PHOTOGRAMMETRIC INVESTIGATION ON THE UPHEAVAL OF WATER SURFACE IN THE STRAIT, HAYATOMO SETO (APPLICATION OF PHOTOGRAMMETRY TO HYDROGRAPHY 3)

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Abstruct

In order to determine the datum level in the narrow strait the upheaval of water surface must be investigated. The method of terrestrial photogrammetry was applied for this purpose, and the observation and reduction were made for Hayatomo Seto with two synchronized cameras and stereoplotter, Autograph A7.

It is found that the upheaval occurs in the northern coastal area and its maximum magnitude is about 90 centimeters high in the case of the westerly maximum current, and that the photogrammetry is definitely available to observe the figure of the water surface.

1. Introduction

It has become necessary to obtain the water depth in a harbor or a strait more precisely than before due to the increase of ship's draft, and thus the effect of the change of water surface cannot be ignored. It is, therefore, important to investigate the feature of upheaval or other change of the surface, as well as to study how to observe them efficiently.

For this purpose aerial photos might be applied to investigate the water surface in various parts of a stream, by means of stereoparallax measurement of floating objects, e. g., artificial floating targets or natural foams photographed on two overlapping frames. Generally, it is necessary to photograph synchronously with two cameras from planes in order to obtain the undulation of water surface. In the method of the aerial measurement, however, two air-crafts connected with some radio-system must be prepared for controlling synchronous photography, and it is obviously difficult to determine the height of upheaval with a desired accuracy even if the synchronous photography would be possible from two planes. Thus the authors applied the method of terrestrial photogrammery which is considered to be more precise than the aerial surveying.

The survey was made in September 1964, in the Hayatomo Seto in Northern Kyusyu, where the predominant upheaval occurs accompanied by tidal currents. In the present paper we shall show the excellent applicability of terrestrial photogrammetry to the investigation of the figure of the water surface.

2. Setting of Photographing Station and Photography

Cameras employed were a pair of synchronized Wild P 30 Phototheodolites. The accuracy of synchronization of camera was adjusted before each exposure to be less than 10^{-2} second. By such a fore-adjustment the displacement of a floating target in the investigated area during the mis-synchronous exposures by two cameras was controlled under 2 to 3 centimeters. The construction of the floating target is shown in Fig. 1, the size of its photographed image being about 0.1—1.0 millimeters. The size of target was so large that it could generally be seen even behind the crest or sprang. Distribution of the targets was carried out with the high speed patrol boat "Hatakaze" and the hydrographic surveying boat "Hesaki", and ten targets were distributed on the sea surface for each photographic chance.

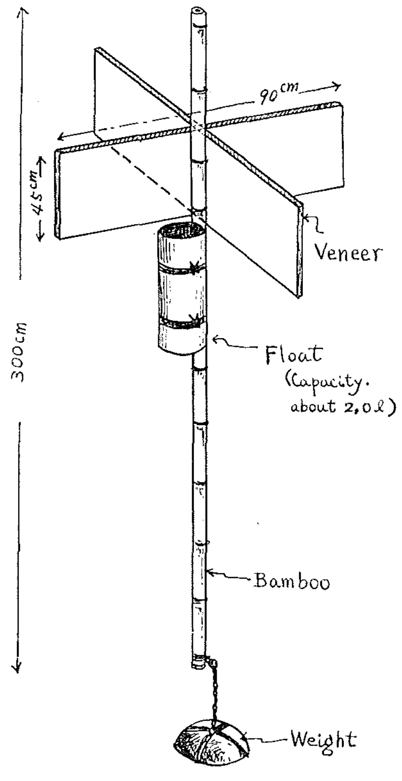

Fig. 1. Floating Target.

Camera stations were selected in the precinct of Mekari Shrine (in Kita-Kyusyu city) as shown in Fig. 2. The photographing base length was 44,58 meters, and the cameras were set in parallel swing photographing, i. e., each camera axis was 20° left to the base line and set in horizontal plane (see Table 1).

The time required for distributing and picking-up the targets was so long that it was impossible to extend the photographic area by another parallel averted method. Moreover, photographing at the time of maximum velocity of eastward tidal current was carried out under the counter-light. Consequently the measurement of the elevation of water surface was difficult because of the silhouetted pair pictures, and thus discussion on the case of eastward current will be omitted in this paper.

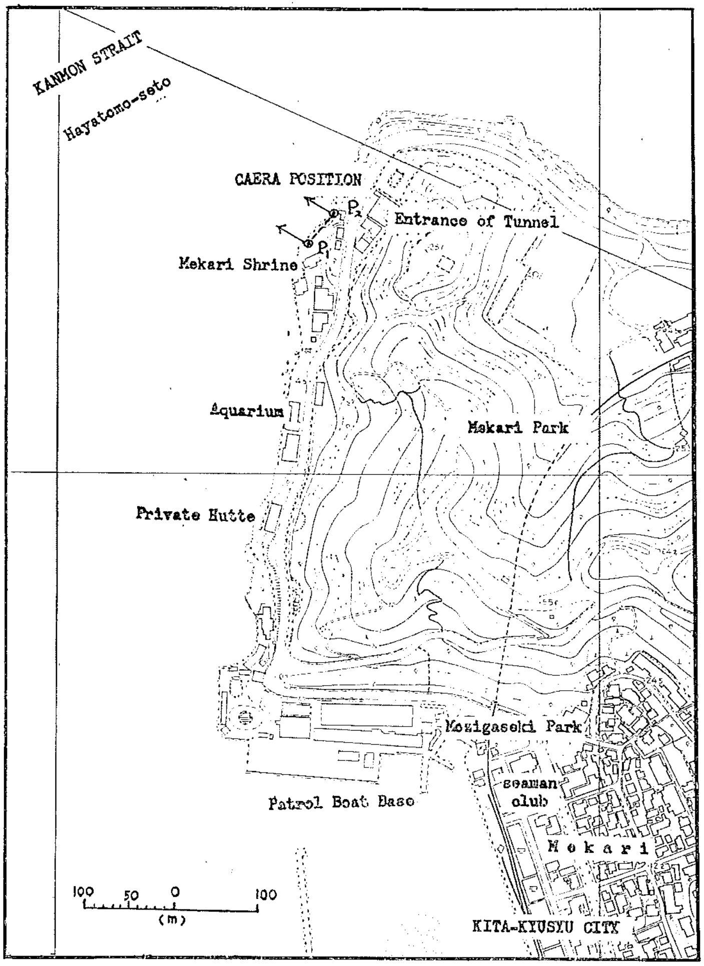

Fig. 2. Camera Station.

TABLE 1. PHOTOGRAPHIC DATA

Date	Time	Weather	Camera Position	Plate No.	Direction of Photography	Exposure	Remarks
Sept. 8 1964	h m 10 35	clear up	P1	1	Horizontal 20° left	1/100 s.	Mwc: 10 21 (h m) 10 targets
			P2	11	same	same	
	13 23	same	P1	5	same	same	Ttc: 13 14 10 targets
			P2	15	same	same	
	16 18	cloudy	P1	8	same	same	Mec: 16 31 10 targets
			P2	18	same	same	

Notes: (1) Difference of two camera-heights is 8.5 cm.
(2) Height of one camera is 122.0 cm.
(3) Signals in above table means:
Mwc: Maximum westerly current
Ttc : Turn of tidal current
Mec : Maximum easterly current

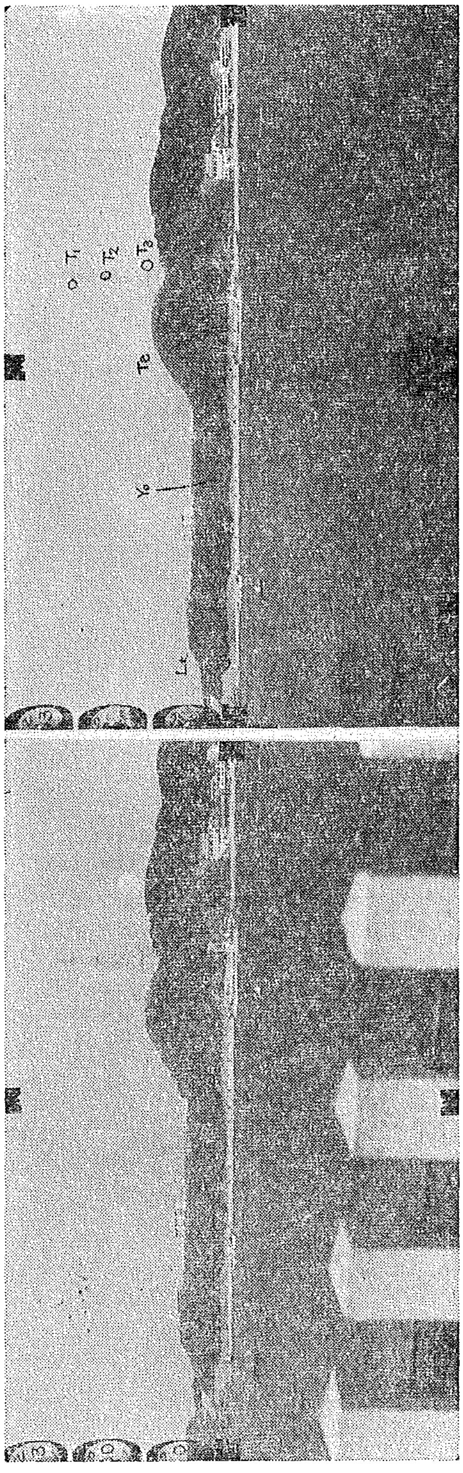

Fig. 3. Synchronous Photographs of Stream in Hayatomo-Seto.

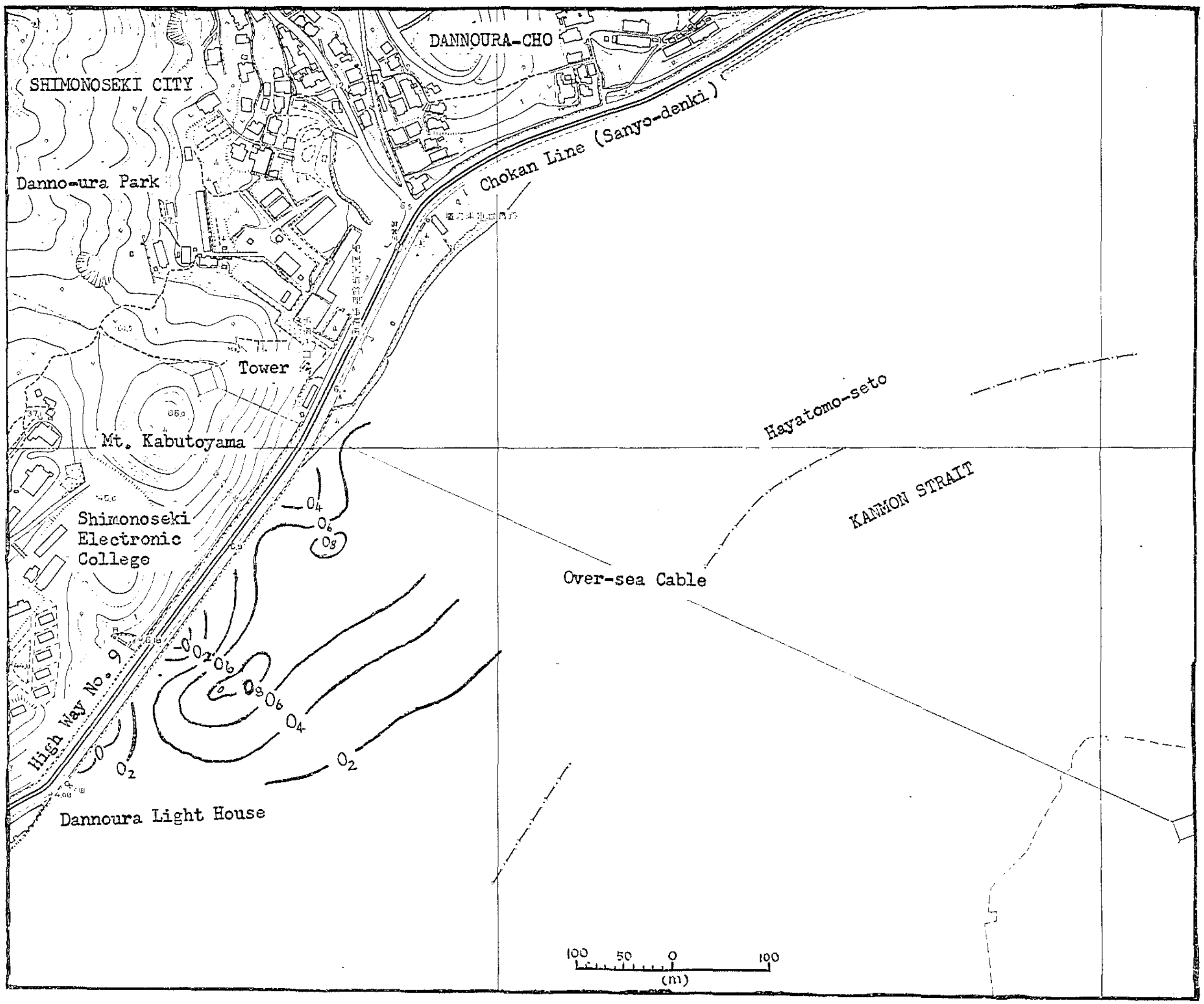

Fig. 4. Contour Map of Swelling at the Time of Maximum Westerly Current, 10h 35m (J.S.T.) on Sept. 8, 1964.

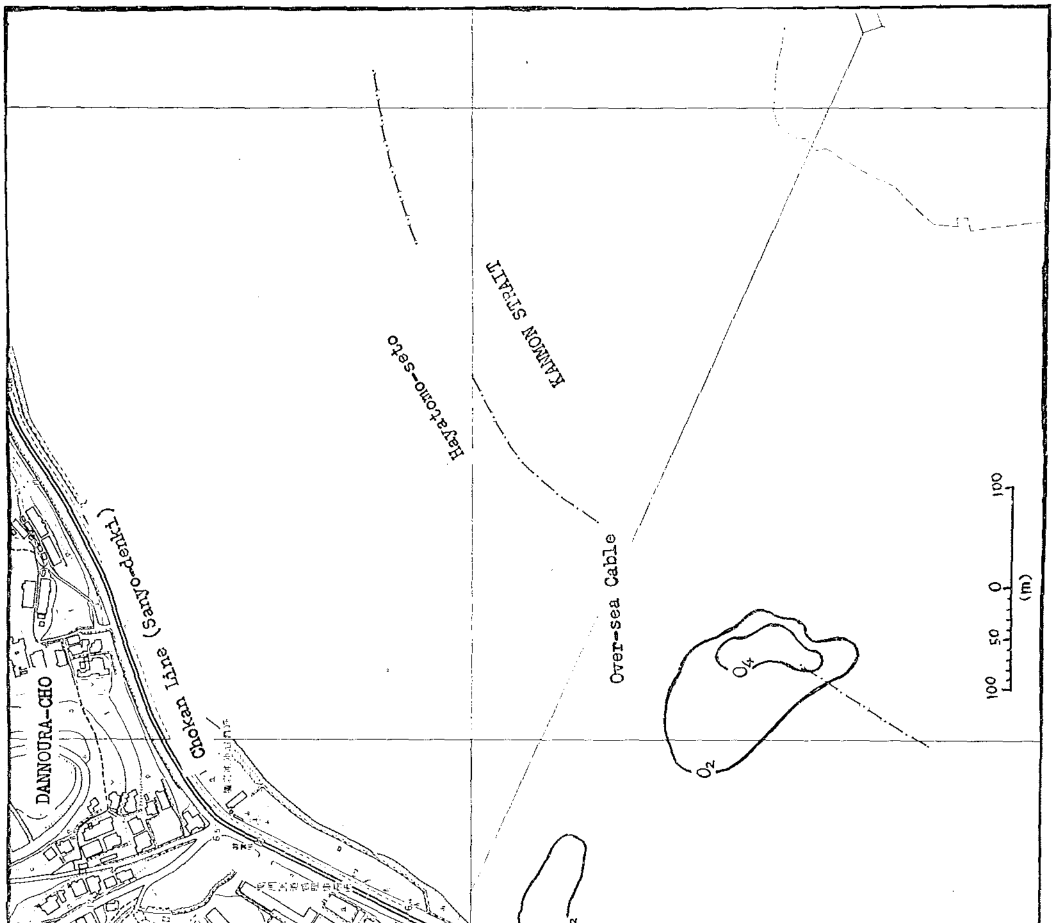

Fig. 5. Contour Map of Water Surface at Turn Time of Tidal Current, 13h 23 m (J.S.T.) on Sept. 8, 1964.

For the control points of orientation six points on the opposite side to the cameras of the strait were selected; these were three junctions of the frames on a tower of oversea electric cables on Mt. Kabuto-Yama, top of the light-house of Dannoura, and two corner points of the notice letter boards for navigators "yo" and "te" on the wall of the coastal dike. These control points are marked on the photographs in Fig. 3, a pair of stereophotographs for the westerly stream. These points were surveyed with a TM 10 Sokkisha Theodolite.

3. Measurement of the Local Elevation of Water Surface

Plotting was made by means of the A7 Autograph with an instrumental scale 1 : 2,000 and a mapping scale 1 : 500. In order to measure the vertical height of the water surface the images of floating targets were utilized, and to increase the measuring points many natural foams were also utilized. By the resulted plotting the undulation of the stream surface in this strait at the times of maximum westerly current and of turning current were clarified as expected. Figs. 4 and 5 are the contour maps in 20 centimeters height difference of upheaval. The zero level of the contour lines in these figures are the sea level at a certain point below the light house in each instance of exposure.

4. Discussions

In order to obtain the accuracy of measuring the surface undulation, we have assumed that the surface was flat at the time of turn of current. Then the root mean square error was obtained from the observed height about 58 points on the surface except for a certain area where some systematic rise was found. The error thus estimated is $\pm$ 0.072 meters.

It seems rather peculier that such area was found in the central portion even at the turning time. The height was 20 to 40 centimeters, while the water level along the opposite coast was almost constant. The constancy will be seen by curve (b) of Fig. 6 representing the undulation of the water surface in the close vicinity of the opposite coast at the turning time plotted against the horizontal distance along the coast. The numbers given in the abscissa denote the ones of marks attached the coast. The curve (a) of Fig. 6 represents also the undulation of the water surface in close vicinity of the opposite coast at the time of westerly maximum current. For these curves a point of 14.72 meters below the centre of the lens of the light house was adopted as the zero point of the height of the water surface, which was approximately coincides with the mean sea level and was not the same of the zero point of Fig. 4. The water level along the coast had the undulation of 50 to 70 centimeters in case of westerly maximum current as shown in Fig. 6, while as stated before it was almost constant in case of turning current. This peculiar rise might be explained by the fact that the water surface would be affected by the submarine topography and the shape of the coast (see Fig. 7).

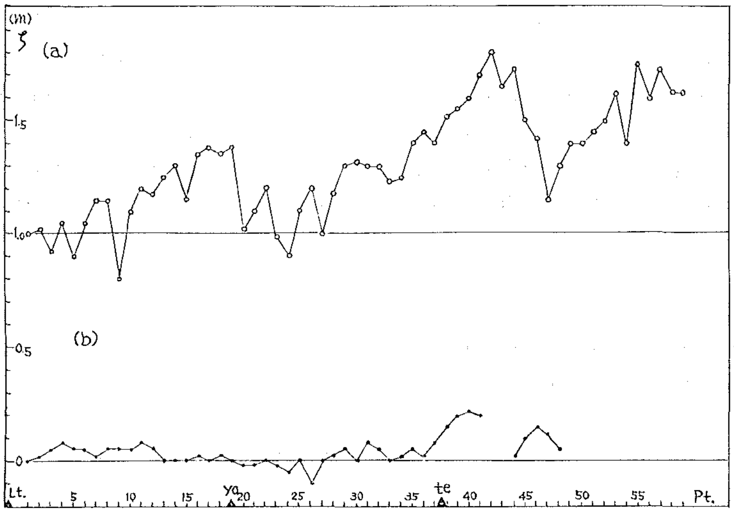

Fig. 6. Undulated Water Surface along the Coast in case of the Westerly Maximum, 10h 35m (a) and the Turn Time, 13h 23m (b).

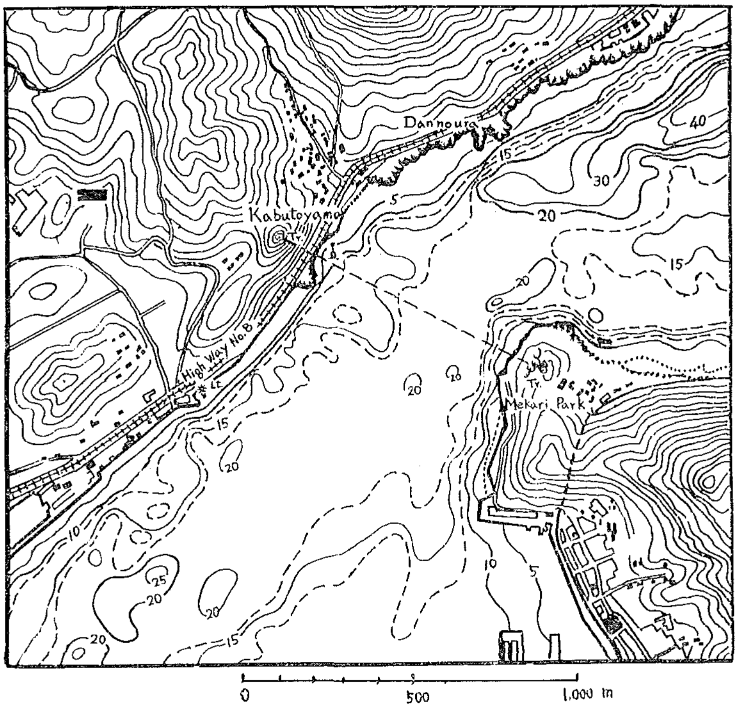

Fig. 7. Submarine Topographic Chart.

Fig. 4 shows the distribution of the local elevation of water surface. It is clearly seen that the upheaved area lies in the northward coastal part and does not exist in the central portion of the strait. The maximum magnitude of this upheaval is 90 centimeters in height. This phenomena will be considered to be also related to the submarine topography (see Fig. 7) in this strait, that is, caused by confluence of the two flows: the main flow with the velocity of about 7 to 8 knots in the upper layer and the ascending flow due to the conflict with the shallow of 10 meters depth. The upheaval in the alongshore area may be considered to be formed by the similar process.

5. Conclusions

The datum level for the water depth is generally obtained from the mean sea level with the correction Z_0 which is defined as a sum of four components M_2, S_2, K_1 and O_1 in tidal variation. However, in the case of the inclined sea surface like in the strait, we must determine Z_0 more precisely from the tidal records given at a large number of stations distributed along the coast. For example, the value of Z_0 lies in the range of 0.80 to 2.10 meters in the present water area which is 14 Kilometers long in the Kanmon Strait. Thus in actual hydrographic survey we have to adopt various values of Z_0 for each case. However, it has now become clear that a correction of upheaval must be taken into account for in order to obtain accurate water depth more than the tidal correction for Z_0. It should be remarked here that the change of water surface by the current is of course a function of time. Precise experiments will be made for the broad area using photographs taken at the both sides of the strait in future.

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