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Geomorphometric Analysis of Al -Teeb River Meanders Between Al-Sharhani Basin and Al-Sanaf Marsh, Eastern of Misan Governorate, Iraq

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Abstract: The current research deals with the morphology of river course meanders, which can be defined as one of the main geomorphological aspects of the course of the Al-Teeb river in the eastern parts of the Misan governorate, between Al-Sharhani basin and Al-Sanaf marsh. This phenomenon was studied according to the fundamentalist approach by analyzing the spatial relationship between this phenomenon and other natural factors such as the structure, surface, climate, and water resources that led to its occurrence. This relationship was inferred through the application of four morphometric equations for measuring this phenomenon, namely the sinuosity ratio, range and direction, symmetry ratio, and the meander wavelength to width ratio. The results showed that there are 16 meanders, the ratio of which ranged between 1.6 and 4.7, which represent the lowest and highest recorded values, respectively. Some of the meanders were characterized by high symmetry, as is the case with Al-Makhada 1 meander, while others had lower symmetry as with Al-Kiy'ad 1. for meander wavelength to width ratio values tended to differ according to the variation in erosion rates.

Introduction:

River meanders are one of the geological occurrences that result from river erosion, often found to be the river channel pattern of the late maturity and aging stage of rivers (Kasvi et al., 2017). River meanderings are defined as a geomorphological phenomenon that develops automatically in individual river channels during the geomorphological stages referred to by Davis, 1905 of the river erosion cycle, where some river banks in areas of geological weakness are exposed to lateral erosion and sedimentation processes on the opposite bank, which leads to their meandering, and with their development, the river becomes bent (Goudie, 2004). The description of the meandered rivers is used when referring to rivers that flow over broad flood plains and have winding streams. All such rivers show a clear tendency to form meanders as they tend to create alternating fluctuations in their flow from one side to another (Charlton, 2007). In addition, it changes constantly as a result of the difference in slope and variation of the river's current, as well as the ground structure and geological formations of the river valley. Accordingly, the meanders usually seem to translocate and move towards the lower parts of the river. In a late stage of the geomorphological cycle, especially in the late old stage, the river meanders may reach their greatest extension, depending on the course length and width, river current intensity and its slope characteristics, as well as the system of the river’s evolution and the stages of growth it passed through (Fryirs & Brierley, 2012).

The lack of a straight course of river basins is a general phenomenon that occurs in all rivers of the world, including the Al-Teeb basin. It is very rare for rivers to remain straight for a distance of more than ten times their width, except for some rivers that follow a line of refraction, where the direction of the river is closer to straightness, particularly during its initial stages (Migon, 2010). The modern idea behind the formation of river meanders is that the current, by its nature, carries a kind of compound energy that is constantly dispersed and transformed as a result of movement and friction. Since nature tends to lose or transform energy regularly, the transfer of energy to any part of the current will be equal to the alternative part, equivalent to it but in the opposite direction (Sissakian et al., 2014). This proves that river meanders are one of the natural ways of losing or transforming the energy of the river current in an orderly manner. In general, the river course near the concave side tends to be deeper and the current is stronger than it is near the convex part because the water is higher near the concave side than near the convex one (Panizza, 1996).

The main problem is to create an understanding of the nature and characteristics of geomorphological factors and processes that cause the phenomenon of river meanders in the course of the Al-Teeb river between Wadi Al-Sharhani and Al-Sanaf marsh, which is a seasonal river flowing in the eastern Tigris region in Misan Governorate - Iraq. It is hypothesized that the geomorphological factors and processes, represented by the ground structure, surface, climate, water resources, and natural vegetation, as well as the processes of weathering, erosion, transport, sedimentation, and tectonic activity, have an influential and direct role in forming and shaping the meanders of Al-Teeb river in eastern Misan Governorate.

The research aims to clarify the extent of the spatial relationship that exists between the geomorphological factors and processes on the one hand and the formation of river meanders in the course of the Al-Teeb river on the other hand, and to identify each of the spatial variations of this phenomenon, the reason for its distribution in particular regions, plus its morphometric characteristics (standard). It also attempts to present a brief idea about the ability of geomatics technologies to provide research with high-quality information, digital maps, and satellite images.

Materials and Methods:

A set of methods was used to analyze and explain this phenomenon, including spatial spread patterns, formation factors, and the geomorphological processes affecting it. This mainly relied upon geospatial data that is represented by the digital elevation model (DEM) data type (SRTM) with a discriminatory accuracy of 30 m, issued by the US Department of Defense, and the satellite images of the US satellite Landsat ETM + 8Bands for the year 2017 with a distinct accuracy of 15 m, topographic maps of scale 1/100000, issued by the General Authority for Iraqi Survey, as well as the geological and hydrological maps of scale 1/250000 issued by the Iraqi Geological Survey. These datasets were managed using GIS software and remote sensing (ArcGIS V.10.8, EARTH GIS V.1.6, GLOBAL MAPPER V.11, SURFER V.10, GOOGLE EARTH PRO V.7.1), after which a spatial database was created for the search area. Topological analysis and several spatial matching processes were performed to all layers, after which the transition to the stage of geomorphological analysis and interpretation of the phenomenon in question was carried out through the presentation of models that explain the processes of interaction between factor, process, structure and time on the one hand, and the formation of river meanders, their diffusion patterns, and their morphometric (standard) characteristics on the other hand. A set of morphometric coefficients was used to measure the torsion ratio, extent, and direction of the curve, as well as to clarify the symmetry standard for the meander, measuring the length of the turning wave and the average width of the turning path. The following are the most important types of morphometric parameters used in the research:

1. Meander ratio criterion = true stream length / ideal stream length (Nagata et al., 2014).

2. Criterion of range and direction of turn: This parameter was used to measure the degree of deviation of the turning course from the direction of the main run (Zavodinsky & Gorkusha, 2014).

3. Symmetry ratio criterion = A / A + B * 100 (GREGORY & WALLING, 1968);

Where A represents the length of the stream before the turning point at the apex of the bend at the Y point, and B is the length of the stream past point A at the end of the x and y turn.

4. Criterion (meander wavelength / average meander width): This criterion was used to define the areas within a meandering course at which the erosion processes are active, which in turn increase the meander range (Langbein & Leopold, 1966).

The sinuosity Ratio; is sometimes called the curve coefficient, and it is one of the morphometric parameters for measuring the dimensions of river meanders. It is represented by the ratio of the real length of the river to the shortest distance that the river can take between any two points of its course. According to Leopold and Wolman (1960), the riverbed is divided into several patterns that are determined according to this parameter, as its ratio ranges between (1.1 - 4). If the ratio is less than (1.1), then the stream is considered straight, whereas if the ratio ranges between (1.1 - 1.5), the course is considered bent. In case the percentage exceeds that range, then the course is considered a curve (meandering).

Range and Meander Direction; is one of the important morphometric parameters in the study of river meanders, as it helps in identifying the intensity of activity for each of the precipitating and sedimentary geomorphological processes. If the range ends at the top of the concavity, this enables us to measure the erosion processes. The range at the top of the convexity enables us to measure sedimentation processes (Iwata et al., 2003). The range is also used in determining the direction of geomorphological processes, through the determination of the turning course direction

that took the same direction as the axis of the range. In addition, it is used in measuring the degree of deviation of the detoured stream from the direction of the mainstream (Kasvi et al., 2017).

Study Area:

The study area is represented by the southern Al-Teeb River basin within the Iraqi territory, which is located in the eastern parts of Misan Governorate within what is known as the Eastern Al-Jazirah region in the southeast of Iraq (Figure 1) within a longitude (47°08′0.1″E - 47°18′44.3″E) and latitude (32°02′2.3″N - 32°29′38.3″N). The sediments of the Al-Teeb basin are bordered from the south by Al-Sanaf marsh into which it mouths. The southern Al-Teeb basin is one of the seasonal rivers in the Misan governorate, with an area of 334,585 km^2 and a circumference of 165,785 km. As for the total length of the basin, it reached about 51,688 km, starting from its upper sources inside the Iranian lands, where the source basins are located, and mouths into Al-Sanaf marsh. The highest height in the basin reached 220 m, whereas the lowest height is 10 m above sea level. The river runs from the north towards the south and enters the Iraqi borders at an area called Jeshmet Laila and runs towards the southern end. Through its course, it approaches the Wadi Al-Sharhani basin, which is one of its main tributaries inside the Iraqi territories, and it continues along its course until it reaches the western parts of the hills of Al-Band, after which and the river runs into a deep valley until it ends at the western sides of Al-Sanaf Marsh (Intisar Qassim Hussein, 2014; Bashar F. Maaroof, 2017).

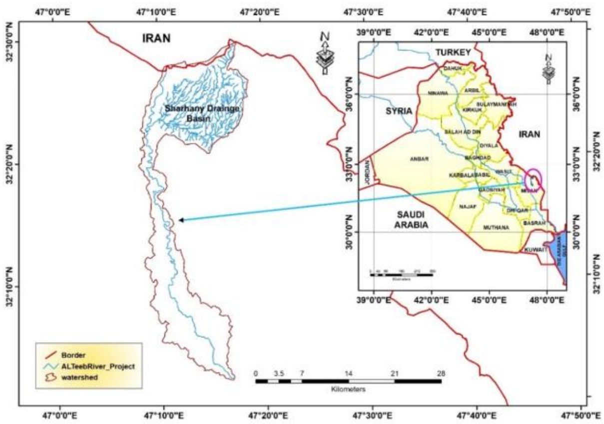

Figure 1. The location of the study area in Iraq.

The study area is covered with quaternary period deposits of up to 80%, which are deposits of the Pleistocene and Holocene eras of water origin, represented by marine sediments and estuaries (Barwary & Slewa, 2014). Muqdadiya and Bai Hasan consider from essential formations and spread further in the northern parts to the Muqdadiya and Bai Hasan formation which consists of sand, gravel, alluvial, and conglomerates rocks as well as sedimentary rocks in form of cycles. This formation dates back to the late Pliocene, and the river environment is the dominant sedimentary environment for this formation (Maitham Ali Al-Ghanmi, 2015).

Bai Hasan Formation dates back to the Upper Pliocene Era, having the same sedimentary environment as the Muqdadiya formation. The contact between the two formations determines the appearance of the first layer of thick crushed stone containing sandstone and mudstone (Fadhil Kassim Al-Kaabi, 2009). Surface flow sediments are exposed in northern and some southeastern parts, dating back to the Holocene period, and are characterized by containing large quantities of secondary brown gypsum from the overlap of sand, silt, and clay. The sediments of the floodplain spread in a wide range on both sides of the Al-Teeb river, starting from the northern parts of the region to the southern parts of the Al-Sanaf marsh. Sand dune sediments spread in some parts of the northern region and took the shape of the plates whose thickness does not exceed one meter, or in the form of dunes that may reach 5 meters in thickness, caused by the blowing of winds in the northwest-southeast direction (Hatem K.S. Al-Jiburi, 2005).

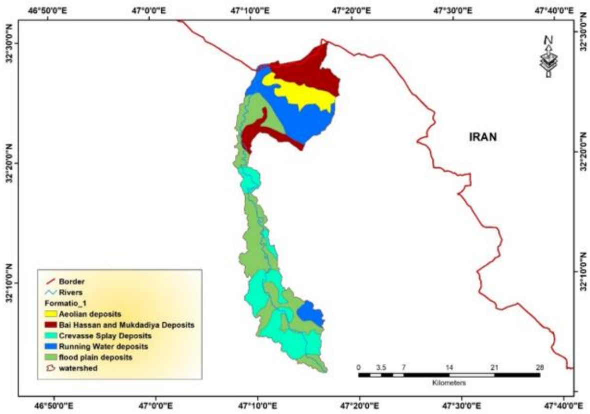

Figure 2. Geological formations of the study area.

The study area was affected by the regional tectonic movements that led to the rise and fall of the geological formations (Maaroof et al., 2021), eventually resulting in the formation of a complex structural system represented by the presence of several convex and concave folds and several surfaces and subsurface faults (Intisar Qassim Hussein, 2014). In general, the linear structures prevailing in the region take the northwest-southeast direction, corresponding to the directions of the axes of the river turns in the region. The density of these structures led them to be weaker areas in the geological formations prepared in light of different geomorphological processes, and these, in turn, result in the formation of the geomorphological features of the river meanders (Almutury & Al-Asadi, 2008). The study area is part of the Iraqi alluvial plain characterized by its surface's general flatness. There are some exceptions in the eastern areas, as they are characterized by a gradual slope which includes a contour line of over 220 m above sea level, located in its easternmost parts, and represents the highest elevation. The contour line is 10 m above sea level and flows in the far south into the mouth of the Al-Teeb river in the Al-Sanaf marsh, as shown in (Figure 3) (Sabah Y. Yacoub, 2010).

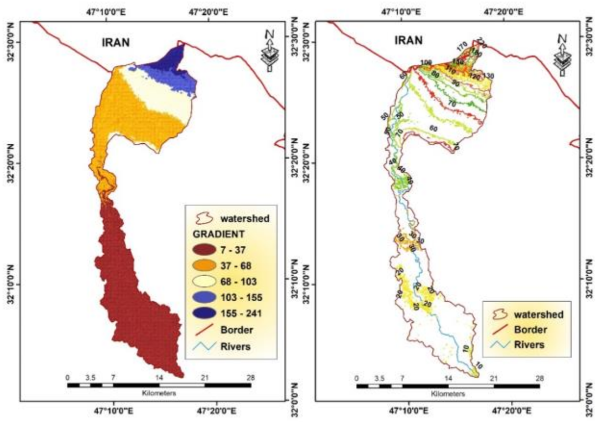

Figure 3. Contour line and the gradual slope of the study area.

There is a clear seasonal variation in the rates of the main climatic elements (temperature, rain, and wind) in the study area, according to the Amarah meteorological station data for the period (1980-2009). The temperatures increase during the summer months (June, July, and August) with its highest rate in July (29.1) °C. the lowest temperature was recorded in January, reaching (6.3) °C (Bashar F. Maaroof, 2022). The rain is characterized by its fluctuation and seasonal fall and maximum in January (34.5) mm, and the lowest was recorded in May (2.1) mm. The north and northwest winds prevail in the study area, and their speed increases during summer, reaching their highest speed in July (5.4 m/s) (Bashar F. Maaroof, 2018), whereas the speed decreases in winter, reaching its lowest speed in January (2.5m/s).

Table 1. The climate of the study area, (Al-Amara climate data center for the period 1980-2009)

Month	Average temperature (°C)	Rain (mm)	Average wind speed (m/sec)
January	6.3	34.5	2.5
February	8.2	22.6	2.7
March	12.2	31.7	2.7
April	18.4	13.3	3.4
May	23.8	2.1	4.5
June	27.2	—	5.4
July	29.1	—	5.4
August	27.9	—	4.7
September	24.1	—	3.7
October	18.9	5.7	3.1
November	14.1	14.5	2.8
December	7.9	19.7	2.7

Results and Discussion:

1. Sinuosity Ratio:

There are 16 meanders in the course of Al Teeb River, which were spatially differentiated in terms of the meandering ratio (Table 2 and Figure 4) the highest meandering rate was in the Shabeeji 1 meander in the central parts of the basin, reaching 4.793. The lowest meandering was recorded at the Um Al-Wawiyah meander in the southern parts of the basin, being 1.602. The rest of the ratios differed from this trend.

Table 2. Actual length, ideal length, and sinuosity ratios of Al Teeb river meanderings.

Name of Meander	Actual Length (km)	Ideal length (km)	Sinuosity ratio
Makhadah 1	1.204	0.492	2.447
Makhadah 2	1.645	0.817	2.013
Makhadah 3	1.076	0.418	2.574
Makhadah 4	1.645	0.774	2.125
Makhadah 5	1.038	0.568	1.827
Makhadah 6	1.333	0.828	1.609
Makhadah 7	1.325	0.499	2.655
Makhadah 8	1.764	0.981	1.798
Al-Ukhaydhir	0.684	0.381	1.795
Al-Kay'ad 1	2.212	1.045	2.116
Al-Kay'ad 2	1.451	0.330	4.396
Al-Shubeeji 1	2.432	0.489	4.973
Al-Shubeeji 2	1.514	0.926	1.634
Al-Rumaiyla	1.820	0.850	2.141
Um Alwawiyah	1.435	0.895	1.603
Al-Ukhtayt	1.568	0.924	1.696

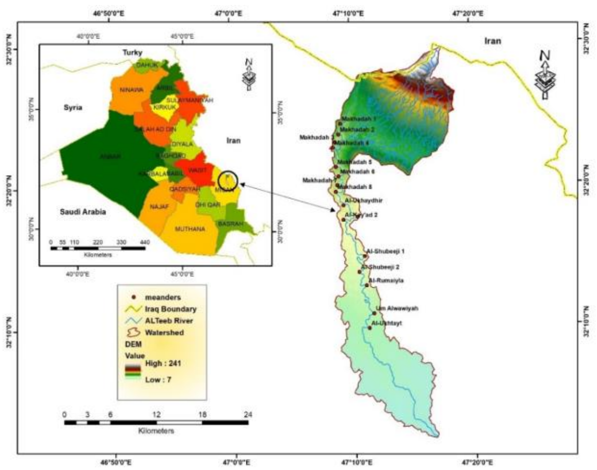

Figure 4. Location of meanders in the area of study.

The variation in the meandering ratio of the bends of Al Teeb river is due to the variation in the rocky nature of the area, which ranges between fragile rocks and weak resistance to erosion and weathering processes and thus is vulnerable to these processes, which consequently leads to an increase in the rate of meandering. Solid rocks tend to be more resistant to these processes, which leads to a decrease in the proportion of this factor. Furthermore, increasing the regression value leads to a decrease in this ratio, and vice versa in the case of areas with a slight slope. In addition, the seasonal variation of the climatic processes affects the severity or weakness of the weathering and erosion processes that, in turn, sculpture and strip the banks on the one hand, and sediment the crumbs onto the opposite banks, on the other hand, thereby increasing the meander and torsion, the increase in the quantities of water drainage during rainstorms stimulates erosion operations, which in turn carve out concave banks and sediment onto the convex banks, and this process is accompanied by an increase in the rate of meandering. The processes of tectonic activity and the resulting linear aspects aren’t less important in influencing the ratio of this parameter (Maaroof & Kareem, 2020).

2. Range and Meander Direction:

There is a large variation in the value range of the study area's meanders (Table 3 and Figure 5) the highest value was in Al Shubeeji 1 meander is 931.712 m, whereas 239.379 m was recorded for Al Ukhaydir, in the region, whereas (239.379m) has been recorded for Al-Ukhaydhir, being the lowest recorded value.

The reason for the spatial variation of the range values of the meanders in the study area is attributed to several reasons. The geological factor is represented by the rock diversity, as the resulting variation in the rates is in response to river erosion processes, as the flood plain (Fig. 2). The erosion processes increase on the concave side, which corresponds to the sedimentation processes on the convex side (Fig. 5). In addition, the slope factor has a significant effect, as a positive correlation exists between the degree of slope and the erosion rates, whereby both would increase simultaneously. Besides, basic elements of climate, especially rain, also have an important role, as the rise in precipitation is followed by an increase in the water flow quantities. This consequently increases erosion rates. In case the range values decrease, as with Al-Ukhdayir meander (Fig. 6), this indicates a condition that is relatively less affected by the factors mentioned above.

Figure 5. Al-Shubeeji 1 Meander in the study area.

Figure 6. Al-Ukhaydhir Meander in the study area.

The directions of the meanders recorded a clear discrepancy at all levels of the study area. The meanders Makhadah 1, Makhadah 2 (Figures 1 and 2), Makhadah 6, and Al-Shabeeji 2 took a western direction, whereas each of (Makhadah 3, Makhadah 4, Makhadah 8, and Al-Kay'ad 2 the northwest direction. Makhadah 5, Makhadah 7, and Al-Ukhaydhir meander tended towards a southwestern direction (Table 3).

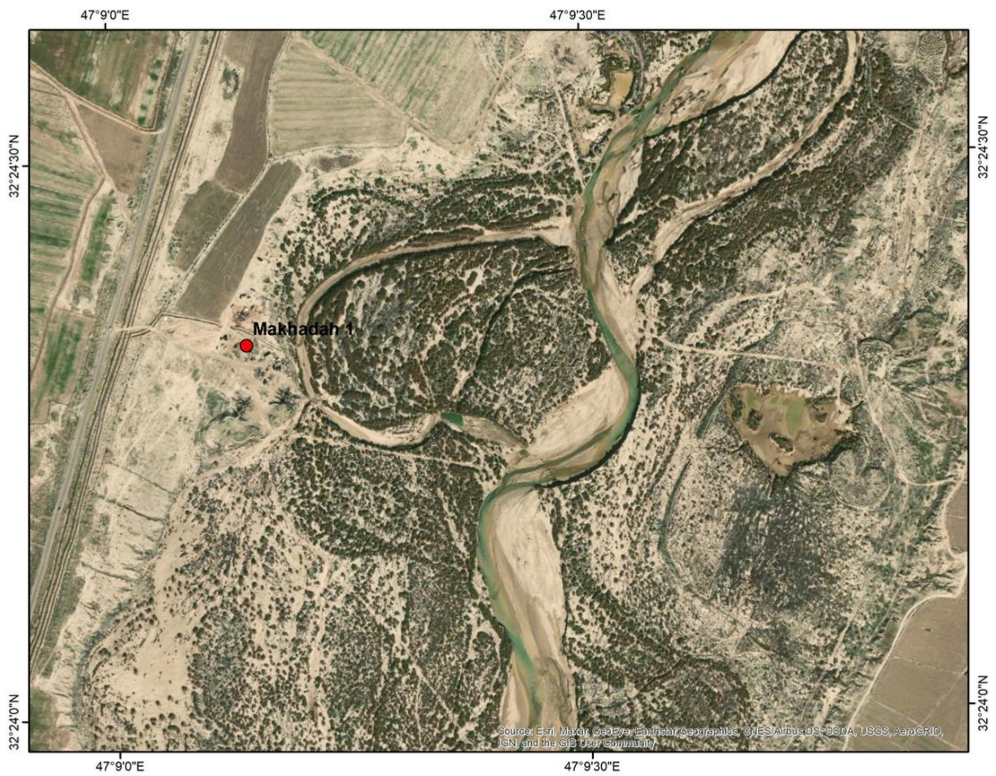

Figure 7. Makhadah 1 Meander in the study area.

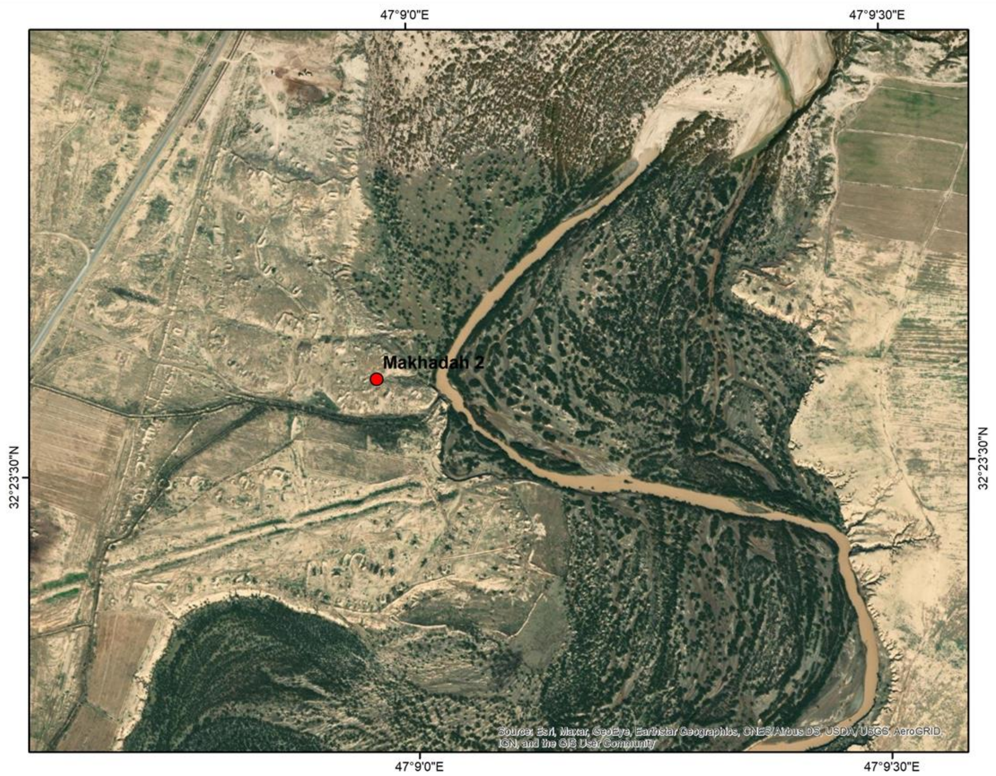

Figure 8. Makhadah 2 Meander in the study area.

Table 3. Range and Meander Direction of Al Teeb Rever.

Name of Meander	Range	Direction
Makhadah 1	476.936	West
Makhadah 2	691.798	West
Makhadah 3	492.129	Northwest
Makhadah 4	642.327	Northwest
Makhadah 5	464.192	Southwest
Makhadah 6	496.229	West
Makhadah 7	602.879	Southwest
Makhadah 8	744.316	Northwest
Al-Ukhaydhir	239.379	Southwest
Al-Kay'ad 1	906.561	Southeast
Al-Kay'ad 2	656.386	Northwest
Al-Shubeeji 1	931.712	Southeast
Al-Shubeeji 2	461.044	West
Al-Rumeyla	736.805	Northeast
Um Alwawiyah	434.958	Southeast
Al-Ukhtayt	598.981	Southeast

3. Symmetry Ratio:

There was a variation in the symmetry ratios of the meanders of the study area, even at the level of the two halves of symmetry (X and Y). Each of the meanders (Makhadah 1, Al-Ukhdaydhir, Al-Shabeeji 1, Al-Shabeeji 2, and Al-Rumayla) were symmetrical (Table 4 and Figure 9). The remaining meanders were asymmetrical. The probable reason for the asymmetry can be traced back to the increase in the effectiveness of erosion processes at one end of the symmetry (X and Y), that work on the concave banks in the two parts (XA and YA) (Figure 10), as well as the sediment onto the convex banks. This situation seems to be increasing, especially in the part (YA), whereas other natural factors of structure, surface, and climate have both a direct and indirect effect on stimulating the mass erosion processes that contribute to the edge formation in asymmetric meanders.

Table 4. Symmetry rate values for the meanders of the Al Teeb river.

Name of Meander	Side X		Symmetry rate side X	Side Y		Symmetry rate side Y	Symmetry degree
	Length A	Length B		Length A	Length B		
Makhadah 1	289	306	48.5	339	314	51.9	Symmetric
Makhadah 2	623	246	71.6	418	460	47.6	Asymmetric
Makhadah 3	370	216	63.1	302	402	42.8	Asymmetric
Makhadah 4	619	341	64.4	243	460	34.5	Asymmetric
Makhadah 5	309	198	60.9	336	481	41.1	Asymmetric
Makhadah 6	344	448	43.4	334	527	38.7	Asymmetric
Makhadah 7	824	294	73.7	259	570	31.2	Asymmetric
Makhadah 8	416	514	44.7	286	527	35.1	Asymmetric
Al-Ukhaydhir	232	213	52.1	194	154	55.7	Symmetric
Al-Kay'ad 1	768	349	68.7	630	463	57.6	Asymmetric
Al-Kay'ad 2	427	184	69.8	593	247	70.5	Asymmetric
Al-Shubeeji 1	883	741	54.3	635	760	45.5	Symmetric
Al-Shubeeji 2	445	372	54.4	375	321	53.8	Symmetric
Al-Rumayla	472	416	53.1	479	505	48.6	Symmetric
Um Alwawiyah	434	356	54.9	436	264	62.2	Asymmetric
Al-Ukhtayt	654	274	70.4	483	332	59.2	Asymmetric

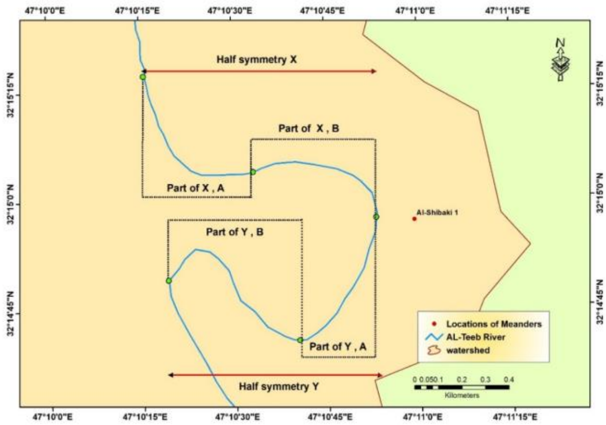

Figure 9. Semi-symmetry of Al-Shubeeji 1 meander.

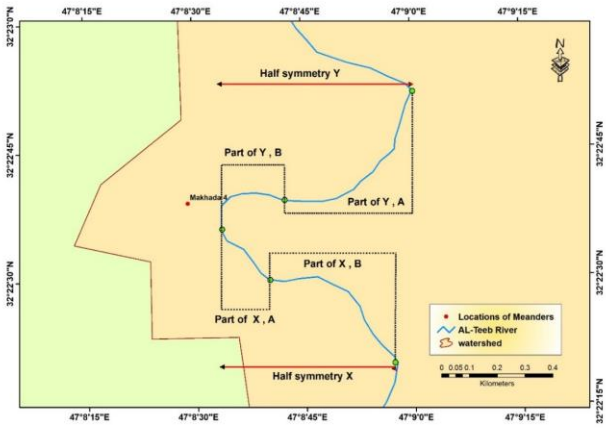

Figure 10. Semi-symmetry of Al-Makhadah 4 meander.

4. Meander wavelength to width ratio:

This criterion is used to express the correlation that exists between the meander wavelength and the average width of the meandering stream (Centurioni et al., 2008). It is measured by dividing the turning course into four sections, separated by five points (A, B, C, D, E). The distances between the sections are not necessarily equal, but the locations of the points are fixed. The point (C) represents the peak of the reflection wave and its position is fixed in the middle. The location of the two points (A and B) is to the left, whereas the two points (E and D) are located to the right of point C (Figure 11). The main objective of using this criterion is to define the areas within the diverted riverbed in which the erosion processes are active, as these in turn increase the meander range.

Through the data, the highest was recorded for this criterion was in Al-Ukhtayt meander, which is located in the far south of the basin (Figure 4), as it reached (37.8) (Table 5). This is clear evidence of the relative activity of erosion processes, including erosion, transport, and sedimentation. In addition, this meander falls within the aging phase of the geomorphological cycle (Divesian) The geomorphological characteristics of this phase are represented by the meandering of the riverbed that appears to be U-shaped, with relative activity of the lateral erosion process and the sedimentation process on the opposite side, which eventually leads to an increase in the meander range. The lowest value was in the Al-Kay'ad 2 (Fig. 4) (11.7). This indicates the lack of erosion activity due to its structural condition, as the location of this meander, corresponds to the (northwest-southeast) direction. The erosion activity is impeded, as well as the occurrence of this meander within sediment formation slopes.

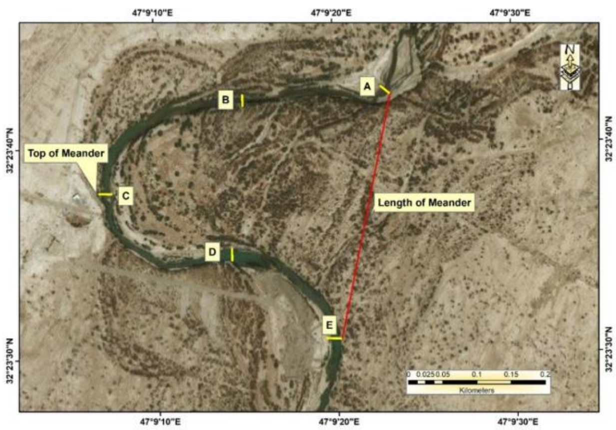

Figure 11. Makhadah 8 meander.

Table 5. Meander wavelength to width ratio.

Name of Meander	Meander course width (m)					Average meander width	Wavelength (m)	Wavelength to width ratio
	A	B	C	D	E			
Makhadah 1	17	17	22	25	17	19.6	492	25.1
Makhadah 2	36	37	33	34	37	35.4	817	23
Makhadah 3	20	31	19	33	35	27.6	418	15.1
Makhadah 4	33	40	24	34	25	31.2	774	24.8
Makhadah 5	23	25	25	29	23	25	568	22.7
Makhadah 6	30	29	26	23	23	26.2	828	31.6
Makhadah 7	21	17	21	17	21	19.4	499	25.7
Makhadah 8	35	29	33	26	23	29.2	981	33.5
Al-Ukhaydhir	30	31	21	30	20	26.4	381	14.4
Al-Kay'ad 1	29	23	31	27	33	28.6	1045	36.5
Al-Kay'ad 2	22	30	36	25	28	28.2	330	11.7
Al-Shubeeji 1	21	34	43	26	34	31.6	489	15.4
Al-Shubeeji 2	31	21	39	32	31	30.8	926	30
Al-Rumayla	34	30	28	31	34	31.4	850	27
Um Alwawiyah	26	31	26	28	33	28.8	895	31
Al-Ukhtayt	23	22	19	22	36	24.4	924	37.8

Conclusion:

There are 16 meanders in the course of the Al Teeb river, which differ spatially and have varying values of the meandering ratio. The highest meandering ratio was in the Al-Shabeeji 1 meander in the central parts of the basin, there is also a great variation in the range of the study area's meanders, and symmetry ratios of the meanders in the study area. This indicates that the basin falls within the late maturity stage of the geomorphological cycle. The geomorphological characteristics of this stage are represented by the meandering of the riverbed with the relative activity of the lateral erosion process and the sedimentation process on the opposite side, which leads to an increase in the meanders range. This indicates that there is a lack of erosion activity due to its structural condition, as the location of this meander corresponds to the northwest-southeast direction that hinders the erosion activity.

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التقييم الجيومورفومتري لمنعطفات نهر الطيب بين حوض الشرهاني وهور السناف، شرقي محافظة ميسان، العراق

المستخلص:

تناول البحث مورفولوجية المنعطفات النهرية، وهي أحد المظاهر الجيومورفولوجية الرئيسة لمجرى نهر الطيب في الاجزاء الشرقية من محافظة ميسان بين وادي الشرهاني وهور السناف، وقد تمت دراسة هذه الظاهرة وفق المنهج الاصولي من خلال تحليل العلاقة المكانية بين حدوث هذه الظاهرة وبين العوامل الطبيعية (البنية، السطح، المناخ، الموارد المائية) التي أدت الى حدوثها ، وقد تم الاستدلال على هذه العلاقة من خلال تطبيق أربعة معادلات مورفومترية خاصة بقياس هذه الظاهرة (نسبة التعرج، المدى والاتجاه، نسبة التناظر، طول موجة الانعطاف الى عرض المجرى المنعطف) ، وقد اظهرت نتائج هذا البحث بان هنالك 16 منعطفاً تراوحت نسبة تعرجها بين (4.7) وهي أعلى قيمة الى (1.6) وهي أدنى قيمة، كذلك فقد تراوحت نسب المدى بين (931.7)م لمنعطف الشبيجي1 وهي أعلى قيمة و(239.3)م لمنعطف الاخيضر وهي ادني قيمة ، وقد امتازت بعض المنعطفات بقيم تناظر مرتفعة كما في منعطف مخاضة ، في حين امتاز البعض الآخر منها بقيم تناظر منخفضة كما هو الحال في منعطف الكيعاد1، اما بالنسبة لمعيار طول موجة الانعطاف الى عرض المجرى المنعطف فهو الآخر كانت قيمه متباينة بسبب تباين معدلات التعرية.

الكلمات المفتاحية: الجيومورفولوجيا النهرية، المنعطفات النهرية، الخصائص القياسية للمنعطفات النهرية، التقنيات الجيومكانية.