The possibility of water surface slope measurement with airborne laser profiling method

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ABSTRACT

The shape of water surface, distribution of its slopes, shows a reduction of its potential energy and also reflects a diversity in its motion. We have utilized the Cameron's effect photogrammetrically for measuring the velocities of flood water surface. Then recently a videogrammetrical method has been developed to analyze the 2 dimensional velocity distribution in short time intervals automatically.

But in the Cameron's effect measuring, it is sometimes more difficult to measure the parallax differences in such image conditions that there are no clear floating objects or have bad orientation circumstances, so that we can not get the appropriate distribution of surface water velocities. Here, we suppose if the airborne laser profiling method could be introduced to measure a figure of the water surface as an another approach to grasp the flow appearance based on a view that the slopes of a flow surface should reflect its motion.

The airborne laser profiling system has an IR laser range finder exactly connected with a 2 axes garbomirror scanner that makes parallel scanning lines and transmits the pulses in a high frequency of 25KHz, so we can obtain spatially uniform and dense reflection data. And the measured ranges and their scan angles of the reflection points are converted into the map coordinate data with such other data measured at the same time as the kinematic differential GPS data and its complementary data from the position and orientation system.

We are to discuss the possibility to measure the slopes of water surface in this paper introducing our airborne system and some samples of our case studies.

1. Introduction

The airborne laser profiling system, ALTM 1025 that had been developed by Optech Inc. under our specifications, makes a very dense DEM data, so we can get sort of an aerial image whose pixels have the coordinates.

And a high spatial resolution of those DEM makes us easily to analyze the micro relief of a terrain such as riverbed forms, stream surface and so on. Additionally, because ALTM 1025 has a cleaver performance in post processing which takes away reflections from trees or constructions except for ground, we can also get a good DEM of the woody terrain.

The micro reliefs of a terrain reflect the result of various slope process or flow process. Then it is very useful for the erosion control to predict the subsurface agency from the micro relief analysis.

This report describes the outline of the airborne system and case studies about the ABE river as a running water and the lake KONUMA as a calm water.

2. Airborne laser profiling

2.1 ALTM 1025

(1) Airborne subsystem

ALTM 1025 had been developed in connection with survey work on obstacle tree felling ranges to power lines to detect the wire more than 10mm from a position above 150m and coniferous sharp tree tops without being left. The system is composed of an airborne measuring subsystem and a ground post-processing subsystem.

Fig.1 shows the airborne subsystem, which is comprised of sensor head, computer and recorder racks, GPS receiver and power supply. Some devices are housed in sensor head such as laser transmitter and garbomirror scanner, position and orientation system (POS) sensor and CCD video camera. GPS antenna is laid on the front roof. RTK navigation subsystem is loaded unconnected with ALTM subsystem, which is

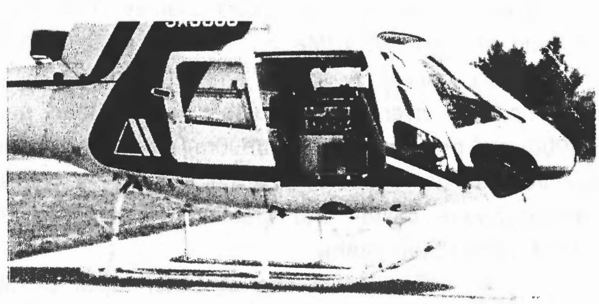
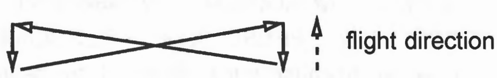


Fig.1 Airborne subsystem

comprised of antennas and receivers of GPS and beacon, PC and display. And also the ground GPS are included for kinematic deferential processing by carrier phase.

GPS and POS are complementary to each other. GPS provides a long term accuracy but sometimes troubled by outage, multipath and nose in the short term. On the other, POS has a good accuracy in the short term but suffers from a long term drift. This integrated positioning system provides a very good accuracy by compensating each other for their weakness.

The garbomirror scanner oscillates in the two directions, flight path direction and its perpendicular, and generates a parallel scanning lines by harmonizing with flight speed.



oscillating pattern

The coordinates and elevation of laser beam reflecting points are determined by GPS position, POS orientation, scanning angles and ranges of laser, so that we have to measure the relative position of each sensors before flight.

Table 1 shows principal specifications of the ALTM 1025.

Table 1 specifications

	ALTM 1025
Laser wavelength	1064 nm
Laser repetition rate	25 kHz
Laser pulse divergence	0.25 mrad, 1.2 mrad
Laser pulse duration	13 ns
Range resolution	1 cm
Range accuracy	15 cm (single shot)
Scan amplitudes	0 - 11.3 deg.(half)
Scan rate	25 Hz (22.6 deg.)
Scan angle resolution	0.01 deg.
Scan angle accuracy	0.05 deg.

(2) Ground post-processing subsystem

The ground post-processing subsystem comprises such devices as a data processing PC with 10 GBytes memories, data analyzing PC, data reader and so on.

The logical sequence of data processing of the ground post-processing is shown in Fig.2.

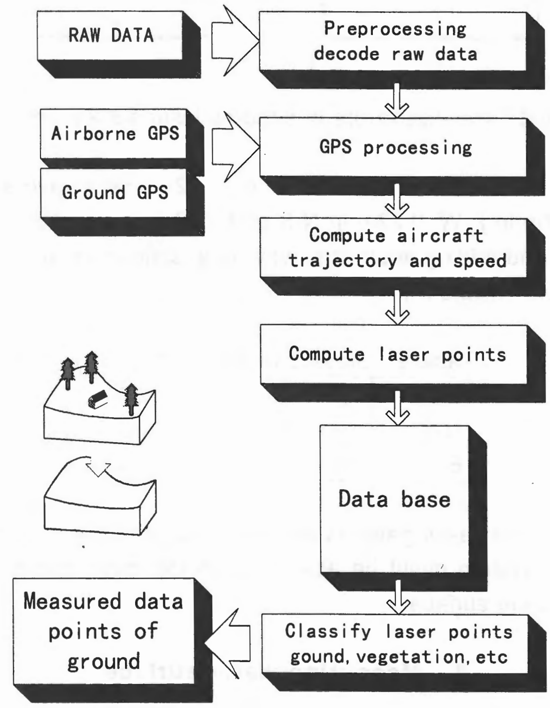


Fig.2 Logical sequence of post-processing

The ground post-processing subsystem has an excellent software that provides a DEM without trees, buildings and other constructions. This classifining the laser points software is based on J. Lindenburger (1993), that eliminates those unnecessary laser points running a filter along the scanning lines.

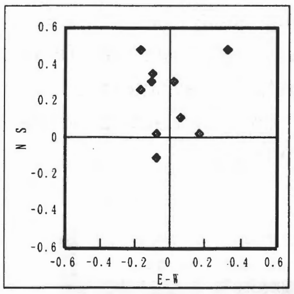
2.2 Accuracy of data

The measured laser point includes an complex error derived from each devices of airborne system.

The errors derived from accuracy of each device are as follows (Angle data are converted into length in case of flight height 400 m).

Position (GPS+POS)	10 - 30 cm
Scanning angle	35 cm
Roll and Pitch	6 cm
Heading	60 cm

Fig.3 shows the relative errors between actual survey and air survey targeting ground control points on our heli-mentenance factory. The distribution of error ranges from about +0.5m to -0.5m ; E-W +0.33~-0.17m,



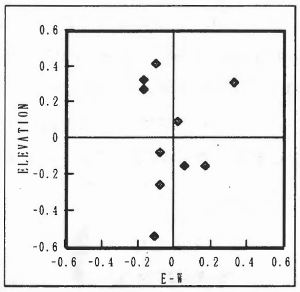


Fig 3. Relative errors of airborne laser survey (m)

N-S +0.48~-0.11m and elevation +0.32~-0.54m ; average -0.01m in E-W, 0.22m in N-S and 0.02m in elevation.

And adding another survey data, statistic become as follows (Table 2).

Table 2 Statistic of the error (n =21)

E-W	$\mu = -0.01m$	$\sigma = 0.17m$
N-S	$\mu = +0.11m$	$\sigma = 0.22m$
EL.	$\mu = +0.01m$	$\sigma = 0.21m$

This result gave us an impression that our airborne laser system might be able to catch the micro reliefs on the water surface.

3. Measuring water surface

3.1 Reflection from water surface

It is known that the water surface reflects the IR laser beam. The airborne laser bathymetry had been developed to chart the shallow sea water and such system are already put to practical use. In these system, the IR laser beam(e.g.1064 nm) is used to determine the range between water and aircraft.

Although the water surface reflects about 95% of beam energy, the receiver is not always able to get the reflection. The main blocking factors are as follows; a) water surface is near specular and incidence-reflection angle is large, b) the sun exists right above and the receiver refuses its powerful reflectance and c) heavy mist disperse the energy and its return become very weak.

However, these factors are easily taken away by selecting the weather conditions for survey. In particular, the water body are generally large in the field and many ripples and wavelets exist on its surface generated by breeze or motion of its oneself, so that we could be able to survey the micro relief on the water surface under right weather conditions.

3.2 Survey spots and data processing

(1) Survey spots

As the survey area, the middle courses of the ABE river and the lake KONUMA on the top of Mt. AKAGI volcano are chosen.

The ABE river in this course has a steep bed (8/1000) and broad width (about 500m), its bed materials vary from sands to boulders which build up a typical braided channel pattern and streams flow in the lower channel (about 50m width).

The lake KONUMA is one of crater lakes of Mt. AKAGI, whose diameter is about 350m and elevation is 1473m. Its catchment basin is almost closed but at southern part of basin there is a drainage controlled by a man-made dam for water resource.

Both survey had done on such conditions that a flight height is about 400m above the ground and flight speed is about 50km/h normally.

(2) Data processing

The raw data of survey each spot are converted into measured ground points data(UTM coordinates) by the ground post-processing subsystem.

It needs to adjust these data to maps to convert their coordinates system from UTM to a rectangular coordinates (generally the conversion starts from WGS84(BLH), because UTM is for our convenience).

(UTM →) WGS84(BLH)→ WGS84(XYZ)→
BESSEL(XYZ)→ BESSEL(XYH)→ BESSEL(XYH')

However, because our purpose of this report is not adjust these data to the map coordinates rigidly but find out an possibility to survey a relief(slopes) on the water surface by the airborne laser system, we decide to use directly the UTM data corrected by GPS data of the ground control points in the swath zone and cross flight data.

We also decide to choose SURFER converting the measured ground points data to DEM and 3D surface processing; SURFER is a grid-based contouring and three dimensional surface plotting graphics program manufactured by Golden Software, Inc..

Fig.4 shows bird's-eye and side views of a water surface sample before and after processing. These DEM are created in 50cm grid spacing because the space of each shot is about 25cm and that of each scanning line is about 40cm. The DEM before smoothing has many spikes, whose height range 15-20cm in average, derived from the wavelets on the surface and the little disorder of scanning. To remove these noise, we have processed the data by the matrix smoothing procedure of SURFER; number of columns and raws of center are ten.

This result shows us that the water surface has a gentle slope of 1.5~2.0 ‰ in general and some micro reliefs of few cm high.

4. Micro reliefs on the water surface

4.1 The ABE river

Although the survey for the ABE river had been made along its course between the TAMAHATA bridge and RYUSAI bridge, we report a result derived from the data of the TAMAHATA bridge vicinity in this paper.

An aerial video mosaic map of the study area is shown in Fig.5. A shaded relief map and a gradation map processed from the DEM are shown in Fig.6 and in Fig.7 respectively.

As these figures vividly show us the details of river bed form and their relative dimensions, we are be able to speculate about the flood flow states. For instance, by looking at Fig.6 we can easily suppose that the flood stream gaining a violent tractive force at the narrowed channel would scatter many boulders right in front of that channel.

Fig.8 shows the micro relief diagrams of stream surface whose portions are indicated in Fig.6. The contour intervals are 5cm in a. and f. and 2cm in the other. These diagrams give a sign of the braided river where the riffles and the pools appear alternately along the channel. The slope of steam surface varies from 3 ‰ to 30 ‰ It can immediately be understood that the slope become large at the narrowed channel(b.) and particularly large at the channel built by boulders(f.).

4.2 The lake KONUMA

Fig.9 is an aerial photograph of the lake KONUMA looking down from east-south direction and the survey area is a south half of the lake. We can see the dam site at southern end of the lake.

The survey had made on the windy day, and there were many ripples on the surface propagating from north-west to south-east.

Fig.10 is the contour map of the lake surface after smoothing. From this figure we perceive that the lake surface is not a plane but a wavy surface.

Although, where a contour line of 1473.2m(upper) extremely bend toward south, there might remain the error originated by rolling, a general strike of this contour make us perceive that the lake surface upheaves at the south-east half.

The other pattern of contours to deserve to mention is a wing like form of them on the southern portion of the lake. There is the dam for water resource. And so it drains lake water, that a water level near the dam drops down to about 1472.9m.

Fig.11 is the block diagrams of a slope distribution of lake surface striped along the north-south direction(a.) and those of southern portion of the lake. These results make us speculate that in spite of a superficial calmness the lake water goes on moving under the various exterior conditions

5. Conclusions

It becomes clear through this work that the airborne laser profiling is possible to survey a water surface reliefs and slopes. And these informations are effective for such a hydrological engineering as the erosion control, water supply and so on.

But it need further works to put this method to practical use. Especially, it is important to fix the smoothing filter size that relates on the magnitudes of micro reliefs. And it also important to detect the aerial data appropriately; the more excess a rolling or pitching of aircraft are, the more difficult to correct the data.

The airborne laser profiling system that has a high density of beam shot provides us the data just like an image and besides quickly products many effective informations. We would aspire to work not merely on the water surface but on various subiects.

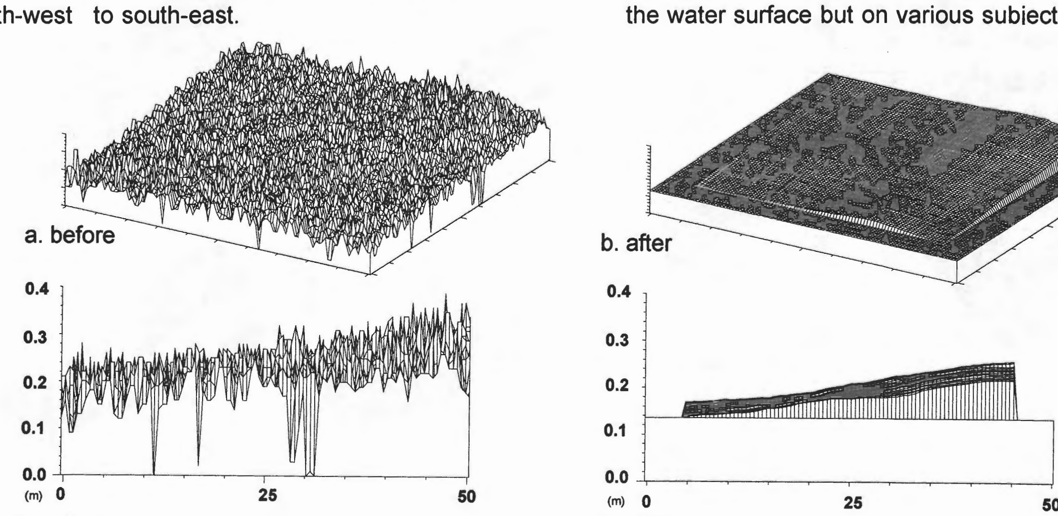


Fig.4 Water surface before and after processing

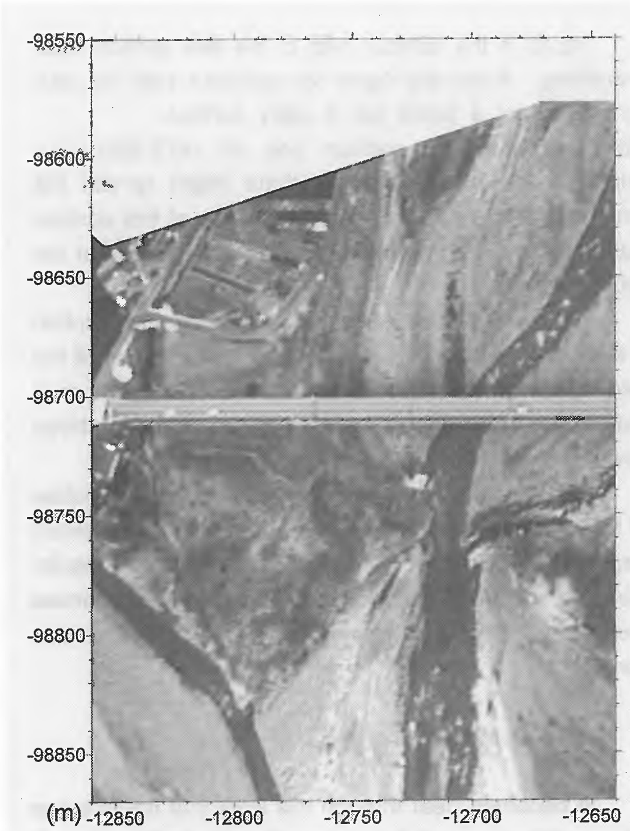


Fig.5 Video mosaic map

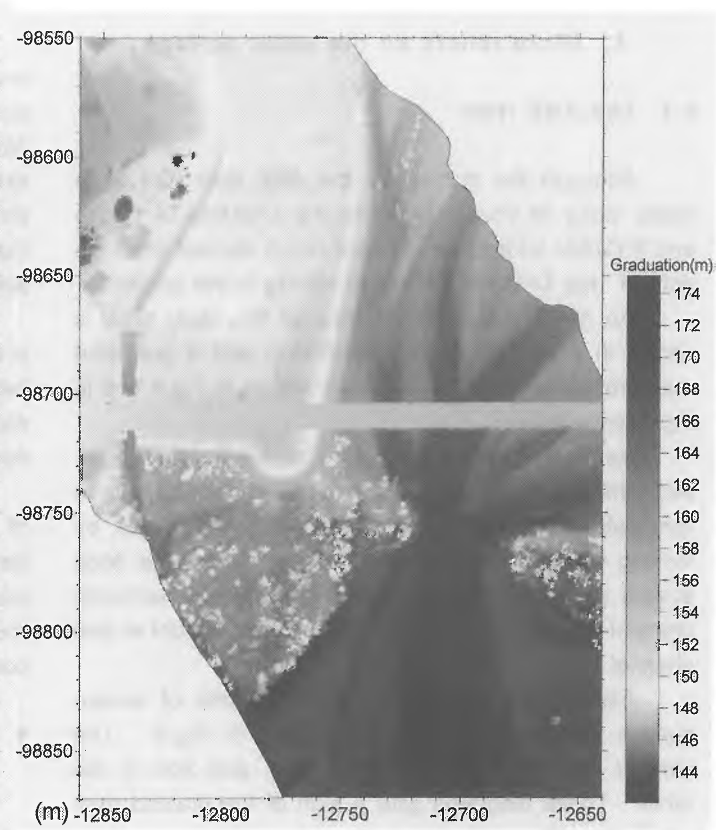


Fig.7 Gradation map

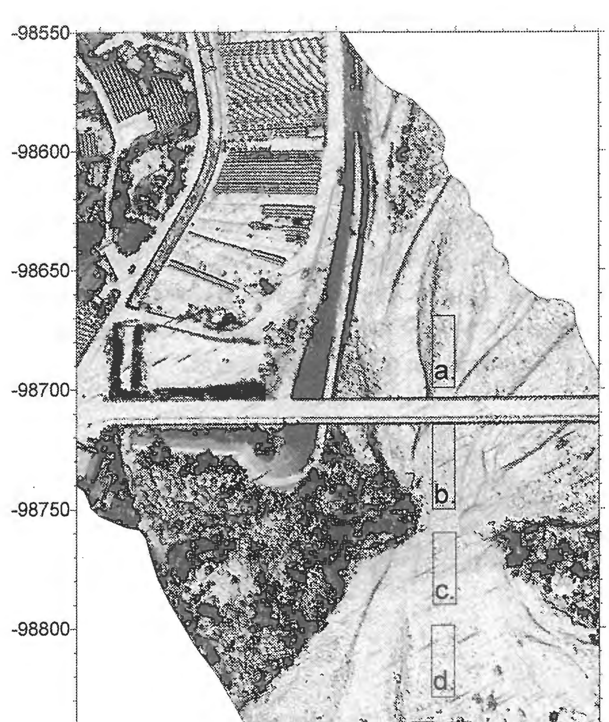


Fig.6 Shaded rerief map

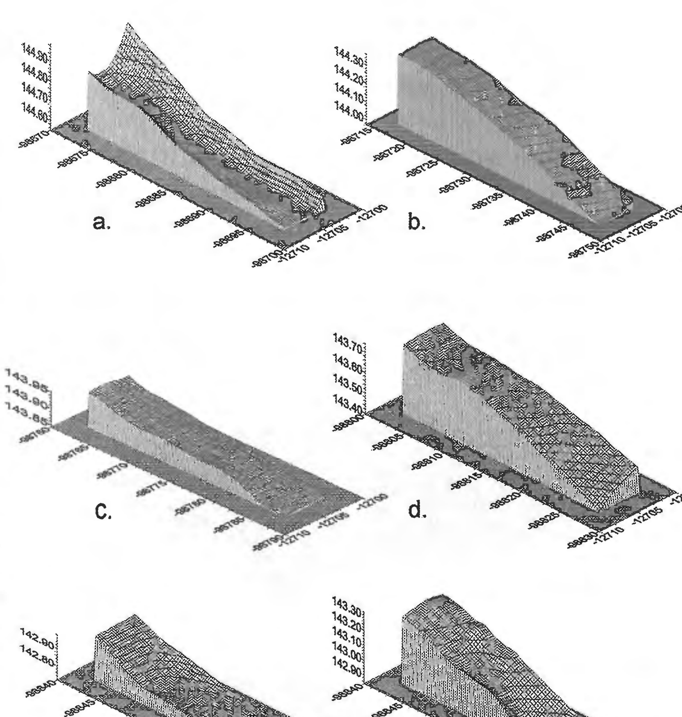


Fig.8 Micro relief diagrams of stream sarface (m)

6. Reference

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Fig.9 Aerial photograph of lake KONUMA

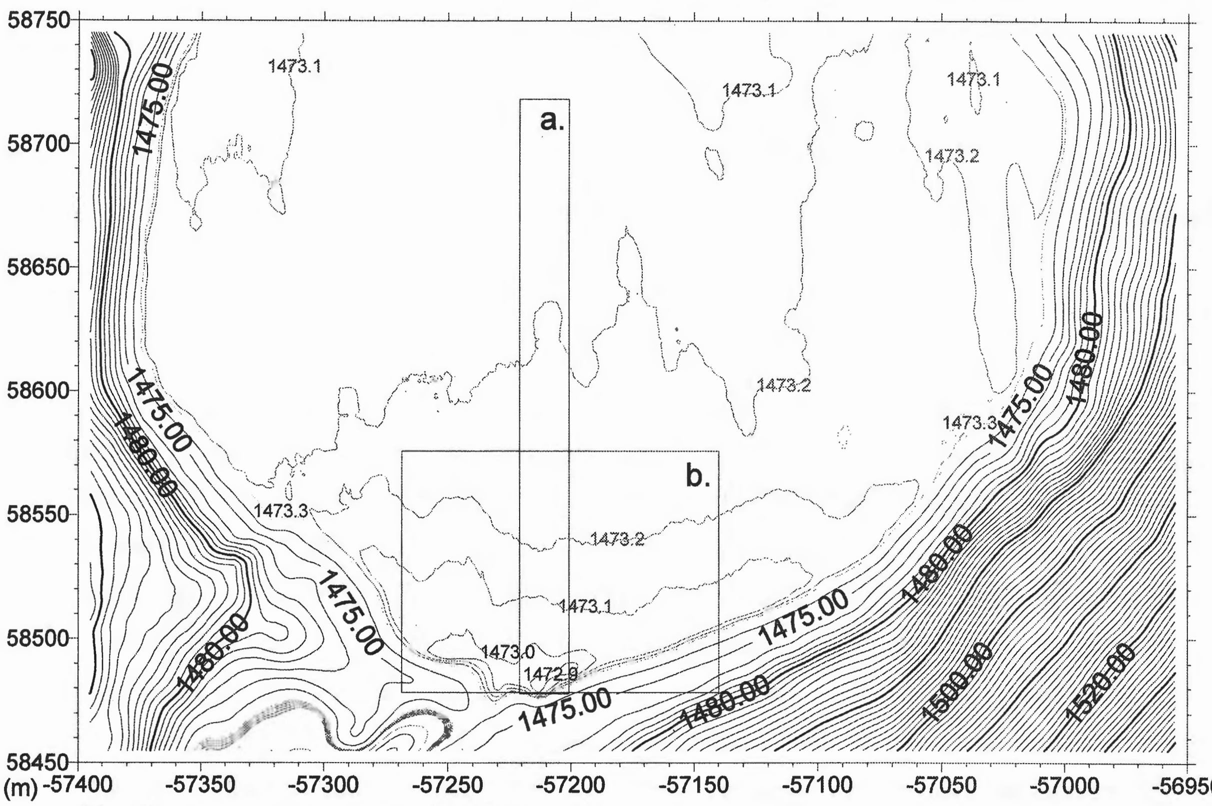

Fig.10 The contour map of lake KONUMA

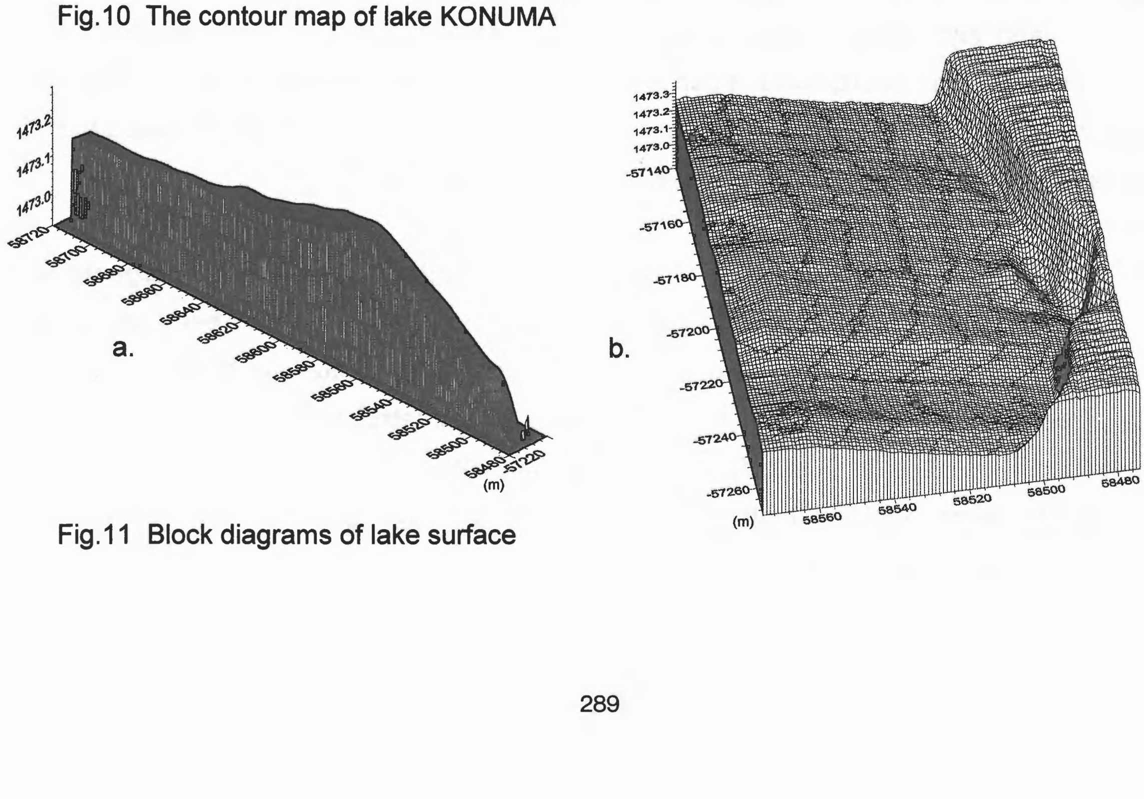

Fig.11 Block diagrams of lake surface