Determining and Measuring the Shift of the Tigris Riverbanks at the Baghdad University Camp between the Years 1962- 2013 Using the Geometrical Method and GIS

Mahdi Mustafa Ali[1], Alaa S. Mahdi[2]

[1]Surveying Department, Institute of Technology, Middle Technical University, Baghdad- Iraq
[2]Remote Sensing Unit, College of Science, University of Baghdad, Baghdad- Iraq

Abstract: ***The Tigris River passes throw Baghdad City, from the north entrance to the confluence with Diala River in the south, dividing it into two main parts namely: Al-Risafa in the eastern side of the city, and Al-karkh in the western side with about 49 km long. Tigris Riverbanks, like most Rivers in the world, changes its path according to the changes in the river characteristics. The Tigris River has the largest meandering in Baghdad, Al-Jadriyah. So, the Riverbanks are usually exposed to erosion in the Concave (Dora) side and deposition in the convex side adjacent to the Baghdad University Camp (BUC). The study area locates in the central part of Baghdad City, and lies between Lat. (33˚17′ 3.79″-33˚15′ 27.16″) N , Long. (44˚21′ 20.27″- 44˚24′3.73″) E. The available data consist of, a Controlled Mosaic Aerial Photograph (dated/1962), and WorldView-1 pan satellite image/2013 were obtained from the Iraqi "State Organization on Survey". The aim of this study is to determine and measuring the magnitude of erosion and deposition happened to the Tigris Riverbanks for the period extended between the (1962 – 2013). For this purpose, a proposed Geometrical Method with GIS Graphic Tools was implemented. The cross-sections are taken for each 250 meters to measure these magnitudes. The results show that, the maximum values for both, (erosion and deposition) were 63 m and 352 m respectively.***

Keywords: RS, GIS, Worldview-1 Pan Satellite Image /2013, Mosaic Aerial Photo, 1962, Tigris Riverbanks, Change Detection, and Geometrical Method

1. Introduction

Most of rivers in the Youthful stage or in the Mature stage, subject to changes in their riverbanks especially in the meandering part. These rivers usually subject to daily, monthly, annual, or longer period to change according to the characteristics of those rivers. Some of changes are possible to be visually sensed, and the others are impossible to be sensed unless using suitable calculation methods. One of the most changeable targets on the earth surface is the river. The changes in the Tigris Riverbanks, as a longitudinal target, could be monitored by taking cross-sections to the river course for a specified interval. This interval value depends upon the purpose of which the cross-sections are build. So, in this study the interval was 250m. The proposed geometrical method is highly depends on the river cross-sections to measure the magnitudes of erosion and deposition. More details about rivers, change detection, and the cross-sections are illustrated below. The rest of this paper is organized as follows: The **next section**, includes the **location** and the **extent** of the study area. **Section Three**, gives a **Scientific Overview** about **rivers**, **change detection**, and **cross-sections** for a river. **Section Four,** deals with the **materials** and the **Geometrical Method** that used to detect changes in the Tigris riverbanks. **Section Five** refers to the **Results** and **Discussion**. **Sections**, **six** and **seven**, refer to **Acknowledgements** and **References** respectively.

2. Area of Study

The Baghdad University camp is situated in the central part of Baghdad City, between Al-Jadriyah Bridge and the Doubled-storey Bridge, and lies between Lat. (33˚17′ 3.79″-33˚15′ 27.16″) N, Long. (44˚21′ 20.27″- 44˚24′3.73″) E, started from nearby of Al-Jadriyah Bridge about 60m and continued to a distance of 5.250 Km which represents the end of the university camp. From the geomorphologic perspective, Baghdad earth surface is mostly homogeneous and it is specified as a plain, and has elevations ranged between 33 to 36 meters above Mean Sea Level (MSL), the Figure-1, (a, b, & c), shows the Iraqi map including the location of Baghdad City (the Capital of Iraq) and the location of the study area.

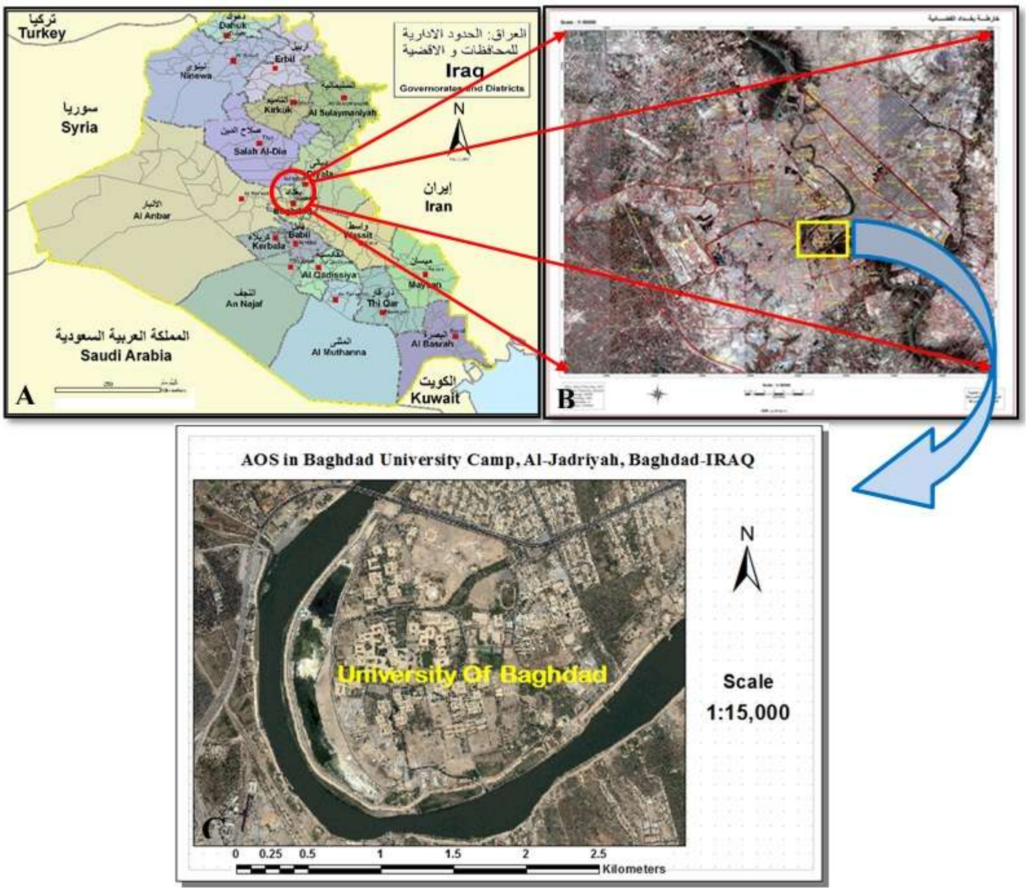


Figure 1: a, b, & c- Shows the Location of the Study Area

The **study area** is a region that has the dimensions, **4.21 km** length and **3 km** width, and has an area of **12.63 km^2**. It represents the Baghdad University Camp and its adjacent area. The University Camp bounds the Tigris River about **4.655 km**. Finally, the Dora side is the opposite riverbank, it is mostly consists of residential and agricultural areas.

3. Scientific Overview

3.1 The Rivers

It seems that there is no unique definition for the generic term "river" because many definitions are found in the literature of Hydrology. But generally, Rivers are part of the hydrological cycle and considered as natural flowing watercourse laying between the upstream (Source) and downstream (mouth), usually freshwater, flowing towards lake, sea, ocean, or another river. Water generally collects in a river from precipitation through a drainage basin from surface runoff and other sources such as groundwater recharge, springs, and the release of stored water in natural ice and snow. Potamology is the scientific study of rivers while limnology is the study of inland waters in general. Small rivers have different names such as stream, creek, brook, rivulet, and rill. River's characteristics vary between its upper and lower course, so there are a high relationship between the channel slope, depth, and its width. These three characteristics are a function of discharge in the river system. Generally, rivers are characterized in three main types according to the Davis's river "ages" criteria, namely:

1) **Youthful River**: A river with a steep gradient that has very few tributaries and flows quickly. Its channels erode deeper rather than wider.
2) **Mature River**: A river with a gradient that is less steep than those of youthful rivers and flows more slowly. A mature river is fed by many tributaries and has more discharge than a youthful river. Its channels erode wider rather than deeper.
3) **Old River**: A river with a low gradient and low erosive energy. Old rivers are characterized by flood plains. Examples are the Tigris, Euphrates, **[1]**.

3.2 Change Detection Process

Change detection refers to the process of identifying differences in the state of Earth's surface features by observing them at different times. Changes can usually be determined from satellite images that are acquiside at different times for the same area. There are a variety of change detection techniques that have been developed. But it seems that there is no universally optimal change detection technique. The choice of any change detection technique is dependent upon the application, the type of dataset used, and the efficiency of the operator as well as the objective of change detection process, **[2]**.

3.3 River Cross-Sections

Generally, cross-section is an imaginary line results from the intersection between a vertical plane and a surface to show the slopes in the perpendicular direction to the center line of that surface. The cross-section of a river can be determined by measuring the distances of many sequent points with regular (or irregular) intervals and their depths that locate along, and normal to, the center line of the river starting from the left riverbank to the right riverbank, as shown in Figure-2, using a total station or any other device. These measurements can be used to create a graph as a visual representation in the XZ plane. The graph could be obtained by joining the plotted points of what the river cross-section looks like as shown in Figure-3. Cross-sections in the past were taken to the left and right of the center-line using hand tools, tape and surveying range pole. Today, it is possible to use modern methods likes GPS data, laser range-finders, echo sounders, or digital terrain models (DTM) to produce cross-sections for grade designing, **[3]**.

The information compiled from multiple river cross-sections can be used to find the area of the cross-sections, wetted perimeter, hydraulic radius, discharge and other hydraulic requirements to make decision of the site suitability. The measurement of the discharge of a river means the measurement of the volume of water passing a given cross-section per second as shown in Figure 3.

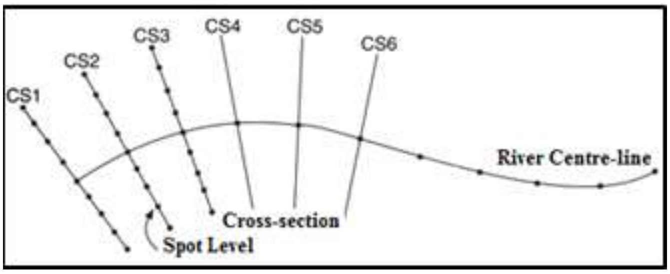


Figure 2: Shows The Horizontal Plan of River Cross-Sections

In ordinary hydrographic surveying, sounding means determining the depth of the water at various points in the waters that adjoining the land in rivers, lakes, or seas. These depths are used for plotting charts for planning under-water works, or determining volumes of discharge, hydraulic radius, used to find the cross-sectional area and wetted perimeter of the river etc. Most sounding is now done by sonic methods, which consist in measuring the time taken for a sound impulse to be transmitted to the bottom of the river, lake, or sea, **[4]**.

Most of projects, before the designing and construction stages, need necessary data from the site like as-built map, contour map, cross-sections, etc. This study focuses on the Cross-sections, so that the aims of which are:

1) To investigate the shape and morphology of a river.
2) To compare straight and meandering sections of the same river
3) To investigate discharge and velocity and the factors which influence it, both across the channel and along its length.
4) To investigate changes in channel morphology along the length of the river.
5) To compare rivers in different locations, **[5]**.

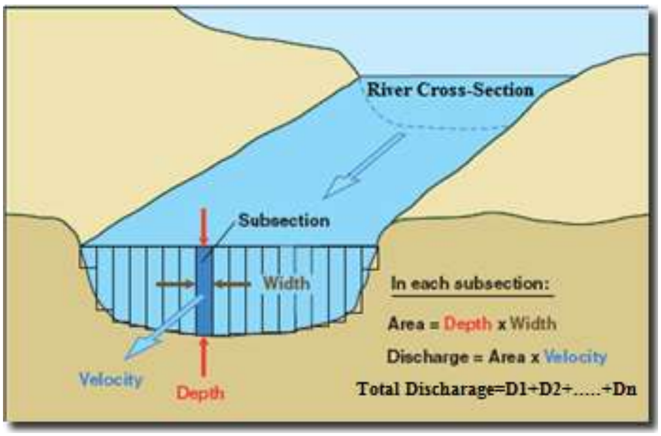


Figure 3: The River in 3D with its Cross-Section and discharge Calculation, (Source: Internet-Modified)

4. Materials and Methodology

The material and working methodology can be summarize as the following;

4.1 Materials

Materials consist of two basic components, datasets and software, as described below:

4.1.1 Datasets

1) A rare original controlled Mosaic Aerial Photograph (MAP) exposure at 1962. The source of this mosaic is the State Organization on Survey (SOS) - Baghdad, Iraq. The lack of space data before the last 50 years led to select the appropriate alternative by reference to the old aerial photographs. So, the accuracy of the aerial photograph (spatial resolution) is still higher than the current very high resolution satellite images. Knowing that the oldest satellite image that could be obtained is Landsat MSS (MSS data are available after 1972), which has low resolution (90 meters) and is not suitable for good change detection. Table (1) shows the Coordinates of the Upper Left Corner (ULX) and the Lower Right Corner (LRX) in pixels, and other details of the controlled MAP, while Figure (4) shows the photograph itself.

Table 1: The Information of Mosaic Aerial Photograph, 1962

Mosaic Ariel Photograph 1962 / Coordinates Extent (pixel)				Raster Information			Spatial Reference/ Scan Resolution
				Columns / Rows	Pixel Size/ Format	Raster Size / Pixel Depth / Pyramid	
ULX	-0.50	ULY	0.50	1568/ 2272	1x1 / PNG Image	10.19 MB / 8Bit / Nearest Neighbor	Undefind / H: 600 dpi, V: 600 dpi
LRX	1567.50	LRY	-2271.50				

Figure 4, shows the rare Original Controlled Mosaic Aerial Photograph. This photograph had been exposure in April, 1962. As Seemed from the figure, the University Camp was still not built.

ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Figure 4: Illustrate the Original Controlled Mosaic Aerial Photograph, 1962, (Source, SOS)

2) WorldView-1 (WV_1) is one of the very high resolution satellite images. This sensor has only panchromatic (pan) mode with a maximum spatial resolution of 0.5m., WorldView-1 Pan Satellite Image (PSI)/2013 is obtained from SOS. Table 2, shows the Image Extent [UTM Coordinates of the Upper Left Corner (ULX) and the Lower Right Corner (LRX)] and other details, while Figure 5, shows the WorldView-1 pan satellite image 2013 itself.

Table 2: The Extent of The WorldView-1 Pan Very High Resolution Satellite Images, 2013

WorldView-1 Pan Sat. Image 2013/ UTM Coordinates Extent (m)				Raster Information			Spatial Reference/ False E./ False N./ Central Meridian/ S.F.
				Columns / Rows	Pixel Size/ Format	Raster Size / Pixel Depth / Resampling	
ULX	432770	ULY	3687017	37786 / 35840	0.5m / TIFF	1.26 GB / 8Bit / Nearest Neighbor	WGS_1984_UTM_Zone38N / 500000 m / 0 m/ 45˚E / 0.9996
LRX	451683	LRY	3669078				

4.1.2 Software

Many software packages such as ERDAS v. 8.4, ArcGIS v. 10.4.1 are used to construct and process the basic database. These software are very useful for changes detection calculations.

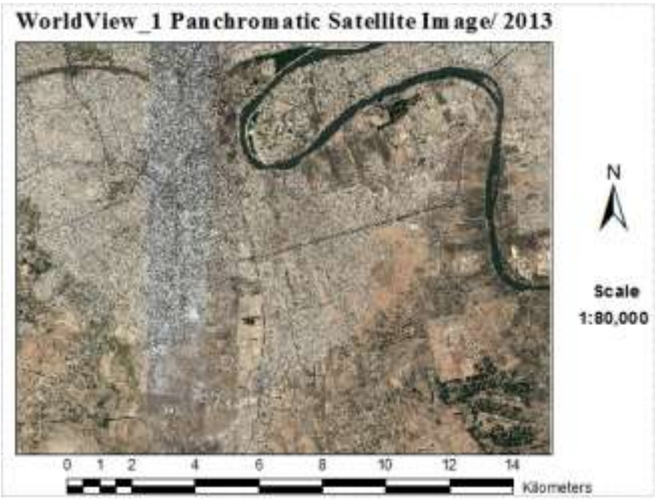


Figure 5: The WorldView-1 Pan satellite image, 2013, (Source, SOS)

4.2 Methodology

In this research, the proposed Geometrical method will be used to obtain the magnitudes of shifting that happened to the Tigris Riverbanks for the period from (1962 – 2013). Figures (6) shows the flowchart of this method and the main steps to be performed. The following articles summarize each step of this method.

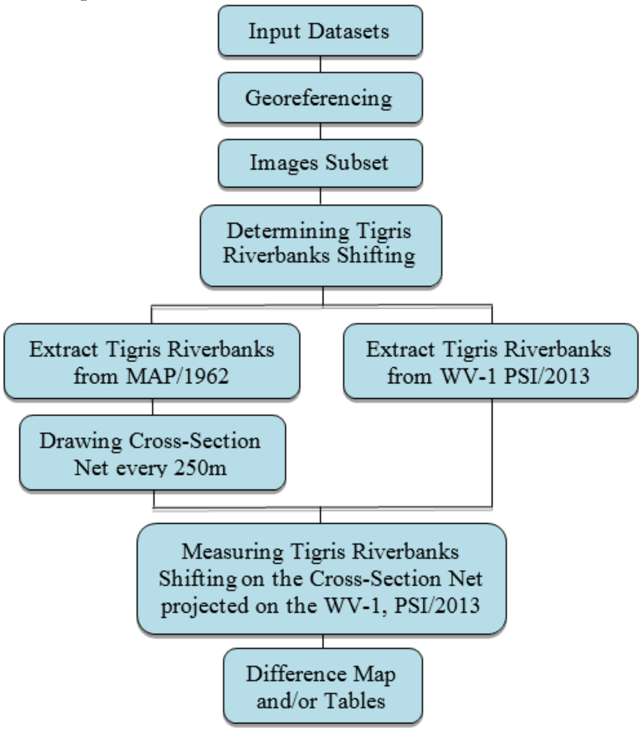
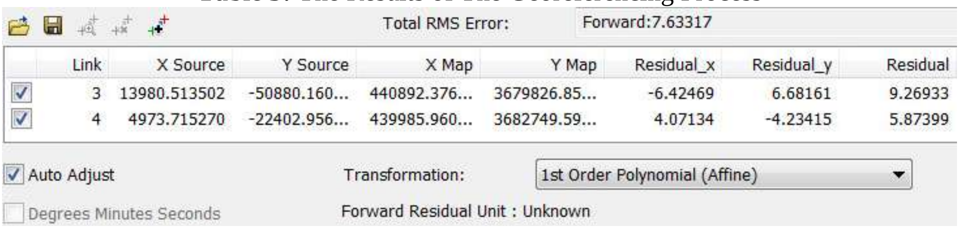


Figure 6: A Flowchart Showing The Procedure of The Proposed Geometrical Method, (Designed)

4.2.1 Georeferencing

The Mosaic Aerial Photograph, 1962 is georeferenced onto the WorldView_1 Panchromatic, 2013 (WV_1, Pan) satellite image using image-to-image 1st order polynomial (Affine) georeferencing transform. Four points selected in the Mosaic Aerial Photograph considered as reference points appear in the satellite image were used for georeferencing. Nearest neighbor resampling method and a pixel size of 0.5mx0.5m are used. Root Mean Square Error (RMSE) of the georeferencing process was **7** pixels due to the difficulty of selecting sharp features in the mosaic aerial photograph. Table 3, shows the results of the georeferencing process, where, figure 7, shows the Georeferenced Mosaic Aerial Photograph, 1962. In the other hand, Table 4, shows the Information of the Georeferenced Mosaic Aerial Photograph, 1962.

Table 3: The Results of The Georeferencing Process



Total RMS Error: Forward:7.63317

	Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
☑	3	13980.513502	-50880.160...	440892.376...	3679826.85...	-6.42469	6.68161	9.26933
☑	4	4973.715270	-22402.956...	439985.960...	3682749.59...	4.07134	-4.23415	5.87399

☑ Auto Adjust   Transformation: 1st Order Polynomial (Affine)

☐ Degrees Minutes Seconds   Forward Residual Unit : Unknown

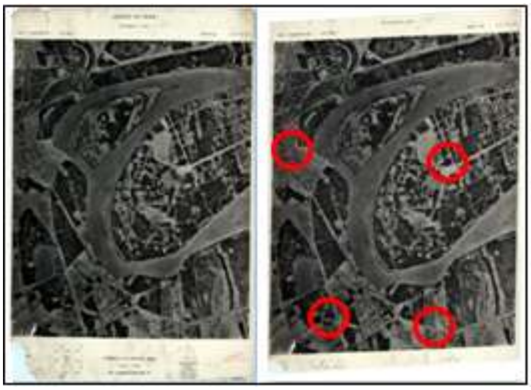


Figure 7: The Mosaic Aerial Photograph, 1962: The original (left) and the Georeferenced (right)

Table 4: Shows the Information of the Georeferenced Mosaic Aerial Photograph, 1962

Mosaic Ariel Photograph 1962 / UTM Coordinates Extent (m)				Raster Information			Spatial Reference/ False E./ False N./ Central Meridian/ S.F.
				Columns / Rows	Pixel Size/ Format	Raster Size / Pixel Depth / Resampling	
ULX	439516.00	ULY	3684959.00	9489 / 11109	0.5m / IMG Image	301.59 MB / 8Bit / Nearest Neighbor	WGS_1984_UTM_Zone38N / 500000 m / 0 m/ 45°E / 0.9996
LRX	444260.00	LRY	3679405.00				

4.2.2. Image Subset

Both, Georeferenced Mosaic Aerial Photograph, 1962 and WorldView_1 Pan Image, 2013, were subset with a suitable extent specified in the Table 5, below, figures, (8&9) show the subset of the above data.

Table 5: The UTM Coordinates of Subset Extent (m)

UTM Coordinates of Subset Extent (m)			
ULX	440000	ULY	3683000
LRX	444210	LRY	3680000

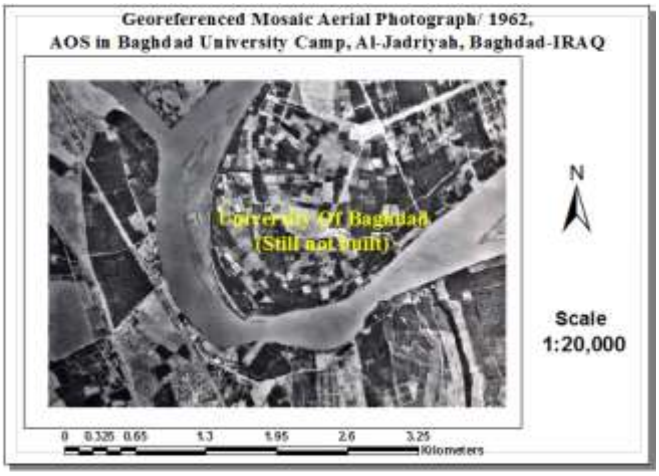


Figure 8: The Subset Georeferenced Mosaic Aerial Photograph, 1962

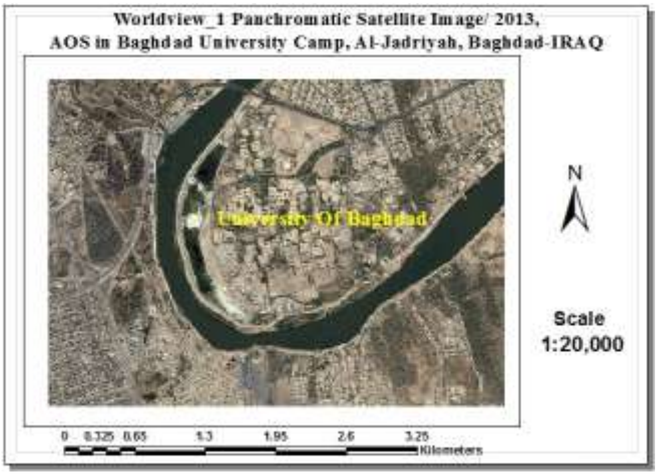


Figure 9: The Subset WorldView-1 Pan Satellite Image, 2013

4.2.3 Procedure of Change Detection Using Geometrical Method

This method is used to detect changes in the Tigris Riverbanks within the study area. The Geometrical method needs to construct two layers, each layer represents the edges of the Tigris riverbanks. The first layer refers to the Georeferenced Mosaic Aerial Photograph (MAP), 1962 named RiverBank_1962, while the second layer refers to the WorldView_1 Panchromatic Satellite.

Image (PSI) acquired in 2013 named RiverBank_2013. These two layers are prepared by polyline option in GIS as shown in Figures (10, 11) and Figures (12, 13) respectively.

The steps of the method:

1) A loop was drown representing the Tigris Riverbanks_1962 using the polyline option one of the GIS Graphic Tools as shown in the Figures (10&11).
2) Another loop was drown representing the Tigris Riverbanks_2013, also using the same polyline option, as shown in the Figures (12, &13).

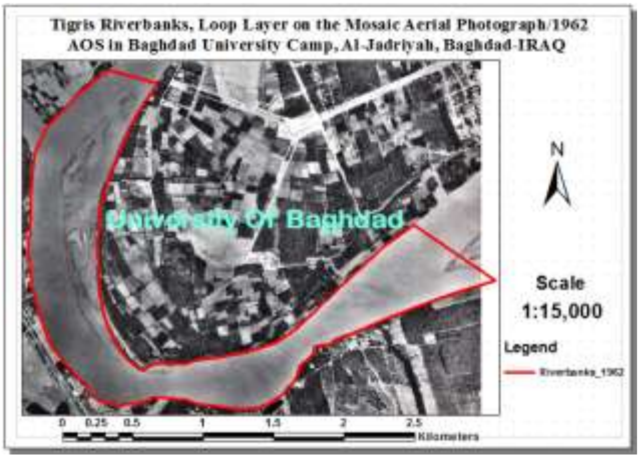


Figure 10: Drawing The Loop of Tigris Riverbanks on the Mosaic Aerial Photograph, 1962

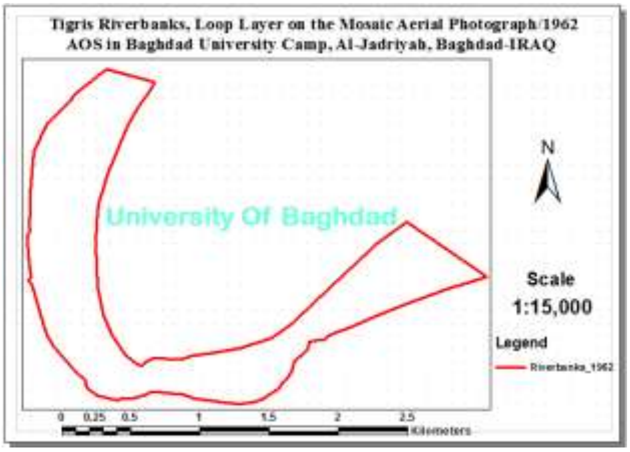


Figure 11: The Tigris Riverbanks Layer _1962

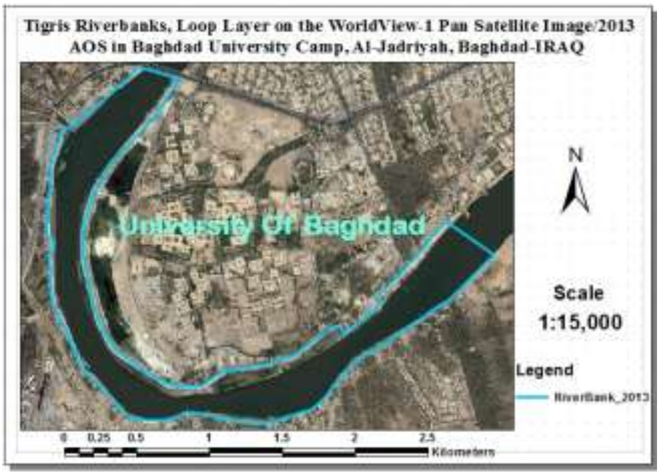
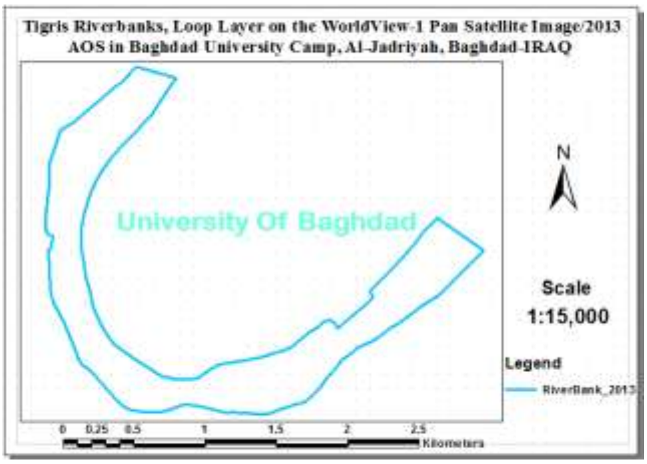


Figure 12: Drawing the Loop of Tigris Riverbanks on the WorldView_1 Pan Satellite Image, 2013



Figures 13: The Tigris Riverbanks Layer, 2013

3) To determine the movement of the Tigris Riverbanks between the years 1962 and 2013, a difference map should be prepared. Firstly, the Riverbanks layers_1962 and 2013 (as shown in the Figures, 11 and 13) are viewed simultaneously in a new layer as shown in the Figure (14). Secondly, the new layer is manually categorized to determine the areas of deposition and erosion as viewed in the Figure (15) which shows the final difference map and its Categories. The white area between the two categories represents the overlapped area between the two input datasets.

To apply Features Category in the legend of the difference map, follow the path below:
(From the table of content Selected Layer/ from the main menu select Insert/ choose layer (or layers) to include legend/ Next/ set the legend properties/ Next/ Set legend frame (or put it default)/ Next/ set legend Items (or put it default)/ Next/ set legend spacing (or put it default)/ Finished.

Visually, the area of deposition is larger than the area of erosion. The movement of the Tigris Riverbanks, the migration of the river, is visually obvious as the legend indicate.

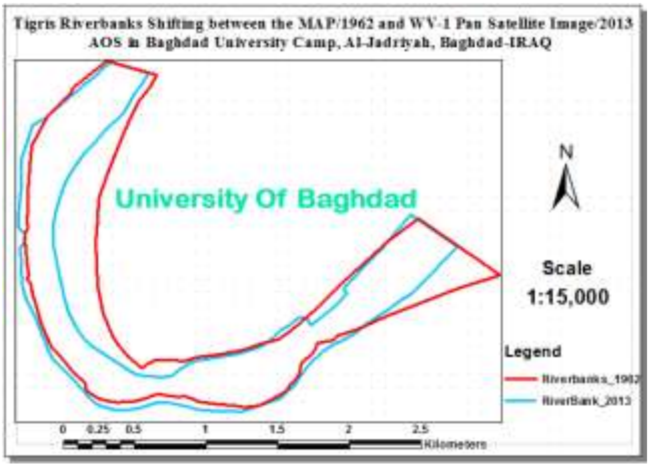


Figure 14: The Tigris Riverbanks Shifting Map between 1962 and 2013

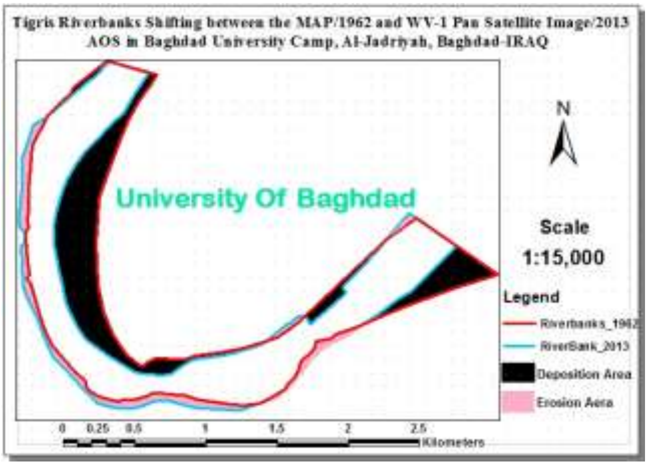


Figure 15: The Final Difference Map of the Tigris Riverbanks between 1962 and 2013

4) A reference Cross-sections of 250m were plotted on the Tigris Riverbanks layer_1962 along the center-line of the river to measure the magnitude of the deposition and erosion in each of these Cross-sections as shown in the Figure (16). The length of cross-sections are different from one to another according to the river width in the year 1962. These cross-sections are drown using the drawing tools in GIS and saved as a layer named "Line 3".

5) The layer "Line 3" is viewed on the Tigris Riverbanks layer_2013, see Figure (17), to determine and then to measure the magnitude and the direction of the Tigris riverbanks due to the reference cross-sections. The direction of the riverbanks is considered to the left or to the right of the center-line of the Tigris River. The left side of the river is adjacent to the Baghdad University Camp while the right side is adjacent to the Dora district. Visually, it is obvious that the displacement of the Tigris Riverbanks_2013 from those at 1962 was different quantitatively (the amount of the displacement) and qualitatively (deposition or erosion) as shown in the Figure (18).

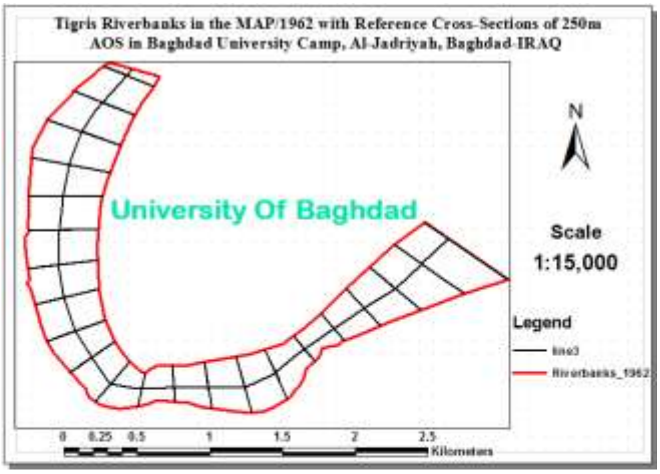


Figure 16: Shows the Cross-sections on the Tigris Riverbanks, 1962

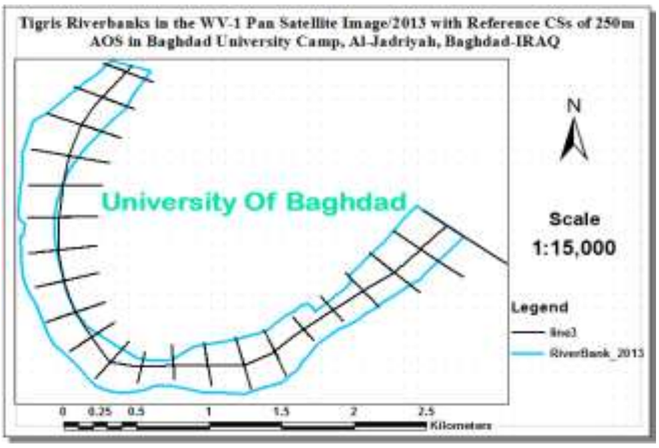


Figure 17: Shows the Cross-sections on the Tigris Riverbanks, 2013

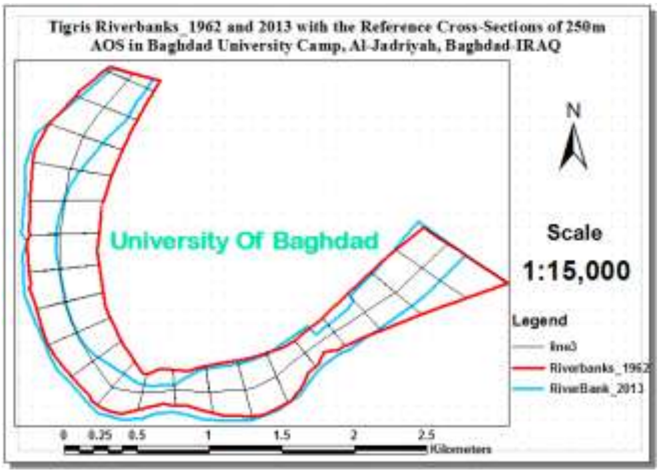


Figure 18: Shows the Reference Cross-sections on the Tigris Riverbanks_1962 and 2013

5. Results and Discussion

5.1 Results

5.1.1 Area Measurement

5.1.1.1 Area of Deposition and Erosion

To compute the areas of both deposition and erosion**,** follow the path below:
(From the table of content, Selected Layer / from the tools bar select the "measure tool"/ choose "measure an area"/ compute the area by clicking the boundary of the required part / double click on the beginning point to end the measuring process).

For this purpose, the Final Difference Map of the Tigris Riverbanks between 1962 and 2013 (see Figure 15), is used. So, all areas of the deposition and erosion are identified as indicated in the legend. Referring to the same Figure, the black area is deposition while the violet area is erosion. Each of these categories consists of many parts. The deposition parts were arranged in sequent starting from the upstream of the river, in the left side bank, clockwise direction and then to the right side. These parts are named D1, D2, D3, and D4, while the erosion parts are named E1, E2, E3, and E4 also arranged in the same system. The sequence of all parts became D1, E1, D2, E2, D3, E3, E4, and D4 as shown in the Figure (15). The results obtained are mentioned in the Table (6) as follows:

Table 6: Shows the areas of the deposition and erosion in both sides of the Tigris River

Part No.	Deposition m^2	Side	Erosion m^2	Side
1	493 152	Left	7 281	Left
2	30 158	Left	9 259	Left
3	122 081	Right	121 752	Right
4	10 711	Right	32 771	Right
Total	656,102		171003	

5.1.1.2 Area of the Tigris River

The boundary of the Tigris River at the study area in the year 1962 is highly different from itself in the year 2013. It is necessary to measure its area in the years above and then many Conclusions can be obtained. The two river areas were measured for the two years mentioned above were as follows:
Area of Tigris River_1962= 2,064,184 m^2 , Area of Tigris River_2013= 1,578,869 m^2.

5.1.2 Displacement Measurement

5.1.2.1 The variation of Tigris river width

The Tigris river width is variable from cross-section to another. Every cross-section length was measured on both, the MAP/1962 and the Worldview-1, PSI/2013. The cross-sections of the MAP/1962 are considered as a reference to the Worldview-1, PSI/2013 to determine the changes in the river widths. Table (7) shows the variations in the Tigris river widths for each cross-section on the two input images.

Table 7: Shows the variations in the width of the Tigris River between 1962 and 2013

CS No.	Width of Tigris River (m)		Diff. (m)	CS No.	Width of Tigris River (m)		Diff. (m)
	1962-MAP	2013-WV_1 PSI			1962-MAP	2013-WV_1 PSI	
0+000	366	287	79	2+750	251	241	-10
0+250	452	364	88	3+000	249	193	56
0+500	541	402	139	3+250	324	354	-30
0+750	551.5	376	175.5	3+500	400	396	4
1+000	509	278	231	3+750	373	363	10
1+250	482	241.5	240.5	4+000	228.5	294.5	-66
1+500	483	244.5	238.5	4+250	252.5	220	32.5
1+750	472.5	249	223.5	4+500	344.5	300.5	44
2+000	465	237	228	4+750	455	355	100
2+250	418.5	263	155.5	5+000	588	384	204
2+500	396	318	78	5+250	697	402	295

5.1.2.2 The Displacement of Tigris riverbanks

The reference cross-sections net of 250m are designed on the MAP/1962 and viewed on the WV-1 PSI/2013 as shown in the Figure (16). The benefit of this process is to determine and then to measure the displacement of the Tigris riverbanks on the WV-1, PSI/2013 as shown in the Figure (19). This figure shows a part of the study area. The brown color represents the deposition area while the blue color represents the erosion area. Using the measure tool in GIS, the length of the deposition and erosion along each cross-section is measured.

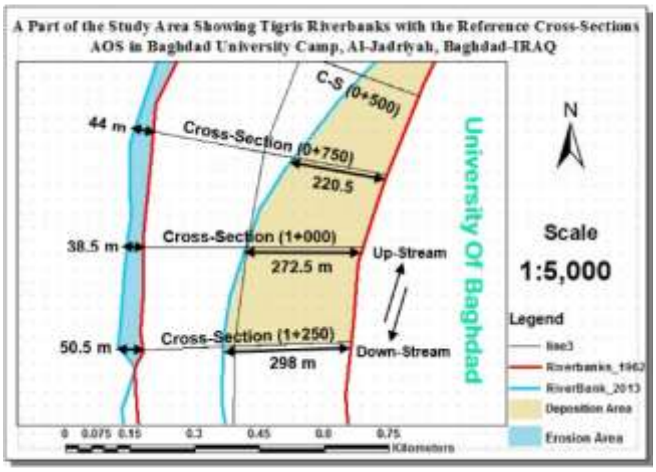


Figure 19: Shows the Reference Cross-sections on the Tigris Riverbanks_1962 and 2013

Table (8) records the displacement in every cross-section, for the deposition and the erosion as well as the river side, caused by the movement of the Tigris Riverbanks adjacent to the Baghdad University Camp in Al-Jadriyah between 1962 and 2013.

Table 8: The Tigris Riverbanks Displacement

CS No.	Distance (m)		CS No.	Distance (m)	
	Left Side Deposition	Right Side Erosion		Left Side Deposition	Right Side Erosion
0+000	56	-25	**2+750**	74	63
0+250	61.5	-25	**3+000**	108.3	52
0+500	140	0	**3+250**	20	50
0+750	220.5	44	**3+500**	23	18.5
1+000	272.5	38.5	**3+750**	13	8
1+250	298	50.5	**4+000**	-32	34
1+500	277	38.5	**4+250**	65	40
1+750	262.5	39	**4+500**	36	-13
2+000	247.5	19	**4+750**	15	-86
2+250	192.5	33.5	**5+000**	-13	-217
2+500	114	36	**5+250**	-59	-352

5.2 Discussion

The Results in this study depends on two main elements. The first is the personal experience to prepare the required layers especially the opinion of the reference cross-sections net, and the second is how to use it to visually and computationally obtaining the reliable results.

1) The area of deposition and the area of erosion are manually measured (return to 5.1.1). As expected from the difference map shown in Figure (15), the area of deposition is larger than the area of erosion as below.
From Table (6): **Deposition Area (A_D)** = 656 102 m^2,
Erosion Area (A_E) = 171 003 m^2.
Diff. in Area= A_D - A_E =485 099 m^2
Rate of Change = A_D/A_E = 656 102 /171 003 = 3.8/1 = 380%.

Donem	Olk	m^2
194	00	99

2) The area of the Tigris River/1962 (as a loop not polygon) and the area of the Tigris River/2013, as mentioned in the paragraph numbered 5.1.1, was measured. The following results was obtained:
Area of the Tigris River/1962 (**A1**)= 2,064,184 m^2, **Area of the Tigris River/2013** (**A2**)= 1,578,869 m^2.
The difference in area between the area of Tigris River/1962 and the area of Tigris River/2013:

Δ Area (Diff. in Area)=**A1-A2**=2,064,184-1,578,869 =485 315 m^2=194.126 Donem

Donem	Olk	m^2
194	03	15

6. Acknowledgements

The author wish to acknowledge "The State Commission on Survey", presented in Eng. Hussain H. Jabour, Assistance manager, and also grateful to the "GIS and mapping Department" presented by Eng. Suaad Jasim, and operators: Zainab Tariq, and Widad Salman for their help in providing the "mosaic aerial photograph" captured in April, 4 1962 as well as the WorldView_1 Pan Satellite Image/2013 for this research, and then for their contributing to present this paper.

References

[1] Henkel M., 2010. "21st Century Homestead: Sustainable Agriculture II: Farming and Natural Resources". https://books.google.iq/books?isbn=1312939680.
[2] Lu et al. 2004."Change Detection Techniques". International Journal of Remote Sensing,Vol 25, no.12,2365-2407.

https://www.google.iq/search?source=hp&q=Lu_etal_2004+Change+Detection+Techniques&oq.

[3] http://www.geography-site.co.uk/pages/skills/fieldwork/fluvial/cross.html.

[4] Clendinning J., 1960, The Principles Of Surveying, 2nd ed. Universal library OU 158243, O.B.E., B.Sc.(Eng.) Surveyor-General, Gold Coast, 1926-1938 , London Black Ie And Son Limited Glasgow, England. https://archive.org/stream/principlesofsurv030822mbp#page/n251/mode/2up

[5] http://www.rgs.org/OurWork/Schools/Fieldwork+and+local+learning/Fieldwork+techniques/Rivers.htm