

REGULAR ARTICLE

Evaluation of River Hydromorphology Using the Morphological Quality Index (MQI): A Case Study of the Megun–Fasham River Section

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All data will be shared on request.

Institutional Review Board Statement

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Abstract

Over the past two decades, riverbeds in mountainous areas have been manipulated by humans due to their tourist attractions. Today, river geomorphology has entered a new era and turns to the basis of studying environmental changes which are used to River canal management. So, studying the trend of hydromorphological of this river is very essential. The purpose of this study was to evaluate the hydromorphological conditions of a part of Jajrood River from Meghun to Fasham using MQI method. In this regard, the desired information was collected using field observations, remote sensing science and geographic information system. After preparing satellite images, the river was intercepted and divided into 7 sections using the MQI method. The first and second phases determined the quality of the intervals and the number of changes. The study results show that there have been many changes in the bed in this part of the river. In the northern parts, due to the limitation of the river on both sides, the intensity of changes is less, while in the middle parts of the river, according to the numerous constructions on both sides of the river, the intensity of destruction is also higher. One of the most important issues in using MQI method is the researcher level of expertise. Data collection is based on a combination of remote sensing, GIS analysis and field navigation and should be done by operators with background and appropriate training in river geomorphology because having specialized knowledge of river geomorphic concepts is necessary for the application of MQI.

Keywords

Aquatic environment; Hydromorphology; Damaged River ecosystem; Restoring.



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Introduction

Rivers are the source of life and the foundation of human activities. With the progress of urbanization, people have made many uses of rivers in different ways. However, over-channelization and diversion of rivers, sluice control projects, and the discharge of a large number of industrial and agricultural pollutants have also affected the ecological status of rivers to varying degrees. As a result of the irrational use of the river, water pollution, insufficient ecological water, and the shrinking of the aquatic environment are apparently widespread, and the ecological problems of the river are increasing (Ren et al., 2022). With the rapid development of industry and agriculture, the intensity of human exploitation of rivers has gradually increased, so rivers have been under a lot of pressure from human activities, and some of the service functions of rivers show the process of degradation (Pan et al., 2016). Humans profoundly alter river landscapes by altering watersheds, climate, and channels, which in turn alter hydrologic, biological, and sediment fluxes through river systems (James & Marcus, 2006).

Human impacts on rivers result from a wide range of activities, from stabilization of local floodplains to watershed-level effects of large dams to global changes in precipitation through greenhouse gas emissions. Regardless of the specific stimulus or scale of concentration, impacts often alter the

connections within a river system that exchange water, sediment, and fauna between river landscape components. Components include channels, riparian zones, floodplains, terraces, and hillsides. Changes in connectivity may be the most common feature of human impacts on river systems (Wohl, 2001, 2004).

To restore the damaged river ecosystem to a healthy state, effective ecological restoration measures should be implemented (Pan et al., 2016). The term "river regeneration" is used to describe the adaptive processes by which rivers recover their geomorphic status after disturbance (Fryirs & Brierley, 2000). River restoration is a growing focus of scientific activity that draws on a long history of intervention in watercourses for various economic and social reasons and indicates the changing dynamics of the relationship between nature and society (Smith et al., 2014). Human activities have caused the destruction of rivers and streams and as a result disruption in providing valuable services. Therefore, the restoration of these ecosystems can bring many benefits that contribute to the well-being of society (Garcia et al., 2020). Rivers provide a wide range of ecosystem services, habitats for rare and endangered species, and water for use by human communities. Over the past 200 years, rivers have been degraded by human impacts, requiring large investments in restoration and rehabilitation (Tedford & Ellison, 2018).

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Considering the diversity and complexity of river systems, prioritization and targeting of key actions is effective and efficient for any river management strategy (Beechie et al., 2009). Rinaldi et al. (2017) introduced a set of tools developed in the framework of the European REFORM (Restoring Rivers for Effective Catchment Management) project. These tools are specific hydro morphological assessment methods that include a set of clearly defined steps and represent the REFORM hydro morphological assessment methods.

Meanwhile, the morphological quality index (MQI) is used to evaluate the overall morphological conditions of a river as a result of changes that occur on a relatively long-term scale (i.e., about the last 100 years) (Belletti et al., 2018). The MQI approach is based on the judgment of an expert who has knowledge and experience. Its design is relatively simple and does not take much time. This approach is based on considering the processes and aims to evaluate the morphological quality. Reference conditions are defined in the approach to dynamic processes and functions that are expected to occur normally in a given physical context. The key scale of this approach is access to the river, which can be defined as follows: General identification and setting of landscape units as well as parts, definition of types of enclosure, scope of identification of types of morphology and consideration of other factors. The morphological quality index consists of 28 indices, which are divided into three main components: geomorphological function, channel and artificial regulation. This approach seeks to provide a comprehensive and overall assessment of the state of the river to facilitate the understanding of stress and reaction conditions (i.e. cause and effect), thus supporting the identification of possible management operations (Rinaldi et al., 2017). The purpose of this study is to investigate the hydro morphological changes of a part of Jajrood River from Migun to Fasham using MQI method.

Materials and methods

Study area

The study area is part of the Jajrood River in northeastern Tehran in Iran, which is located in the Lavasanat basin and covers from the south of Meghun to Fasham in the north of the Latian Dam (Figure 1). The study area length is 9.2 km. Jajrood River is located 30 km northeast of Tehran, which flows from northwest to southeast and flows from the source area (Alborz Mountains) to lower altitudes and enters the Latian dam. This river originates from Klon Bastak mountains in the north of Darbandsar village, Fasham, Meygon, Damavand, and Ahar branches flow into this river. The river, with a length of 40 km and an area of 710 square kilometers, has a slope of 7.7 and a gravel river, cut sand.

The average annual water flow in Latian station is 6.61 cubic meters per second and the maximum annual average is 21.8 and the minimum annual average is 3.2 and the minimum monthly average is 0.13 in November and finally, the maximum instantaneous flow (at Rudak station) is 60 cubic meters in seconds. Geologically, the study area is located on the Karaj Formation (middle tuff section), Tehran alluvium, and conglomerate. All these formations belong to the Cenozoic period. In terms of altitude from 1535 meters to 2500 meters and from south to north is added to the height of the region.

Research tools

Physical instruments: The topographic map of 1:25000 related to the Mapping Organization of Iran and geological maps of Iran 1:100000 series prepared by the Geological Survey of Iran were used to identify features and formations, as well as satellite images of Earth Google and Landsat 8 was used to identify and adapt terrain to the ground. 1:500 aerial photographs of the area have also been used to accurately identify riverbed changes.

Conceptual instruments: Topographic and geological maps were digitized using Geographic Information System (GIS) software so that the necessary information can be organized, analyzed, displayed and managed.

- 1) In this research, ArcGIS, AutoCAD and ENVI Microsoft Office software sets have been used in general.
- 2) Aerial and satellite images have been used in remote sensing software to accurately identify changes and analyze data. Then, the data collected through field observations, remote sensing and Good Environmental Status (GES) were analyzed using MQI method and the quality of intervals and the amount of changes were determined.

MQI

First phase: The first phase of the MQI method consists of four steps.

Step 1: In this step, the characteristics of geology, geomorphology, climate and land use of the entire catchment area are examined, the result of which is the identification of physiographic units. Table 2 shows the characteristics and status of the intervals in general in the study area. Thus, intervals 2 and 7 are in average condition, intervals 1-3-4-5 are in weak condition and interval 6 is in very weak condition.

Step 2: In the second stage, the side limitation of the river is examined with more details, and three limited, relatively limited and unlimited situations (from free parties) are identified. These terms are used for natural valleys, which in turn are limited in width to ancient slopes or terraces. While artificial factors (border guards) are protected, urban sprawls and areas are not considered as limiting factors. And they are not directly in contact with the slope plate and are defined as "constraint index" in relation to the width of the alluvial plate and the width of the channel.

Step 3: At this stage, the canal morphology is based on the canal constraint and the planimetric pattern is divided into seven classes: direct, sinusoidal, rivet, single canal, circulatory artery, and rotating artery. For more details in this step, the riverbed configuration method can be used for a single channel area.

Step 4: Due to the discontinuity in the channel, such discontinuities hydrological sub river, dams (tilt bed) especially for periods limited to, changes associated with channel width, the width of the alluvial plain and stream sediment loads to periods of relatively homogeneous. These bodies usually represent the initial units for assessing morphological conditions for several kilometers (Esmaili & Valikhani, 2018). In natural or artificial hydrological disturbances, the continuation of significant changes in sediment discharge or transfer can be considered. Artificial disturbances are mainly detected by the construction of dams. Similarly, regulatory barriers or diversion structures are commonly considered as access restrictions.

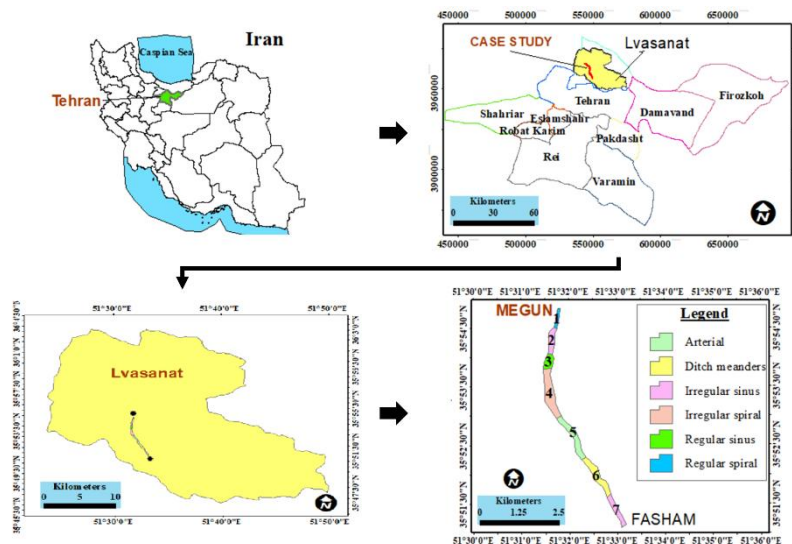


Figure 1. Location of the study area.

Table 1. A summary of the general situation and division method

Stages	Measure	Output
Step 1: Public Position and Identification Physiographic units	-Physiography unit -Sections	Geological features and Geomorphology
Step 2: Definition of various valley constraints	Types of river constraint modes Unlimited PC ratio C -Unlimited U	Lateral constraints
Step 3: Identify different morphological types	Morphological typology Limited Anastomosis: Single Channel, Wandering Artery, Relative to unlimited and unlimited: direct, sine, Torsion, sinusoidal with alternating barriers, arterial, Wandering, branching anastomosis	Planimetric feature (Sine indices, Arterial, anastomosis)
Step 4: Segmentation of intervals River canal	Intervals	More discontinuities in Hydrology of bed slopes, width Channel, width of alluvial plain, Bed sediments

Table 2. Characteristics and status of intervals

Interval	Patterns	Features	Morphological status	MQI score
1	Winding meanders without shortcut channels	Approx., Slope 4.5, existence of protection on both sides of the river, existence of 18 transverse structures, cascade morphology, rapid and rising water, existence of gardens, vials, fishponds around the river, existence of embankment in parts of the river	weak	45%
2	Irregular sinuosity	Approx., Slope 1/5, sand sediments, rubble and sand, creation of artificial canals and water withdrawal from the river	average	53%
3	Trench Meander	Sabta Limited, recreational areas and villas around the river. The morphology of the platform in this interval C and rising water, the presence of numerous longitudinal and lateral obstacles, are moderate adjustment indicators of the severe type.	weak	43%
4	Regular spiral meanders	Sand and gravel, the presence of longitudinal and lateral obstacles, the width of the river 3 to 8 meters, the morphology of the platform and rising waters	weak	48%
5	Irregular sinuosity	Relatively unlimited, platform morphology, form and rise, longitudinal and lateral sedimentary barriers, timber within the river route, slope of 4.8, the presence of transverse structures,	weak	39%
6	Regular Sinuosity	Covered with rubble and sand, platform and rapids morphology, longitudinal and lateral barriers, significant reduction of vegetation	very weak	28%
7	direct	Unlimited, covered with rubble, rising water, sand harvesting	average	51%

Table 3. List of indicators as a function of the main aspects (continuity, morphology and vegetation (and evaluation components), functional, artificial and channel adjustment.

Channel adjustments (CA)	Artificial (A)	Functional (F)	dimensions	coefficients
	A1, A2, A3, A4, A5	F1	length	continuity
	A6, A7	F2, F3, F4, F5	lateral	morphology
	A8 (A6)	F6, F7, F8	Channel pattern	
CA1	(A4, A9, A10)	F9	Cross-section	
CA2, CA3			More sediments	
	A9, A10, A11	F10, F11		
	A12	F12, F13	Plant coverage	

Second Phase: Evaluation structure and indicators

The following three aspects have been considered to evaluate the morphological quality of river sections (Lemay et al., 2021): (i) Continuity of river processes, including longitudinal and transverse continuity; (ii) Channel morphological conditions include channel pattern, cross-sectional shape and closure sediments; (iii) Plant coverage.

These aspects are analyzed in the form of three components: 1. Geomorphological functions of river processes and shapes (F, 2. Artificial structures (A) and 3. Channel adjustments (CA).

A set of 28 indicators is used in the MQI method, which includes aspects in rows (and components in columns). Each indicator is scored on a three-point basis: A is related to undisturbed conditions or insignificant changes; B relates to moderate changes; and C relates to highly altered conditions. In addition to the combined value of MQI, 11 sub-indices that represent the conditions of specific elements (such as artificiality, longitudinal and lateral continuity, vegetation) can be calculated and can be used to identify the main types of changes in a riverbed.

Results and discussion

Hydromorphological conditions (Mandarino et al., 2024) are assessed using the MQI scoring criteria, with lower scores representing natural landscapes and higher scores representing man-made landscapes (Moshe et al., 2022; Rinaldi et al., 2016; Rinaldi et al., 2013). The study area was first divided into 7 intervals according to geomorphological features,

Interval 1:

The bed of this river in this period consists of a mixture of rubble and coarse sand. This range is of limited type. The river is located on both sides of the valley. The average slope of the river in this interval is 4.5 degrees. The average height of this range is 2000 meters. Residential and industrial areas are located on both sides of the river. The width of the canal varies from 3 to 7.5 meters, and its pattern is winding meanders without shortcut canal. At 90% of the length of this interval, guards are seen on both sides of the river. There are also 18 transverse structures such as bridges, culverts and streams in this range. Also in this period, several embankments are observed in contact with the river. According to the study of El Hourani et al. (2022), since there are only a few river sections with transverse, backwater or piped structures, the

reason for the poor condition must stem from the parameters of the cross-banks, flow variability and depth variance. Its morphology is in some parts of the cascade, rapid and rising waters (Figures 2 and 3).

Interval 2:

In this interval, the river is adjacent to the margin on both sides, so this interval is also limited. Residential, recreational and private areas are located along the river. The slope of the river in this part is on average 1.5 degrees and its average height is 2000 meters. The width of the canal varies from 2 to 7 meters. The channel bed is made of sand, rubble and sand sediments. Morphologically, it has an irregular sinusoidal pattern. In study of Li et al. (2024) and Abad and Garcia (2009) mentioned that a sinusoidal curve symmetrical in the direction of flow has been proposed as an ideal description of river meanders. However, it may not be suitable for asymmetric river bends. In such cases, the Kinoshita curve is used to describe river bends by adding third-order terms, which allows for planar shapes with skew and fattening.

This period has also had changes due to its proximity to the surrounding settlements, which include 1. Change of use and new constructions around the river, 2. Creation of artificial canals and withdrawal of water from the river, including human interventions in the riverbed (Figures 4 and 5).

Interval 3:

This river is partially limited. In some parts of the river, it is connected to the riverbank on both sides. Its pattern is of the ditch meander type. The communication road is located along the river, which has led to the formation of recreational and private areas around the river. In some parts, the river is connected to the slope on one side. Its bed is covered with rubble, which in some parts are located longitudinally and laterally along the river. Its morphology is platform and rising water. Its width varies from 2.5 to 7 meters. C-adjustment indices in this interval were of severe type. Its MQI is 0.43, which is in a weak position (Figures 6 and 7).

Interval 4:

The bed of this river is rubble and sand. The width of the river varies from 3 to 8 meters. Its pattern is regular spiral meanders. Longitudinal and lateral barriers are seen within the canal. On both sides of the river are residential areas that are mostly villages. Platforms and risers are observed along the canal (Figures 8-10).

Interval 5:

This river passes by Fasham. Its pattern is irregular sinuity. Its morphology is platform, mold and water, and shapes such as longitudinal sedimentary barriers and lateral barriers are also observed within the canal. The height of this range is about 1950 to 1900 meters. Its average slope is 4.8 degrees. In most parts, the river is connected to the riverbank on one side. There are several timber obstacles along the river. As well as numerous transverse structures that have been constructed on the river. In this period, like the other three periods, several residential areas can be seen on both sides of the river. This has changed the shape of the river in some parts. During this period, the branch overflows to it. This range is equal to 0.39 which is in a weak position. In other words, the amount of changes has been high during this period.

Interval 6:

This interval has a regular sinusoidal pattern. The riverbed is also covered with rubble and sand. The slope of the river in this part is less and is about 4.1 degrees and its average height

is 1888 meters. Its morphology is platform and fast water. Longitudinal and lateral barriers can be seen inside the canal, which in most places blocks the river. The amount of vegetation in this period has decreased compared to other periods. There have been many changes during this period.

Interval 7:

This interval has a straight pattern and is open on both sides. Its bed is full of rubble, which is protruding in most of the bed. Its width varies from 6.5 to 9 meters. Its morphology is watery. Its average height is 1800 meters. Residential areas have also been formed around this period.

The hydromorphological evaluation of the Jajrood River from Meghun to Fasham, utilizing the Morphological Quality Index (MQI), indicates considerable differences in the river's state over seven separate sections. Table 4 presents the MQI scores for every reach, whereas Figures 17 and 18 offer visual representations of the attributes of Reach 7. This part examines these findings, relates them to wider studies, and considers their significance for river management.



Figure 2. Existence of transverse structures on the river in interval 1



Figure 3. Existence of pools around the river in interval 1.



Figure 4. Existence of longitudinal barriers within the river channel in interval 2.



Figure 5. Existence of wooden barriers inside the canal and steep slope of the riverbank.



Figure 6. Existence of a steep slope along the river in interval 3.



Figure 7. Existence of obstacles in the river in interval 3.



Figure 8. Existence of rising water in the course of river water in interval 4.



Figure 9. Existence of timber obstacles in the river water path in interval 4.



Figure 10. Existence of longitudinal obstacles and two-way river in interval 4.



Figure 12. Existence of rubbles and rising water along the river in interval 5.



Figure 13. View of the river in interval 5 and unstable slopes along the river.



Figure 14. Manipulation in the river channel in interval 5.



Figure 15. Existence of water bumps and obstacles in the river route in interval 6.



Figure 16. Existence of wooden barriers in interval 6.

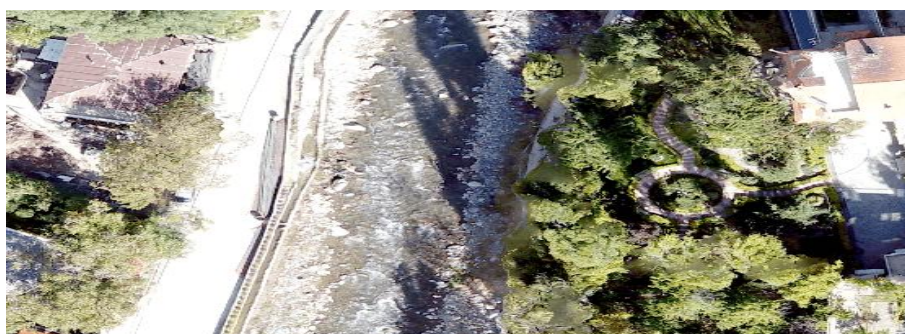


Figure 17. Existence of sand bed and rubbles in interval 7.



Figure 18. Sand harvesting in interval 7.

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Table 4 displays the scores for 28 MQI indicators, categorized into three components, geomorphological functionality (F), artificial structures (A), and channel adjustments (CA), for every reach. The total MQI scores vary from 0.28 (very low) in Reach 6 to 0.53 (moderate) in Reach 2, demonstrating a range of conditions influenced by both natural and human elements. Levels 1, 3, 4, and 5, with MQI ratings of 0.45, 0.43, 0.48, and 0.39, respectively, are deemed inadequate. For instance, Reach 1 achieves high marks in artificiality indicators, including A3 (transverse structures, score: 6) and A10 (bank protections, score: 6), because it features 18 structures such as bridges and culverts, along with significant embankments. Likewise, Reach 5 displays high CA1 (6) and CA2 (6) scores, signifying considerable alterations of channels due to wooden barriers and adjacent housing projects.

Reach 6, exhibiting an MQI score of 0.28, is in the poorest state, primarily due to elevated artificiality (A10: 6, A12: 6) and decreased vegetation cover (F13: 5). The consistent winding pattern in this section, along with longitudinal and lateral obstacles, indicates significant morphological degradation, probably resulting from urban and recreational intrusion. This coincides with Mandarino et al. (2024), who discovered that urbanization can significantly affect river morphology. On the other hand, Reaches 2 and 7, which have scores of 0.53 and 0.51, are in mediocre condition. Reach 7 notably takes advantage of an unobstructed channel and reduced artificial structures (A1–A5: 0–3), facilitating the continuation of natural processes such as sediment movement, as explained by Wohl (2004).

These scores indicate a spatial trend: northern areas, such as Reach 7, exhibit superior morphological quality owing to reduced human interference, whereas middle reaches (3–6) suffer significantly from alterations in construction and land use. This trend reflects the observations made by James and Marcus (2006), who indicated that human influences are especially evident in regions with high land use intensity, like the middle reaches of the Jajrood.

Figures 17 and 18 depict the hydromorphological features of Reach 7, which enhance its comparatively higher MQI score (0.51, average). Figure 17 depicts a riverbed blanketed with stones and sand, illustrating a natural sediment pattern. The linear channel configuration and absence of side restrictions facilitate active sediment movement, an essential element in preserving geomorphological integrity (Wohl, 2004). The jutting debris in Figure 17 suggests ongoing sediment transport, aligning with the low channel adjustment scores (CA1: 0, CA2: 0) shown in Table 4, since the channel maintains its original shape.

Figure 18 shows sand extraction in Reach 7, a specific human impact. This action adds to a moderate artificiality score (A11: 3), though its impact is not as severe as the extensive structural modifications (e.g., embankments,

transverse structures) observed in other areas. Pan et al. (2016) propose that localized resource extraction, such as sand harvesting, can harm river ecosystems but tends to have a less severe effect than extensive urban development or channelization. The largely unaltered vegetation in Reach 7 (F12: 3, F13: 0) enhances its average state, since vegetation reinforces banks and sustains ecological connectivity (Rinaldi et al., 2017).

The findings in Table 4 and Figures 17 and 18 emphasize the necessity for focused restoration initiatives in the Jajrood River. The unfavorable to extremely unfavorable conditions in Reaches 1, 3, 4, 5, and 6 arise from human-made structures and alterations in land use that interfere with longitudinal and lateral continuity (Lemay et al., 2021). Eliminating or reducing unnecessary features, like culverts or bank reinforcements, might reestablish natural flow and sediment processes. Reach 7, in its almost natural condition, serves as a blueprint for rehabilitation in other reaches. Reach 2's typical state, despite various human modifications such as artificial canals, indicates a possibility for rejuvenation, as highlighted by Fryirs and Brierley (2000) in their study on river restoration.

The MQI approach significantly depends on the researcher's knowledge, since evaluating indicators such as F9 (cross-sectional shape) or A10 (bank protections) can be subjective (Moshe et al., 2022). Moreover, gathering data via field observations, remote sensing, and GIS requires significant time and expense. Future research might investigate the use of automated remote sensing to enhance this process while ensuring precision.

The MQI evaluation indicates that the northern sections of the Jajrood River, such as Reach 7, exhibit superior conditions, whereas the middle sections are impacted by human-induced deterioration. Table 4 measures these alterations, while Figures 17 and 18 depict the equilibrium between natural processes and localized effects in Reach 7. These results highlight the necessity for restoration approaches to tackle artificial obstacles and promote sustainable river management in developing regions.

Conclusions

Systematic study of the river is one of the important goals in the geomorphology of the river. Field scaling of intervals can provide important information on fluvial processes. Assessment of river hydro morphological conditions is now considered as a key step in assessing river ecological conditions. This type of assessment requires understanding of the process and providing an overall assessment of river conditions. The MQI method is a suitable method for examining riverbed conditions. The spatial scale of MQI application is the riverbed and the total conditions of the river crede (example of active canal and flooding of adjacent plains/new barracks) are considered in the evaluation. Basin (e.g. sediment flux (and location scale) as well as substrate conditions are also considered. One of the most important issues in applying the MQI method is the level of expertise of the researcher. GIS analysis and field surveys should be done by operators with appropriate background and training in river geomorphology because having specialized knowledge of river geomorphic concepts is necessary for the application of MQI.

The level of professional background of the incumbent is an essential factor that may lead to bias in the use of the scoring system. Another noteworthy point is that due to the costs and feasibility of using this method, quantifying the time required to use MQI is not accurate, as it depends on a set of factors (competence, level of training and experience of the operator; availability Data and other information (for example, having a map layer of management interventions and practices significantly reduces this time). The time required to apply this method in a riverbed depends on the number of intervals from the same section or river under evaluation. This method can be used in rivers and beds that have a hydrometric station.

The study area is known as a recreational and tourist area due to its mountainous location, suitable climate, river, proximity to the city of Tehran, and this causes many permitted and unauthorized constructions around the river, manipulation of the riverbed, pollution. The changes that have taken place in the Jajrood riverbed due to these illegal withdrawals have caused serious damage to the banks of this river during rains.

Table 4. Score of MQI method indicators in the study area

Index	Limit 1	Limit 2	Limit 3	Limit 4	Limit 5	Limit 6	Limit 7
F1	0	0	0	3	5	0	0
F2	5	5	5	5	3	3	0
F3	3	3	0	3	5	5	5
F4	2	0	2	2	0	0	2
F5	3	3	0	2	2	3	0
F6	0	0	0	3	3	0	0
F7	3	3	3	5	5	3	3
F8	3	3	3	3	2	2	3
F9	0	2	5	5	5	3	0
F10	5	3	0	2	6	6	2
F11	3	0	3	0	0	3	3
F12	2	0	2	2	2	3	3
F13	0	3	3	0	0	5	0
A1	3	0	5	3	3	3	0
A2	0	6	2	0	3	0	0
A3	6	6	3	3	3	3	3
A4	0	0	0	0	0	0	0
A5	3	3	0	3	3	3	0
A6	0	6	3	6	3	0	3
A7	6	0	2	3	3	3	0
A8	0	3	0	3	3	3	0
A9	3	0	0	3	0	0	0
A10	6	3	3	6	6	3	0
A11	3	0	6	2	2	2	0
A12	2	2	6	6	6	3	0
CA1	0	2	4	3	6	3	0
CA2	3	3	6	6	6	3	0
CA3	0	4	2	4	4	4	4
Total	71	74	63	86	89	68	33
MQI	0.45	0.53	0.43	0.48	0.39	0.28	0.51

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