DTM GENERATION OF THE OCEAN TIDAL TERRAIN USING PHOTOGRAMMETRIC TECHNIQUES, GIS AND GPS

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ABSTRACT

Hydrographic Ground Truthing (HY-GRO) was a project currently carried out by the Ocean Mapping Group (OMG) at the University of New Brunswick. One of the purposes of this project was the investigation of the relationship between acoustic mapping data and the actual ocean seabed bathymetry. In order to facilitate the comparison, ground truthing information was generated in the form of DTM using stereo aerial photography of tidal areas at low tide.

In this paper all aspects of the photogrammetric part of HY-GRO are discussed and generally the photogrammetric mapping of the tidal areas with the use of both metric and non-metric cameras is investigated. Small-format non-metric cameras were proven to be inadequate for tidal terrain mapping. Kinematic GPS was used for the establishment of ground control and it is found to be suitable for the tidal terrain both in terms of accuracy and speed. The DTM of a tidal area of Saint John Harbour was generated based on photogrammetrically collected data using the CARIS GIS. Perspective views, contour maps, colour-coded classifications of heights, slopes and aspects were produced from the DTM. Finally the accuracy of the DTM was also investigated and it is found to be in the magnitude of 16 centimetres.

1. INTRODUCTION

In November 1991, the Ocean Mapping Group (OMG) of the University of New Brunswick (UNB), Canada started a project entitled Hydrographic Ground Truthing (HY-GRO). The project was funded by a three year NSERC strategic grant and incorporates 23 organizations in Canada and U.S.A including universities, federal and provincial departments, and the U.S Navy. The main objective was to investigate the relationship between actual sea-bed characteristics (topography, composition and texture) and those obtained from acoustic measurements and to test the performance of various bathymetric systems. The Bay of Fundy was selected for this investigation because of its tidal ranges of up to 16 m, which allow sea-bed acoustic mapping from vessels at high water and physical and remote sensing sea-bed observations at low water levels. In particular, the three Canadian sites chosen were the Saint John Harbor, Passamaquoddy Bay and Parrsboro Approaches.

Acoustic mapping data have been collected by the following acoustic ocean mapping systems installed aboard four vessels:

- Navitronics Seading sweep system.
- Simrad EM-1000 multibeam system with sidescan sonars.
- Chirp Sonar subbottom profiler.
- SEISTEC high resolution subbottom profiler.
- Mesotech and Klein sidescan sonars.
- RoxAnn acoustic sediment classification instrument.
- Vertical beam echo sounder.
- Acoustic altimeter on BROWSER.

Ground reference information has been collected using a variety of sensors. The actual sea-bed characteristics were determined using:

- Stereo aerial photography.
- Airborne remote sensing (Compact Airborne Spectrometer Instrument) and Satellite remote sensing.
- Underwater photography (BROWSER camera).
- Bottom samples from cores and grabs.
- Physical samples.
- Terrestrial survey of the surficial geology.
- Placement at known locations, of specially designed objects of known shape, composition and acoustic properties.

This paper deals with the determination of the sea-bed topography by photogrammetric means. The required final product was a Digital Terrain Model (DTM) of selected tidal areas with an accuracy of 25 cm to be used as ground truthing information for testing the performance of the acoustic ocean mapping systems.

The tidal terrain is a special type of terrain that differs significantly from that of the mainland. Therefore the topographic survey of the tidal areas poses some special difficulties. In this paper the use of photogrammetry for tidal terrain mapping is investigated by using both metric and non-metric cameras. It was decided to include a non-metric, small format camera to investigate its suitability for tidal terrain mapping and to ascertain whether economic gains can be realized by its use instead of an aerial metric camera. The use of relative kinematic GPS for the establishment of ground control on a tidal terrain is also investigated. Finally the accuracy of a photogrammetrically generated DTM over tidal areas is established. Perspective views, contour maps, shaded relief representations, colour-coded representations of height, aspect and slope classes were also produced based on the DTM.

2. OCEAN TIDES

Ocean tide is the response of the ocean to the periodic fluctuations in the tide-raising forces of the moon and the sun (Forester, 1983). It is a periodic phenomenon where the period (T) is the time interval between successive low waters (LW) or high waters (HW). The range (R) of the tide is the height of the high water above the low water (see Figure 2.1).

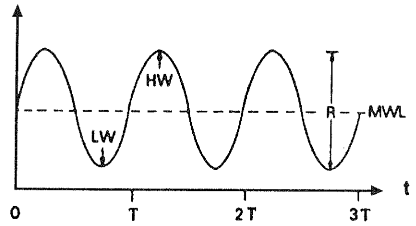

Figure 2.1
Ocean tide as a sinusoidal wave at a fixed location over an interval of time (Forester, 1983).

The ocean tides are classified in four categories, according to the uniformity of spacing and the number of HW (or LW) during a complete lunar day. For the areas of interest, the ocean tides belong to the semidiurnal (SD) type. The SD tide shows two almost equal HWs and LWs about uniformly spaced over the period of a complete lunar day.

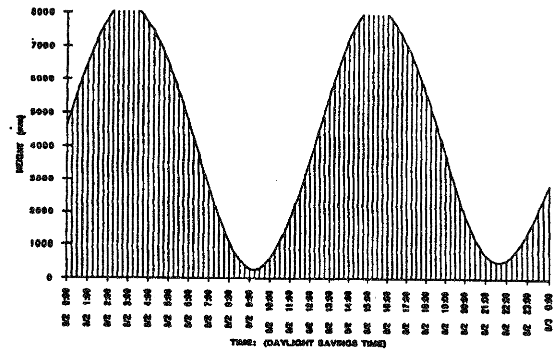

Figure 3.1
Tidal curve for August 2, 1992 for Saint John N.B.

3. PHOTOGRAMMETRIC MAPPING OF TIDAL AREAS AT LOW TIDE

The tidal areas introduce special difficulties when photogrammetric mapping methods are used. These problems can be caused either by the tidal terrain or by the tide itself.

3.1 Problems caused by the ocean tide

The objective of the stereo aerial photography part of HY-GRO project was to photogrammetrically map as large a tidal area as possible. That means that the photogrammetric flight mission must occur during or near the lowest low tide. The same is valid also for the placement and measurement of the ground control points. The HY-GRO project was carried out during the period between June and September, when the weather is the optimum for ground, aerial and acoustic surveys. For each of these months the days that show the lowest low tide were selected by looking at the tidal prediction tables for the areas of interest. In each month a window of three successive days has adequate low tides for the aerial mission and the establishment of the ground control. Being a SD type, the tides in the areas of interest show two low and two high waters during a 24 hour interval. From the two low tides the most convenient one has to be selected. For example for the flight mission, the tide that occurs when the illumination conditions are better is preferred. In any case, the low tide that occurs at night is not considered. The tidal curve for the 2nd of August 1992 for Saint John area is illustrated in Figure 3.1. It is clear that the available time for performing the aerial and ground surveys is not only limited to a window of three days monthly but for those specific days, usually only one of the two daily low tides can be used and only for a period of approximately two hours. That is very critical because the aerial and ground surveys cannot be performed in bad weather and on cloudy or foggy days. These time restrictions add dramatically to the cost and effort of carrying out the project.

3.2 Problems caused due to the special type of the tidal terrain

a) Lack of well defined and stable features that can be used as ground control points. Since there are no well defined and stable features that can be used for ground control in the seabed of the tidal area, permanent and stable **artificial photogrammetric targets** have to be placed. This provides great difficulty because the tidal forces pass twice a day over the targets. Therefore the targets must be very stable to resist the tidal water forces. A problem in designing artificial targets is the contrast that has to be created with their background. The variety and the dynamic nature of the radiometric characteristics of the tidal terrain make it difficult and uncertain to predict the contrast between target and background in black and white photographs even when the targets reflect adequately. But a highly reflecting target almost always creates good contrast with the tidal terrain in colour photographs. These problems were overcame in the current project by targets (see Figure 3.2) that consist of a 1/2" (1.3 cm) plywood with white glossy arborite (formica) glued to their face side, which is attached to 1 m long, 3/4 " (1.9 cm) re-enforcement bar drilled and tapped to accept a 1" (2.5 cm) long, 1/4" (0.6 cm) bolt. The re-enforcement bar is anchored to the ground until the target becomes unmovable. The designed targets have the following characteristics :

* **Stability.** In order to test the stability of the targets, a number of targeted control points were re-measured nearly 20 days after their placement and initial measurement. It was concluded that the targets showed virtually no movement from their original positions. It is suggested that the time between the placement of the targets and the acquisition of the aerial photographs must not be greater than 20 days since the arborite starts to separate from the plywood, and the plywood to tilt from its horizontal position. The condition of the targets must be inspected at least a day before the flight.

* **Contrast.** The white glossy arborite on the top surface of the target reflects greatly and creates a very good contrast with the tidal terrain when colour film is used. The identification of the targets in the photographs was accomplished very easily and without mistakes. These designed targets were not only used in the seabed but also in places like the sides of roads, inside bushes and on bare ground. It was found that if the flight was carried out when the sun is directly above the area then all the targets were very visible and distinct in the photographs. Problems may arise in the case of very poor illumination and low solar angle like the one that occurs on a late afternoon flight. In such conditions targets maybe disappear mainly due to the long shadows that are created by the low sun angle. In order for the targets to retain their high reflectance, they have to be cleaned shortly before the photographic flight mission.

* **Shape and size.** The shape of a target has to be symmetric to its center to more accurately place the measuring mark of the photogrammetric instrument and thus to increase the accuracy of the photogrammetric observation of the target. Additionally a distinctly symmetrical shape helps in the identification of the

target in the photograph. Moving in this direction it was decided that the shape of the target be square, with 40 x 40 cm^2 dimensions, which is appropriate for the photo-scale used.

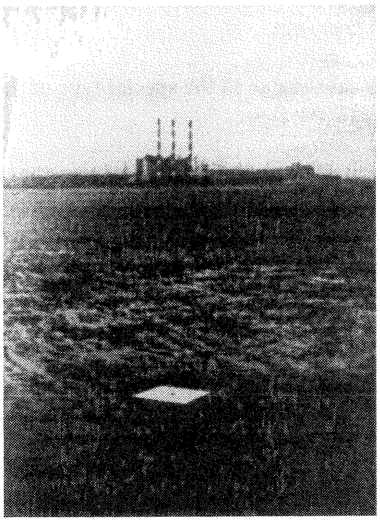

Figure 3.2
The specially designed artificial photo-target in the tidal terrain of Saint John Harbour

b) Lack of features and stable patterns in tidal terrain. Being a part of the seabed, the tidal areas are often featureless without showing any pattern. But even if patterns exist, and some features appear in the tidal area, there is a high probability that the dynamic nature of the tide will change them rapidly. Some additional problems are introduced in these cases:

* Difficulties in achieving stereo vision over featureless tidal areas.

* Lack of features that remain stable during the time between camera exposures (especially when the exposures occur on different days). Therefore, it is very difficult to find features that can be used as pass and tie points for connecting the photographs into a block. A solution to this problem is the mechanical marking of the images using a point transfer instrument, in order to create artificial pass and tie points. But this is not as accurate and often impossible in cases of extended featureless areas, because of the very weak stereo perception in those areas.

Features that create a pattern on the seabed and can be used as pass or tie points are stones, rocks, and sea plants. The use of stones can be misleading, because they may have moved during the time between exposures. But usually big stones remain in place during a low tide period. If pictures are taken on different days, even big stones are unreliable. Sea plants can be used as tie or pass points, but their use is limited due to their usually large and irregular shape.

Color photography is preferred for tidal terrain mapping since color photographs show more radiometric detail than the black and white ones and help in both the stereoscopic perception and identification of pass, tie and control points. For the extended areas of difficult stereo vision a photogrammetric solution is impossible. In these cases it is suggested to spread just before the flight a number of highly reflective items (like the white arborite that it was used for the construction of the control points) over the tidal terrain, establishing in this way patterns and some of these items can also be used as tie and pass points.

4. USE OF NON-METRIC, SMALL-FORMAT CAMERA TO MAP A TIDAL AREA AT LOW TIDE

When a non-metric camera is used for tidal terrain mapping, a number of additional problems are introduced:

-The unknown and unstable internal geometry, and the large systematic errors of the non metric cameras require the use of a photo-variant self-calibrating bundle adjustment. The application of such an adjustment introduces the following problems when it is applied to the tidal terrain:

* The tidal terrain is nearly flat and the use of the bundle adjustment is difficult when it deals with a combination of a flat terrain and vertical photography because of the high correlations between the unknowns.
* Self calibrating bundle adjustment requires dense and well distributed control points. Its accuracy is also affected by the density and distribution of object points in the images. In the tidal terrain it is difficult to establish control points and the number of well defined features that can be observed in the images are very limited.

-The small format of the non-metric cameras greatly increases the number of photographs covering an area and thus more tie, pass and control points are needed. Furthermore more stereo-models have to be connected to form the block which can result in erroneous blocks, taking into account the weak connections caused by the lack of appropriate pass and tie points and the flatness of the terrain.

To solve the last of these problems the acquisition of the aerial photography in a smaller than the required scale was proposed and then enlarged to the desired scale in a high quality enlarger. A non metric 500 EL/M Hasseblad camera was used. Aerial photography was taken in 1/15000 scale and then enlarged by 4 times to the desired 1/3750 photo-scale which is a good scale for achieving the required accuracy.

Even though this approach seemed to be promising it proved inadequate, partly because it:

- results in an inability to closely approximate the principal point of the images because of the cropping of the original images during the enlargement process.
- degrades the image quality thus making the photogrammetric observations of the tidal object points even more difficult.
- reduces the side-lap and over-lap and eliminates precious control and other object points on the images as result of the cropping effect . It was found that the mean image loss of the enlarged images was more than 10% of the original image area.
- introduces very large image distortions which, if are not effectively compensated for, can deteriorate the results dramatically.
- makes the use of data snooping for gross error detection impossible because of the low reliability and the inadequate observation quality of the enlargements.

All the above combined with the correlation and over-parameterization problem that accompanies the photo-variant self calibrating bundle adjustment make the use of the small-format non-metric cameras inappropriate for tidal terrain mapping.

The analytical plotter DSR11 was used for the photogrammetric measurements and the photo-variant self-calibration bundle adjustment programs UNBASC2 (Moniwa, 1977) and GEBATV (El Hakim and Faig, 1981) were used for the aerotriangulation process.

Metric cameras on the other hand offer the following advantages :

-Self-calibration is not required since the metric cameras are pre-calibrated, have fiducial marks and minimum image distortions. As a result, aerotriangulation by independent models can be applied. The method of independent models :

* is not as sensitive to flat terrain and vertical photography.
* uses the perspective centers as pass points, which strengthen the connection of the models.
* does not require dense control and image points.

-Less photographs are needed to cover the tidal areas of interest with the required scale resulting in a great reduction at the model connections, the unknown parameters and the control points.

-They have high image quality compared with the enlargements and therefore offer better measurement accuracy, easier selection of pass and tie points and reduced numbers of small gross errors.

-The acquisition of the photographs is controlled much better, and the areas of interest are covered properly.

When the cost of covering the same tidal areas with metric and non-metric cameras was compared, it was surprisingly found that for having in hand the desired final photographic product it is more expensive to use non-metric cameras than metric ones. The reason for this is the high cost of the enlargement of the small format images. In recent years, the developments of the color image copiers enable us to enlarge images by digital scanning rather than by using purely optical means. The laser scanned copier, unlike the photographic enlarger, does not introduce significant image distortions (e.g. CLC-200 enlargement accuracy is approximately 15 μm (Warner and Andersen, 1992)). Moreover the enlargements made with the laser scanned copier are much cheaper, almost 1/10th of the cost of conventional enlargements. The problem that still remains, even when a color laser copier is used is the cropping of the image.

Concluding the preceding discussion it is suggested that the tidal terrain is mapped using only metric cameras.

5. FROM AERIAL PHOTOGRAPHY TO DTM OF TIDAL AREAS

Defining the objectives and the area of interest. The DTM which was based on photogrammetric observations of heights of points at the sea-bed was generated in order to be used as ground truthing for testing the accuracy and the general response of the acoustic methods for ocean mapping tasks. Because the expected accuracy of the acoustics was quite high and the investigation of the degree of their sensitivity to small objects was of great interest, features that show abrupt changes in height must be selected as the test objects. Since the tidal areas are mostly flat and featureless the only such objects that were found at the areas of investigation were three rocks close to McNamara point in Saint John Harbour (see Figure 5.1). One of the rocks is small with sizes about 25 m by 54 m and the other two are bigger, 40 m by 90 m and 60 m by 142 m respectively.

In order for the DTM produced by photogrammetric methods to be used as ground truthing it must have an accuracy that is higher than the most optimistic estimation of the accuracy achieved by the acoustic methods. It was decided that a DTM with 25 cm accuracy will be sufficient for the test.

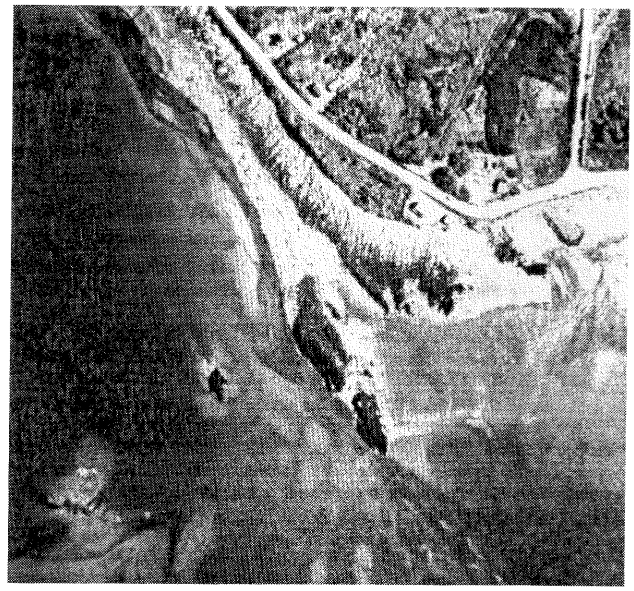

Figure 5.1
The three rocks test tidal area in Saint John Harbour.

Acquisition of the aerial photography. The acquisition of the aerial color photography was carried out on the 20th of September 1993 at 10:30 am. A metric camera Wild RC-10 was used for the acquisition of the vertical photography at a 1/4000 scale. The whole Saint John Harbour area was covered with 35 photographs having an over-lap of 60% and side-lap of 30%. The tidal area of interest (the three rocks) was also covered by five photographs with 80% over-lap.

Collection of the DTM primary data. The static method (photogrammetric observations of spot heights) was used for measuring of the DTM primary data. The photogrammetrically observed spot heights were collected using composite sampling. The sea-bed is very flat with the exception of the three rocks and the features of interest are mainly these rocks. The smaller rock was covered by photogrammetric observations of spot heights at a grid interval of 40 cm. The grid interval for the other two rocks was 80 cm for one, and 1 m for the other. The rest of the area was covered by a grid with an interval of 10 m. Since the rocks show abrupt changes in elevation and contain a number of small and big stones, selected spot heights were photogrammetrically observed in places where they were needed in order to represent the surface better (see Table 5.1).

Table 5.1
Number of spot height observations according to the type of sampling and the sampled feature.

	40 cm grid	80 cm grid	1 m grid	10 m grid	selective	total
small rock	3714				708	4422
big rock a			5743		950	6693
big rock b		3222			712	3934
surrounding areas				2881	637	3518
total	3714	3222	5743	2881	2997	18567

DTM generation. The photogrammetrically collected DTM primary data were processed in a Sun-Sparc station using the CARIS GIS. The digital terrain model was generated using the TIN method. Contour maps, perspective views, shaded relief representations, superimpositions of digital images of the area with contours, superimposition of perspective views with contours and colour-coded representation of height, aspect and slope classes were consequently produced (see Figures 5.2 to 5.3).

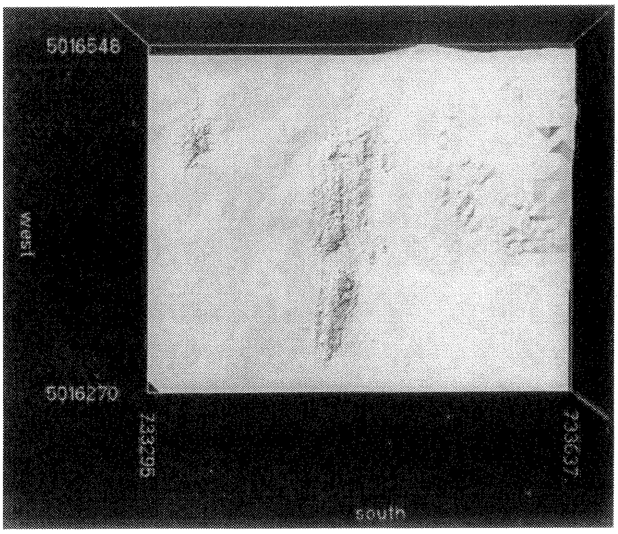

Figure 5.2
Normal view of a shaded relief representation of the test area computed from the DTM.

Accuracy analysis of the DTM. The "absolute" accuracy of the produced DTM can only result from the comparison with the real terrain. Since that is not possible, the accuracy of the DTM has to be established by a comparison with height measurements of the same terrain obtained by an independent method with a higher order of accuracy. Such a method is the tacheometric field survey.

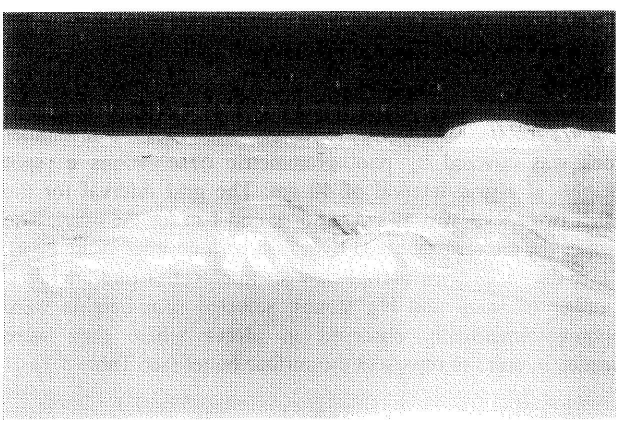

Figure 5.3
Perspective view of the test area computed from the DTM.

To facilitate the accuracy evaluation of the DTM, 743 ground points (check points) were measured by tacheometric field survey. The vast majority of these points (about 90%) lies on the three rocks. The height accuracy of the tacheometric survey was at the 10 cm level. The heights obtained by the tacheometric survey were compared with the heights interpolated from the DTM at the same planimetric positions. Therefore the data that was used for the accuracy evaluation of the DTM consisted of height differences at the check points. It has to be mentioned that the two methods of computing the heights namely the tacheometric and the DTM interpolation are totally independent since for the DTM generation, no ground survey was applied but only GPS and photogrammetry.

For the statistical analysis of the height differences the following are considered (Petrie and Kannie, 1990): algebraic mean (M), mean error (me), root mean square error (rms) and standard deviation (σ). These statistical expressions were calculated for all the height differences (n = 743 points).
The better statistical way to describe the accuracy of the DTM is the standard deviation σ. As can be seen from Table 5.2, the standard deviation is 23 cm when all the check points are taken into account.

Table 5.2
Statistical properties of the check points, for the total number of check points, and for the total number except the 8 blunders (reduced).

	number of check pts	algebraic mean M(m)	mean error me (m)	rms (m)	standard deviation σ (m)	max height difference (m)
total	743	-0.001	0.16	0.23	0.23	1.97
reduced	735	0.01	0.15	0.19	0.19	0.71

Table 5.3
Number (and percentage) of check points that have height differences smaller than a particular multiple of the standard deviation.

	mean error < |0.6745 σ|	standard error < |σ|	standard error < |2σ|	maximum error < |3σ|	maximum error < |4σ|
total	447 (60.2%)	581 (78.2%)	714 (95.1%)	734 (98.8%)	737 (99.2%)
reduced	362 (49.8%)	515 (78.2%)	707 (96.2%)	729 (99.2%)	735 (100%)

Table 5.4
Number (and percentage) of check points that have height differences larger than a value.

	> 0.2 m	>0.3 m	>0.4 m	>0.5m	>0.75 m	> 1 m	>1.5 m
total	228 (30%)	91 (12%)	36 (4%)	20 (2%)	8 (1%)	4 (0.4%)	2 (0.2%)
reduced	220 (29%)	83 (11%)	28 (3%)	12 (1%)	0 (0%)	0 (0%)	0 (0%)

Table 5.3 indicates that the distribution was indeed normal in all the cases. From the same table it can be observed that outliers exist when all the check points are considered. Eight points have height differences over 75 cm (see Table 5.4).
When the eight points that show the maximum height differences that can be regarded as blunders were re-observed in the stereo-model, it was discovered that they all lie at an area of one of the two big rocks that is covered by shadow. That was quite expected because it is very difficult to observe points in the shadow. It was also found that most of the points that show large height differences lie in shadow areas.
When the eight points were regarded as blunders and were removed from the data set (reduced case) the standard deviation improved from 23 cm to 19 cm (see Table 5.2). In this case 3% of the height differences are over 40 cm, 11% over 30 cm, and 29 over 20 cm (see Table 5.4). It is speculated that the removal of all the points that have been observed in the shadow can improve the accuracy by few more centimetres. In this case the areas in shadow can be re-observed using another stereo-model of the same strip since the sun angle and-as a result-the position of the shadow changes.
From the preceding discussion it can be concluded that the standard deviation was at the 19 cm level and it can be even better if additional points are observed in another stereo-model at the areas that were covered by shadow.

Furthermore Ackermann and Schneider (1992) indicate that the final accuracy of the DTM must take into account both the standard deviation of the observed height differences and the standard deviation of the check heights. If σ_{ch} is the standard deviation of the check point heights obtained by tacheometric field survey, σ_{DTM} is the standard deviation of the check point heights obtained by DTM interpolation, and σ_u the standard deviation of the "observed" height differences, then:

$$\sigma_u^2 = \sigma_{DTM}^2 + \sigma_{ch}^2 , \quad (5.1)$$

and the final accuracy of the DTM is 16 cm. This level of accuracy is very satisfactorily if one takes into account the very abrupt elevation variations on the surface of the rocks, and the height accuracy of the ground control points (5 cm).

6. ESTABLISHMENT OF GROUND CONTROL ON THE OCEAN TIDAL TERRAIN USING KINEMATIC GPS

The geodetic survey provides high accuracies in the establishment of the ground control points but it is time consuming. Since the duration of a low tide and thus the available time for performing the geodetic survey on a tidal area is less than two hours it is obvious that several days maybe needed for the establishment of the ground control points. A method that is not as accurate but much faster is the relative kinematic positioning using GPS (Global Positioning System) observations (carrier phase measurements of GPS signals), and it was decided to be investigated and used for the establishment of the ground control points.

Nineteen ground control points were established close to the three rocks. The specially designed artificial target was used for the targeting of most of them except for three ground control points on the surface of the rocks that were targeted with white painted crosses.

The ground control points were selected to be uniformly distributed, close to the rocks, and at different elevations. Five of the control points were established on the sea-shore, three on the top of the rocks, and the rest on the flat tidal sea-bed.

The coordinates of a ground control point were known from geodetic survey. This point was the common point of two baselines along the shoreline outside the tidal terrain. The two baselines were established with the conventional static GPS technique just before the kinematic survey. Data were collected for two hours to resolve the carrier phase ambiguities. The common point of the two baselines served as a base (reference) point and data was collected at that station throughout the kinematic survey. The kinematic survey was initialized by occupying the known baselines for two minutes. Then the "rover" was moved to the next ground control point and one minute observation was taken. At the end of the survey the starting (initializing) point was revisited for data closure and one minute of observations were taken again (closure of the loop). Two kinematic sessions (two closed loops) were completed by two independent groups. Each group consisted of two persons: one carrying the antenna and the other the "rover" receiver. The kinematic survey at the tidal area was completed in less than two hours. The GPS receiver that was used was an Ashtech XII.

The collected GPS data was processed using the NADTRAN software. The base point and the initialized points were obtained from the process of the static observations and then they were held fixed during the processing of the kinematic observations.

The GPS survey provided latitudes and longitudes (φ, λ) and geometric heights (h) with respect to the GRS80 which is the ellipsoid that is used by the GPS community.

Since the DTM was required to be in UTM coordinates, the ellipsoidal latitude and longitude (φ, λ) of the ground control points were converted to UTM Easting and Northing (E, N) and the geometric heights to orthometric heights (information about the geoidal height of the particular ground control point was acquired by using the Canadian Geoid Version 2.0(a) software written by the Geodetic Research Services Ltd.)

The resultant orthometric heights were compared with the orthometric heights obtained by precise leveling of the same ground control points. The mean difference was 5 cm and the maximum difference 7 cm.

It was shown that the relative kinematic GPS survey is fast (the survey of the nineteen ground control points lasted less than two hours) and gives orthometric heights with a 5 cm accuracy, planimetric positioning with a 2 cm accuracy, and has the additional advantage that no visibility is required between the base station and the rover. Therefore it is an appropriate method to use for establishing control points on the tidal terrain.

7. CONCLUSIONS

It is concluded that the use of any kind of survey is difficult to apply for tidal terrain mapping. Photogrammetry, even though it encounters some difficulties, seems to be the only effective method for the mapping of the tidal terrain since it provides an enormous amount of data with a minimum of required time spent on the site. In featureless tidal areas of difficult stereo vision, photogrammetry should be complemented by ground field survey. This paper highlighted the advantages, discussed the problems of using photogrammetry for the mapping of the ocean tidal terrain and proposed some solutions that will be hopefully used as guidelines for future and more extensive applications of photogrammetry in tidal areas and may save some time, effort and money.

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