Scientific Research and Essays Vol. 5 (19), pp. 2965-2974, 4 October, 2010
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 ©2010 Academic Journals

Full Length Research Paper

Determining the effects of Degirmendere River on Trabzon Harbor after construction of Black Sea highway on Black Sea coast

A. Akar[1]*, E. Gokalp[1], H. F.Bayata[2] and O. Akar[1]

[1]Department of Geomatics, Karadeniz Technical University, Trabzon, Turkey.
[2]Cadastral and Survey Program, Erzincan University, Erzincan, Turkey.

Accepted 6 July, 2010

Alluvium, which is composed of sand, rubble, stone and soil, is carried by stream and rivers into harbors, bays and dams. Transported alluvium is accumulated as the time went by at the bottom and causes decrease in depth level. Degirmendere watershed receives lasting and heavy precipitation. This precipitation occasionally causes overflowing of the Degirmendere Stream and therefore causes flood and heavy erosion. In this study, images belonging to the years 2000, 2003 and 2008 were determined using satellite. In this, alluvium resulting from the erosion is carried by the Degirmendere Stream into the Black Sea and discharged from the closer district into the harbor entrance of Degirmendere. This is done in comparison with previous years because of the Black Sea Coastal Road construction. Three dimensional map (shaded relief) showing submarine topography of Trabzon Harbor was made and compared with the map made in 2000 using the same method. In the conducted application, horizontal position data were determined with RTK GPS and also depths were measured with prepared mechanical sounding lead. A total of seven sections on the digital maps obtained with the sounding measurements conducted in the years of 2002 and 2009 were transected with the aim of investigating the transformation that is occurring in time. Transformation was examined by forming graphics from the transected sections. Increase was observed in depth values in the courses frequently used by heavy tonnage ships, but decrease in depth was determined in the area where small ships and boats existed.

Key words: Degirmendere, Black Sea, alluvium, transformation.

INTRODUCTION

Utility of seas in terms of both tourism and commerce provides great contribution to the economy of countries having coastline. Therefore, coast protection, pollution prevention and sustainability of natural sources are extremely important in terms of meeting the safe marine transportation of ships used for both tourism and trading.

Soil erosion has been recognized as a serious environmental and soil degradation problem. It can reduce soil productivity and increase sediment and other pollution loads in receiving waters (Deng et al., 2008). Without doubt, one of the events that threaten aquatic environments such as dam, lake, lagoon and bay is the uncontrollable sediment transportation by streams into these environments (Kalkan, 2009). In regions where erosion-caused pollution is high, but awareness to such troubles is poor, such environments are rapidly affected and significantly damaged (Kalkan and Alkan, 2005).

The trouble emanating from erosion is the same for our harbors providing great contribution for the country’s economy. Ships calling at our harbors should be protected from these detrimental effects for their safe entrance and departure. Submarine topography of the commercially important harbors must be prepared at regular intervals and transformation occurring in time should be examined together with the measurements conducted in the past years. If there is a critical situation posing danger, then the required works for solution of this problem and precautions taken will help to prolong the life

*Corresponding author. E-mail: alperakar24@gmail.com.

Figure 1. The alluvium transportation by the Degirmendere stream into the harbor.

span of our ports.

Before the Black Sea Coastal Road construction, the Degirmendere Stream was discharged into the Black Sea at a distance approximately 900 m further away from the harbor entrance. The alluvium which is composed of sand, stone and rubble, is being carried by the stream into the sea and dispersed in the sea. Thus this alluvium did not build up at the entrance and inside the harbor, in order not to cause any increase at the marine bottom.

With the Black Sea Coastal Road construction, the Degirmendere Stream started to discharge into the sea at a distance of 150 m closer than the former point. In the Eastern Black Sea Coast, main wave direction northwest-north and general coastline gradient east-west, net sediment (rubble and sand) transport direction is from west to east (Yuksek et al., 2007). In the year 2006, a fishing port was constructed in the eastern part of the port. This port has prevented alluvium distribution in the sea together with the marine current in the transportation direction. As a result, the alluvium has accumulated in the harbor and its entrance, and so level of the sea bottom has been raised. Especially, this situation can be clearly seen during the days when precipitation is quite heavy. In Figure 1, the alluvium carried by the Degirmendere Stream after rainfall is clearly seen.

In this study, effects of the Degirmendere Stream and newly constructed fishing port on the Trabzon Harbor are investigated. Transformation amount in the sea bottom was determined by comparing the topographical map produced in this study with the topographical map of the sea bottom produced in 2002. In the stage of hydrographical map of the harbor, depth measurement was conducted with mechanical sounding lead, and location information belonging to these sounding points was also transiently obtained with RTK GPS measurement method.

MATERIALS AND METHODS

Depth measurements

The depth measurements, perpendicular to water surface were conducted with the aim of determining topographical features of the submarine bottom. This operation is called sounding and the point at which its depth is measured is also called sounding point. In the classical surveying, the sounding amounts to the leveling (Esen and Gundogdu, 2009).

Hydrographic surveys are similar to the classical surveying methods in many aspects. The most important difference between these two indicated surveying methods are: inability to physically see the surveying sites unlike the classical surveying methods and the continuous motion of the water surface (Erener and Gokalp, 2004).

A range of hydrographic methods have been used in the marine environment to model sea floor topographic features. For example, side-scan sonar, optical techniques (e.g. laser line scanners and multi spectral imaging) has been widely used in the marine environment to produce detailed images of the sea floor. However, most of these methods are not suitable because of the high costs (Gibbings and Raine, 2005). Therefore, in this study, mechanical sounding lead was preferred because it provides the required precision with low cost. Precision depth of the method is admitted to be ± 0.1 m in still waters where the depth is less than 30 m. Precision of the wire sounding calculated as ± 0.01*H in the depths varied between 30 and 2000 m (Ozgen and Algul, 1977).

Position measurements

In the hydrographic measurement studies, because hydrographic measurement vehicle is generally on the move, it is compulsory that depth and position measurements with respect to a sounding point must be conducted at the same time and within short notice (Karasu et al., 1998). Global positioning system (GPS) technology has made it possible to survey coastal regions with greater positioning precision, ease and speed than was before (Work et al., 1998). High accuracy RTK positioning using the GPS is one of the most widely used surveying techniques (Ahn et al., 2005). RTK GPS is the dynamic GPS positioning technique using short observation time; this system provides precise results in real time

(Lee and Ge, 2006). The RTK technique has one big advantage over post processing positioning-calculated positions which are available directly in the terrain (Bakula et al., 2009).

RTK as a principle of measurement is similar to differential GPS (DGPS). However, this method uses the carrier wave phase data that differs from the code measure. Because the carrier wave phase measures are more accurate than code measures, RTK method gives more precise results than DGPS (Gokalp and Gungor, 2001). RTK is currently a carrier phase observation processed (corrected) in real-time, resulting in position that coordinates to a 1 to 2 cm accuracy level that is available to the surveyor in the field (Sumpter and Asher, 1994).

RTK GPS involves a reference station transmitting its raw measurements or observation corrections to a rover receiver via a telemetry link. RTK uses the carrier signal in addition to the code signal. The remote receivers use transmitted RTK data to compute a corrected position. A communication link must exist between the base and remote receivers such as a very high frequency or ultrahigh frequency radio, a cellular telephone, or any other medium that can transfer digital data (Bakula et al., 2009).

Application

Trabzon Harbor has an approximately rectangular form, the main breakwater length of which is 1135 m, smaller one 440 m and the auxiliary breakwater length 380 m.

In this study, the measurements were conducted in two days. From the depth measurements of total 337 sounding points, 50 of them in the morning of the first day, 92 of them in the morning of the second day and 195 of them in the afternoon were conducted with mechanical sounding lead and their position information was determined with RTK GPS.

The studies conducted in technical stage go into division as *in situ* and office studies.

In situ studies

In this study, the map of the Trabzon Harbor part of the Trabzon Province was used. Before *in situ* studies, it was decided that the sounding measurement must be performed within the predetermined line.

An expedition was organized to Trabzon Harbor, where we conducted our study, so as to determine the lines on which the measurements of sounding points were going to be conducted. When the study area was examined, it was deemed suitable that the measurements must be conducted along the lines determined according to the bitts along the coast of harbor.

Before the hydrographical surveying, the field was visited with the aim of determining the polygon points where the reference receiver was to be set up because these points were going to be used in obtaining position information of the sounding points. Within the scope of thesis conducted in 2002, two polygons connected with KTU GPS network were determined.

Mechanical sounding lead is composed of a mechanical sounding that can show the depth measurements and a GPS receiver giving coordinates for the points where the depth measurements are conducted.

The prepared mechanical sounding lead was fixed in the middle part of hydrographic measurement vehicle so that it would be least affected by waving motions. 25 m long steel tape (ST) was used for depth measurements. These measurements were easily and accurately conducted by this tackle mechanism (Figure 2). Horizontal and vertical location values of sounding point were instantly determined by using RTK GPS during the depth measurement. The measurements were conducted on days when the sea wave motions were minimum as far as sticking to predetermined lines.

Hydrographic measurement vehicle was halted at the sounding point and after that mechanical sounding lead was dived into the water. When the lead weight got to the bottom by the help of the tackle on the apparatus the lead was made tight by moving it back and forth and the related value on the SMT was read. Simultaneous position information of this sounding point was determined with RTK.

GPS was recorded by hand-held computer. Orthometric heights belonging to the sounding points were measured with RTK GPS; waving motion in the sea was determined by using these values and taken into account as wave correction value for all of the sounding points.

Another correction value on sounding points was also mean sea level (MSL) values taken from Trabzon-II mareograph station. Annual MSL and sea level values belonging to the days on which measurements were conducted were obtained. The discrepancy between obtained values was added to the conducted depth measurements as correction value.

Office studies

Measurements were done using hydrographic measurement vehicle because of the waving motion in the sea, and so the required accuracy of the measurements was adversely affected. Wave-effect due to waving motion can be determined with the measurements conducted by means of RTK GPS. In the measurement conducted with RTK GPS, the height values obtained from the defined datum is recorded as height value of measured sounding point into hand-held computer. Using these values, waving amount in the sea was monitored with the gained calculations. Location was simultaneously determined as RTK GPS in every sounding point where depth measurement was conducted. Orthometric height value of the related point was determined with RTK GPS. Wave-effect observed during the measurement was calculated by evaluating these height values. In the calculations, these values determined for all of the sounding points were taken into account in determining depth values of the related points as correction value:

$$H_a = \frac{H_t}{n} \quad (1)$$

where,

n: Measured sounding point number.
H_t: Total of orthometric height values measured with RTK GPS.
H_a: Average height, which was determined according to chosen datum as reference value, of mobile antenna.

$$V = H - H_a \quad (2)$$

where,

V: Difference of the measurements from average value.
H: Orthometric height values measured with RTK GPS.

Wave height "V" value was obtained by deducting H_a value from orthometric height "H" value measured in the sounding points.

The measurements were completed in two days as part time and full time. Distance between mobile GPS device and sea surface was measured and entered into GPS receiver as device height value before every measurement period was started. In the measurements, waving movements were individually examined everyday because height value "H" that entered into GPS receiver could affect the sounding points. Waving effect seen during the measurement was calculated by deducting H_a value, separately

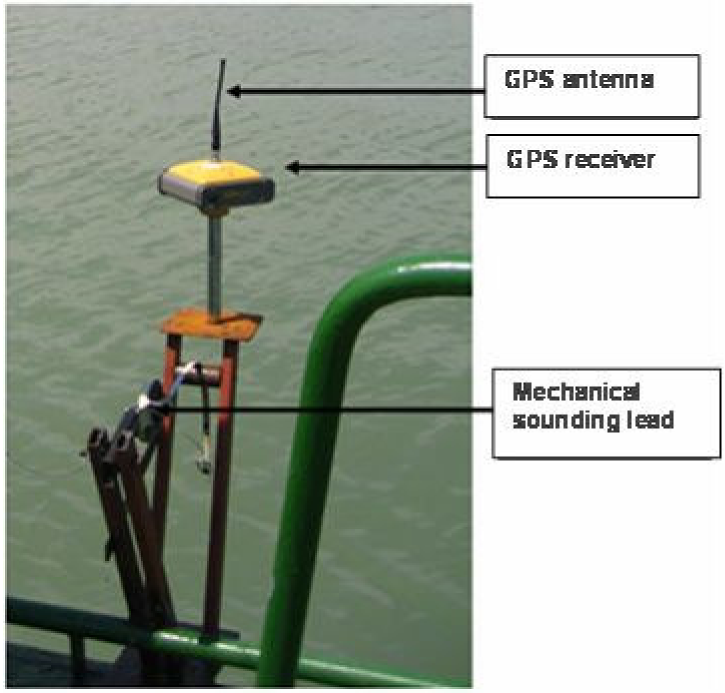

Figure 2. Mechanical sounding lead.

calculated for each day, from the orthometric height values belonging to every sounding point. The obtained values were examined and it was observed that waving effect that appeared differed in sounding points and correction amount, which was because waving got to about 10 cm.

The values of waving heights (V) were taken into account in determining depth values measured with mechanical sounding lead.

Accordingly, the corrected depth values belonging to every sounding point were calculated by the following equation:

$$Hd' = Hd - V_i \quad (3)$$

where,

Hd': Depth value, the waving effect of which was removed,
Hd: Depth value measured with mechanical sounding lead,
V_i: Wave heights for sounding points.

Another correction values taken into consideration in determining depths is also sea level differences which occurred with sea level fluctuation (fall and rise).

By using annual mean sea level (AMSL) value covering measurement days and daily mean sea level (DMSL) values, the differing amounts taken during the measurement days were calculated by the following equation and taken as correction value for the points:

$$Hd'' = Hd' + AMSL - DMSL \quad (4)$$

In this way, the final correction amount was also determined and depth amounts (Hd") between sea surface and bottom were calculated. In determination of alteration in sea bottom of the harbor, the differing amounts that appeared with alteration in the sea level were 8 cm for the first day and 11 cm for the second day. By taking into consideration these values, depth values were determined.

RESULTS AND DISCUSSION

Three-dimensional display of Trabzon Harbor sea bottom

Firstly, Digital Elevation Model (DEM) was made up by using depth values belonging to 337 sounding points which were calculated with correction values. Then 3D model belonging to sea bottom of Trabzon harbor was generated via ArcGIS by using DEM. Three-dimensional display belonging to Trabzon harbor in Figure 3 was created using the data belonging to year 2009. Three-dimensional display belonging to Trabzon Harbor in Figure 4 was created using data obtained from the thesis study entitled “Mapping the sea bottom using RTK GPS and lead-line in Trabzon Harbor” (Erener, 2002).

In the area known as Small Harbor, where the measurement in the regions near to the coast could be conducted in the year 2002, the region that varied between 25 and 75 m was surrounded with buoys in the year 2009 due to the fillet that occurred in the sea in time. The measurement could not be conducted with hydrographical vehicle in this region because depth value dropped under 1 m. In the result of this, depth values in these areas were calculated with the program by interpolating and it was seen that the values were greater than the anticipated values. In the region surrounded with buoys, it was observed from the shaded relief map that

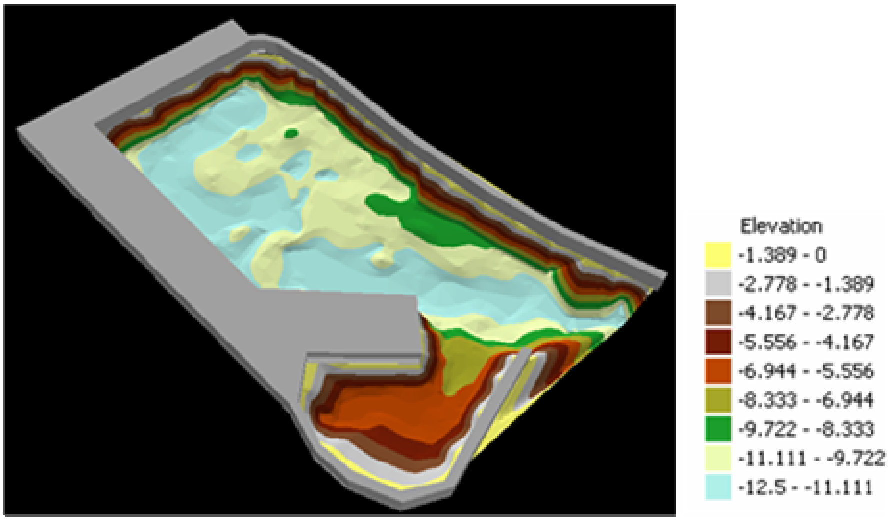

Figure 3. 3D model of Trabzon harbor bottom in the year of 2009.

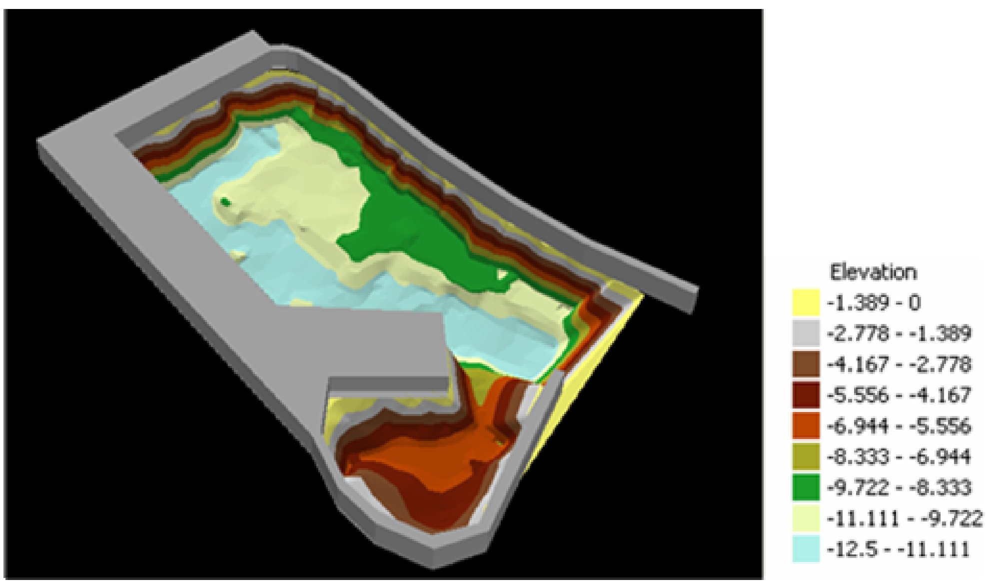

Figure 4. 3D model of Trabzon harbor bottom in the year of 2002.

there were also drops that varied between approximately 1 and 2 m in depth values in this area.

Study on the alteration in Trabzon coast in time using satellite images

In this study, analysis of alteration that occurred in time was visually conducted. The images used in the study included the area from Besirli Region to the airport site. The images and their features are as follows:

1. Belonging to the year 2000, having 30 m resolution, multispectral, Landsat ETM+.
2. Belonging to the year 2003, having 4 m resolution, multispectral, IKONOS.
3. Belonging to the year 2008, having 2.4 m resolution, multispectral, QuickBird.

In determination the change in time, firstly, satellite images belonging to the years 2000 and 2003 were compared, and then satellite images belonging to the years 2003 and 2008 were compared. ERDAS 8.6 was used for change analysis. Landsat ETM+ belonging to the year 2000 has a 30 m resolution. By increasing the resolution of the image, in order to make an image analysis where details are much clearer, this image was digitized with panchromatic band and its resolution was

Figure 5. The change in the coast between 2000 and 2003.

decreased to 15 m.

Brovey Transform fusion technique deteriorates spectral feature of imagines during the fusion but it retains the details in comparison with other methods (Gungor, 2008). In this study, Brovey Transform technique was preferred because visual analysis was conducted using the details.

When the change that occurred in Trabzon Coast in time was studied with satellite images, it was seen that the breakwater was constructed in front of Faroz Harbor numbered as 1 and the embankment was made in Ganita Region numbered as 2 as part of the Black Sea Coastal Road, as it is clearly seen in Figure 5.

When the images belonging to the years 2003 and 2008 were examined it was seen that the area where fishing port next to Faroz Harbor numbered as 1 was completely filled, the area numbered as 2 was filled in 2000 (this is where Black Sea Coastal Road was constructed), and the region numbered as 3 covering Degirmendere was filled and there the road continued (Figure 6). In this way, the Degirmendere Stream started to discharge into the sea at a distance of 150 m closer than the former point. It was seen in the region numbered 4 that a new fishing port having approximately 250 m distance to Degirmendere was constructed.

In the satellite image taken in the year 2003, a classification was made using supervised classification method in order to determine the alluvium transported by Degirmendere Stream. Four classes, vegetation, sea, settlement, alluvium were selected on the used image for application. As it is also clearly seen from the classified image, the alluvium that originated as a result of erosion in rainy days was discharged from the point being too close to the harbor entrance into the sea and transported inside of the harbor via current (Figure 7).

Determination of amount of depth change in the harbor by way of cross sections

Contour curves belonging to inner side of the harbor were generated by using the obtained depth values as a result of sounding points that were conducted in the years 2002 and 2009 and digital maps obtained. Then, totally seven cross-sections were generated along with breakwater, in the middle part of the harbor and south part of the harbor with 25 m intervals on these maps. The change that appeared in depth values in time was investigated by forming graphics with the generated sections.

In the main breakwater, where the AA cross-section (Figure 8) was transected and the graphic generated with the obtained data was analyzed, it was observed that there was a decrease up to 67 cm related to the depth values in the region, west part of the harbor, where ships belonging to the harbor were anchored; there was also an increase up to 72 cm in the middle part of the harbor, and there was a decrease up to 63 cm in the entrance of the harbor.

When the DD cross-section (Figure 8) that was transected along the middle part of the harbor was analyzed, it was observed that there was an only decrease up to 37 cm related to the depth in the region near to the entrance of the harbor, and also there was an increase up to 144 cm in other parts of the harbor.

When the EE cross-section (Figure 8) that was transected from the quay including related parts of the harbor where mine loading and unloading were made for heavy tonnage ships, 140 cm increase was observed in

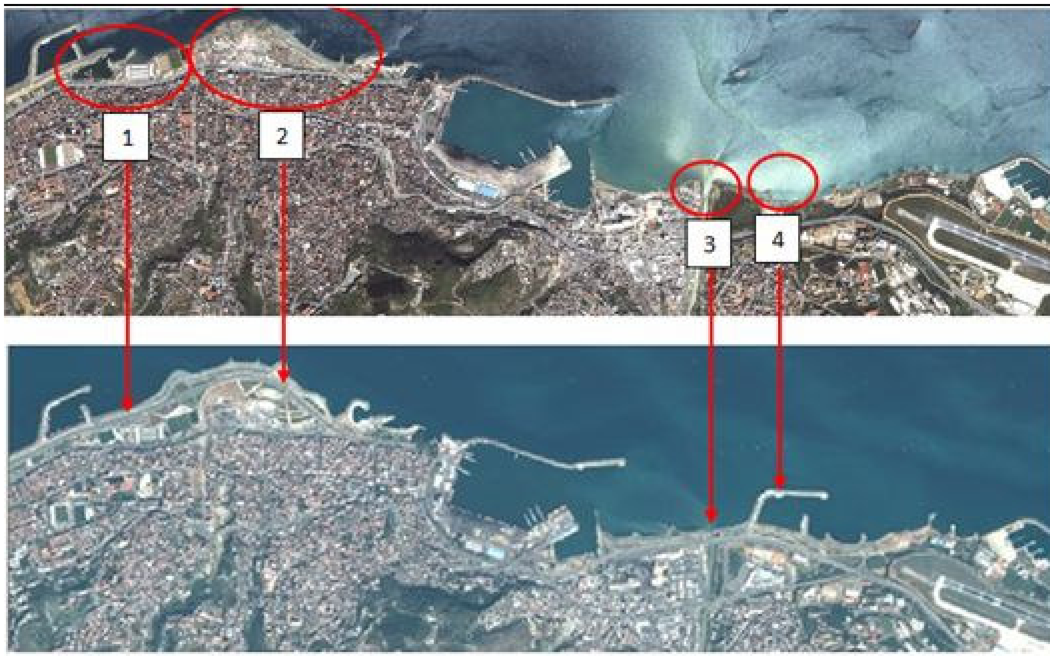

Figure 6. The change in the coast between 2003 and 2008.

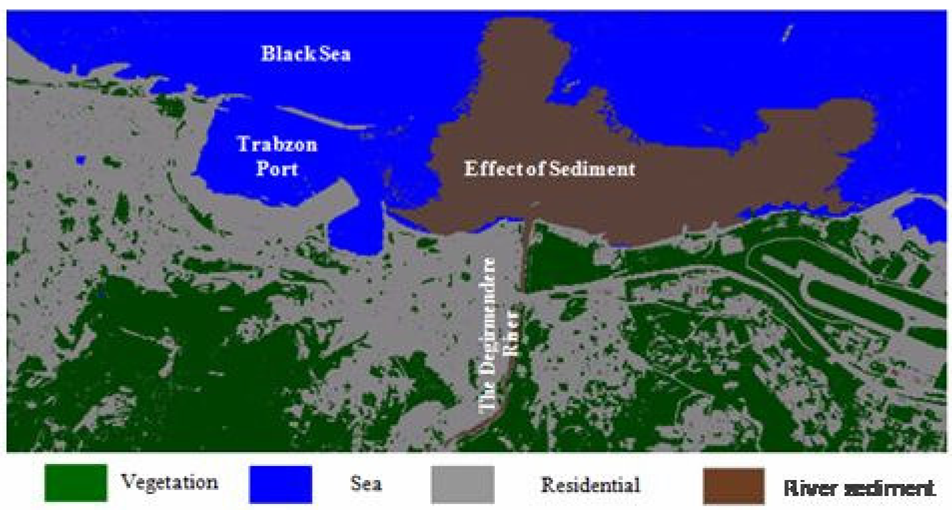

Figure 7. Classified satellite image using supervised classification.

depth values in the loading parts, but decrease up to 103 cm was observed in the corner parts and ships did not dock.

The BB cross-section (Figure 8) was transected from the region including the quay where freight shipment and passenger were at maximum level. When the related graphic was analyzed, increase up to 92 cm was observed in depth values along the north-south line where traffic was heavy but decrease up to 32 cm was determined in the last parts of the cross-section where ships traffic was not heavy.

When the FF cross-section (Figure 8), that was transected from the middle part of the harbor, where ship traffic was heavy, along with south- north direction, was analyzed, it was generally observed that there was an increase and maximum decrease was 218 cm in depth values but there was minor decrease in only a few points.

The GG cross-section (Figure 8) was transected with the aim of investigating the change that occurred in the harbor entrance. When the obtained data were examined, some decrease was determined in depth values almost in all of the points. The greatest decrease was determined as 183 cm.

The CC cross-section (Figure 8) was transected with the

Figure 8. Cross-sections.

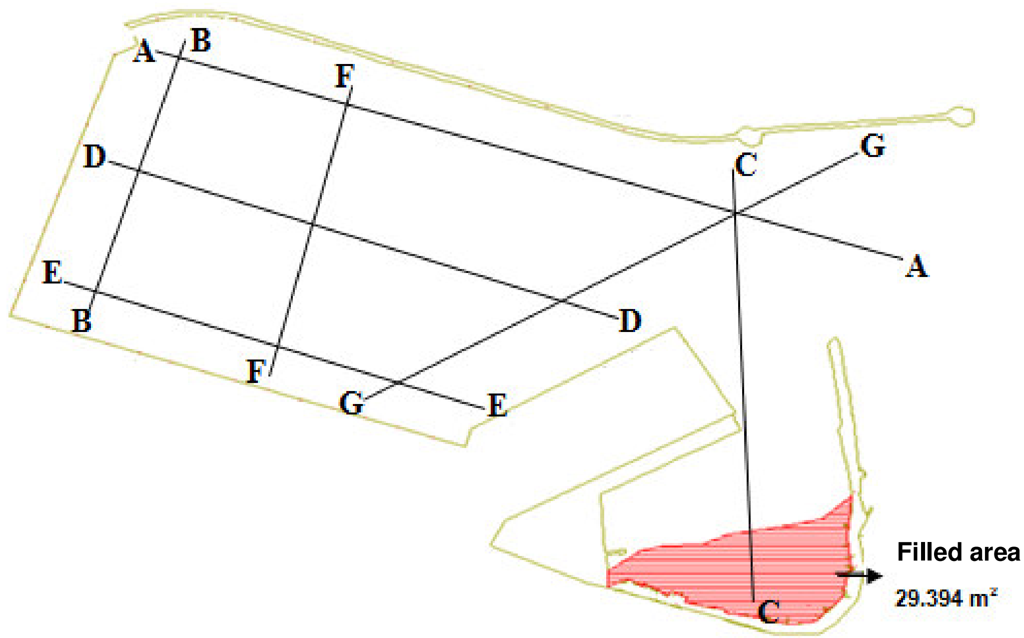

Figure 9. Cross-sections and filled area.

aim of determining the change that occurred inside of Small Harbor. Increase was observed at the least in depth values in the parts near the main breakwater but in general decrease was determined in the parts approaching the harbor entrance and this decrease reached to 166 cm. However, the measurements could not be conducted in some areas of Small Harbor; however, the measurements were conducted in 2002 in the final application because depth values fell down under 1 m. It should not be overlooked that the change in the cross-section transected from here could be determined more specifically because the measurement could be conducted in this area.

As a result of conducted studies, it was observed that the greatest fill quantity was inside of Small harbor. The measurement could be conducted inside of Small harbor in 2002 but could not be conducted in the final application. It was not possible to come in with the hydrographic measurement vehicle because this area was surrounded with buoys. However, coordinates of the buoys were determined with RTK GPS with the aim of determining the change in this area. The fill area formed by combining these buoy points covered a part of 29.394 m^2 as shown on the digital maps (Figure 9).

CONCLUSION AND SUGGESTION

As a result of conducted measurements and assessments, three dimensional topographical maps belonging to the sea bottom, one of which was obtained by using data in 2009 and the other in 2002, were compared and the following results were obtained.

When the graphics obtained by means of cross sections from digital maps generated by using the data belonging to the years 2002 and 2009 were examined, it was observed that there was an increase up to 218 cm in the courses used by heavy tonnage ships. It was determined that there was a decrease up to 183 cm in the courses used by small tonnage ships. In the meantime, it was determined that the depth fall down under 1 m in Small harbor in time, the amount of filling covered an area with 29.394 m^2 and there was a decrease up to 166 cm in the other areas.

In the measurements conducted in the main breakwater, where the depth value was increased in the middle part of the main breakwater, 1 m decrease was observed towards the side of the main breakwater.

In the depth values, about 1 m decrease was observed in the harbor entrance but about 1.5 m increase in the middle part of the harbor.

When the obtained results were examined, it was seen that the transported alluvium dispersed by way of the propellers of motor and the currents in the courses frequently used by heavy tonnage ships and the sea bottom depth increased in the parts where shipping was heavy. However, in the areas where shipping was not heavy and small ships and caiques were situated, the alluvium transported by the Degirmendere Stream settled in the sea bottom in time and this caused a decrease in the depth because the currents were not effective.

In the Trabzon Province which receives lasting and heavy precipitation, the rainfall leads to landslides and soil erosion. The change that occurred in time in the coast was examined by using satellite images belonging to Trabzon Province in the years 2000, 2002 and 2008, and it was determined that the alluvium resulting from the erosion was carried by the Degirmendere Stream into the Black Sea and discharged from 150 m closer district into the Trabzon Harbor because of the Black Sea Coastal Road construction. The fishing port constructed in 2006 prevented disposal of the alluvium with the marine current from the harbor entrance because the solid matter (rubble and sand) transportation direction has been from west to east. In this study, it was thought that this problem would severely threaten Trabzon Harbor in the forthcoming years. For this reason, 1). The stream water should be discharged from further point into the sea via pipeline infrastructure; 2.) before the stream water bearing the alluvium is discharged into the sea, it should be reserved in particular areas and discharged into the sea after the solid matters such as stone, soil, sand etc. are settled; 3.) the entrance of Trabzon Harbor, the areas where shipping is not available and interior part of Small harbor should be periodically dredged, and so increased sea bottom level should be decreased up to the safe levels for entrance and departure of the ships.

REFERENCES

Ahn YW, Kim D, Dare P, Langley RB (2005). Long Baseline GPS RTK Performance in a Marine Environment Using NWP Ray-Tracing Technique under Varying Tropospheric Conditions. 18th International Technical Meeting of The Satellite Division of The Institute of Navigation, Long Beach, California. 13-16 September: pp. 2092-2103.

Bakula M, Oszczak S and Pelc-Mieczkowska R (2009). Performance of RTK positioning in Forest Conditions: Case Study. J. Surv. Eng., pp. 125-130.

Deng ZQ, de Lima João LMP and Jung HS (2008). Sediment transport rate-based model for rainfall-induced soil erosion. Catena. 76(1): 54-62.

Erener A (2002). Mapping the Sea Bottom Using RTK GPS and Lead-line in Trabzon Harbor. MSc, Karadeniz Technical University,Trabzon, (Published in Turkish).

Erener A, Gökalp E (2004). Mapping the Sea Bottom Using RTK GPS and Lead-Line in Trabzon Harbor. FIG Working Week 2004, Athens, Greece.

Esen Ö, ve Gündoğdu İB (2009). Marine Maps in History and Today, and The Importance of Marine Maps. Union of Chambers of Turkish Engineering and Architects Chamber of Survey and Cadastre Engineering, 12th Scientific and Technical Assembly of the Turkish Surveyors, Ankara, Turkey, (Published in Turkish).

Gibbings P, Raine S (2005). Evaluation of a Hydrographic Technique to Measure On-Farm Water Storage Volumes. Agric. Water Manage., 78: 209-221.

Gokalp E, ve Güngör O (2001). Using RTK (Real Time Kinematic) GPS on Application of Development. J. Surv. Cadastre Eng. Geodesy, Geoinf. Land Manage., 87: 38-47.

Gungor O (2008). Multi Sensor Multi Resolution Image Fusion. PhD Dissertation, Purdue University, Indiana, USA.

Kalkan Y, ve Alkan RM (2005). The Areas Covered by Water and Hydrographic Surveying. Union of Chambers of Turkish Engineering and Architects Chamber of Survey and Cadastre Engineering, 10th Scientific and Technical Assembly of the Turkish Surveyors, Ankara, Turkey, (Published in Turkish). http://www.hkmo.org.tr/resimler/ekler/B3D8_115_ek.pdf.

Kalkan Y (2009). Hydrographic Surveying in Dam and Sediment Movements. Union of Chambers of Turkish Engineering and Architects Chamber of Survey and Cadastre Engineering, 12th Scientific and Technical Assembly of the Turkish Surveyors, Ankara, Turkey, (Published in Turkish.

Karasu S, Özölçer İH, Birben AR, Önsoy H ve Güner MS (1998). The Effect of Groins on Eastern Blacksea Coasts and The approach of Digital Model. Union of Chambers of Turkish Engineering and Architects Chamber of Civil Engineering, 6th National Coastal Engineering Symposium. Mersin, Turkey, pp. 263-279, (Published in Turkish).

Lee IS, Ge L (2006). The performance of RTK-GPS for surveying under challenging environmental conditions. Earth Planets and Space, 58: 515-522.

Ozgen MG, ve Algül E (1977 Surveying Engineering: I- Hydrographic Surveying. İ.T.Ü. Library. 1086. Istanbul.

Sumpter CW, Asher GW (1994). Real-Time Kinematic GPS for Cadastral Surveys. ASPRS/ ACSM, http://libraries.maine.edu/Spatial/gisweb/spatdb/acsm/ac94105.html.

Work PA, Hansen M, Rogers WE (1998). Bathymetric surveying with GPS and heave, pitch, and roll compensation. J. Surv. Eng., 124(2): 73-90.

Yuksek Ö, Önsoy H, Kömürcü Mİ, Kankal M ve Akpınar A (2007). Evaluation of The Coastal in Terms of Blacksea Highway. 6th National Coastal Engineering Symposium. (Published in Turkish). İzmir, Turkey. http://www.e-kutuphane.imo.org.tr/pdf/3813.pdf.