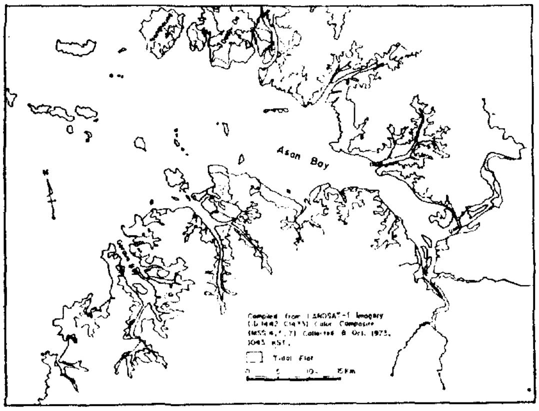

Fig. 4. Simplified Shorelines and Tidal Flats in the Vicinity of Asan Bay.

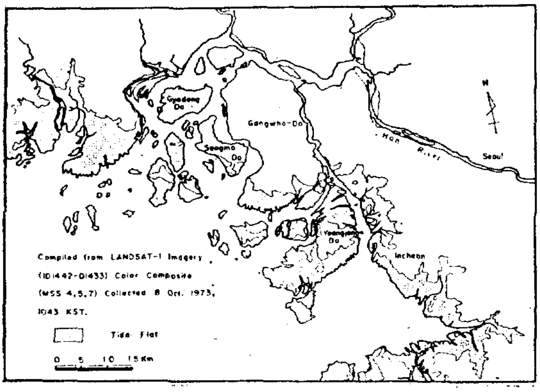

Fig. 5. Shorelines and Tidal Flats of Incheon Bay Area at Near High Tide.

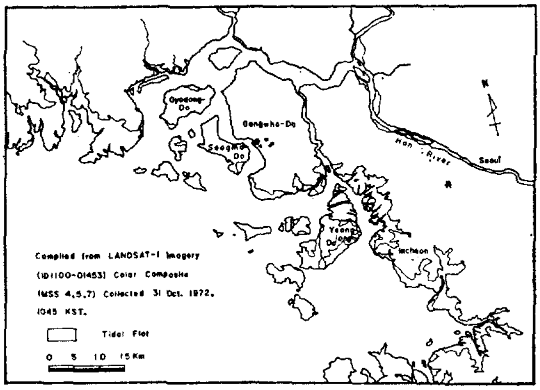

Fig. 6. Shorelines and Tidal Flats of Incheon Bay Area at Near Low Tide.

Haeju-Yeonan Coast, and Siheung Bay covered a considerable area. On the original color imagery, the main channels of Han River discharge, and the drowned submarine topography near the coast of Haeju-Yeonan were well identified.

Fig. 6 was drawn from the imagery collected on 8 October 1973 during the tidal cycle near low water. The data collection time was 2 h 4 m after a low water of 272 cm and the tidal elevation was estimated as 380 cm at Incheon (Table 2).

Tidal flats in Fig. 6 appear much more extensive than those in Fig. 5 over all areas. In a south-west direction from Gangwha-Do, there are shown many island-like tidal flats which can be called shoal or bank formations in the lateral sides of the main channels. To the offshore, most tidal flats show ria-styled shoreline features and there appear little intertidal deposits near the mouth area of the Han River due to strong discharge.

3. Distribution patterns of suspended sediments in the mid west sea : The synoptic distribution patterns of suspended sediments in the study area were well delineated from two different frames of LANDSAT MSS 5 data. By density slicing of black and white imagery, the relative levels of suspended sediment concentrations were clustered into *four or five* classes (Fig. 7, 8). In large lake or inner bays where turbidity variations are so significant, some scientists had reported that automatic density slicing processes of LANDSAT data are effective for the study of water properties (David *et al.*, 1974; Mausel *et al.*, 1973).

MSS 5 data gave the best identifiability of relative suspended sediment concentrations in the mid West Sea among four MSS bands of data and another report has also supported this fact (Klemas *et al.*, 1973).

Suspended sediment concentration or turbidity increases with class number as shown in Fig. 7 and Fig. 8. In both Figures, there are shown three large clusters of relatively high suspended sediment concentrations with shape of a tongue which are supposed to represent submarine bank formations, and between them two narrow channels of relatively low suspended sediment concentrations are also shown. These characteristic patterns are related to the bathymetry of the area which is well demonstrated in Fig. 9. This means that the distribution patterns of turbidity or suspended sediment concentrations in the mid West Sea are under the dominant effect of submarine topography, and the principal direction of synoptic current circulation is coinciding with the development of these narrow channels.

Meteorological factors such as precipitations and winds of the area during the period of data acquisition (CMO, 1973 and 1974) were reviewed, but they seemed not to be so closely related with those turbidity patterns.

Many large tidal flats which are not connected with islandse are developed in northern two submarine bank formations and much more complicated topography associated with Deogjeog Islands Group are developed in southern submarine bank formation.

The above mentioned three large shallow bank formations seem to have originated from a submarine delta formed by the old Han River discharge. About 17,000 years ago, there was so called late Wisconsin and at that time, the mean sea level was about 100 m lower than at present (Weyl, 1970). This means that all of the study area might have been exposed to atmosphere during that latest ice age. Relating to this, the three shallow bank deposits were thought to be submarine delta formations and the two deep and narrow channels being old Han River beds.

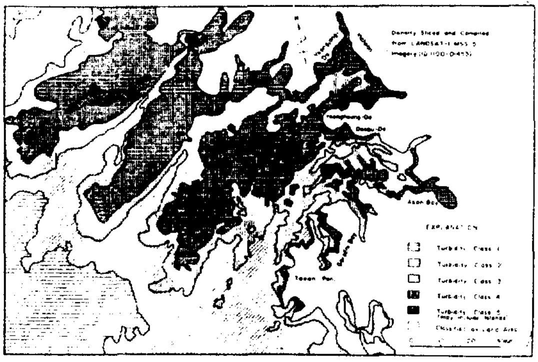

Fig. 7. Turbidity Distribution in the Mid-West Sea of Korea on 31 October 1972.

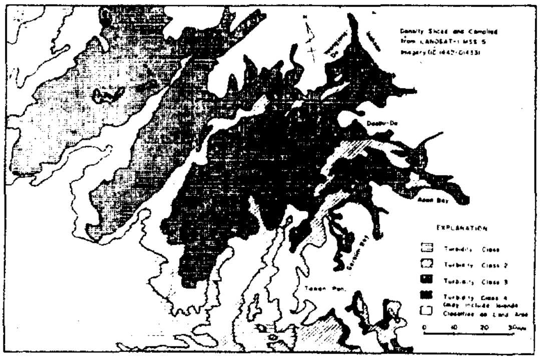

Fig. 8. Turbidity Distribution in the Mid-West Sea of Korea on 8 October 1973.

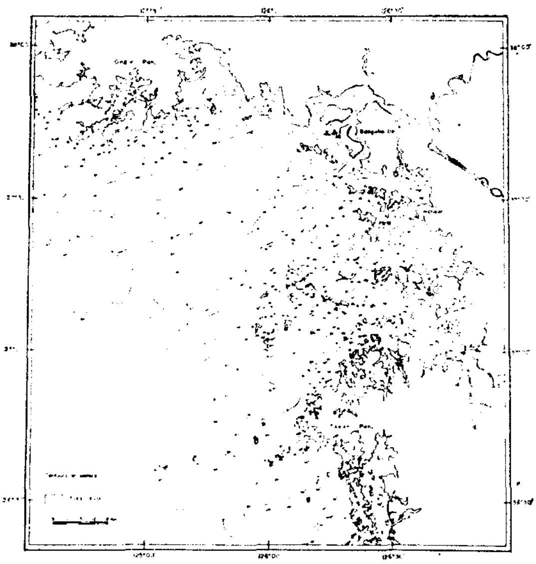

Fig. 9. Topographic Map of Mid-West Sea of Korea

Turbidity class 4 in Fig. 7 and class 5 in Fig 8 represent typical features of suspended sediment concentrations as a function of water depth. In the offshore areas of Taean and Ongin Peninsulas, the relative turbidity appears unexpectedly low inspite of being coastal areas. This might be due to there being no significant river systems eveloped.

CONCLUSIONS

LANDSAT provided good data for delineation of coastal features such as shorelines, coastlines, and tidal flats. In addition, the data were very effective in classification of relative suspended sediment concentrations by the density slicing process.

The coastal feature mapping from color composite imagery was possible up the scale of 1/25,000 with generally acceptable resolution. In the near future, the applicability of remotely sensed data seems to be extended easily to various fields of oceanographic research and development works in Korea as in other developed countries. The results obtained in this work can be summarized as follows.

1. The basin areas of Garolim Bay with reference to the tidal power plan were measured as 38 km^2 at tidal elevation of 3.4 m, 85 km^2 at tidal elevation of 4.8 m, and 104 km^2 at mean high water level, from the LANDSAT imagery.
2. Coastal features of mid West Sea were well delineated from the LANDSAT color composites and they seemed to be under the dominant influences of Han River discharge and prevailing tidal phenomena.
3. In the mid West Sea, there appeared three tongue-like-clusters of high suspended sediment concentrations and two narrow and deep channels between them. These patterns are closely related to bathymetry and water circulations in the area.

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